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6th BALKAN POWER CONFERENCE

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6th BALKAN POWER CONFERENCE

Paper Session

Renewable Energy I

Chairman: Prof. Pavlos Georgilakis

1. Croatia´s RES potential for Decentralized Power Production (Schneider, Ban, Duic, Bogdan)

2. Ways to Mimimize the Greenhouse Gas Emissions. Romanian Approach (I. Manicuta, M. Manicuta)

3. Electricity from renewable sources - a new opportunity for companies from SEE (Škerbinek, Špec)

4. Energetic Efficiency of Geothermal Resources in the Republic of Macedonia (Nikolovski)

5. Renewable Energy in Western China – Part I: Potentials (Xu, Su, A.F. Gubina)

6. Renewable Energy in Western China – Part II: Support Policy (Xu, Su, A.F. Gubina)

7. Romanian Green Certificates Market – results and lessons learned (Vladescu, Lupului, Vasilevschi, Ghinea)

8. Structural, Morphological and Optical Properties of Electrodeposited Films of Cuprous Oxide for Solar Application (V.P.Georgieva, M.T.Georgieva)

9. Exploring the potential of biogas from waste water in Isolated Locations (Stoilkov, Borozan,Krkoleva)

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6th BALKAN POWER CONFERENCE

Paper Session

Renewable Energy II

Chairman: Dr. Nataša Markovska

1. Target Site Rošijana for Demonstration of RES Application in Isolated Region (Zlatanovic, Marius, et. al.)

2. Testing of Internet Wind Data for Regional Wind Climate Assessment at Deliblatska Peščara site (Zlatanovic)

3. Techno-economic characteristics of wind energy use (Bukarica, Bozevic Vrhovcak, Tomsic, Pasicko)

4. Potential for PV application in the mountainous and highlands regions of Croatia (Desnica, Desnica Frankovic, Rakic)

5. Estimation of Costs for Implementation of a PV System in an Isolated Region (Krkoleva, Borozan)

6. Feasibility Analysis of Wind-plant in the Region of Deliblatska Peščara (Serbia) (Rajakovič, Đurišić, Mikičić, Bubnjević)

7. Exploratin of wind energy potential in Republic Of Macedonia (Vladimir Dimcev, Krste Najdenkoski, Vlatko Stoilkov)

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6th BALKAN POWER CONFERENCE

Panel Session

RES: Investments and Regulatory Framework in the Balkans

Chairman: Prof. Nikos Hatziargyriou

1. Mr. Michael Weber, EGL, Austria
2. Mr. Zoran Stanić, HEP, Croatia
3. Dr. Nataša Markovska, Macedonian Academy of Sciences and Arts, Macedonia
4. Mr. Gorazd Škerbinek, Energy Agency of Slovenia, Slovenia
5. Prof. Pavlos Georgilakis, NTUA, Greece
6. Dr. Uroš Desnica, “Rudjer Boškovič” Institute, Croatia
7. Mr. Andreas Tuerk, Joanneum Research

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WAYS TO MINIMIZE THE GREENHOUSE GAS EMISSIONS. ROMANIAN APPROACH

Ioan Manicuta - OPCOM
Maria Manicuta - ANRE

-

6th Balkan Power Conference

I. INTRODUCTION

II CARBON EMISSIONS TRADING – A NEW WEAPON AGAINST GLOBAL WARMING

III. PROMOTION OF RENEWABLE RESOURCES

IV. NUCLEAR POWER - NOT ONLY AN OPTION, BUT A REAL NEED

V. ROMANIAN APPROACH

VI. CONCLUSIONS

INTRODUCTION

- The international treaty on climate change - the Kyoto Protocol – entered into effect on February 16 2005.
- Under the Kyoto Protocol, the EU countries must reduce their CO_2 emissions to 8 percent below 1990 levels by 2010 and the United States target is 7 percent below 1990 emissions.
- Unfortunately, the most important producer of greenhouse gas emissions, The United States, did not ratify Kyoto Protocol.
- The challenge for energy supply over the next 50 years is how to meet the rapidly growing demand for energy services from a growing population while limiting the greenhouse gas emissions.

INTRODUCTION

In this context we see the following ways to fight against climate change by limiting the greenhouse gas emissions:

• Carbon emissions trading (EU-ETS – EUA, along with CDM/JI mechanisms of Kyoto Protocol - CER/ERU);

• Promotion of renewable resources;

• Return to nuclear power promotion.

CARBON EMISSIONS TRADING – A NEW WEAPON AGAINST GLOBAL WARMING

- The only mandatory carbon emissions trading program is in Europe. It was created in conjunction with the Kyoto Protocol and caps the amount of carbon dioxide that power plants and fuel-intensive manufactures in the 25 EU countries are allowed to emit.

- In US nine Eastern states are developing a regional cap-and-trade program that will require large power plants from Maine to Delaware to reduce their carbon emissions and California is attempting to place greenhouse gas limits on automakers. Separately, a small group of companies has voluntarily agreed to cap their carbon emissions in the U.S. as part of an experimental market that is based in Chicago (CCX).

CARBON EMISSIONS TRADING – A NEW WEAPON AGAINST GLOBAL WARMING

- The first phase of the EU trading program (EU-ETS) runs from 2005 to 2007 and the caps will be lowered from one year to the next one. Even so detailed plant-by-plant limits are not finalized yet in all the EU countries, participants estimate that EU-wide industrial emissions will drop as much as 5% by 2008. The cost to European industry over the 2005-2007 period is estimated to be a few billion dollars, based on initial market prices for carbon dioxide of about 7 euro/t.

- The second phase of EU-ETS runs from 2008 to 2012, by which time the European Union must lower its carbon emissions to 8% below 1990 levels.

CARBON EMISSIONS TRADING – A NEW WEAPON AGAINST GLOBAL WARMING

• Market volatility resulted from long positions announced after one year of the first phase application (last days of April – May 2006).

• Globalization of emission trading:

- In the second phase (2008-2012) the CER/EUR trading will be also included in EU-ETS;

- The project to connect the Community International Transaction Log (CITL), the heart of EU-ETS, at the International Transaction Log (ITL) is developed by the Secretariat UNFCCC

PROMOTION OF RENEWABLE RESOURCES

- Renewable resources include hydro, wind, solar, bio-fuels, geo-thermal, wave and tidal energy. Of these, wind, solar, geo-thermal, and wave/tidal are abundant, but only wind is currently economical and easy to harness.
- Wind has made enormous strides in the last 15 years especially in EU countries. The European wind energy industry installed 6,183 MW of new capacity in 2005, bringing the cumulative wind capacity in EU at a total of 40,504 MW at the end of 2005. There was an 18% increase over the 2004 EU cumulative total of 34,372 MW.
- The countries with the most important wind capacities are Germany (17,000 MW) and Spain (9,000 MW).

PROMOTION OF RENEWABLE RESOURCES

- The different countries uses a number of methods to support the investments in renewable resources development (renewable energy certificates, feed in tariff, etc.).
- However, we believe that for next two or three decades the renewable resources will be not the answer to reach the emissions reduction targets, because their present relative high cost and their intermittent nature.
- In the long and medium term, it is very possible that renewable energy systems (wind, wave and solar power) together with increased energy efficiency and the possible development of fusion power, to be sufficient to cut back the emissions of carbon dioxide. But, in the short term, we think that there may be no alternative to nuclear energy use.

NUCLEAR POWER - NOT ONLY AN OPTION, BUT A REAL NEED

- Nuclear is the only existing power technology which could replace coal in base load. It is a foregone conclusion that up to 2020 global reliance on fossil fuels and large hydro will remain strong, albeit with special emphasis on the role of natural gas and efficient cleaner fossil fuel systems. However, total reliance on these energy sources is not sustainable.
- Nuclear energy is and will remain in the years to come the only way to supply the large scale electricity the countries will need at lowest cost as compared with oil and gas (providing economy), face the global warming (providing environment protection) and last but not least, avoid tensions on oil and natural gas markets (providing ethics).

NUCLEAR POWER - NOT ONLY AN OPTION, BUT A REAL NEED

- Nuclear pros and cons - are detailed in the paper.
- It is so important that the nuclear option has to be re-examined.
- The public perception of nuclear dangers did not necessarily accord with reality. Fewer people had been killed in nuclear power generation than in other forms of energy productions, and that modern nuclear stations being designed were inherently much safer than those involved in the notorious accidents at Three Mile Island in the US in 1979 and Chernobyl in Ukraine in 1986.
- Furthermore if new nuclear power stations will be built, they will be sited near existing nuclear sites, and it will be highly unlikely that fresh “Greenfield” sites would be chosen.

ROMANIAN APPROACH

- Romania signed the United Nations Framework Convention on Climate Change (UNFCCC) ratified the Kyoto Protocol to the UNFCCC (Law no.3/2001), committing itself **to reduce the greenhouse gas emissions** with 8%, in the first commitment period 2008-2012, comparing to the base year (1989).

- The year 1989 was established as the base year for Romania as it expressed the country's best economic output potential directly linked to its emissions potential.

- The economic decline resulted in a relevant decrease in greenhouse gas emissions.

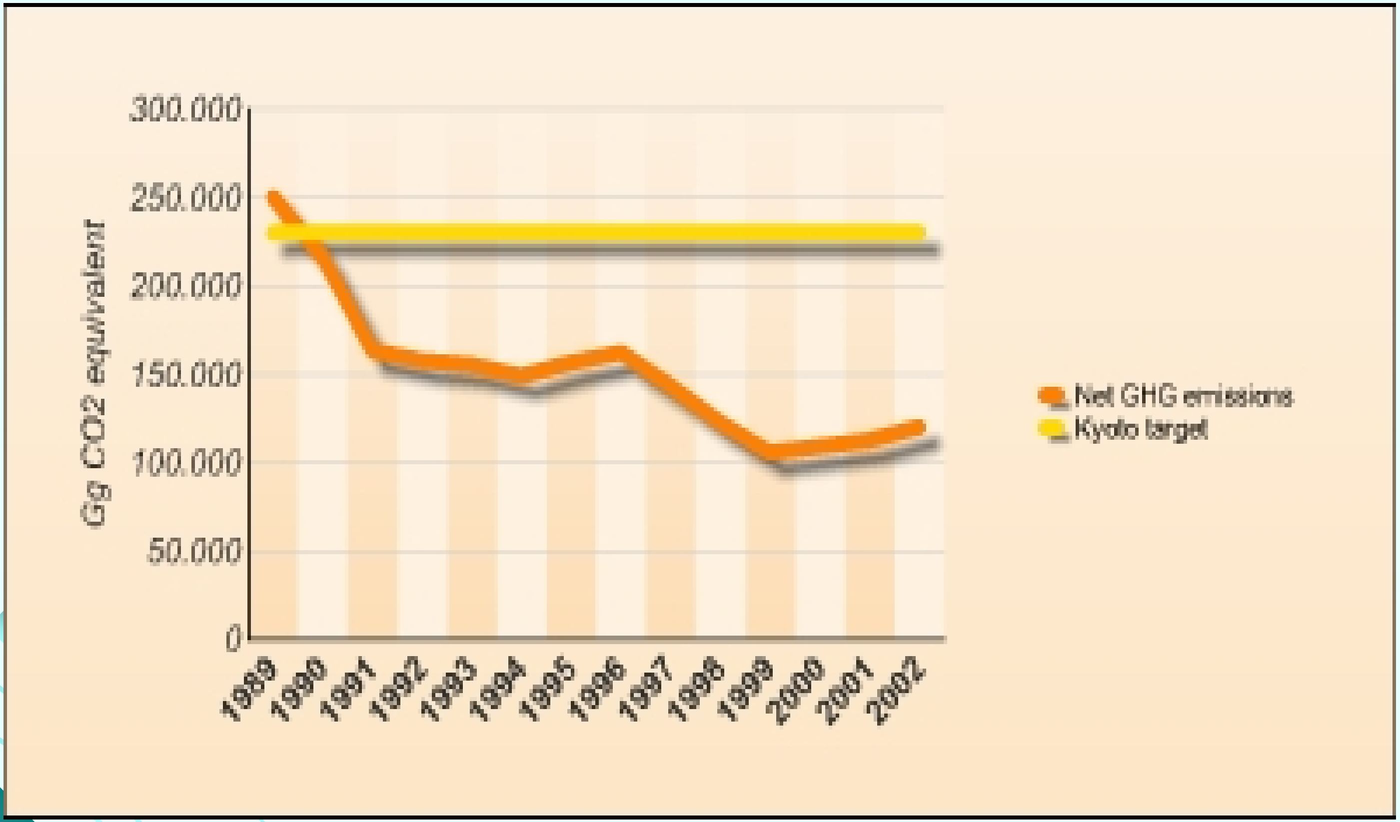
ROMANIAN APPROACH

- In 2005, Romania managed for the fourth time to submit the UNFCCC Secretariat the national greenhouse gas inventory with all its components, meeting also the requested deadline. According to this document, the Romania's total greenhouse gas emissions calculated in CO2 equivalent, decreased by 46% in the period 1989-2003.

- Romania will meet the Kyoto Protocol's 8% greenhouse gas emissions reduction target in the first commitment period, even considering the slight increasing trend of the greenhouse gas emissions noticed after 1999.

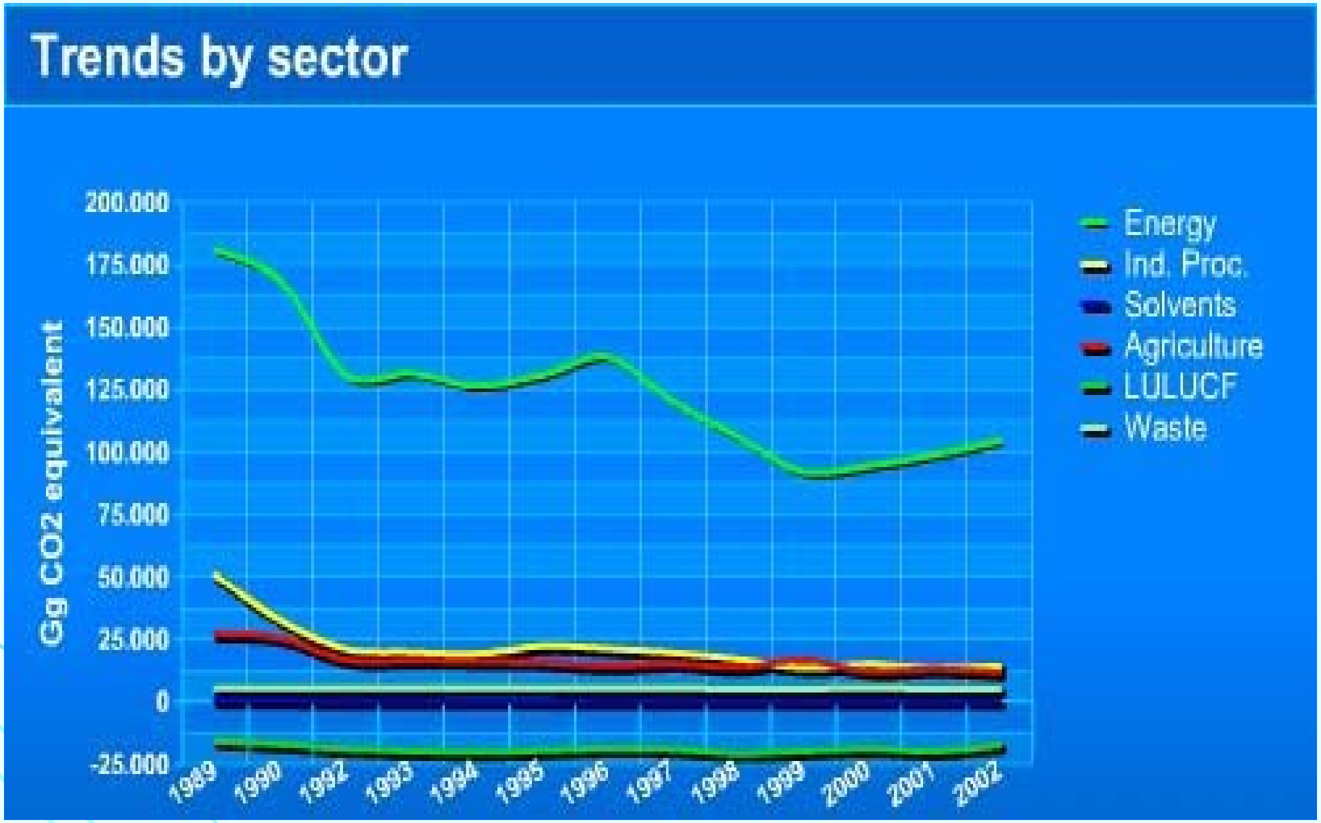
- Starting with the 2005 submission, emissions were reported using the new software programme CRF Reporter developed by the UNFCCC Secretariat.

ROMANIAN APPROACH



The total Romania greenhouse gas emissions in CO2 equivalent in the 1989-2002 period

ROMANIAN APPROACH



The trends of greenhouse gas emissions in Romania by sectors in the 1989-2002 period

ROMANIAN APPROACH

- In the first half of 2005, the Romanian Ministry of Environment and Water Management issued Romania's first National Strategy on Climate Change (Government Decision No. 645/2005), which presents the framework for implementing Romania's climate change policy in the period 2005-2007.

- The National Action Plan on Climate Change develops the individual policies and concrete measures to be further developed and implemented under the National Strategy on Climate Change.

ROMANIAN APPROACH

- The Ministry of Environment and Water Management also proposed a Government Decision draft with a view to establish a trading scheme for the greenhouse gas emissions certificates in Romania.

- As in almost all European Electricity Exchanges, the Romanian Electricity Market Operator (OPCOM) has as future objective to perform transactions with greenhouse gas (CO2) emissions certificates on its trading platform.

ROMANIAN APPROACH

- Regarding the **promotion of renewable resources**, the Romanian Government prepared a Strategy to develop the use of renewable energy sources (Government Decision No.1535/2003) and established a system to promote electricity generation from renewable resources (Government Decisions No. 443/2003, 1.892/2004 and 958/2005).

- According to the Romanian Government target which derived from the EU accession negotiation process, a mandatory quota of gross electricity domestic consumption to be supplied from renewable resources by 2010 – 2012 was established.

ROMANIAN APPROACH

Mandatory quota applied to electricity suppliers (%)	Year
0.7	2005
2.22	2006
3.74	2007
5.26	2008
6.78	2009
8.3	2010-2012

- Another important step in promoting the use of renewable resources has been made with the Romanian Green Certificates Market that began operating in November 2005. This market is administered by OPCOM and operates on a monthly basis.

ROMANIAN APPROACH

- **Nuclear power** is a reality for the last ten years in Romania. The Unit 1 of Cernavoda NPP, which began its operation with excellent results in December 1996, covers almost 10% of national electricity gross consumption. The commissioning of Unit 2 is also envisaged for the next year.

- According to the National Strategy for Development of Nuclear Sector in Romania (Government Decision No.1259/2002) 3 more nuclear units will be under operation in 2020. The achievement of this ambitious program depends on the financial sources that could be attracted in the future.

CONCLUSIONS

- We consider that the main tools in fighting the climate change by limiting the greenhouse gas emissions are: carbon emissions trading (EUA along with CER/CRU) the promotion of renewable resources and continuing to develop nuclear power.

- The nuclear power is and will remain in our opinion the main alternative in fighting climate changes in the coming years. It provides large scale electricity supply at lowest costs copes with the global warming and last but not least, avoids tensions on oil and natural gas markets.

CONCLUSIONS

• Romania benefits from significant hydro generation installed capacities, free of greenhouse gas emissions and has made important steps towards the three directions mentioned above to be in line with the international efforts made in the fight against the climate change.

• If the promotion of renewable resources and the emission trading process are in an incipient stage, the nuclear power is already a reality in Romania and represents the main generation technology that our country intents to develop in the future.

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cosmo

ENERGETSKA EFIKASNOST NA GEOTERMALNITE RESURSI VO REPUBLIKA MAKEDONIJA

- osnovni podatoci za energetskiot resurs vo Makedonija
- momentalno raspolo`ivi kapaciteti
- tehni~kata iskoristivost
- tretman vo zakonskata regulativa
- procenka na prose~nata cena na proizveden kWh vo sega{ni uslovi na finansirawe i rabotewe

ENERGETIC EFFICIENCY OF GEOTHERMAL RESOURCES IN THE REPUBLIC OF MACEDONIA

- presentation the basic data of energetic resources in Macedonia
- current available capacities
- technical usage
- the treatment by the legislative
- evaluation of the average prize for produced kWh in current condition of financing and working

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kategorizicija na hidrogeotermalnite resursi

(vo zavisnost od temperaturata i dominantnata faza na fluidot)

- voda so niska temperatura
- voda so sredna temperatura (do140^{0}S)
- voda so visoka temperatura i suva para (140-350^{0}S)

categorization of hydro geothermal resources

(depending on the temperature and the dominate faze of the fluid)

- water with low temperature
- water with medium temperature (to 140^{0}S)
- water with high temperature and dry steam (140-350^{0}S)

teritorijata na Makedonija pripa|a na dva tektonski sistema

- Zapadniot del na Makedonija i Povardarieto - kon Dinaridite (Helenidite)
- Isto~nomakedonskite planinski tereni i kotlinski depresii - segmenti od Srpsko-Makedonski masiv

- Krai{tidna zona - Karpato-Balkanidite (posebna zona po dol`inata na granicata so Bugarija)

the territory of Macedonia belongs to two tectonic systems

- the western part of Macedonia included Povardarie - to Dinaridis (Helenidis)
- the eastern macedonian mountain terrain and valley's depressions - segments of the Serbian-Macedonian massive

- Kraistidna zone - Karpat-Balkanidis (particular zone along the Bulgarian border)

konduktivni hidrogeotermalni sistemi

- terciernite baseni na Ov~e Pole
- Tikve{
- Del~evsko - Peh~evskiot basen
- basenite vo Skopskata, Strumi~kata, Gevgeliskata, Polo{kata i Pelagoniskata kotlina

conducive hydro geothermal systems

- tertian basins of Ovce Pole
- Tikves
- Delcevo-Pehcevo's basin
- basins in Skopje's, Strumica's, Gevgelija's, Polog's and Pelagonija's valley

konvektivni hidrogeotermalni sistemi

- Skopskata kotlina
- Ko~anskata kotlina
- Strumi~kata kotlina
- Gevgeliskata kotlina
- Ke`ovica
- Toplik - Topli dol na planinata Ko`uf
- Toplec kaj Dojran
- Proevci kaj Kumanovo
- Strnovec,
- Zdravevci na rekata Povi{nica kaj Kratovo
- Sabotna voda kaj Veles
- sistemite vo zapadna Makedonija - Kosovra{kata i Debarskata bawa i Bani~e na rekata Pena kaj Tetovo

convective hydro geothermal systems

- Skopje's Valley
- Kocani's Valley
- Strumica's Valley
- Gevgelija's Valley
- Kezovica
- Toplik - Topli Dol on the Kozuf Mountain
- Toplec near Dojran
- Proevci near Kumanovo
- Strnovec
- Zdravevci on the Povisnica River near Kratovo
- Sabotna Voda near Veles
- systems in western Macedonia - Kosovraska and Debarska's spas and Banice on the Pena River near Tetovo

Glavni geotermalni poliwa vo Makedonija
Main geothermal fileds in Macedonia

Bilans na hidrogeotermalnite resursi vo R. Makedonija (sostojba 2004)
Balance-sheet of hydrogeothermical resources in RM (state 2004)

hidrogeotermalen sistem		lokalitet		temperatura	protok	eksploataciski rezervi	toplinska sila
hydro geothermal system		locality		temperature (c°)	yield (l/sec.)	exploitation reserves (l/sec.)	heat power (mwt)
Skopska kotlina	Skopje Valley	Volkovo	Volkovo	25	60	20	2.10
Skopska kotlina	Skopje Valley	Katlanovo	Katlanovo	50	20	15	10.45
Kumanovska bawa	Kumanovo spa	Dupnatina	Borehole	31	6	4	0.52
Strnovec	Strnovec	ST-5, PEB	ST-5, PEB	47	50	46	9.05
Zdravevci	Zdravevci	ZD-3,4,5,6	ZD-3,4,5,6	48	22	20	4.02
Dobrevo	Dobrevo	Dupnatina	Borehole	28	12	8	0.94
Podlog - Ko~ani	Podlog Kocani	Dupnatina	Borehole	75	650	300	94.14
Istibanwa-Vinica	Istibanja-Vinica	ID-3,4,5	ID-3,4,5	68	73	73	20.78
Strumi~ka kotlina	Strumica Valley	Bansko	Bansko	70	82	50	14.65
Gevgeliska kotlina	Gevgelija Valley	Negorci	Negorci	50	100	80	16.74
Gevgeliska kotlina	Gevgelija Valley	Smokvica	Smokvica	65	180	120	32.65
Dojran	Dojran	Toplec	Toplec	28	28	10	1.17
Ko`uf	Kozuf	Toplik	Toplik	21	2	2	0.18
Rakle{	Rakles	Dupnatina	Borehole	26	5	2	0.22
Veles	Veles	Sabota v.	Sabota v.	21	5	5	0.44
[tip	Stip	Ke`ovica	Kezovica	57	8	7	1.67
Tetovo - r. Pena	Tetovo-Pena R.	Bani{te	Spa	30	10	10	1.26
Debarska bawa	Debar spa	Bani{te	Spa	50	120	100	16.74
Kosovra{ka bawa	Kosovraska spa	Kosovrasti	Kosovrasti	48	100	60	12.05
vkupno ∑	**total ∑**				**1473**	**933**	**239.92**

metodi za odreduvawe na geotermalniot potencijal

methods for determination of geothermal potential

- se zemaat predvid pove}e hidrogeolo{ki, geolo{ki i geotermalni veli~ini koi se pove}e ili pomalku definirani ili zemeni so odredeni aproksimacii

- there are viewed more hydrogeoloic, geologic and geothermal sizes that are more or less defined or taken with certain proximities

- Vo R. Makedonija, vo momentot postojat 7 geotermalni proekti i 6 bawski kompleksi kade se iskoristuvaat geotermalnite vodi
- Site ovie geotermalni proekti se zapo~nati vo 80-tite godini od minatiot vek, dodeka bawskite kompleksi se od mnogu poran period
- Postojat verodostojni dokumenti za geotermalnite sistemi Ko~ani (Podlog-Bawa), Istibawa (Vinica), Bansko, Gevgeliska kotlina i dr.

- In RM there are current 7 geothermal projects and 6 spa complexes where geothermal water is used.
- All these geothermal projects started in the 80's in the previous century, and spa complexes are dating from earlier period.
- There are valid documents for the geothermal systems (Kocani), Podlog Spa, Istibanja (Vinica), Bansko, Gevgelija Valley etc.

U~estvo na poedine~ni energenti vo energetskiot bilans na R. Makedonija

Participation of particular energetics in energetic balance-cheet in RM

tipovi energenti		godi{na potro{uva~ka (TJ)	u~estvo vo vkupnata potro{uva~ka (%)
types of energetic		**annual consumption (TJ)**	**participation of total consumption (%)**
jagleni	coals	59 700	56,13
drvo	wood	10 097	9,49
te~ni	liquid	33 044	31,07
obnovlivi	renewable	500	0,47
hidroenergija	hydroenergy	2 498	2.35
geotermalna	*geothermal*	*510*	*0,48*
vkupno	**total**	106 347	100

ZAKLU^OCI

- geotermalnata energija ne e "nov" i nepoznat energetski izvor vo Makedonija
- registrirani se nad 50 izvori i pojavi na mineralini i termomineralni vodi so vkupna izda{nost od nad 1400 lit/sek. i doka`ani eksploatacioni rezervi od okolu 1000 lit/sek. so temperaturi vo granicite 20 - 79°S
- maksimalno raspolo`iva sila od 173 MW, t.e. kapacitet za godi{no proizvodstvo od 1.515.480 MWh toplinski ekvivalent
- geotermalnata energija se koristi vo 8 termalni bawi so vkupen protok od 250 l/s so vkupna toplinska sila od 35 MW i godi{no iskoristuvawe od1112,5 TJ

CONCLUSIONS

- geothermal energy is not a "new" and unknown energetic source in Macedonia
- there are have been registered above 50 sources and appearances of minerals and term mineral waters with total abundant of more than 1.400 l/sec and prove explanation reserves about 1.000 l/sec with temperature limits from 20 to 70°C
- maximum available power of 173 MW or annual capacity production of 1.515.480 MWh/year heating equivalent
- term mineral water is used in 8 thermal spas with total yield of 250 l/sec with total thermal power of 35 MW and annual use of 1.112,5 TJ

PREPORAKI

- so relativno mali vlo`uvawa kapacitetot mo`e da se zgolemi za 4-5 pati
- poddr{ka na dr`avata, odnosno tretman na geotermalnata energija kako energent od posebno op{testveno zna~ewe
- promena na odnosot kon ovoj vid energija i re{avawe na pravnata regulativa
- idnite istra`uvawa da se naso~at vo registriranite predeli (Kratovsko-Zletovska vulkanska oblast, Vardarska zona i Srpsko-makedonski masiv)

RECOMMENDATIONS

- with relative small investments the capacity can be raised 4-5 times
- government support that, i.e. treatment of geothermal energy as energetic with special social significance
- change of try attitude towards this kind of energy and solution of the legal regulation
- Future researches should be directed in registered regions (Kratovo-Zletovo's volcano region, Vardar zone and Serbian-Macedonian massif)

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ENERGETSKA EFIKASNOST NA GEOTERMALNITE RESURSI VO REPUBLIKA MAKEDONIJA

ENERGETIC EFFICIENCY OF GEOTHERMAL RESOURCES IN THE REPUBLIC OF MACEDONIA

Romanian Green Certificates Market

— results and lessons learned —

Gherghina VLĂDESCU
Luminiţa LUPULUI
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Smaranda GHINEA

6th Balkan Power Conference

Ohrid, Republic of Macedonia

31st May – 2nd June 2006

ROMANIAN power market operator

European Legislation

E.U. Directive 77/2001

Provides new measures concerning the promotion of the electricity produced from RES on the internal electricity market.

Primary Legislation

"ROAD MAP "(GD 890/2003)

Sets the specific tasks and targets, as well as the evolution milestones for the Romanian power market.

GD 1535/2003

Assess the RES potential in Romania and establishes the strategy for RES development in the context of Romania adhesion to EU.

GD 443/2003

Adapts the provisions of the EU Directive 77/2001 (on the promotion of production of electricity from RES on the internal market) to the Romanian specific conditions.

GD 1892/2004

Establishes the promotion system for the electricity produced from RES.

GD 958/2005

Modifies and completes the GD 443/2003 concerning the promotion of the production of electricity from RES.

Secondary Legislation

ANRE Ord. 52 / 2005

Establishes the tariff for the electricity acquisition from the hydro producers which have not portfolio contracts and for the electricity sold by the producers which participate in the system for E-RES promotion.

ANRE Ord.46 / 2005

Modifies the quota obligation for GC acquisition by the electricity suppliers, for 2005

ANRE Ord. 45 / 2005

Allocation procedure for the amount of money collected from the penalties imposed to the suppliers for quota non-compliance.

ANRE Ord. 40 /2005

Regulation for Green Certificates Market organization and functioning.

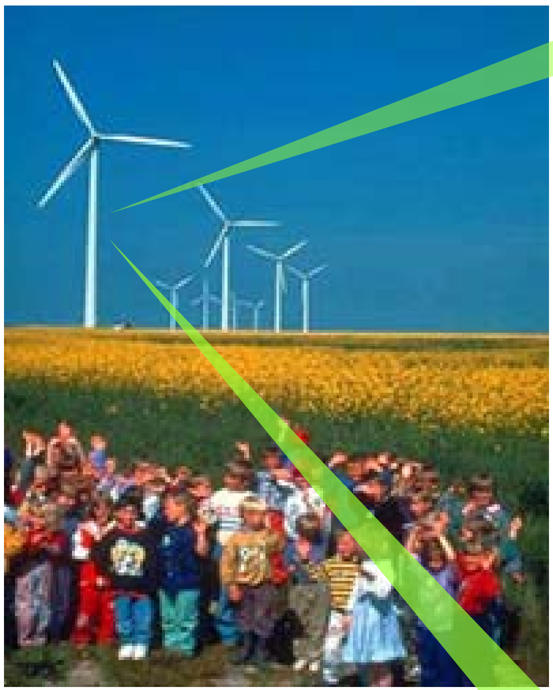
Ord. ANRE 23 /2004

Procedure for surveillance of the guarantees of origin issuing for the electricity produced from RES.

In august 2005was issued the first CG in Romania

In November 2005 occurs the first tranzaction on the Centralized Green Certificates Market in Romania

Electricity are traded separately from Green Certificates



Green Certificate Price

Are traded the environmental benefits

- Bilateral Contracts
- CGCM

Green Certificates Market

Green Certificate 1MWh

Electricity MWh

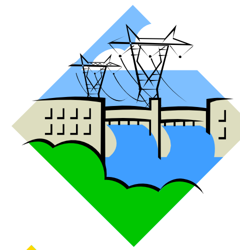
- Bilateral Contracts
- DAM as Priority Production

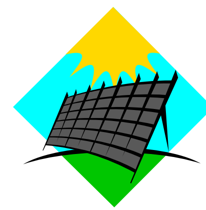
Electricity Market

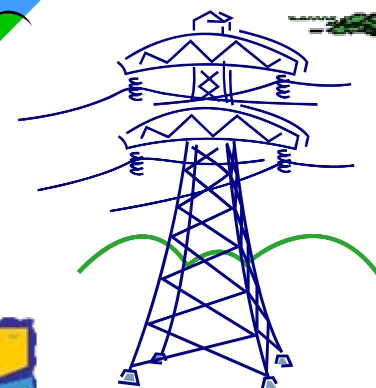
Electricity Price

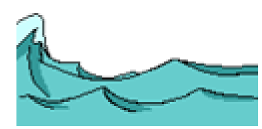
Renewable Energy Sources eligible to receive GC

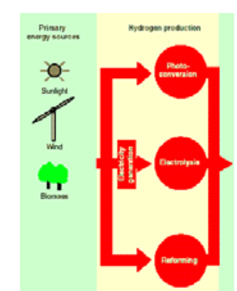
- **Hydro power plants ≤ de 10 MW**
  new or modernized starting with 2004
- **Photovoltaic**
- **Biomass**
- **Wind**
- **Geothermal**
- **Waves**
- **Hydrogen produced from RES**











Support system for E-RES

Established by Government Decision

Fixed Quantities – mandatory quota

Variable price – determined on the market

Minimum and maximum values established by Government Decision (24 €/certificate – 42 €/certificate)

For producers protection

For consumers protection

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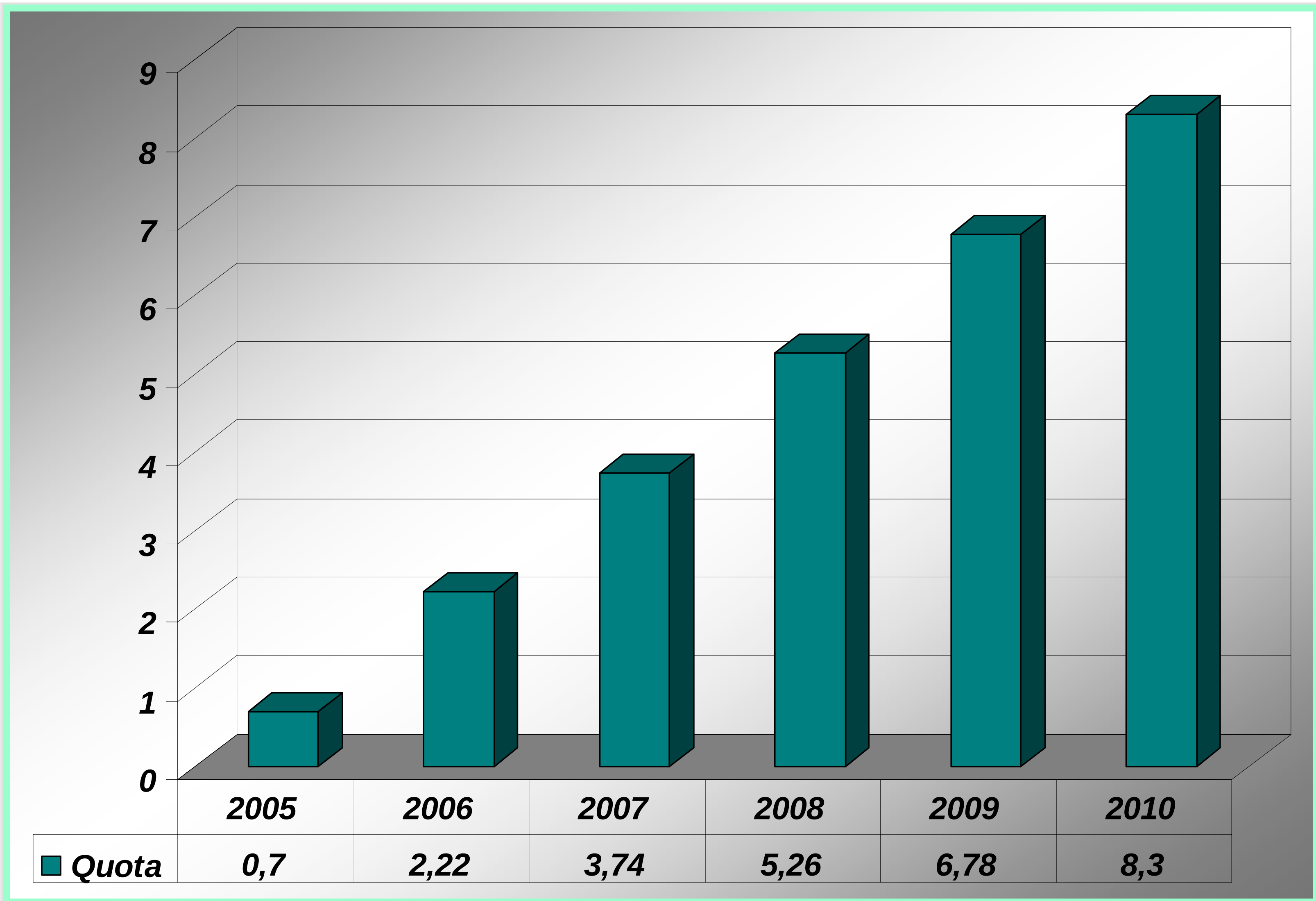
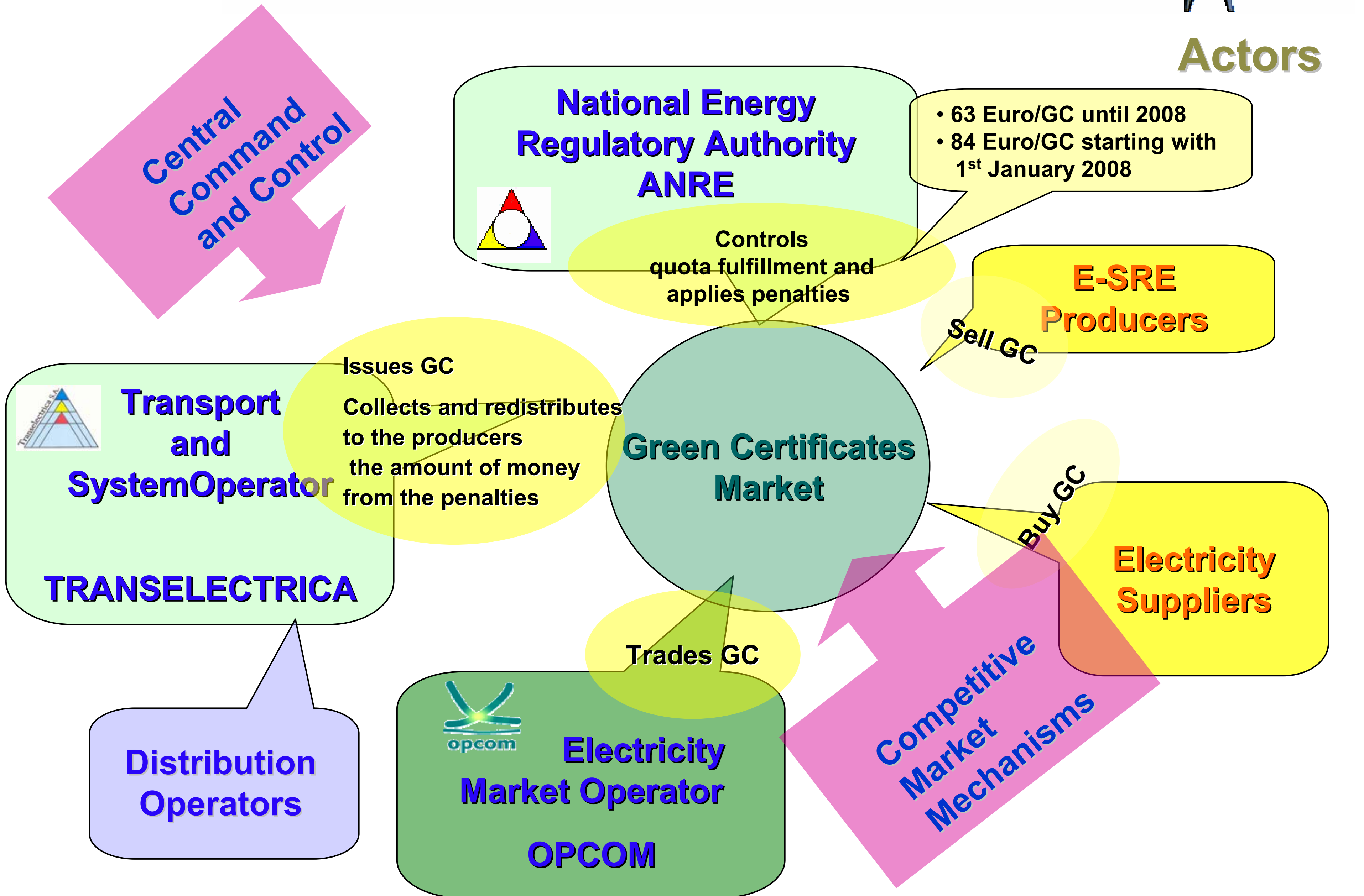
Quota for E-RES until 2010

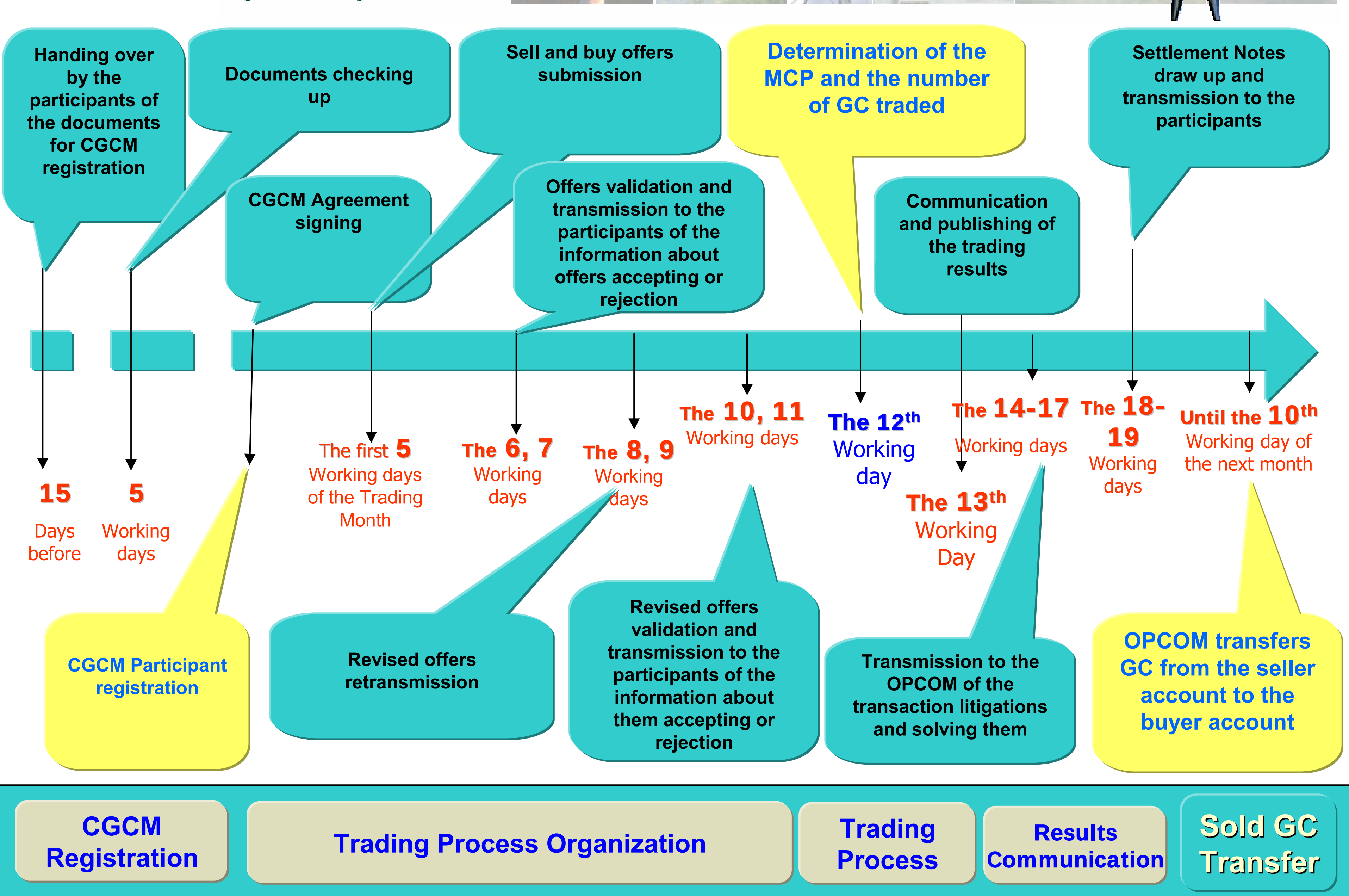


	2005	2006	2007	2008	2009	2010
Quota	0,7	2,22	3,74	5,26	6,78	8,3

Actors


Central Command and Control
National Energy Regulatory Authority ANRE
• 63 Euro/GC until 2008
• 84 Euro/GC starting with 1st January 2008
Controls quota fulfillment and applies penalties
E-SRE Producers
Sell GC
Issues GC
Collects and redistributes to the producers the amount of money from the penalties
Transport and SystemOperator
TRANSELECTRICA
Green Certificates Market
Buy GC
Electricity Suppliers
Trades GC
Distribution Operators
opcom
Electricity Market Operator
OPCOM
Competitive Market Mechanisms

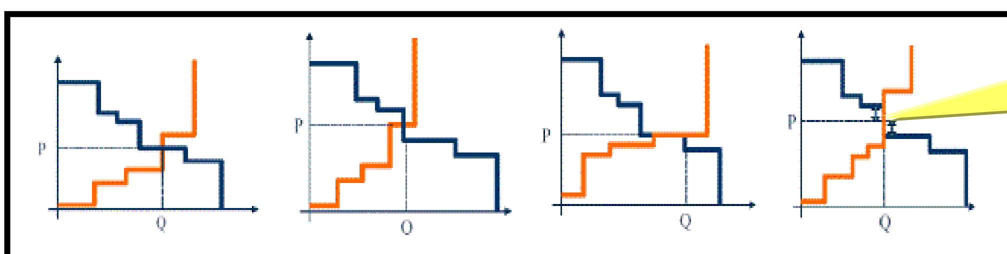
Centralized Green Certificates Market Organization and Operation



CGCMCP and the Number of GC traded on the CGCM

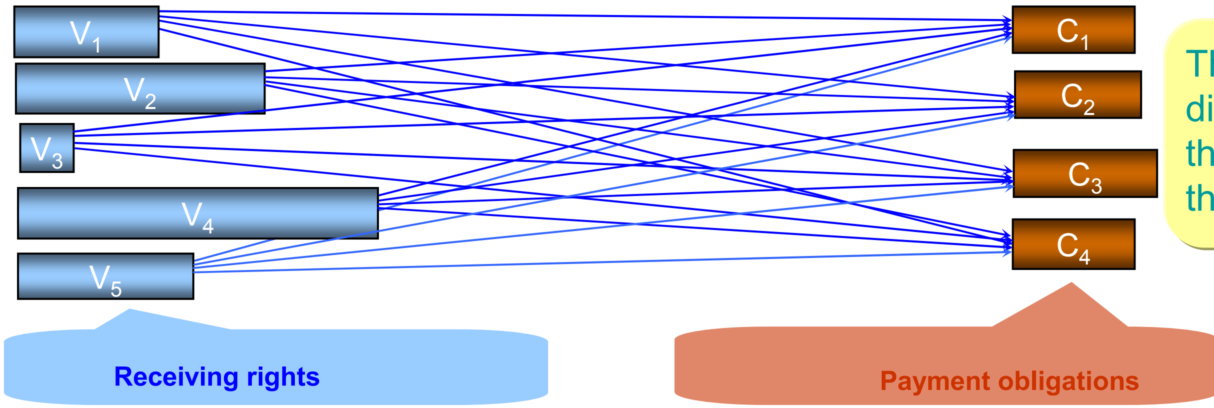
CGCMO determines:

- **Demand curve** – Combining all pairs price-quantity of the buying offers and sorting the price descending, in a single curve
- **Offer curve** – Combining all pairs price-quantity of the selling offers and sorting the price ascending, in a single curve
- **CGCMCP and the Number of GC traded** – the intersection point between the demand curve and the offer curve



$$\text{CGCMCP} = \frac{P_{max} + P_{min}}{2}$$

Transactions settlement on the Centralized Green Certificates Market



The payments of a participant are distributed **pro-rata** to all participants that have rights to receive money from the transaction.

$$S_{pay,\,j} = S_{pay} \times \frac{S_{receive,\,i}}{\sum S_{receive,\,i}}$$

Bilateral Settlement : x * y contractual relations

$$S_l = p_l \times q_l$$

S_l – the value of the monthly settlement
pl, ql – the price and the number of CG traded

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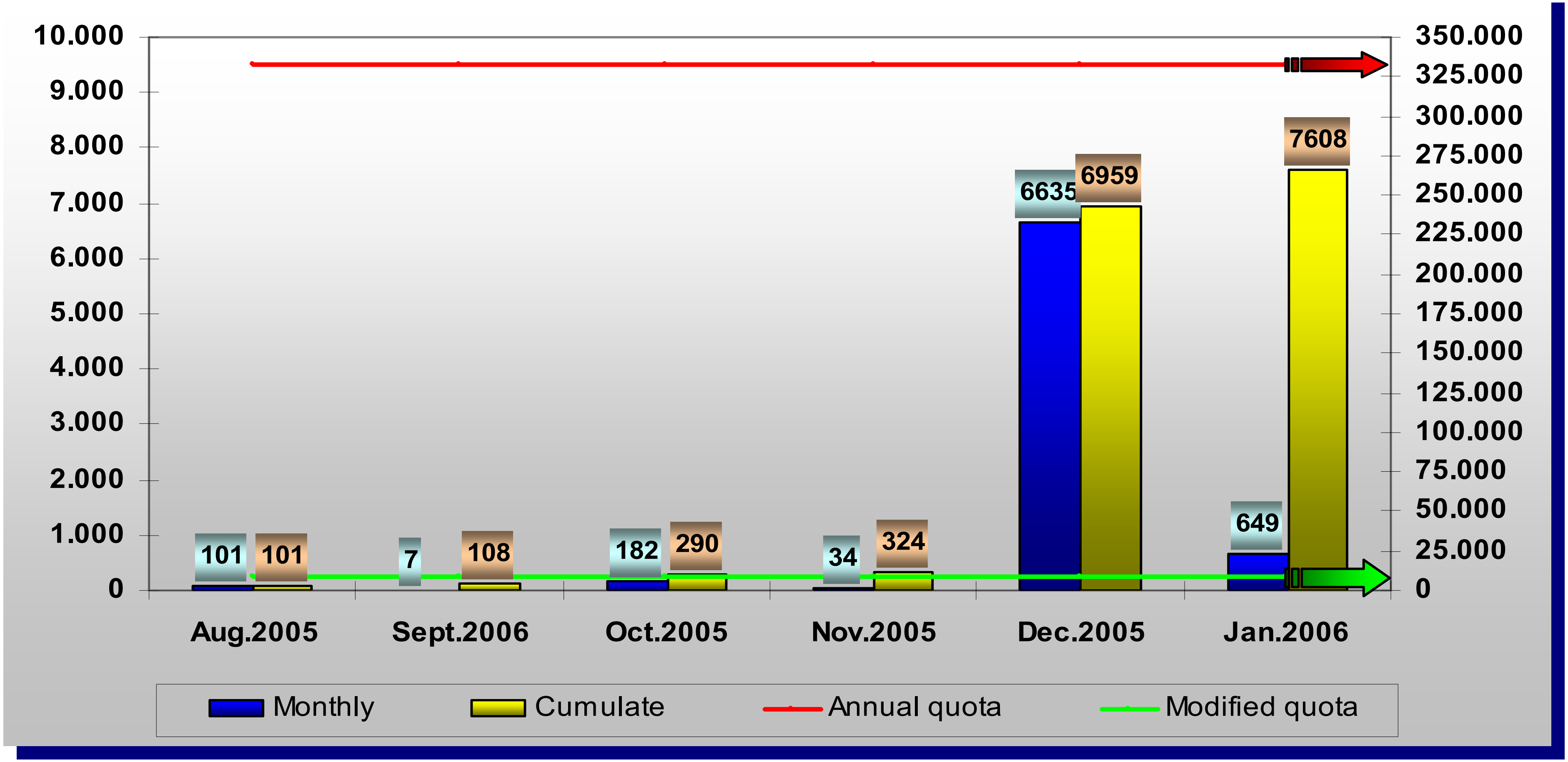
- ***Draws up the bilateral settlement***
- ***Does not interpose like central and contractual part between the market participants***
- ***Determines the monthly mutual obligations***
- ***In case of financial obligations non-fulfillment, the participants are liable for each other***
- ***Monthly settlement***

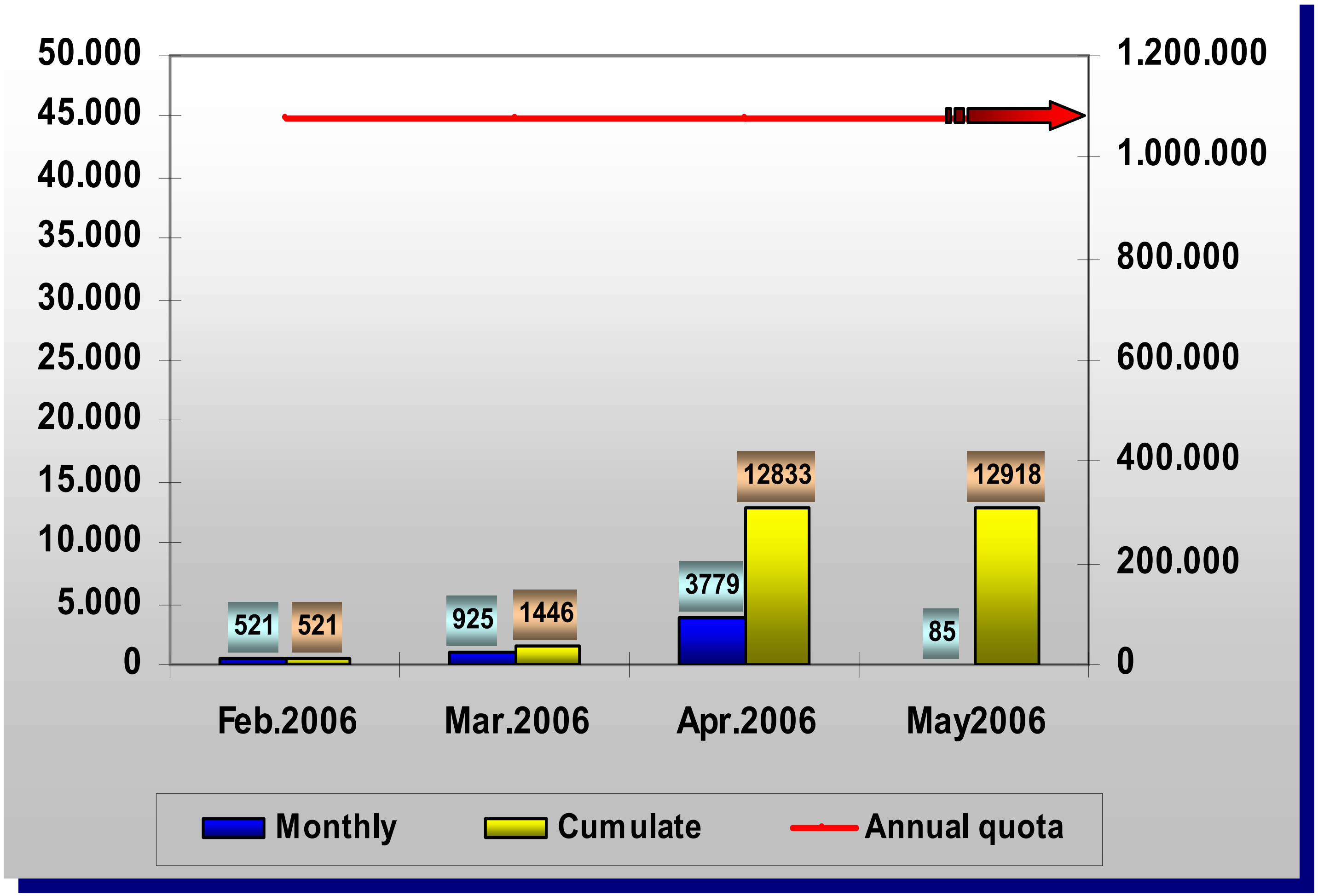
Number of GC issued by TSO

2005

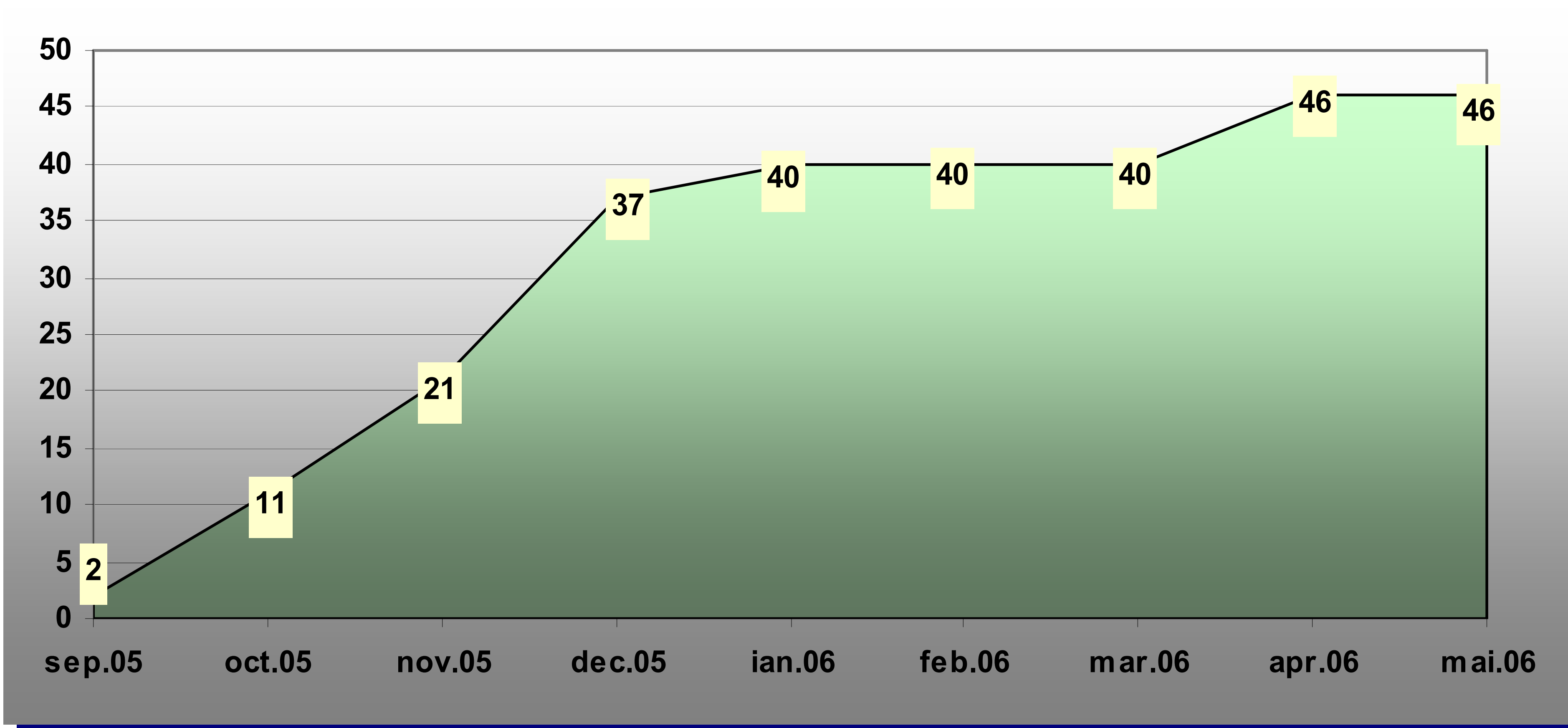


Number of GC issued by TSO

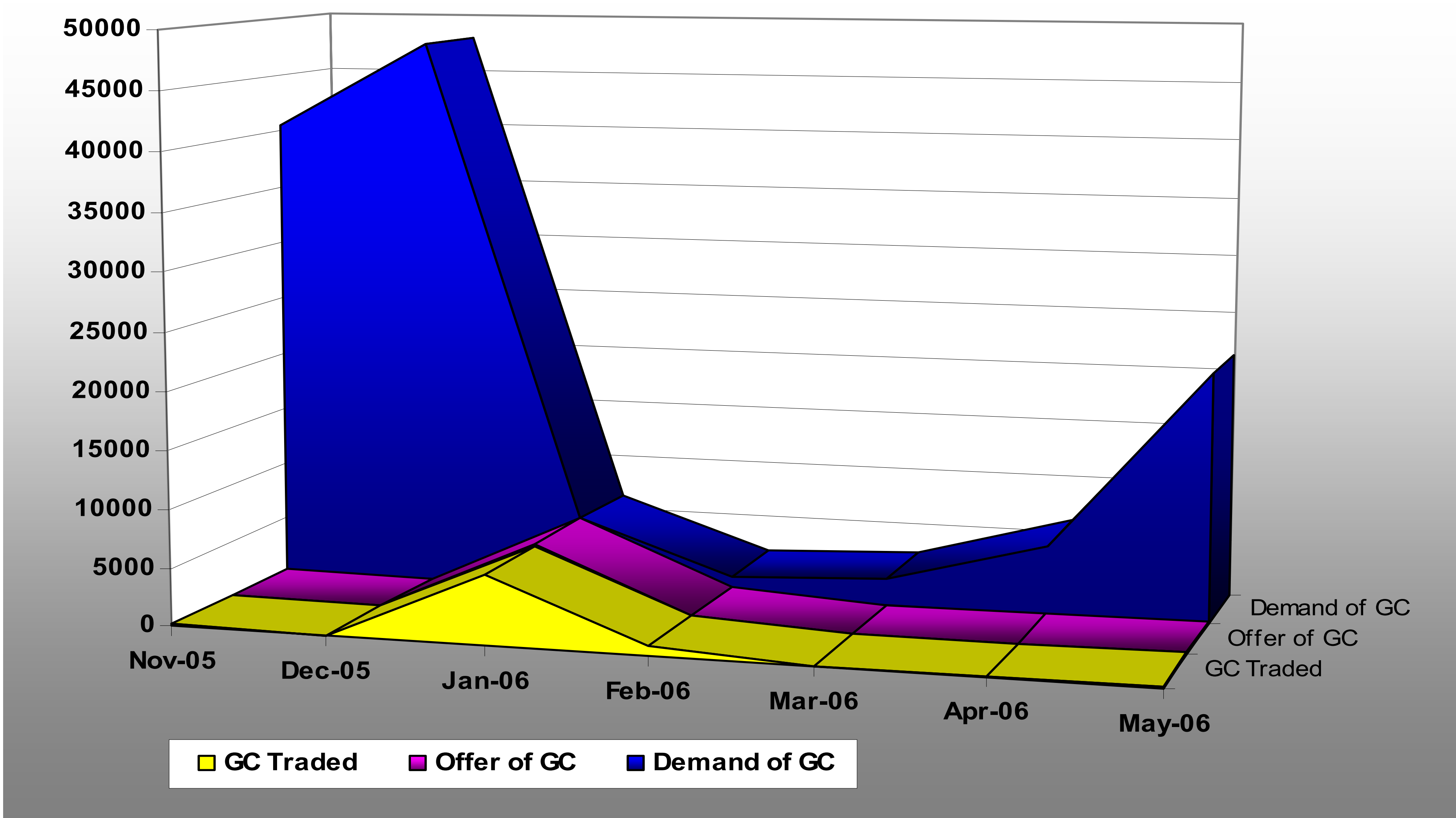
2006



The evolution of the number of participants



Offers and GC traded on CGCM



Centralized Green Certificates Market Clearing Price Evolution

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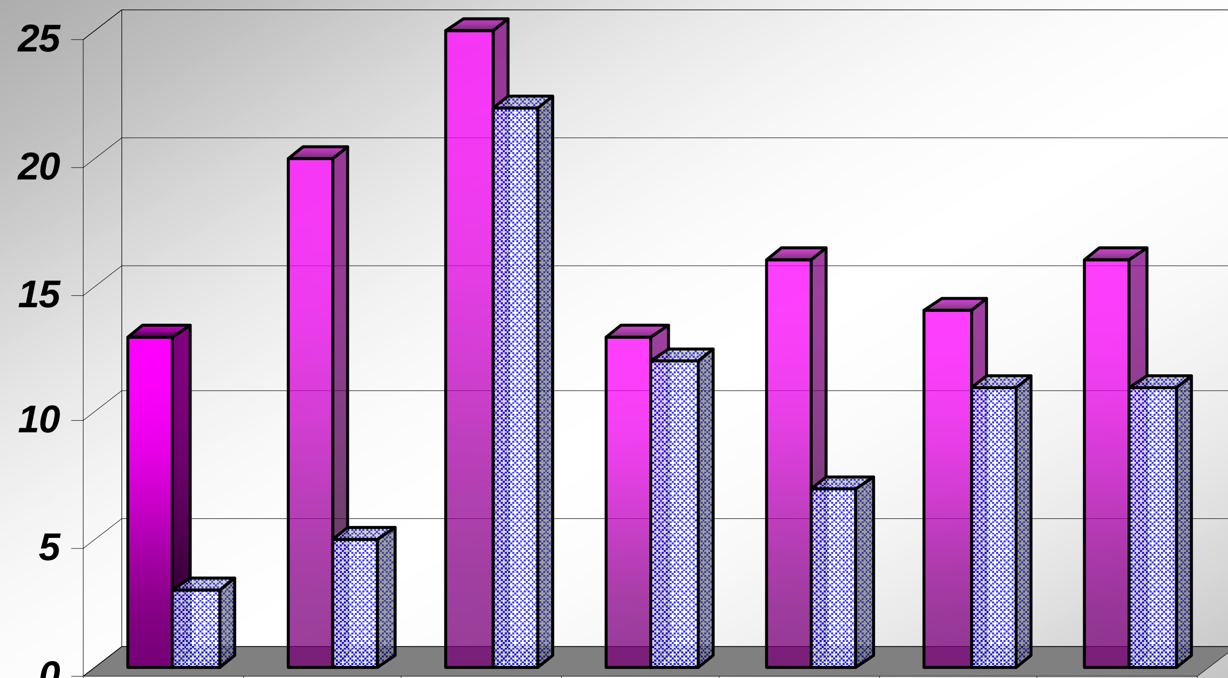
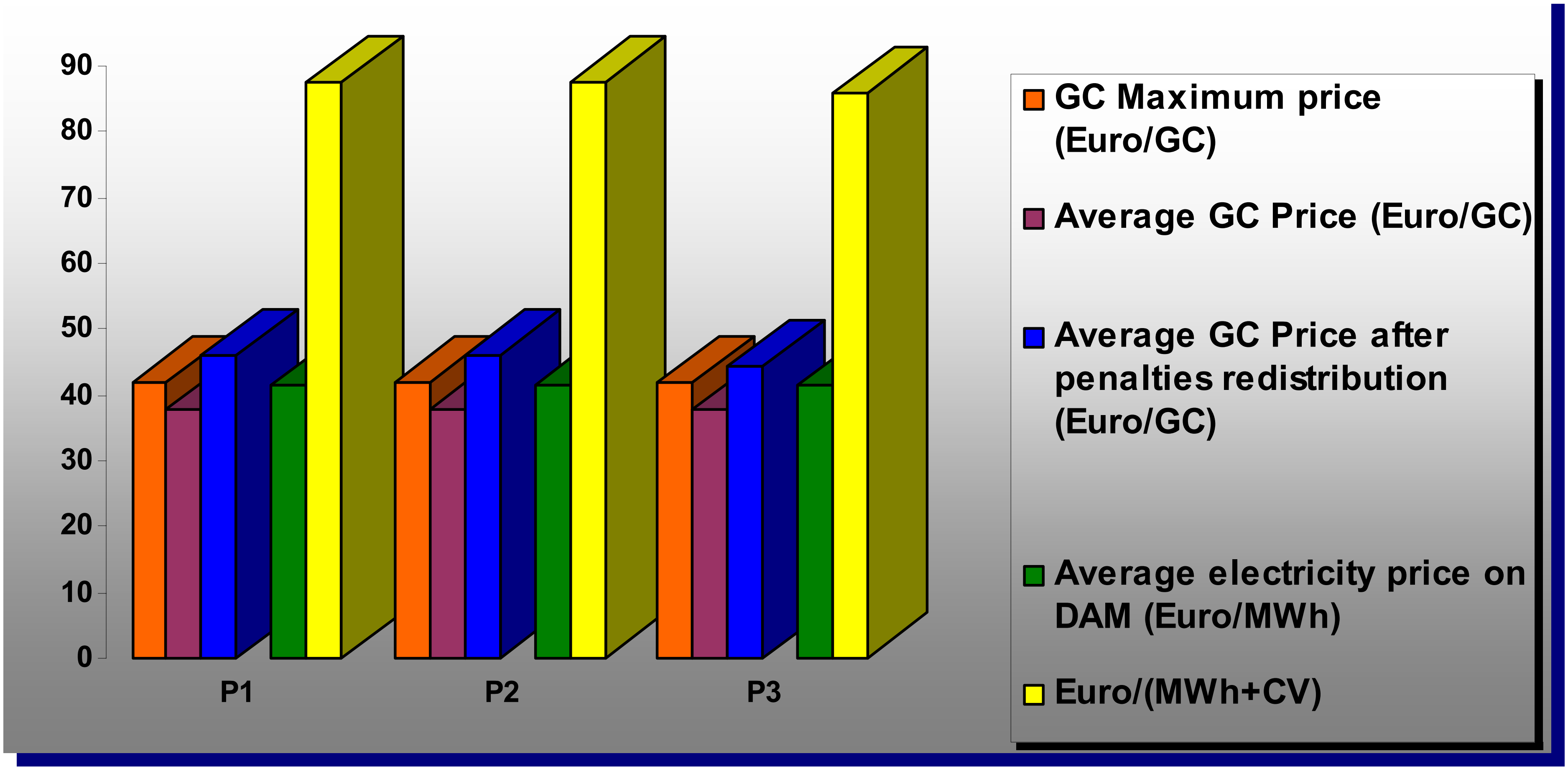
Number of participants that offered and traded on CGCM



	Nov.2005	Dec.2005	Jan.2006	Feb.2006	Mar.2006	Apr.2006	May2006
Offered	13	20	25	13	16	14	16
Traded	3	5	22	12	7	11	11

Producers revenues (GC + Electricity)



Conclusions

- Romanian market for Green Certificates is still in the process of formation
- The producers which are also suppliers of electricity hinder the market fluidity because they keep the Green Certificates received for the own quota fulfillment
- 18 suppliers was penalized for a total of 752 Green Certificates missing from the quota of 2005
- The amount of money from the penalties was redistributed to 3 producers which have activated on the market in 2005
- There are some projects in developing stage for new power plants which use RES
- The Green Certificates Market is a system designed to stimulate the electricity production from RES and we are waiting for new producers of E-RES

Thank you for your attention

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EXPLORING THE POTENTIAL OF BIOGAS FROM WASTE WATER IN ISOLATED LOCATIONS

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ABSTRACT

Biomass is one of the very first energy sources included in human daily activities. **Biogas**, obtained by bioconversion of organic matter is a complex anaerobic fermentation process involving the action of microorganisms for **methane producing**.

In this paper, biogas from waste water and energy production in isolated locations is investigated. The basic reason that motivated this work is treating **animal waste** and **waste water** in **industry processes** with the technology of anaerobic digestion resulting in **reducing environmental pollution** and generate relatively cheap and readily available source of energy in **sheepfolds and dairy farms**, as well as in isolated settlements. The gas produced can be used for **space and water heating, cooking, lighting and as RES for electricity production**

INTRODUCTION

- Pollution of the air and water from **municipal, industrial and agricultural operations** is at a very high level and continues to grow. Governments and industries are constantly on the lookout for technologies that will allow **more efficient and cost-effective waste treatment**.

Anaerobic digestion (AD) - technology that can successfully treat the organic fraction of wastes.

When used in a fully-engineered system, AD not only provides pollution prevention, but also allows for **sustainable energy, compost and nutrient recovery**.

As the technology continues to mature, AD is becoming a key method for both **waste reduction and recovery of a renewable fuel and other valuable co-products**.

INTRODUCTION

-Biogas is a mixture of methane (also known as marsh gas or natural gas, CH4) and carbon dioxide, it is a renewable fuel produced from waste treatment.

-AD is basically a simple process carried out in a number of steps that can use almost any organic material as a substrate - it occurs in digestive systems, marshes, rubbish dumps, septic tanks and the Arctic Tundra.

As methane is very hard to compress, its best use is for stationary fuel, rather than mobile fuel. It takes a lot of energy to compress the gas (this energy is usually just wasted), plus there is the hazard of high pressure. A variable volume storage (flexible bag or floating drum are the two main variants) is much easier and cheaper to arrange than high pressure cylinders, regulators and compressors.

BENEFITS RESULTING FROM THE USE OF AD TECHNOLOGY

1) Waste Treatment Benefits

- Natural waste treatment process;
- Requires less land than aerobic composting or landfilling;
- Reduces disposed waste volume and weight to be landfilled;
- Reduces concentrations of leaches.

2) Energy Benefits

- Net energy producing process;
- Generates a high-quality renewable fuel;
- Biogas proven in numerous end-use applications.

BENEFITS RESULTING FROM THE USE OF AD TECHNOLOGY

3) Environmental Benefits

- Significantly reduces carbon dioxide and methane emissions
- Eliminates odors;
- Produces a sanitized compost and nutrient-rich fertilizer;
- Maximizes recycling benefits

4) *Economic Benefits*

ELECTRICAL ENERGY AND BIOGAS

The average expected energy content of pure methane is **9,27 – 11 kWh/m3**; natural gas has an energy content about 10% higher because of added gas liquids like butane.
The particular characteristics of methane, the simplest of the hydrocarbons, make it an excellent fuel for certain uses. With some equipment modifications to account for its lower energy content and other constituent components, biogas can be used in all energy-consuming applications designed for natural gas.

Biogas is commonly burned in an internal combustion engine to generate electricity. Practical experience with small-scale internal combustion engines with a rated capacity of less than **200 kW** indicate an electrical conversion efficiency of less than **25%**. Larger engines can have a greater conversion efficiency. One engine supplier claims to have an engine with an electrical conversion efficiency that averages **38% for engines in the 600-1000 kW range**.

ELECTRICAL ENERGY AND BIOGAS

When biogas is used to produce electricity, there is the added potential for harvesting hot water and steam from the engine's exhaust and cooling systems. Combining hot water and steam recovery with electricity generation may provide an overall conversion efficiency of 80% or more. Biogas is also burned in boilers to produce hot water and steam used for heating and sanitary washing.

OTHER APPLICATIONS OF BIOGAS

Biogas is also successfully compressed for use as an alternative transportation fuel in light- and heavy-duty vehicles. To obtain usable methane, the biogas is scrubbed of its carbon dioxide, hydrogen sulfide, and water. After scrubbing, the technique of fueling with biogas is basically the same as that used for compressed natural gas (CNG) vehicles. It is estimated that worldwide around one million vehicles are now using CNG as a transportation fuel.

BIOGAS AS RENEWABLE SOURCE IN ISOLATED LOCATIONS

The applications of biogas as renewable source of sustainable energy for different isolated locations have been investigated:

1 – for small settlements, where the wastewater and solid waste are dominant for AD

-home use, meaning use of electrical energy-

2 – for farms with food processing facilities such as sheepfolds and small dairies, where manure and food processing residuals are dominant for AD.

-use of energy for hot water and quite small amount of energy for lighting-

BIOGAS AS RENEWABLE SOURCE IN ISOLATED LOCATIONS

Taking into consideration the type of engine for electricity generating, for isolated locations the most appropriate is internal combustion engine for both types of locations.
For the second type – sheepfolds and small dairies, the most appropriate is combined direct (burning) and indirect (electrical energy) use of biogas

BIOGAS AS RENEWABLE SOURCE IN ISOLATED LOCATIONS

For larger farms, depending on the farm capacity, the quantity of waste, the type of energy needed and the possibility of grid connection, the gas turbine for electricity generating may be more recommendable.
An example: the farm with capacity of 500 cows will generate 100 kilowatts of power that is enough for 65 homes.

Effluent from the digester will be processed through a solids separator, with the solids to be composted for commercial nursery use.

The remaining liquid may be disposed (pumped) to the lagoon(s) and later used to fertilizer cropland.

BIOGAS AS RENEWABLE SOURCE IN ISOLATED LOCATIONS

The two pilot projects for building combined sheep manure / food processing wastewater treatment plant have been projected in the frame of RISE Project FP6 INCO CT-2004-509161 for one isolated sheepfold consisting of 3500 sheep on Korab (Fezlievo Bachilo with 2000 and Belancha with 1500 sheep) and for one isolated settlement with several households (Kichinica, near Mavrovo).

BIOGAS AS RENEWABLE SOURCE IN ISOLATED LOCATIONS

TABLES: ESTIMATED MONTHLY WASTEWATER QUANTITIES, BIOGAS CAPACITY AND CALORIFIC VALUE OF BIOGAS FOR:

I. LOCATION KICHINICA

II. LOCATION BELANCHA

III. FEZLIEVO BACHILO

THANK YOU FOR YOUR ATTENTION

LABORATORY FOR ENERGY POLICY

Renewable Energy in Western Region of China – Potentials and Support Policy

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Energy Research Institute, National Development and Reform Commision, Beijing, China
Andrej F. Gubina,
University of Ljubljana, Faculty of Electrical Engineering, Ljubljana, Slovenia

LABORATORY FOR ENERGY POLICY

Content

- Overview of the development in the renewable energy sources (RES) in the Western region of China.
- RES potentials of Western China,
- Recommendations for RES policy for the region,

LABORATORY FOR ENERGY POLICY

Renewable Energy in China

- China is a developing country
  - No GHG mitigation obligations by Kyoto Protocol.
  - Chinese GHG emission levels are increasing rapidly
    - China’s size and its quick economy growth in the recent two decades,,
  - GHG reduction is of great importance.
- Promoting Renewable Energy is an important measure for China to decrease Greenhouse Gas emission and to establish environment friendly society.
- China is taking steps to increase the share of RES.
  - Chinese Government adopted “Renewable Energy Law” in Feb. 28, 2005
  - “Renewable Energy Law” came to force in Jan.1,2006.

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Matched Regulations

- The bylaws providing for regulations and policy for RE law have been established.
  - Adoption of national implementation strategy entitled “Temporary methods for electricity price and cost allocation management for renewable energy”
  - The proposal of these Temporary methods is to stimulate power generation from renewable energy.
- To promote RE in China the successful International Experience will be used.
- The proposed instruments include:
  - Feed-in Tariffs (especially suitable for Western Region China)
  - Concession/Tendering: to decrease the cost of Renewable energy
  - PBF (Public Benefit Fund), combined with Feed-in Tariffs.

Western Region of China

- The potentials of renewable energy have been investigated in Western Region of China (WRC)
- WRC includes 12 provinces and one municipality directly under the Central Government.
  - Chong Qing,
  - Gansu,
  - GuangXi.
  - Guizhou,
  - Inner Mongolia,
  - Ningxia,
  - Shanxi,
  - Qinghai,
  - Sichuan,
  - Tibet,
  - Xinjiang,
  - Yunnan.

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Map of WRC

WRC : Area and Population

- The total area of WRC is 6.85 Million km2, occupying 71 % of China.
- By the year 2005, the total population of WRC was 369.866 million, some 28.29 % of China population.
- GDP Value of WRC in 2005
  - GDP: 3,317.255 billion Yuan (RMB), accounting for 16.98 % of China mainland GDP.
  - GDP per capita: only 8,968.79 RMB, some 59.97 % of the average level of China.
  - Big differences in GDP:
    - Guizhou, below 300$,
    - Shanghai, more than 4,000$.

Poor income of farmers in WRC

Geographical Conditions of WRC

- Vast expanses of land and beautiful scenery in WRC,
- Steep mountains and torrential rivers occupy most of the area, such as Himalayas, Pamir Mountain, Nujiang River and west Yunnan Rivers.
- Arable land is scarce and poorly inhabitable.

- Snow Mountain in Tibet

LABORATORY FOR ENERGY POLICY

Brahmaputra River

Renewable Potentials: Hydro Power

- WRC has plenty of renewable energy resources, especially hydro, solar, wind and geothermal energy.
- Hydropower: The economically viable hydropower resources in China amount to 378.5 GW, 81.5 % of which is in WRC. South-West of China is the most concentrated area for small scale hydropower resources, amounting to 67.8 % resources of China.

	Theoret. Reserves (GW)	**Exploit. Amount (GW)**	**Installed Capacity (GW)**	**Electricity Generat. (TWh)**
China Total	163.47	87.006	24.852	79.982
WG Total	118.602	53.033	10.337	38.232
Inner Mongolia	2.622	0.676	0.0484	0.08
Guangxi	6.51	2.717	1.359	4.273
Chongqing		2.00	0.801	3.233
Sichuang	12.06	6.842	3.282	13.149
Guizou	6.102	3.201	0.908	3.324
Yunnan	23.23	10.507	2.190	9.211
Tibet	40.00	16.219	0.159	0.183
Shanxi	6.448	2.167	0.428	0.952
Gansu	5.787	1.381	0.333	1.179
Qinghai	6.796	2.618	0.214	0.713
Ningxia	0.044	0.023	0.0032	0.008
Xinjiang	9.003	4.68	0.608	1.927

Solar Energy

- China has favorable solar conditions
  - The annual solar irradiance is between 3.3 - 8.4 GJ/m2.
  - In over 2/3 of China solar irradiance is above 5.8 GJ/m2 p.a.
  - The annual sunlight time is greater than 2000 hours.

Regions	Annual Sunlight (hours)	Annual irradiance amount (therm /cm^2)
West Tibet, South East of Xinjiang, West Qinghai, West Gansu	2800-3300	160-200
South-East Tibet, South of Xinjiang, East Qinghai, South of Ningxia, Middle part of Gansu, Inner Mongolia, North of Shanxi, North-WRC of Hebei	3000-3200	140-160
North of Xinjiang, South-East of Gansu, South Shanxi, North Shanxi, South-East of Hebei, Shandong, Henan, Jilin, Liaoning, Yunnan, South of Guangdong, South of Fujian, North of Jiangsu, North of Anhui	2200-3000	120-140
Hunan, Guangxi, Jiangxi, Zhejiang, Hubei, North of Fuujian, North of Guangdong, South of Shanxi, South of Jiangsu, South of Anhui, Heilongjiang	1400-2200	100-120
Sichuan, Guizhou	1000-1400	80-100

Wind Energy

- China has rich wind resources.
- Theoretical wind potential at 10 m above the surface is estimated at 3,226 GW

- Technically exploitable amount is 253 GW.

Province	Wind Resource (GW)
Inner Mongolia	61.78
Xinjiang	34.33
Gansu	11.43

Geothermal Energy in China

- Geothermal resources are classified by temperature:
  - High temperature (t ≥ 1500C),
  - Middle temperature (900C ≤ T < 1500C) and
  - Low temperature (600C ≤ T < 900C, 400C ≤ T < 600C and 250C ≤ T < 400C).
- Most of the geothermal energy in China is middle- and low temperature resource.
- Proven geothermal resources are 9.251×10^{19}J/a.

Geothermal Power Generation in Tibet

- Most of the high temperature resources are distributed in Himalayas geothermal region of Tibet.
- Tibet is leading in geothermal applications of China. The total installed capacity of geothermal power plants in Tibet is 28 MW.

- Yang Bajing Geothermal Power Station

RES Support and Development Barriers

- To increase the share of renewables, a comprehensive regulatory framework is needed.
- EU: national targets for the consumption of RES-E
  - Choice of preferred support mechanism.
  - Mechanisms have mixed success in RES-E promotion
    - Effectiveness, cost efficiency, compatibility with the internal market, and the ability to develop different technologies.
- The main objectives of support mechanisms were:
  - Removal of economic barriers by introducing financial support mechanisms and promotion schemes, and
  - Mitigation of non-economic barriers,
    - e.g. administrative barriers, market imperfections, technical obstacles and grid restrictions.
- In deployment of RES-E, two aspects are important:
  - Sufficient financial support and
  - Reduction of barriers to RES development.

Barriers to RES Development in China

- Compared to East Region and Middle Region of China, West Region of China (WRC) is the poorest region of China.
- Most people in WRC live in the countryside
  - Unfavorable conditions for economic development and energy supply.

Barriers Analysis

- Nearly 30 million people can't access electricity in China, mostly in WRC, especially in Yunnan, Sichuan, Guangxi and Chongqing.
- Big gap between the demand for electricity and the purchase ability in no-electricity area of WRC.
  - Road construction is decreasing the meadow in Tibet

Financing Problems

- Due to low energy prices,
  - the rate of return on investment is very low,
  - decreasing the investment interest from local government, industry groups and private equity.
- For renewable energy projects there is no equal investment system, which is customary to conventional energy projects.

Suggested Support Instruments for WRC

- The steps to set up RES support policy that need to be investigated include:
  - Setting of the goals of renewable energy development strategy,
  - Definition of methods, financial instruments and activities for RES promotion,
  - Definition of responsibilities,
  - Setup of a process for monitoring and evaluation of progress towards targets, and
  - Policy review/improvement process.
- China should take the international experience as a reference to promote renewable energy development.

Financing of RES Projects in Tibet

- In the future years, hydropower, geothermal energy and solar energy projects will constitute the main renewable construction projects of Tibet.
- The complex geological features and difficult transport conditions for fossil fuel
  - increased the costs of conventional energy projects and
  - decreased the gap between the construction costs of RES and conventional energy sources.
- This is why RES projects have better opportunities in Tibet.

LABORATORY FOR ENERGY POLICY

Solar, wind, geothermal projects in Tibet

- Because of its dispersed nature, wind power and photovoltaic projects are more economical than construction of diesel oil power plant and extending electricity grid.
- Solar PV and wind power projects:
  - government investment is the main financing channel in Tibet.
- Geothermal thermal, biomass and wind projects:
  - CDM (Clean Development Mechanism) should be introduced and used in Tibet.

Wind and Biomass Projects

- Compared to other CDM project, wind projects in Tibet can get approved more easily,
  - Methodology for wind power generation projects has been approved by the Executive Board of UNFCC.
- Tibet also has a lot of storage grain.
  - Ideal resource to covert into ethanol.
  - This can provide fuel for transportation and to substitute the petroleum consumption in Tibet.

Promoting CDM projects in Tibet

- The geothermal energy has been widely used for heating, vegetable growing, recreational facilities, health protection and tourist industry.

The geothermal energy

- Market potentials for geothermal energy are far from exhausted. You are welcome to see for yourselves!

Engineering and Naval Architecture,
University of Zagreb

Croatia's RES potential for Decentralized Power Production

Advanced Decentralised Energy Generation Systems in Western Balkans (ADEG)

Sixth Framework Programme (FP6)

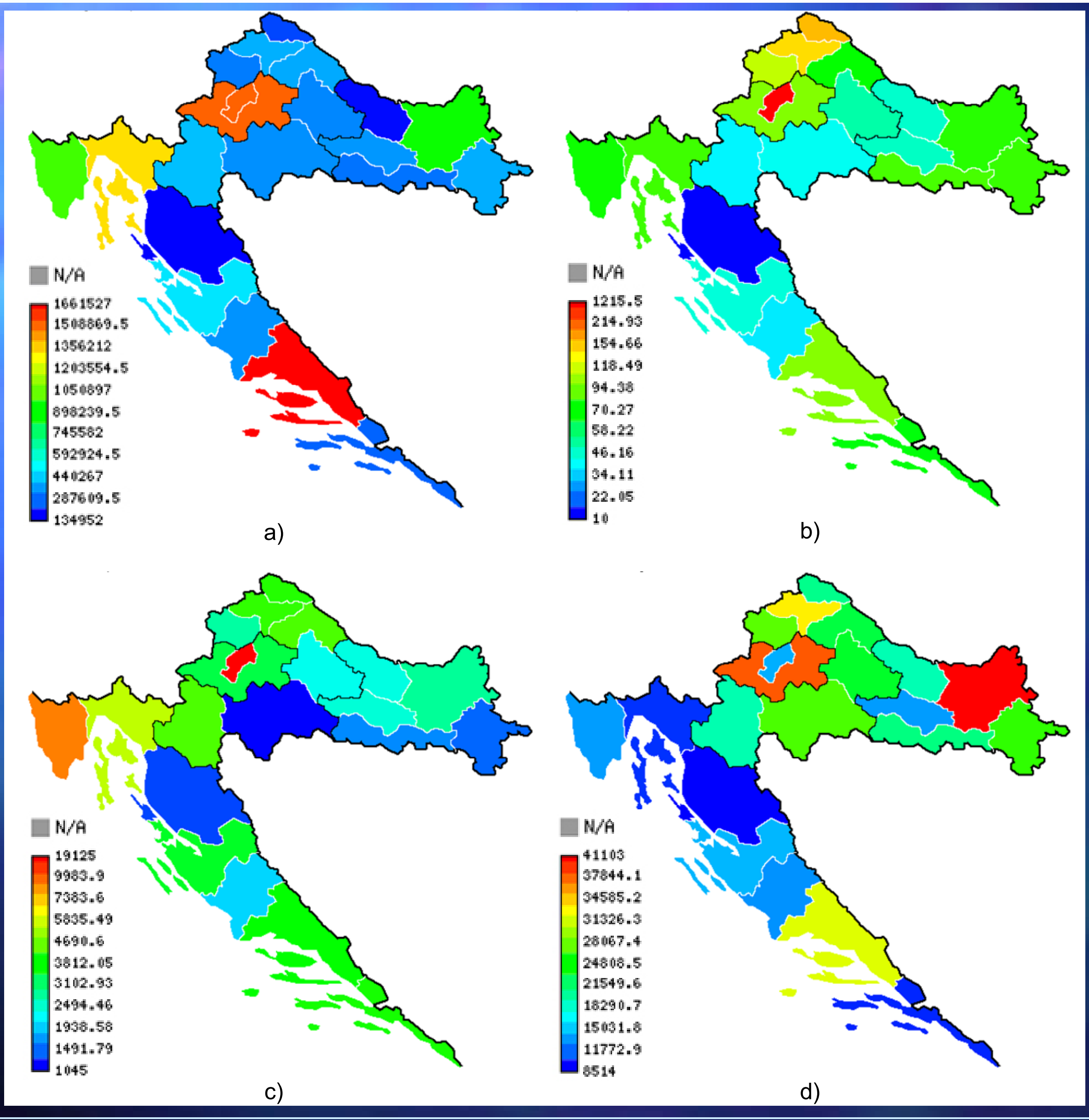
Doc. dr.sc. Daniel R. Schneider

Prof. dr.sc. Željko Bogdan, Prof. dr.sc. Neven Duić, dipl.ing. Marko Ban

Introduction

- Croatia, now for a decade already, has been experiencing increased electricity consumption, predicted to be approximately 0.5 TWh annually.
- Croatian power system is now stretched to the limit of its generating capacity and the construction of new facilities is imperative.
- South-East Europe region plays an important role not only as a transit centre for gas and electricity as well as for Russian and Caspian Sea region oil exports → the Energy Community of SEE.
- Removal of geographical constraints on the delivery of power supplies, gradual liberalization of energy markets (adoption of the new EU Directives 2003/54/EC and 2003/55/EC on the Internal Market in Electricity and Natural Gas),
  privatization of the utility companies and new environmental legislation → new factors in conventional power production systems in Croatia.
- Energy supply security, climate change mitigation and economic competitiveness → Decentralized Energy Production based on RES.

Map of DEG-RES potential in Croatia



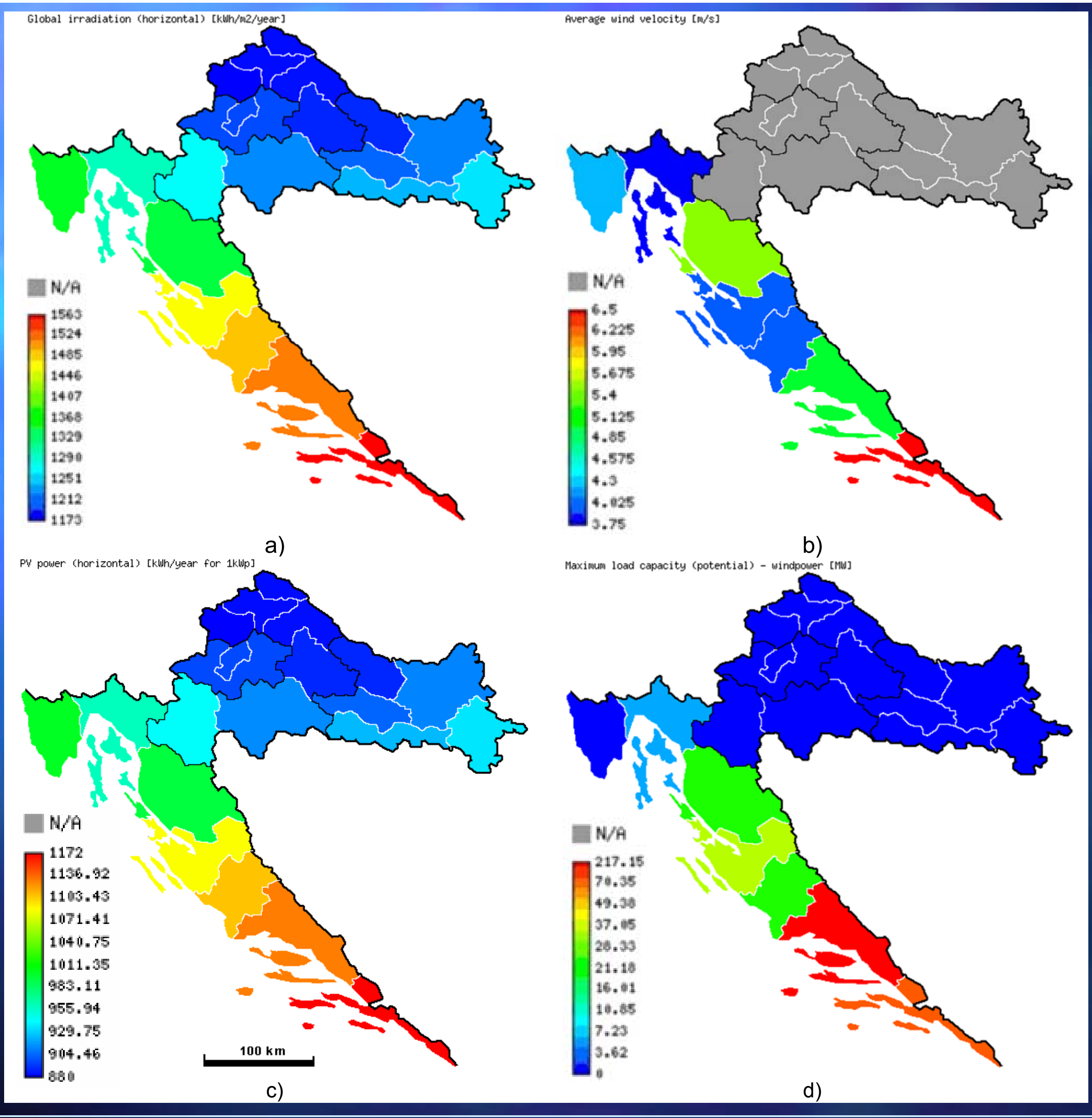
a) Total electricity consumption (MWh)

b) Population density (people/km^2)

c) Nominal GDP per capita ($US) in 2003

d) Total number of rural (agricultural) dwellings

Solar and wind power



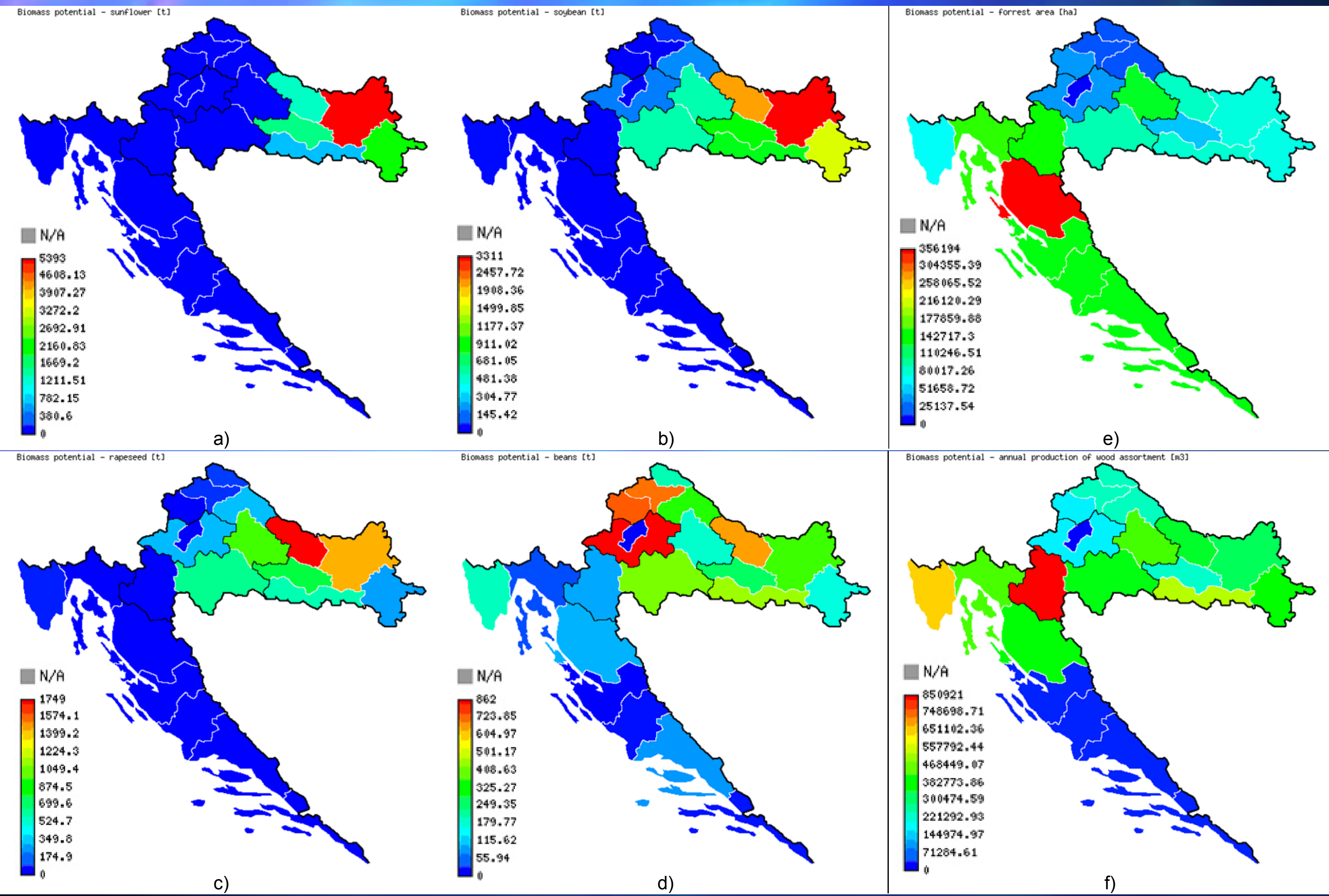
a) Global horizontal irradiation ($kWh/m^2/year$)

b) Annual average wind velocity (m/s)

c) PV power (horizontal) (kWh/year for 1 kW_p)

d) Maximum load capacity of potential wind facilities (MW)

Biomass potential



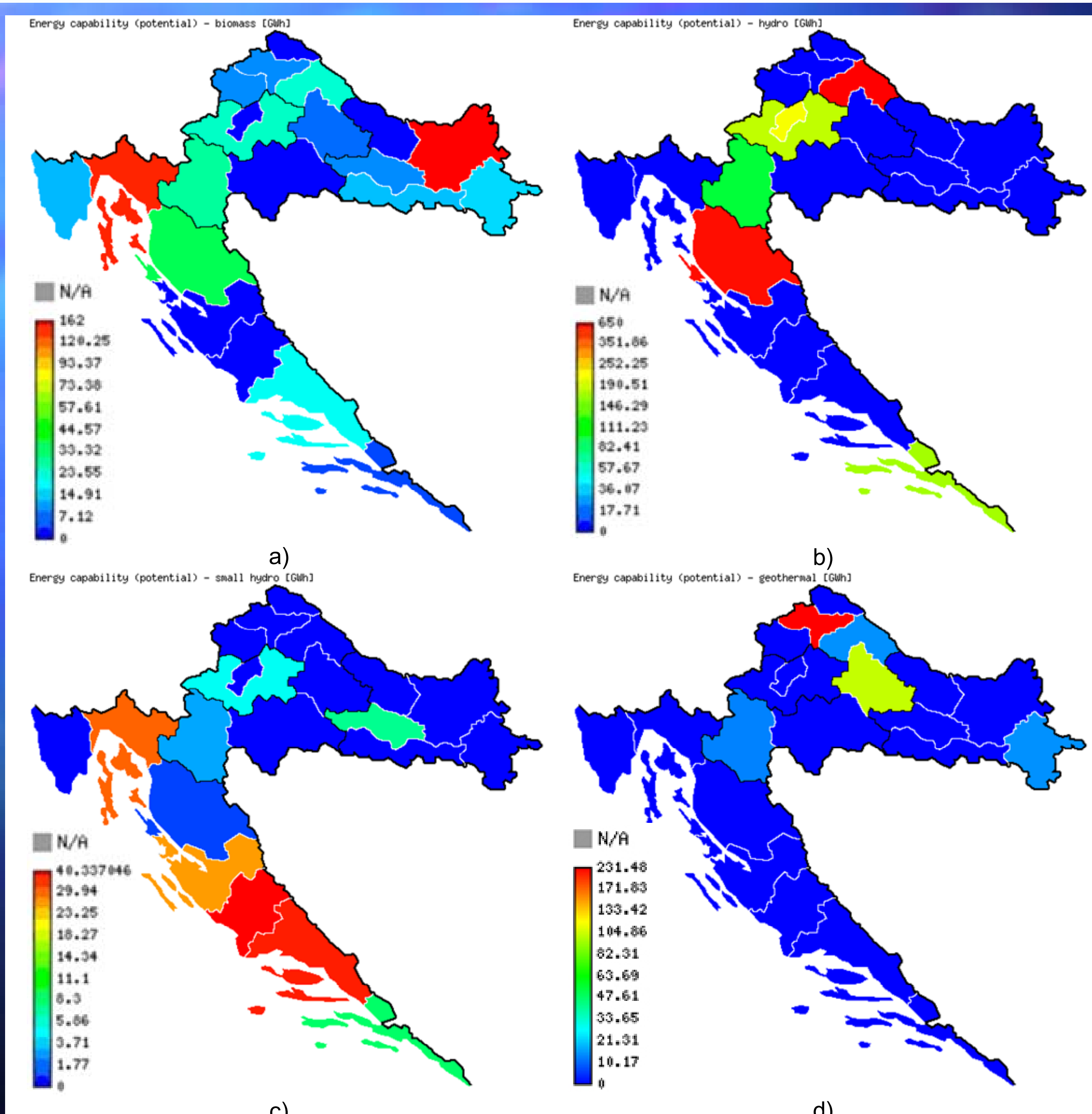
Agricultural biomass potential (t):

a) sunflower
b) soybean
c) rapeseed
d) beans

Woody biomass potential:

e) forest area (ha)
f) Annual production of wood assortment (logs, firewood, wood residue) (m^3).

Biomass, hydro and geothermal energy



Energy capability of potential facilities (GWh):

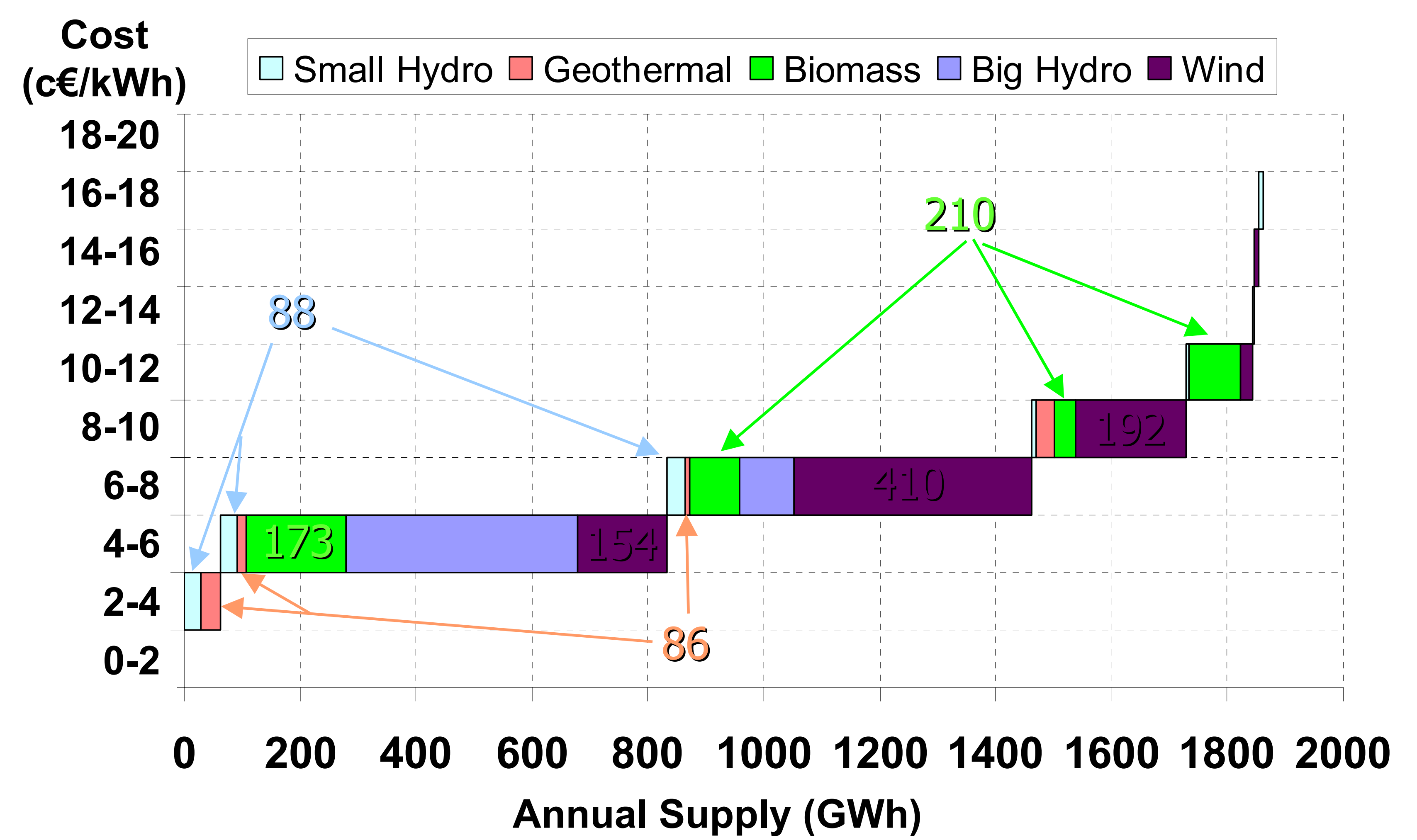
a) biomass

b) big hydro power plants

c) small hydro power plants (<10 MW)

d) geothermal facilities

RES cost – supply curve for 2010



Cost of electricity (c€/kWh) with the energy produced (annual GWh) from a specific energy source (wind, biomass, geothermal and hydro)

Conclusion

The DEG based on RES in Croatia will find its niche easier for users:

- that will produce electricity (and heat) for their own needs (like agriculture, wood and food processing industry) → they could control and reduce their costs for energy and achieve some sort of energy independence (e.g. applying cogeneration plant that uses biomass).
- located in remote rural areas where there is no electricity network or the network capacity is insufficient (off-grid applications).

Examples of potential application of DEG based on RES in Croatia include:

- **Tourist facilities** that are situated in remote isolated areas on islands and in mountains where there is no possibility of network connection or it would be too expensive to connect or is not permitted by environmental laws (e.g. in national parks and nature reserves): hotels and apartment houses, restaurants, auto-camps, nautical marinas, sports and entertainment centers, mountain houses/chalets, facilities in rural and hunting tourism;
- Cooling facilities for temporary storage of fish, meat etc., field ambulances (for electrical medical appliances and cooling of medicines), electrical fences for livestock ranching, autonomous electrical livestock/game feeders and water-troughs, for lightning and operation of agricultural facilities, hatcheries;
- Irrigation in deltas of rivers, water desalination on islands;

Conclusion

- Telecommunication (base) stations, meteorological stations, lighthouses, road signs, public lightning, different autonomous monitoring systems (pollutant emission monitoring, forest fire protection, technical protection of individual facilities etc.);
- Households (permanent and weekend settlements) in isolated and rural areas (mountainous and coastal/island regions);
- Saw mills situated near small rivers, in which power from the small hydro power plants could be used;
- Hybrid combination of solar systems or wind turbines with LPG or diesel aggregates could help solve the problem of energy infrastructure on islands and other remote locations (region of Adriatic Croatia) → development of traditional island activities with the engagement of local resources and workforce, which in turn, could reduce depopulation of islands.

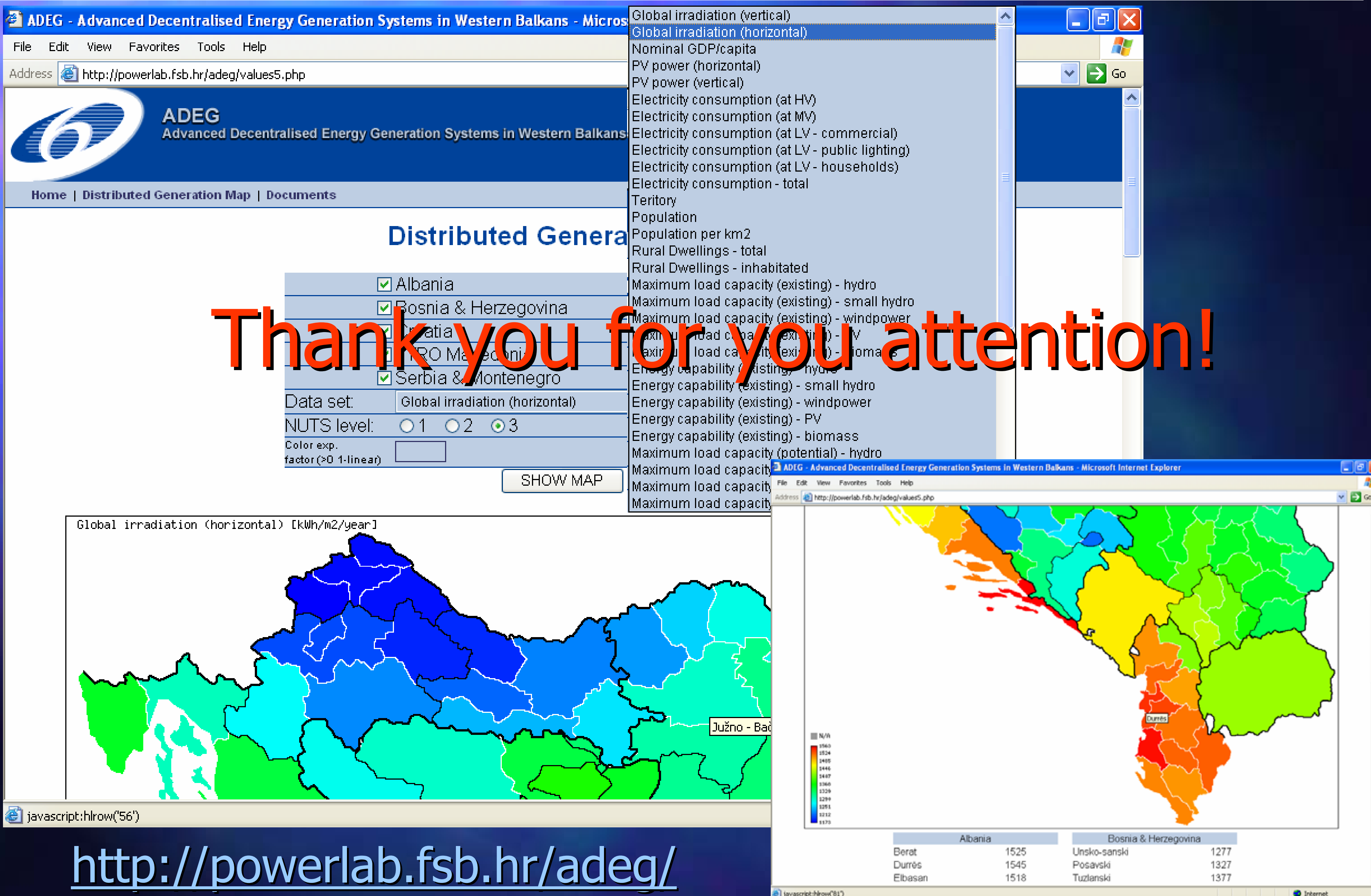
Among all DEG systems based on RES that were analyzed, the most profitable ones are:

- technologically mature **wind power** systems,
- facilities that produce power from **biomass**.

1367 GWh in 2010

Min. 5.8% - 1100 GWh in 2010

ADEG database



Thank you for you attention!

http://powerlab.fsb.hr/adeg/

Javna agencija RS za energijo

Gorazd Škerbinek, Andrej Špec

ELECTRICITY FROM RENEWABLE SOURCES - A NEW OPPORTUNITY FOR COMPANIES FROM SEE

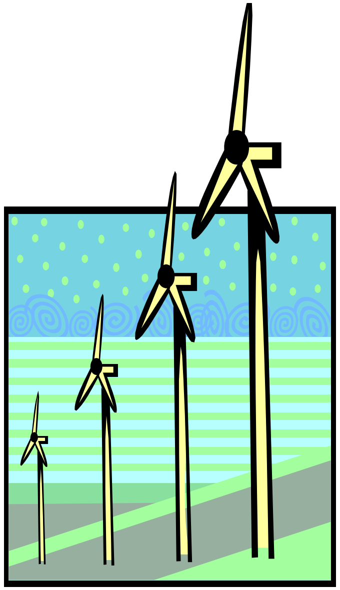
6th Balkan Power Conference

Ohrid, 2 June 2006

Presentation outline

1. Guarantees of Origin (GoOs) and Tradable Green Certificates (TGCs),
2. RECS certificates
3. Use of RECS certificates in SEE countries

Electricity from renewables – two markets

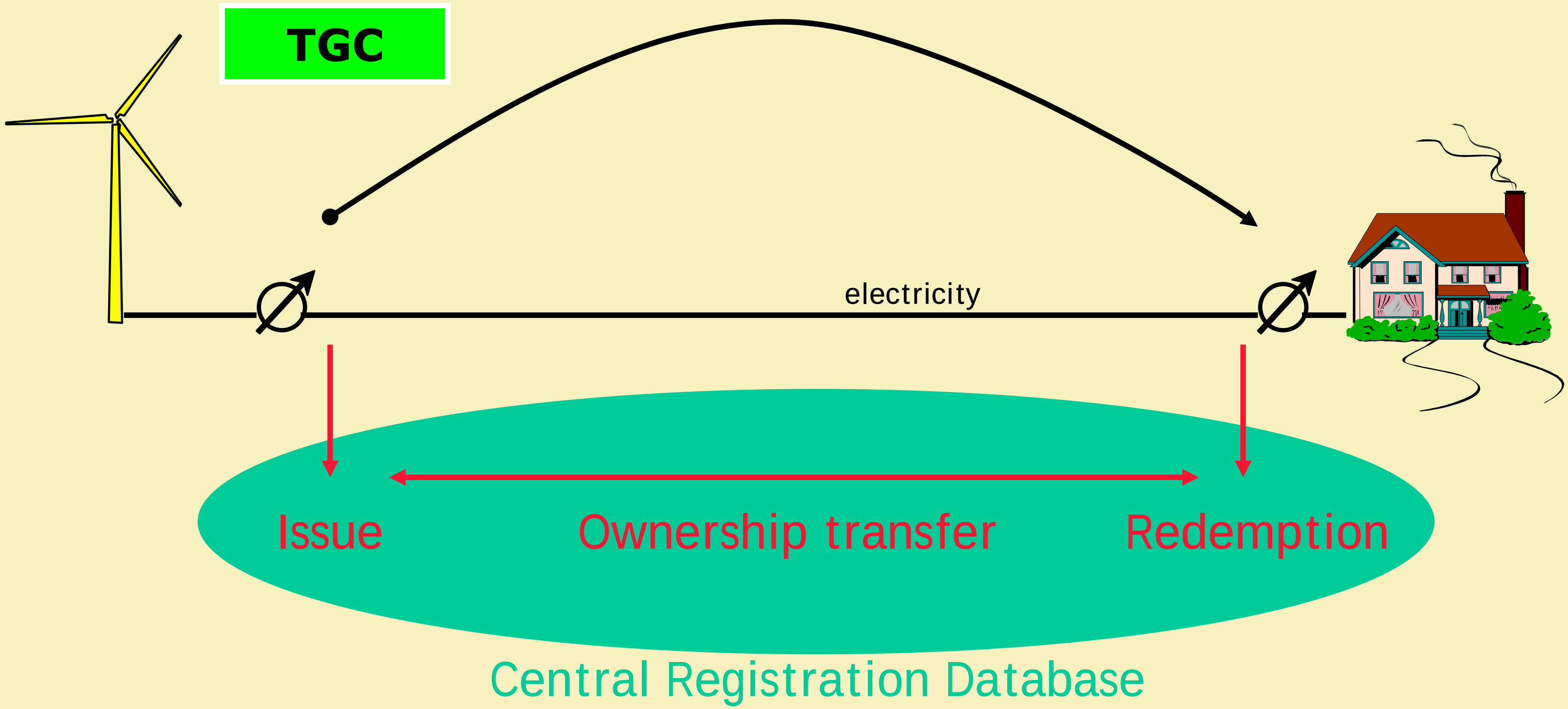


Environmental added value - certificates = **Certificate market**

Electricity – kWh = **Energy market**

Life Cycle of a TGC

3. REDEMPTION – Represents an evidence that added value of electricity due to its production from renewables was used.

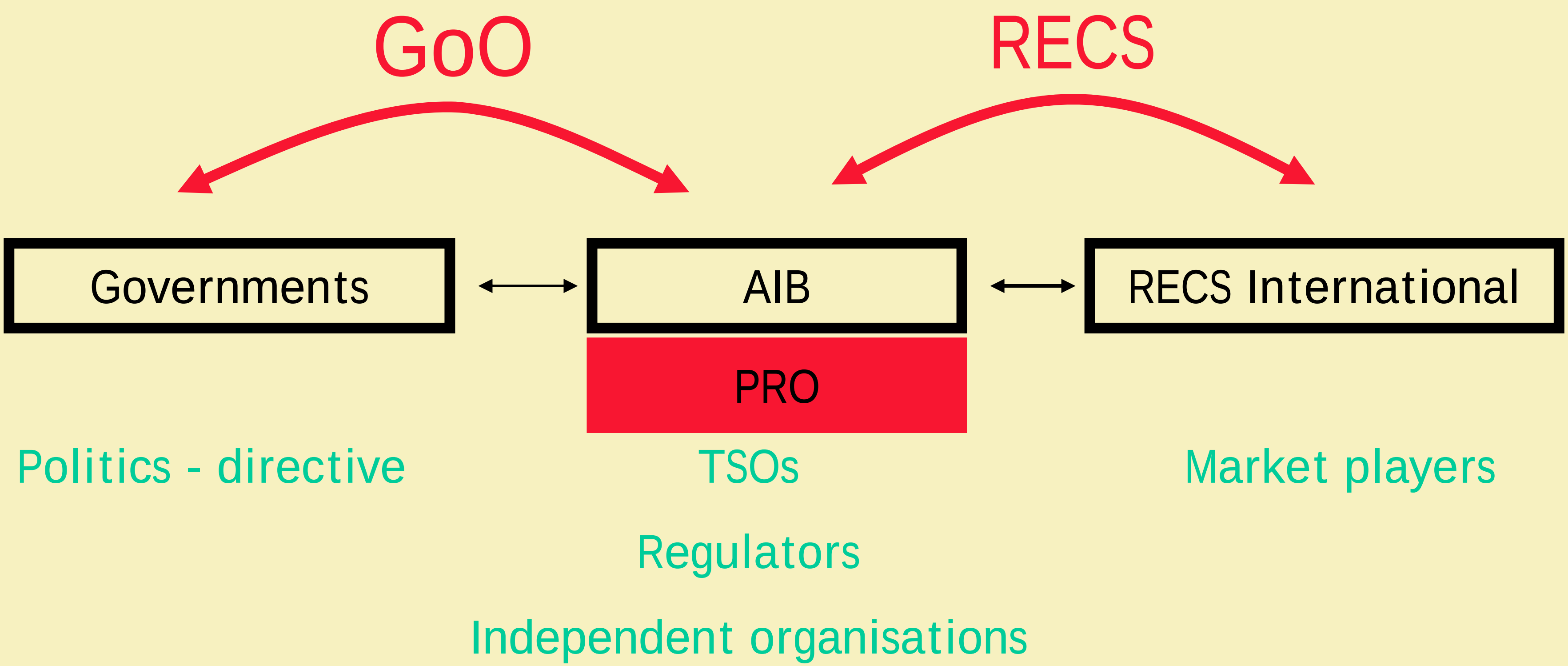


RECS system of Tradable Green Certificates

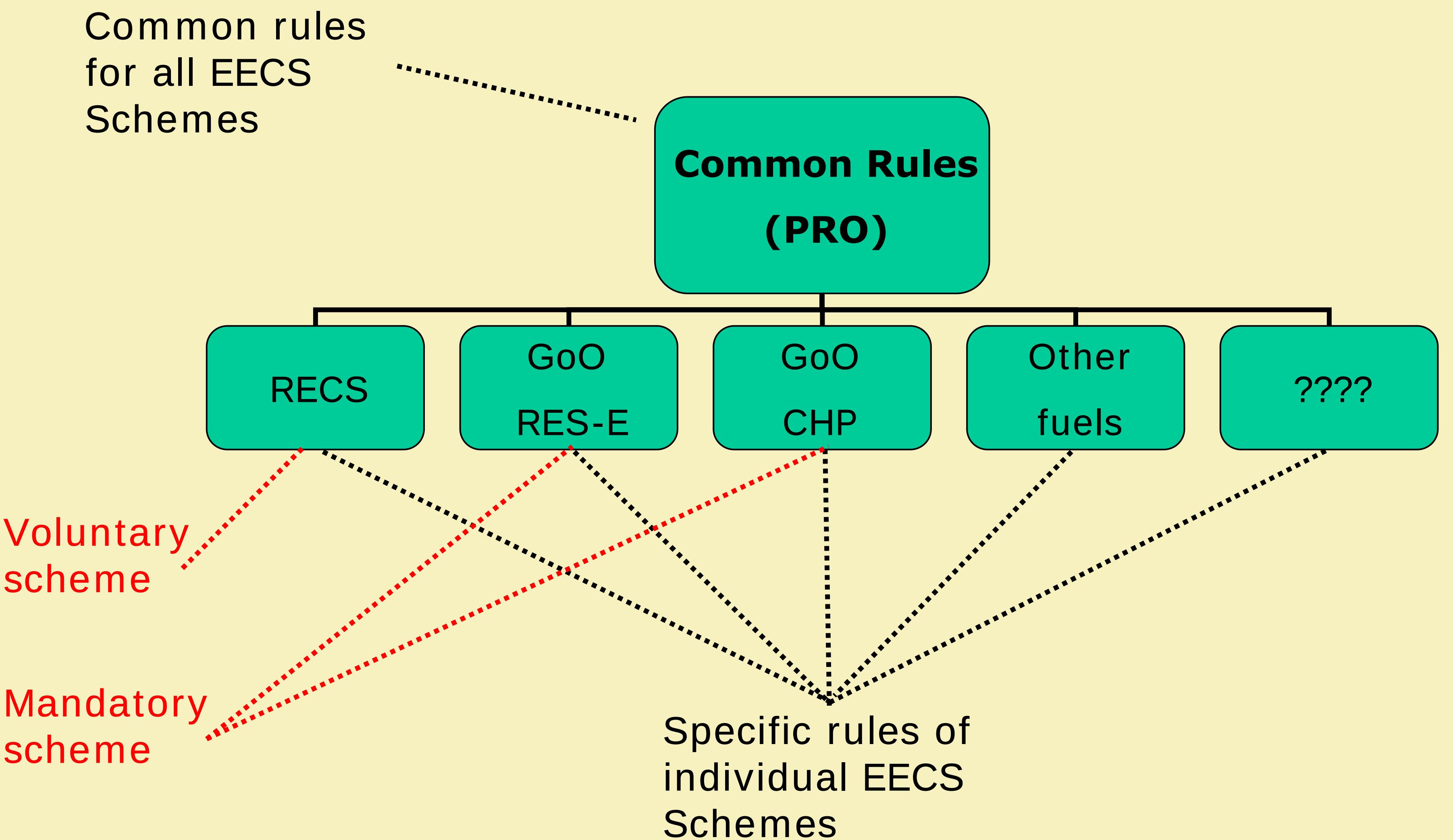
- The most widespread TGC system in Europe with well defined rules;
- Started as a voluntary initiative to create a uniform system for cross-border certificate trading in 2001;
- RECS International - Association of traders;
- AIB – Association of Issuing Bodies;
- More than 100 market players trade certificates in over 14 countries in Europe;
- Strict rules for accreditation and auditing of generation plants – prevention of multiple issuing;
- Each IB is responsible for functioning of the system in its domain.
- AIB is responsible for developing the system and for preparing common rules – EECS PRO.

RELATION BETEEN RECS AND GoO

- GoOs are by their nature a form of certificates that can be used for the same purpose as RECS.
- Requirements of RECS are stricter than the basic requirements for GoOs.
- RECS – luxury form of GoO.



The concept of EECS



Use of TGCs and GoOs

- Green electricity products :
  - Reliable and trustworthy trademarks, supported by TGCs or GoGs;
- Obligatory fuel mix disclosure for suppliers:
  - Possibility of using GoO central registration database;
- Monitoring the fulfilment of prescribed RES-E quotas:
  - State authorities can prescribe minimum RES-E quotas for suppliers. They have to redeem adequate number of TGCs or GoO;
- Meeting of national indicative targets of RES-E:
  - Only after 2010. Adequate agreement between the countries will be needed;
- Implementation of certificate based RES-E support systems;
- Export of green electricity;
  - Currently the most promising option for SEE countries.

Possibilities for SEE countries

- Large RES-E potential in the majority of SEE countries;
- Markets in most SEE countries will in the next years be developing and demand for RES-E will not be high;
- In some EU markets there is constant demand for RES-E;
- Energy Community Treaty: RES-E directive will be implemented, although the date is yet unknown;
- The introduction of GoO system in SEE will probably not happen in the very near future;
- Possible fast and reliable solution for the interim period:

INTRODUCTION OF RECS SYSTEM IN SEE COUNTRIES

Option 1 (establishing own RECS system):

- Naming of Issuing Body for a SEE country;
- Finding of all necessary supporting agents, such as Production Registrars and Auditing Bodies, by the IB;
- Establishing of Central Registration Database;
- Drafting of the Domain Protocol;
- Application for the membership in AIB;
- Start of certificate issuing only after becoming a full AIB member and after the approval of the Domain Protocol by the AIB General Meeting.

According to the Slovenian experiences this process lasts at least one year.

Option 2 (joining already established domain):

- Decision to join a certain domain with established Issuing Body;
- Change of the Domain Protocol of that domain is needed (at least the definition of the domain);
- Start of certificate issuing only after approval of the modified Domain Protocol by the AIB General Meeting.

Much faster and probably cheaper solution. It could be finished in a few months.

Energy Agency of the Republic of Slovenia as IB for Slovenia is ready to take the role of IB for any country willing to join RECS system.

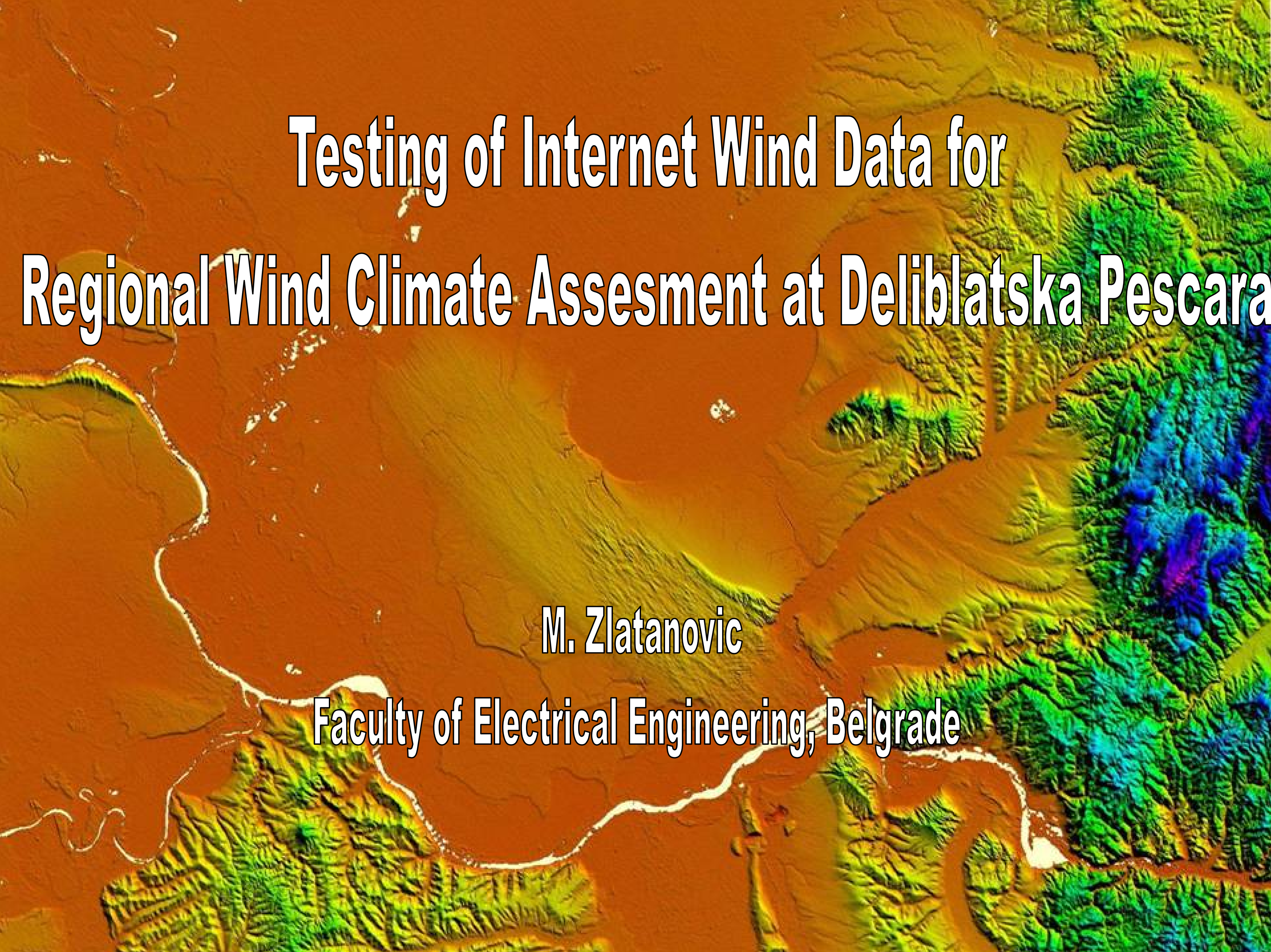
Contact information

Energy Agency of the Republic of Slovenia
Strossmayerjeva ulica 30
SI-2000 Maribor
Slovenia
Phone: +386 2 234 03 00
Fax: +386 2 234 03 20
Web pages: http://www.agen-rs.si/
E-mail: recs@agen-rs.si

Javna agencija RS za energijo

Thank you for your attention !

Strossmayerjeva 30, 2000 Maribor	p. p. 1579
Telefon: [02] 234 03 00	Telefaks: [02] 234 03 20
www.agen-rs.si	info@agen-rs.si



Testing of Internet Wind Data for Regional Wind Climate Assesment at Deliblatska Pescara

M. Zlatanovic

Faculty of Electrical Engineering, Belgrade

Planning of wind potential resources exploatation

- no wind atlas of Serbia exists
- the existing publications are not complete

wind properties based on metstation data

1. Modeling of met stations
2. validation of met database

Metstation modeling

- position and quality of instruments
- calibration
- orography
- roughness
- obstacles
- staff

met database validation

sources

-national meteorological organizations

-metstations

-airport stations

-international synoptis network

-internet data

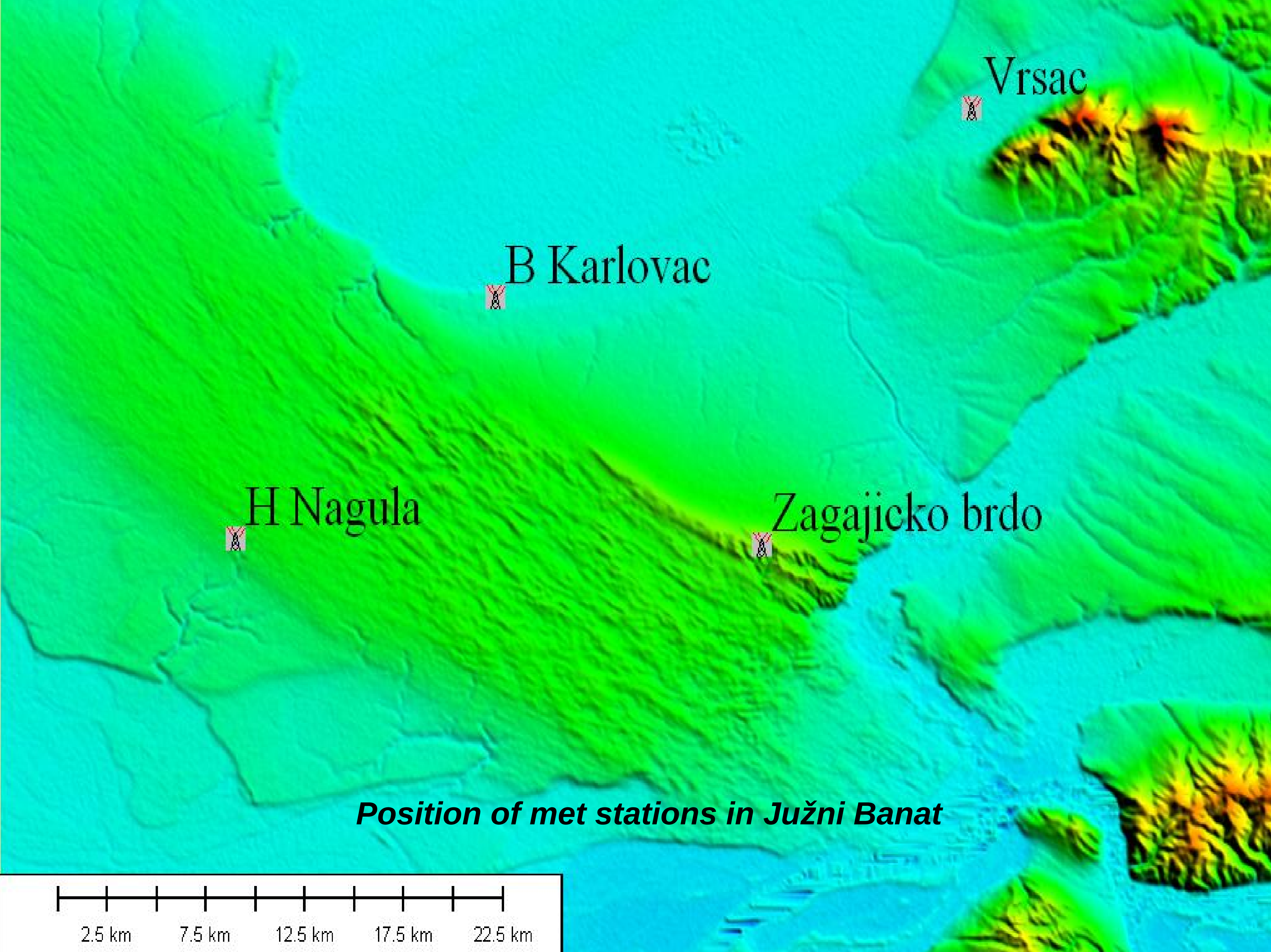
Measurements

-land

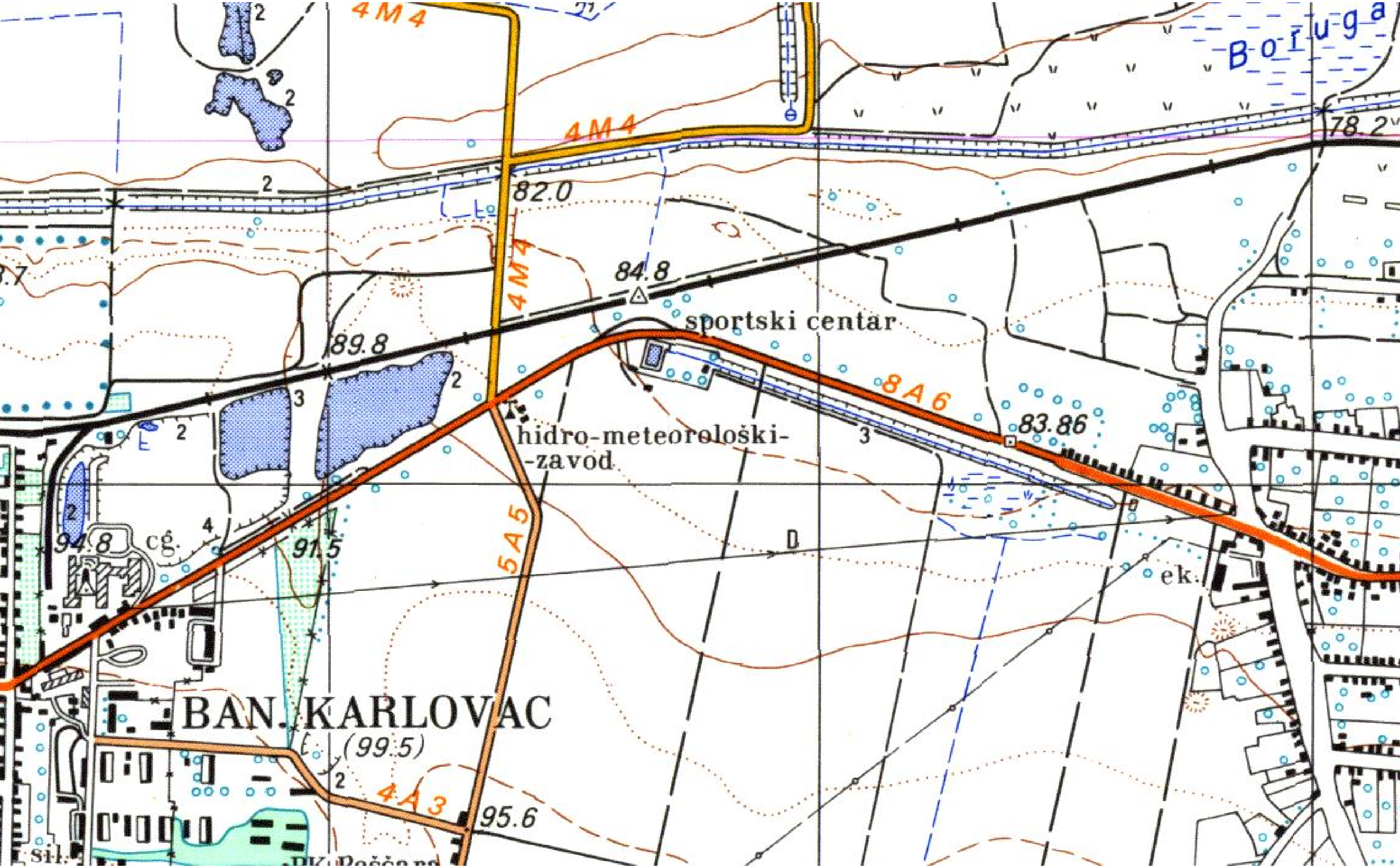
-satellite

Satellite measurements not satisfactory

Fig 1. Principal met station locations in Serbia



Position of met stations in Južni Banat

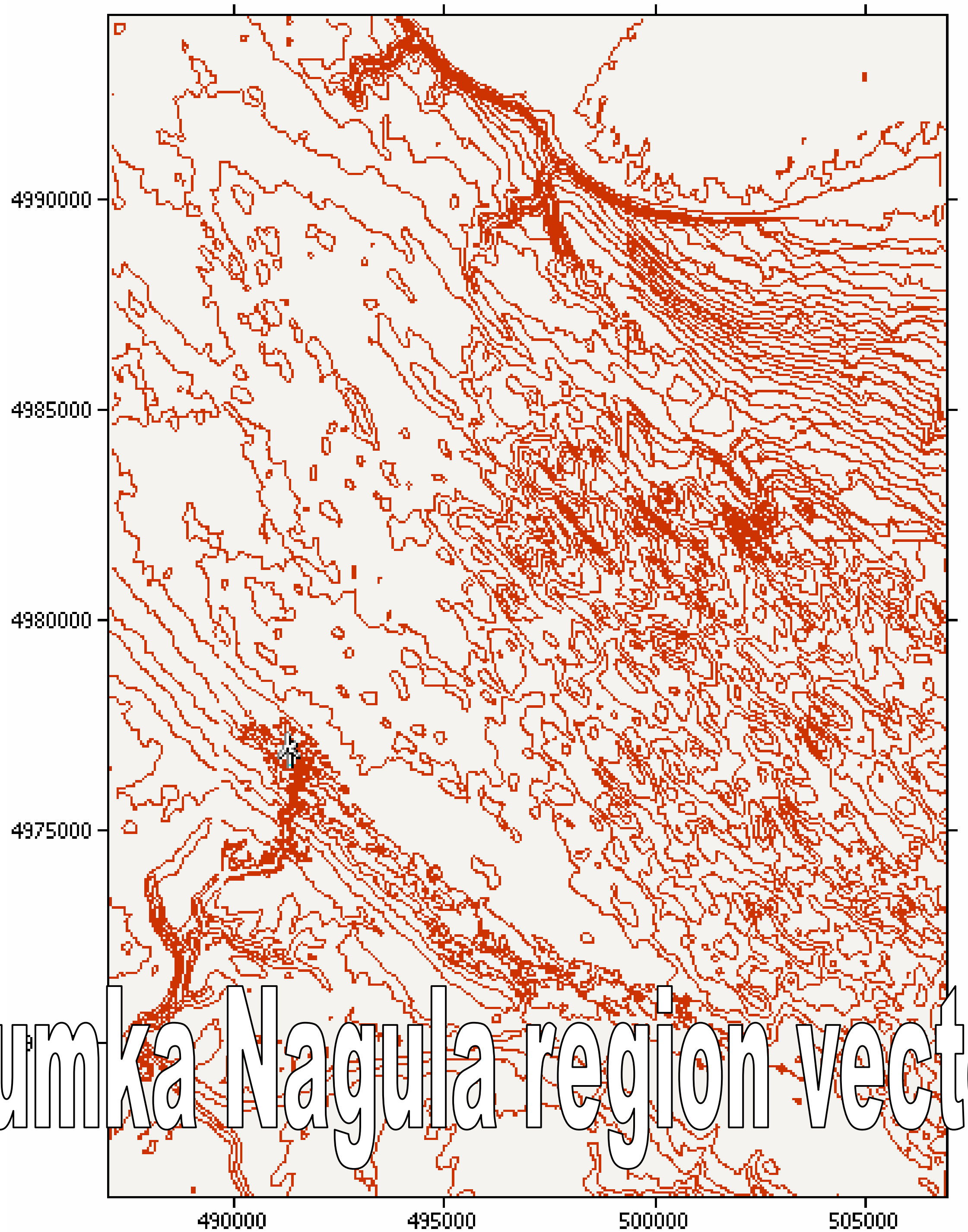


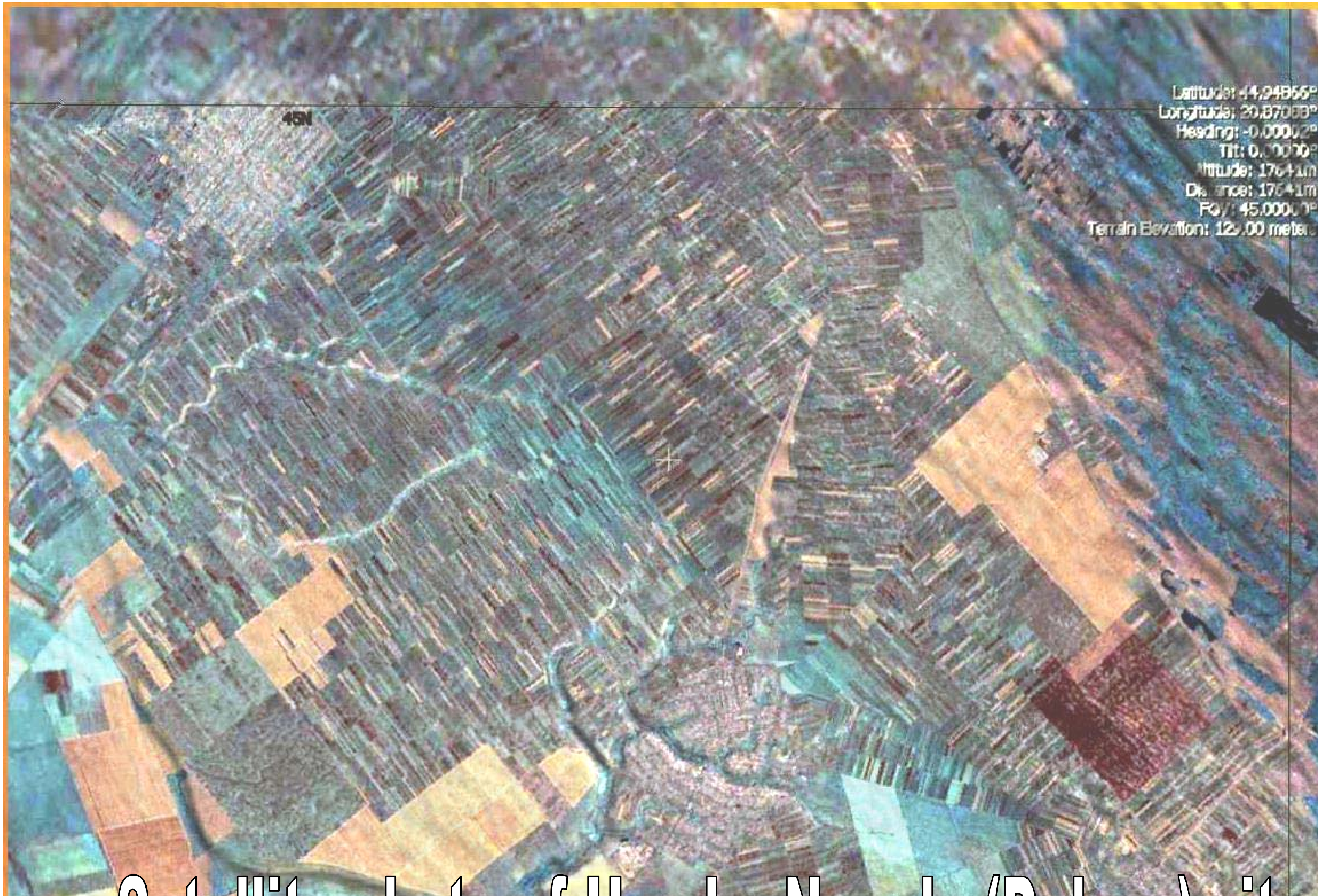
Map around Banatski Karlovac met station

Met Station Banatski Karlovac

Wind mast at Dolovo

Humka Nagula region vector map





Satellite photo of Humka Nagula (Dolovo) site

Reference database - wind measurement mast

Databases

- metstation ordered data
- metstation normal rounded-off data
- internet website data

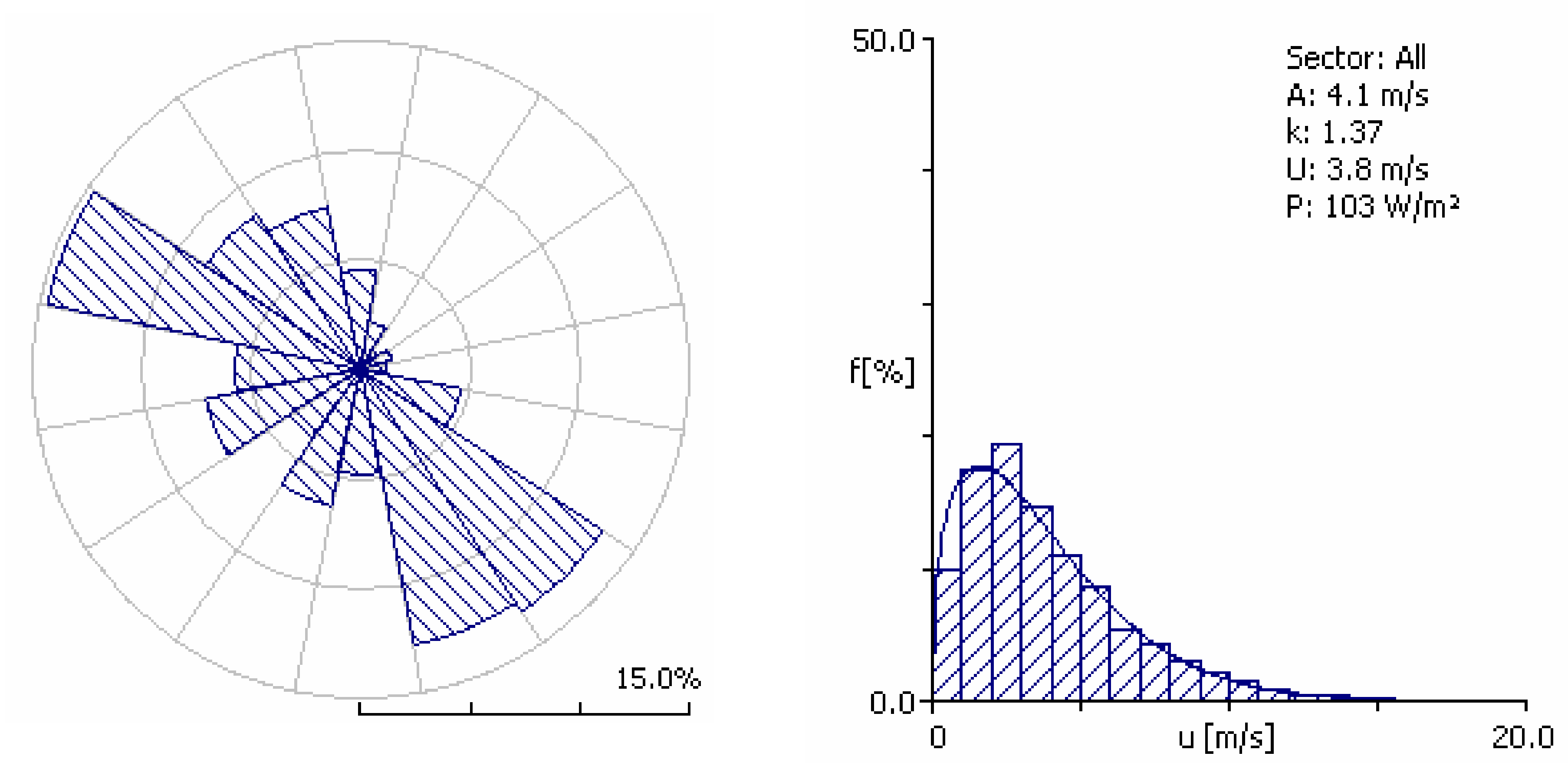
Table I - model testing

March 2005 self prediction at measurement mast

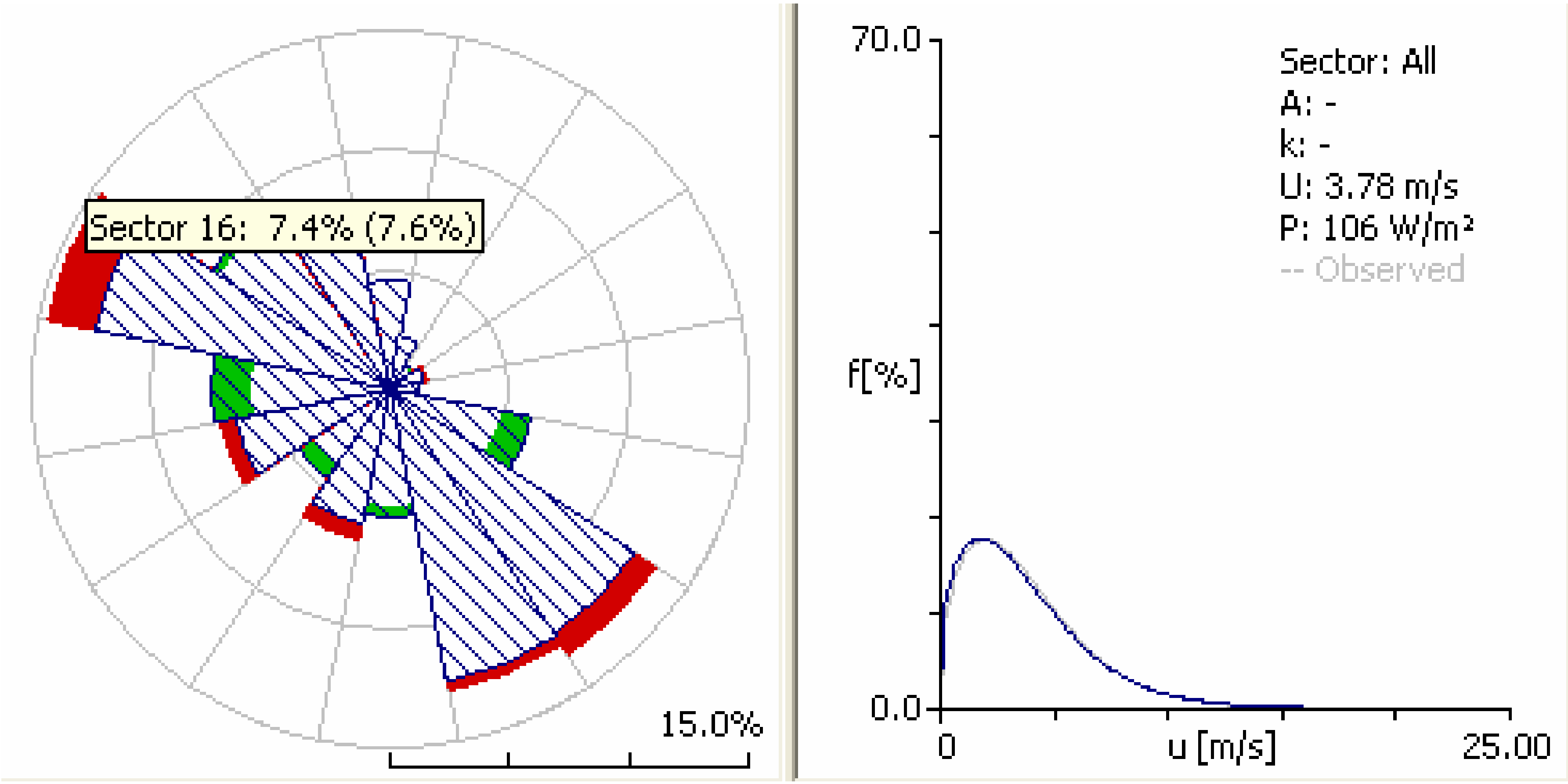
Wind mast data 40 m			
	Weibull fit	Combined	Discrepancy
Mean wind speed	6.11 m/s	6.14 m/s	0.40%
Mean power density	218 W/m²	218 W/m²	0.01%
Met station data at 10 m			
Mean wind speed	4.15 m/s	4.20 m/s	1.21%
Mean power density	103 W/m²	103 W/m²	0.01%

Ordered metstation data

- Banatski Karlovac
- year 1997
- hourly averaged
- taken every hour
- 0.1 m/s discretization



Observed wind climate from Banatski Karlovac, 10 m met station, 1997



Self tests of wind data from Banatski Karlovac met station 1997 year

Table II Predicted Deliblatska Peščara region mean wind speed at 40 m (1997)

Variable	Mean	Min	Max
Weibull-A	6.1 m/s	5.6 m/s	6.4 m/s
Weibull-k	1.54	1.51	1.57
Mean speed	5.51 m/s	5.05 m/s	5.80 m/s
Power density	267 W/m²	201 W/m²	311 W/m²
RIX	0.0%	0.0%	0.6%
Elevation	134.9 m	75.0 m	177.4 m

Standard metstation data

- Banatski Karlovac
- year 2005 - March
- hourly averaged
- taken every hour
- 1 m/s rounded-off

40 m

Table III Predicted wind at Deliblatska Peščara from met station data-March 2005

Variable	Mean	Min	Max
Weibull-A	6.3 m/s	5.9 m/s	6.7 m/s
Weibull-k	1.86	1.81	1.91
Mean speed	5.61 m/s	5.20 m/s	5.92 m/s
Power density	223 W/m²	172 W/m²	260 W/m²
RIX	0.0%	0.0%	0.6%
Elevation	134.9 m	75.0 m	177.4 m

40 m

Table IV Predicted wind at Deliblatska Peščara from mast station data- March 2005

Variable	Mean	Min	Max
Weibull-A	6.8 m/s	6.2 m/s	7.1 m/s
Weibull-k	2.58	2.49	2.69
Mean speed	6.01 m/s	5.52 m/s	6.33 m/s
Power density	205 W/m²	155 W/m²	238 W/m²
RIX	0.0%	0.0%	0.6%
Elevation	134.9 m	75.0 m	177.4 m

website data

- Banatski Karlovac
- year 2005 - March
- hourly averaged
- taken every three hours
- 1 m/s rounded-off
- some missing data
- sampling non regular

a) Original met station data

b) Data from the web site

Table V Mean values from met station data and from web site (March 2005)

Original met station data	Unit	Measured	Weibull-fit	Discrepancy
Mean wind speed	m/s	4.17	4.15	0.49%
Mean power density	W/m^2	101.16	103.02	1.85%
http://meteo.infospace.ru	Unit	Measured	Weibull-fit	Discrepancy
Mean wind speed	m/s	4.26	4.24	0.30%
Mean power density	W/m^2	103.37	105.30	1.87%

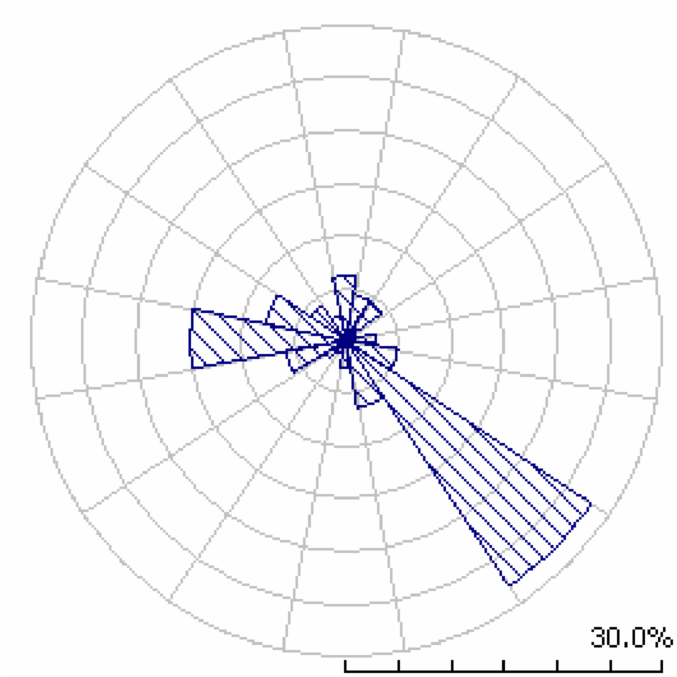
Comparison with reference data

data source

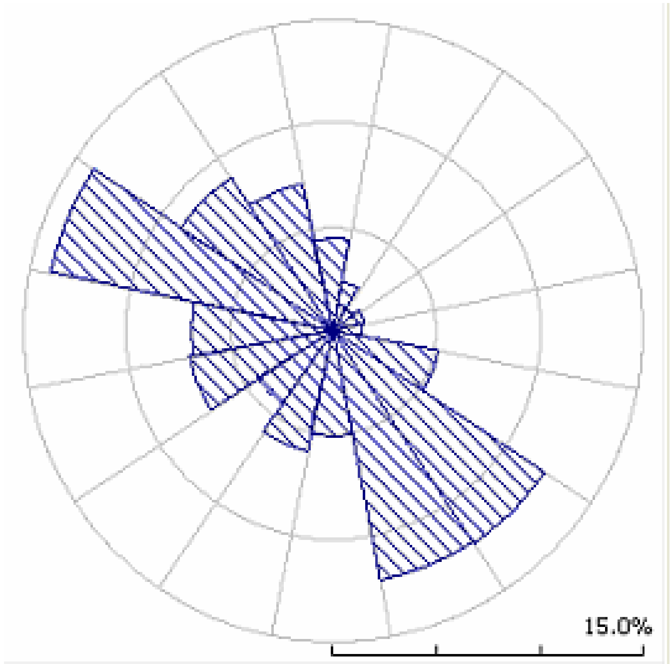
- web site at Banatski Karlovac
- year 2005 - March
- hourly averaged
- taken every three hours
- 1 m/s discretization
- non regular sampling

Location for comparison

Measuring mast 40 m a.g.l.



a) measured by mast sensor



b) Predicted from web site

Conclusions

The possibility of wind climate prediction in Deliblatska Peščara region in North Serbia using scarce met data from the internet address http://meteo.infospace.ru was tested.

The testing was performed for relatively windy month March 2005 year.

Comparison is based on wind data from 40 m mast located at Humka Nagula as the reference and from the nearby met station Banatski Karlovac.

It was found that rounded-off hourly averaged data taken every hour at the met station Banatski Karlovac give satisfactory results compared to more precise 0.1 m/s discretized original wind velocity values.

Relatively scarce hourly averaged website data taken each third hour with rounded –off 1 m/s wind velocity were used to predict wind climate of Deliblatska Peščara. This procedure was found satisfactory regarding the mean wind velocity, but less effective concerning wind rose. The wind rose difference may be due to not enough precise model.

For wind energy potential assessment at selected site both, more precise modeling based on roughness, orography and obstacles data, as well as more improved wind data base are required.

Sector		Wind climate			
number	angle [°]	freq. [%]	Weib-A [m/s]	Weibull-k	U [m/s]
1	0	4.5	6.4	1.63	5.74
2	23	2.4	5.1	1.31	4.74
3	45	1.3	3.4	1.19	3.17
4	68	1.6	2.7	1.60	2.40
5	90	1.4	2.8	1.16	2.62
6	113	5.2	5.6	1.17	5.33
7	135	12.3	8.7	1.51	7.85
8	158	12.2	6.8	1.61	6.12
9	180	5.1	7.2	1.99	6.39
10	203	5.9	5.8	2.24	5.18
11	225	4.3	5.0	1.88	4.44
12	248	7.1	5.8	2.06	5.09
13	270	6.8	6.3	1.72	5.61
14	293	13.9	6.1	1.94	5.38
15	315	8.9	6.3	2.00	5.62
16	338	7.2	6.6	2.06	5.80
All			(6.3)	(1.54)	5.70

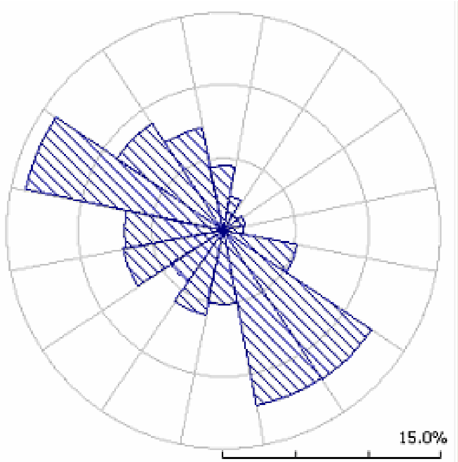


Fig 9 Predicted wind at Dolovo wind mast site 40 m (1997)

c

The possibility of wind climate prediction in Deliblatska Peščara region in North Serbia using scarce met data from the internet address http://meteo.infospace.ru was tested. The testing was performed for relatively windy month March 2005 year.

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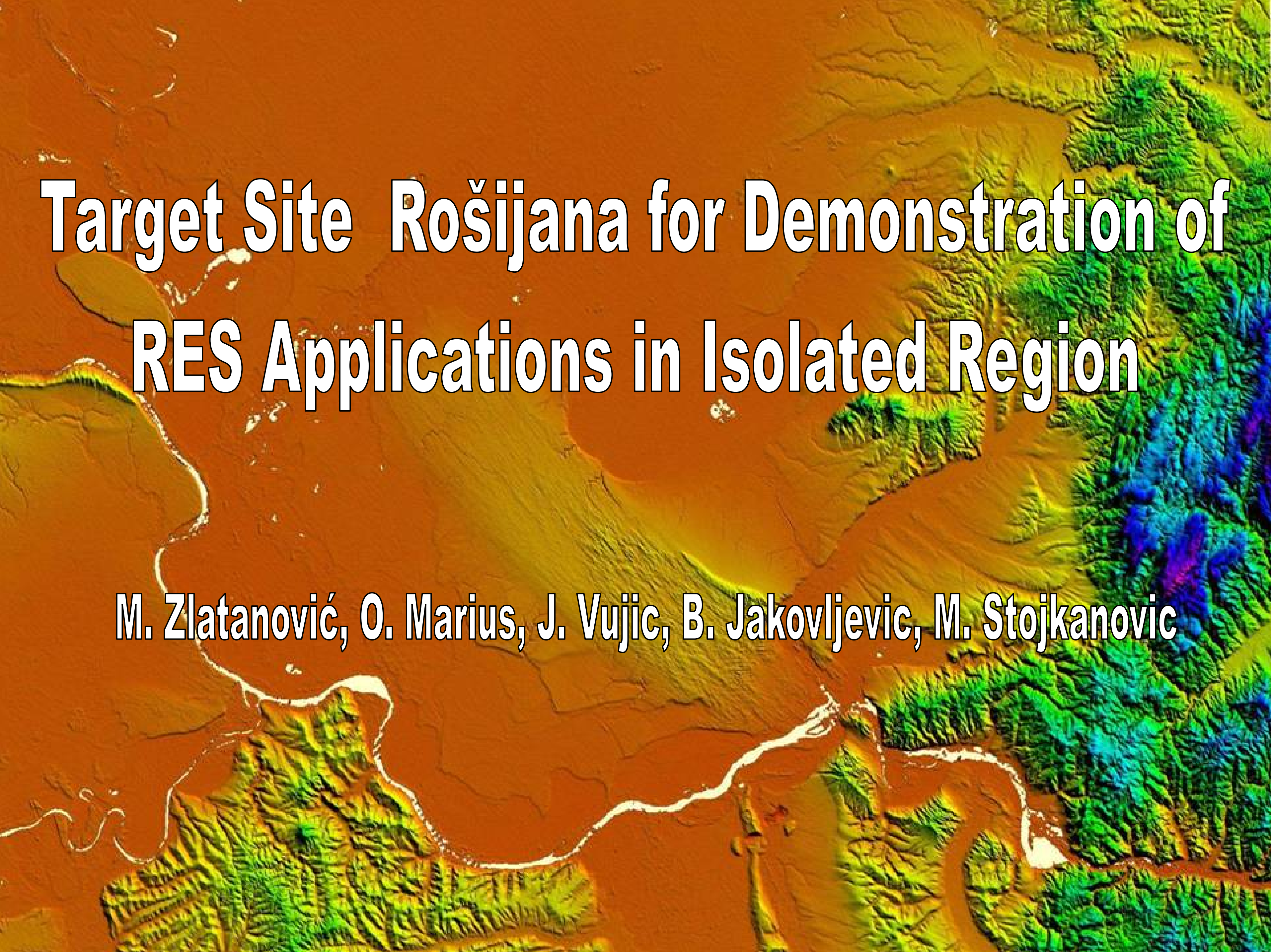
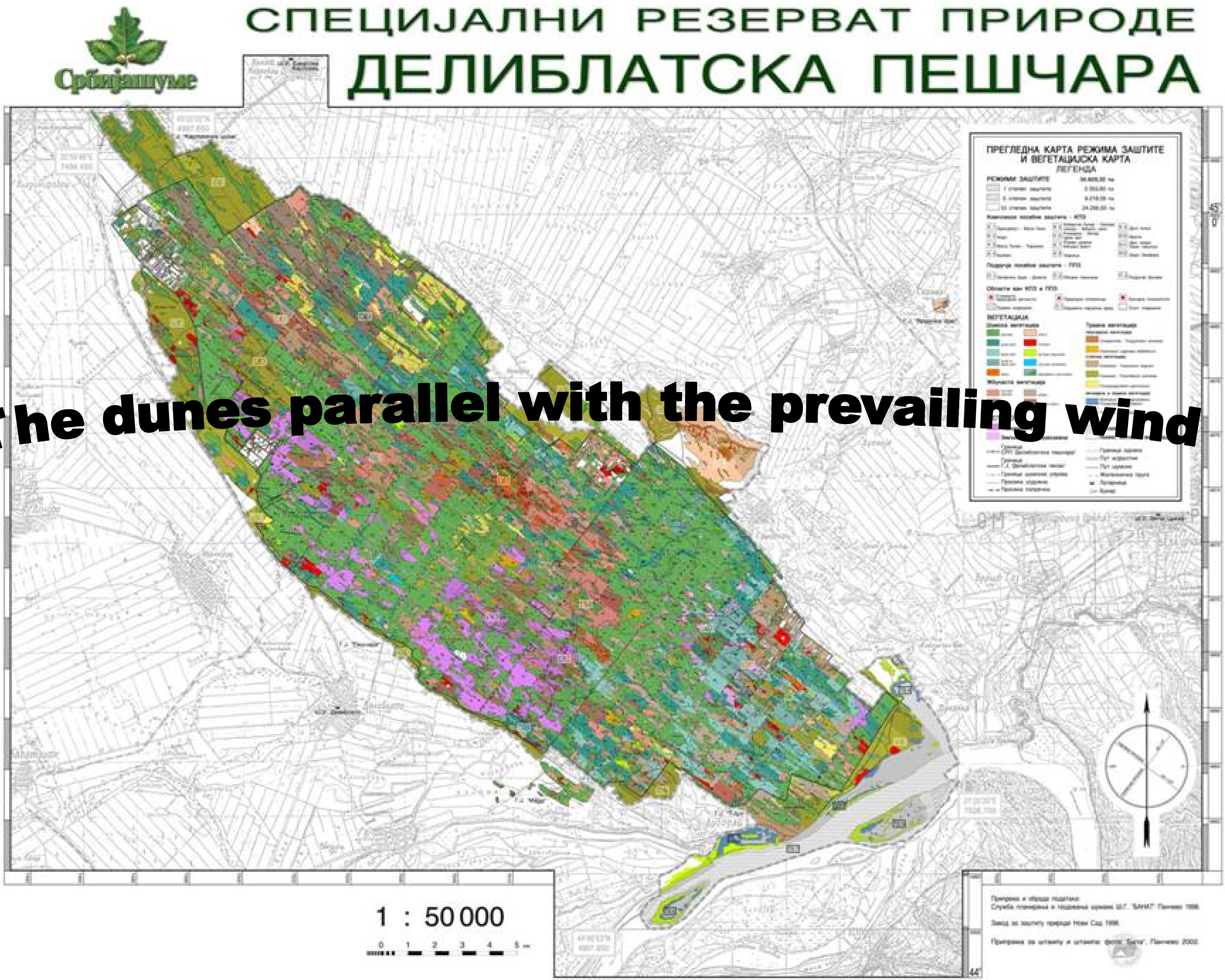
Target Site Rošijana for Demonstration of RES Applications in Isolated Region

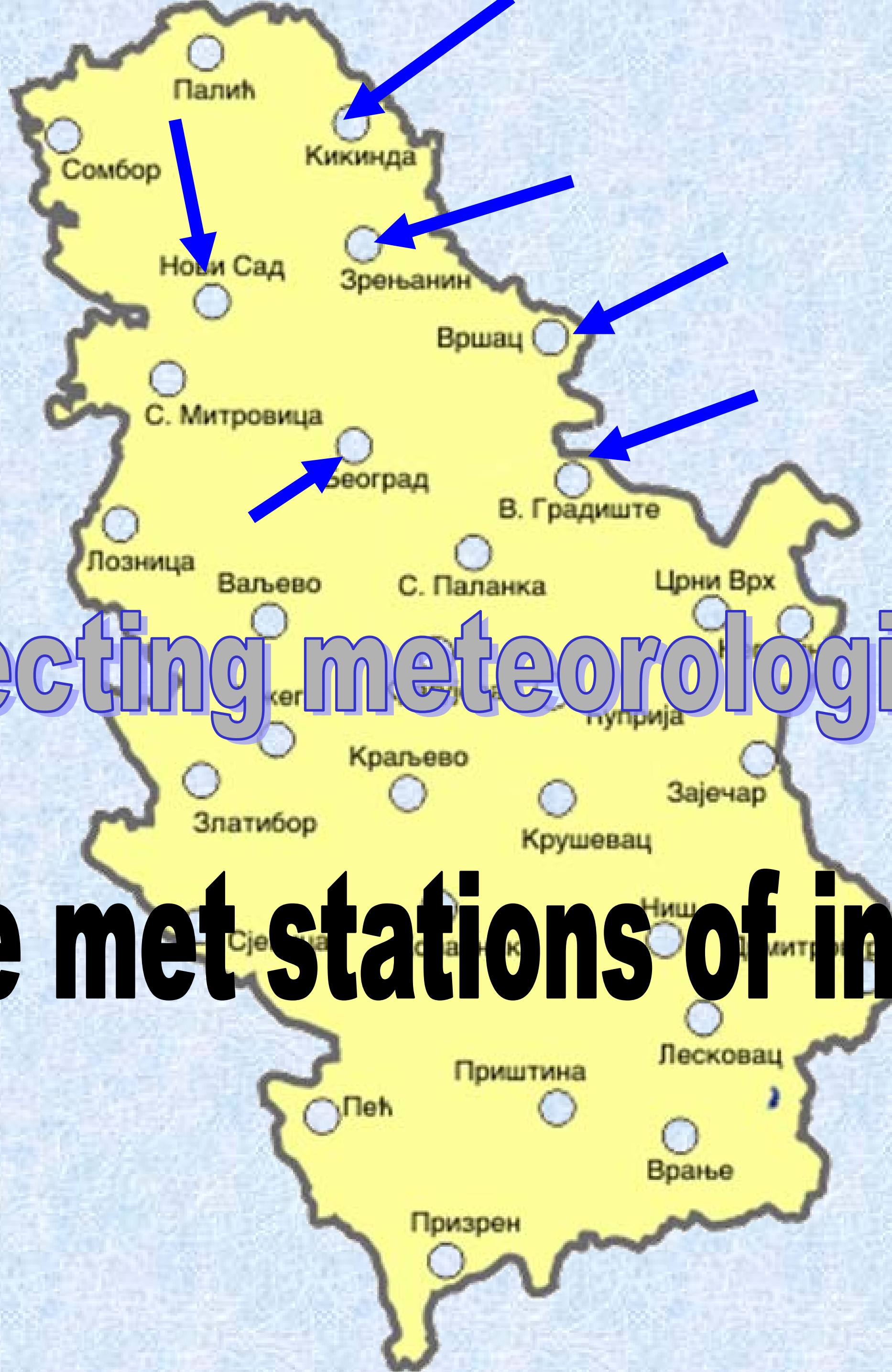
M. Zlatanović, O. Marius, J. Vujic, B. Jakovljevic, M. Stojkanovic





The dunes parallel with the prevailing wind

Collecting meteorological data



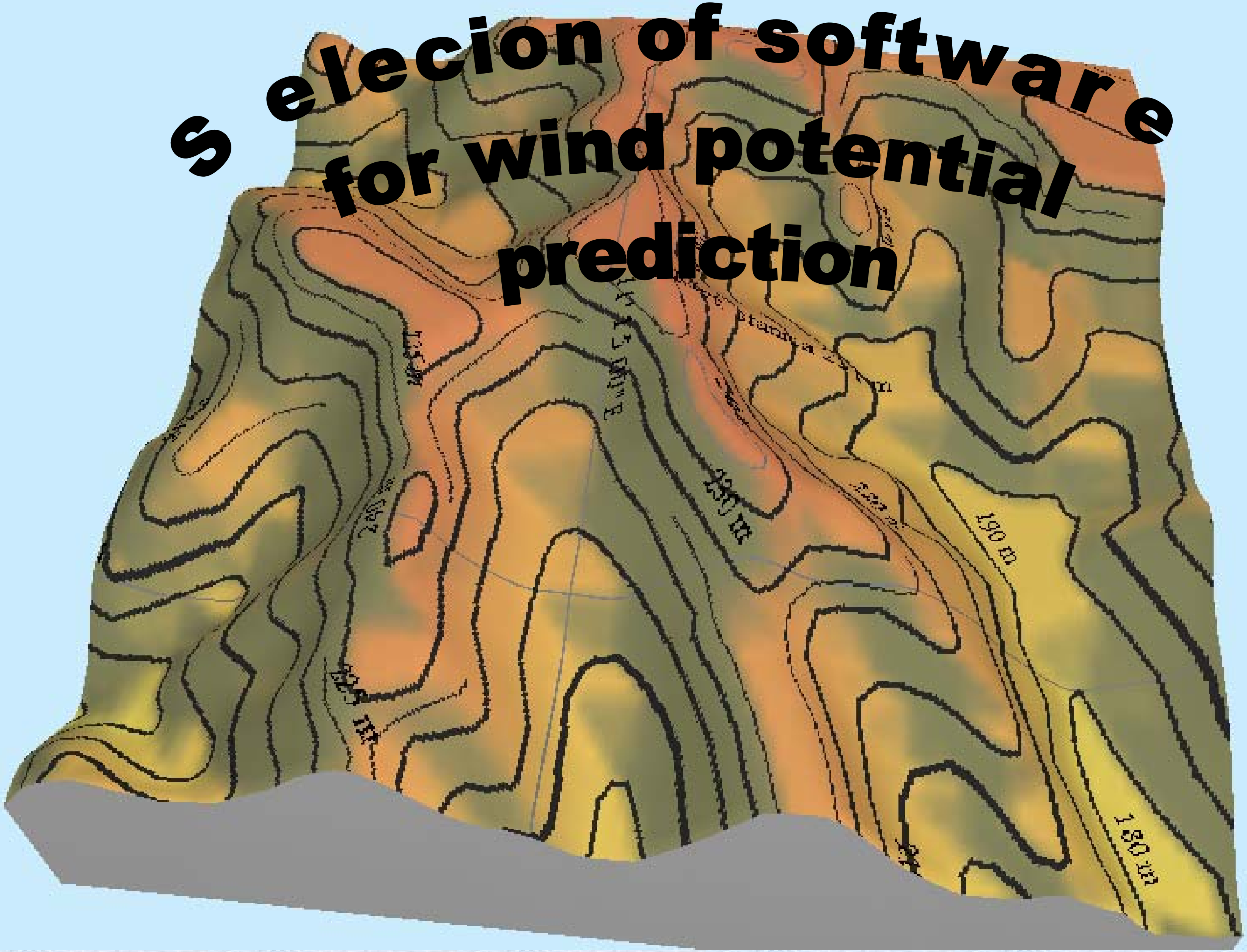
the met stations of interest

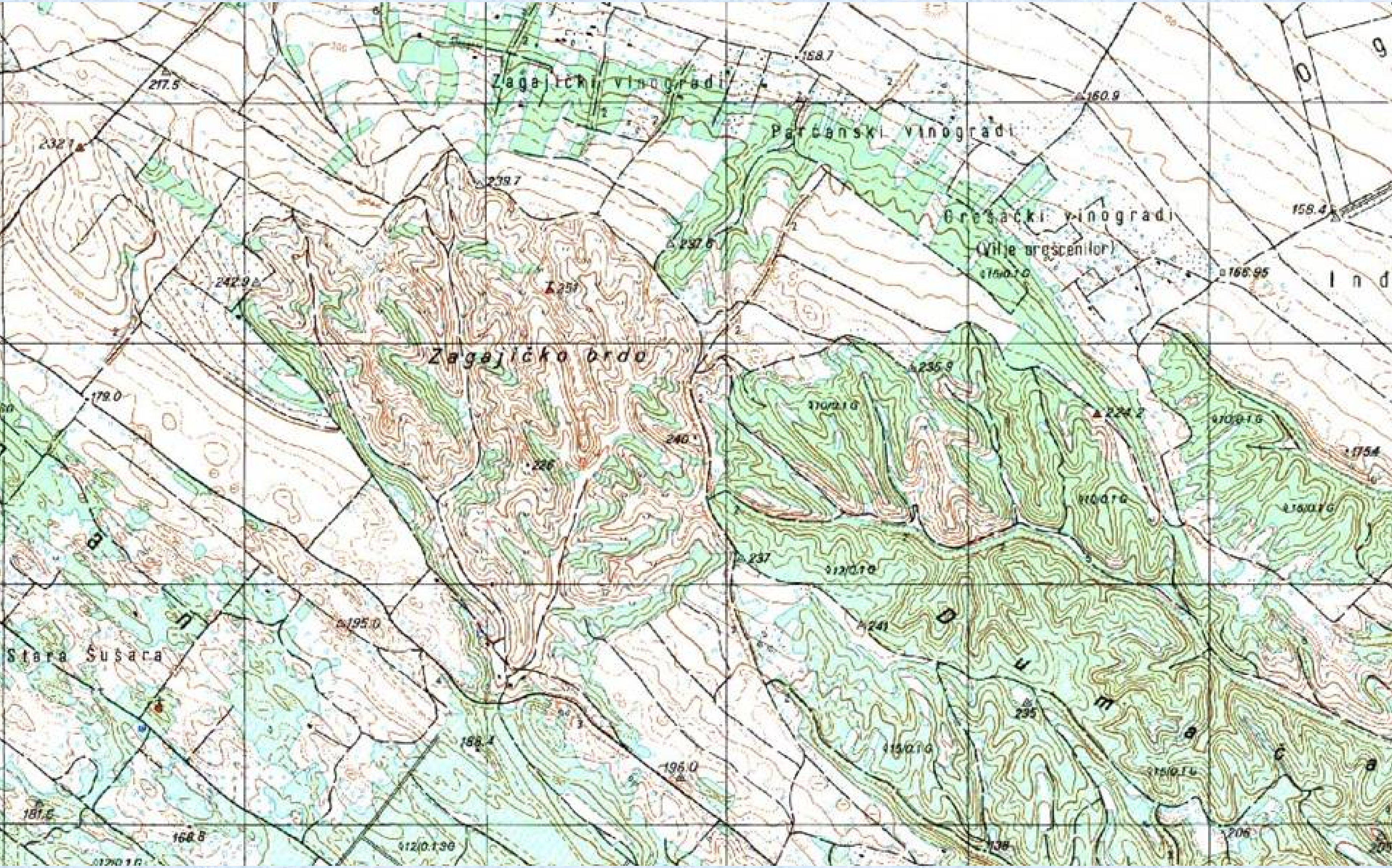
Closest met station
Helimaks wind must position
Seleuš
Vršac
Alibunar
Banatski Karlovac
Uljma
Sočica
Vladimirovac
Kuštilj
Izbište
Iam
SERBIA
Straža
Jasenovo
VOJVODINA
Dolovo
Mramorak
Bela
Socol
Banatska Palanka
Bavanište
Ram
Baziaş
Gaj
Dubovac
Danube
Skorenovac
Kovin
Banatski Brestovac
GREAT HUNGARIAN PLAIN

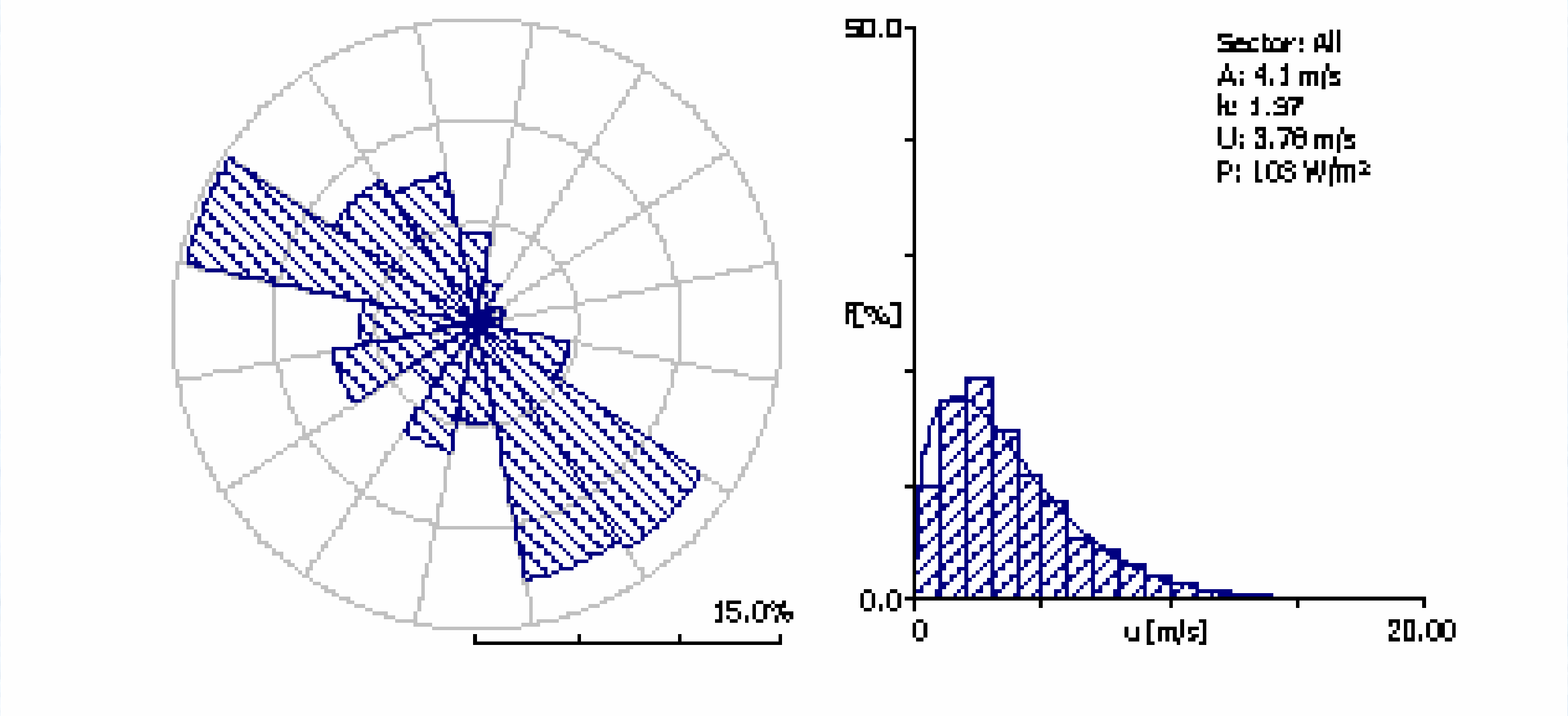
Selection of wind measuring equipment

NRG wind must and sensors

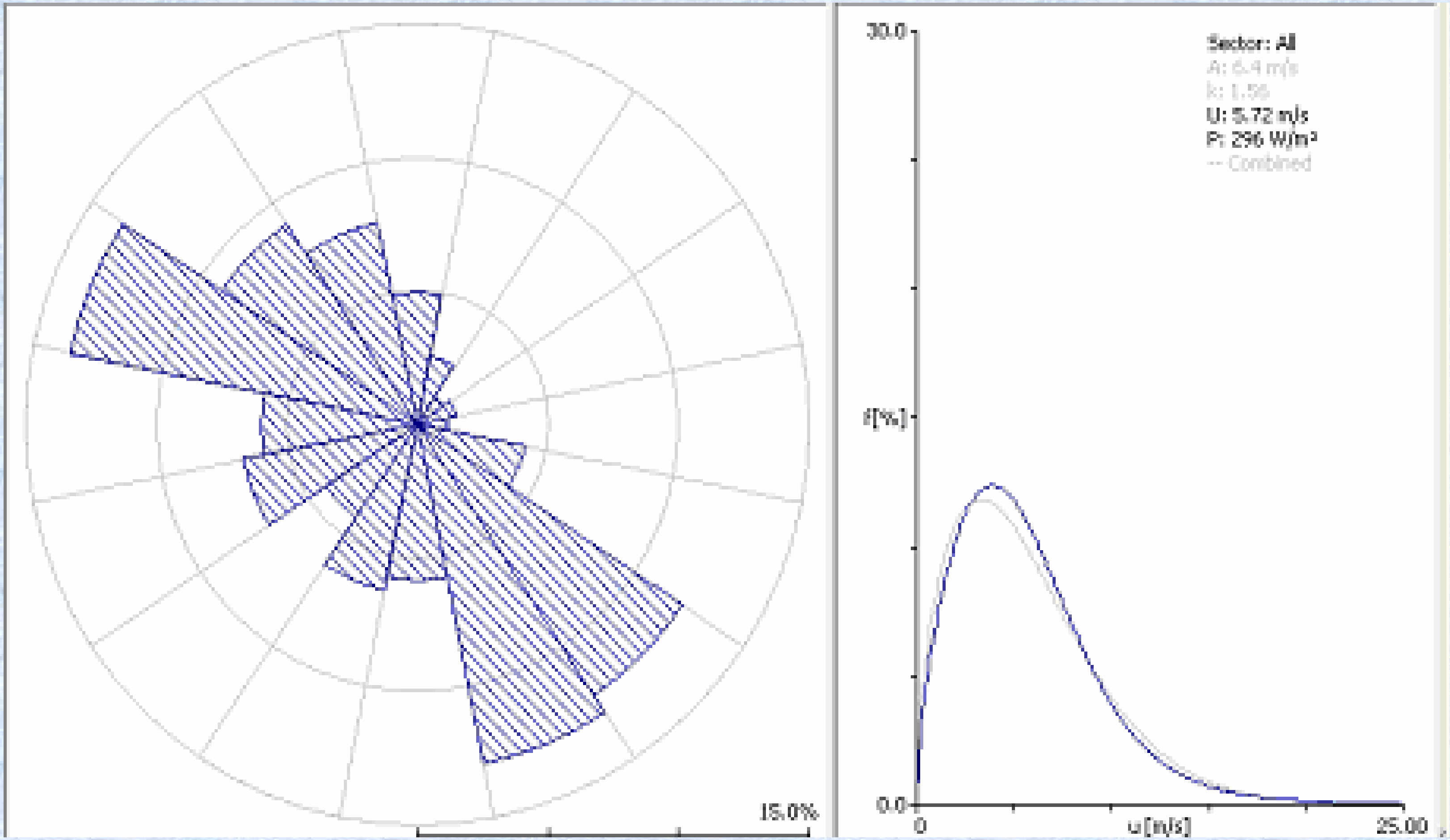
S elecion of software for wind potential prediction




Zagajički vinogradi
Parčanski vinogradi
Orešački vinogradi
Zagajičko brdo
Stara Šušara
D u m a č a
Ind
217.5
232.1
239.7
242.9
237.6
251
179.0
226
240
237
195.0
241
235.9
224.2
235
188.4
196.0
168.7
160.9
158.4
166.95
168.8



Wind rose and Weibull velocity distribution at Banatski Karlovac 1997

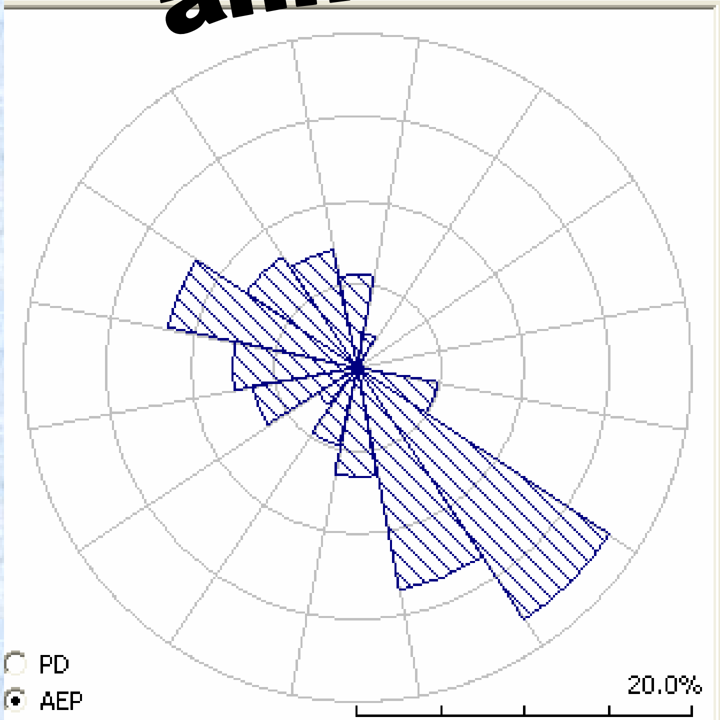


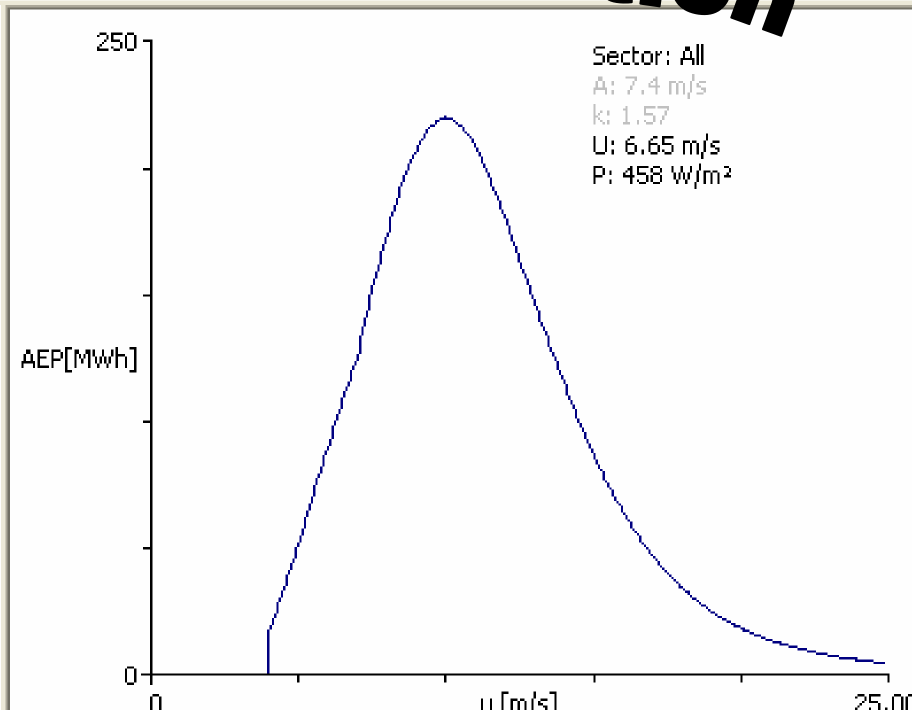
Predicted wind characteristics at Zagajičko brdo site

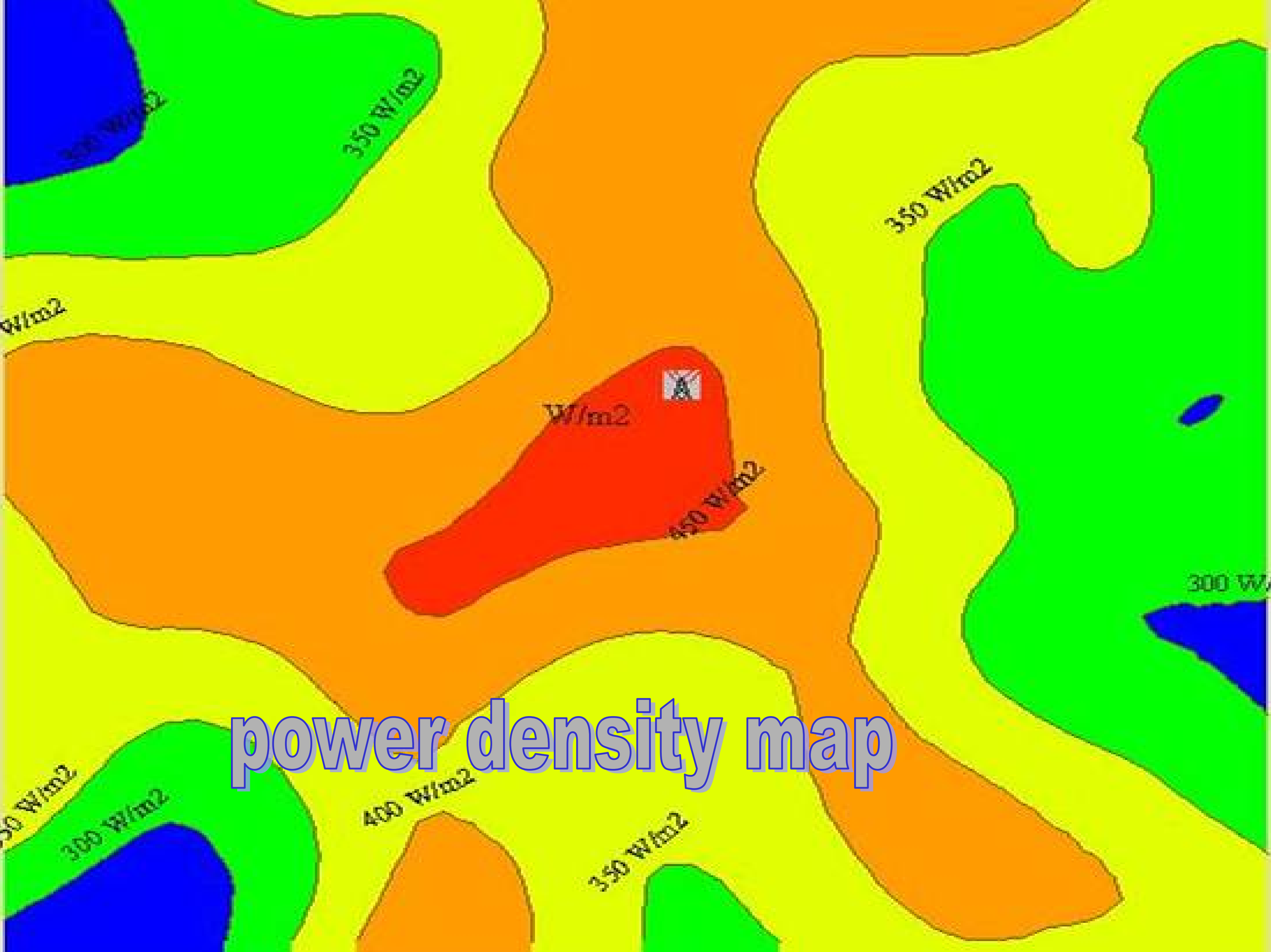
Banatski Karlovac
Zagajičko brdo
(509006.5,4984578.0)
4995000
4990000
4985000
4980000
4975000
4970000
500000
505000
510000
515000
189.6
[m]
251.0

annual energy production

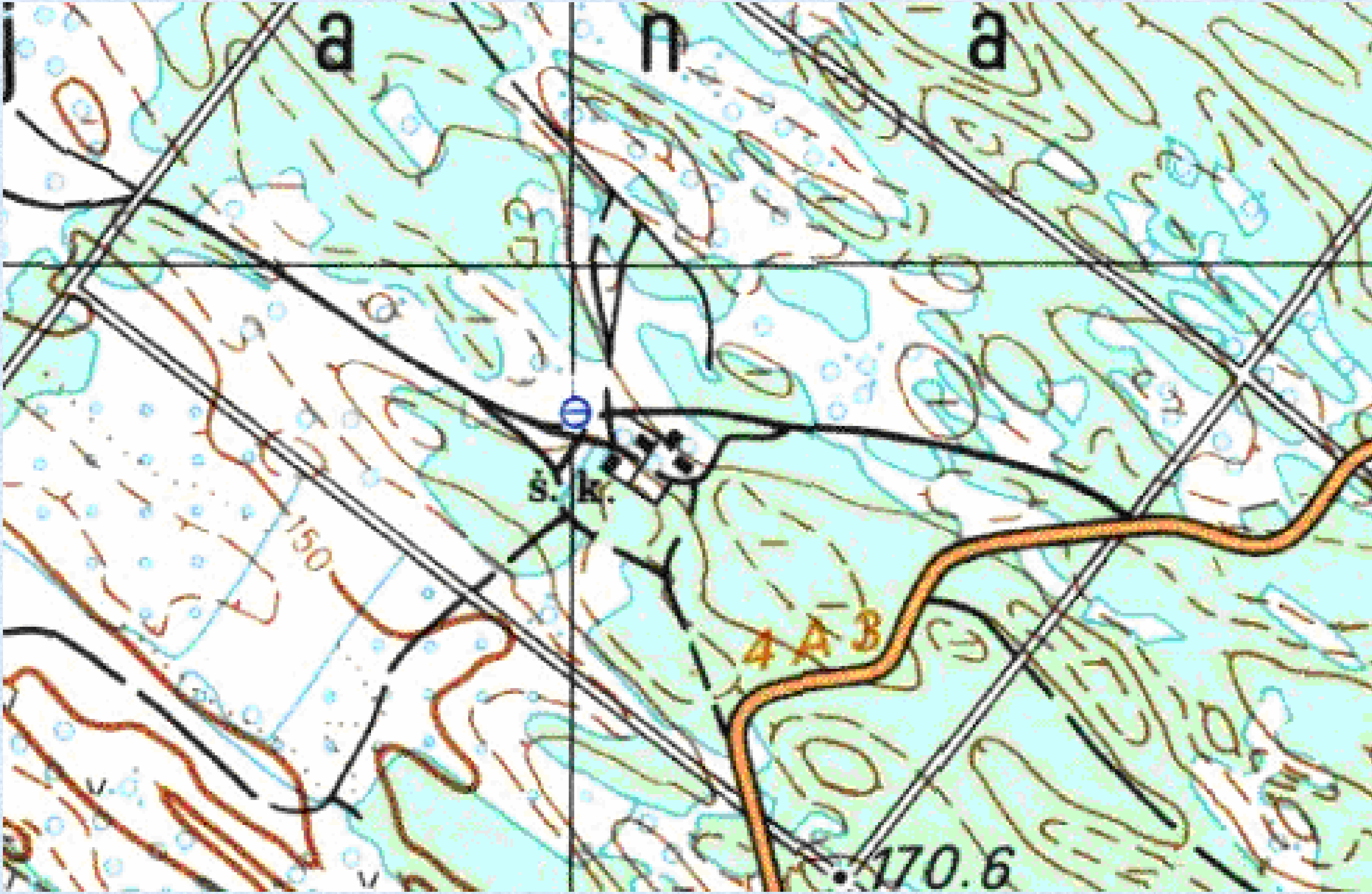
Sector		Wind climate				Power		
number	angle [°]	frequency [%]	Weib-A [m/s]	Weibull-k	speed [m/s]	power [W/m²]	AEP [GWh]	wake [%]
1	0	4.6	8.2	1.50	7.38	670	0.102	0.0
2	23	2.6	6.3	1.28	5.80	420	0.040	0.0
3	45	1.4	4.0	1.14	3.79	147	0.010	0.0
4	68	1.6	3.2	1.59	2.91	38	0.003	0.0
5	90	1.5	3.4	1.12	3.22	94	0.007	0.0
6	113	5.1	6.9	1.27	6.38	568	0.091	0.0
7	135	12.0	9.8	1.52	8.83	1121	0.334	0.0
8	158	11.9	7.8	1.61	6.99	517	0.249	0.0
9	180	5.4	8.2	1.93	7.26	465	0.120	0.0
10	203	6.0	6.8	2.21	6.04	235	0.087	0.0
11	225	4.4	6.2	1.95	5.47	197	0.053	0.0
12	248	7.0	7.2	2.04	6.38	297	0.119	0.0
13	270	6.9	7.7	1.74	6.83	435	0.139	0.0
14	293	13.6	6.9	1.96	6.15	278	0.216	0.0
15	315	8.7	7.2	2.01	6.38	302	0.148	0.0
16	338	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.132	0.0
All			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.0






power density map
350 W/m2
350 W/m2
W/m2
W/m2
450 W/m2
300 W/
400 W/m2
300 W/m2
350 W/m2


must mounting site



j a n a
š. k.
150
4A3
170.6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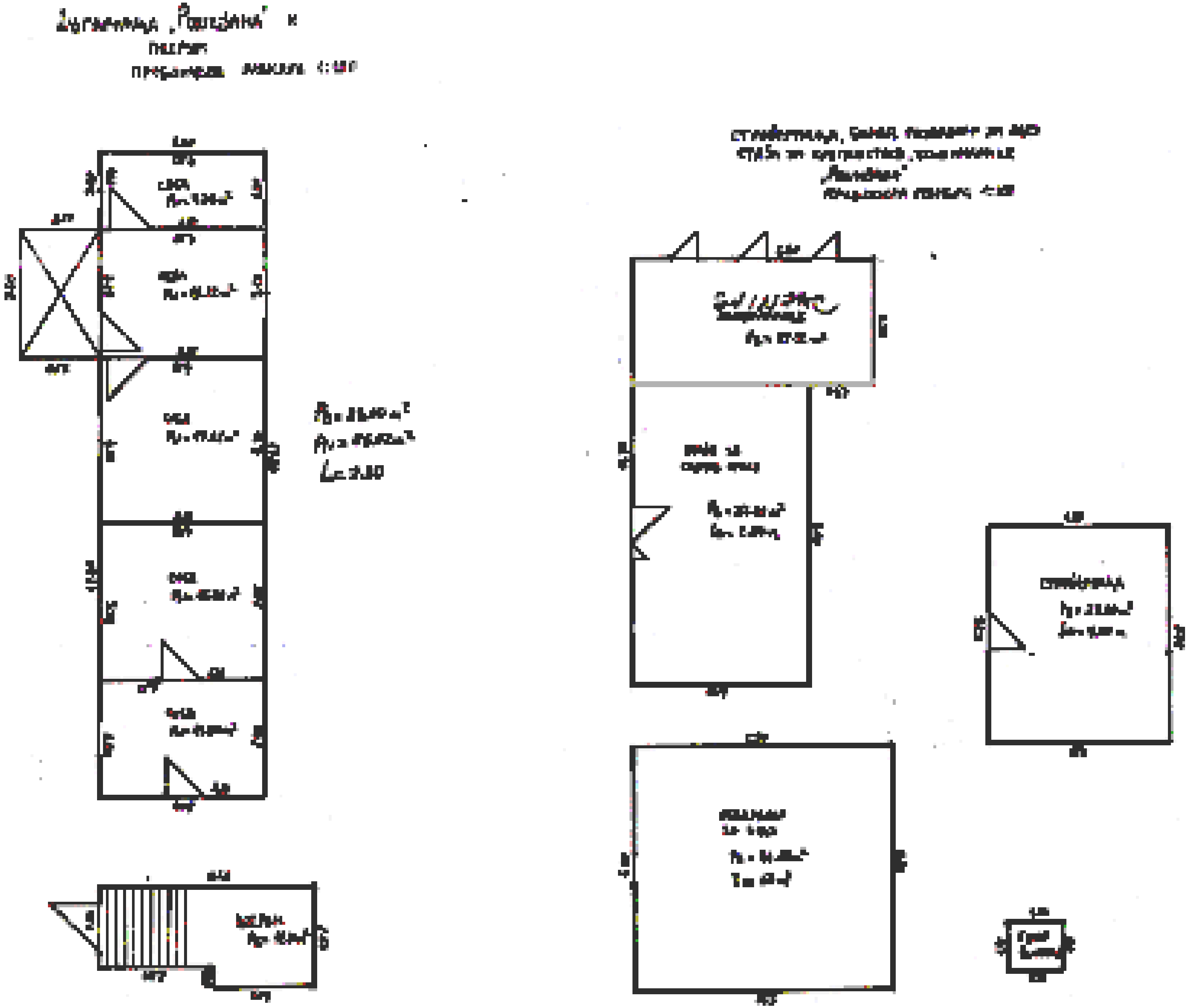


Future eco house will consists of the following units:

-residential house,

-workshop house,

-mechanical house with the equipment for water supply,

-artesian well,

-water pull and

-the garden

Rošijana has the place for the resident family of about four members responsible for maintenance and operation.

Two principle groups of visitors were considered:

- hunters and

- other groups

The other group includes schoolboys, tourists, researchers, nature organization, visitors and experts from outside countries and all other people interested in visiting the largest sandy area in Europe and its surroundings with nearby river Danube, Djerdap canyon and large hydropower station.

The electric load of Rošijana house was calculated taking into account the following planned data:

-The hunting season lasts from 1st. of May to 14th of February with the highest season in December and January

- Maximum 8 poeple are planned to be in the house, but this number is in average 3 depending on the season and the day of the week

-Special two week camps are mostly organized in July and August with about twenty poeple

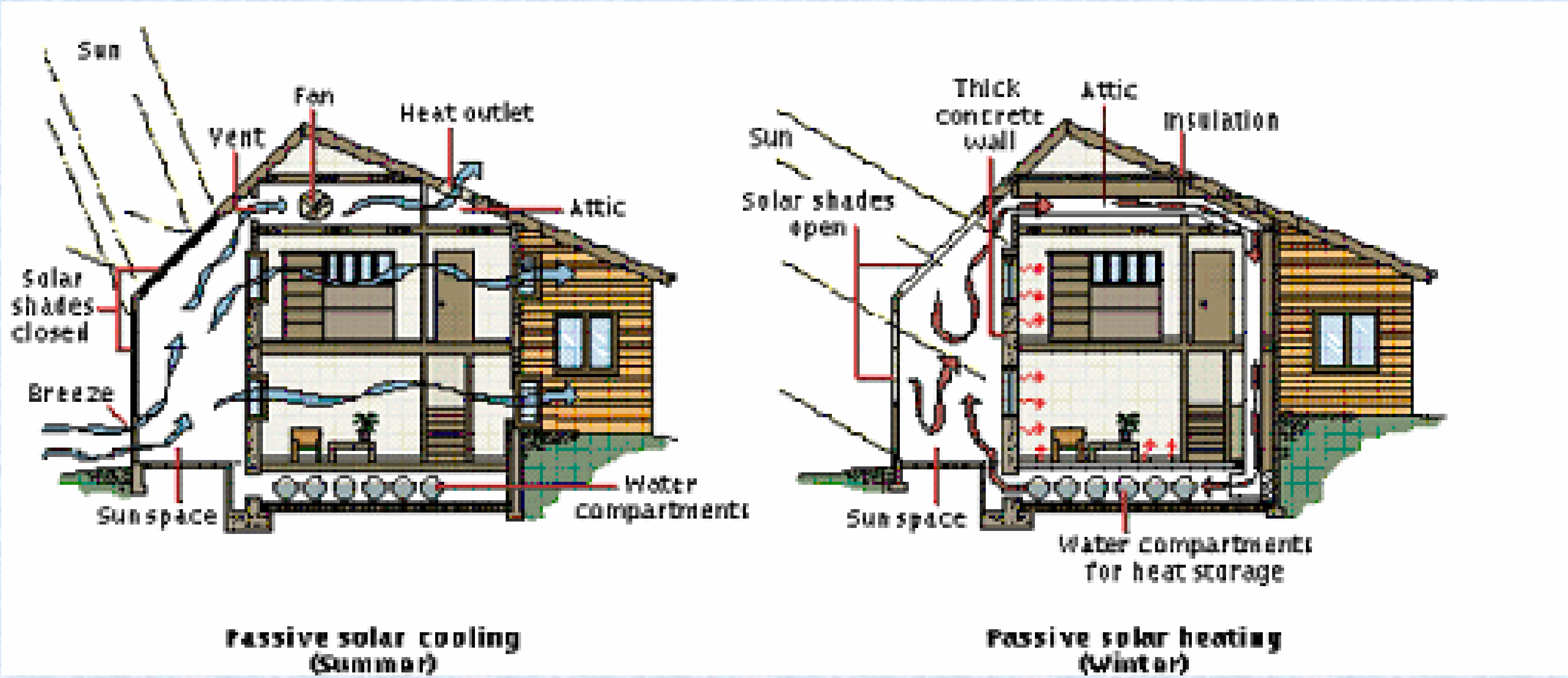
-- The education lessons will be organized in principle from Jun to September.

February

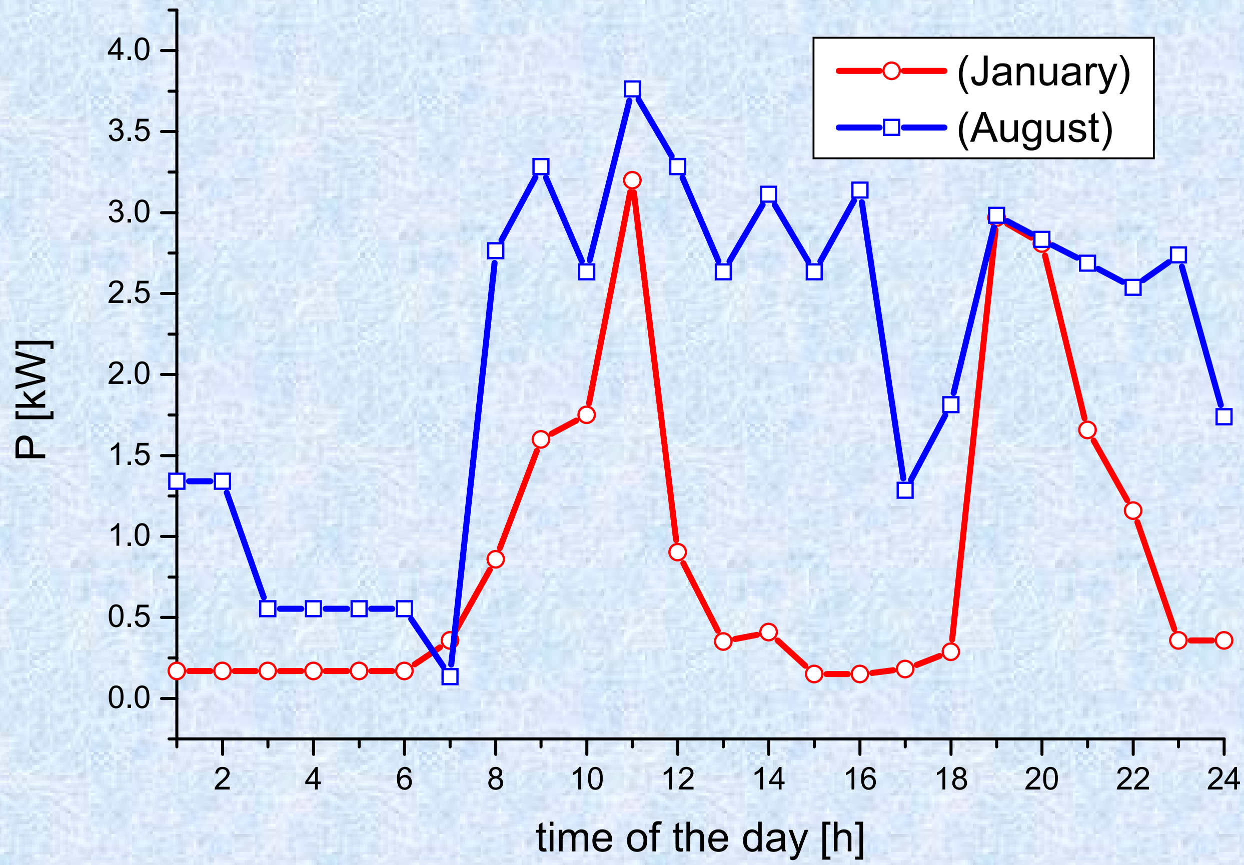
Appliance	Number of items	Size per one(W)	Total power (W)	Timing	Total hours	Priority (1 or 2 or 3)	Energy (Wh)
Light bulbs, house	22	18	396	06-09; 17-24	3	1	1188
Light bulbs, workshop	39	18	702	06-09; 17-24	0.5		351
Light bulbs, garden	11+4	18+25	298	18-07	3		894
Freezer	1	200	200	00-24	6		1200
Thee/coffee-machine	1	320	320	07-20	1.5		480
Air conditioning	1	1500	1500	0	0		0
Boilers	1	1500	1500	08-09;18-20	2.5		3750

February

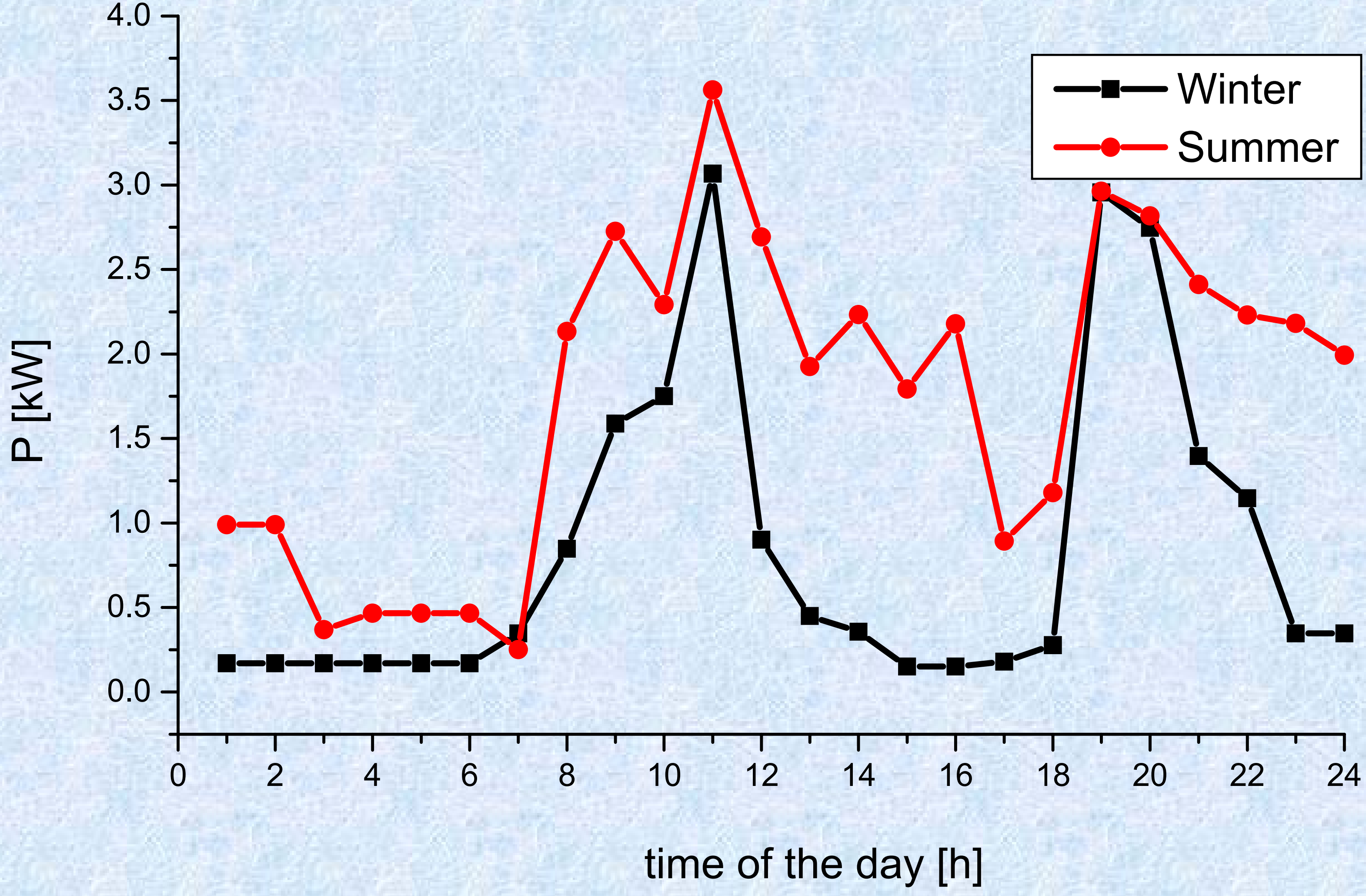
Water pump	1	2000	2000	00-24	0.5		1000
Washing machine	1	1500	1500	00-24	2		3000
Computers	2	400	800	00-24	3		2400
Internet	1	50	50	00-24	24		1200
TV	2	400	800	00-24	3		2400
Video beam	1	800	800	10-12	0.5		400
Miscellaneous	1	150	150	00-24	3		450



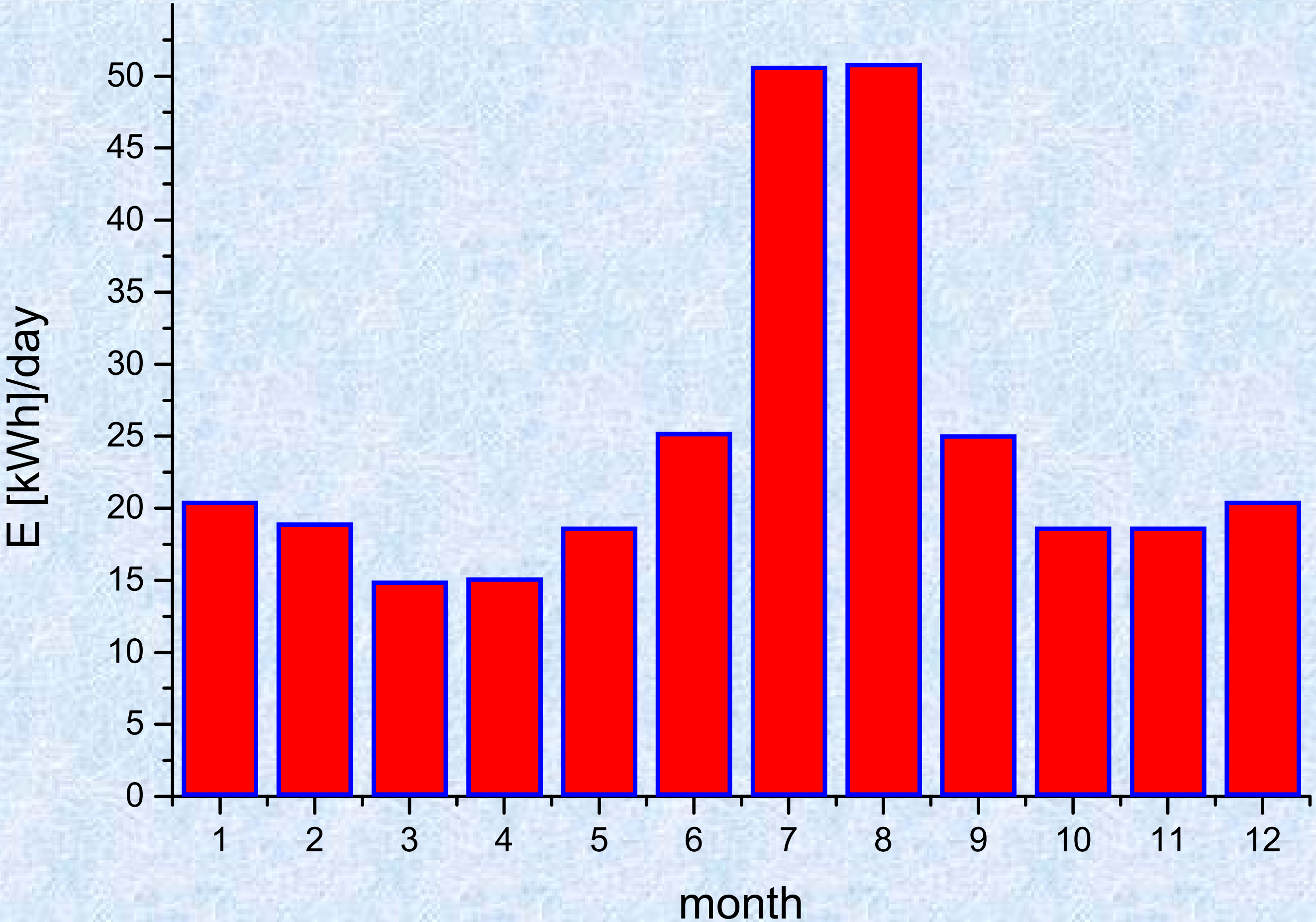
Sun
Fan
Heat outlet
Vent
Attic
Solar shades closed
Breeze
Sun space
Water compartments
Passive solar cooling (Summer)
Thick concrete wall
Attic
Insulation
Sun
Solar shades open
Sun space
Water compartments for heat storage
Passive solar heating (Winter)



(January)
(August)
P [kW]
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
2
4
6
8
10
12
14
16
18
20
22
24
time of the day [h]

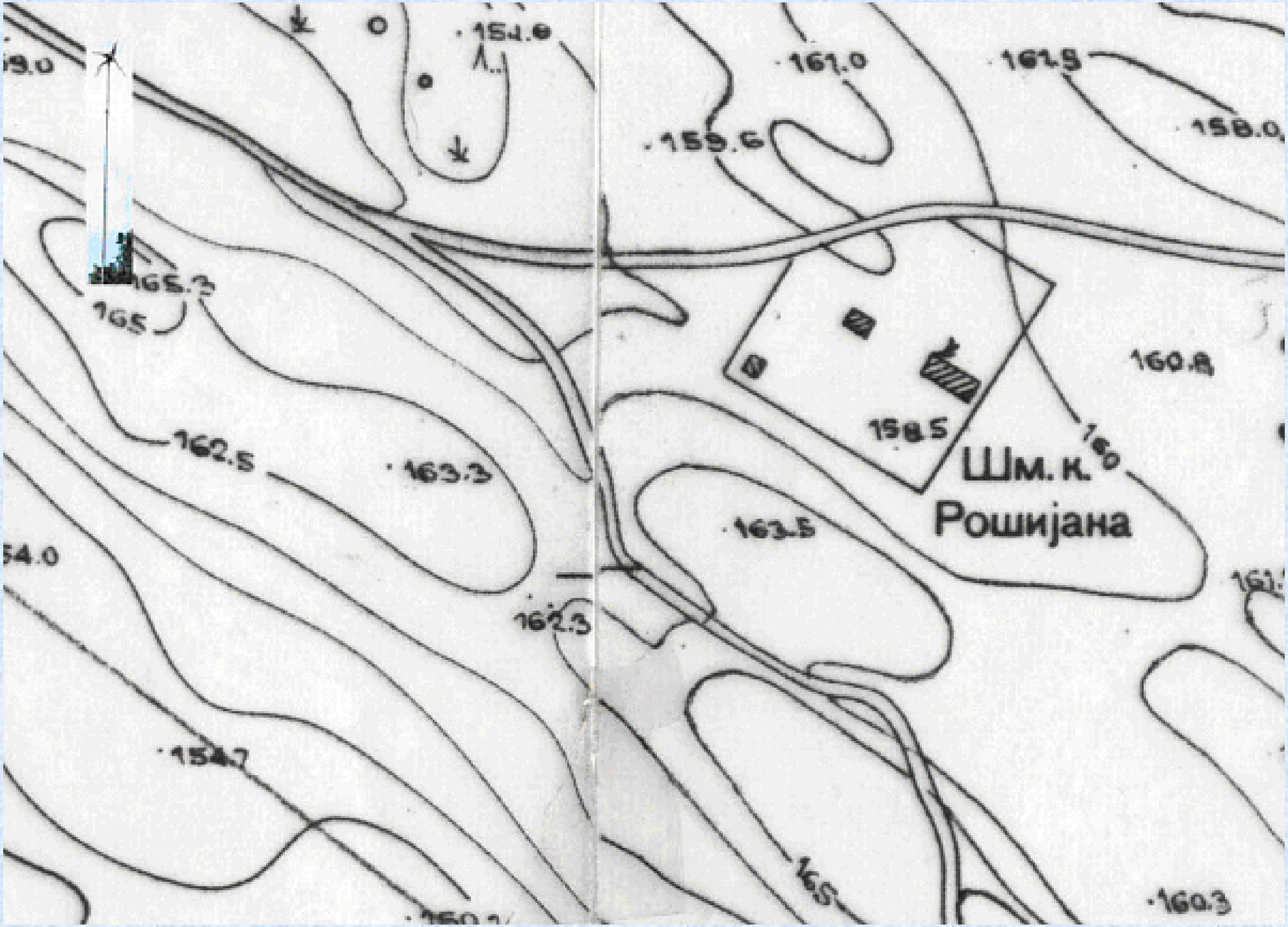


P [kW]
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
2
4
6
8
10
12
14
16
18
20
22
24
time of the day [h]
Winter
Summer



E [kWh]/day
0
5
10
15
20
25
30
35
40
45
50
1
2
3
4
5
6
7
8
9
10
11
12
month

	E [kWh/day]	E [kWh/month]
January	20.526	636.306
February	19.014	532.392
March	14.96	463.76
April	15.19	455.7
May	18.715	580.165
June	25.296	758.88
July	50.695	1571.545
August	50.901	1577.931
September	25.116	753.48
October	18.714	580.134
November	18.714	561.42
December	20.524	627.874
Year	24.9	758.30
	Total year [kWh]	**9100**



154.0
161.0
161.5
155.6
158.0
165.3
165
160.8
158.5
160
Шм. к.
Рошијана
162.5
163.3
163.5
54.0
162.3
154.7
165
160.3

-Maintenance crew consists of 2 to 5 members or one family during the year

-3 to 8 hunters during hunting season, May to February with peak in December and January

-Special educational and scientific camps will be organized during July and August with approximately 20 attends for two weeks

- In accordance to power demands shown in the table 1. and taking in to consideration future power demands, 20kW wind turbine is chosen as main power supply of the eco house "Rošijana“.

- During winter months, when temperature reaches -15°C, biomass and passive solar heating will be provided. Electrical heating will support these types of heating if it is found necessary. Electrical energy will be used for ventilation and cooling as well.

Weather Data

"NASA Surface meteorology and Solar Energy"

Average Temperature (° C)													
Lat 44.9 Lon 21.05	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	-1.86	-1.11	4.28	8.94	13.8	17.0	20.6	21.3	16.3	9.92	3.39	-1.51	9.32

Average Wind Speed at 50m (m/s)													
Lat 44.9 Lon 21.05	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	4.26	4.55	4.30	4.33	3.83	3.63	3.74	3.75	4.01	4.11	4.05	4.41	4.08

Average Daily Radiation on Horizontal Surface

Average Daily Radiation on Horizontal Surface (kWh/m^2/day)												
Lat 44.9 Lon 21.05	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
10-year Average	1.40	2.13	3.15	4.26	5.25	5.85	6.22	5.47	4.05	2.59	1.57	1.23

Heating Design Temperature (° C)													
Lat 44.9 Lon 21.05	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
9-year Average													-8.32

Cooling Design Temperature (° C)													
Lat 44.9 Lon 21.05	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
9-year Average													25.8

Heating Degree-days below 18 ° C													
Lat 44.9 Lon 21.05	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Sum
10-year Average	608	535	425	281	142	56	14	12	79	246	429	597	3424

Test was performed with 10 kW windturbine

Grid type	-	Isolated-grid	
Peak load	kW	**10**	
Wind turbine rated power	kW	10	
Number of turbines	-	1	
Wind plant capacity	kW	10	

Hub height	m	60.0	
Wind speed at hub height	m/s	4.2	4.2
Wind power density at hub height	W/m²	85	
Wind penetration level	%	100.0%	
Wind energy absorption rate	%	80%	
Array losses	%	5%	
Airfoil soiling and/or icing losses	%	5%	
Other downtime losses	%	2%	

Annual Energy Production		Estimate Per Turbine	Estimate Total
Wind plant capacity	kW	10	10
	MW	0.010	0.010
Unadjusted energy production	MWh	8	8
Pressure adjustment coefficient	-	0.94	0.94
Temperature adjustment coefficient	-	1.02	1.02
Gross energy production	MWh	7	7
Losses coefficient	-	0.87	0.87
Specific yield	kWh/m²	167	167
Wind plant capacity factor	%	6%	6%
Renewable energy collected	MWh	6	6
Renewable energy delivered	**MWh**	**5**	**5**

House and power source (wind generator) will be connected by underground power cable. Control room with equipment for monitoring of wind turbine and generator will be located in maintenance building of the House. If found necessary, in the same building together with generator control equipment, power control and monitoring, then autotransformer, UPS, inverters, battery emergency backup supply and other devices should be located.

Conclusions

Eco house Rošijana is planned to be located inside the special nature reserve Delibaltska Peščara which is the largest sand dune region in Europe.

The eco house will be powered by RES since no grid connection exists in this rural region.

The most critical rules of environment protection which are mandatory in special nature reserve are to be satisfied - conservation and upgrading of sandy area special nature reserve including the protection measures regarding forestry policy, agricultural use, water resources management and sand exploitation.

By constructing a wind turbine the wind energy will be used for the electricity production and water supply helping all the activities in special nature reserve and promoting the sustainable use of RES, energy efficiency, new recyclable material application and WWT.

Contribution to development of urban infrastructure, tourism, hunting, water supply and research activities.

By constructing a wind turbine the wind energy will be used for the electricity production and water supply helping all the activities in special nature reserve and promoting the sustainable use of RES, energy efficiency, new recyclable material application and WWT.

Based on regional wind climate the municipalities surrounding the nature reserve are expected to change their economy towards electricity production from wind.

Rošijana eco house is planned to be the center of enormous importance for the demonstration of RES use, dissemination of related knowledge and the education of people that has to change their own job and to go to the wind related activities.

Potential for PV application in the mountainous and highlands regions of Croatia

Uroš Desnica

“ Ruđer Bošković” Institute, Bijenicka cesta 54, Zagreb, Croatia

EU project RISE (Renewables for Isolated Systems..)

Paper Session: Renewable Energy I.
6th Balkan Power Conference, Ohrid, May 31 - June 2, 2006

Croatia:

-considerable variations in topological and climatic conditions.

21.0% of total Croatian territory is mountainous; **higher than 500 m**

25.6% is between **200-500 m** above the sea level.

Uroš Desnica

Montainous, highlands region - characteristics:

-**dispersity of population:** less than 20 inhabitants/km^2

-**economically underdeveloped** – very little places to find work

-**difficult terrain:** forested mountains

-**no grid in many parts** (border regions with BiH and in *Velebit* region)

- **outstanding natural beauty: National Parks *Plitvice Lakes*, *River Krka*, *Sjeverni Velebit*, *Risnjak*, *Una river region*.....** (4 of 7 in Croatia)

RES opportunities - many of the drawbacks can be turned into advantage

- **RES applications are ideal just for remote areas with low population density**

- **rough and woody terrain**:
  - the gridlines are difficult to set and even more difficult to maintain.

    the prospects of RES distributed locally and connected as **micrograds** - an inviting and economically viable option.

- **pristine nature:**

  an oasis in the overpopulated and polluted Europe, -fresh air, clean spring water, ecologically grown food,

- **Prospects of eco tourism and sustainable development**

Within the EU Project

we have been analysing several typical locations:

Selection Criteria of location of test PV system :

- **economically jusitifiable**

-**typical one**, **potential for a larger scale implementation of proposed PV solution**

- **expected characteristics:**
  modest household,
  low electricity consumption covering primarily basic needs
  small scale PV installation.

Inland location: BUSEVIC Altitude: 600 m, Latitude: 44° 36’, Longitude: 16° 02’

Una-river

Busevic village is located on the rolling hills at the highlands near the Una river,

The village comprised **65 households**, nowadays only **seven are inhabited periodically**

Only one house has been inhabited permanently for the last three years. The house was rebuilt by the authorities, the 220V AC installations in the house were provided with renovation.

The PV off-grid system would serve to supply basic electricity needs:

Uroš Desnica
Paper Session: Renewable Energy I.

Additional/alternative inland locations

Homoljac, Municipality Plitvička Jezera, National Park

Homoljac is a small village placed by the road Rijeka-Senj-Plitvička jezera (R-S-Pj). The visited house was completely burned down during the war. Currently two brothers, around their 30-ies, and old mother live in the house.

Grabušić, Municipality Udbina, 1 Household,

Grabušić is nested in mountains comprising few dispersed houses; few km among each other. In the visited household two older people and their son (round 30 years old) live permanently.

Plitvice Lakes National Park,

Uvalica , Located at the central region of the Park. Electric lines were destroyed, an elderly couple lives there permanently.

Bigina Uvala

Several houses refurbished, Inhabitants have not returned yet. Only one women lives there

Corkova uvala an object owned by the NP Authorities in the most remote part of NP. Would serve as a center for scientists and environmentalists investigating the Park area

Study included:

1. **Determination of the Load,**
2. **Detailed simulation (Meteonorm, PVSYST, RETScreen programs)**
3. **Optimization of all system parameters**
4. **Optimal Design of PV system**
5. **Economical, ecological, social.... analysis,**

1. Determination of the Load:

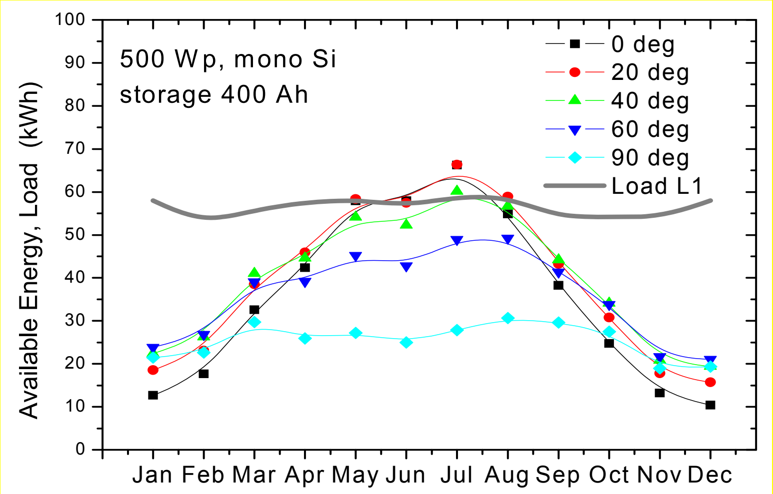
Primary needs:

-**light in the house and the barn**,
-**water pump** (for pumping water from the cistern into reservoar under the roof),
-**freezer**, **TV set**

Total estimated load <u>L1 = 677 kWh/year</u>):

Additional important needs (<u>L2 = 1100 kWh/year</u>):

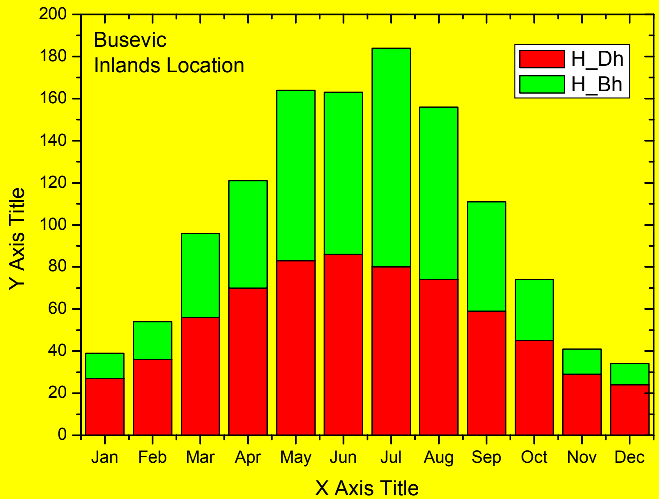
refrigerator,
small apliances,
possibly milking machine



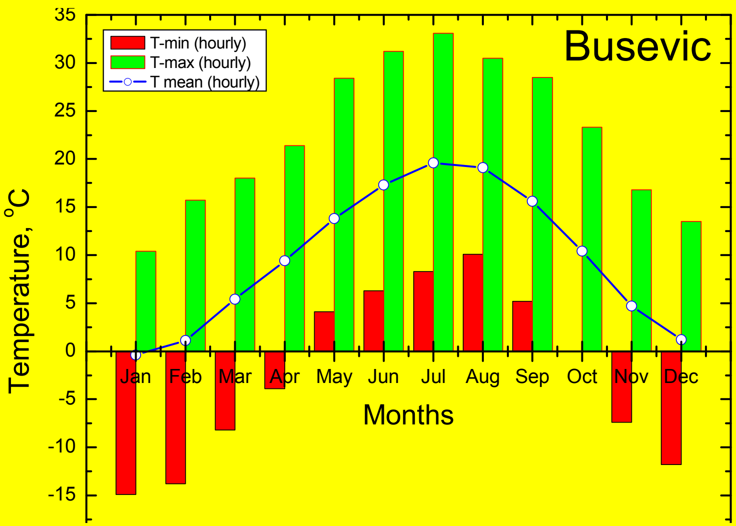
2.a. Detailed simulation – Meteonorm

Climatic Conditions at the selected location Busevic,

Since there are no near-by meteo-stations, which would measure climatological data at or close to the selected location, we have used computer program ***Meteonorm*** **(**both monthly averages and hourly values for typical year are calculated).



Monthly average of **global solar radiation on horizontal** surfaces (kWh/m2 per month), shown as sum of Direct component (H_Bh) and Diffuse component (H_Dh).



Monthly averages of **Air Temperature** (°C) as well as extreme temperatures in each month: T_{min} and T_{max}

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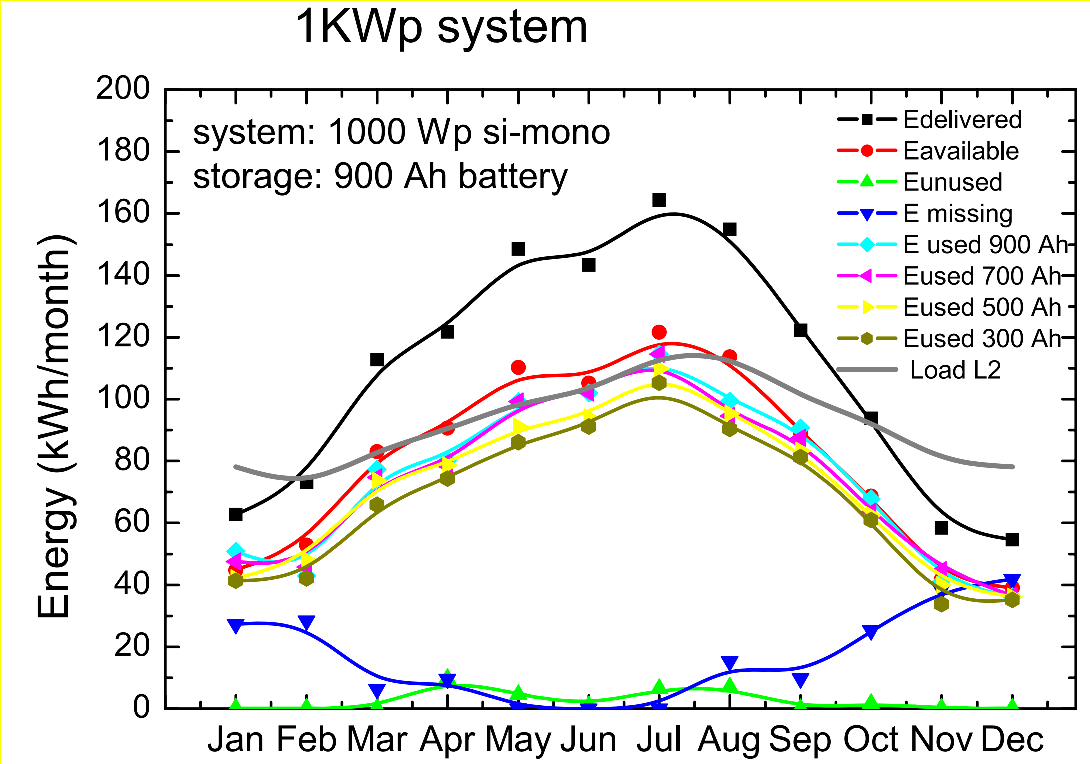
Paper Session: Renewable Energy I.

2.b. Detailed simulation – PVsyst

Technical aspects of the system: a house in village Bušević



Minimal E_{unused}, Large solar coverage of L (88% of L2)
Maximal E_{used}, Minimal Losses

2.c.Detailed simulation – RETScreen financial aspects, selected location Busevic

Realistic domestic prices (conservative, all inclusive)

1 kWp System Costs on the fully commercial basis (all taxes and expenses included):

Total Cost: 7879 €

Yearly cost of the loan:
(over the warranted lifetime of modules) **1008 €/year**

Energy cost 1.05 €/kWh
(for 960 kWh/year)

Still quite expensive, but bringing grid is even more expensive:

Continental locations

(Analysis for few sites in region of ***Lika***)

No.	Continental location	Number of users at the locations	Price of bringing grid (data from *ElektroLika*)
1	**Bušević**	**3**	**120 000 €**
2	**Homoljac**	**3**	**42 500 €**
3	**Vujinove Glave**	**20**	**178 000 €**
4	**Ćorkova Uvala** Plitvice National Park	Plitvice Lake, Object for scientists	**N/A**
5	**Grabušić**	**3**	**100 000 €**
6	**Uvalica**	**2**	**170 000 €**
7	**Melinovac**	**1**	**160 000 €**

The same 1 kWp PV system (continental location village Bušević):
(fully commercial price: 7879 €)

If all **ALREADY EXISTING possibilities for incentives and subsidies** (depending on the location) **are used**:
(Law about regions of special governmental care, National Gazette, NN. 26/03 , Croatian Bank for Rebuilding and Development (HBOR), Environment Protection and Energy Efficiency Fund (EPEE), Fond for regional development........)

1 kWp PV system , price **with subsidies**:

Total: 1576 €

Yearly cost of the loan: 302 €/year
(over the warranted lifetime of modules)

Energy cost: 0.32 €/kWh

Conclusions:

Economic aspects for PV system in Croatia:

1) Price of PV electricity depends

a) ***on location*** (sun potential, range 30%)

b) ***on location*** (for which subsidies are eligible, factor 4x !)

Even fully commercial price cheaper kWh than grid, subsidized prices much cheaper than diesel, but good loan necessary to bridge capital costs

2) Ecologically excellent

3) Socially – PV (and other RES) excellent opportunity to push economy and transform disadvantages of mountain region into advantages and chance for both solid and renewable growth and development

Potential for PV application in the mountainous and highlands regions of Croatia

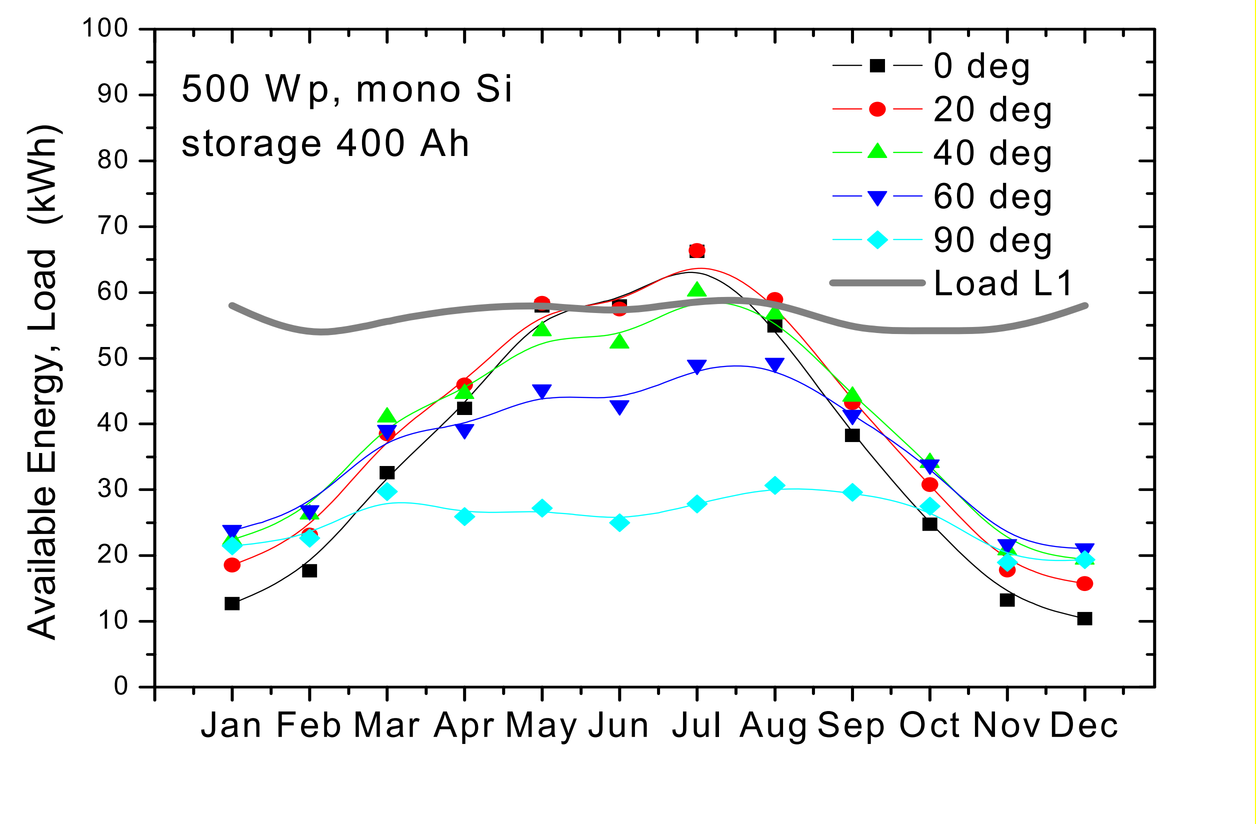
Administratively, the Busevic village belongs to poor Donji Lapac County.

The whole region was heavily devastated during the last war; most of the houses are still in ruins.

The village comprised 65 households, nowadays only seven are inhabited periodically.

Only one house has been inhabited permanently for the last three years. The house was rebuilt by the authorities, the 220V AC installations in the house were provided with renovation.

Lokacija: selo Bušević



Proračun optimalnog nagiba kompjuterskim programom Meteonorm

1. Određivanje potreba (prosječni dan u svakom mjesecu, oznaka L1)
2. Određivanje optimalnog nagiba modula – kompromis: sto više iskoristive sunčeve energije ukupno iukupno i što više zimi

2) Odrediti potrebe za strujom (najvažnije i one važne ali manje prioritetne)

LOKACIJE:

Kontientalne, seoske (Bušević)
Prioriteti:

1) Svjetlo za kuću i staje
2) Zamrzivač
3) Punjač mobitela
4) Pumpa za vodu
5) TV aparat
6) Hladnjak
5) Muzilica ......

drva (biomasa!) ima u izobilju i bez troška – za kuhanje, grijanje, pa i grijanje vode (iako je to donekle problem)

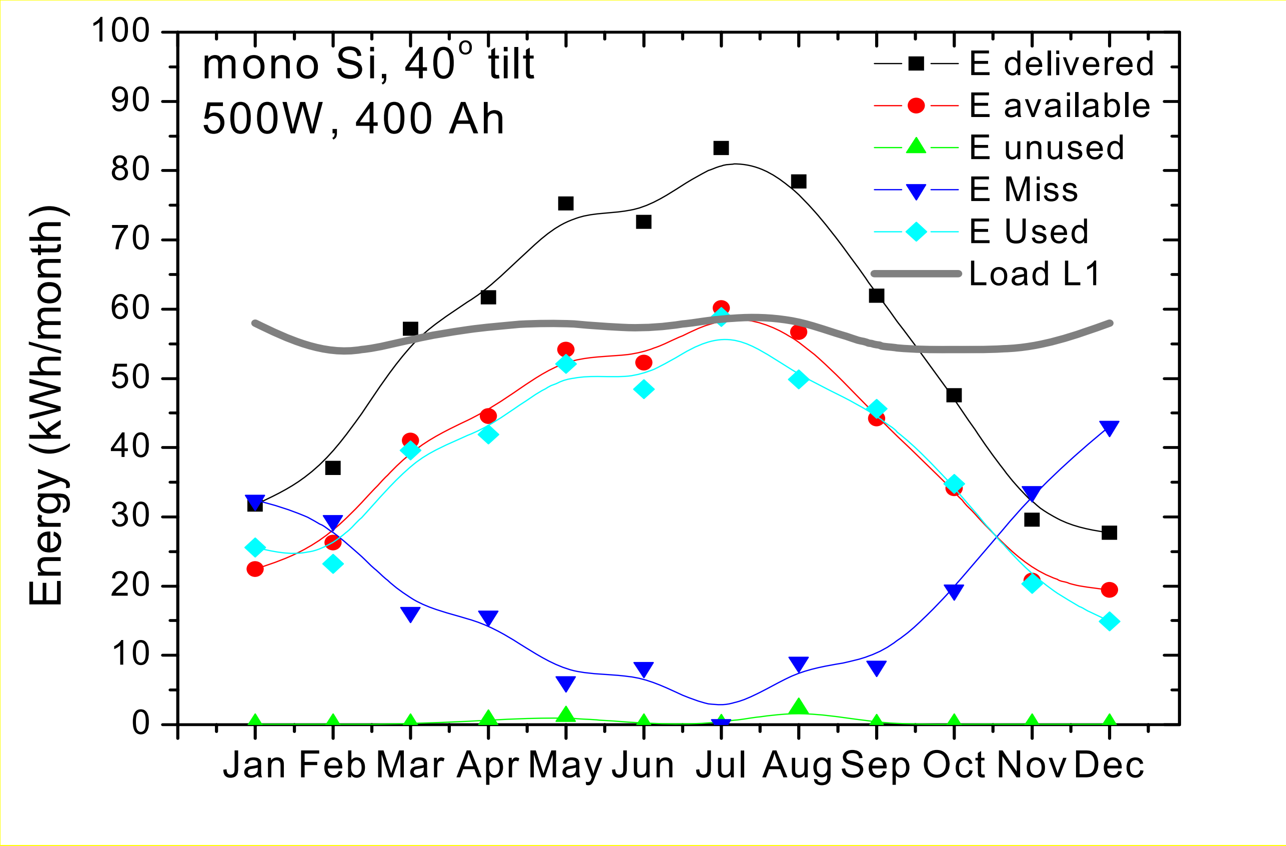
Kuća-restoran- marina (otok Žut)
Prioriteti:

1) Svjetlost za kuću i dokove
2) Punjač mobitela i punjač za kompjuter
3) Mašina za led
4) Mašina za kavu (espresso)
5) Mali kućanski aparati (mikser...)
6) TV set (or at least radio)
7) Priručni hladnjak

Za kuhanje je na raspolaganju plin iz boca (također za veliki frižider i frizer) – dolazi brodom

Dizel generator se koristi povremeno, za brzo punjenje akumulatora jahti, itd) Dizel se koristi samo koji sat danju, jer je bučan i smrdi, relativno skupo gorivo.

Lokacija: selo Bušević



Proračun dobivene energije i cijena kompjuterskim programom PVSyst.

3. Dimenzioniranje sistema. Konkretno, 3.8 m2 modula efikasnosti 13.3%, akumulator 400 Ah
4. Proračun ukupne isporučene energije (teoretski maksimum), stvarno iskoristive energije, neiskorištene energije, energije koja nedostaje

Cijena PV sistema (za osnovne potrebe) za kontinentalnu lokaciju Bušević

5 solarnih panela, svaki od 100 Wp, cijena 574 €/modul (20 godina garancije)
4 solarna akumulatora, svaki od 100 Ah, cijena po komadu 177 €/100 Ah
(pretpostavljena zamjena svakih 6 godina)
Ostalo: okvir za module, inverter, regulator, montaža 600 €

Sistem ukupno 4128 €

Godišnja cijena otplate svih troškova na sasvim komercijalnoj osnovi: 538 €/year.

Cijena energije: 1.13 €/kWh.

Bez poticaja ipak vrlo skupo.

S druge strane, dovođenje mreže je ipak daleko skuplje:

Cijena PV sistema (za osnovne potrebe) za kontinentalnu lokaciju Bušević:

Cijena **na potpuno komercijalnoj osnovi**, i svi troškovi uključeni:
Ukupno 4128 €/sistem (500 Wp snaga)
Cijena otplate svih troškova na sasvim komercijalnoj osnovi: 538 €/year.
Cijena energije: 1.13 €/kWh.

Postoje, međutim brojne mogućnosti za pomoć i poticaje, ovisno o lokaciji:
Zakon o područjima posebne državne skrbi , Narodne novine No. 26/03 ,
Hrvatska Banka za Obnovu i Razvitak (HBOR)
Fond za zaštitu okoliša i energetsku učinkovitost (ZOFU)
Fond za regionalni razvoj
....

Isti osnovni 500 Wp PV system, kad se uračunaju poticaji postaje **znatno jeftiniji**:
Ukupna investicija: 826 €
Ukupna godišnja otplata (uključuje otplatu kredita, održavanje i zamjenu akumulatora svakih 6 godina)
169 €/godina (mjesečni obrok: 14€)
Cijena solarne struje: 0.35 €/kWh

Cijena PV sistema ovisi, dakle, o puno faktora:

Lokacija (koliko sunca)
Lokacija (koji poticaji i stimulacije se mogu dobiti)
Koliko struje treba (izborom štednih potrošača potreba se jako smanjuje)
Vrsta sistema (način korištenja)

Posebno su atraktivni **mali sistemi** koji se koriste samo vikendom, jer se tada najskuplji dio uređaja – solarni moduli – znatno smanjiti u odnosu na akumulator.

Tako će mali sistem, od kojeg očekujemo samo nekoliko (ŠTEDNIH!) žarulja i poneki mali potrošač struje (pumpa za vodu, punjač mobitela ili punjač kompjutera) moći nabavit za ispod 400 €.

Mali sistem koji uključuje još i pogon frižidera koštat će oko 1000 €.

Jednostavni PV sistemi su idealni i za samogradnju.

FP6 Project RISE
(Renewables for Isolated Places...)

Prices to bring grid to Maritime locations are even higher
(Analysis for some small islands in Zadar region)

Number	Name of the island	Number of houses	Permanently inhabited	Approximate location	Municipality
1	LAVDARA	20	1	DUGI OTOK	SALI
2	KATINA	10	2	DUGI OTOK	SALI
3	GLAMOČ	3		DUGI OTOK	SALI
4	KRKNATA	7		DUGI OTOK	SALI
5	BURNI ŠKOLJ	2		TELAŠČICA	SALI
6	FAFARIKULAC	1		TELAŠČICA	SALI
7	SKARDA	12		IST	ZADAR
8	BABAC	20	5	PAŠMAN	Sv.Filip I Jakov
9	ŽIŽANJ	24		PAŠMAN	TKON
10	KOŠARA	Fish farm		PAŠMAN	TKON
11	GANGAROL	25	1	PAŠMAN	TKON

GRID PRICE:
DP “Elektra” ZADAR

423 000 €

766 000 €

141 000 €

513 000 €

292 000 €

282 000 €

515 000 €

U. Desnica, I. Raguzin
6th BPC, Ohrid June 2, 2006

In selected house, Mr Jovo Ovluka lives with his wife and a grown up son.

Their only occupation has been agriculture and goats rising. Currently, they have a herd of 30 goats.

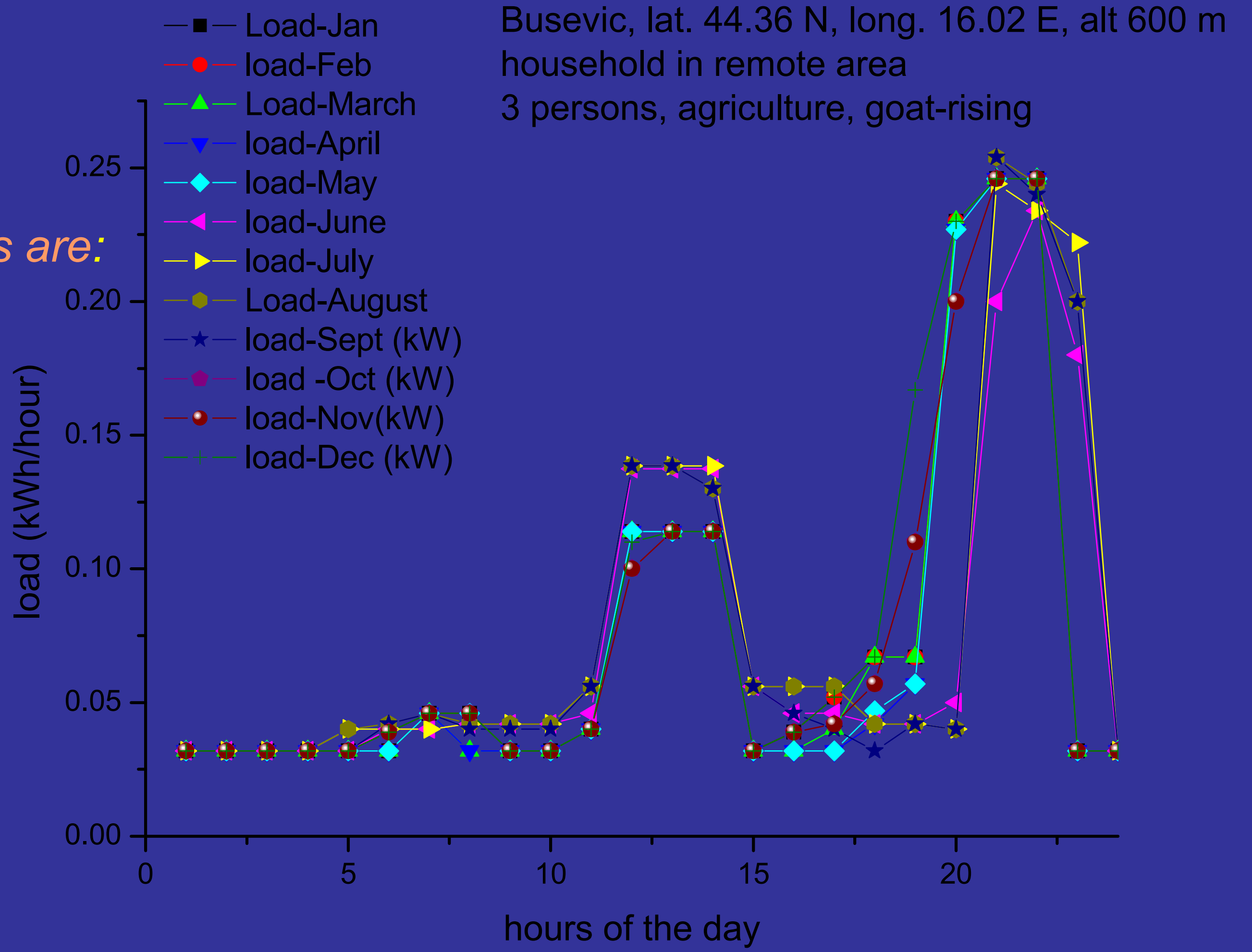
Providing refrigerating facilities, they would like to start cheese production and diversification of other products.

At present, their basic needs are:

- Lights
- Deep-freezer
- Boiler (thermal solar)
- Radio/TV

Optionally:

- Well-pump
- Milking machine
- Washing machine



Potential for PV application in the mountainous and highlands regions of Croatia

Uroš Desnica
Paper Session: Renewable Energy I.

Potential for PV application in the mountainous and highlands regions of Croatia

Uroš Desnica

Paper Session: Renewable Energy I.

Estimation of Costs for Implementation of a PV System in an Isolated Region

A.Krkoleva, V.Borozan
Faculty of Electrical Engineering-Skopje
6th Balkan Power Conference

Contents:

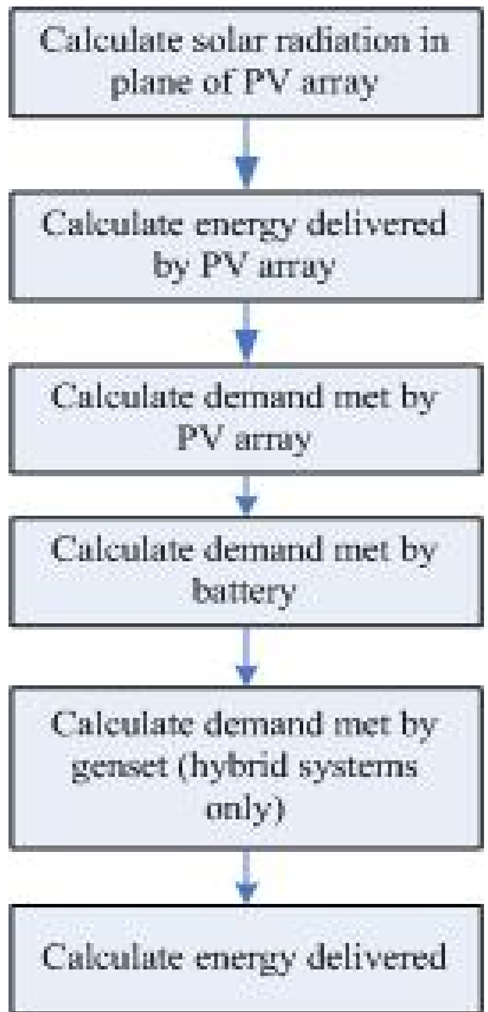
Introduction

- Preliminary estimation of costs associated with the implementation of RES technology solution at one of the selected sites in Macedonia – sheepfold Fezlievo Bacilo
- Software packages with modules for optimization of the design of RES for electricity in isolated regions (HOMER, HYBRID2 and RETScreen)
- Preliminary analysis done with RETScreen

Study case Fezlievo Bacilo

- Geographical data: latitude 41˚47’9”, longitude 20˚35’41”, altitude 1950 m
- Number of employees: 10
- Number of sheep: 3000
- Remote location
- Populated only during the wormer part of the year, from May till October

Photovoltaic Project Analysis Model

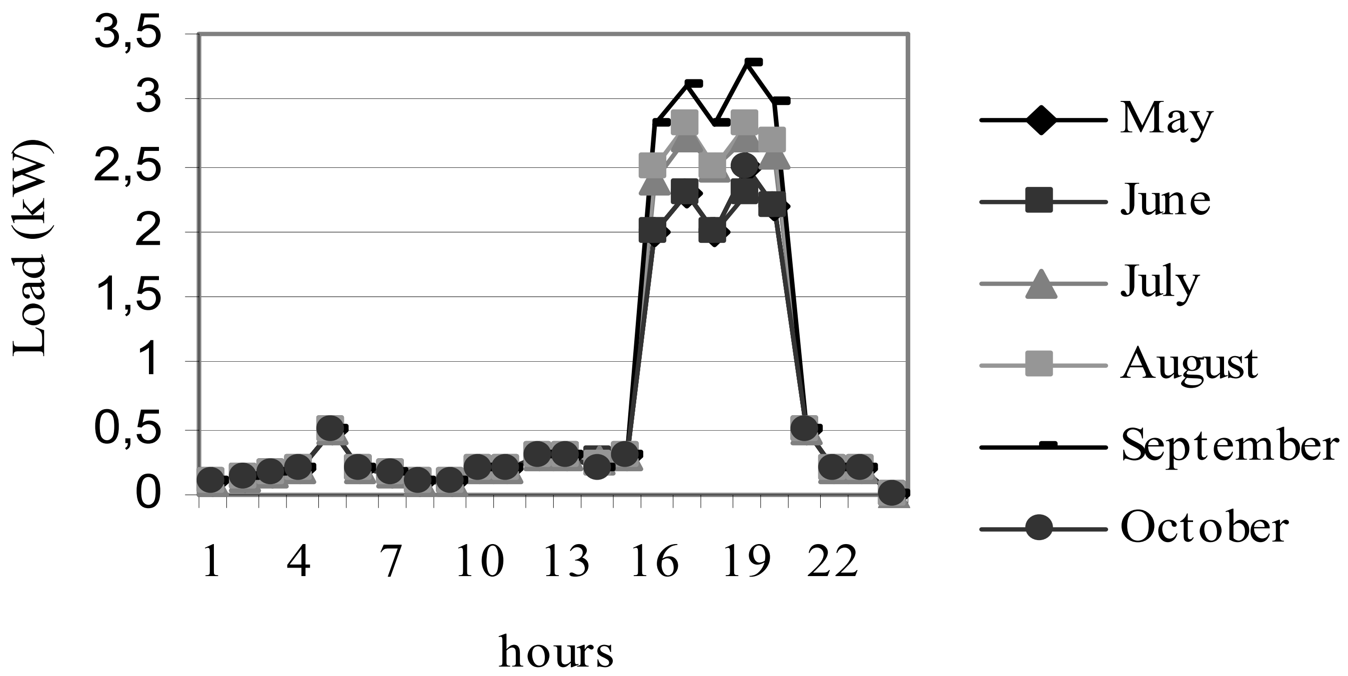


Load identification

Appliance	Size (W)	Timing	Hours per week	Days per week
Light bulb 1	18	05-06 19-23	5	7
Light bulb 2	12	19-24	4	7
Refrigerator	300	0-24	12	7
Milk pasteurization machine	3000	16-21	5	7
TV/Radio	40	20-22	2	7

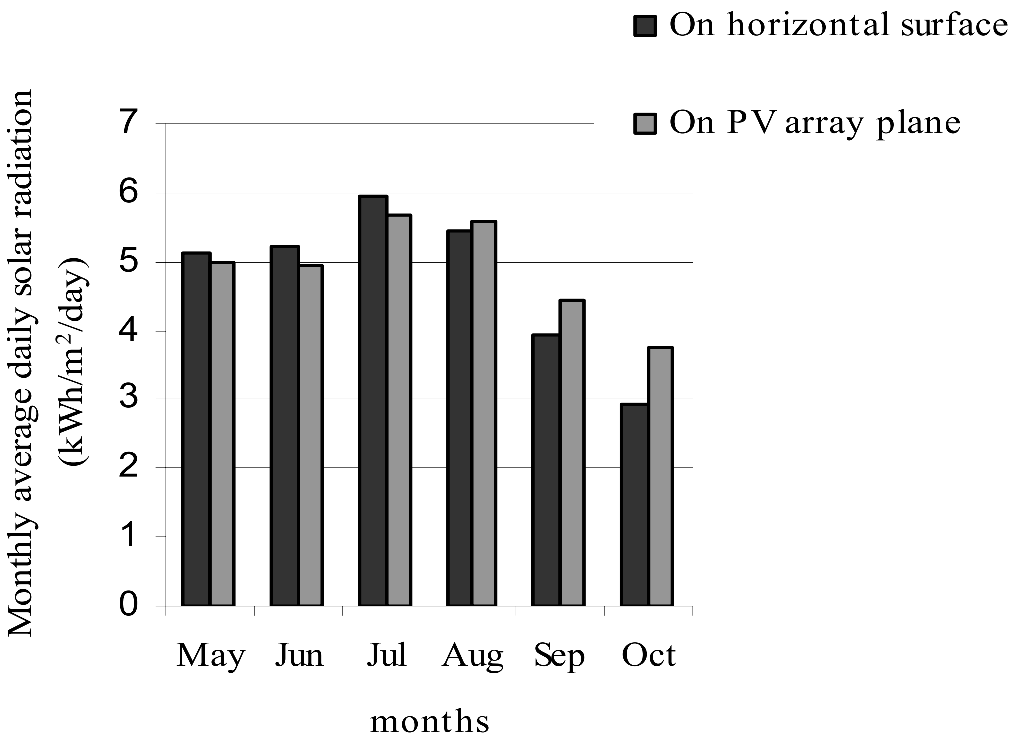
Load data for a typical day in May

Load identification



Daily load curve for an average day during the months when the sheepfold is inhabited

Solar radiation data



Monthly average daily solar radiation at selected location

Description of the PV system

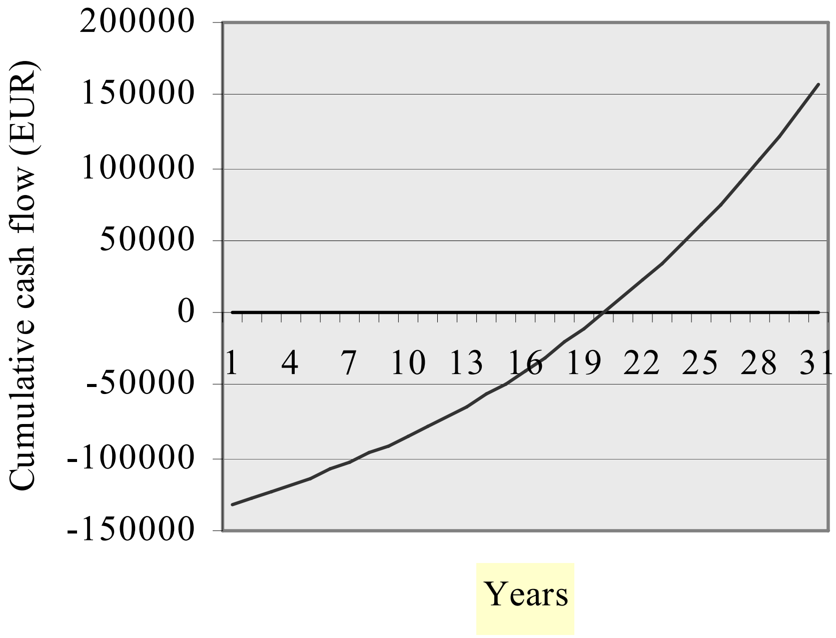
- Modules with mono-Si cells are chosen
  - Selection criteria: price from suppliers, product availability, warranties, efficiencies, etc
- Nominal module efficiency: 11%
- Array with nominal power of about 6 kWp
- Array area of 54.2 m^2 (43 modules).
- Array controller (Maximum Power Point Tracker)
- Battery (24V, efficiency 85%)

Cost analysis and financial summary

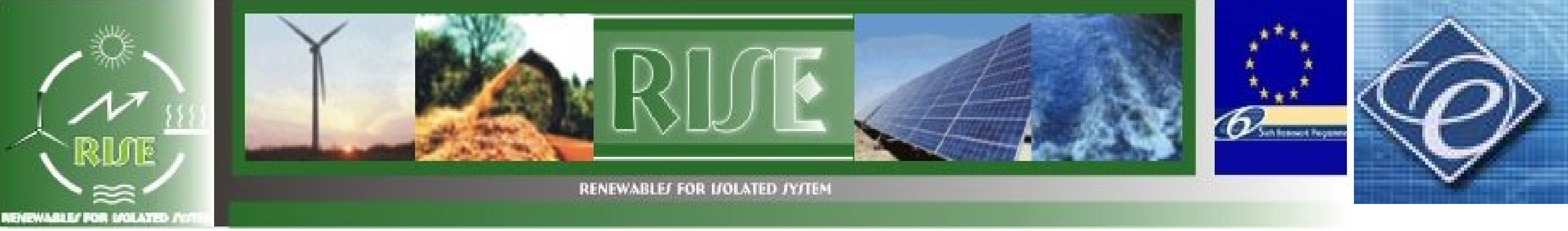
- Data for possible prices of:
  - energy equipment (PV modules)
  - balance of equipment (module support structure, inverter, batteries and other electrical equipment.
- Initial costs: equipment installed on site, design study, installation and transport

Cost analysis and financial summary

- Base case: diesel aggregate

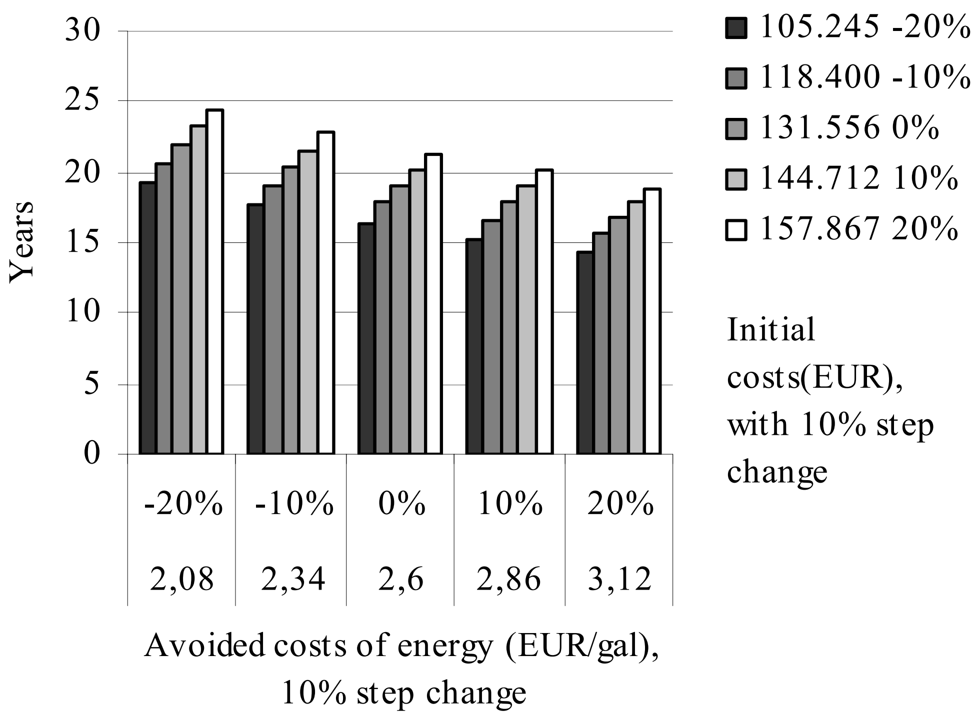


Cumulative cash flow when PV system replaces a diesel aggregate



Cost analysis and financial summary

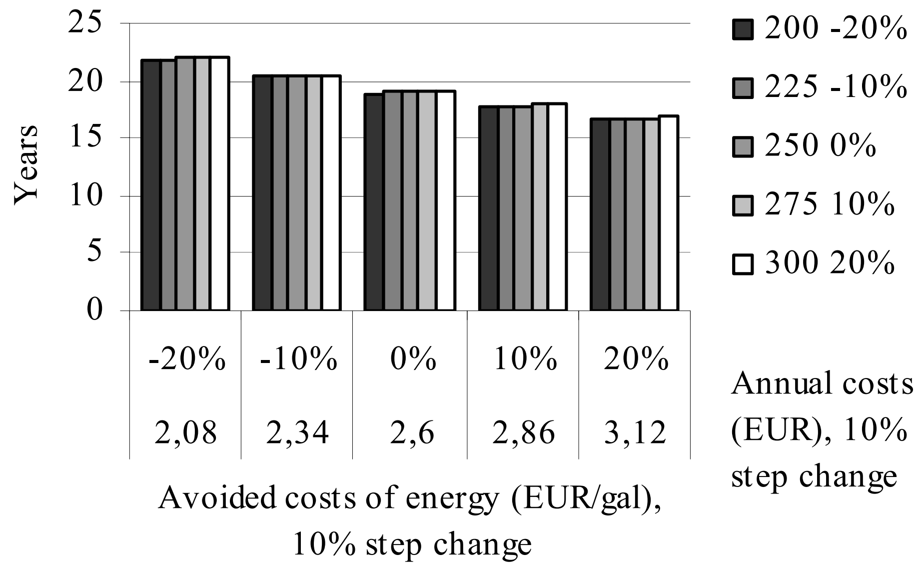
- Sensitivity analysis



Sensitivity analysis graph showing the year-to-positive cash flow when the avoided costs of energy and the initial costs are changed with 10% step change

Cost analysis and financial summary

- Sensitivity analysis



Sensitivity analysis graph showing the year-to-positive cash flow when the avoided costs of energy and the annual costs are changed with 10% step change

Conclusion

- The year to positive cash flow is nineteen years when the diesel aggregate is replaced with a PV system
- The intervention becomes more attractive if social benefits (improvement of production process, quality of life, better economic performance) are taken in consideration
- If implemented, could contribute to demonstration of PV technology performances in local conditions, increasing thus the possibility to replicate to similar locations

Economic and Environmental evaluation of Large Solar Water Heating System installed in Macedonian Sheepfold

ICEIM-MANU

Nikola Bitrak, Mirko Todorovski, Natasa Markovska

6^{th} *BalkanPowerConference*

Ohrid, 2.5.2006

Contents

I. Introduction

- Average solar radiation - 3.8 kWh/m2/day

- Total annual solar radiation:
  - minimum of 1,250 kWh/m2 in Northern part
  - maximum of 1,530 kWh/m2 in the South Western part,
  - average of 1,385 kWh/m2.

Mass implementation of Solar Thermal Systems

Barriers:
- Low Electricity prices,
- Non-available investments,
- Low level of awareness,

Driving forces:
- Favorable climatic conditions,
- Ever increasing oil prices,
- Introduction of a new electricity tariff system,

II Study case (performed under the EU FP6 project RISE, FP6-INCO-509161)

A. Methodology

RETScreen International Renewable Energy Project Analysis Software

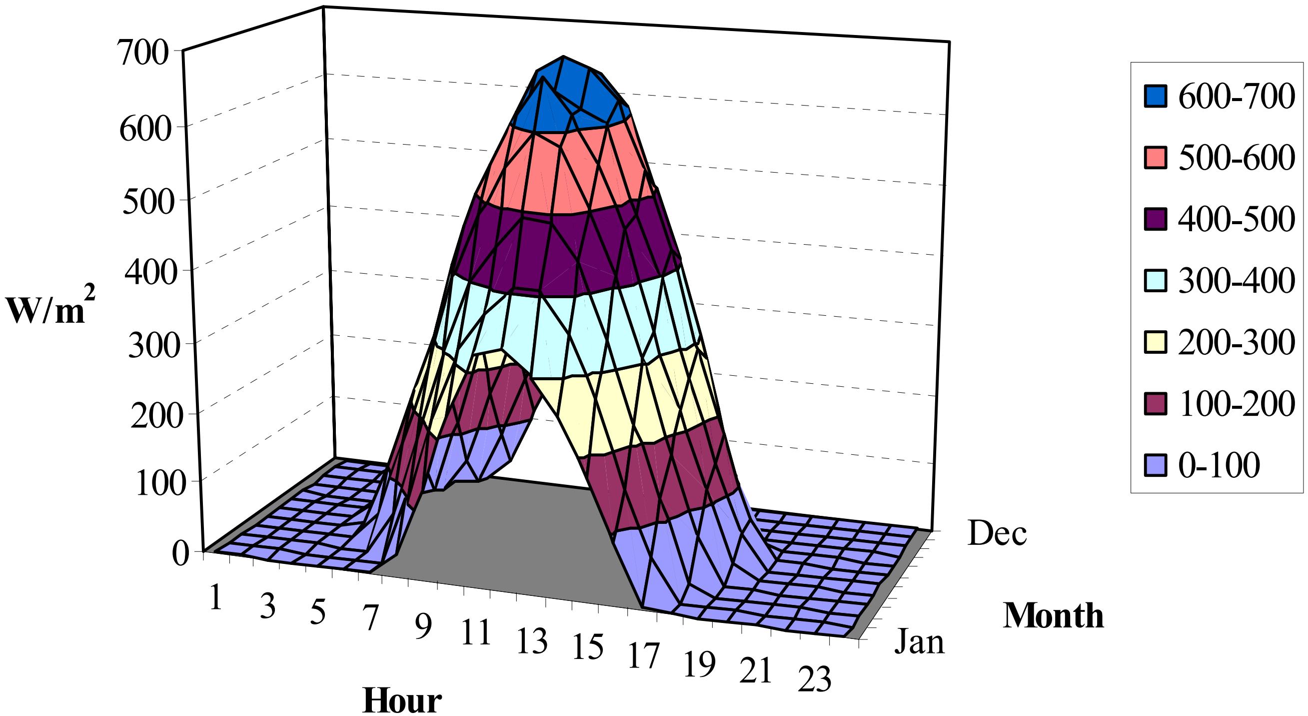
- Evaluated parameters: *energy production, life-cycle costs and greenhouse gas emission reductions.*

- Also includes: *product cost, weather databases and a detailed online user manual.*

B. Location

- "Fezlievo Bachilo" is located near the Albanian border, in the National Park Mavrovo, altitude of about 1950 m
- Populated from May until October; about 3000 sheep,10 employees.
- Hot water needs: 2000 liters per day (60˚C for cheese production and hygienic purposes).
- No systematic measurements of Solar Radiation.
- Application of the METEONORM software to calculate the hourly values for the whole year for all solar radiation types and the all other meteorological data.

Hourly Distribution of Global Solar Radiation at Fezlievo Bachilo



C. Large Solar Water Heating System

Hot Water Solar Collector Characteristic

Solar Collector		
Collector type	-	Glazed
Solar water heating collector manufacturer		Austria Email
Solar water heating collector model		Sunlight 2500 -T
Gross area of one collector	m^2	2.53
Aperture area of one collector	m^2	2.4
Fr (tau alpha) coefficient	-	0.72
Fr UL coefficient	(W/m^2) / °C	4.15
Suggested number of collectors		13
Number of collectors		13
Total gross collector area	m^2	32.9

Storage and BOS Characteristics

Storage		
Ratio of storage capacity to coll. area	L/m²	80
Storage capacity	L	2,631
Balance of System		
Heat exchanger/antifreeze protection	yes/no	Yes
Heat exchanger effectiveness	%	80%
Suggested pipe diameter	mm	19
Pipe diameter	mm	38
Pumping power per collector area	W/m²	10
Piping and solar tank losses	%	1%
Losses due to snow and/or dirt	%	3%
Horz. dist. from mech. room to collector	m	10
floor from mech. room to collector	-	0

Costs

- The investment costs: estimated to 9,867 € (equipment costs, transportation and installation).
- O&M costs: estimated to 55 € per year (about 0.6 % of the investment costs).
- Periodic costs of 500 € every 10 years for valves and fittings.

Base case Water Heating System:

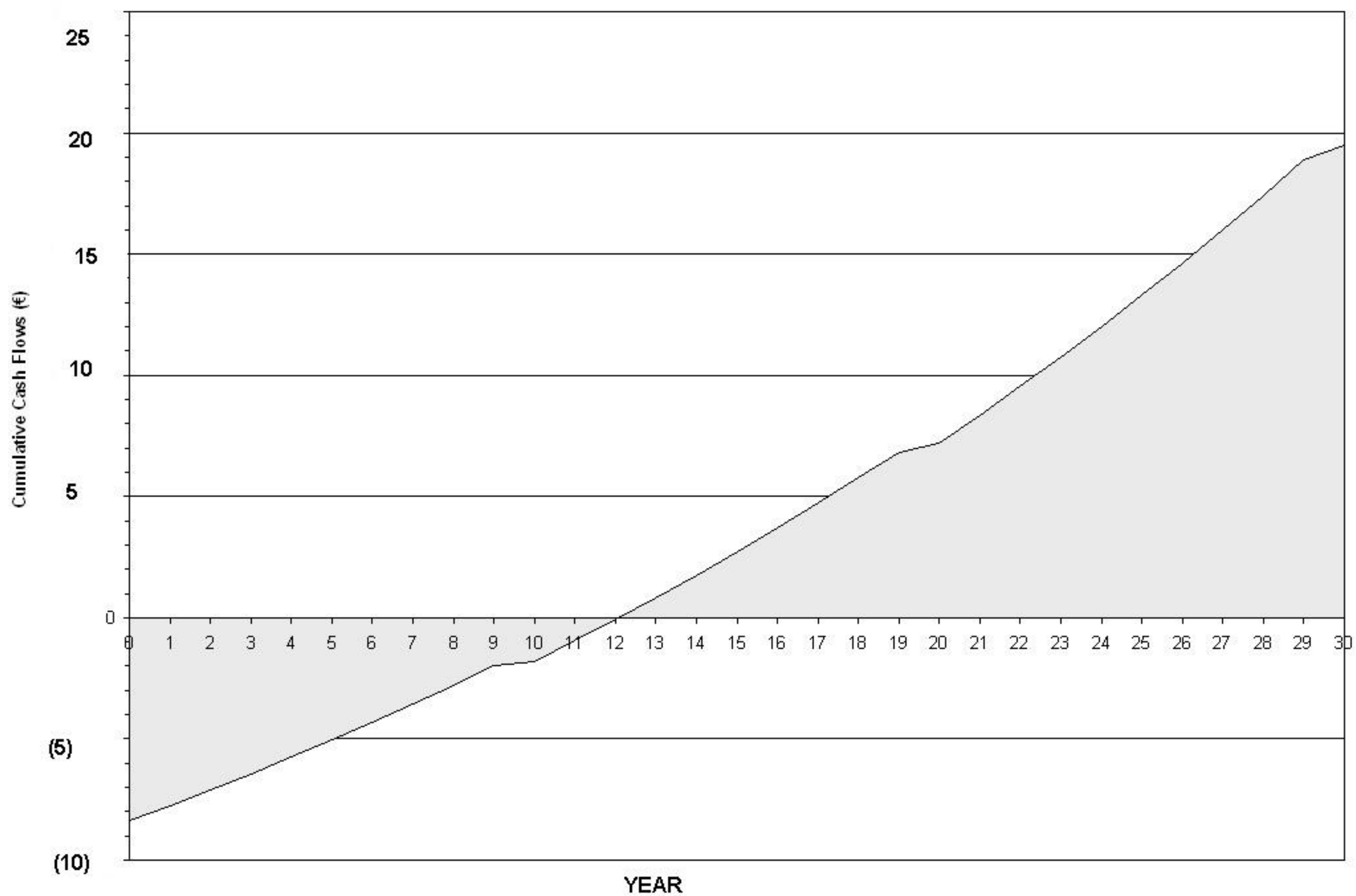
Diesel Generator, efficiency 80%.

D. Economical Evaluation

Annual Energy Production and Financial Feasibility

Specific yield	kWh/m^2	247
System efficiency	%	64%
Solar fraction	%	43%
Renewable energy delivered	MWh	8.12
Renewable energy delivered	GJ	29.22
Pre-tax IRR and ROI	%	8.7
After-tax IRR and ROI	%	8.7
Simple Payback	yr	13.8
Year-to-positive cash flow	yr	12.1
Net Present Value - NPV	€	667
Annual Life Cycle Savings	€	59
Benefit-Cost (B-C) ratio	/	1.07

Cumulative cash flow



E. Environmental Evaluation

GHG Reduction

CO2-eq emission factor	t/MWh	0.336
Average GHG reduction	t CO_2/yr	2.48
Renewable energy delivered	MWh/yr	8.12
GHG emission reduction cost	€/t_{CO2}	-24

III. Conclusion

- The economic indicators for large hot-water systems are attractive since the avoided costs of heating energy (diesel oil) are pretty high. But even in this case the payback period is longer then 10 years, mainly due to the high investment costs and no grants conditions.

- The sensitivity analysis has shown that any variation in the renewable energy delivered, initial costs and avoided cost of heating energy by a ±20% will not change the economic indicators in such a manner that the project may become unviable if it was viable before.

…

- On the other hand, such system is a win-win measure for GHG abatement, since the emission reduction costs are negative meaning that the project saves certain amount of emissions, saving at the same time considerable fuel costs.

- In addition, this project will considerably improve the quality of life at the location and will contribute to advanced cheese production process. This in turn will produce higher incomes and better social situation in the region.

Thank You For Your Attention!

Macedonian Academy of Sciences and Arts,
Research Center for Energy, Informatics and Materials

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Research Assistant
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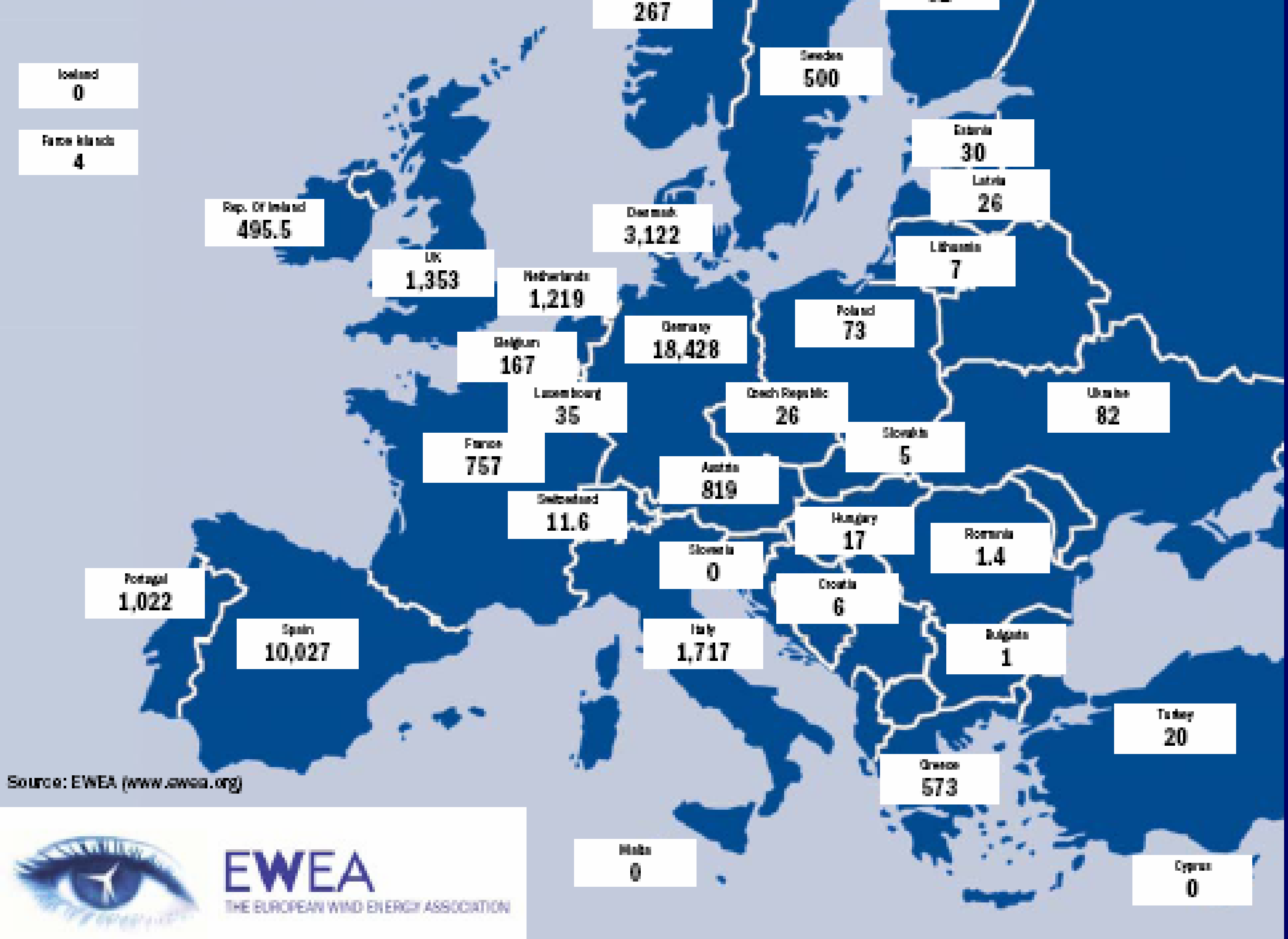
FEASIBILITY ANALYSIS OF WIND-PLANT IN THE REGION OF DELIBLATSKA PEŠČARA
(SERBIA)
Željko Đurišić, Nikola Rajaković, Dušan Mikičić
Faculty of Electrical Engineering, Belgrade
Momčilo Bubnjević, ACIES Engineering, Belgrade

WIND POWER INSTALLED IN EUROPE BY END OF 2005 (CUMULATIVE)

EU – 40,504 MW
ACCESSION COUNTRIES – 28 MW
EFTA COUNTRIES – 279 MW



Source: EWEA (www.ewea.org)

EWEA
THE EUROPEAN WIND ENERGY ASSOCIATION

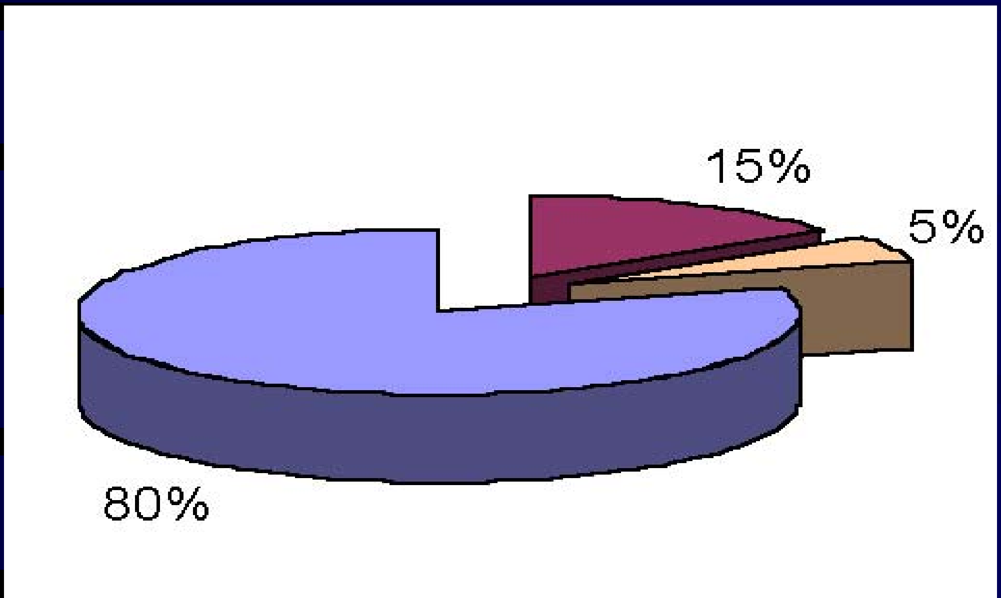
COSTS STRUCTURE FOR WIND PLANT PROJECTS

- Investment costs (*capital costs)* – *costs of purchase, transport, wind-generator construction and its connection to the network;*

- Production costs (*running costs*) – *operational costs, repair, land renting, etc.*

- Costs of financing - *depend on national credit policy*

TYPICAL COSTS STRUCTURE FOR SMALL WIND PLANT (8MW) PROJECTS



Costs of purchase and transport of wind-turbine, including mast and other equipment (*ex –work costs*) (~80%)

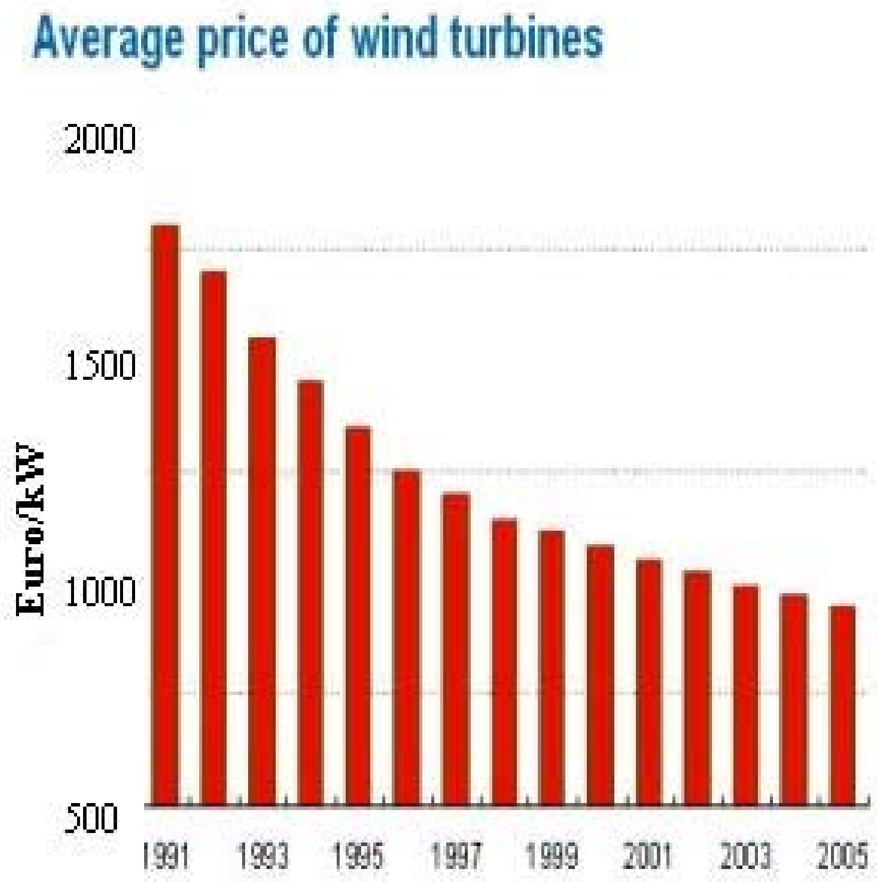
Construction costs (~15%)

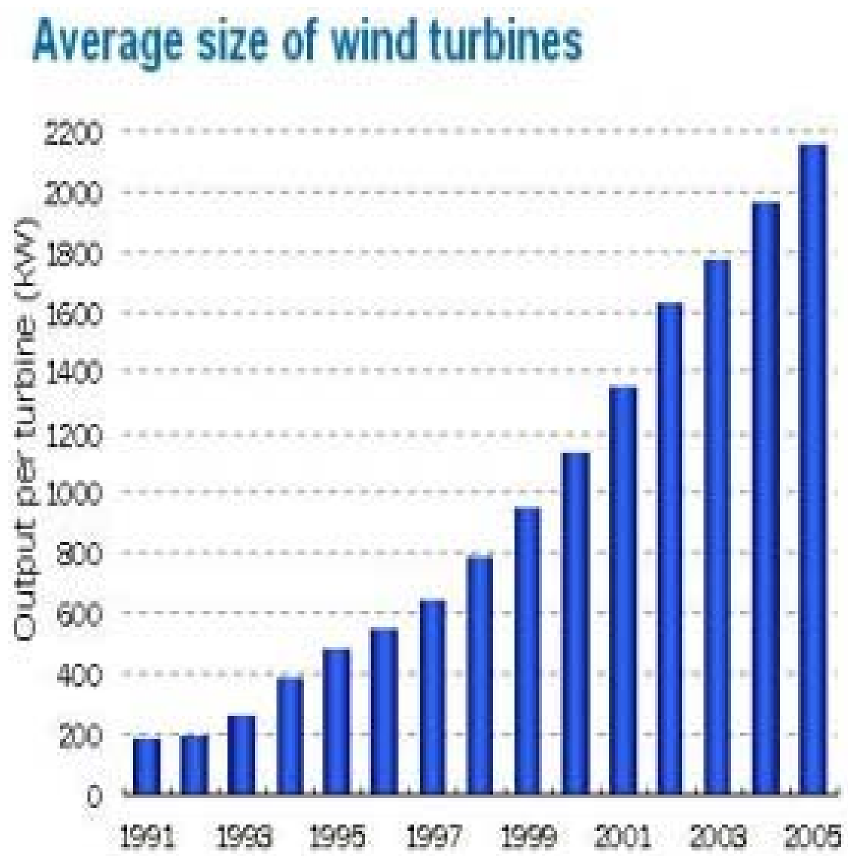
- *building road and telecommunication infrastructure*
- *building works (foundation)*
- *connection to electric network*
- *other costs*

Project development costs (~5%)

- *land*
- *measurements of wind potentional*
- *project documentation*
- *insurance*
- *rate of interest in project life period*
- *administrative taxes*

TRENDS IN AVERAGE PRICES AND IN AVERAGE SIZES OF WIND TURBINES





WIND-PLANT ECONOMY

- available wind potentional
- wind turbine availability
- wind turbine lifetime
- project financing elements

Model for calculating electric energy production costs in a wind-plant

$$c = \frac{a \cdot I_{tot}}{A \cdot E} + m$$

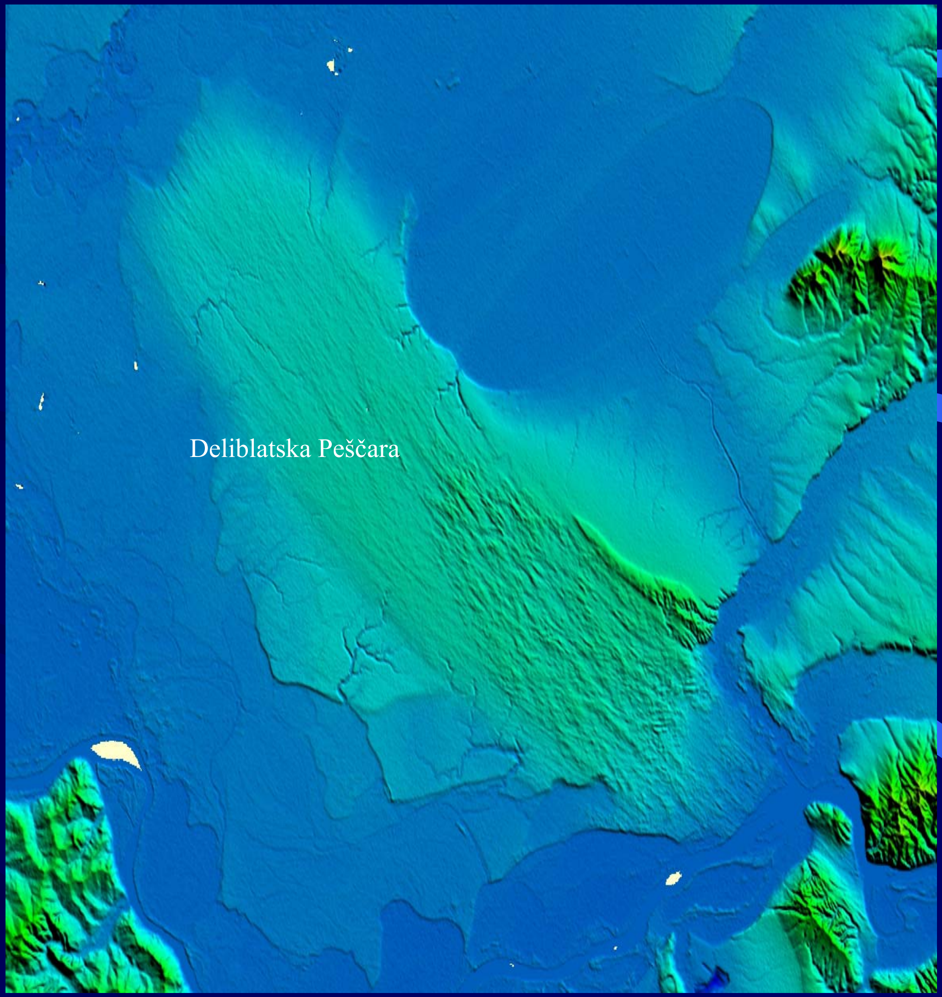
c – price of electricity production (Euro/kWh),
I_{tot} – total investment per 1m^2 of wind turbine rotor,
A – wind plant availability,
E – annual energy production per 1m^2 of rotor (kWh/m^2),
m – operational costs (Euro/kWh).
a – actualization factor,

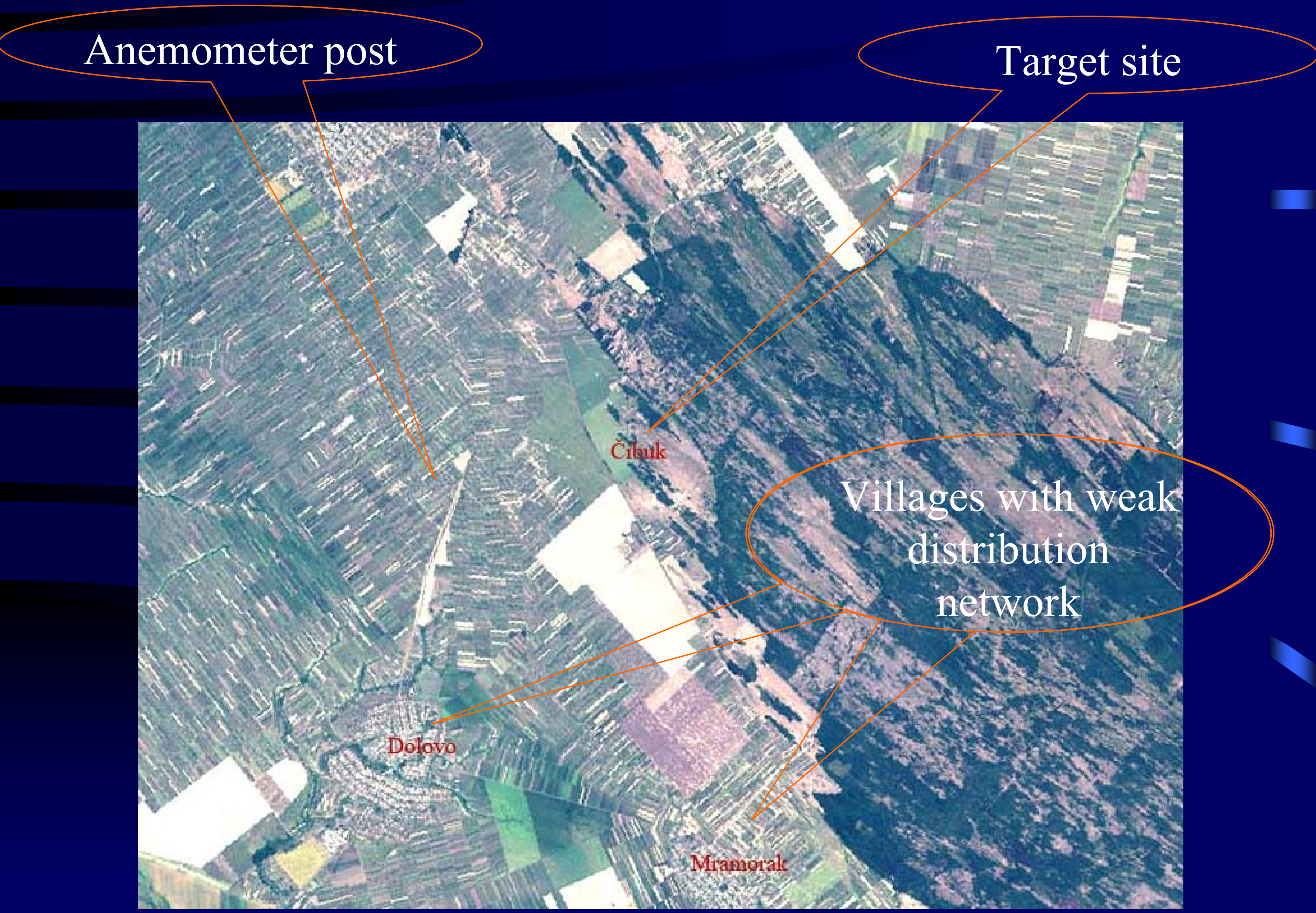
$$a = \frac{i(1+i)^n}{(1+i)^n - 1}$$

i - rate of interest,

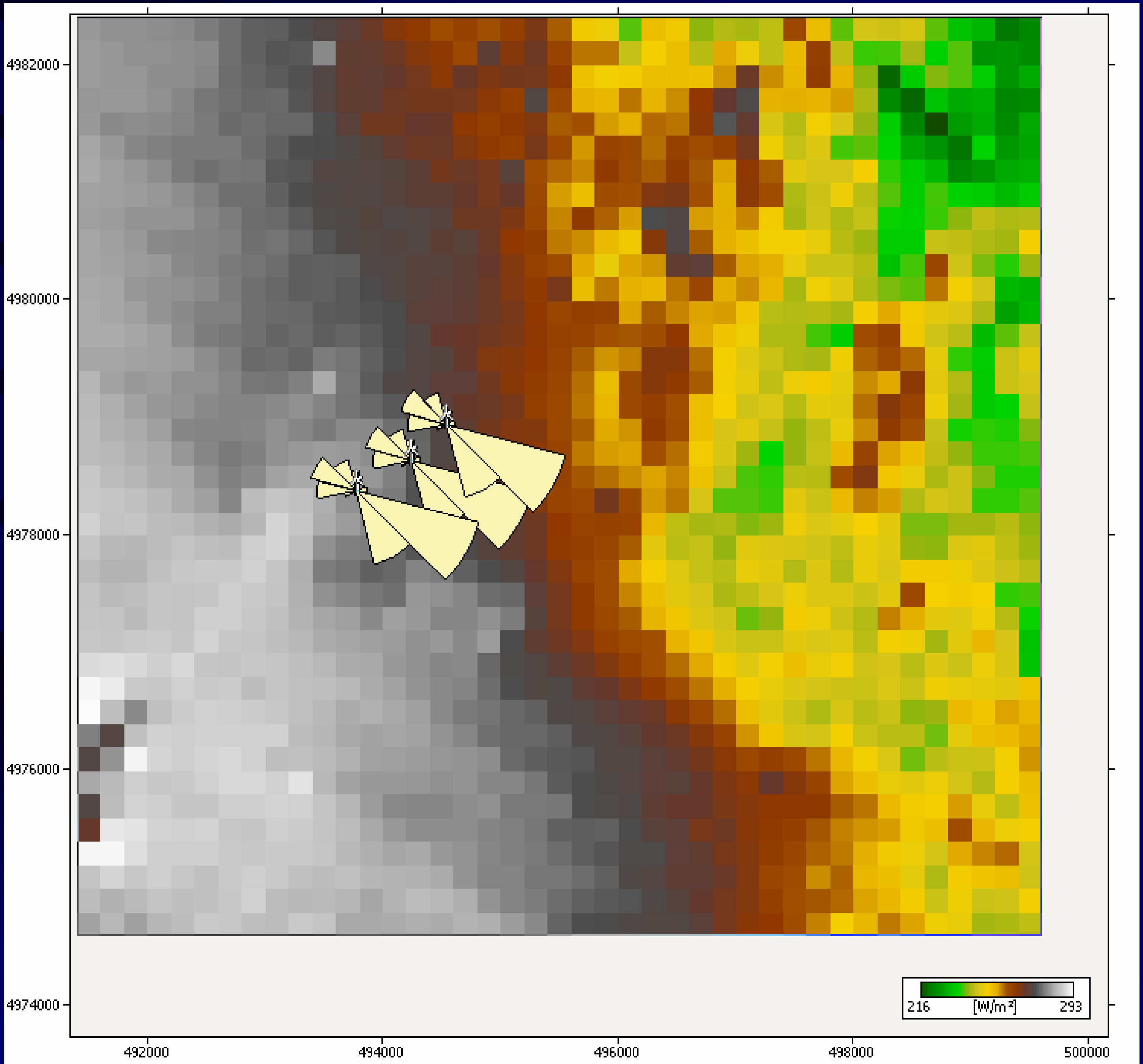
n - amortization period.

Location and orografy given by a satelite photo of target zone – Deliblatska Peščara

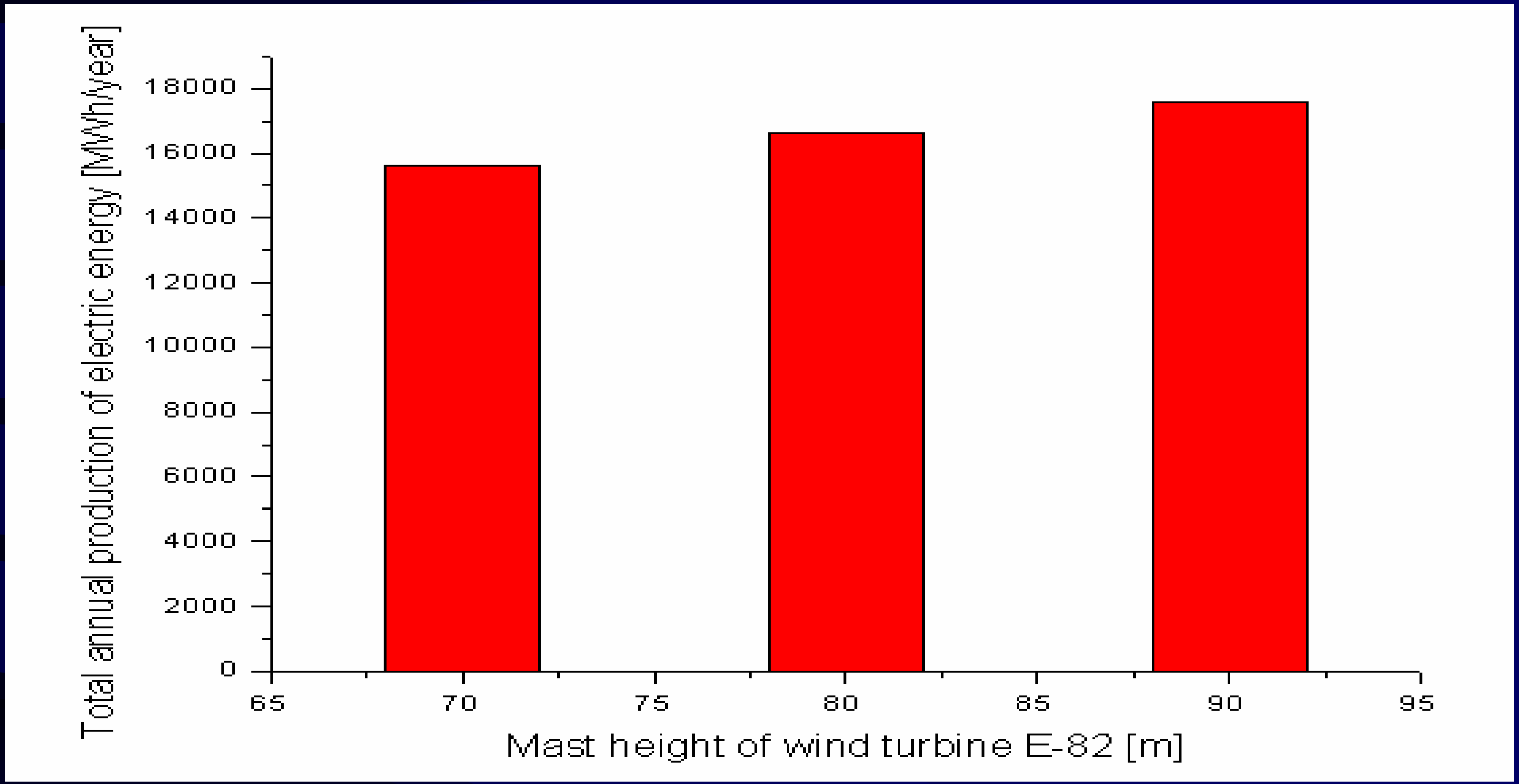



Anemometer post
Target site
Villages with weak distribution network
Čibuk
Dolovo
Mramorak

Wind potential and wind rose estimated on potential wind plant micro locations using WaSP



Estimated electricity production for a wind-plant of 6MW (3×2MW) installed power



Expected capacity usage factor (τ) on yearly basis:

$$\tau = \frac{16,6 \cdot 10^6}{8756 \cdot 6000} 100 = 31,6\%$$

Following input data are specified in this analysis:

I_{tot} = 1,25 · 4 740 000 ≈ 5 900 000 Euro

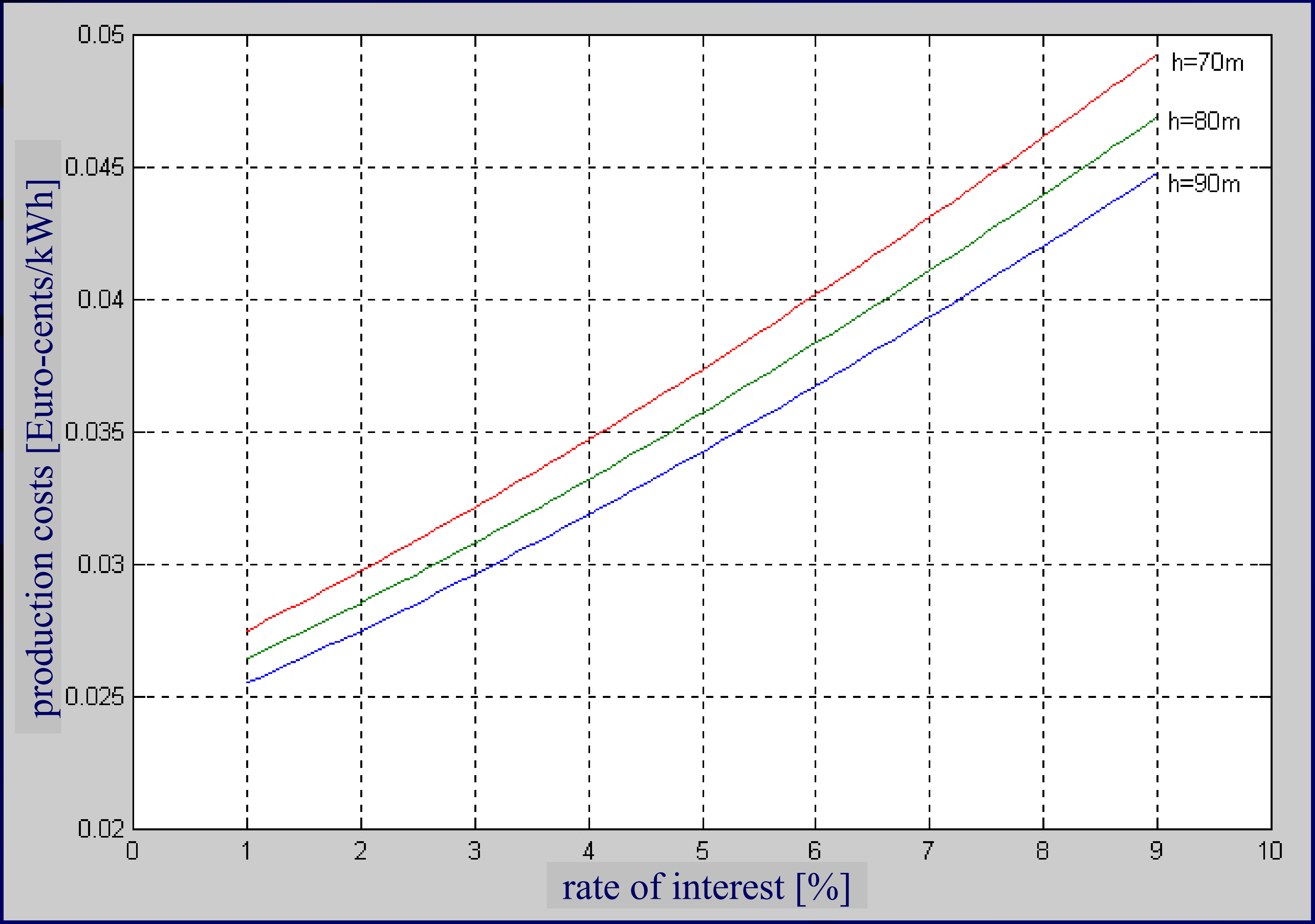
amortization period - $n = 25$ years,

operational costs - $m = 0{,}1$ Euro cent/kWh ,

rate of interest - i varies from 2 to 8%,

availability - A =98%.

Electric energy production costs for perspective wind-plant of 3×2MW power at target site Čibuk



SUMMARY

- Target location has a good wind potential with annual average speed of 6,5 m/s calculated at 80m height above ground.
- Annual production of perspective wind-plant has been determined, amounting 16600 MWh/year for the selected wind-turbines 3×ENERCON (E-82) mounted on a 80m mast
- Capacity usage factor of 31,6% is above the average for locations in countries of European Union.
- For a rate of interest between 4 and 6%, production costs are between 3,5 and 4 Euro-cent/kWh. These costs can be significantly reduced if the turbine is installed on a higher mast, where wind conditions are better, and if more convenient project financial terms are provided.
- For the analysed location, low costs of transport, connection to the distribution 20kV network and maintenance costs should be expected.

EXPLORATION OF WIND ENERGY POTENTIAL IN REPUBLIC OF MACEDONIA

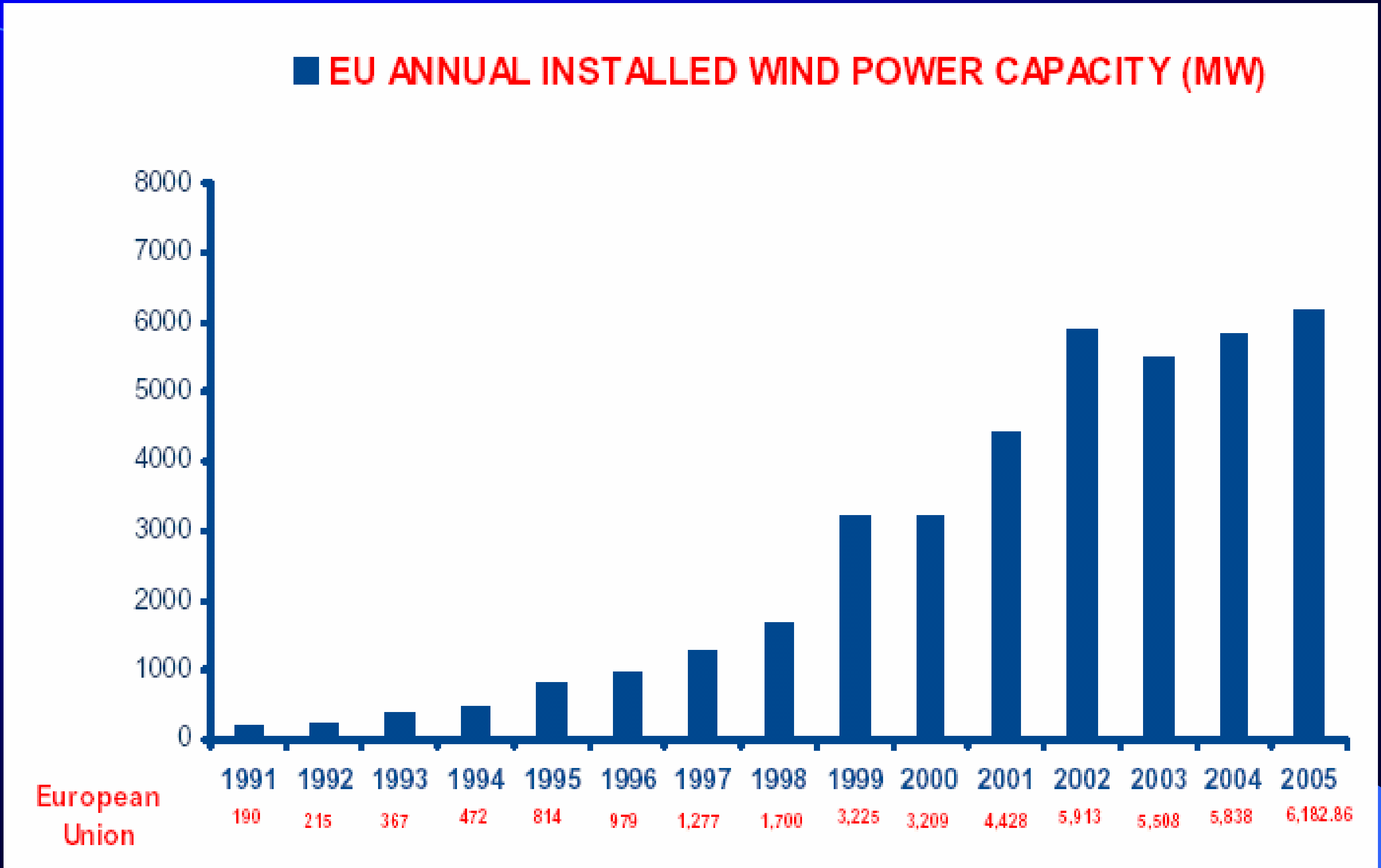
Vladimir Dimcev, Krste Najdenkoski, Vlatko Stoilkov

Faculty of Electrical Engineering - Skopje

Balcan Power Conference, Ohrid 2006

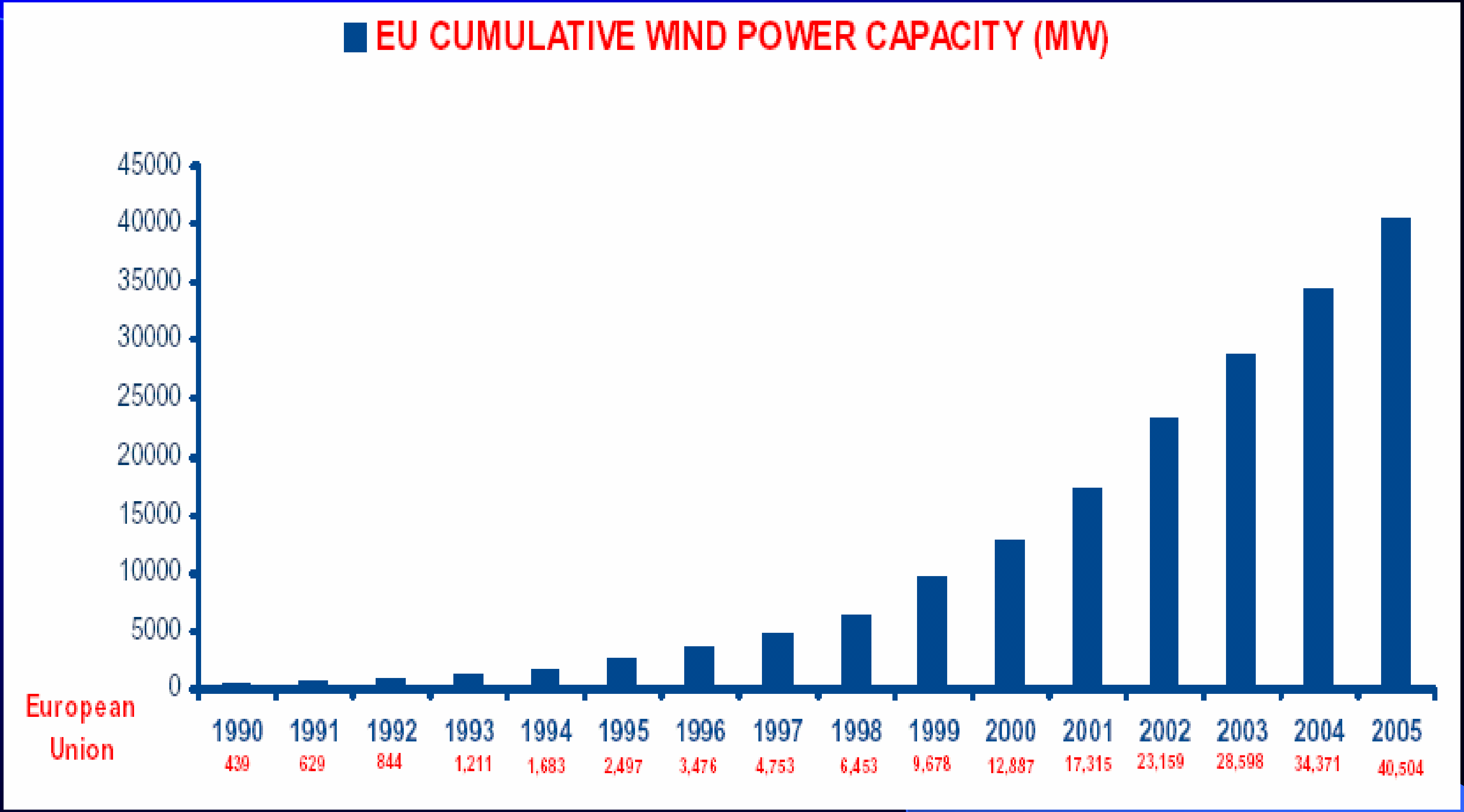
Introduction

Over the last ten years, cumulative wind power capacity in the EU has increased by an average 32% per year over the ten year period from 1995 to 2005.
In 2005, the European market grew by 6%, to 6,183 MW (from 5,838 MW in 2004).



Introduction

With the installation of a record 6,183 MW in 2005, wind energy has achieved the European Commission's 40,000 MW target for 2010 (1), five years ahead of time.



Introduction

In Macedonia there is no accurate knowledge of country's wind resources and it is a major barrier for any possible development of the utilization of wind power.
The available wind speed information in Macedonia originates from the national network of meteorological stations, which - as in the rest of the world – used alone are not sufficient for accurate wind resource assessment.

- Plan for investigation of wind resources and potential

- The plan is consisting of three main phases:

    1) preparation of wind atlas which is numerical modeling based on geophysical and meteorological inputs,

    (wind Atlas was prepared in May and June 2005)

    2) conducting of measurement campaign on the most promising sites defined from the atlas

    (measurement campaign of wind parameters on selected sites – start 2006)

    3) preparation of feasibility studies as basis for possible erection of wind farms.

II Wind Energy Atlas

The Wind Atlases are based on numerical modeling of the large-scale climatology of the atmosphere. The inputs for modeling are typically taken from global databases:

-the wind field could be taken from the NCEP/NCAR database,

-the land-use from the GLCC data base of United States Geological Survey

-and the height information of the country from the SRTM30 database by National Geospatial-Intelligence Agency and NASA.

This information is validated with all other available information (e.g. maps, satellite images, etc.).

The used model is MASS (Mesoscale Atmospheric Simulation System), a numerical weather model developed by MESO, Inc.

The model simulates the fundamental physics of the atmosphere including conservation of mass, momentum and energy, as well as the moisture phases and it contains a turbulent kinetic energy module that accounts the effects of viscosity and thermal stability on wind shear.

MASS is a dynamical model which creates great computational demands, especially when running at high resolution. Hence MASS is coupled to a simpler but much faster program, WindMap a mass-conserving wind flow model.

Wind Maps

The Atlas is consisting of wind speed maps at four heights 40m, 60m, 80m and 100m. The map of predicted wind speed at 80m is shown on Fig. 1.

The map shows that the best wind resources in Macedonia is generally found along high mountain ridges, while lowlands and valleys are likely to have much lower average wind speeds. The predicted mean wind speed at 80m height on the ridge tops varies from 6,5m/s to 8,5m/s.

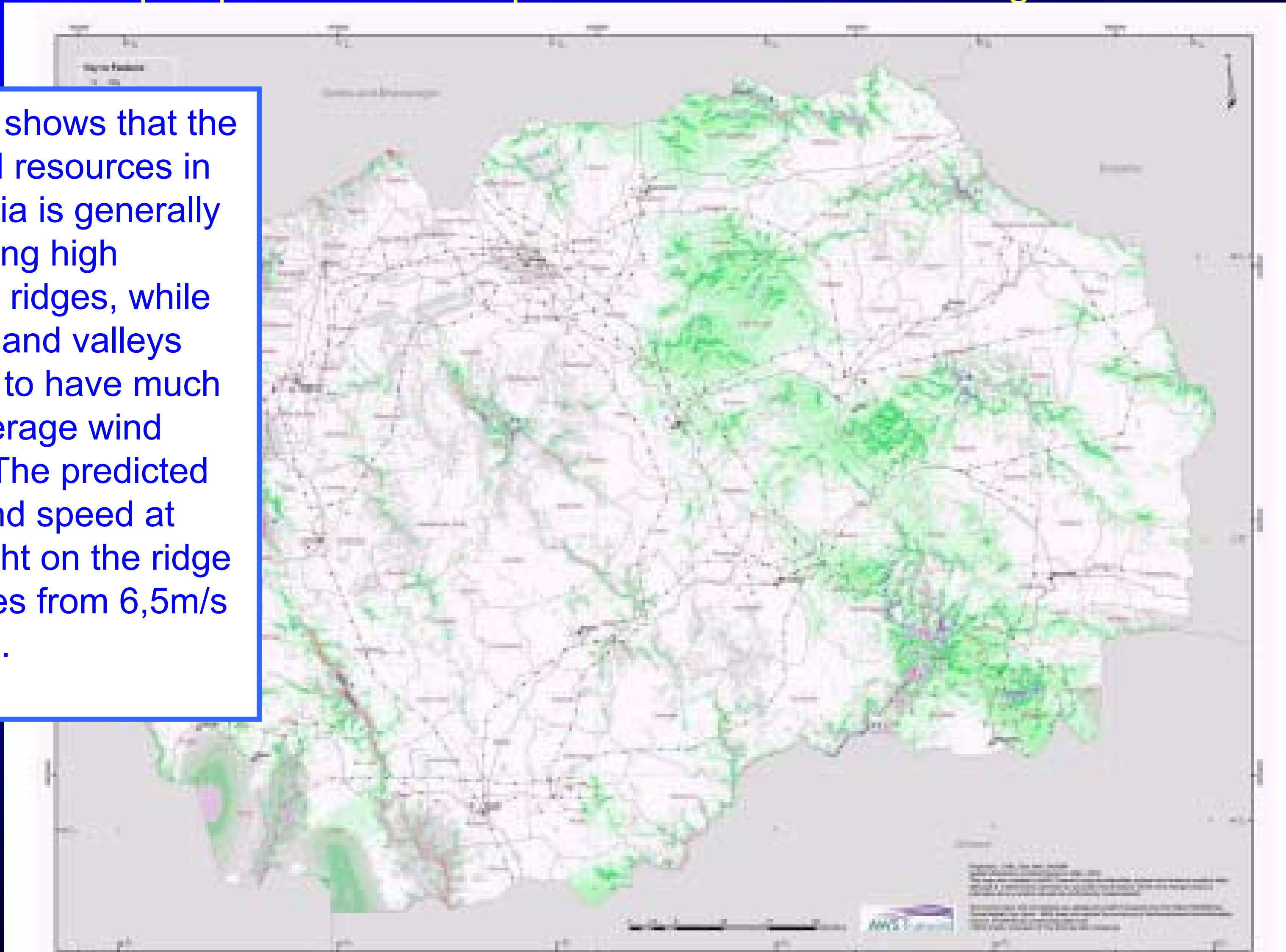


Fig. 1. Wind Resource of Macedonia - mean annual wind speed at 80 meters

Site Selection

The analysis done throw MASS model identified 15 candidate sites for wind farms, which were selected and ranked on the base of predicted mean wind speed, wind plant size, turbine output, cost of energy, interconnection cost and other factors. A brief summary of parameters for each site is provided in Table 1. The predicted wind resource at each point on the map was combined with elevation and temperature data to estimate the net annual output of 1,5 MW turbine with a 77m rotor diameter and 80m hub height.

The GIS-based approach considered the factors like: the cost for new transmission lines for connection to existing electricity grid, the cost for new access roads, terrains with slope greater than 20% based on SRTM digital elevation model, the gross turbine output was reduced by 12% to account planned maintenance and outages. These factors were combined with the minimum output for wind farm of 25 MW to predict the cost of energy (COE).

The selected 15 candidate sites have a potential plant capacity between 25 MW and 33 MW. The cost of energy (COE) for the sites range from \$0,07/kWh to \$0,094/kWh, assuming a 25MW plant capacity, 15% fixed charge rate and no subsides or other incentives for wind projects. The predicted mean wind speed ranges from 6,7 m/s to 8,4 m/s.

Site selection

General site data				25 MW Capacity				
ID	LON	LAT	Avg Elevation (m)	SPD 80m (m/s)	PWR 80m (W/m2)	AREA (km2)	DENS (MW/km2)	MW
1	21,02	41,25	1896	8,41	700	2,1	12	25
2	20,7	41,41	2079	7,97	502	2,1	12	25
3	22,39	41,35	566	7,35	482	2,2	11,5	24,9
4	20,82	41,54	1994	7,63	482	2,1	12	25
5	20,52	41,26	2088	7,85	690	2,1	12	25
6	21,95	42,31	1159	7,53	518	2,1	12	25
7	22,3	41,25	1453	7,45	581	2,1	12	25,4
8	22,27	41,4	641	6,96	370	2,2	12	26,4
9	20,81	42	2511	8,06	640	2,1	12	25,4
10	22,56	41,23	408	7,04	502	2,2	11,4	25
11	22,46	42,13	2003	7,3	488	2,1	12	25
12	22,18	41,15	1998	7,43	666	2,2	12	25,9
13	20,72	41,8	2134	7,13	413	2,1	12	25
14	21,38	41,72	2319	7,29	566	2,3	12	27,4
15	22,45	41,78	1577	6,68	384	2,2	12	25,9

Site Selection

The field inspection of selected sites was carried in 2005.
The purpose of the inspection was to assess the accuracy of the data used in the site selection, to assess the suitability of mountain ridge for installation of meteorological masts and wind turbines, to check the quality of roads, any restricted areas such as military facilities or telecommunication towers and microwave links.
After the site screening was completed and careful consideration of all obtained data by the Atlas were made, four sites are recommended for wind measurement campaign.

1-Site 7 - Kozuf Mountain.
2-Site 10 – Ranovec Mountain, Bogdanci
3-Site 16 – Sasavarlija, Stip
4-Site 20 – Bogoslovec, Sveti Nikole

Site 7 - Kozuf Mountain has greatest potential for development of wind farm. It is large open grassland and the top of the ridgeline consists of gently rolling hills. The site elevation between 1300m to 1760m may produce problems during installation phase and maybe for maintenances of turbines.


23 5 2006


23 5 2006

Site 10 – Ranovec Mountain, Bogdanci, the ridge has 450-500m elevation and an east-west orientation in an area where the wind is predominantly from the southeast. The vegetation on the site is grass and low shrubs and the site is located between three 110kV lines linked into triangle.


23 5 2006

Site 16 – Sasavarlija, Stip the site was identified by ESM people. It is located several kilometers to the southeast from the town of Stip on highland with several dispersed hills and a maximum elevation of 996m. The predicted mean wind speed at 80 meters is 5,81 m/s with capacity factor of 22,44%.


22 5 2006

Site 20 – Bogoslovec, Sveti Nikole the site was also identified by ESM people. The site is on short ridge of up to 750m elevation. The site has moderate winds of 6,0 – 7,0 m/s at 80 m according to the wind map and is estimated to have the potential to accommodate wind farm to 10 MW


22 5 2006

Measurement Campaign

The objective of measurement campaign is to:

-install,

-measure and

-analyze the wind parameters on four locations with promising potential of wind energy.

The final goal is to obtain valid results for feasibility studies of wind energy potential on selected locations and final decision for building wind farms. This is the next phase, after the preparation of Wind Atlas, in overall scientific determination of regions and locations with promising wind energy potential.

This initiative is perfectly fitted with governmental strategy for developing of renewable resources, as well as with the strategy of EU to develop renewable sources.

The possible development of wind power plants in the near future will also have positive implication on the local economy.

Measurement Equipment

For the realization of the measurement campaign four complete measurement stations are provided, which will be installed on 4 previously chosen sites.
The height of the towers is 50m, this is a trade off between being as close possible to hub heights of today's wind turbines (80m or higher) and reducing cost of towers (lattice towers with that heights are expensive).

The measurements system is consisting of:

- -three anemometers,
- -two wind direction vanes,
- -thermometer.

All sensors are by NRG Systems, USA and high quality anemometer on the top of the towers are made by RISO, Denmark. The wind speed sensors are calibrated according to the MEASNET standard with accuracy class of 0,1m/s, which is used by the wind industry in Europe. The wind direction is measured in two different heights for redundancy. Temperature is measured at 2 m, which is a meteorological standard.

In addition to sensors there are data loggers inside weather proof cabinets with communication capabilities over GSM line.

Data processing

All sensors are sampled every 2 seconds, average values, standard deviation, maximum and minimum values are saved every 10 minute, according IEC 61400-12.
The data is stored on a data cards in the data loggers.
The data loggers will send data once per day via GSM to dedicated computers.

The measurements should continue at least 12 months.

All data received via remote communications will be archived monthly into a complete database.
Incoming data will be checked regularly for any signs of equipment damage and/or malfunction.

Conclusion

The paper explains latest developments considering exploration of Macedonian wind resources.

A Wind Atlas of Macedonia was created in 2005.
The maps formed the basis for a GIS-based selection of 15 prospective sites where measurements should be done.

Another five additional sites were proposed by ESM (now ELEM).
From those 20 sites, after on sites visits four most promising sites were chosen for further measurement campaign.

Four complete measurement stations were provided, which will be installed in May/June, 2006.

After installations of the stations, the planned measurement campaign will start for 12 -15 months.

The final goal is to provide reliable results for feasibility studies of wind energy potential on selected locations and final decision for building wind farms.

RES:
Investments Opportunities & Regulatory Framework in Croatia

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" Ruđer Bošković" Institute, Bijenička cesta 54, Zagreb, Croatia
and WP4 leader in EU project RISE (Renewables for Isolated Systems..)

and
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PANEL SESSION: RES: Investments and Regulatory Framework in the Balkans
6th Balkan Power Conference, Ohrid, May 31 - June 2, 2006

Croatia: RES POTENTIALS (RE SOURCES):

Analized in **National energy Programs – NEP y. 1997**
(SUNEN for solar energy, EWIND for wind energy, COGEN for cogeneration....)

Solar: According to the SUNEN National Energy Program, the total economical potential of solar energy is cca 100 PJ (28 TWh).

Wind: Some Croatian islands and part of the Adriatic coast are good potential site locations for wind energy. According to the ENWIND National Energy Program the total energy potential of wind is: 209 MW on the islands, and 163 MW on the Coast

Biomass: In 2001, bio-energy accounted for 3.3% of the total energy supply of Croatia and the total energy potential of biomass is 39 PJ.

Small hydro: The total potential energy capacity of small hydro sources is 177 MW.

Geothermal: Some geothermal reservoirs in the northern part of Croatia. Total potential estimated at 839 MW_t , installed : 36.7 MW_t).

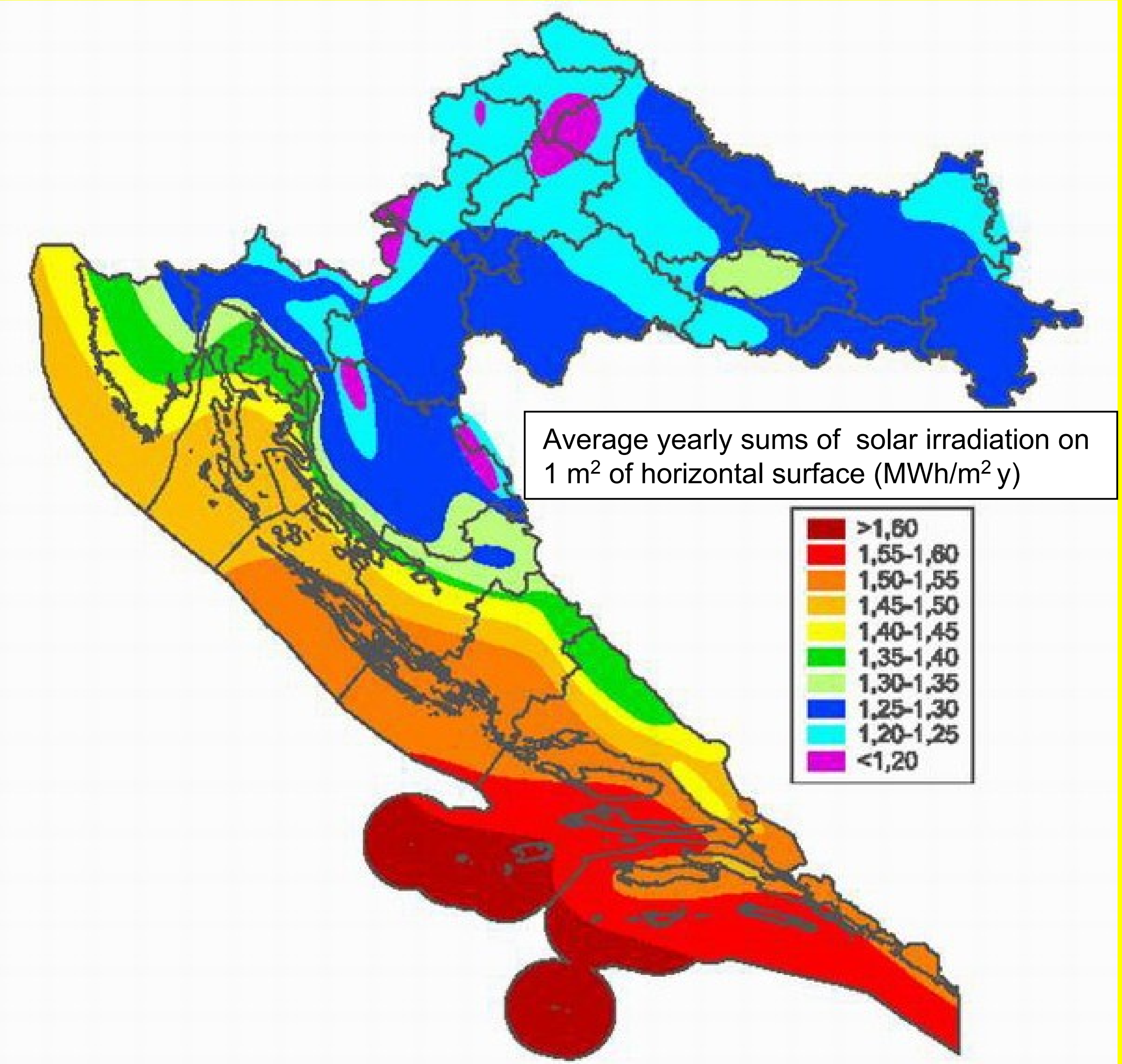
CONSIDERABLE POTENTIAL FOR MANY RES

BUT LITTLE REALY HAPPENED!

U. Desnica, I. Raguzin
6th BPC, Ohrid June 2, 2006

PANEL SESSION: RES: Investments and Regulatory Framework in the Balkans

SOLAR ENERGY



CROATIA: Average yearly sums of solar irradiation on each m^2 of horizontal surface

U. Desnica, I. Raguzin
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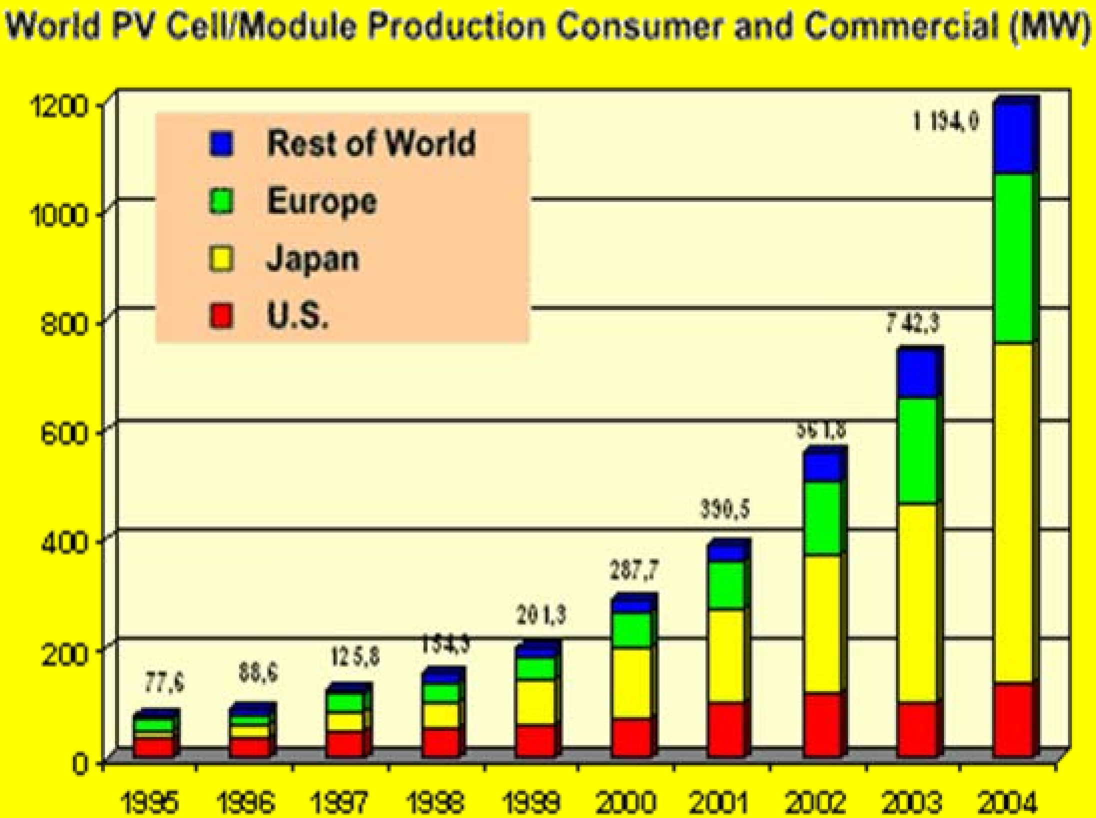
Croatia presently utilizes much less of solar energy than many EU countries with less sun

location/region	yearly average, kWh/m^2 day	July, kWh/m^2 day	January, kWh/m^2 day
Dubrovnik (coast, south)	4.4	7.0	1.8
Split (coast, middle part)	4.2	6.6	1.7
Istra (coast, northern part)	3.4	6.0	1.2
Slavonija (inlands)	3.4	6.0	1.0
Zagreb (inlands, city)	3.2	5.7	0.9-1.0
northern Europe (The Nederland, Denmark, U.K., south of Sweden)	2.6-3.0	5,0-5,6	0.4-0.5
mid Europe, (most of Germany& France etc)	3.0-3.2	5.2-5.8	0.5-1.0
south of Europe (south of Greece, of Spain....)	4.4-4.8	7.2-7.6	1.8-2.6

A comparison of daily global solar radiation (10-y. averages) at horizontal planes for different parts of Croatia and EU.

Electricity from Solar – Croatia: **Potential for investments, PV**



Growth not recorded for ANY industrial product!

EU till end of 2005:
1794 MWp installed
(645 MWp in 2005 alone)

EU15 average:

1.5 Wp/capita

In analogy, for Croatia :

6.5 MWp

(actually installed no more than 1 % of that)

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Thermal from Solar – Croatia: **Potential for investments**

In EU till the end of 2005 installed cca 15.7 millions m^2 of thermal collectors
(Croatia's neighbors: Greece cca 3 millions m^2, Austria over 2 millions m^2........)

In analogy, present potential in Croatia: 0.3 – 1 million m2
(actually installed few %, or less)

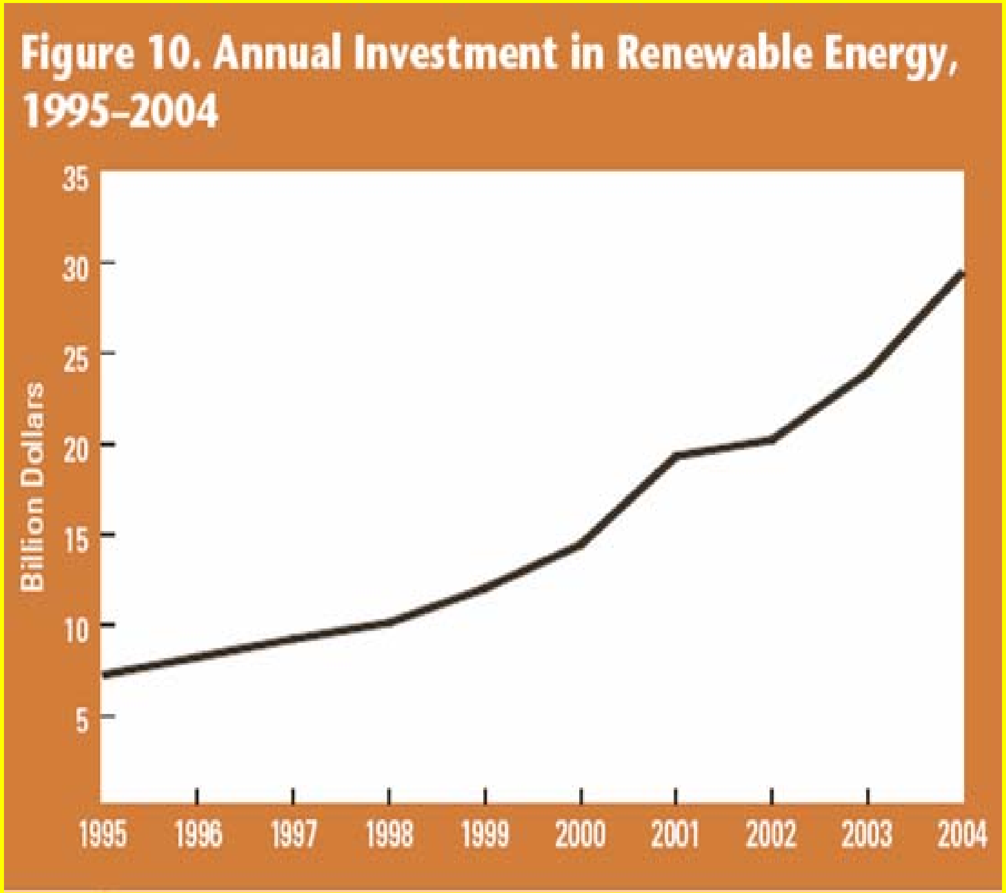
In touristic areas excellent correlation between solar energy irradiation and DHW (domestic hot water) load

EU goal till 2010 g: 100 millions m2.

Ultimate potential (for DHW only): 1-1,5 m2/capita), hence
over **500 millions m2 for EU**

4-6 millions of m2 of thermal solar collectors in Croatia

Renewables now make 20–25% of global power sector investment.



http://www.ren21.net/globalstatusreport/RE2005_Global_Status_Report.pdf

In 2004, about $30 billion invested in RES capacity and installations + additional $4–5 billion in new PV plants

The grid-connected PV grew by 60% *per year* from 2000–2004.

In Croatia, presently, share of RES is negligible – an excellent business opportunity!

CROATIA – Current situation in Power sector

- **Croatian power sector is dominated by the national utility - *Hrvatska Elektropriveda* (HEP)**

- **total capacity installed in the country is approximately 3,800 MW**

- **HEP owns 50% of the 632 MW Krško nuclear power plant which is located in Slovenia**

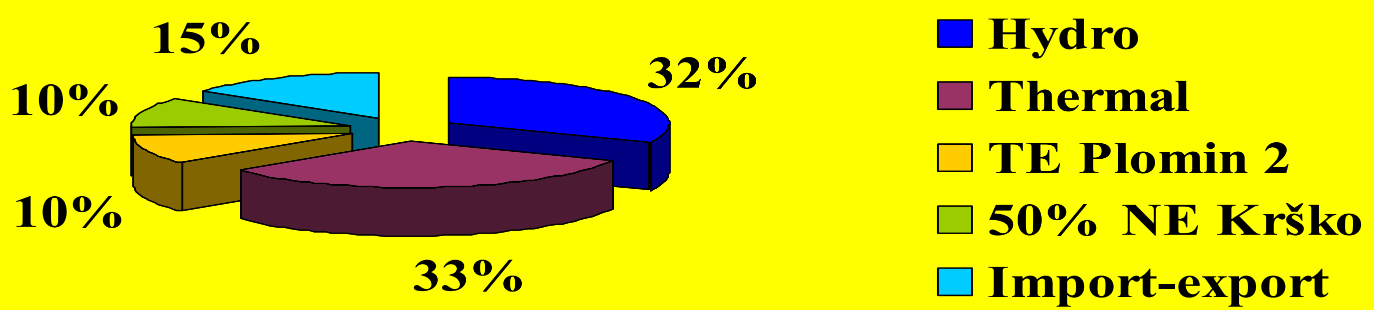
- **Also electricity from coal-fired TPP on the territories of**
- **B & H and Serbia, with a total capacity of 650 MW**

- **the installed electricity generation capacity (y. 2003) was mainly hydro (2 076 MW, 58%) and thermal (1 729 MW, 42%)**

CROATIA – Current situation in Power sector

BASIC DATA

Total consumption	**15.526 GWh**
Hydro plants	4.896 GWh
Thermal plants	5.087 GWh
TP Plomin 2	1.616 GWh
50% NE Krško	1.623 GWh
Imports-exports	2.304 GWh



System Peak load – 2673 MW

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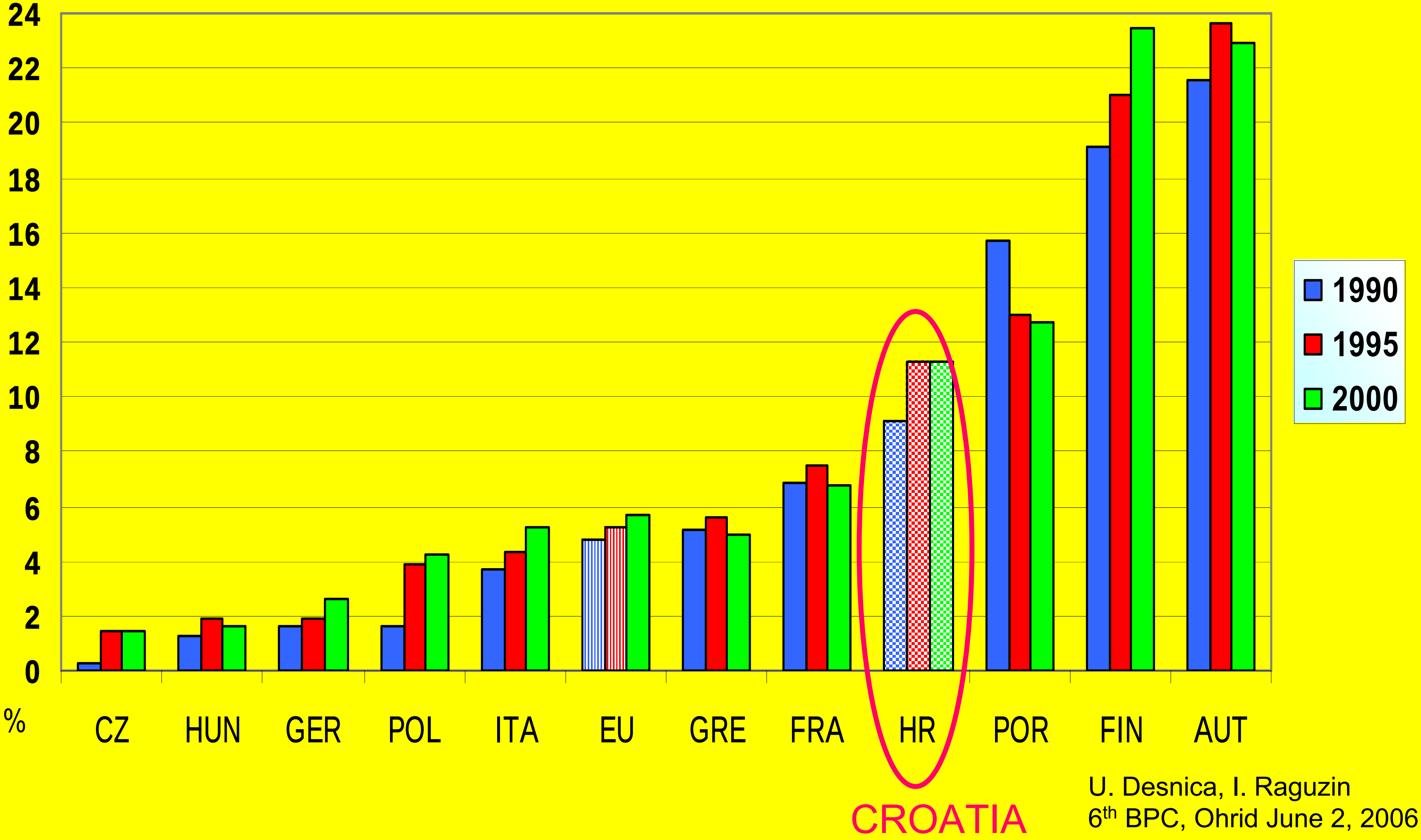
Current situation

RES share in total electricity consumption (with large scale hydro power includeed)



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CROATIA - Current situation

Primary Energy Self Supply in Croatia

Present and prognosis in ‘business as usual’ scenario

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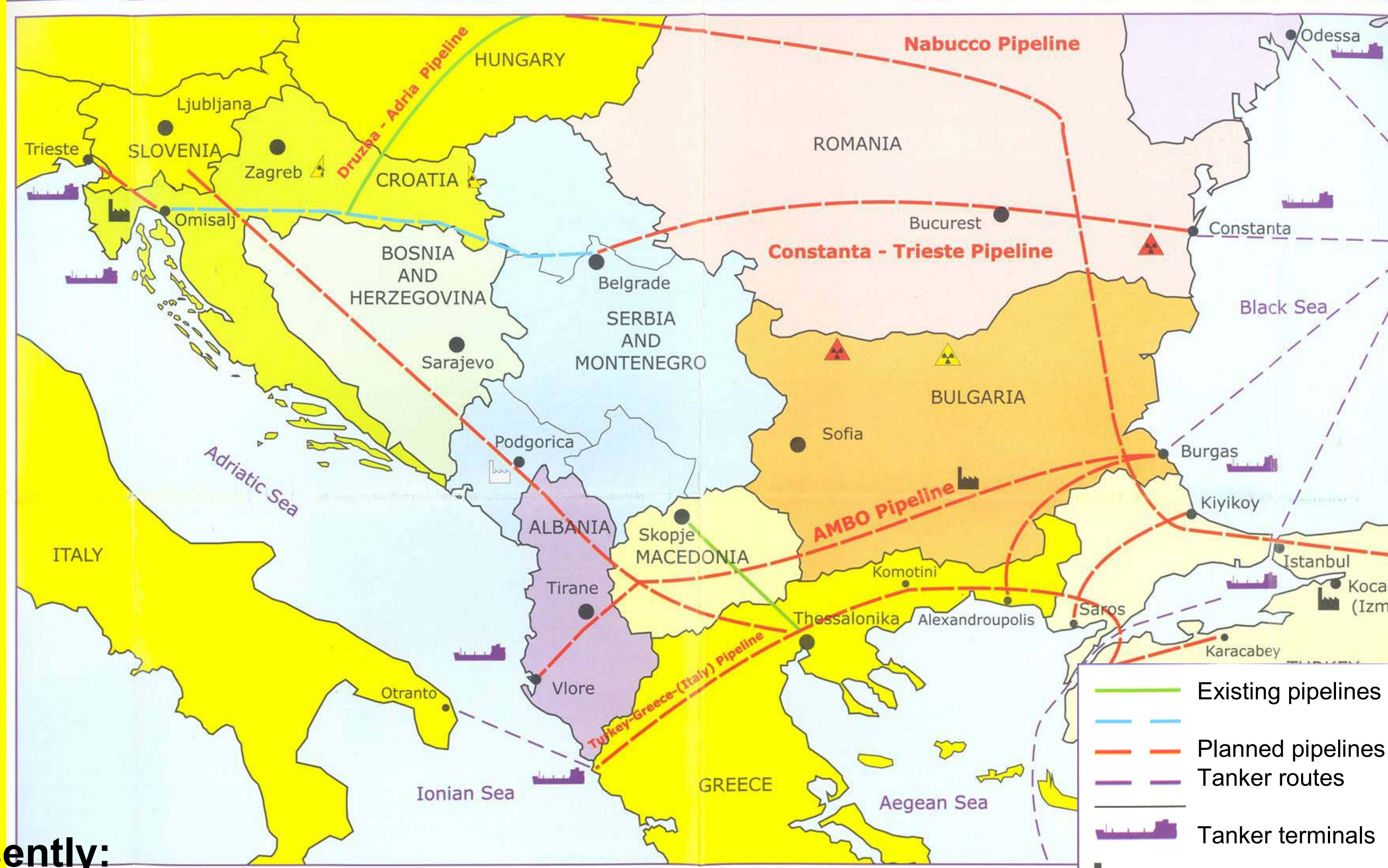

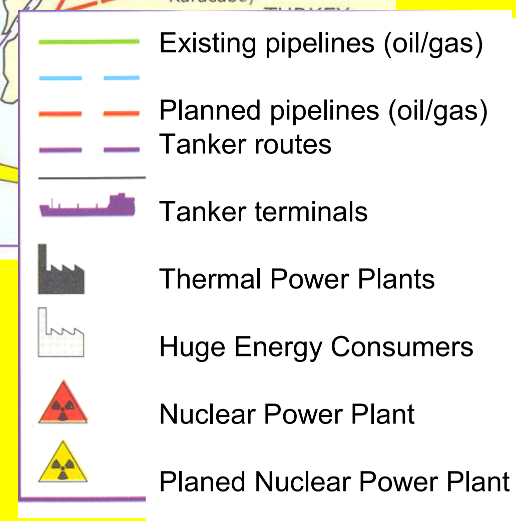

Presently:

Investments in potentially dangerous energy resources/objects
Negligible investments in RES sources or EE measures

Potential Danger in Balkan Energy Future:

The development of the Balkans as a source of dirty and "cheap" energy and a transit region for oil and gas from the countries east of the EU.

Source: http://www.bankwatch.org/balkan_energy

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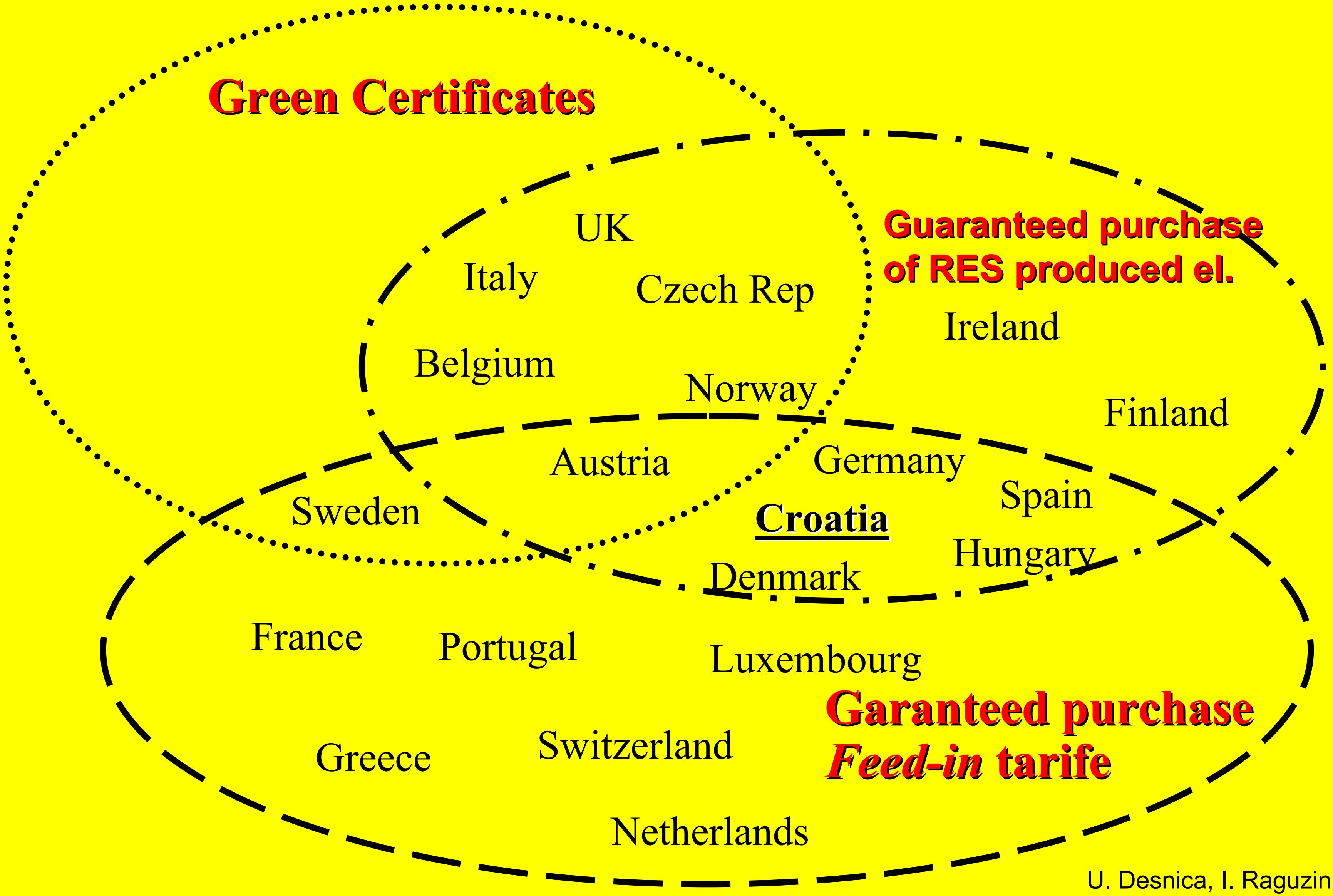
This gloomy situation with RES in Croatia may change soon:

Reforms in Energy Sector in Croatia

1997 National energy Programs – NEP

- 1998 Strategy of development of Energy Sector
- 2001 Energy laws (first change)
- 2002 Energy for Croatia in 21. century
- **2003 Environment Protection and Energy Efficiency Fund (EPEEF)**
- **2004 Energy laws – changes + 2 new laws**
- 2005 Law on production, distribution and supply of heat
- **2006 Secondary legislation (by-laws) RES in the process**

Comparison of politics in Europe regarding RES



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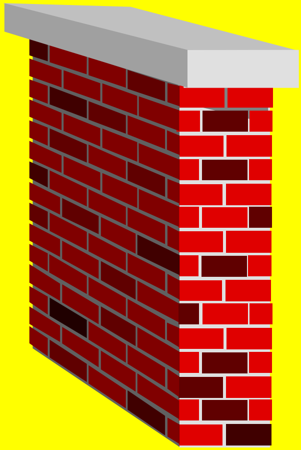
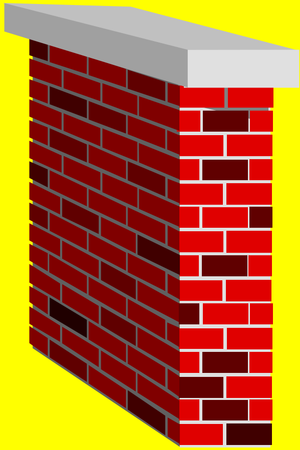
RES regulative framework

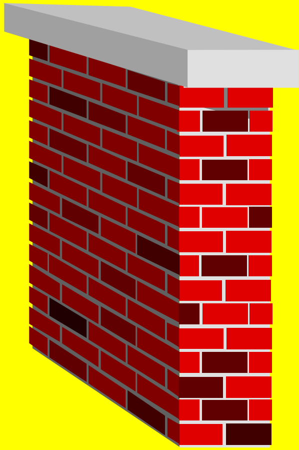
Environmental Protection and Energy Efficiency Fund



Tariff system for electricity production from RES and cogeneration



Ordinance on minimum share of electricity produced from RES and cogeneration



In process of acceptance:

Secondary legislation (by-laws) RES

Grid Code

- Technical and other prerequisites for user connection to the system...

Ordinance on the Use of RES and Cogeneration

Specify RES to be used for energy production, conditions and possibilities for their use (type, technology)......

Regulation on Minimum Share of Electricity Produced From RES and Cogeneration

- The Government, by way of a regulation, specifies a minimal share of electricity produced from RES and cogeneration, which the supplier is obligated to purchase (for the period from 2005 to 2010)

Ordinance on the conditions/criteria for obtaining the status of an eligible (privileged) producer

- stipulate the types of plants for granting the energy subjects the status of beneficial electric energy status, minimal conditions for granting the status, ...

In the procedure for acceptance:

Secondary legislation (by-laws) RES (2)

– Tariff System for Electricity Production from RES and Cogeneration

- determine the producer's right to an incentive price payable by the market operator for energy supplied.....

- Compensation (charge) for Providing Incentives for RES and Cogeneration

The purpose of the charges is cost coverage of the market operator in view of implementation of the tariff system for RES generation and cogeneration.....

- Establishing of the Market operator (MO)

- Entering into contracts with all suppliers to comply with the decree on the minimum share of electricity produced from RES and cogeneration
- Collecting funds from the charge for incentivizing RES and cogeneration from the suppliers......

Establishing of the Transmission and Distribution System Operator

- Securing access to the network, Operation and maintenance, development and construction of the transmission system, and a portion of reactive power generation, Connecting system users to the transmission system as provided for in the energy law, Taking over from eligible customers total electricity produced when engaging generation facilities

In the procedure for acceptance:

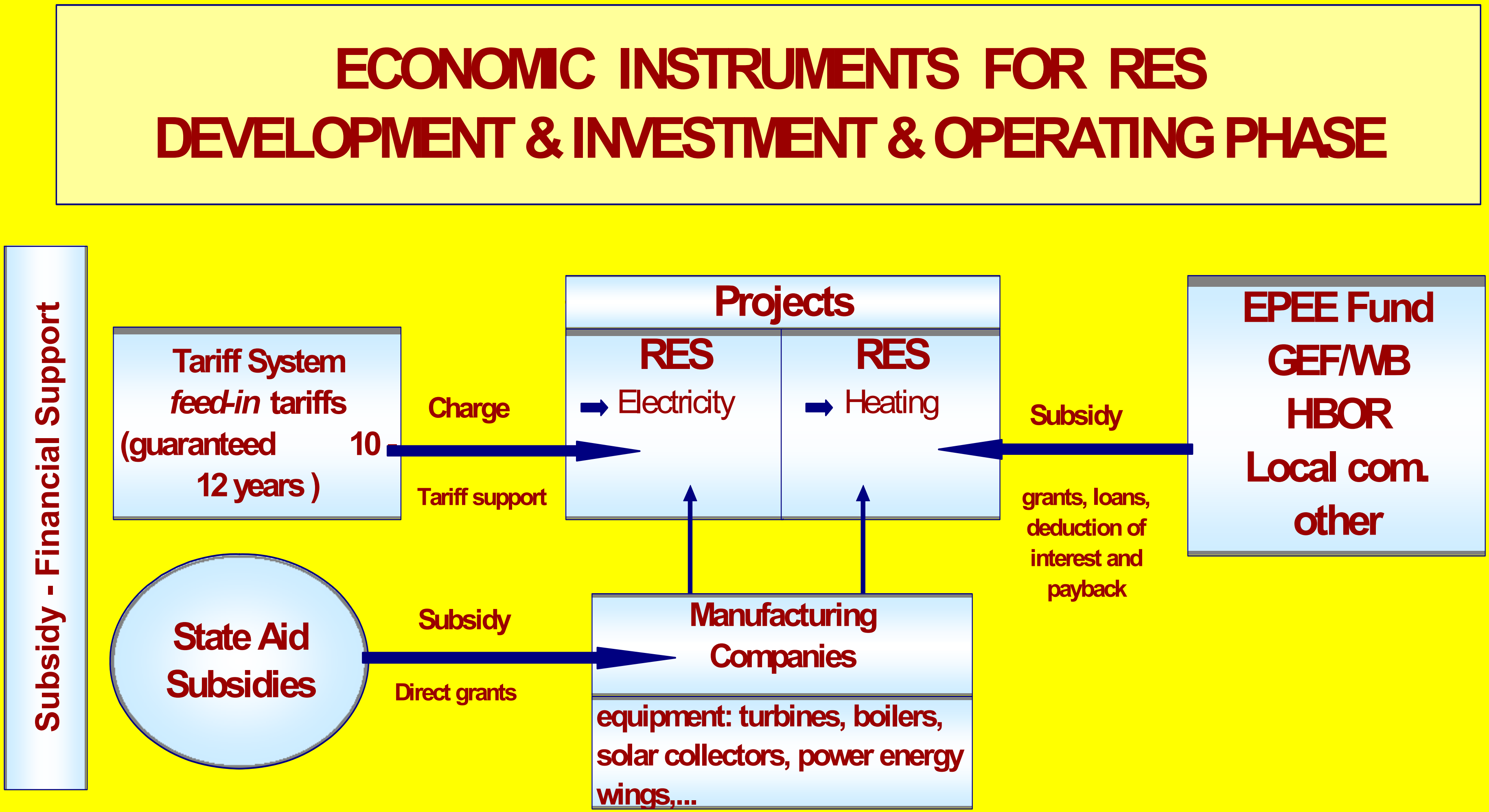
Secondary legislation (by-laws) RES (2)

- Tariff System for Electricity Production from RES and Cogeneration
  - Working version:..

Type of RES	C (HRK)
PV plants, up to 30 kW	3,25
PV, above 30 kW	2,95
Hydroplants	0,73
windplants	0,59
plants on biomass	0,51
geothermal plants	0,66
plants on biogas and liquid bio	0,88
biogas from wastewater treatment	0,22
combination of the above	0,60
other RES (see waves, tides etc.	0,60

1 EURO = 7.3 HRK

Economic instruments for RES



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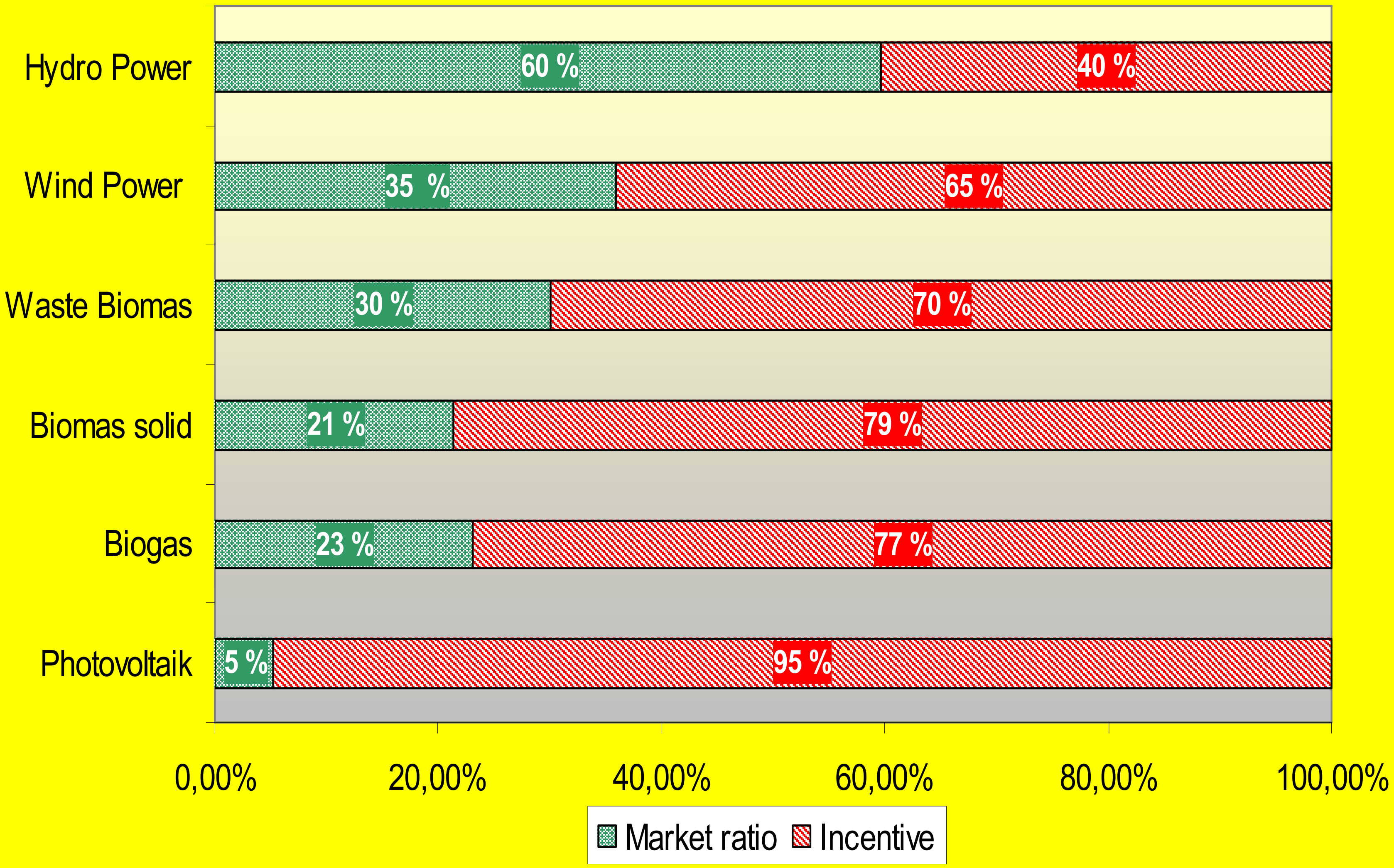
Example of Austria regarding % of incentives for different RES



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Decree on minimum share of electricity produced from RES and cogeneneration

1. timeframe by 2010
2. defining minimum RES use stimulation target or quota:
   - share in consumption breakdown
   - installed capacity in MW
3. who is in charge
4. method for collecting incentives and appointment of financial mechanism operator
5. obligation of reporting on and documenting fulfillment of the requirements

Croatian Policy Goals

Minimum share of RES-E by 2010

	2010 year
MW	400
GWh	1200
Share RES 2010 %	5,8

Average impact to electricity price 1.1%

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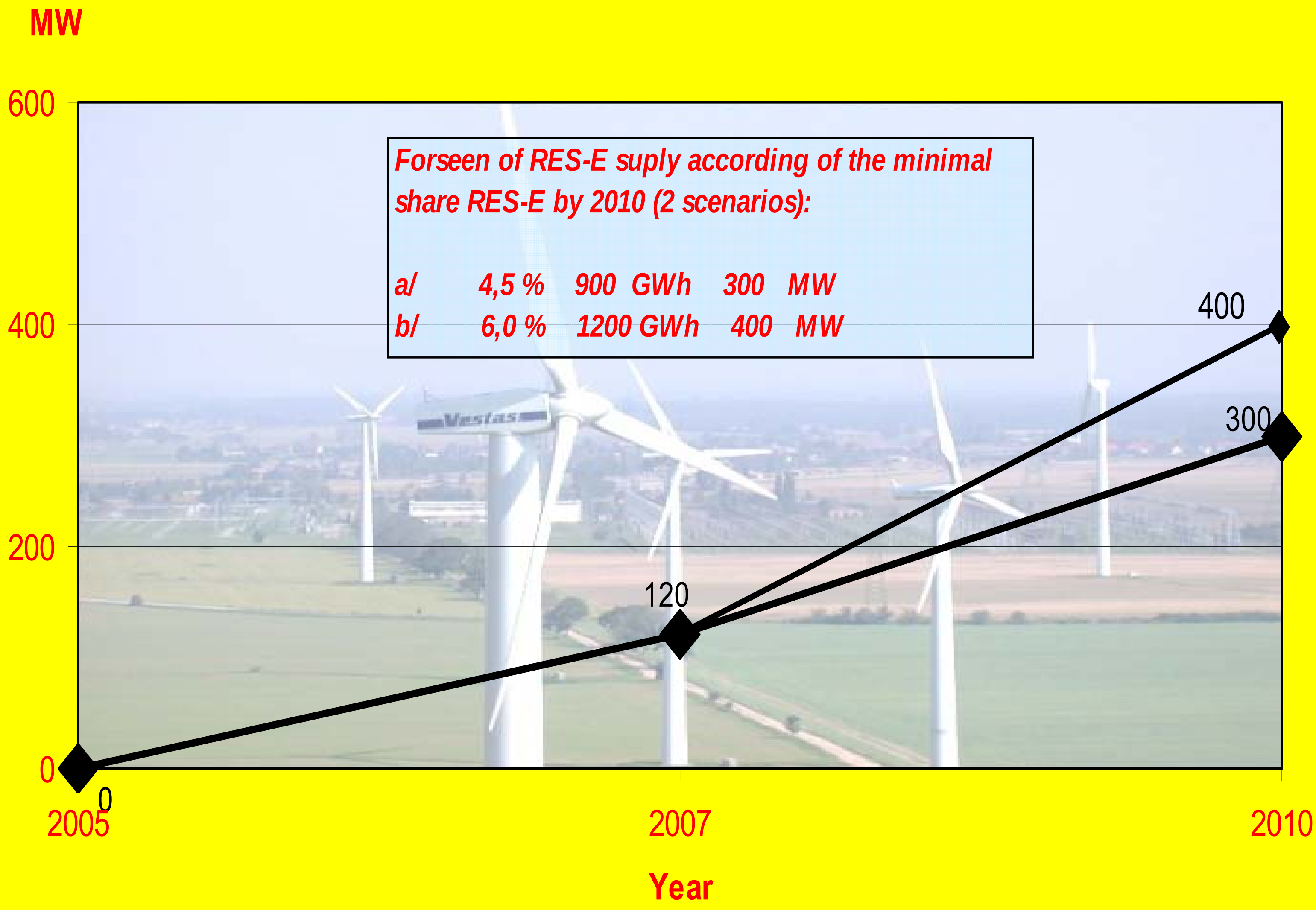
Timeframe RES-E



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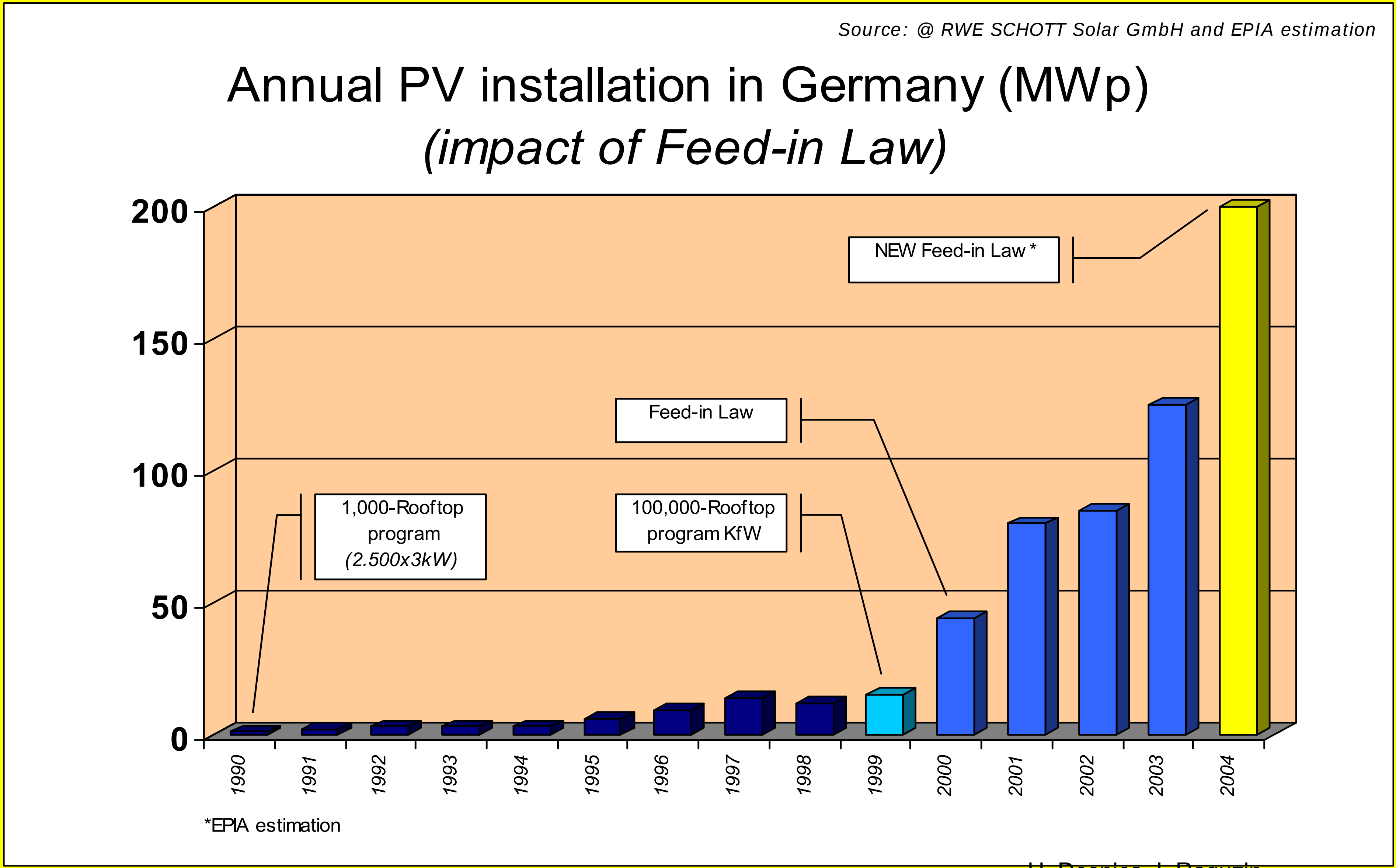
Arguments for Optimism for Croatia:



Technical challenges associated with the integration of wind power into power systems

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Sixth Framework Programme, DG Research, International Cooperation

Contract: INCO-CT-2004-509205

Contents

- Introduction
- Effects of wind power
  - Power system
  - Power system operating costs
  - Power quality
  - Power imbalances
  - Power system dynamics
  - Transmission planning
  - Wind forecasting
  - Wind power curtailment
- Conclusions and future research

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Introduction

- Grid integration concerns have come to the fore in recent years as wind power penetration levels have increased in a number of countries.
- Wind intermittency is one of the strongest challenges to wind power development.
- Transmission availability can be a barrier to wind power development since favorable wind locations are often in areas distant from existing transmission.

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Effects on power system

- Wind power production is variable, difficult to predict and cannot be taken as given. This leads to the allocation of extra reserves.
- A large geographical spreading of wind power reduces variability and decreases occasions of near-zero or peak wind power output.
- Power system size, generation capacity mix (inherent flexibility) and load variations have an effect on how intermittent production is assimilated into the system.

Impacts on system operating costs

		Wind impact on operating costs ($/MWh)			
Study	Wind penetr. (%)	Regulation	Load following	Unit commitment	Total
UWIG/Xcel	3.5	0	0.41	1.44	1.85
PacificCorp	20	0	2.50	3.00	5.50
BPA	7	0.19	0.28	1.00-1.80	1.47-2.27
Hirst	0.06-0.12	0.05-0.30	0.70-2.80	na	na
We Energies I	4	1.12	0.09	0.69	1.90
We Energies II	29	1.02	0.15	1.75	2.92
Great River I	4.3				3.19
Great River II	16.6				4.53
CA RPS	4	0.17	na	na	na

Power quality

- The location and intermittent nature of wind turbine machines can cause power quality problems: voltage dips, frequency variations, and low power factor.
- Power quality problems caused by wind power are best solved at the point of interconnection of wind power to the utility grid.
- New state-of-the-art wind generators utilize power electronics and variable-pitch turbines that allow the wind turbine to produce energy at various wind speeds.

Power imbalances

- Power imbalances could be caused when the produced wind power is lower or higher than the needed wind power to serve the system load.
- Bonneville Power Administration (BPA) used to charge all generators, including wind developers, $100/MWh when they failed to deliver scheduled power and caused power imbalances. In 2002, BPA stopped this power imbalance penalty for wind developers.
- Eltra, the utility serving western Denmark that has the largest wind penetration in the world as compared to the size of its power system, conducted power imbalance studies and the conclusion is that Eltra has to look new ways to handle excess generation when wind generation exceeds the load requirements of western Denmark.

Power system dynamics

- If conventional power generation with synchronous generators is on a large scale replaced with wind turbines that use either asynchronous squirrel cage induction generators or variable-speed generation systems with power electronics, the dynamics of the power system will at some point be affected, and perhaps its stability, too.
- By taking adequate measures, the stability of the power system can be maintained while increasing the wind power penetration.
- For example, constant-speed wind turbines can be equipped with pitch controllers in order to reduce the amount of over-speeding that occurs during a fault; by combining them with a source of reactive power (e.g. static condenser or static VAR compensator) to supply the large amount of reactive power consumed by a squirrel cage generator after a fault; or by changing the mechanical and/or the electrical parameters of the turbine.

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Transmission planning

- There is high concentration of wind power in windy areas, where the load is usually low, so there is a need for strong transmission grid. However, because of the rapid implementation of wind power, the reinforcement of the grid has not been planned.
- In most areas of the world with deregulated power markets, existing transmission planning practices do not look ahead towards expanding the transmission grid to serve high wind resources.
- Federal Energy Regulatory Commission (FERC) introduced economic transmission planning, which is planning to build transmission to reduce congestion and not just for reliability purposes. Economic transmission planning represents an opportunity to access remote wind resources.

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Wind forecasting

- Wind forecasting is increasingly showing value for the improved scheduling of wind energy. The system operator wants to receive wind power forecasts that run hour-by-hour for the next few days to reduce the unit commitment costs.
- Using current state-of-the-art methods, the accuracy of the next day hour-by-hour wind power forecast has a mean absolute error of 10-15% of the rated (nameplate) capacity of the wind park.
- Due to the smoothing effects of geographic dispersion, system-wide forecasting errors for multiple dispersed wind plants may be reduced by 30-50% when compared with the errors of individual wind plants.

Wind power curtailment

- In most European countries, renewable energy sources have priority access to the grid.In economic terms, wind power should be on top in merit due to its marginal price of almost zero.
- The curtailment of wind power at certain times could reduce the overall system integration costs. Curtailment of wind power could arise because of *network limitations* or *system aspects*.
- Local limitations could give rise to a need to constrain the output of a group of wind generators (example of wind power curtailment because of *network limitations*).
- At times of low system demand, a minimum level of conventional generation must be kept connected to ensure system stability and control, and to ensure that the demand can be met on a day-ahead basis. This is especially a problem in systems dominated by nuclear power due to the high minimum load capability (example of wind power curtailment because of *system aspects*).

Future research

1. Varying amounts of wind generation.
2. Market structure and imbalance energy pricing.
3. Correlation of load and wind forecasting errors.
4. Varying generation portfolio and fuel cost mix.
5. Simplified models and methods.
6. Wind penetration definition.
7. Transmission congestion.

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Conclusions

- The main technical challenges that are associated with the integration of wind power into power systems were presented.
- These challenges include effects of wind power on the power system, the power system operation cost, power quality, power imbalances, power system dynamics, and impacts on transmission planning.
- Wind power impact on system operating cost is small at low wind penetration (about 5% or less). At higher wind penetrations, the impact will be higher, although current results suggest the impact remains moderate with penetrations approaching 20%.

International RES Seminar
"Promoting Excellence in RES in the Balkans" ,
Ohrid, 2 June 2006

ECONOMIC AND ENVIRONMENTAL ASSESSMENT OF PROSPECTIVE RENEWABLE ENERGY SOURCES IN MACEDONIAN CONDITIONS

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Content

1. Introduction

- RES technologies and sustainable development
- Environmental aspect of the energy sector in Macedonia
- Identification of the prospects for implementation of the new RES

Selected country-specific RES technologies

No.	RES technology	Base unit
1	Mini hydro power (4 plants of 1 MW)	4 MW plant
2	Wind power plants	1 MW
3	Geothermal heating for greenhouses and hotels	1 plant
4	Biogas from small agricultural industries	1 plant
5	Grid-connected solar PVs	1 kW
6	Solar heater for hot water in individual houses	1 unit
7	Large solar heaters for hot water in hotels, hospitals, public buildings	1 unit

Economic and environmental evaluation

- Use of the **software tool GACMO** (GHG costing model);
- Comparison to the **baseline scenario** (total baseline GHG emissions in 2010 are assumed as 18 Mt CO_2-eq);
- Calculation of the **GHG emissions reduction** (ton CO_2-eq) if the given technology is implemented, as well as **average mitigation costs** (US$ per ton of CO_2-eq reduced).

2. The examined RES technologies

2.1. Mini hydro power plants

General inputs:		
Discount rate	6%	
Reduction option: Hydro power plants		
O&M	1.0%	
Activity	4	MW
Investment in hydro power	1,500	US$/kW
Capacity factor	2,000	hours
Electricity production	8,000	MWh

Reference option: Lignite fueled power plant		
O&M	2.0%	
Investment saved	1,200	US$/kW
Efficiency	0.33	
Annual fuel saved	87,273	GJ
Cost of fuel saved	24.00	US$/ton
Cost of fuel saved	3.20	US$/GJ
CO_2-eq. emission coefficient	0.142	tons CO_2-eq/GJ
Capacity factor	7,000	hours

Costs in US$	Reduction Option	Reference Option	Increase (Red.-Ref.)
Total investment	6,000,000	4,800,000	
Project life	30	30	
Lev. investment	435,893	348,715	87,179
Annual O&M	60,000	96,000	-36,000
Corrected lev. investment	435,893	99,633	336,261
Corrected annual O&M	60,000	27,429	32,571
Annual fuel cost		279,273	-279,273
Total annual cost	495,893	406,334	89,559
Annual emissions (tons)	Tons	Tons	Reduction
Total CO_2-eq. emission	0	12,424	**12,424**
US$/ton CO_2-eq.			**7.21**

2.2. Wind power plant

General inputs:		
Discount rate	6%	
Private discount rate	10%	
Reduction option: Wind turbines		
O&M	1.5%	
Activity	1	MW
Investment in wind turbines	1,000	US$/kW
Capacity factor	1,850	hours
Electricity production	1,850	MWh
Power purchase price	0.01735	US$/kWh

Reference option: Lignite fueled power		
O&M	2.0%	
Capacity value of wind	10%	
Investment saved	1,200	US$/kW
Efficiency	0.33	
Annual lignite saved	20,182	GJ
Cost of fuel saved	24.00	US$/ton
Cost of fuel saved	3.20	US$/GJ
CO_2-eq. emission coefficient	0.142	ton CO_2-eq/GJ

Costs in US$	Reduction Option	Reference Option	Increase (Red.-Ref.)
Total investment	1,000,000	120,000	
Project life	30	30	
Lev. investment	72,649	8,718	63,931
Annual O&M	15,000	2,400	12,600
Annual fuel cost		64,582	-64,582
Total annual cost	87,649	75,700	11,949

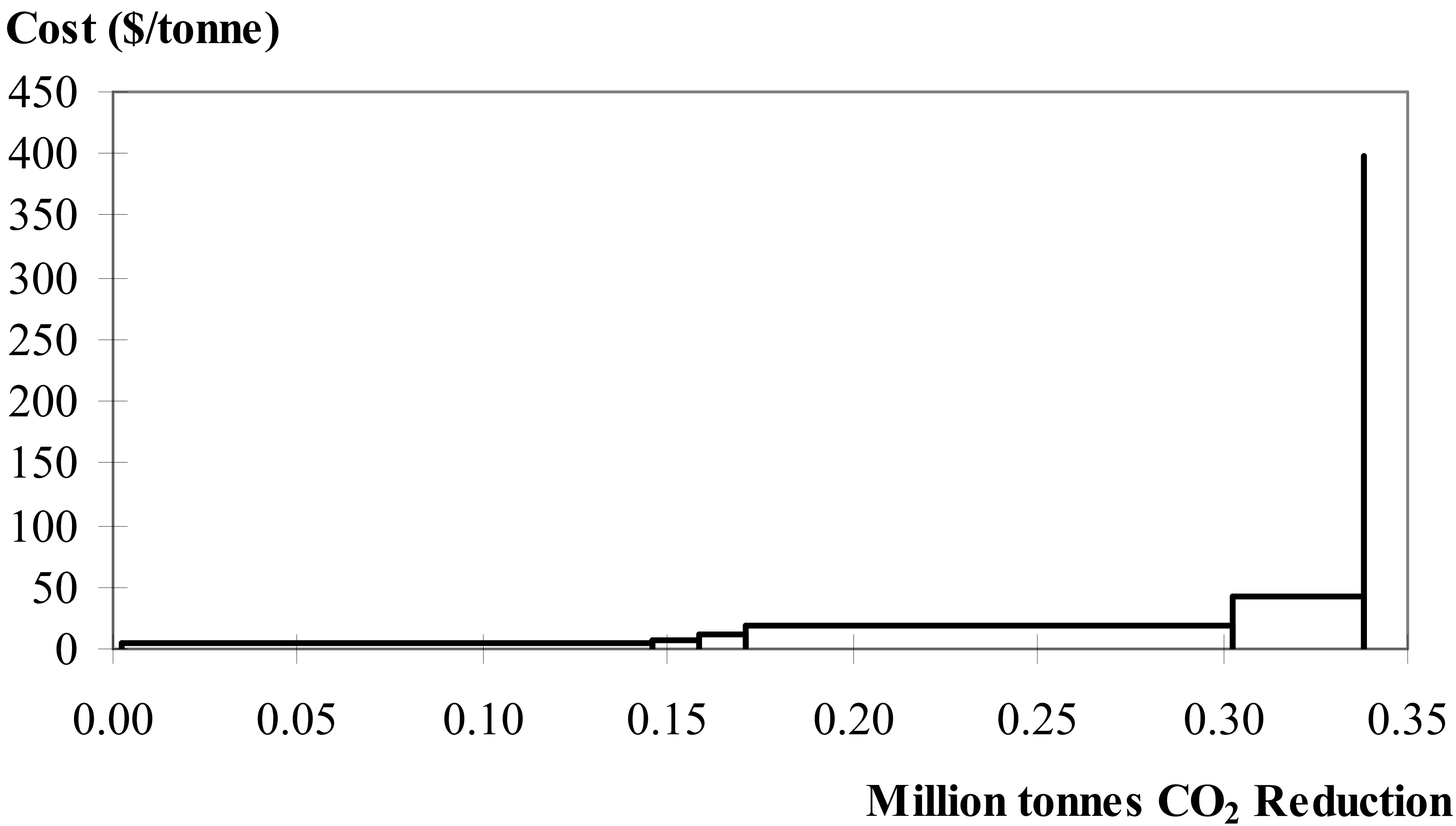
Annual emissions (tons)	Tons	Tons	Reduction
Total CO_2-eq. emission	0	2,873	**2,873**
US$/ton CO_2-eq.			**4.16**

3. Marginal cost of the prospective RES implementation

- **The most cost effective option**: geothermal energy in greenhouses and hotels. However, **relatively low potential for GHG emissions reduction;**
- **Most expensive option:** PVs connected to electric grid;
- **The total achievable reduction** (if all considered RES technologies are implemented) in 2010 is estimated to be **0.34 Mt CO_2-eq**, which is **1.88%** of the baseline emissions.

Economic and environmental effectiveness of the RES technologies

RES technology	Specific costs US$/t CO_2-eq	Unit type	Emission reduction t CO_2-eq	Units penetrating in 2010	Emission reduction in 2010		
						Cumulative	
					Per option Mt/year	Mt/year	Percentage of baseline in 2010
Geotherm. heat.	-187.15	1 unit	2,269.34	1	0.0023	0.0023	0.01%
Wind turbines	4.16	1 MW	2,872.98	50	0.1436	0.1459	0.81%
Mini hydro power	7.21	4 MW	12,423.71	1	0.0124	0.1583	0.88%
Large solar heater	11.70	1 unit	62.16	200	0.0124	0.1708	0.95%
Residential solar heater	19.35	1 unit	1.32	100,000	0.1320	0.3028	1.68%
Biogas from agro-ind. sewage water	43.21	1 digester	11,699.89	3	0.0351	0.3379	1.88%
Grid connected PVs	398.22	1 kW	1.10	500	0.0006	0.3384	1.88%



Marginal cost abatement curve of the RES technologies for the year 2010

4. Limiting barriers to RES implementation

4.1 Financing

- The largest constrain to RES implementation;
- Not available or limited national sources for the initial investment even in the case of "no regret" technologies;
- Quite low potential for attracting foreign investments.

Possible improvements:

- Rationalization of energy prices;
- Introduction of economic incentives, such as import duties and tax deduction;
- Creation of Financing Facility for Sustainable Energy.

4.2 Private and public decision-making

- Lack of actual awareness of the situation and of possibilities for environmentally and economically beneficial interventions in the energy sector;
- Inertness and reluctance to new technologies;
- Different interests of the stakeholders;
- The leading role of the economic criterion in the decision-making.

4.3 Required infrastructure

- Lack of the required infrastructure in terms of institutions, legislative framework and economic incentives, as well as personnel capable to deliver the required technical, managerial and financial services;
- No specialized institutions for promotion and support of RES technology transfer;
- The national legislation fails to address necessary commitments, having the situation further impaired by the complex and inefficient administration;
- The transfer and diffusion of RES technologies in the country could not be realized without all stakeholders' support, including substantial "buy in" from the private sector;
- Development of specialized national private companies that would assume the financing and execution of RES technologies' breakthrough is strongly recommendable.

5. Conclusion

The total achievable reduction (if all considered RES technologies are implemented) in 2010 is estimated to be 0.34 Mt CO_2-eq, which is 1.88% of the baseline emissions.

Compared to the other abatement technologies in the energy sector, that are energy efficiency technologies, the RES technologies appear to be less attractive from both, environmental as well as economical aspect.

Nevertheless, contributing to sustainable energy development, the RES technologies should be a part of the national energy policy.

In that sense, the removal of the limiting barriers to RES implementation, should be a great challenge to all stakeholders: government, industry, households and small businesses, academic sector, NGOs, international organizations and donors.

HEP d.d. – Implementation of RES Investments and Regulatory Framework

Zoran Stanić

Environmental Coordinator

HEP d.d.

6th Balkan Power Conference, 31. May – 2. June 2006.

Ohrid, Republic of Macedonia

Table of Contents

Introduction

- Energy sector reform is underway in the Republic of Croatia in line with EU legislation
- The reform includes the setting up of the Croatian electricity market and HEP's restructuring
- Reform processes are governed by a set of national energy laws
- Preconditions were created for the setting up of electricity market

HEP Group's Profile

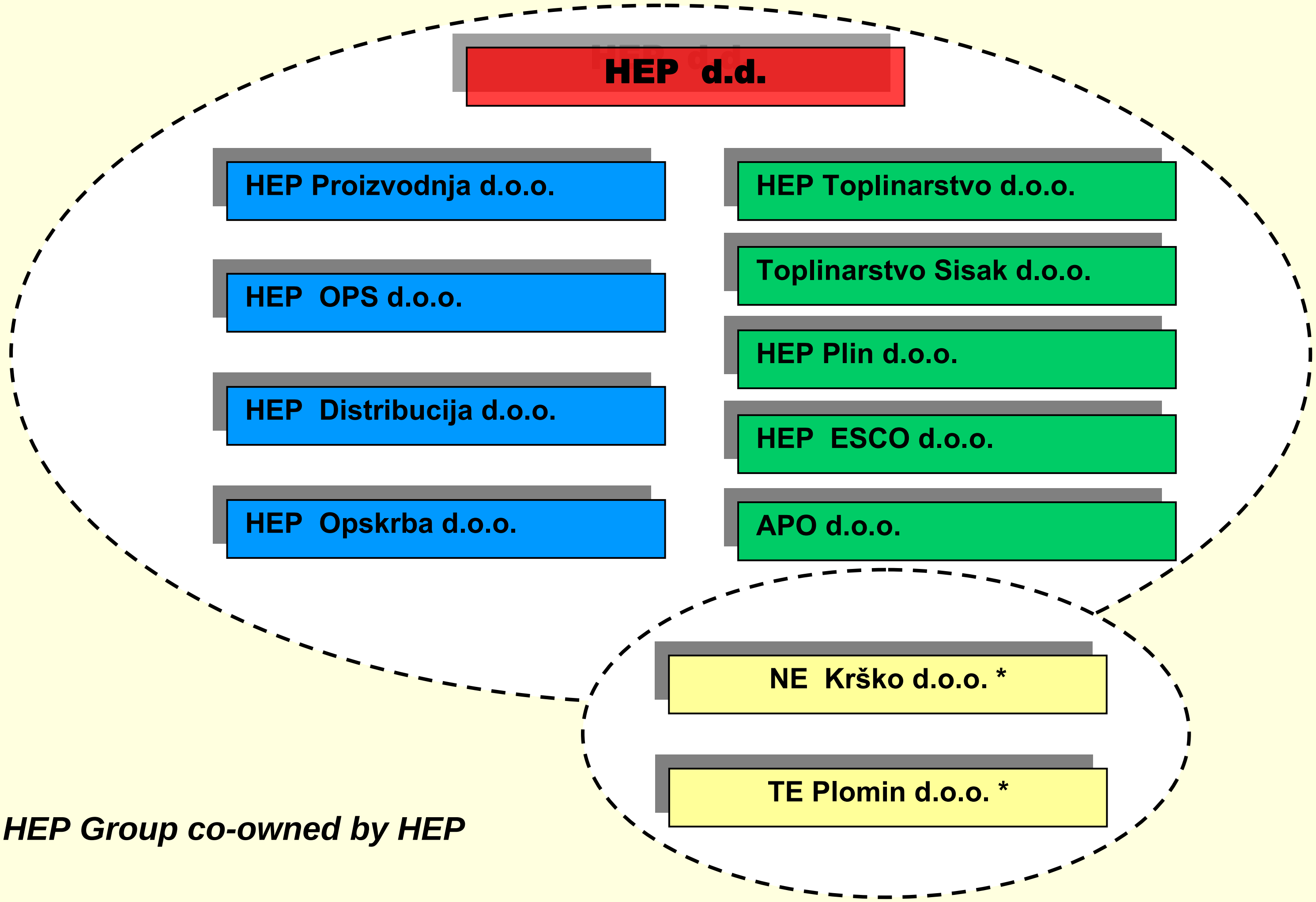
- Generation, transmission and distribution of electricity across the territory of the Republic of Croatia
- Heat generation and distribution via district heating systems (Zagreb, Osijek and Sisak)
- Gas distribution and supply in the Slavonija region (Osijek, Đakovo, Našice, Slatina, Valpovo and Donji Miholjac)
- Energy Efficiency Projects
- Environmental Protection Projects (among others - nuclear waste disposal)

HEP Group's Profile

Year 2004:

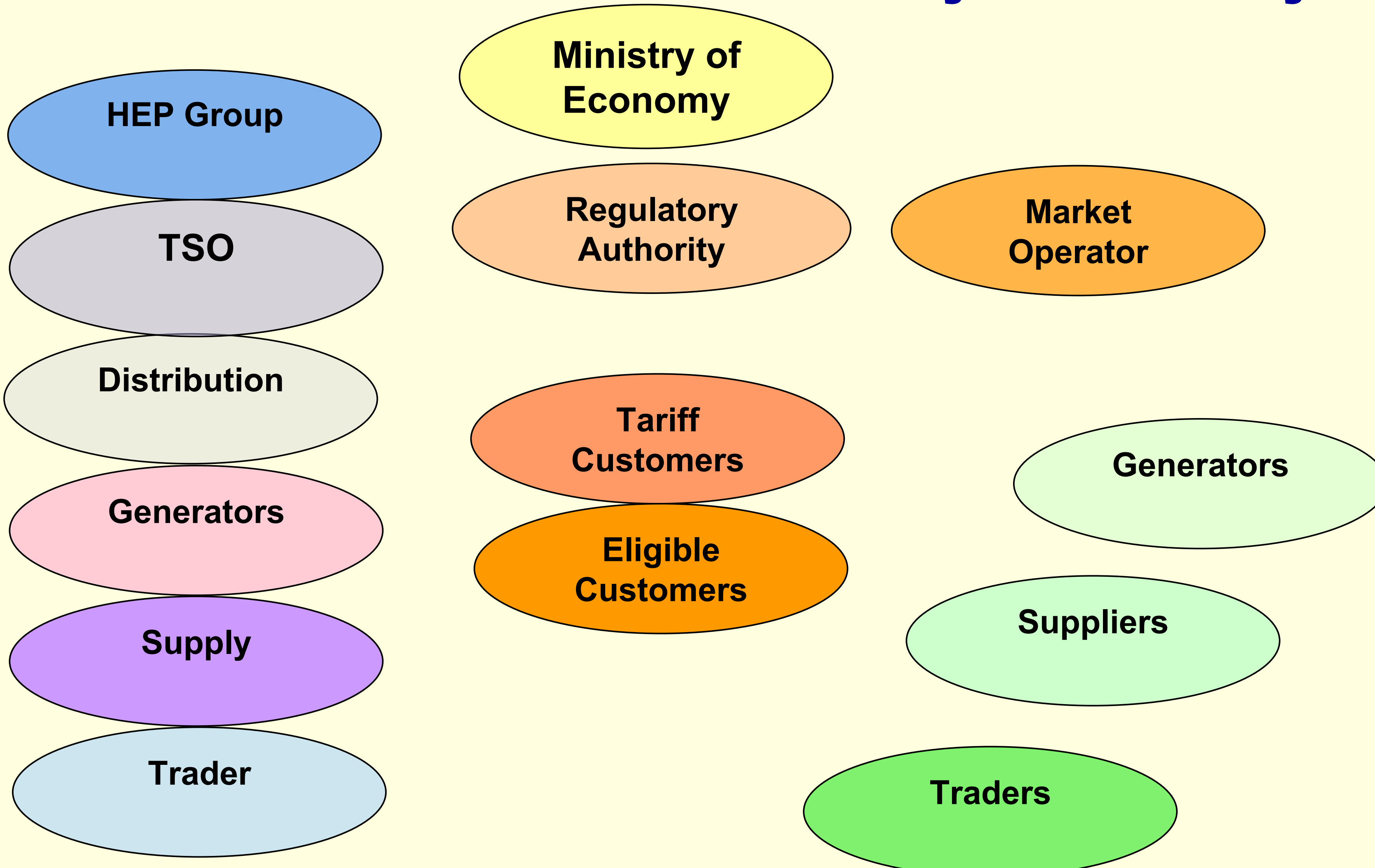
• Available capacity:	4012 MW
• Peak load:	2792 MW
• Total consumption of electricity:	16.1 TWh
– *number of customers*	*2,200,000*
• Annual consumption growth:	~ 3.7 %
• Sales of natural gas	157m m^3
– *number of customers*	*54 650*
• Sales of heat & steam	1.9 TWh & 733 000 tonns
– *number of customers*	*116 000*
• Revenue:	**EUR 1.2 billion**

HEP Group's Profile - structure



*** - company outside HEP Group co-owned by HEP***

Power Sector Reform and Electricity Market Players



Legislation

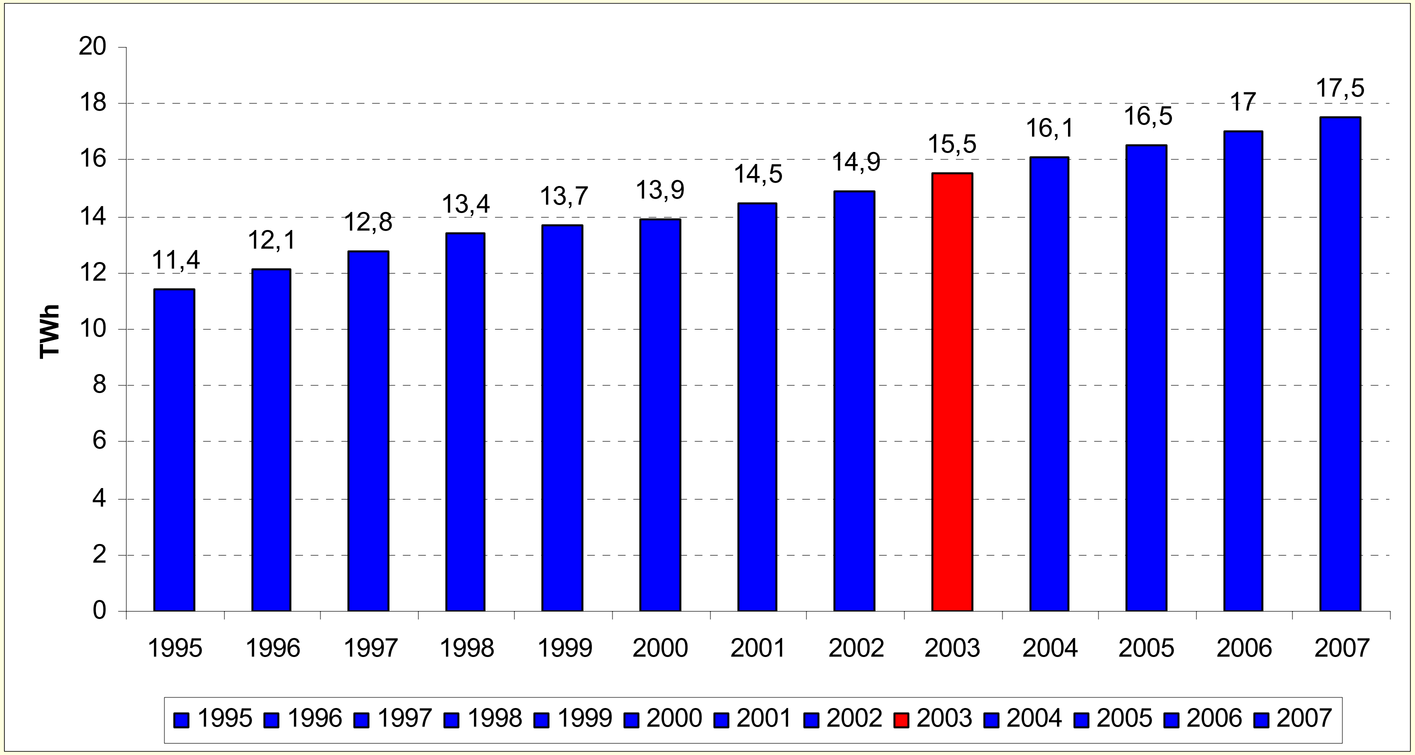
- Company Act
- Act on Amendments to the Energy Act
- Act on the Regulation of Energy Activities
- Electricity Market Act
- Gas Market Act
- District Heating Act
- Consumer Protection Act
- Environmental Protection Act
- and other legislation

Timescale for market opening

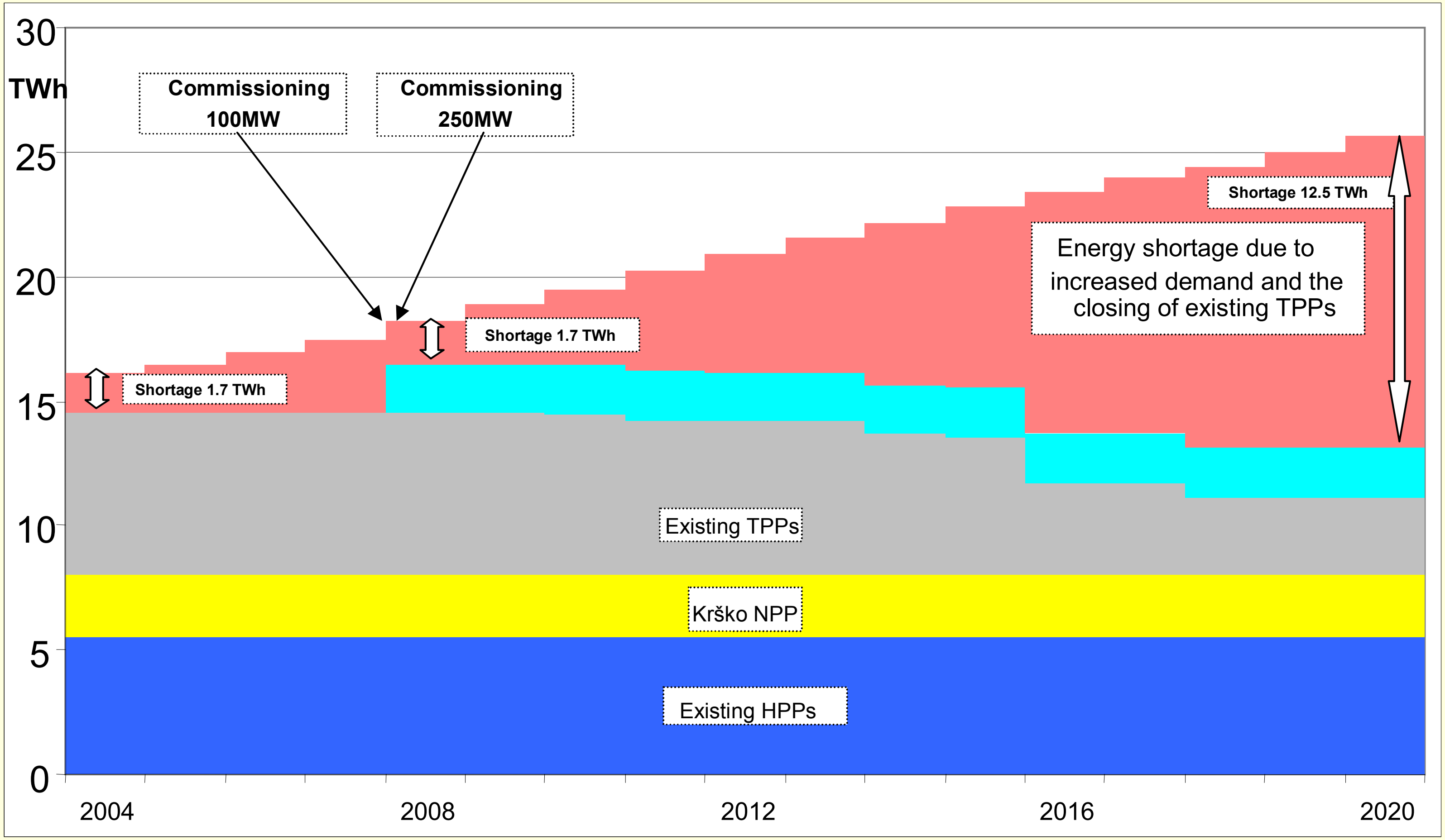
Currently, there are 39 eligible electricity customers, and the dynamics of electricity market opening will be the following:

- 1 July 2006, for customers with consumption exceeding 9 GWh,
- 1 July 2007, for entrepreneurs,
- 1 July 2008, for all customers

Trends in Electricity Demand



Business Growth and Key Investment Projects



Key Investment Projects

Thermal Power Plant	Type	Fuel	Capacity (MW)	Gas Pipeline	Investment (EUR million)	Earliest Completion Date
TE-TO Zagreb CHP	Combined Cycle Cogeneration	Natural Gas	100	Existing Long-Term Gas Supply Agreement with INA	65	end of 2007
Sisak TPP	Combined Cycle	Natural Gas	250	Mala GEA	150	end of 2007
Osijek TPP	Combined Cycle	Natural Gas	250	Connection to Hungary or Serbia	170	end of 2009
Plomin TPP	Condensing	Coal	500		500	

Hydro Power Plant	Capacity (MW)	Possible Output (GWh)	Investment (EUR million)	Earliest Completion Date
Lešće HPP	40	94	80	2008
Podsused HPP	43	215	150	2009
Drenje HPP	39	185	125	2011

Promotion of Investment in Renewables

- According to draft secondary legislation - obligatory connection to the grid
- Feed-in system with financial incentives
  - for privileged RE producers

    (small HPPs<10MWe, Wind, Biomass, Solar...)
  - CHP as a privileged producer

- PPA contracts with investors
  - 2 small HPPs
  - 1 small natural gas fired cogeneration plant
  - wind farm on the island Pag
  - 1 small landfill gas fired cogeneration plant – Jakuševac
  - PPAs for the development of 2 new wind farms near the city of Šibenik and the city of Obrovac
  - all PPAs will be modified in accordance with new legislation

Renewable Capacity in HEP's Ownership

- **HEP is traditionally oriented towards RE** - hydro power plants
- 40 - 60 % of total generation (5 – 7 TWh), depends on hydrology
- 52 % of total installed generating capacity, (26 units - 2071 MWe)
- in 2003, all **HPPs received a "green energy" certificate** for 100 % generation from renewable sources, issued by a German certification agency TÜV Bayer
- potential to offer **green energy and green certificates** in the market

European Experience with Wind Generation

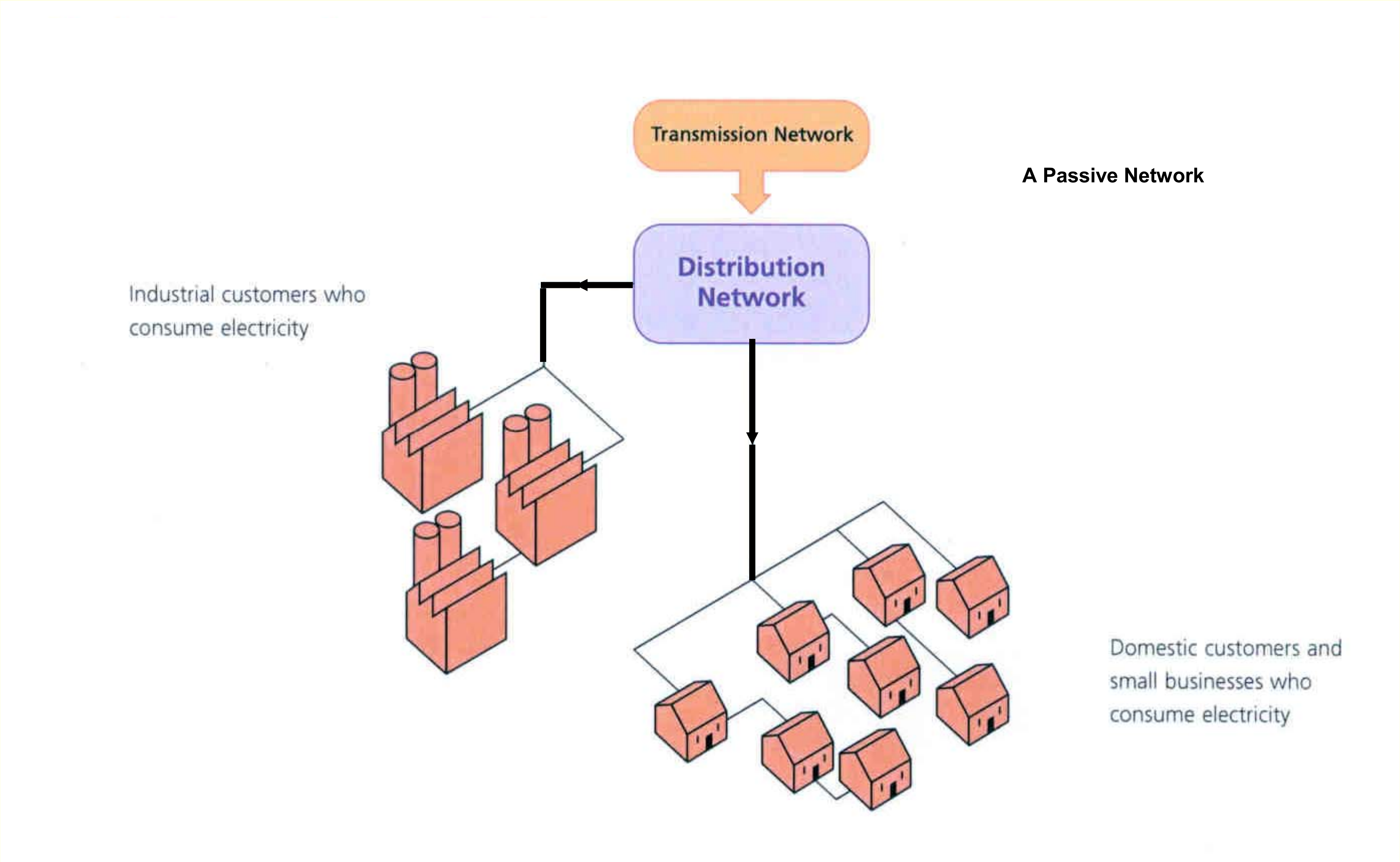
- Wind Generation Capacity Factor in Northern Europe ~20%
- Required back-up Fast Response Generation
- System Stability and Voltage Control
- Maximum Wind Penetration Level ~20%
- Grid Connection Difficulties
- Obstacles to Network Access

Distribution and Transmission Infrastructure

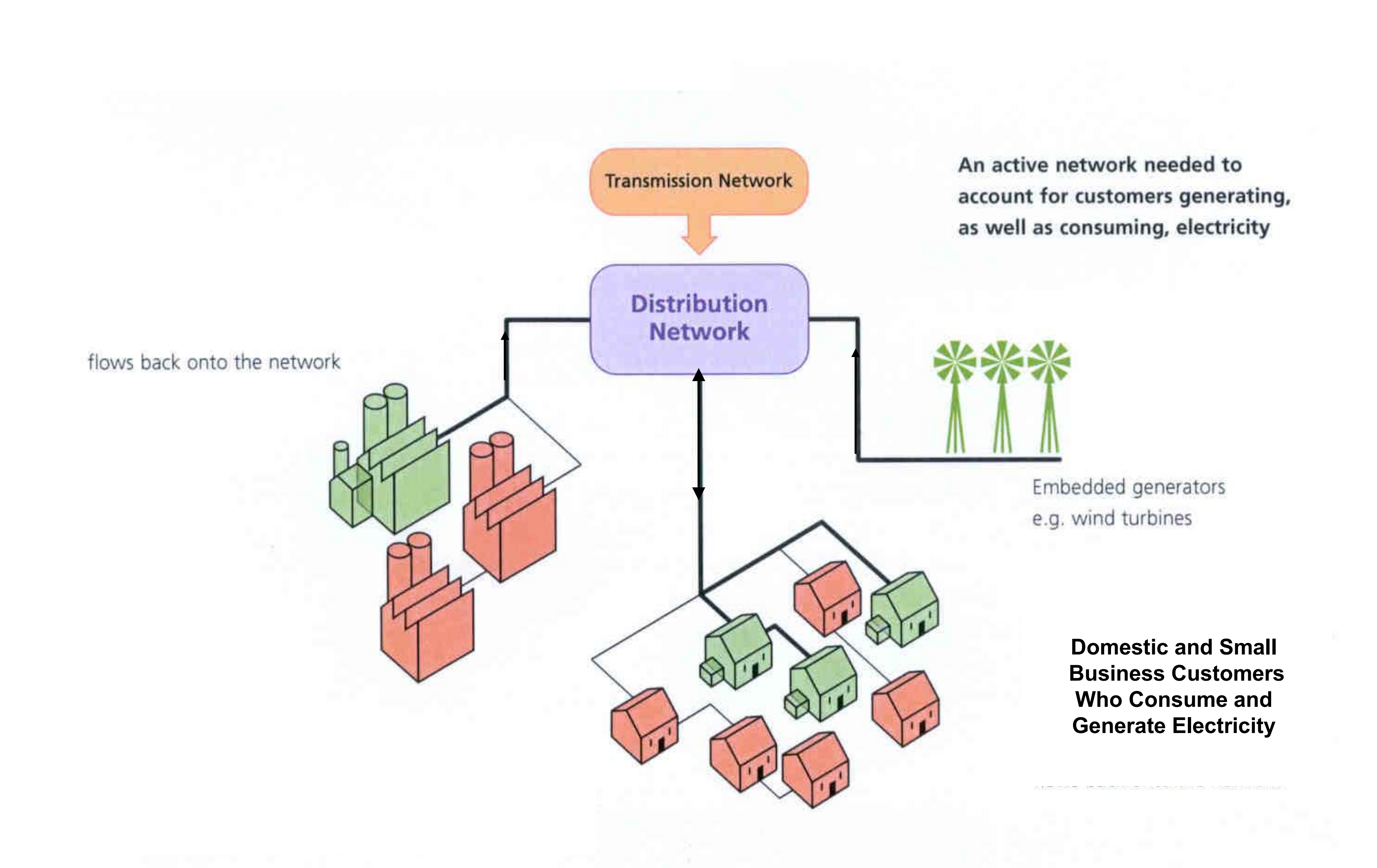
- Much of New Renewable Generation to be Connected to Existing Distribution Systems Leading to Issues in:
  - Power Control
  - Voltage Control
  - Short-Circuit Levels

- Concentrations of Renewable Generation will Lead to Necessary Extension of High Voltage Grids Leading to:
  - Higher Costs due to Remoteness of Source
  - Possible Public Opposition to New Line Construction
  - Undergrounding, Submarine Connection, HVDC Transmission

Today's Power Distribution System



Tomorrow's Power Distribution System



Conclusion

- Political Motivation of Renewables
- Growth of Renewable Generation Inevitable
- Main Advantages – Greener Generation and Improved Diversity of Source
- Subsidy Required for Forseeable Future
- On-Shore Wind only Technology Approaching Maturity
- Competition with Conventional Generation is Healthy
- Innovation will Abound but Decision-Makers Ignorance is Widespread
- Prospects for Croatia

HEP GROUP MISSION STATEMENT

To provide secure and reliable electricity supply to its customers at minimum cost.

HEP GROUP VISION STATEMENT

To remain an integrated corporation that will become a player in the regional market, a Croatian energy *cluster* consisting of a group of related *multiutility* businesses and one of key enablers of Croatian economic growth

Thank you for your attention

Javna agencija RS za energijo

Gorazd Škerbinek

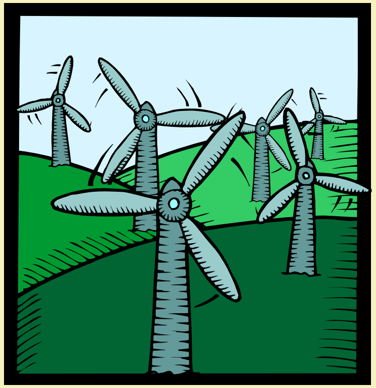
REGULATORY FRAMEWORK FOR INVESTMENTS IN ELECTRICITY GENERATION FROM RENEWABLES

6th Balkan Power Conference, Panel session
RES: Investments and Regulatory Framework in the Balkans

Ohrid, 2 June 2006

Electricity from renewables

- Brings environmental benefits at the global level;
- Unwise use can bring negative impact on environment at the local level;
- Relying on a single source of renewable electricity can significantly deteriorate security of supply;
- Development of renewable electricity must be accompanied by adequate network development.



RES-E in the Balkans

- High potential for RES-E development - hydro and other sources;
- Hydropotential partly exploited, other sources almost nothing;
- Energy Community Treaty (ECT) will establish a framework for further development and investing into new RES-E projects;
- Stimulating RES-E is obviously not the top priority of ECT – market liberalisation first;
- The role of SEE countries is to develop adequate energy policies and regulatory framework;
- RES-E markets in SEE are not yet developed – possibility of financing RES-E projects through exporting RES-E to EU countries.

The regulator’s role

- Responsibilities of regulators in the field of renewables are different, since the Directive 2001/77/EC does not assign any direct role to them;
- In some countries regulators have many direct responsibilities in RES-E;
- Slovenian Energy Agency is one of the regulatory authorities with rather limited roles in the field of renewables and their promotion;

All regulators are responsible at least for setting conditions/tariffs for connecting new generators to the grid and for network charges. Their acting must be in line with the national energy policy.

Javna agencija RS za energijo

Strossmayerjeva 30, 2000 Maribor	p. p. 1579
Telefon: [02] 234 03 00	Telefaks: [02] 234 03 20
www.agen-rs.si	info@agen-rs.si

JI/CDM opportunities in the West Balkan energy sector

Andreas Tuerk

JOANNEUM RESEARCH, Institute of Energy Research, Graz, AUSTRIA

Kyoto Protocol's Flexible Mechanisms

The UNFCCC distinguishes between:

- **Annex 1 countries**: industrial countries and economies in transition. They have quantitative reduction targets (in the Annex B of the Kyoto Protocol)
- **Non-Annex 1 countries:** developing countries with no binding reduction targets

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Introduction

How can Annex-1 countries reach their Kyoto targets?

1. By domestic measures

2. By the use of project based „flexible mechanisms“ of the Kyoto Protocol: IET, JI and CDM

- Austria for example purchases 35 Million tones of CO2e in the Kyoto period from JI an CDM credits (Austrian JI/CDM programme)

JI and CDM: principle

- **Joint Implementation (JI):** Annex I country invests and carries out a project to reduce greenhouse gas (GHG) emissions in **another Annex I country**. JI projects generate Emission Reduction Units (ERUs) from 2008-2012.

- **Clean Development Mechanism (CDM):** Annex I country carries out a project to reduce greenhouse gas (GHG) emissions in a **non-Annex I** country. CDM projects generate Certified Emissions Reductions (CERs) from begin of the project to 2012.

For every ton of CO2e a project reduces compared to the baseline, one ERU or one CERs is generated!

JI and CDM: principle

Investor Country

Govt and companies want to reduce GHG emissions

They invest in a project in e.g. in a developing country or Economy in Transition

€

Investment

CERs, ERUs

Host Country

Large bandwidth of opportunities for projects that reduce emissions e.g.

- Renewable energy
- Energy efficiency
- Biomass energy
- Waste
- Afforestation/Reforestion

Project produces CERs or ERUs

CERs and ERUs can be transferred to the investor country!

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Who buys CERs and ERUs?

- Annex I – governments to meet their Kyoto targets

  Some countries such as Austria have special purchase programmes

- European companies for compliance in the EU ETS
- Non-European companies for Kyoto compliance
- Financial institutes for trading purposes

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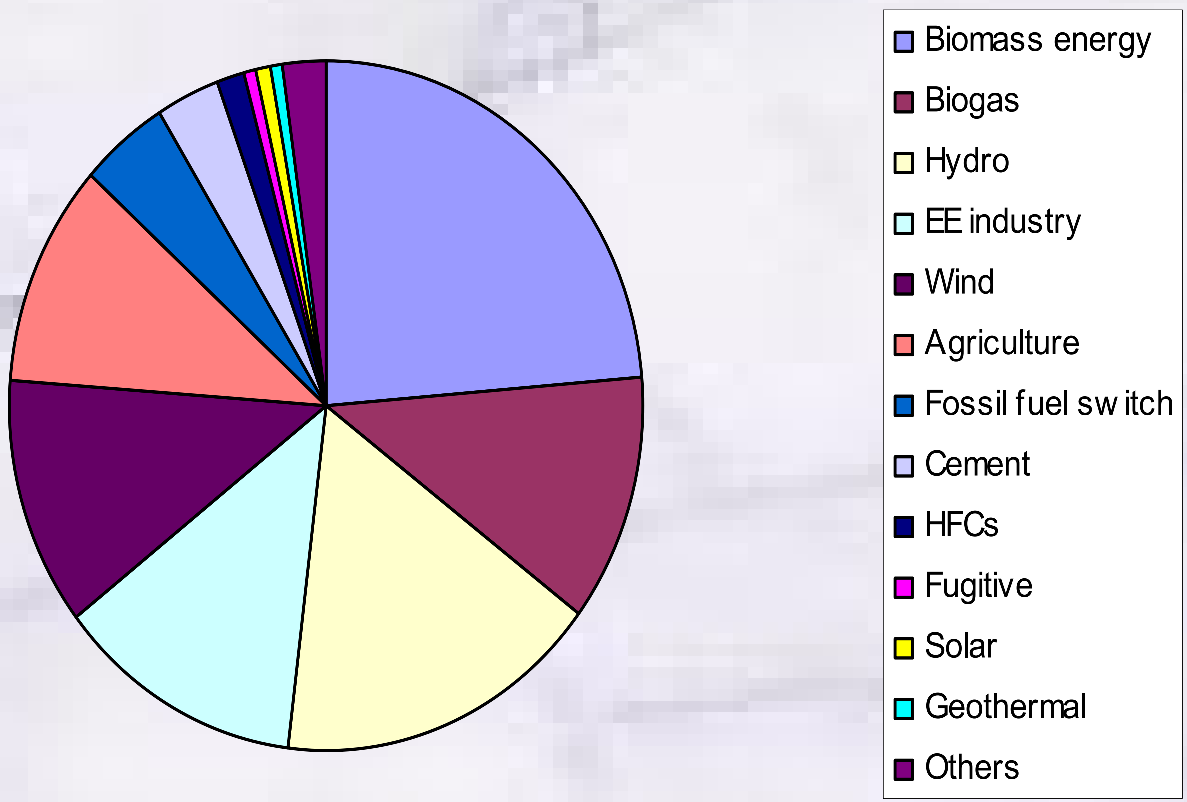
Basic requirements for JI/CDM

- Emission reductions from JI/CDM projects must be **additional** in host country
- JI/CDM projects must be approved by the host country
- Must lead to sustainable development in host country
- Some project categories such as nuclear power projects are not eligible
- Before CDM projects can generate CERS and ERUs the have to be registered by the responsible organs of the UN Climate Secretariat.

Booming JI and CDM market

CDM Market (PDDs) - Sector Overview

- **195 CDM projects registered**
- **2000 in the pipeline**



Source: UNEP Risoe, 2006

Status of the Kyoto Protocol ratification

Country	Ratification in	JI or CDM?
Romania	2001	JI
Bulgaria	2002	JI
Slovenia	2002	JI
Macedonia	2004	CDM
Albania	2005	CDM
Croatia	End of 2006	JI
Serbia	End of 2006	CDM
Bosnia and Herzegovina	?	CDM

JI/CDM: Good opportunities for the energy sector of West Balkan countries

- By attracting foreign investors for the financing of projects to modernize the energy sector. As investors can sell CERs and ERUs they have an additional incentive to invest.

- Transfer of technology and know-how from industrialized countries

- West Balkan energy sector has a high reduction potential. JI/CDM could provide especially good opportunities to modernize old coal fired thermal power plants as well as to expand renewable energy sources.

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Sucessful examples of JI/CDM in selected Balkan Countries

- A significant number of JI projects implemented already in other South Eastern European countries (e.g. in Bulgaria and Romania)
- West Balkan countries lagging behind
- In Bulgaria and Romania special focus on hydro power, energy efficiency and biomass projects

Example: Hydro Power JI Project in Bulgaria

Example: Vacha Cascade Joint Implementation Project

- Construction of a new hydro power plant
- modernization of 4 existing power plants (with Austrian technology, Austrian investor)
- 1.139.997 t CO_2 reduction from 2008-2012 compared to the baseline scenario
- 1 Mt CO_2 was purchase by the Austrian JI/CDM programme

JI/CDM Opportunities in West Balkan countries

- **Hydro Power** particularly in Bosnia and Herzegovina, Serbia, Montenegro, Albania
- **Rehabilitation of coal fired power plants** in Serbia, Montenegro, Bosnia and Herzegovina
- **Fuel switch from oil/coal to gas or biomass** in Croatia Bosnia and Herzegovina, Macedonia, Serbia
- **Wind**: Albania, Bosnia and Herzegovina, Croatia
- **Solar**: Albania, Croatia, Montenegro

(Source: International Emissions Trading Association)

And the future?

West Balkan countries may need ….

- help to identify suitable projects
- help to build capacity to enable JI/CDM projects

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Renewable Energy Sources: The recent initiative for the implementation of Directive 2001/77/EC and the Kioto Protocol in the Greek legal system

Dr Ioannis Tzortzis
Attorney at Law at the Supreme Court
Regulatory Authority for Energy, Greece
Legal Energy Expert, EU

Ohrid, June 2006

1. The timing

- It took more than a year and a half, three provisionary Law Drafts, two public consultations for the *Greek Regulatory Authority for Energy (RAE)* to complete the drafting of a workable Legal Act for Renewable Energy Sources (RES) and the implementation of Directive 2001/77/EC on the “Development of Renewables” and the Kioto Protocol on the “Reduction of CO2 gas emissions”.

- Just a week ago on May 23rd , a groundbreaking Law Draft was submitted by the *Minister of Development* to the Greek Parliament, for the creation of a radically new legal framework for the RES in Greece.

2. The aims

- To introduce the ideas of better regulation and legal simplification in the procedure of granting licenses for power generation from RES.
- To reach the targets of 20,1% until 2010 and 29% until 2020 for the contribution of RES electricity generation to the overall power supply, according to the requirements of Directive 2001/77/EC.
- To make the best possible use so far of all RES which in Greece are in such an abundance, with the main priority being given to wind and solar energy.
- To create a rigid and safe legal environment for the attraction of a large scale of foreign and national capital investment, the size of which has never been seen before in Greece.
- To satisfy the provisions of the Kioto Protocol with regard to curtailing CO2 gas emissions.

3. The main provisions I

- **New strict short deadlines** for the licensing procedure with regard to RES have been imposed, so that the time period for granting a license is to **decrease from three years to under 12 months.**

- The **number of the authorities** involved in the licensing procedure is being **reduced from about 45 to under 11.**

- The **power selling contracts' validity period** is being **extended to 20 years (12+8)** according to the RES producers discretion.

- The **priority given** to RES is for the first time with **no limit**.

4. The main provisions II

- The **preliminary environmental approval** is incorporated in the **first stage of the power generation licensing procedure**, according to Directive 96/61/ EC for the "Integrated Pollution Prevention and Control (IPPC)", in order to create **safe investment conditions**.

- The **exemption of the obligation to grant a license** is being extended to a large number of RES applications: a. **Geothermal** up to 500 kWe, b. **Biomass or bio-fuel** up to 100 kWe, c. **Photovoltaic** up to 150 kWe, d. **Wind** up to 50 kWe (System), 40 kWe (large islands), 20 kWe (little islands), e. Any other up to 50 kWe.

- The introduction of a radical new system for granting **certificates of origin guarrantees** according to Directive 2001/77/ EC with RAE being the competent authority for Greece.

5. The new tariffs and tax exemptions

- The **tariffs** of selling electricity generated by RES to the System or the Grid are being hugely **increased by up to 600%** and **differentiated** according to the relative technology (in Euros):

Wind:	73 (System)	84.6 (Islands)
Sea wind:	90	
Hydroelectric<15 MWe:	73	84.6
Solar/Photovoltaic<100 kW:	450	500
Solar/Photovoltaic>100 kW:	400	450
Solar non Photovoltaic<5 MW:	250	270
Solar non Photovoltaic>5 MW:	230	250
Geothermal, biomass, etc.:	73	84.6

- In a **new Tax Law** which is going to be enacted next autumn, some 20% of the total cost for buying wind generators or solar panels, will be exempted from tax.

6. The current situation

Technology	Licenses for use (MW)	Licences for installation (MW)	Licenses for generation (MW)	Annulled licenses (MW)	Applications (MW)
Wind	514.5 (84.6%)	915.8 (87.2%)	4983.5 (89.5%)	523.6(82.2%)	25527.6(92.1%)
Biomass	24.0 (3.9%)	27.9 (2.7%)	92.3 (1.7%)	21.8 (3.4%)	386.2(1.4%)
Geothermal	0.0 (0.0%)	0.0 (0.0%)	8.0 (0.1%)	0.0 (0.0%)	335.5(1.2%)
Hydro<5MW	69.2 (11.4%)	105.6 (10.1%)	483.9 (8.7%)	91.6 (14.4%)	1438.4(5.2%)
Photovoltaic	0.8 (0.1%)	0.9 (0.1%)	2.2 (0.0%)	0,1 (0.0%)	43.1(0.2%)
Total	**608.5**	**1050.1**	**5569,9**	**637.1**	**277730.7**
In relation to the total of generation licenses	**10.9%**	**18.9%**			

7. The way forward

The new Law is yet to be tested. During the autumn of 2006, RAE is to commence an impact analysis through public dialog with regard to assessing the implementation of the new Law on RES, and promoting its basic principles.

Thank you for your attention.

Emission Trading

Elektrizitätsgesellschaft Laufenburg AG

content

- EGL AG / market overview, what happened so far
- Co2 trading aspects
- market mechanism
- behaviour of the market participants, experience in the compliance market
- EUAA one uniform trading good in Europe

ownership.
13% public; 87% Axpo Group.

EGL is an operationally independent member of the Axpo Group:

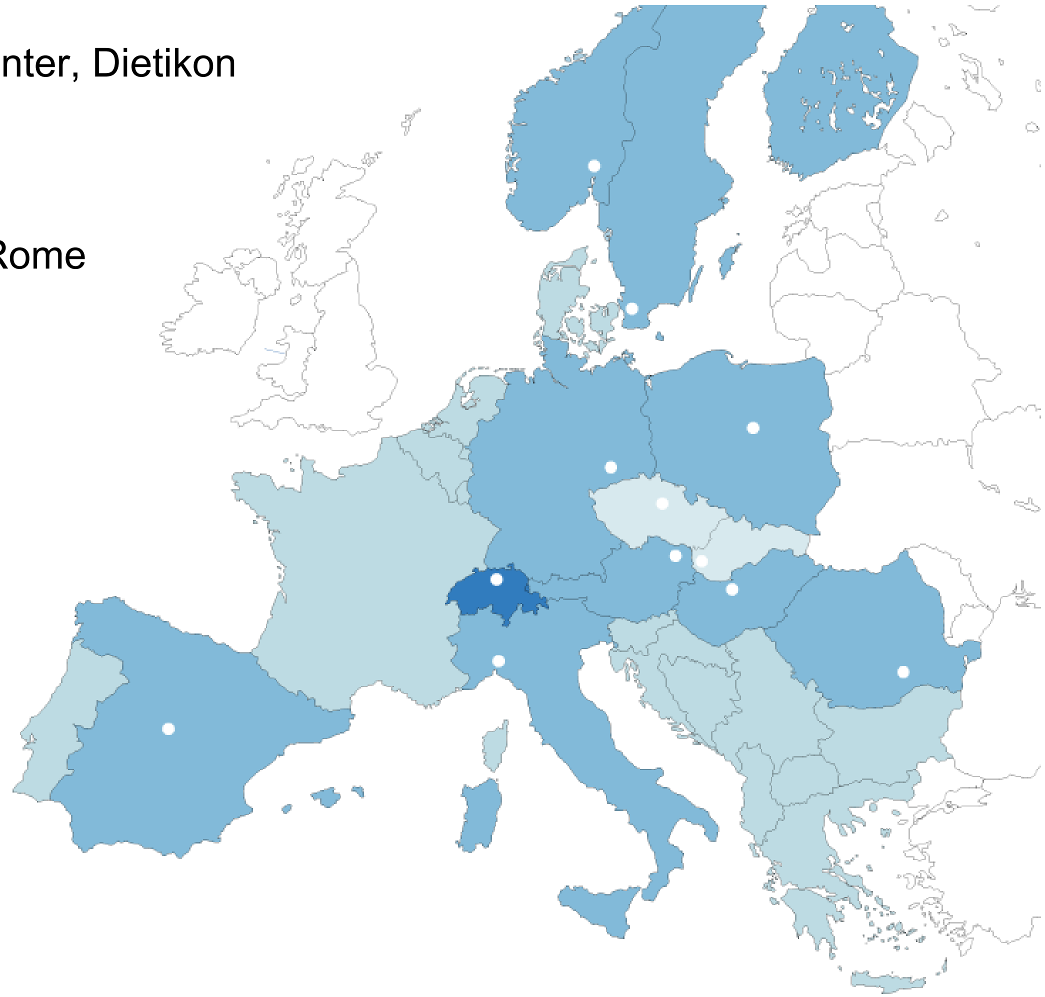
- turnover 04/05 3 € Mrd.
- operating profit 04/05 45 € Mio.
- 322 employees
- 12.6% free float
- 87.4% Axpo Group
- listed on the SWX Swiss Exchange

local presence.

EGL Headquarters and Trading Center, Dietikon
Deriwatt AG, Dietikon
EGL Grid AG, Laufenburg

EGL Italia S.p.A., Genoa, Milano, Rome
EGL Polska Sp. z o.o., Warsaw
EGL Austria GmbH, Vienna
EGL España, S.L., Madrid
EGL Deutschland GmbH, Leipzig
EGL Nordic, Oslo
EGL Romania SRL, Bucharest
Arpad Energia Kft., Budapest
EGL Sverige AB, Malmö
EGL Slovakia, Bratislava
EGL Czech Republic, Praha
EGL Greece, Athens

EGL Markets



EGL's approach to the topic CO_2

- **through to a EU - directive a new commodity was generated**
  - there is no elementar need to trade CO2 like oil, gold or orange juice
  - EGL decided 2003 to go into this market
  - reason for that was, the strong correlation between electricity / gas / cole / oil and EU Allowances
  - existing business relation to the hugh emitters

EGL is not effected in the moment through this EU derective

  - pure trading approach (2300 deals ~ 25,1 Mio. tonns of CO2)
  - but from 2007 we will have in Italy a natural possition because of 4 CCGT power plants

introduction in trading CO_2

overview:

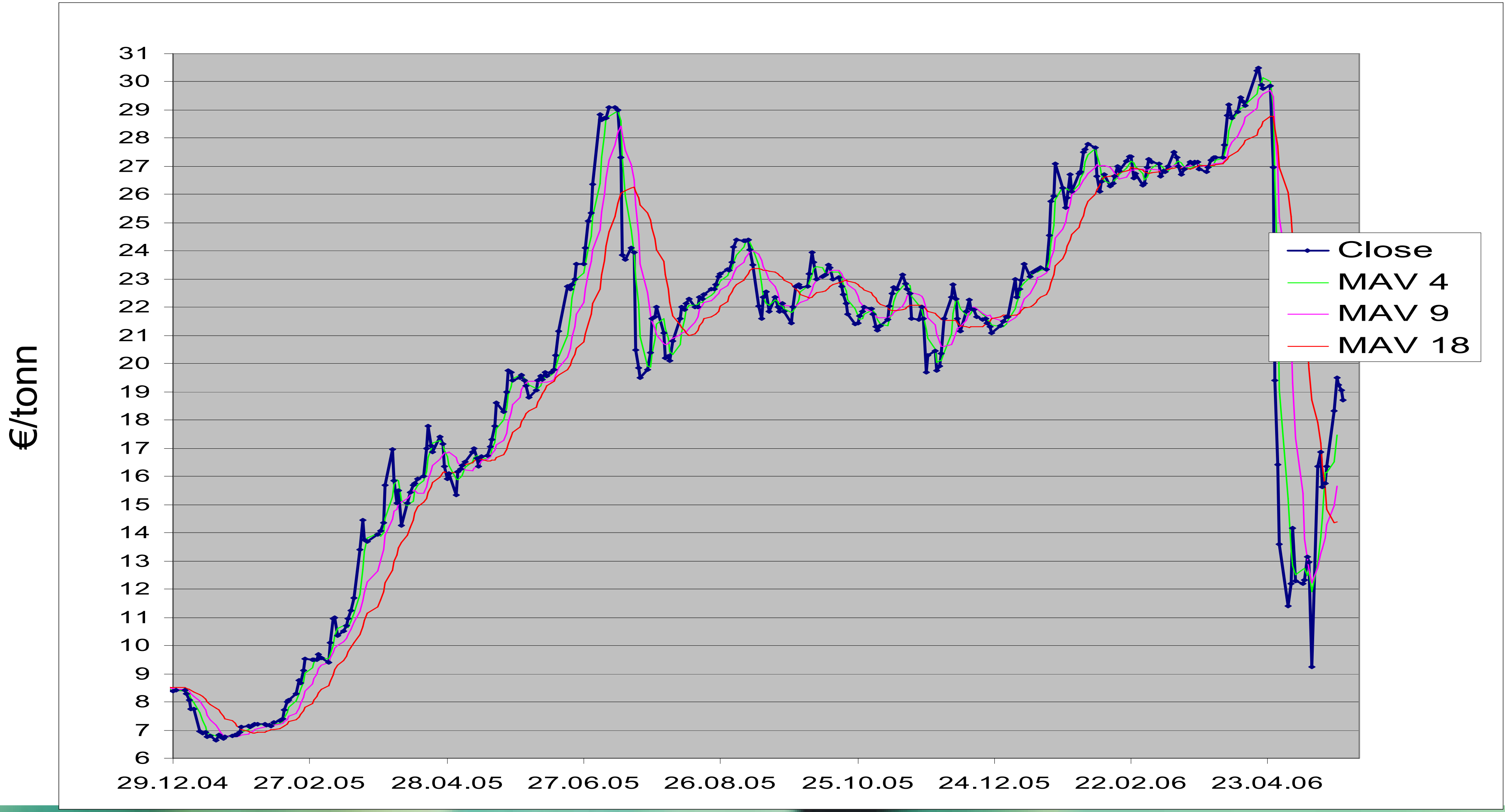
• minimum price:	6,35€/t
• maximum price:	31,00€/t
• maximum daily trading range:	9,50€/t
• 250 day volatility:	94,16%
• today`s 30-day-volatility	249,54%

- **correlations:**

EUAA vs. Cal 07 BL GER	84,9 %
EUAA vs. Cal 07 Gas NBP	86,9 %
EUAA vs. dated Brent	83,3 %

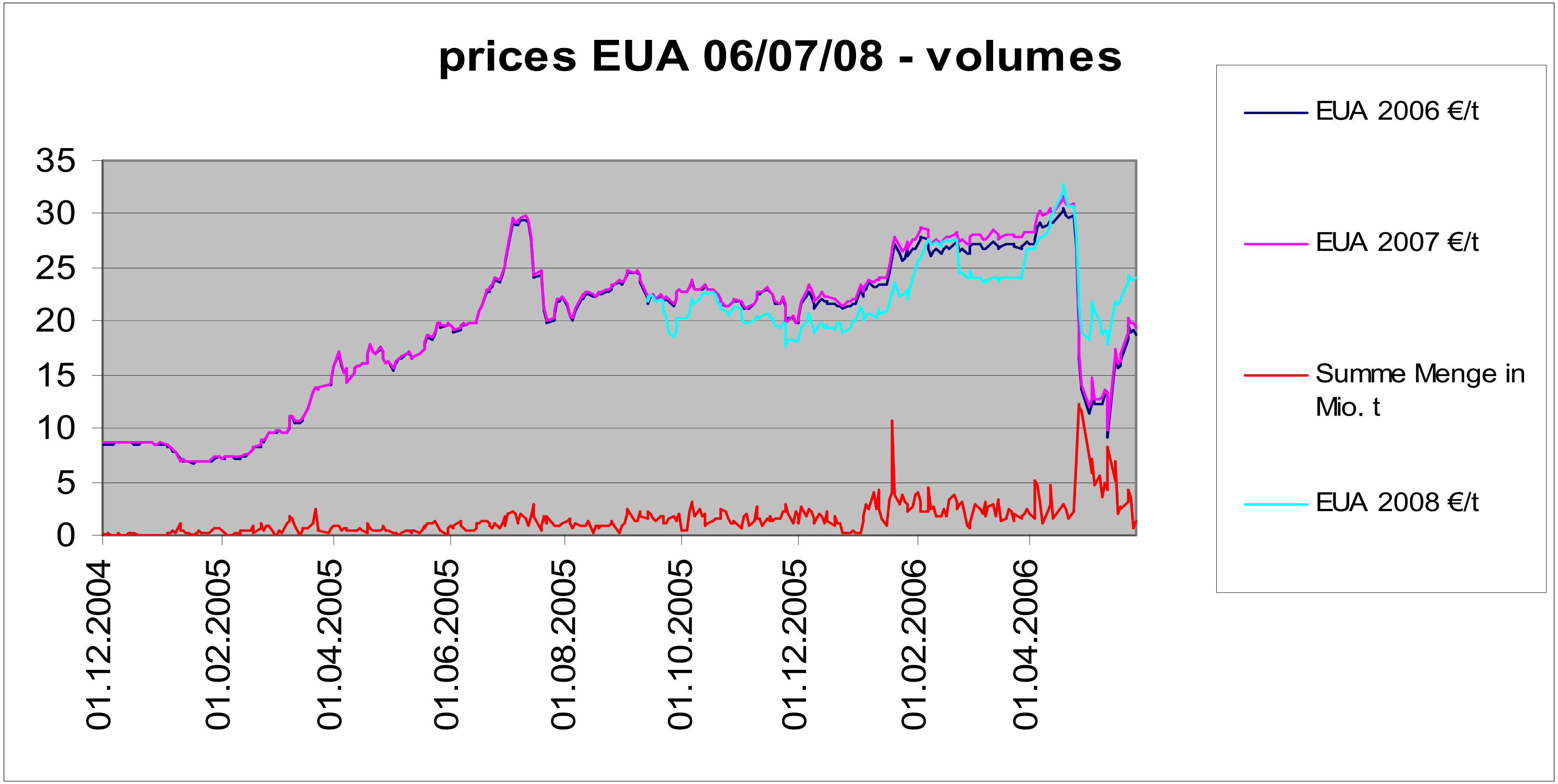
EGL

price development for EUA´s

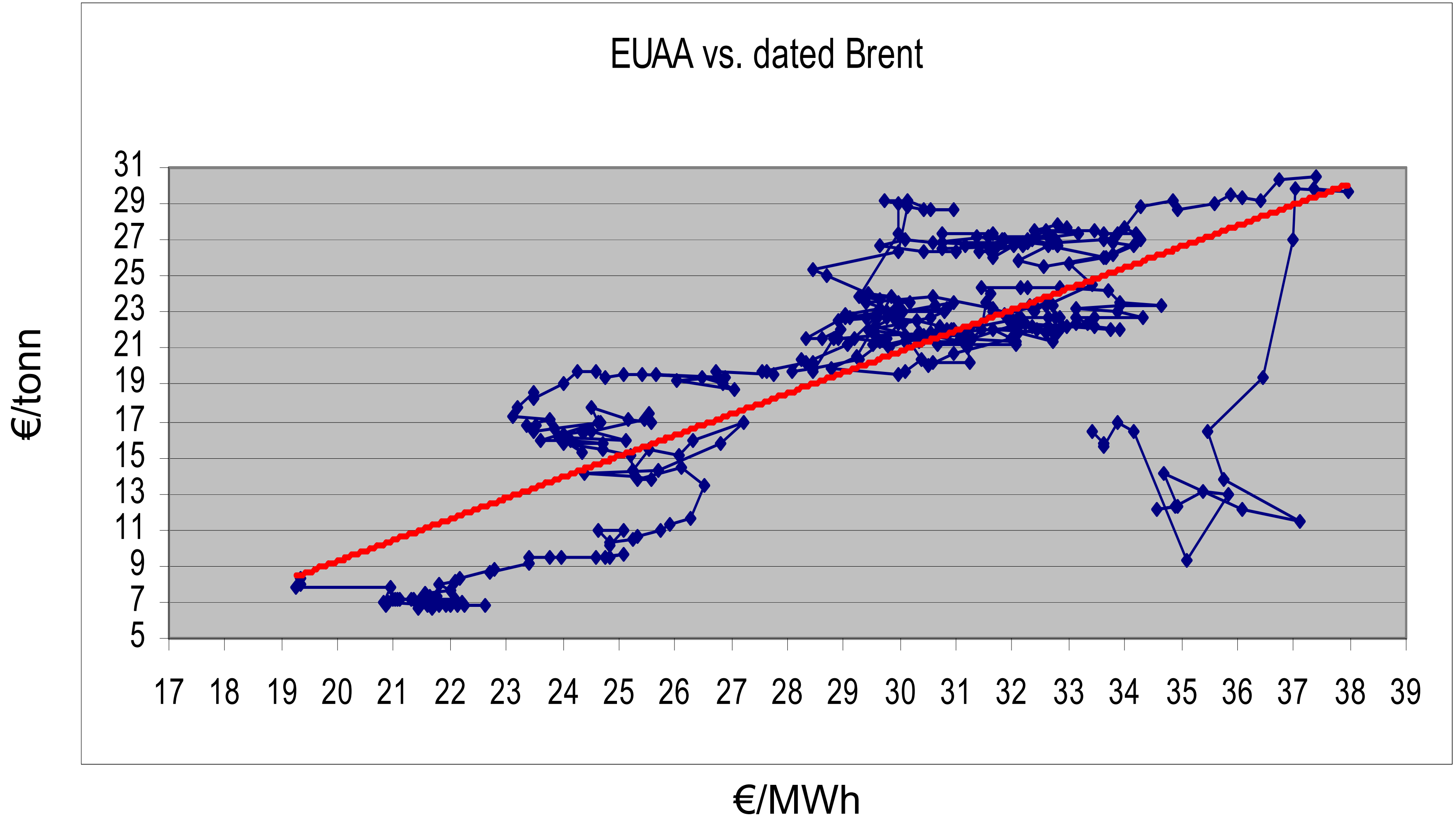


EGL

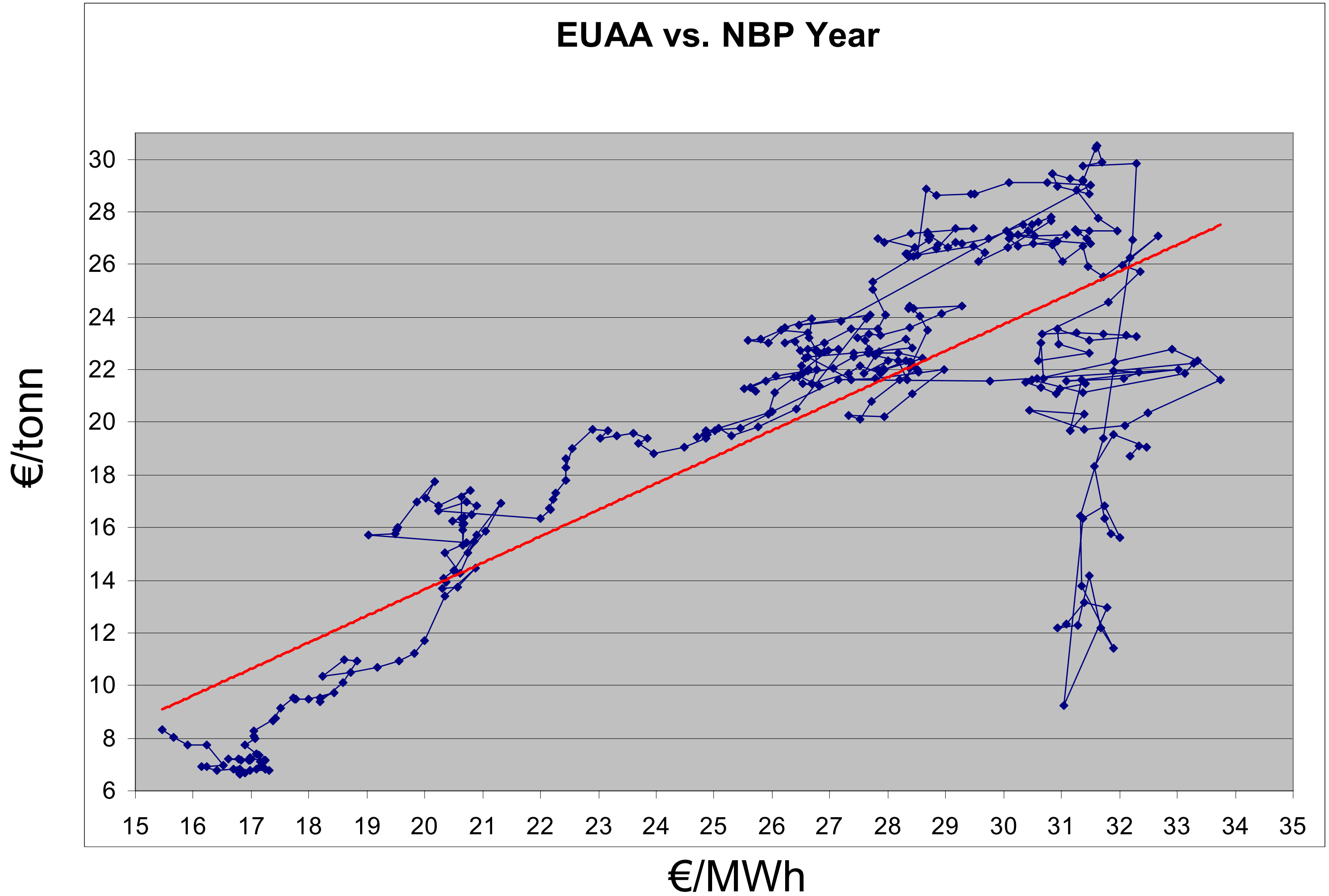
prices- & volumes development for EUA´s



correlation CO2 - oil

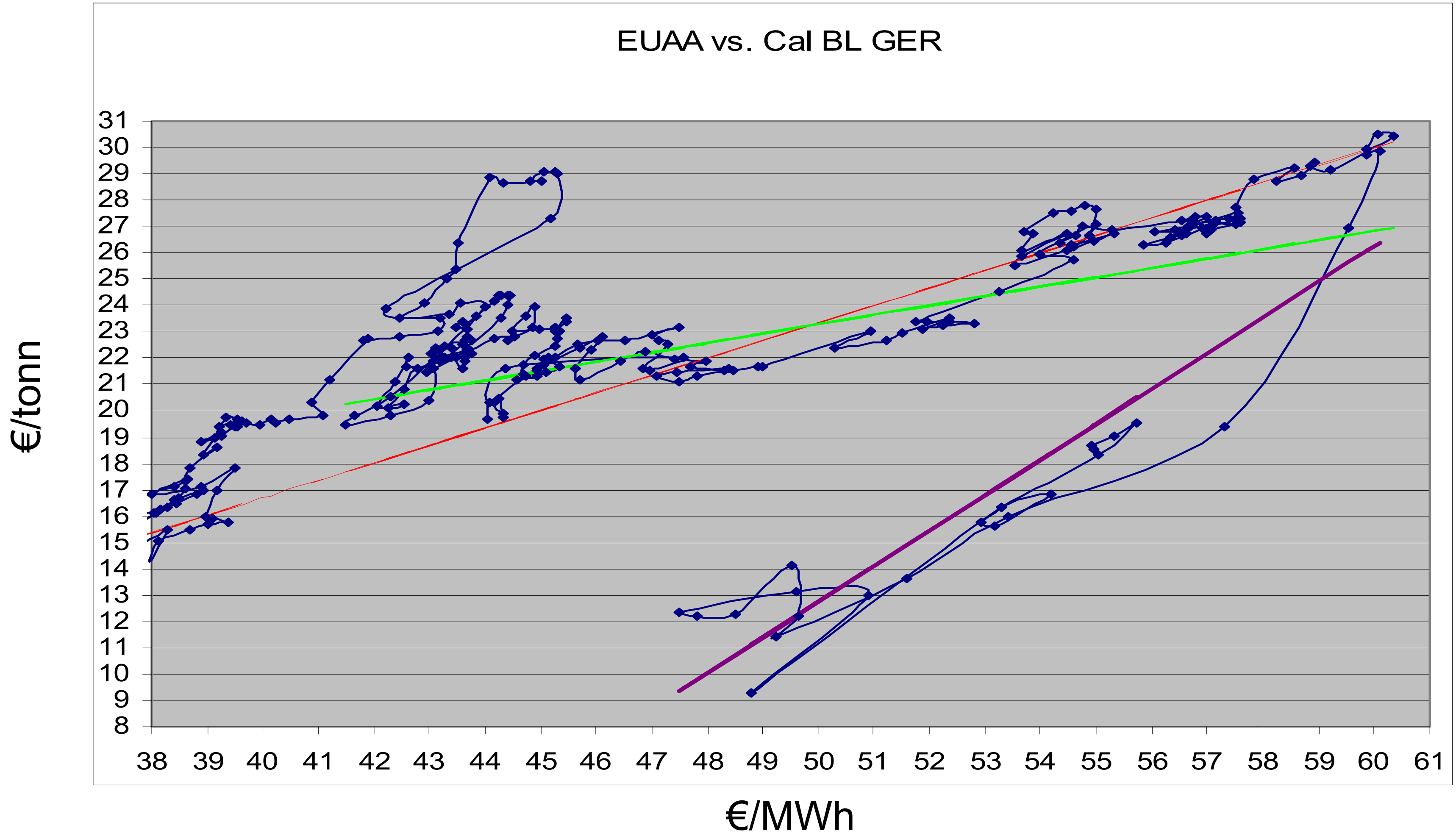


correlation CO2 – Gas (National Balancing Point UK)



EGL

correlation CO2 – electricity Germany



market mechanism

- **spot:** delivery of the certificates immediately, t+2
  payment relatively short periode after delivery
- **forwards:** conditions are fixed today, delivery and payment take place at a later date
- **OTC Deals:** bilateral, direct with companies and brokers (fees), banks (fees)
  trading times Mo-Fr 8 – 17:00
- **financial products:** futures & options
- **Exchanges (fees):** spot, forward und futures
  trading times Mo-Fr 8 – 17:00 daily
  continious trading, auction
  EEX, ECX, EXAA, Nordpool, Powernext,…

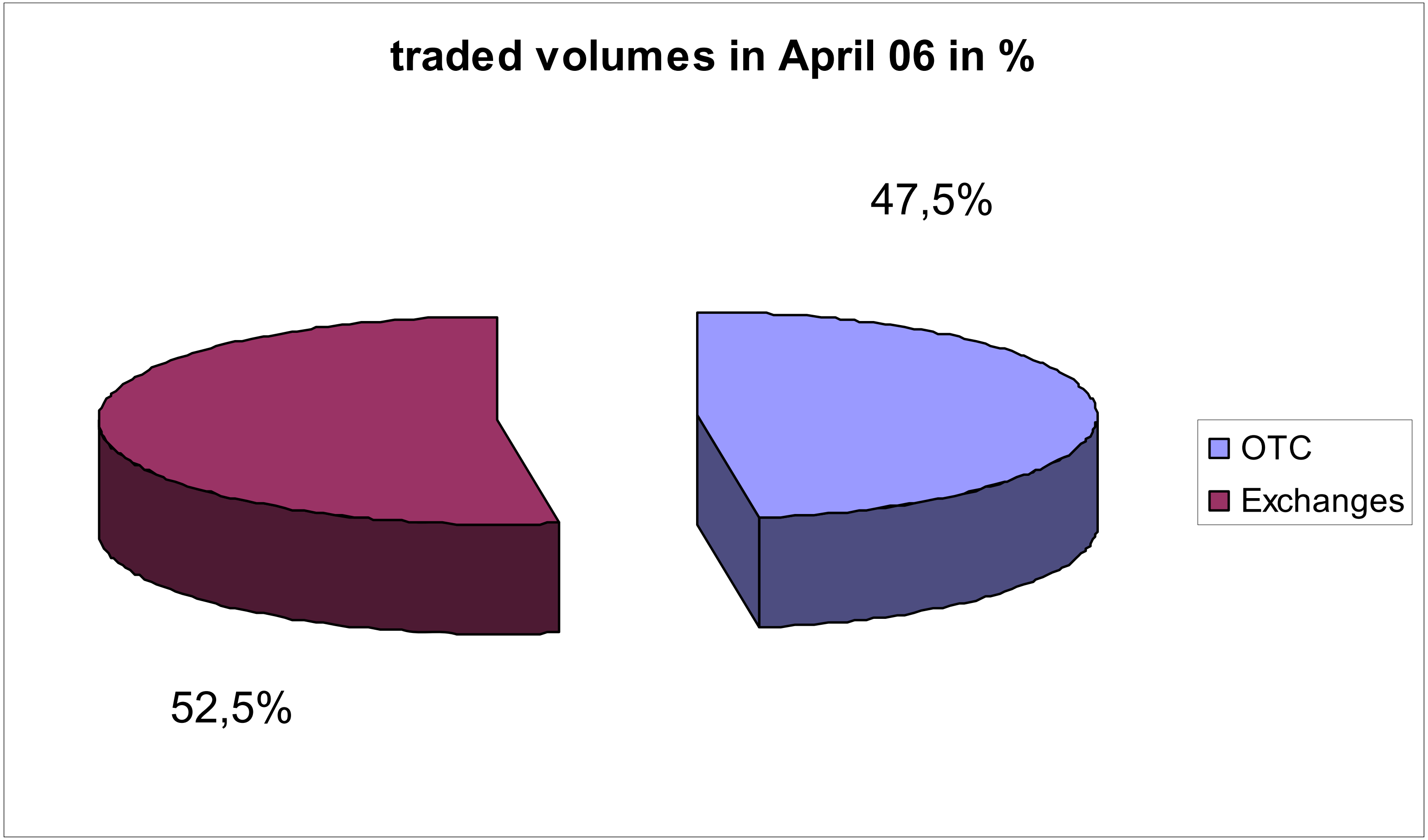
behaviour of the market participants

- **northern Europe:** very good trading structure (Nordpool)
- **southern Europe:** very conservative, very often indirect active
- **Austria:** fears for the NAP 2 is very big, conservative trading
- **Germany:** very professional
- **UK:** most active country at the CO_2 market, financial centre of Europe
- **big emitters:**

  electricity producers: continuous trading, using all market instruments

  paper & cement industry: continuous trading, first via banks → OTC, exchanges

behaviour of the market participants



questions for CO2 related companies

Is your company a trading company ?

Do you have access to the traded market ?

e.g. trading companies, exchanges, broker,..

Do you have a person which is responsible for Co2 trading?

Do you have any ideas about Emission contracts and its legal impacts?

In the compliance market the most are not?

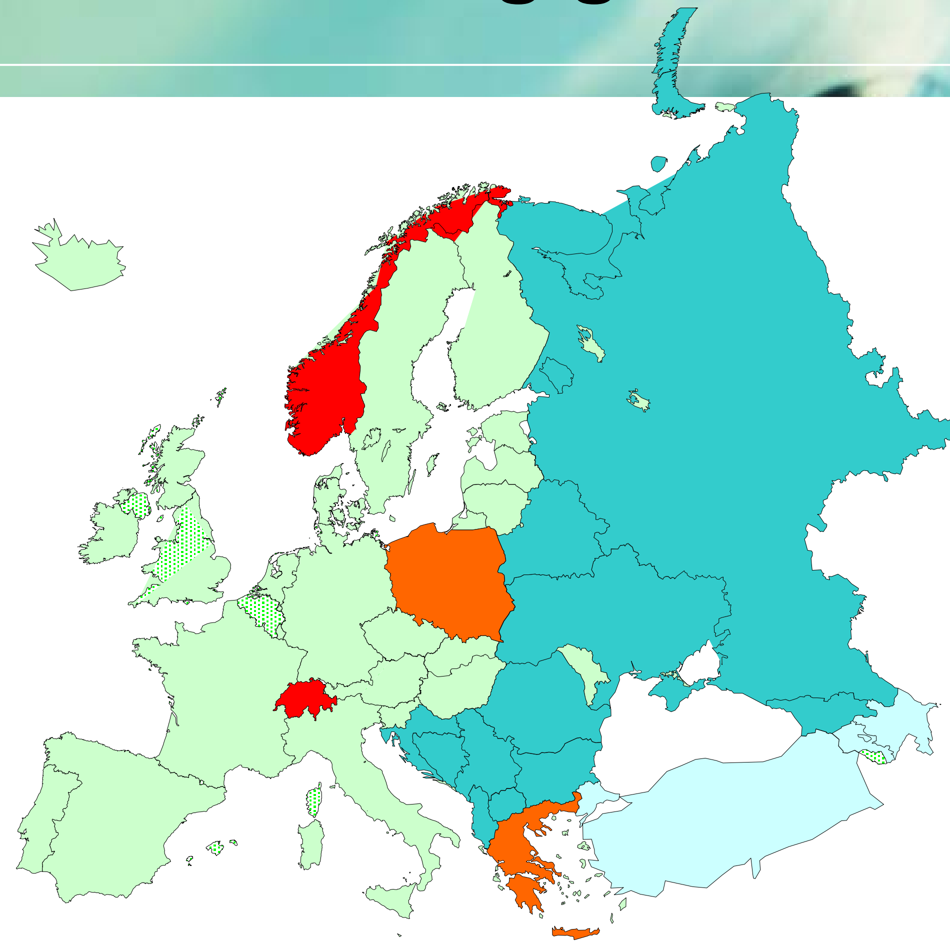
EUAA one uniform trading good in Europe

- EUAA one uniform trading good in Europe

In general YES, but !

EUAA one uniform trading good in Europe

- ok
- Soon, not yet*
- 2008 or later
- Turkey
- Swizzerland, Norway



* Poland, Malta, Greek, Cyprus

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Renewable Energy in Western China – Part I: Potentials

Xu Xiangyang, Su Zhengmin, Andrej F. Gubina

Abstract-- **This paper is the first in a two-part series that present an overview of the development in the renewable energy sources (RES) in the Western region of China. In the first part, we present the RES potentials of Western China, and in the second part, we propose some recommendations for RES policy development for the region, based on the European Union experience and international best practice.**

In this paper, we analyze the abundant renewable energy resources in WRC with different energy specifications. Despite of its size, China is a developing country with rapid economy growth. Consequently, greenhouse gas (GHG) emission levels are increasing rapidly, so their reduction is of great importance. Development of renewable energy sources (RES) is a key to the sustainable development of China while pursuing the low GHG emissions goals. We focus on China's WRC as the most important region for development of renewable energy in the future years.

Index Terms— **biomass, China, EU, geothermal, renewable energy sources, solar, wind.**

I. Introduction

ENERGY efficiency improvement and development of renewable energy sources (RES) are key to sustainable development. For example, the European Union now imports 50 % of its energy needs, while in 25 years, the share is forecast to rise to 70 %. Coupled with the increasing share of fossil fuel, this situation makes EU vulnerable economically, politically and with regard to the environment. As an attractive option to diversify the EU's energy supply, RES are available locally, they bring environmental benefits and they contribute to employment and the competitiveness of the European industry. By the year 2010, the EU set the goal to double the share of renewable energy in national gross energy consumption to 12 % (White Paper "Energy for the future", [1]) and to provide 21 % of the electricity from RES (RES-E). The Directive on the promotion of renewable electricity (RES-E Directive) on the internal market, is aiming at reaching a 21% share of renewable electricity by the year 2010 for the EU-25 and specifying indicative targets for all 25 member states [2].

The Kyoto Protocol made strict requirements on GHG emission levels and their reduction for developed countries. European Union has committed the member states to reduce GHG emissions by 8 % in 2012, compared to 1990 level. The EU countries have listed renewable energy development as an important measure to reduce GHG emissions. To follow-up on its commitment to reduce its dependency on fossil fuel imports, as highlighted in the Commission's Green Paper on Security of Energy Supply [3], and to reduce greenhouse gas (GHG) emissions, a joint strategy for promotion of renewable energy sources in EU has been set up.

II. RES in China

As a developing country, China does not have GHG mitigation obligations in Kyoto Protocol. At the same time, due to China size and its quick economy growth in the recent two decades, Chinese GHG emission levels are increasing rapidly, so their reduction is of great importance. Development of RES is a key to the sustainable development of China while pursuing the low GHG emissions goals, so China is taking steps to increase the share of RES. We investigate the RES potential of WRC as the most promising region for RES development in China.

The WRC includes 12 provinces and the municipality directly under the Central Government of Chong Qing, Sichuan, Guizhou, Yunnan, Tibet, Shanxi, Gansu, Qinghai, Ningxia, Xinjiang, Inner Mongolia and GuangXi, Fig. 1. The total area of WRC is 6.85 Million km^2, occupying 71 % of China. By the year 2005, the total population of WRC was 369.866 million, some 28.29 % of total population in China.

In year 2005, the GDP value in WRC was 3,317.255 billion Yuan (RMB), accounting for 16.98 % of China mainland GDP. (Taiwan, Hongkong and Macao are not included). While the average GDP per capita in China in 2005 was 14,954.889 RMB, in WRC the GDP value per capita was only 8,968.79 RMB, some 59.97 % of the average level of China, and only 34.318 % of the most prosperous Guan Dong province of China.

The difference between East region and WRC is striking. There are vast expanses of land and beautiful scenery in WRC, but the steep mountains and torrential rivers occupy most of the area, such as Himalayas, Pamir Mountain, Nujiang River and west Yunnan Rivers. Arable land is scarce and poorly inhabitable, and the population income is very low, especially with the farmers in WRC. In the year 2001, among the 12 provinces and municipalities, in nine of them the annual average income of farmers was some 1500-2000 RMB, and in the other three it was lower than 1500 RMB. In Tibet, it was only 1404 RMB. In 2001, the average income of farmers in China was 2366 RMB. [4]. The

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difference in per capita GDP between WRC and East Region in China is increasing ever since China implemented the reform and Open Door Policy.

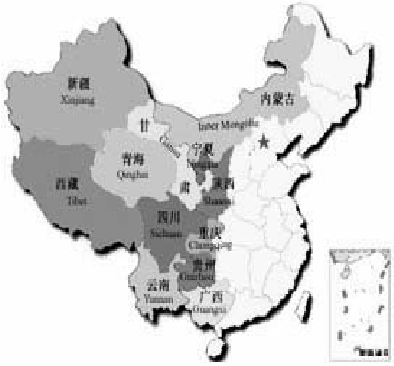

Fig. 1 **Map of WRC**

III. RES IN WESTERN REGION OF CHINA (WRC)

A. Hydropower

WRC (WRC) has abundant renewable energy resources, especially solar, wind and geothermal energy. Hydropower is the most promising RES of WRC. The theoretical hydropower potential in mainland China is 676 GW, of which some 85.5 % are in WRC. The economically viable hydropower resources in China amount to 378.5 GW, 81.5 % of which is in WRC. South-West of China are the most concentrated area for small scale hydropower resources, amounting to 67.8 % resources of China. The theoretical reserves of small-scale hydropower resources (below 50 MW) in China are some 163.47 GW, with 72 % of them in WRC, Tab. 1. The total economically exploitable resources in China amount to 71.31 GW, with 61% of them in WRC [5].The distribution of all hydropower resources in China are increasing from North to South and from East to West.

TAB. 1
SMALL SCALE HYDROPOWER RESOURCES OF CHINA IN THE YEAR 2000

	Theoret. Reserves (GW)	**Exploit. Amount (GW)**	**Installed Capacity (GW)**	**Electricity Generat. (TWh)**
China Total	163.47	87.006	24.852	79.982
WG Total	118.602	53.033	10.337	38.232
Inner Mongolia	2.622	0.676	0.0484	0.08
Guangxi	6.51	2.717	1.359	4.273
Chongqing		2.00	0.801	3.233
Sichuang	12.06	6.842	3.282	13.149
Guizou	6.102	3.201	0.908	3.324
Yunnan	23.23	10.507	2.190	9.211
Tibet	40.00	16.219	0.159	0.183
Shanxi	6.448	2.167	0.428	0.952
Gansu	5.787	1.381	0.333	1.179
Qinghai	6.796	2.618	0.214	0.713
Ningxia	0.044	0.023	0.0032	0.008
Xinjiang	9.003	4.68	0.608	1.927

B. Solar Energy

China is located in a favorable region to use solar energy, as the annual solar irradiance amount is between 3.3 - 8.4 GJ/m^2. The annual sunlight time is greater than 2000 hours, Tab. 2. More than 2/3 of Chinese area can receive solar irradiance amount more than 5.8 GJ/m^2 per year. Most of this area is centered in WRC, [6].

TAB. 2
SOLAR ENERGY AND DISTRIBUTION IN DIFFERENT REGIONS OF CHINA

Regions	Annual Sunlight (hours)	Annual irradiance amount (therm /cm^2)
West Tibet, South East of Xinjiang, West Qinghai, West Gansu	2800-3300	160-200
South-East Tibet, South of Xinjiang, East Qinghai, South of Ningxia, Middle part of Gansu, Inner Mongolia, North of Shanxi, North-WRC of Hebei	3000-3200	140-160
North of Xinjiang, South-East of Gansu, South Shanxi, North Shanxi, South-East of Hebei, Shandong, Henan, Jilin, Liaoning, Yunnan, South of Guangdong, South of Fujian, North of Jiangsu, North of Anhui	2200-3000	120-140
Hunan, Guangxi, Jiangxi, Zhejiang, Hubei, North of Fuujian, North of Guangdong, South of Shanxi, South of Jiangsu, South of Anhui, Heilongjiang	1400-2200	100-120
Sichuan, Guizhou	1000-1400	80-100

In WRC, the most promising solar area are: Tibet, Qinghai, Xingjian, Gansu and Inner Mongolia. These regions are also one of the most abundant solar regions of world, since the annual sunlight duration is greater than 3000 hours in this area. The annual irradiation amount is greater than 6.7 GJ/m^2, and the highest sunlight duration is 3300 hours. The highest annual total irradiation is 8.4 GJ/m^2. Only Sichuan and Guizhou are located in a low solar energy resource region, where the annual sunlight duration is below 1400 hours. The total annual irradiation amounts to less than 4.2GJ/m^2.

C. Wind Energy

China has rich wind resources. While the theoretical wind potential at 10 m above the surface is estimated at 3,226 GW, according to Chinese Academy of Meteorological Science the technically exploitable amount is 253 GW. At the same time, the economically exploitable amount is smaller, however up to now there is no authoritative data about this. Wind resources in WRC are mainly distributed in the North of Yingshan Mountain range in Inner Mongolia, Dabancheng of Xinjian, Alashan Mountain pass of Xinjian, Hexi Aisle and in other locations. There are two big wind regions in China, one is Xijian, Gansu, and Inner Mongolia. The wind density in this region is between 200-300 W/m^2, with the effective wind around 70 %. The other region is along the South-East Sea, Shang Dong and East Liao Ning Sea. Tab. 3 shows the wind potential in WRC.

TAB. 3
WIND ENERGY RESOURCE IN WRC

Province	**Wind Resource (GW)**
Inner Mongolia	61.78
Xinjiang	34.33
WitGansu	11.43

D. Biomass Energy

Biomass energy is deemed CO_2 neutral, so it does not increase the GHG emissions. China has abounded biomass energy resource, which is distributed widely. Biomass energy sources include agriculture crops straw, firewood, excrements of human beings and animals, organic wastewater from industry, city garbage and city sewage. The exploitable amount of biomass resources is about $700 \cdot 10^6$ Mtce (metric tons carbon equivalent). Among them, the straw and stalks contribute $120 \cdot 10^6$ Mtce and firewood some $90 \cdot 10^6$ Mtce, [6].

The biomass resources are rich in South-West of China, especially rich in Sichuan province because of its high forecast bestrew rate, but it is less in North-West of China. Now China is performing the ecological and environmental protection engineering and activities, aimed to protect natural forest and to return infields and grass. In the future, this measure could provide more biomass, as the quantities of straw and domestic waste will increase too. It was estimated that by the year 2010, the straw and domestic waste will increase by 100 % and 160 % of the levels in 1995, respectively. Biomass energy should therefore be listed as the first priority on renewable energy development strategy of GHG mitigation in China. Tab. 4 gives the obtainable amount of biomass resources in three provinces of WRC, as determined in their Renewable Energy development plan.

TAB. 4
THE OBTAINABLE BIOMASS RESOURCES IN THREE PROVINCES OF WRC

	Guangxi		Sichuan		Gansu	
	Total (10^6 Mtce)	Per capita (Mtce)	Total (10^6 Mtce)	Per capita (Mtce)	Total (10^6 Mtce)	Per capita (Mtce)
Straw	7.54	1930	24.18	3530	2.56	1240
Firewood	4.31	1110	6.97	1020	1.02	490
Waste	6.18	1590	14.49	2120	0.81	390
Total	18.03	4630	45.64	6670	4.37	2120

E. Geothermal Energy

According to China National Standard (GB11615-89), the geothermal energy resource can be classified to three levels by temperature: High temperature ($t \geq 150^0C$), middle temperature ($90^0C \leq T < 150^0C$) and low temperature ($60^0C \leq T < 90^0C$, $40^0C \leq T < 60^0C$ and $25^0C \leq T < 40^0C$). Most of the geothermal energy in China is middle- and low temperature resource. The proved geothermal resources are 9.251×10^{19}J/a ($3{,}158 \cdot 10^6$ Mtce/a). Of more than 2,900 geothermal fields in mainland China, there are more than 1,600 geothermal fields, which have been explored and utilized, [6], [7]. It is also worth noting that the operation and maintenance costs of the geothermal power plant are lower than diesel oil power plant.

Most of the high temperature resources are distributed in Himalayas geothermal region of Tibet. With 255 proved high temperature geothermal sources distributed throughout the province, Tibet is leading in geothermal applications of China. The total installed capacity of geothermal power plants in Tibet is 28 MW. In Yang Bajing power plant of Tibet, the installed capacity is 25.18 MW. According to Geothermal Special Committee of China Energy Research Commission, the total geothermal energy potential resources amount at the depth below 2000 meters is 5,800 MW, Tab. 5.

TAB. 5
THE DISTRIBUTION OF GEOTHERMAL ENERGY RESOURCE IN WRC

Province	**Proven Resources**		**Prospective Resources**	
	Area (km^2)	**Minable amount (10^{12}KJ)**	**Area (km^2)**	**Minable amount (10^{12}KJ)**
Yunnan	107.73	2,644	18,528	377,995
Tibet	35.87	512		
Shanxi	11.85	28		
Qinghai	1.0	16		
Xinjiang			147,400	2,865,672
China Total	10,149	92,510	257,047	3,962,319

IV. CONCLUSION

While the least developed of the Chinese regions, the Western Region of China (WRC) has significant renewable energy potential. Its development could aid China's efforts toward sustainable development and energy independence, while at the same time supporting China's efforts for control of greenhouse gas emissions during its phase of intensive development and industrial growth.

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VI. BIOGRAPHIES

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Exploring the potential of biogas from waste water in Isolated Locations

Vlatko Stoilkov, Vesna Borozan, Aleksandra Krkoleva

Abstract—**Biomass is one of the very first energy sources inluded in human daily activities. Biogas, obtained by bioconversion of organic matter is a complex anaerobic fermentation process involving the action of microorganisms for methane producing. In this paper, biogas from waste water and energy production in isolated locations is investigated. The basic reason that motivated this work is treating animal waste and waste water in general with the technology of anaerobic digestion resulting in reducing environmental pollution and generate relatively cheap and readily available source of energy in sheepfolds and dairy farms, as well as isolated settlements. The gas produced can be used for space and water heating, cooking, lighting and as RES for electricity production.**

Index Terms—Biogas, Waste Water Treatment, Anaerobic Digestion, Electricity production

I. Introduction

Around the world, pollution of the air and water from municipal, industrial and agricultural operations is at a very high level and continues to grow. Governments and industries are constantly on the lookout for technologies that will allow for more efficient and cost-effective waste treatment. One technology that can successfully treat the organic fraction of wastes is anaerobic digestion (AD). When used in a fully-engineered system, AD not only provides pollution prevention, but also allows for sustainable energy, compost and nutrient recovery. Thus, AD can convert a disposal problem into a profit center. As the technology continues to mature, AD is becoming a key method for both waste reduction and recovery of a renewable fuel and other valuable co-products.

Biogas is generated when bacteria degrade biological material in the absence of oxygen, in a process known as anaerobic digestion. Since biogas is a mixture of methane (also known as marsh gas or natural gas, CH_4) and carbon dioxide, it is a renewable fuel produced from waste treatment. Anaerobic digestion is basically a simple process carried out in a number of steps that can use almost any organic material as a substrate - it occurs in digestive systems, marshes, rubbish dumps, septic tanks and the Arctic Tundra. As methane is very hard to compress, its best use is for stationary fuel, rather than mobile fuel. It takes a lot of energy to compress the gas (this energy is usually just wasted), plus there is the hazard of high pressure. A variable volume storage (flexible bag or floating drum are the two main variants) is much easier and cheaper to arrange than high pressure cylinders, regulators and compressors.

The current status of AD is the most promising method of treating the organic fraction of animal manure, municipal solid waste (MSW), and other wastes. The policy issues which influence the deployment of AD technology, facility design concepts, the energy, economic and environmental issues relating to AD, and the comparison of alternative treatment processes are to be taken into account when analysing the WWT problematic. HIS document provides an example of the desired layout for a BPC paper and can be used as a template for Microsoft Word versions 6.0 and later. It contains information regarding desktop publishing format, type sizes, and typefaces. Style rules are provided that explain how to handle equations, units, figures, tables, abbreviations, and acronyms. Sections are also devoted to the preparation of acknowledgments, references, and authors' biographies.

II. Benefits resulting from the use of AD technology

1) Waste Treatment Benefits
- Natural waste treatment process;
- Requires less land than aerobic composting or landfilling;
- Reduces disposed waste volume and weight to be landfilled;

2) Energy Benefits
- Net energy producing process;
- Generates a high-quality renewable fuel;
- Biogas proven in numerous end-use applications.

3) Environmental Benefits
- Significantly reduces carbon dioxide and methane emissions
- Eliminates odors;
- Produces a sanitized compost and nutrient-rich fertilizer;
- Maximizes recycling benefits

4) Economic Benefits

III. Electrical energy and biogas

The theoretical methane yield can be shown to be 350 dm^3/kg of chemical oxygen demand converted, but the exact recoverable yield depends on a number of environmental conditions. The ultimate yield of biogas depends on the composition and biodegradability of the organic feedstock, but its production rate will depend on the population of microorganisms, their growth conditions, and fermentation temperature.

Methane produced by the AD process is quite similar to "natural" gas that is extracted from the wellhead. However, natural gas contains a variety of hydrocarbons other than

This work is done in the frame of Renewables for Isolated Systems – Energy Supply and Waste Water Treatment (RISE) Project, FP6 INCO CT-2004-509161.

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methane, such as ethane, propane, and butane. As a result, natural gas will always have a higher calorific value than pure methane. Depending on the digestion process, the methane content of biogas is generally between 55%-80%. The remaining composition is primarily carbon dioxide, with trace quantities (0-15,000 ppm) of corrosive hydrogen sulfide and water.

The average expected energy content of pure methane is 9,27 – 11 kWh/m^3; natural gas has an energy content about 10% higher because of added gas liquids like butane. However, the particular characteristics of methane, the simplest of the hydrocarbons, make it an excellent fuel for certain uses. With some equipment modifications to account for its lower energy content and other constituent components, biogas can be used in all energy-consuming applications designed for natural gas.

Today, it is commonly burned in an internal combustion engine to generate electricity. Practical experience with small-scale internal combustion engines with a rated capacity of less than 200 kW indicate an electrical conversion efficiency of less than 25%. Larger engines can have a greater conversion efficiency. One engine supplier claims to have an engine with an electrical conversion efficiency that averages 38% for engines in the 600-1000 kW range.

When biogas is used to produce electricity, there is the added potential for harvesting hot water and steam from the engine's exhaust and cooling systems. Combining hot water and steam recovery with electricity generation may provide an overall conversion efficiency of 80% or more. Biogas is also burned in boilers to produce hot water and steam used for heating and sanitary washing.

While operating at a technology level requiring specially trained maintenance personnel, a promising near-term application for biogas-fueled electricity generation is the use of gas turbines. For larger-scale systems, combined cycle power stations consist of gas turbines, steam turbines, and waste heat recovery boilers, all working together to produce electricity. Modern gas turbine plants are small in general, environmentally friendly, and visually unobtrusive. At scales of greater than 800 kW does the heat rate equal or surpass an engine-based system and the use of a gas turbine allows a greater fraction of the waste heat to be recovered as potentially more valuable steam.

Besides the biogas-fueled electricity generation and CHP, in many countries, biogas is viewed as an environmentally attractive alternative to diesel and gasoline for operating buses and other local transport vehicles. The level of sound generated by methane-powered engines is generally lower than that generated by diesel engines, which is a positive aspect, particularly in an urban environment. Exhaust fume emissions are considerably lower than the emissions from diesel engines, and the emission of nitrogen oxides is very low.

IV. BIOGAS AS RENEWABLE SOURCE IN ISOLATED LOCATIONS

The applications of biogas as renewable source of sustainable energy for different isolated locations have been investigated:

1. – for small settlements, where the wastewater and solid waste are dominant for AD and
2. – for farms with food processing facilities such as sheepfolds and small dairies, where manure and food processing residuals are dominant for AD.

The two cases are quite different not only in the quality and quantity of the source, but also in the energy needs: while the first one is for home use, meaning use of electrical energy, the second one means basically use of energy for hot water and quite small amount of energy for lighting the living rooms and sheepyards.

Taking into consideration the type of engine for electricity generating, for isolated locations the most appropriate is internal combustion engine for both types of locations. For the second type – sheepfolds and small dairies, the most appropriate is combined direct (burning) and indirect (electrical energy) use of biogas.

For larger farms, depending on the farm capacity, the quantity of waste, the type of energy needed and the possibility of grid connection, the gas turbine for electricity generating may be more recommendable. As an example, the farm with capacity of 500 cows will generate 100 kilowatts of power that is enough for 65 homes. Simultaneously, effluent from the digester will be processed through a solids separator, with the solids to be composted for commercial nursery use. The remaining liquid may be disposed (pumped) to the lagoon(s) and later used to fertilizer cropland.

The two pilot projects for building combined sheep manure / food processing wastewater treatment plant have been projected in the frame of RISE Project for one isolated sheepfold consisting of 3500 sheep on Korab (Fezlievo Bachilo with 2000 and Belancha with 1500 sheep) and for one isolated settlement with several households (Kichinica, near Mavrovo).

Estimated quantities of wastewater, as well as biogas production and calorific value of biogas for projected locations are presented in Tables I, II and III.

V. CONCLUSION

Investigation of Low-Cost, Innovative RES and wastewater Treatment solutions thaat lead to biogas production and energy capacity instalations should be performed and strengthened in forthcoming period as a very promising renewable energy source.

The benefits of such investigations are numerous and comprised in different fields, from waste treatment, trough environment protection and economics to energy generation.

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TABLE I
ESTIMATED MONTHLY WASTEWATER QUANTITIES, BIOGAS CAPACITY AND CALORIFIC VALUE OF BIOGAS FOR LOCATION KICHINICA:

Time Index (month)	PE (per month)	Wastewater (m3/month)	Biogas (m3/month)	Calorific value of biogas (MJ/month)
Jan	1700	255	32,3	809,44
Feb	1800	270	34,2	857,05
Mar	1000	150	19	476,14
Apr	900	135	17,1	428,53
May	900	135	17,1	428,53
Jun	1600	240	30,4	761,82
Jul	1800	270	34,2	857,05
Aug	1700	255	32,3	809,44
Sep	1000	150	19	476,14
Oct	950	142,5	18,05	452,33
Nov	900	135	17,1	428,53
Dec	900	135	17,1	428,53
TOTAL (per year)	**15150**	**2272,5**	**287,85**	**7213,52**

TABLE II
ESTIMATED MONTHLY WASTEWATER QUANTITIES, BIOGAS CAPACITY AND CALORIFIC VALUE OF BIOGAS FOR LOCATION BELANCHA

Time Index (month)	PE (per month)	Sheep (month)	PE Wastewater (m3/month)	Cheese Production Wastewater (m3/month)	Biogas from cheese production wastewater (m3/month)	Livestock Manure Biogas (m3/month)	PE Biogas (m3/month)	Total Biogas (m3/month)	Calorific value of biogas (MJ/month)
May	150	60000	22,5	4,5	12,5	4620	2,85	4635,4	116.161,87
Jun	150	60000	22,5	4,5	12,5	4620	2,85	4635,4	116.161,87
Jul	150	60000	22,5	4,5	12,5	4620	2,85	4639,9	116.274,64
Aug	150	60000	22,5	4,5	12,5	4620	2,85	4639,9	116.274,64
Sep	150	60000	22,5	4,5	12,5	4620	2,85	4639,9	116.274,64
Oct	150	60000	22,5	4,5	12,5	4620	2,85	4639,9	116.274,64
TOTAL (per year)	**900**	**360000**	**135**	**27**	**75**	**27720**	**17,1**	**27830**	**697422,306**

TABLE III
ESTIMATED MONTHLY WASTEWATER QUANTITIES, BIOGAS CAPACITY AND CALORIFIC VALUE OF BIOGAS FOR LOCATION FEZLIEVO BACHILO

Time Index (month)	PE (per month)	Sheep (month)	PE Wastewater (m3/month)	Cheese Production Wastewater (m3/month)	Biogas from cheese w.w.(m3/month)	Livestock Manure Biogas (m3/month)	PE Biogas (m3/month)	Total Biogas (m3/month)	Calorific value of biogas (MJ/month)
May	450	90000	67,5	6	16	6930	8,55	6954,55	174.281,02
Jun	450	90000	67,5	6	16	6930	8,55	6954,55	174.281,02
Jul	450	90000	67,5	6	16	6930	8,55	6954,55	174.281,02
Aug	450	90000	67,5	6	16	6930	8,55	6954,55	174.281,02
Sep	450	90000	67,5	6	16	6930	8,55	6954,55	174.281,02
Oct	450	90000	67,5	6	16	6930	8,55	6954,55	174.281,02
TOTAL (per year)	**2700**	**540000**	**405**	**36**	**96**	**41580**	**51,3**	**41727,3**	**1045686,14**

Structural, Morphological and Optical Properties of Electrodeposited Films of Cuprous Oxide for Solar Application

V.P.Georgieva, M.T.Georgieva

Abstract-**An electrodeposited layer of Cu_2O offers wider possibilities for application and producing low cost cells both in metal-semiconductor and hetero-junction cells structures. Therefore thin films of cuprous oxide have been grown on copper substrates and onto transparent conducting optically glass coated with tin oxide (SnO_2) and indium tin oxide (ITO). This paper reports preparing of Cu_2O films and their structural, morphological and optical characteristics.**

Index Terms-**cuprous oxide, electrochemical deposition, structural, morphological, optical properties.**

I. .Introduction

Among the various metal oxide materials for solar energy applications, a promising material is cuprous oxide (Cu_2O), one of the oldest known semiconductors. The potential for Cu_2O using in semiconducting devices has been recognized since, at least, 1920[1]. Interest in Cu_2O revived during the mid seventies in the photovoltaic community. Several characteristics as: abundance of copper, non-toxic nature, theoretical solar cell efficiency about 9-11%, band gap of 2 eV, optical absorption coefficient and simple and inexpensive process for thin film formation, make Cu_2O favorable material for fabrication of cells in thin form [2].

Different experimental techniques such as thermal oxidation, anodic and chemical oxidation and reactive sputtering exist for preparing Cu_2O films on copper or other conducting substrates. Particularly attractive, however, is the electrodeposition method because of its economy and simplicity for deposition either on metal substrates or on transparent conducting glass slides coated with highly conducting semiconductors, such as indium tin oxide (ITO), SnO_2, In_2O_3 etc. Electrodeposition method of Cu_2O was first developed by Stareck (1937)[3]. It has been described by Rakhshani at al, [4,5] In this work, a method of simple processes of electrolysis has been applied.

This overview reports the method of Cu_2O films deposition on copper substrates and onto conducting glass coated with tin oxide (SnO_2) and commercial conducting glass coated with indium tin oxide (ITO), identification of the deposited films by X-ray difractometry (XRD) and study of surface morphology of the films by scanning electron microscopy (SEM).

This work has been performed within the EC funded RISE project (FP6-INCO-509161). The authors want to thank the EC for partially funding this project.

II. Experimental

A. Preparation of the films

A very simple apparatus was used for electrodeposition. It consisted of a thermostat, a glass with solution, two electrodes (cathode and anode) and a standard electrical circuit for electrolysis. The deposition solution contained 64 g/l anhydrous cupric sulphate ($CuSO_4$), 200 ml/l lactic acid ($C_3H_6O_3$) and about 125 g/l sodium hydroxide (NaOH). Cupric sulphate was dissolved first in distilled water giving it a light blue color. Lactic acid was then added. Finally, a sodium hydroxide solution was added, changing the color of the solution to dark blue with pH = 9[4,5]. A copper clad for printed circuit board, with dimension 50 μm, 2.5×7 cm^2, was used as the anode. Copper clad and conducting glass slides coated with ITO and SnO_2 were used as a cathode. Experience shows that impurities (such as dirt, finger prints, etc.) on the starting surface material has a significant impact on the quality of the cuprous oxide. Therefore, mechanical and chemical cleaning of the electrodes, prior to the cell preparation, is essential.

Copper boards were polished with fine emery paper and shortly dipped in hydrochloric acid. After that, they were washed by liquid detergent and distilled water. The ITO substrates were dipped into solution of sodium hydroxide for a period of 1 h and rinsed with distilled water. The SnO_2 substrates were soaked in chromsulphuric acid for a few hours and rinsed with distilled water. Before using all of them were dried.

Thin films of Cu_2O were electrodeposited by cathodic reduction of an alkaline cupric lactate solution at 60^0C . The deposition was carried out in the constant current density regime. The deposition parameters, as current density, voltage between the electrodes and deposition time were changed. The Cu_2O films were obtained under following conditions: 1) current density j = 1,26 mA/cm^2, voltage between the electrodes V = 0,3 - 0,38 V and deposition time t = 55 min. Close to the value of current density, deposition time and Faraday's law, the Cu_2O oxide layer thickness was estimated to be 5 μm.

The potentiostatic mode was used for deposition the Cu_2O films on glass coated with SnO_2 prepared by spray pyrolisis method of 0.1 M water solution of $SnCl_2$ complexes by NH_4F . The applied potential difference between anode and cathode was constant. It was found that suitable value is V = 0,5 to 0,6 V. The deposition current density at the beginning was dependent on the surface resistance of the cathode. For a fixed value of the potential, the current decreased with increasing film thickness. The film thickness was dependent on deposition current density j of about 1 mA/cm2 at the beginning and deposition time of about 2 h, the film thickness was 5-6 μm approximately. The thickness of deposited film was determined using a weighting method, as $d = m/\rho s$, where m is the mass and s is the surface of the film. A density ρ, of 5.9 g/cm^3 was used.

The deposition of Cu_2O on a commercial glass coated with ITO was carried out under constant current density. The ITO/Cu_2O films was obtained under the following conditions: current density j = 0,57 mA/cm^2, voltage between the electrodes V = 1,1 - 1,05 V and deposition time t = 135 min. The Cu_2O oxide layer thickness was estimated to be about 5 μm.

All deposited films had reddish to reddish-gray color.

B. Structural properties

The structure of the films was studied by X – ray diffraction, using CuKα radiation with a wavelength of 0.154 nm. The Bragg angle of 2θ was varied between 20^0 and 50^0. The XRD spectrums of the films samples, deposited on copper, glass coated by SnO_2 and glass coated by ITO are shown in Fig.1, Fig.2 and Fig.3 respectively. It was found that all films are polycrystalline and chemically pure Cu_2O with no traces of CuO. XRD peaks corresponded to Cu_2O and the substrate material. The XRD spectrums indicate a strong Cu_2O peak with (200) preferential orientation.

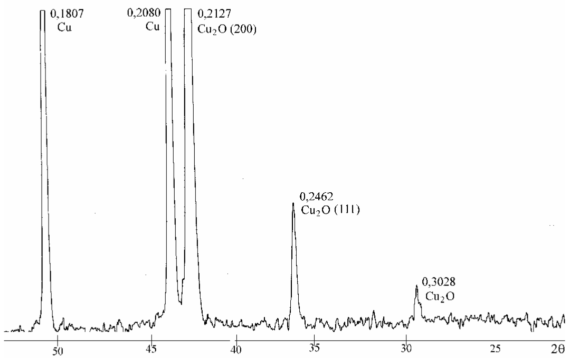

Fig.1.X-ray diffraction spectrum of a Cu_2O film deposited on copper

C. Morphological properties

The surface morphology of the films was studied by a scanning electron microscope JEOL model JSM 35 CF. Fig.4, Fig.5 and Fig.6 show the scanning electron micrographs of Cu_2O films deposited on copper, glass coated by SnO_2 and glass coated by ITO respectively. The photographs indicate a polycrystalline structure. The grains are very similar to each other in size and in shape. They are about 1 μm and less in size for the film deposited on copper, 1-2 μm for the film deposited on SnO_2 and about 1 μm for the film deposited on ITO.

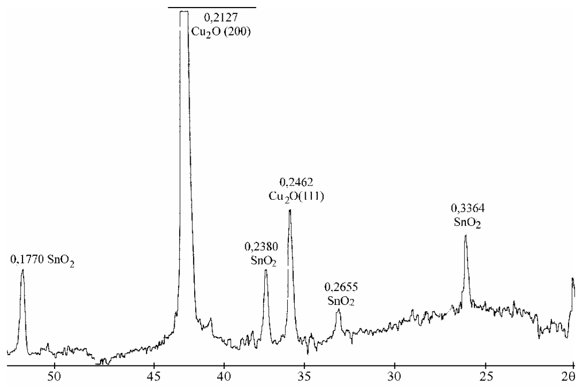

Fig.2.X-ray diffraction spectrum of a Cu_2O film deposited on SnO_2

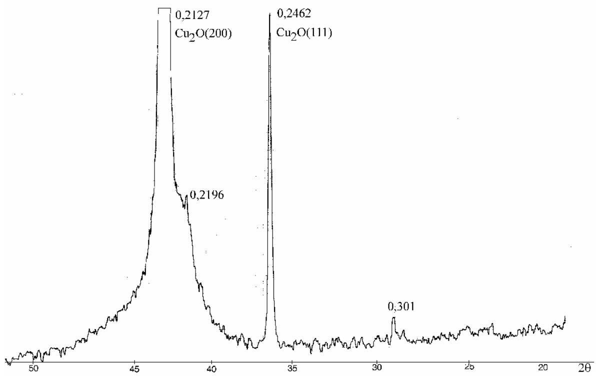

Fig.3.X-ray diffraction spectrum of a Cu_2O film deposited on ITO

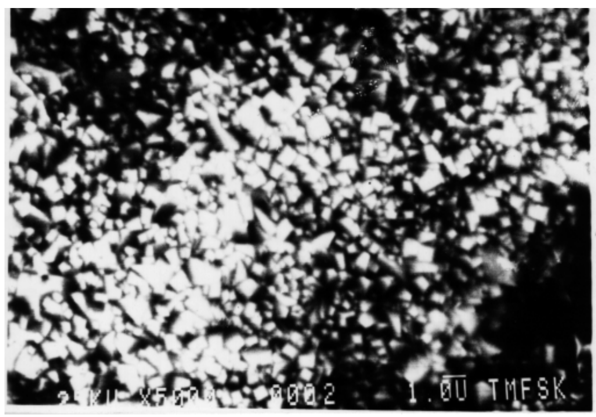

Fig.4. Micrograph obtained from a scanning electron microscope of Cu_2O deposited on copper

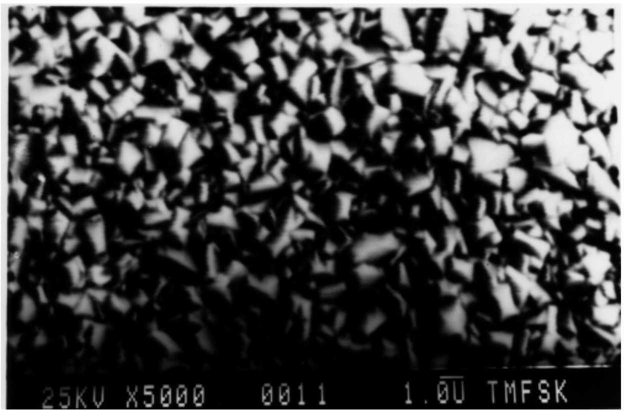

Fig.5. Micrograph obtained from a scanning electron microscope of Cu_2O deposited on SnO_2

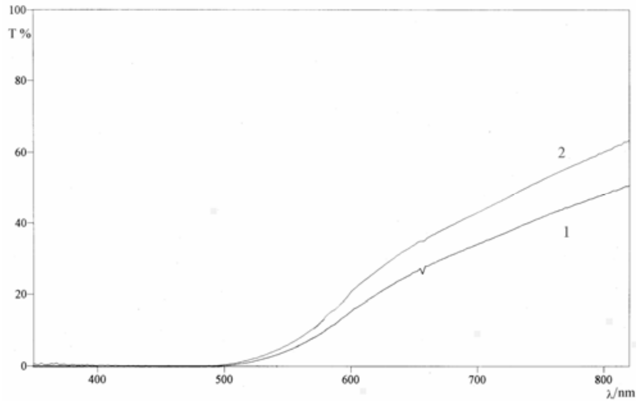

Fig. 7. Optical transmission spectrum of a 0,9 μm thick Cu_2O/SnO_2 film

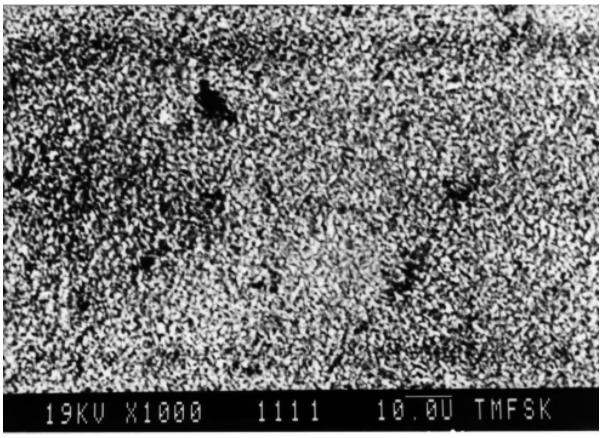

Fig.6. Micrograph obtained from a scanning electron microscope of Cu_2O deposited on ITO

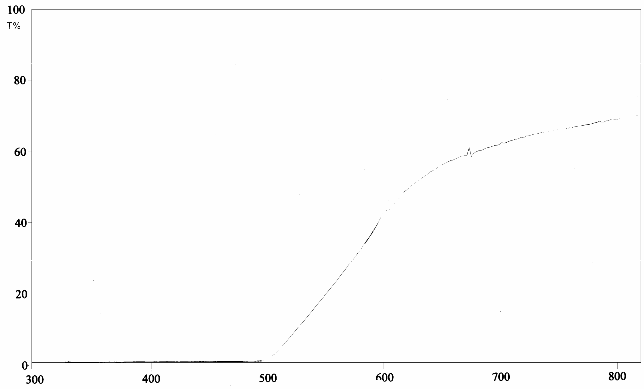

Fig. 8. Optical transmission spectrum of a 1,5 μm thick Cu_2O/ITO film

D. Optical band-gap energy determination

The optical band-gap is an essential parameter for semiconductor material, especially in photovoltaic conversion. In this work it was determined using the transmitance spectrums of the films. The optical transmission spectrums were recording on Hewlett-Pacakard (model 8452 A) spectrophotometer in the spectral range 350-800 nm wavelength. Thin layers of a transparent Cu_2O were preparing for the optical transmission spectrums recording. The optical transmission spectrum of about 1,5 μm thick Cu_2O film deposited on glass coated with SnO_2 is presented in Fig.7. There are two curves, one (1) recorded before annealing and the other one (2) after annealing of the film for 3h at 130^0C.

We can see that there is no difference in the spectrums. The absorption boundary is unchangeable. That means that band gap energy is unchangeable with or without annealing. The little difference comes from different points recording, because the thickness of the film is not uniform.

The transmittance spectrum of about 0,9 μm thick Cu_2O film, deposited on ITO, is presented in Fig. 8.

For determination of the optical band gap energy E_g, the method based on the relation

$$\alpha h\nu = A(h\nu - E_g)^{n/2},$$

was used [1], where n is a number that depends on the nature of the transition. In this case its value was found to be 1 (which corresponds to direct band to band transition) because that value of n yields the best linear graph of $(\alpha h\nu)^2$ versus $h\nu$.

The values of the absorption coefficient α were calculated from the equation

$$\alpha = \frac{A}{d},$$

where d is the film's thickness determined using weighing method, and A is the absorbance determined from the values of transmittance, $T(\%)$, using the equation

$$A = \ln \frac{100}{T(\%)}.$$

Fig.9 and Fig.10 show $(\alpha h\nu)^2$ versus $h\nu$ dependance for the Cu_2O/SnO_2 film and Cu_2O/ITO film corresponding. The intersection of the straight line with the $h\nu$ axis determines the optical band gap energy E_g. It was found to be 2,33 eV for Cu_2O/SnO_2 film and 2,38 eV for Cu_2O/ITO. They are higher than the value of 2 eV given in the literature and obtained for Cu_2O polycristals[2]. This values are in good agreement with band gaps determined from the spectral characteristics of the cells made with electrodeposited Cu_2O films.The value of the energy band gap of Cu_2O/ITO is little higher than the value of Cu_2O/SnO_2 film. The reason is maybe different size of the grains.

Fig.9 shows that there is no different in optical band gap energy determined from the curve plotted before annealing and from the curve plotted after annealing. Also, Fig.9 and Fig.10 show that there is no shape absorption boundary in the small energy range of the photons. Probably defects and structural irregularities are present in the films.

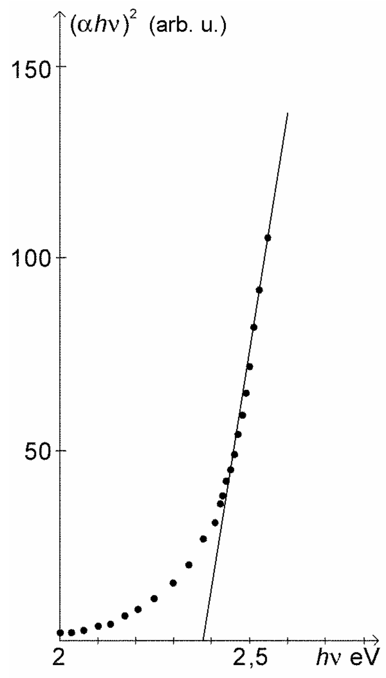

Fig.10. Graphical determination of the optical band gap energy for Cu_2O/ITO film

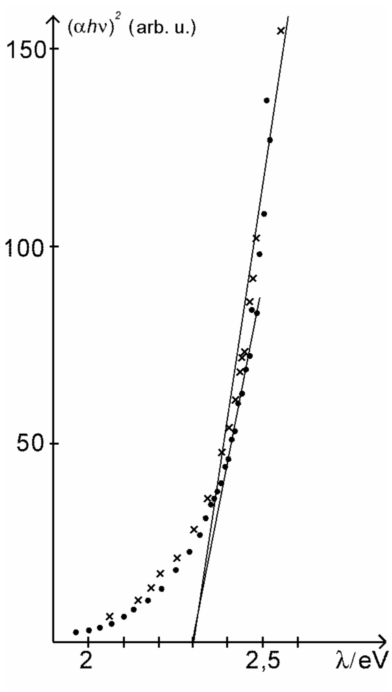

Fig.9. Graphical determination of the optical band gap energy for Cu_2O/SnO_2 film
(x - before annealing; · - after annealing)

III. Conclusion

Polycrystalline thin and uniform films of cuprous oxide with thickness of about 5-6μm were electrodeposited on copper and transparent conducting glass coated with highly conducting tin oxide (TCO) and indium tin oxide (ITO). Electrochemical deposition is an cheapest and simple method for depositing. In this work a method of simple processes of electrolysis has been applied. The film thickness can be controlled by the time of deposition.The structure of the films was studied by X – ray diffraction. It was found that all films are polycrystalline and chemically pure Cu_2O with no traces of CuO. The surface morphology indicate a polycrystalline structure with grains in size about 1-2 μm and less. The optical band-gap of the films was determined using the transmitance spectrums. It was found to be 2,33 eV for Cu_2O/SnO_2 film and 2,38 eV for Cu_2O/ITO.

IV. Acknowledgment

The authors gratefully acknowledge the contributions of all RISE Project Partners: ICCS/NTUA, MEPSO, ICEIM-MANU, BIG, SOLTECH, IES, IRB, INESC Porto, ARMINES, UM, ULJ, UB, UTU and UKIM.

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VI. Biographies

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Ways to Mimimize the Greenhouse Gas Emissions. Romanian Approach

I. Manicuta, M. Manicuta

Abstract -- **This paper presents considerations about the present evolutions regarding the following topics:**

- **the fight against climate change;**
- **the ways to meet Kyoto Protocol targets,**
- **the promotion of renewable resources;**
- **the use of carbon emissions trading as new weapon to battle global warming;**
- **the return to nuclear power use.**

There are presented, through comparison the three ways to fight against global warming from above, reaching the conclusion that the nuclear power remains a strong viable solution. The paper also includes a short description of the Romanian approach in this field.

Index Terms **— greenhouse gas (GHG), emissions, global warming, carbon emission trading, renewable resources, nuclear power,**

I. INTRODUCTION

THE international treaty on climate change - the Kyoto Protocol – entered into effect on February 16 2005. Under the Kyoto Protocol, the EU countries must reduce their CO2 emissions to 8 percent below 1990 levels by 2010 and the United States target is 7 percent below 1990 emissions.

Figure 1 shows a comparison between the greenhouse gas emissions per capita registered in 1995 in the main industrialized countries of the world (source [1]). Unfortunately, the most important producer of greenhouse gas emissions, The United States, did not ratify Kyoto Protocol.

We can say that the challenge for energy supply over the next 50 years is how to meet the rapidly growing demand for energy services from a growing population while limiting the greenhouse gas emissions.

In this context we see the following ways to fight against climate change by limiting the greenhouse gas emissions:

- Carbon emissions trading (along with JI-CDM mechanisms of Kyoto Protocol);
- Promotion of renewable resources;
- Return to nuclear power promotion.

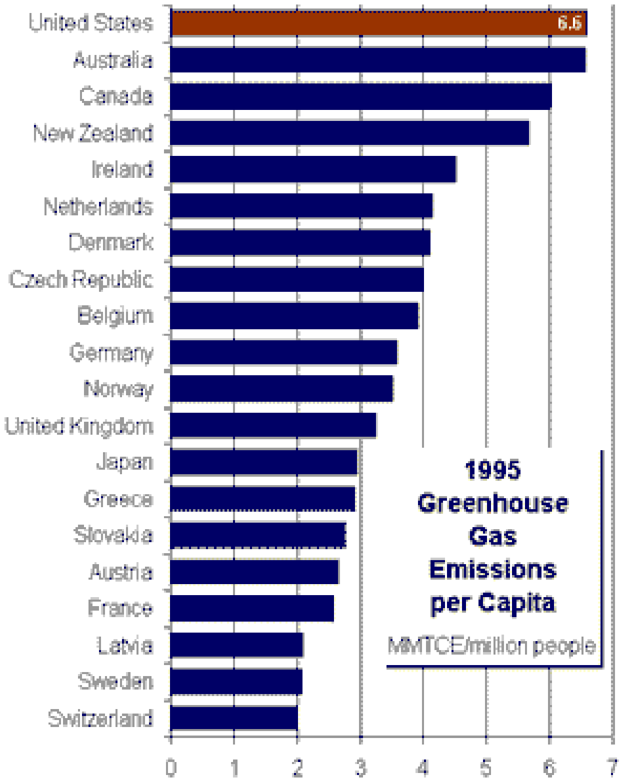

Figure 1 - The greenhouse gas emissions per capita registered in 1995 in the main industrialize countries of the world.

II. CARBON EMISSIONS TRADING – A NEW WEAPON AGAINST GLOBAL WARMING

Environmentalists always said there would be a price to pay for all the carbon dioxide being spewed into the atmosphere. Well, now there is.

While prized resources such as oil, gold and wheat have been traded for decades, there is a budding market for one of the industrialized world's abundant but unwanted byproducts: carbon dioxide, a gas produced when fossil fuels are burned and which many scientists believe causes global warning.

If it succeeds, the new market for carbon emissions will reward business that minimizes their output of this "greenhouse" gas and it will also benefit the environment.

The only mandatory carbon emissions trading program is in Europe. It was created in conjunction with the Kyoto Protocol and caps the amount of carbon dioxide that power plants and fuel-intensive manufactures in the 25 EU countries are allowed to emit.

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A similar program is scheduled to being in 2008 in Canada, which also signed Kyoto Protocol.

By contrast, the United States, one of the few industrialized countries that did not ratify Kyoto Protocol, is many years away from compulsory trading or nationwide caps on carbon dioxide, concepts that are strongly opposed by industry and the Bush administration. However, nine Eastern states are developing a regional cap-and-trade program that will require large power plants from Maine to Delaware to reduce their carbon emissions and California is attempting to place greenhouse gas limits on automakers. Separately, a small group of companies has voluntarily agreed to cap their carbon emissions in the United States as part of an experimental market that is based in Chicago (CCX).

Under the European Union's Emissions Trading Scheme, some 12,000 industrial plants are granted a limited number of emissions allowances, or credits, equaling the amount of carbon dioxide they are allowed to emit. Companies that exceed their limits must purchase credits to cover the difference, while those that produce less carbon dioxide than they are legally permitted can sell surplus credits for a profit. Companies can trade directly with each other or through exchange located throughout Europe. In addition, the Kyoto Protocol provides two other mechanisms to obtain emission allowances based on bilateral agreements to implement projects for emissions reduction: Joint Implementation (JI) and Clean Development Mechanism (CDM).

By giving to the private sector a financial incentive to make their operations more environmentally friendly, proponents believe that this market based approach will accelerate investment in emissions-reduction equipment, create positive reinforcement from investors and spur technological innovation.

Their optimism is based in part on the success of the cap-and-trade system the United States designed more than a decade ago to reduce sulfur dioxide emissions, which cause acid rain. The U.S. sulfur dioxide market, on which the EU's carbon market is based, is widely praised for accelerating emissions reductions at a lower cost than originally anticipated by industry.

But environmentalists and executives said there is much more at stake when it comes to carbon dioxide emissions, both in terms of the ecological benefits and the potential costs to industry.

The first phase of the EU trading program runs from 2005 through 2007 and the caps will be lowered from one year to the next. Even so detailed plant-by-plant limits are not finalized yet in all the EU countries, participants estimate that EU-wide industrial emissions will drop as much as 5 percent by 2008.

The cost to European industry over the 2005-2007 period is estimated to be a few billion dollars, based on initial market prices for carbon dioxide of about 7 euros per ton. (In present the prices are above 27 euros per ton!!). Of course, companies with surplus allowances stand to profit an equal amount.

The second phase of the program runs from 2008 through 2012, by which time the European Union must lower its carbon emissions to 8 percent below 1990 levels.

Canada must cut its emissions by 6 percent to comply with the Kyoto treaty.

In the United States, carbon-intensive industries successfully lobbied against Kyoto Protocol by refuting the threat of global warming itself, and by arguing that the treaty would hurt the global competitiveness of American companies and cause electricity prices to rise. U.S.-based companies that are already engaged in the issue - either because they have factories in Europe, or are part of CCX - believe early involvement could pay off down the line, in large part due to the logistical expertise they are gaining.

CCX participants agreed beginning in 2003 to cut their carbon emissions by 1 percent per year through 2006, or 4 percent below their baseline, which is determined by their average annual emissions from 1998 through 2001.

There is virtually no chance of federal limits on carbon emissions under the Bush administration, which is openly skeptical of the threat global warming poses. But U.S. executives anticipate a cap-and-trade program for carbon dioxide, at least at the state level, within the next decade. The Regional Greenhouse Gas Initiative, which aims to produce preliminary market design, has the support of Connecticut, Delaware, Maine, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island and Vermont.

III. PROMOTION OF RENEWABLE RESOURCES

In addressing the climate changing issue, one of the choices is the promotion of renewable resources. Renewable resources include hydro, wind, solar, bio-fuels, geo-thermal, wave and tidal energy. Of these, wind, solar, geo-thermal, and wave/tidal are abundant, but only wind is currently economical and easy to harness.

Wind has made enormous strides in the last 15 years especially in EU countries. In 1992 the average size of installed wind turbine was 200 kW. In 2002 it was 1.4 MW. Now almost all units being installed are over 2 MW and the biggest are of 5 MW. Over the last ten years, from 1995 to 2005, cumulative wind power capacity in E.U has increased by an average 32% per year.

The European Wind Energy Association (EWEA) reported that the European wind energy industry installed 6,183 MW of new capacity in 2005, bringing the cumulative wind capacity in EU at a total of 40,504 MW at the end of 2005. There was an 18% increase over the 2004 EU cumulative total of 34,372 MW. The countries with the most important wind capacities are Germany (17,000 MW) and Spain (9,000 MW).

In present the different countries uses a number of methods to support the investments in renewable resources development (renewable energy certificates, feed in tariff, etc.).

However, we believe that, for next two or three decades, the renewable resources will be not the answer to reach the emissions reduction targets, because their present relative high cost and their intermittent nature.

In the long and medium term, it is very possible that renewable energy systems such as wind, wave and solar power, together with increased energy efficiency and the possible development of fusion power, to be sufficient to cut back the emissions of carbon dioxide from conventional coal and gas-fired power stations, which are believed to be raising temperatures around the globe.

But, in the short term, we think that there may be no alternative to nuclear energy use.

IV. NUCLEAR POWER - NOT ONLY AN OPTION, BUT A REAL NEED

In the battle to comply with the rapidly increasing World energy demand and to withstand the greenhouse effect, nuclear energy is the only energy source capable to supply abundant quantities of electric energy without emitting carbon dioxide or other greenhouse and polluting gases.

More than 400 GW of electricity capacity must be replaced by 2020 in the European Union countries, due to the aging of existing power facilities and for the new electricity needs. At World wide level about 1000 new large power plants might be needed. The constant availability of cheap energy, plentiful in quantity and with high quality, is one of the most important bases of every economy indeed.

Nuclear is the only existing power technology which could replace coal in base load. It is a foregone conclusion that up to 2020 global reliance on fossil fuels and large hydro will remain strong, albeit with special emphasis on the role of natural gas and efficient cleaner fossil fuel systems. However, total reliance on these energy sources to satisfy the growing electricity demand of the world, especially in the context of two billion additional people who will need it by 2020, is not sustainable.

The role of nuclear power therefore needs to be established with the aim of possible future extensions. In parallel, efforts to develop intrinsically safe, affordable nuclear technology need to be encouraged. Nuclear energy is the only ready available, abundant, cheap, safe when adequately managed and operated, environmentally benign energy source, being "carbon free", capable to supply sufficient energy for a World's bright future.

Nuclear energy is and will remain in the years to come the only way to supply the large scale electricity the countries will need at lowest cost as compared with oil and gas (providing economy), face the global warming (providing environment protection) and last but not least, avoid tensions on oil and natural gas markets (providing ethics).

Even if, there are 433 active reactors (excluding shipboard propulsion units) operating in the world today, with a combined capacity of about 350 GW no aspect of the energy challenge is more polarized than that of nuclear energy. Both the pros and cons are very selective in presenting their arguments, and it is very difficult to get a balanced or objective view of the real trade-offs. While much of the opposition is emotional, deriving from fear of radiation, bombs, and Chernobyl, it is not unlikely that this polarization also arises from the fact that, at present, there may be as many real negatives as positives.

The main plusses presented in favor of nuclear energy are:

- There is a limitless fuel supply.
- It is non-polluting, particularly having no CO2 emissions.
- It has very high energy density, requiring the least fuel for the energy provided.
- It is inexpensive, the produced electricity being cheaper than coal.
- New technology will make it 100% fail safe.
- Nuclear generated electricity costs only 2 cents/kWh.

The major negatives presented by its opponents are:

- Spent fuel storage will always be a problem.
- Radioactive uranium hexafluoride, left over from the concentrating process in large quantities, also has to be stored.
- Uranium 235, which is fissionable without concentration, is not abundant.
- Plutonium can be used to make bombs, and therefore vastly increases the security risk.
- Plutonium is an extremely hazardous and deadly poison.
- Nuclear reactors "are inherently unsafe, and if we have a lot of them, another Chernobyl will be inevitable".

A careful examination of these claims reveals that:

- Technological advances have greatly reduced the amount of spent fuel and there is promise for other further technological advances to mitigate the storage problem.
- U238 is relatively abundant and the technology to concentrate it for light water reactor fuel is mature.
- Using "fast" reactors we do not need U235.
- There are three isotopes of plutonium, and the mix produced by breeder reactors, without complex and expensive further processing, is not "weapons grade."
- The "advanced fast reactor" consumes rather than producing plutonium.
- Barring direct inhalation of particles (which are heavy), plutonium is about as poisonous as lead.
- Modern reactors are safer than most things we do in life, much safer than flying, or mining coal, for example.

We can say that the questions of climate change and its impacts o human society is the most important problem we are faced with this century in the World. It is so important that the nuclear option has to be re-examined, and that public perception of nuclear dangers did not necessarily accord with reality. Fewer people had been killed in nuclear power generation than in other forms of energy productions, and that modern nuclear stations being designed were inherently much safer than those involved in the notorious accidents at Three Mile Island in the US in 1979 and Chernobyl in Ukraine in 1986. Furthermore if new nuclear power stations will be built, they will be sited near existing nuclear sites, and it will be highly unlikely that fresh "greenfield" sites would be chosen.

V. ROMANIAN APPROACH

Romania signed the United Nations Framework Convention on Climate Change (UNFCCC) ratified the Kyoto Protocol to the UNFCCC (Law no.3/2001), committing itself **to reduce the greenhouse gas emissions** with 8%, in the first commitment period 2008-2012, comparing to the base year (1989). The year 1989 was established as the base year for Romania as it expressed the country's best economic output potential directly linked to its emissions potential. The economic decline resulted in a relevant decrease in greenhouse gas emissions.

In 2005, Romania managed for the fourth time to submit the UNFCCC Secretariat the national greenhouse gas inventory with all its components, meeting also the requested deadline. According to this document, the Romania's total greenhouse gas emissions calculated in CO2 equivalent, decreased by 46% in the period 1989-2003. Romania will meet the Kyoto Protocol's 8% greenhouse gas emissions reduction target in the first commitment period, even considering the slight increasing trend of the greenhouse gas emissions noticed after 1999.

Starting with the 2005 submission, emissions were reported using the new software programme CRF Reporter developed by the UNFCCC Secretariat. The national greenhouse gas inventories for the years covered by the period 1989-2002 were recalculated based on the report of the individual review of the greenhouse gas inventory submitted by Romania in 2004.

The total Romania greenhouse gas emissions in CO2 equivalent within 1989-2002 is shown in Figure 2 (source [5]) while the trends of greenhouse gas emissions in Romania by sectors in the period 1989-2002 is given in Figure 3 (source [5]).

In the first half of 2005, the Romanian Ministry of Environment and Water Management issued Romania's first National Strategy on Climate Change (Government Decision No. 645/2005), which presents the framework for implementing Romania's climate change policy in the period 2005-2007. The National Strategy on Climate Change was based on a capacity building project financed by the Danish Environmental Protection Agency and developed through the National Commission on Climate Change in close cooperation with the international consultants and other ministries. The National Action Plan on Climate Change develops the individual policies and concrete measures to be further developed and implemented under the National Strategy on Climate Change.

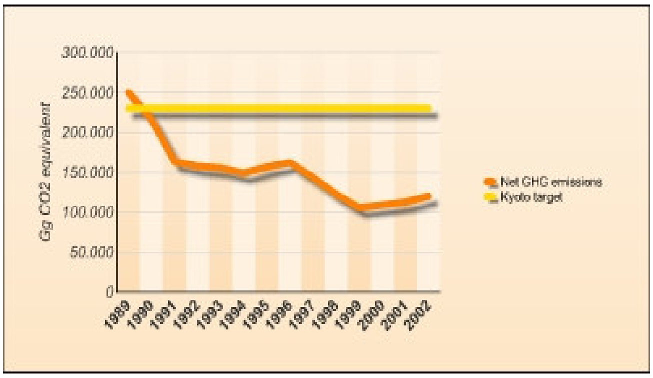

Figure 2 – The total Romania greenhouse gas emissions in CO2 equivalent in the 1989-2002 period

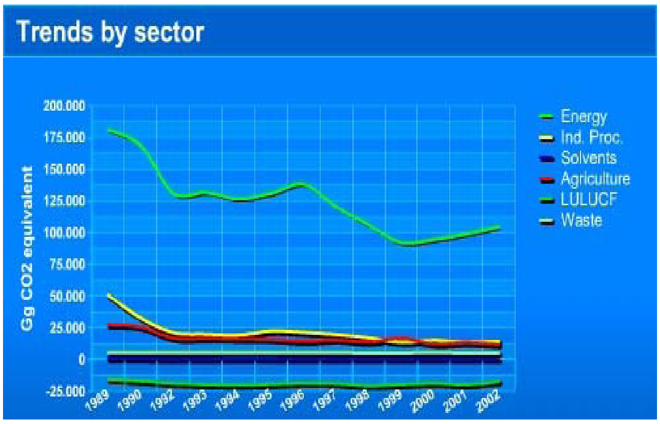

Figure 3 – The trends of greenhouse gas emissions in Romania by sectors in the 1989-2002 period

Besides Romania's National Strategy on Climate Change of Romania and the National Action Plan on Climate Change, the Ministry of Environment and Water Management also proposed a Government Decision draft with a view to establishing a trading schema for the greenhouse gas emissions certificates in Romania.

As in almost all European Electricity Exchanges, the Romanian Electricity Market Operator (OPCOM) has as future objective to perform transactions with greenhouse gas (CO_2) emissions certificates on its trading platform.

Regarding the **promotion of renewable resources**, the Romanian Government prepared a Strategy to developing the use of renewable energy sources (Government Decision No.1535/2003) and established a system to promote electricity generation from renewable resources (Government Decisions No. 443/2003, 1.892/2004 and 958/2005).

According to the Romanian Government target which derived from the EU accession negotiation process, a mandatory quota of gross electricity domestic consumption to be supplied from renewable resources by 2010 – 2012 was established. This mandatory quota (in accordance with [8]) is shown in Figure 4.

Another important step in promoting the use of renewable resources has been made with the Romanian Green Certificates Market that began operating in November 2005.

This market is administrated by OPCOM and operates on a monthly basis.

Mandatory quota applied to electricity suppliers (%)	Year
0.7	2005
2.22	2006
3.74	2007
5.26	2008
6.78	2009
8.3	2010-2012

Figure 4 – Mandatory quota of electricity produced from renewable resources until 2010-2012

Nuclear power is a reality for the last ten years in Romania. The Unit 1 of Cernavoda NPP, which began its operation with excellent results in December 1996, covers almost 10% of national electricity gross consumption. The commissioning of Unit 2 is also envisaged for the next year.

According to the National Strategy for Development of Nuclear Sector in Romania (Government Decision No.1259/2002) 3 more nuclear units will be under operation in 2020. The achievement of this ambitious program depends on the financial sources that could be attracted in the future.

VI. CONCLUSIONS

The main tools in fighting the climate change by limiting the greenhouse gas emissions are: carbon emissions trading (along with JI-CDM mechanisms of Kyoto Protocol), the promotion of renewable resources and continuing to develop nuclear power.

The nuclear power is and will remain in our opinion the main alternative in fighting climate changes in the coming years. It provides large scale electricity supply at lowest costs copes with the global warming and last but not least, avoids tensions on oil and natural gas markets.

Romania benefits from significant hydro generation installed capacities, free of greenhouse gas emissions and has made important steps towards the three directions mentioned above to be in line with the international efforts made in the fight against the climate change.

If the promotion of renewable resources and the emission trading process are in an incipient stage, the nuclear power is already a reality in Romania and represents the main generation technology that our country intents to develop in the future.

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VIII. BIOGRAPHIES

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Romanian Green Certificates Market – results and lessons learned

Gherghina Vlădescu, Luminița Lupului, Constantin Vasilevschi, Smaranda Ghinea

Abstract

The importance of electricity produced from renewable energy sources is associated with the benefits which result from their use: diversification of the energy sources used to produce electricity, abatement of the pollution associated with fossil fuels, green house gas emissions reduction, etc.

At present, the majority renewable energy sources cannot compete on the liberalized electricity market, due to their high costs. In order to assure the use of E-RES and to get it into the electricity market it is necessary to implement systems to assure a supplementary income for the producers of electricity from RES. Romanian Government has chosen to promote E-RES, the Tradable Green Certificates System, which assures the RES technologies development and in the same time, the costs allocated to their support are adjusted by means of market mechanisms which will reduced them and their effects on the electricity consumers.

In November 2005 occurred the first trade on the Romanian Centralized Green Certificates Market. Are reviewed the progress made from the beginning of the Romanian Green Certificates Market till present as well as the lessons learned.

***Keywords* – energy, mechanisms for renewables support, renewable energy sources, support schemes, green certificate, green certificates market.**

I. Introduction

There are many reasons to promote the use of electricity from renewable energy sources (E-RES) but the most important are: economic, environmental and social.

Economic reasons refer to security of energy supply and to development of specific industry which uses RES.

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Environmental reasons consider RES as clean energy sources – exemption for biomass which is considered neutral from the point of view of pollutant emissions – and take into account the contribution of RES to mitigate climate changes.

And finally, the social reasons consider employment, economic and social cohesion.

Because of relative high prices for electricity produced from RES, to increase the use of E-RES presumes the existence of two fundamental elements: financial support mechanisms and an adequate and stable framework for regulation.

To avoid market distortion as much as possible, the support system for RES development must be based on the market mechanisms. Such system based on market forces, transparent, cost efficient which limit price increases and avoid the duplication of support received and, most important, can be international harmonized, is that of tradable certificate system.

Environmental reasons consider RES as clean energy sources – exemption for biomass which is considered neutral from the point of view of pollutant emissions – and take into account the contribution of RES to mitigate climate changes.

II. Romanian Green Certificates Market

The system chosen by Romanian Government to support the electricity from renewable sources is that of Tradable Green Certificates, promoted by GD 1892/2004 for the establishment of the system to promote the production of electricity from renewable energy sources and amended by GD 958/2005, considering the possibility gives by such system to harmonize the support systems in European Union and not lastly, considering the possibility to reduce the prices which are to be beard by consumers.

Increasing the E-SRE production supposes the existence of two fundamental elements: financial support mechanisms and an adequate and stable framework of regulations.

This system awards the producer for each 1 MWh produced in installations which use renewable energy sources with a Green Certificate which confirm that this electricity is „green”. This green certificate is tradable which means that the producer can sell them to earn a supplementary amount of money, apart of the income from the electricity sold on the electricity market.

The eligible renewable energy sources to participate in this system are: wind, solar, biomass, hydro in power plants with a capacity less than 10 MW commissioned or modernized starting from 2004, geothermal, waves, hydrogen produced from RES.

This system has two main characteristics: the quantity is fixed and the price is determined by the market forces.

The System of Tradable Green Certificates combines the advantages of the control and command mechanisms with those of the market mechanisms, imposing a target at the central level by authorities, and leaving to the competitive market mechanisms to determine the participant's behavior. This system induces a behavior to minimize the costs and promotes the most efficient technologies for E-RES generation.

In any market, there are demand for a product and supply of that product. For green certificates market, the commodity is represented by green certificates which are sold by generators that possess them and thereafter, the supply is assured by the generators. The demand can come from electricity suppliers or from those consumers which can prove their "green" orientation. In such cases one says that the system is voluntary. Besides the voluntary systems there are those in which the demand is obtained by means of an obligatory quota.

Romanian system is one with quota obligations imposed on electricity suppliers. The electricity suppliers are obliged to purchase a number of green certificates equal with the obligatory quota multiplied with the amount of the electricity supplied yearly to their final consumers.

According to the national target, the annual share of electricity from renewable sources in the annual national gross consumption of electricity set up by GD 985/2005 are the following :

0.7% in 2005, 2.22% in 2006, 3.74% in 2007, 5.26% in 2008, 6.78% in 2009 and 8.3% in 2010-2012.

A. The command function

The Government commands this system imposing a national target for electricity produced from RES as well as an obligation on a market segment.[1], [2], [4]

B. The control function

The success of such system depends not only upon imposing a quota but also on carrying out the control function. The control must be applied at the generators, in order to issue a correct number of Green Certificates as well as at the suppliers, in order to seek after the quota fulfillment and to apply penalties in case of quota non-fulfillment.

The control of the generators is realized by metering the E-RES delivered into the network by them. The Authority which is charged to control the generators is TRANSELECTRICA, the Romanian TSO. A Green Certificate represents the proof that a generator delivered into the network 1 MWh of E-RES. The suppliers have to own the right number of Green Certificates at the moment when the Control Authority – Romanian Regulator for Energy – asks them to prove the quota fulfillment. The suppliers control is done yearly. Each Green Certificate has an identifier code which contains the information necessary to identify the generator, the technology used as well as its issuing data. This information is registered in Green Certificates Register, centralized and brought up-to-date by Romanian Electricity Market Operator - SC OPCOM SA, in order to avoid double selling.[5]

The suppliers which don't own an adequate number of Green Certificates at the moment of control are obliged to pay a penalty of 63 €/certificate between 2005-2007 and 84 €/certificate starting with 1st January 2008.[1]

While the annual offer of Green Certificates is less than the annual demand, the annual obligatory quota is diminished proportional with the ratio offer/demand in order to protect the consumers. If the number of generators participants in the system are too small and all suppliers are obliged to buy Green Certificates, the offer being too small, the suppliers can be penalized for nonconformity with their obligation even they are not responsible for a such situation. The costs resulted from penalties obviously will be transferred by suppliers to the consumers and consequently the consumer will be confronted with an unfair increasing of the prices.[1]

C. The Market

The generators and suppliers activate on two markets: on the electricity market, where they trade the electricity and on the green certificates market, where are traded the environmental benefits of the electricity production from renewable sources, bearing in mind the fact that the conventional production of electricity not reflect in price all the environmental externalities.

The green certificates price is determined my means of market mechanisms. Are allowed two types of markets for green certificates in Romania:

- A bilateral market, in which producers and suppliers conclude bilateral contracts and where the price of transaction is established by an agreement between the two contractors, and
- A centralized market organized and administrated by the Romanian Market Operator, OPCOM, which is the Romanian Green Certificate Market Operator, too.

The actors involved in the organization and the functioning of the Green Certificate Market, the bilateral market as well as the centralized market, are

- The Regulatory Authority, ANRE
- Electricity generators from renewable sources
- Electricity suppliers
- The Distribution Operators
- The Transport and System Operator (TSO), Transelectrica
- The Electricity Market Operator and Green Certificates Market Operator, OPCOM

C.1. *Regulatory Authority*

The Regulatory Authority has three main tasks:

- Qualifies the installations which use those renewable energy sources that are eligible to participate on the Green Certificates Market as Priority Production

- Supervises the quota fulfillment by the suppliers
- Applies penalties to those suppliers which do not fulfill their obligations

The market has an inferior limitation for the price as well a superior limitation, legally imposed. The minimum price intends to protect the generator against the severe falling for the market price and the superior limit has the scope to protect the consumers. Hereby, the market price of green certificates will oscillate between the two values imposed by the Government.

The minimum and maximum prices set up by Government are 24 €/certificate respective 42 €/certificate, calculated at an exchange rate established by Romanian National Bank for the last working day of December of the previous year.

The penalty is set as one and half the maximum price for green certificate (63 €/certificates) in period 2005-2007 and twice the maximum price (84 €/certificate) starting with 1st January 2008.[1]

C.2. *TSO*

The Transport and System Operator, Transelectrica, receives each month both from the E-RES generators and from the Distribution Operators into whose networks are delivered the electricity produced from RES, data about the amount of electricity produced by the respective generators. Based on this data, verified and validated, TSO issues to each producer a corresponding number of green certificates, a Green Certificate being issued for 1 MWh of electricity from RES delivered into the network.

Certificates has unlimited availability and exist only in electronic format. A certificate is considered “consumed” if the supplier use them to prove the quota fulfillment. The certificates “consumed” are retired and cannot more be used.

The amount of money from the penalties are collected by TSO and has two destinations: to buy the Green Certificates which was offered on the market but remained unsold in the previous year, at the minimum price (24 €/certificates) and the rest of money are redistributed to the generators according to the number of Green Certificates offered on the market and with the technology used, in conformity with the procedure of allocation elaborated by Romanian Electricity Regulator. The producers will have guaranteed the minimum price. This is valid only in the period 2005-2007, if the number of Green Certificates issued is less than the number of Green Certificates needed to comply with the quota. [1]

C.3. *Green Certificates Market Operator*

OPCOM, as Green Certificate Market Operator, organizes the Centralized Green Certificates Market and administrates the whole market for Green Certificates – the centralized market and the bilateral market.

Between the main attributions of OPCOM we can specify:

- Records the participants to the Green Certificate Market
- Records the bilateral contracts between E-RES producers and suppliers
- Set up and manage the Green Certificates Register
- Assures the trading framework for Green Certificates on the Central Green Certificate Market
- Receives the Green Certificate sell/buy offers from the producers/suppliers (consumers)
- Determines and publishes the Centralized Green Certificates Market Clearing Price (CGCMCP) and the number of green certificates traded monthly on the Central Green Certificate Market
- Determines the payment rights and obligation of the Central Green Certificate Market participants

Transactions on the Centralized Green Certificate Market are organized monthly.

The offers for this market represent couples price-number of Green Certificates. Each offer can contain maximum three such couples.

The Centralized Green Certificates Market Clearing Price and the number of Green Certificates traded are determined at the intersection point of the two curves supply of green certificates and demand of green certificates.

The sell offers are aggregated into a single curve being ordered ascending with the price and the buy offers are aggregated into a curve ordered descending with the price. An example of the modality in which are determined the market price and the number of Green Certificates traded are represented in fig. 1. below.

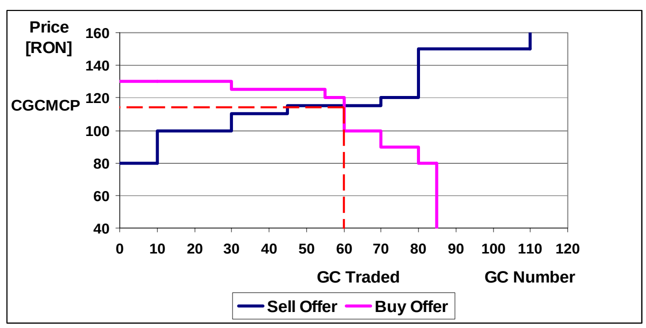

Fig. 1. The modality in which are determined the number of Green Certificates traded and the Centralized Green Certificates Market Clearing Price

To avoid the double selling of certificates, OPCOM set up and update the register for green certificates and transfer the certificates sold from the seller account into the buyer account, both for the centralized and the bilateral market. All transactions are registered in the Green Certificates Register.

III. Market Results and Lessons Learned

TSO issued Green Certificates for Romanian E-RES producers, starting with august 2005. Figure 2 presents the number of GC issued monthly by TSO as well as the cumulated number of GC issued until present.

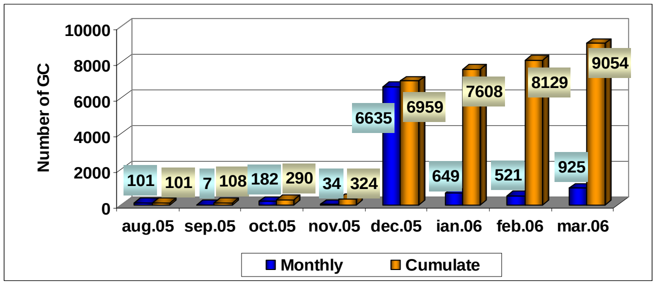

Figure 2. GC issued by Romanian TSO until March 2006.

In August, September, October and November, only two producers received GC, for two wind mills. In December, Hydroelectrica, the main hydro production company in Romania, received the approval to participate on the Green Certificates Market, with 4 hydro power plants less than 10 MW installed capacity, modernized. Hydroelectrica received in December, GC for entire production from these 4 hydro power plants in period January - November 2005. After December, the number of GC issued was quite stable.

Romanian Green Certificates Market had in March 2006, 40 participants: 4 producers and 36 suppliers. All Romanian electricity suppliers have the obligation to fulfill the mandatory quota but only 36 are registered as Green Certificates Market participants until March 2006. We expect that the number of suppliers will increase next months, especially after the application of the penalties at the end of the March 2006. Figure 3 represents the evolution of the number of market participants.

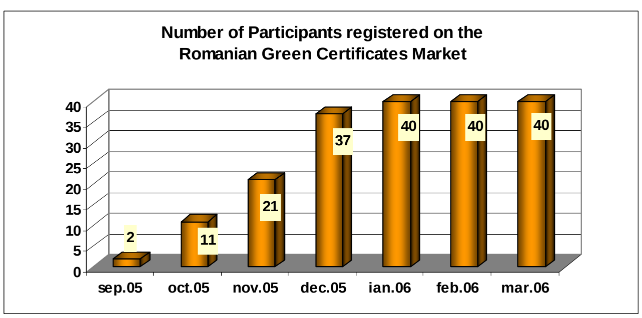

Figure. 3. Number of Participants registered on the Romanian Green Certificates Market.

After five trading sessions, was sold 7265 GC, 7241 for the electricity produced in 2005 and 34 representing GC corresponding to the electricity from RES produced in 2006.

Figure 4 presents the offer, the demand and the number of GC traded from November 2006 until March 2006.

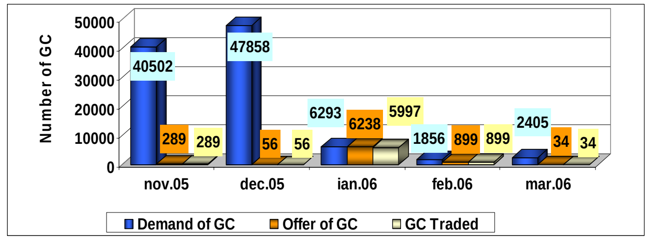

Figure 4. Evolution of the offer, the demand and the number of Green Certificates Traded on the Centralized Green Certificates Market.

In conformity with GD 958/2005 provisions, ANRE, Romanian Regulator for Energy, may diminish the yearly mandatory quota in the first decade of December, in the period 2005-2007, if the number of GC issued is less than the demand, in order to protect the consumers against of a high level of penalties. Because the suppliers submitted the offers in the first 5 working days of December, before quota modification, in this trading month the demand reflects also the initial obligation. After that, the demand and the offer for January and February, trading months for quota of 2005 complying, were balanced.

The offer being less than the demand, the Market Clearing Price was alike the maximum price, except in January when Hydroelectrica offered a high number of GC at a price less than the maximum price and his offer determined the Market Clearing Price. This trend will continue until the number of producers in this market will balance the suppliers need. The market is hindered in this first stage also by the producers which are suppliers too, and which keep theirs GC for the own quota fulfillment. The Market fluidity is so ensured by entering in the market of the producers which are not suppliers too.

Figure 5 and 6 present the evolution on the Centralized Green Certificates Market Clearing Price.

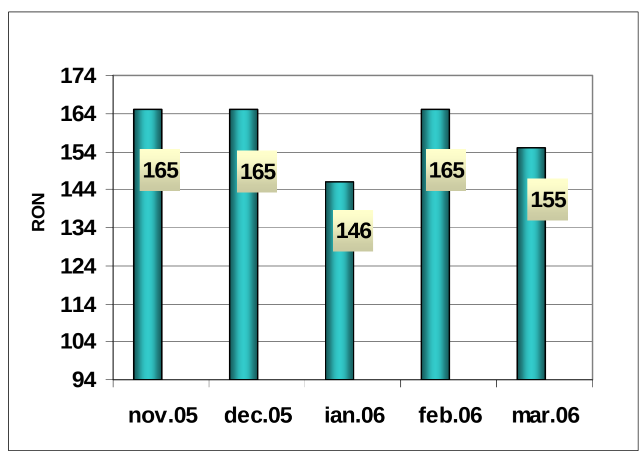

Figure 5. The evolution of the CGCMCP

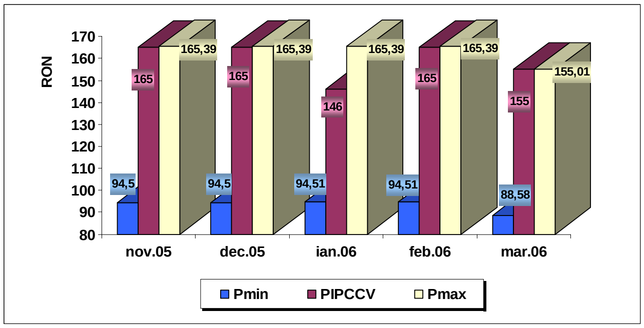

Figure 6. The evolution of the CGCMCP compared with the minimum and the maximum price.

In March 2006, the minimum and the maximum price values changed because of exchange rate which is different from those used in 2005 (the exchange rate established by Romanian National Bank for last working day of December of the previous year).

This trend will continue as long as the producer's number participants in this market will be much less than those of suppliers obliged to purchase Green Certificates. Significant for the correct market functioning is to realize new projects which can produce an increased number of Green Certificates on the market: finalizing the wind farm project on the Black Sea shore as well as developing new biomass and micro-hydropower plants projects.

IV. Conclusions

The main reasons to promote the use of electricity from renewable energy sources (E-RES) are: economic, environmental and social.

Because of relative high prices for electricity produced from RES, to increase the use of E-SRE presumes the existence of two fundamental elements: financial support mechanisms and an adequate and stable framework for regulation.

To avoid market distortion as much as possible, the support system for RES development must be based on the market mechanisms. Such system based on market forces, transparent, cost efficient which limit price increases and avoid the duplication of support received and, most important, can be international harmonized, is that of tradable certificate system.

Romanian Government choose the support for electricity produced from renewable sources the Tradable Green Certificates, considering the possibility gives by such system to harmonize the support systems in European Union and not lastly, considering the possibility to reduce the prices which are to be beard by consumers.

OPCOM has an important role in this system as administrator of the green certificates market – both bilateral and centralized market – and as market operator for the centralized green certificate market.

To avoid the double selling of certificates, OPCOM set up and update the register for green certificates and transfer the certificates sold from the seller account into the buyer account, both for the centralized and the bilateral market. All transactions are registered in the green certificates register.

Romanian market for green certificates has 5 month of functioning.

The market is still in the phase of development. Only four producers joined the market until now, but the five producer will join it soon and. There are projects for wind farms construction on the Black Sea shore, which will be finalized probably until the end of 2006 or until the first semester of 2007.

The market fluidity will be assured by the producers which are not suppliers too. In this stage, the Market Clearing Price reflects the capacity of E-RES deficit and the trend will continue until the offer will balance the demand.

OPCOM as a market operator and in the future as a power exchange, trades two different produces, independently each other and has in view the possibility to trade CO2 emission permits and certificates for energy efficiency (White Certificates), according to the evolution of Romanian policy in climate change mitigation and energy efficiency.

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VI. Biographies

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Energetic Efficiency of Geothermal Resources in the Republic of Macedonia

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Based on current findings of geothermal potential in the Republic of Macedonia, there has been made a try to evaluate its real energetic value. In accordance with available technology that can be use in out country and world wide.

Maximum available 240 MW illustrated perspective and justification fro bigger investment in further investigations, but at the same time there is realistic possibility to have an important participation in the energetic balance of the Republic.

kWh In this presentation the basic data of energetic resources in Macedonia will be showed. Current available capacities, technical usage, the treatment by the legislative, evaluation of the average prize for produced kWh in current condition of financing and working.

I. Introduction

The hydro geothermal explorations in the Republic of Macedonia intensively started to conduct after 1970, after the first effects of the energy crisis. As a result of these explorations, more than 50 springs mineral and thermo mineral waters with a total yield of more than 1400 l/sec., were registered, and proved exploration reservoirs of more than 1000 l/sec., with temperatures higher than the medium year seasons hesitations for this part of the Earth in boundaries of 20 – 79°C, with significant quantities of geothermal energy.

Based on present “know-how” for the geothermal potential of the Republic of Macedonia , a trial is made to estimate its real energetic value in accordance with the available technologies in Macedonia and the world.

This paper will shortly present the available hydro geothermal resources in the Republic of Macedonia according to the results of previous explorations with special respect to the last few years. The next text will present short descriptions of the hydro geothermal resources, the degree of exploration, the prognosis dimensions of the hydro geothermal systems and theirs reservoir environments dimensions where the hydro geothermal fluids occur as well as the quantity of geothermal energy.

Nowadays hydro geothermal resources are the only commercially accepted sources of energy that contain warm - hot water or steam, accumulated in cracked masses or porose sediment structures in different depths from several hundred to 4.000 meters.

Depending on the temperature and the dominate faze of the fluid, hydro geothermal resources are categorized in three groups: water with low temperature which is used to hit housing and office blocks, green houses, thermal pumps and in particular industrial processes; water with medium temperature (to 140 that is used in industrial processes and production on electrical energy used in binary cycle - units which use as working fluid freons, known under abbreviation ORC turbines; water with high temperature and dry steam (which is used to produce electrical energy in turbine's units, and from them 2/3's work in mild area (“flashing”).Underground water from hydro geothermal reservoirs can appear on the surface ground as artesian well (with its own lifting power) or to be pumped using depth pumps. When temperature is above 100, it expands and appears in its own two phases - steam ("flashing").

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II. Geothermal Resources in the Republic of Macedonia

A. Geological characteristics and tectonically location of Macedonia

Republic of Macedonia is situated in the central par of Balkan Peninsula and it has territory of 25.713 km2. Geotectonic location of macedonian territory is determined by its own geographic location. It belongs to alps-kavkazian-hymalai geosynclinal's belt and the generation history of the ground is connected to ancient geosynclinal Tetis and Alp's orogenesis, but in primary position of the original lithosphere of these regions as well as the influence from preAlp's orogenesis.

Generally, according to division of alp's orogen, the territory of Macedonia belongs to two tectonic systems: the western part of Macedonia included Povardarie, belongs to Dinaridis (Helenidis), and on the other hand the eastern macedonian mountain terrain and valley's depressions are segments of the Serbian-Macedonian massive. Along the Bulgarian border there is one particular zone, known as Kraistidna zone that belongs to Karpat-Balkanidis.

B. Geothermal characteristics

According to the geothermal energy transmition, hydro geothermal resources are divided into convective and conductive hydro geothermal systems.

In the group of conducive hydro geothermal systems are included system with dominant conductive transmition of geothermal energy.

In this group of systems in Macedonia there are tertian basins of Ovce Pole, Tikves, Delcevo-Pehcevo's basin, basins in Skopje's, Strumica's, Gevgelija's, Polog's and Pelagonija's valley. In the group of the convective hydro geothermal systems dominates convective way of geothermal energy transmition.

On the territory of the RM the most important convective hydro geothermal systems are: Skopje's Valley, Kocani's Valley, Strumica's Valley, Gevgelija's Valley, Kezovica, Toplik - Topli Dol on the Kozuf Mountain, Toplec near Dojran, Proevci near Kumanovo, Strnovec, Zdravevci on the Povisnica River near Kratovo, Sabotna Voda near Veles, as well as dry systems in western Macedonia - Kosovraska and Debarska's spas and Banice on the Pena River near Tetovo.

In the following text there will be given details of data and parameters for more important hydro geothermal systems in the RM. The location of the main geothermal fields and their hydro geothermal systems which are at current exploitation shown on this photo.

Fig. 1. Main geothermal fields in Macedonia (K. Popovski, E. Micevski, 2001)

III. Energetic Potential Of The Resources

Total balance-sheet of geothermal exploitation reserves in RM (state 2004) is 1.473 l/sec, registered on 17 more important locations and complexes (Table 1 and Fig. 1). Quantity of geothermal energy contained in hydro geothermal systems is determined by many methods for determination of geothermal potential. There are viewed more hydrogeoloic, geologic and geothermal sizes that are more or less defined or taken with certain proximities.

In the table below valorization is made of available hit power of all exploitation geothermal resources in RM. The total maximum available power of 173 MW is gained or annual production capacity of 1.515.480 MWh/year/ effective valorization of one geothermal resource is possible only if there are available data for composition of its users.

Each one separately is causes temperature area for use and possibilities to compose cascade chain for optimal use of available temperature level. According to Lindal's diagram which gives the areas used for proved technology and direct application of geothermal energy recommends low usage limit from 20, however, it has been proved that limit from 15 is a real base for aquaculture (K. Popovski, 1995).

The quality influence is an illustrative technical solution for heating capacity of concrete geothermal source. To reach maximum use of one hydro geothermal system the normal outlet temperature should be 15.

Unfortunately, applied technical solution by users in RM give results with outlet temperatures in winter conditions between 30 and 45, which automatically lowers heating capacity of geothermal resource to 30-50%.

TABLE 1
Balance-sheet of hydrogeothermical resources in RM (state 2004)

Hydro geothermal system	Locality	Temp. (C°)	Yield (l/sec.)	Exploitation reserves (l/sec.)	Heat power (MWt)
Skopje Valley	Volkovo	25	60	20	2.10
Skopje Valley	Katlanovo	50	20	15	10.45
Kumanovo spa	Dupnatina	31	6	4	0.52
Strnovec	ST-5, PEB	47	50	46	9.05
Zdravevci	ZD-3,4,5,6	48	22	20	4.02
Dobrevo	Borehole	28	12	8	0.94
Podlog Kocani	Borehole	75	650	300	94.14
Istibanja-Vinica	ID-3,4,5	68	73	73	20.78
Strumica Valley	Bansko	70	82	50	14.65
Gevgelija Valley	Negorci	50	100	80	16.74
Gevgelija Valley	Smokvica	65	180	120	32.65
Dojran	Toplec	28	28	10	1.17
Kozuf	Toplik	21	2	2	0.18
Rakles	Dupnatina	26	5	2	0.22
Veles	Sabota v.	21	5	5	0.44
Stip	Kezovica	57	8	7	1.67
Tetovo-Pena R.	Baniche	30	10	10	1.26
Debar spa	Baniste	50	120	100	16.74
Kosovraska spa	Kosovrasti	48	100	60	12.05
Total ∑			1473	933	239.92

IV. Valorization of Geothermal Resources

A. *Use of geothermal energy*

Use of geothermal energy in RM is long centuries tradition in the domain of balneology, and there is 40-year old tradition worming greenhouses complexes. So-called energetic crisis in the 70 and 80's from the previous century started the researches in the area of geology in order to find out potential energetic resources as well as systems development of low temperature geothermal water. There have been performed many projects for heating greenhouses complexes, drying agriculture products, heating administrative and industrial objects, basins, preparing sanitary hot water, industry use etc. In RM there are current7 geothermal projects and 6 spa complexes where geothermal water is used. All these geothermal projects started in the 80's in the previous century, and spa complexes are dating from earlier period. There are valid documents for the geothermal systems (Kocani), Podlog Spa, Istibanja (Vinica), Bansko, Gevgelija Valley etc.

B. *Economic aspects (Comparative geothermal potential)*

Macedonia use sources of energy like coal and river hydro energy from domestic origin and important oil. Use of sun energy is insignificant compared to the needs and possibilities and use of natural gas in preparation phase, but it has been imported to. biomasses energy is in the phase of experimental researches.

Coal is the best examined energetic row material in Macedonia.

Total reserves of coal arex103 t. River hydro energy is used insufficiently and the current exploitation of heat equivalent of 411 MW. Energy consumption and participation of particular energetic of total production in RM are shown in table 2.

TABLE 2
PARTICIPATION OF PARTICULAR ENERGETICS IN ENERGETIC BALANCE-CHEET IN RM

types of energetic	**annual consumption (TJ)**	**participation of total consumption (%)**
coals	59 700	56,13
wood	10 097	9,49
liquid	33 044	31,07
renewable	500	0,47
hydro energy	2 498	2.35
Geothermal	*510*	*0,48*
Total	106 347	100

Analyzing presented data from table 2 we can conclude that current participation of geothermal energy from 0,5% in total energetic balance-sheet in the Republic at first sight seems insignificant even it is used most rationally. But in local frames it is confirmed important factor for development of local economy, taking the experiences of energy use in geothermal systems in Kocani, Strumica, Gevgelija etc.

V. CONCLUSION

Geothermal energy is not a "new" and unknown energetic source in Macedonia. It is proved practically as economic justified and competitive to any other energetic in the state. In RM there are have been registered above 50 sources and appearances of minerals and term mineral waters with total abundant of more than 1.400 l/sec and prove explanation reserves about 1.000 l/sec with temperature limits from 20 to 70 with important quantities of geothermal energy. Performed valorization of total balance of geothermal exploitation reserves in the RM (state 2004) is maximum available power of 173 MW or annual capacity production of 1.515.480 MWh/year heating equivalent. Although it is a small country, the RM possesses various appearances of thermal and thermo mineral waters that are used in spa-recreative medical centers in balneology sphere. Geothermal energy from this term mineral water is used in 8 thermal spas with total yield of 250 l/sec with total thermal power of 35 MW and annual use of 1.112,5 TJ.

VI. RECOMMENDATIONS

Taking into account that the current production capacities are based only on natures; appearances and shallow boreholes on locations connected with them. The frontal capacity does not give the real picture of the real size of these energetic resource. Base on current data with relative small investments to continue the started research work in potential geological areas in 80's from the previous century, the capacity can be doubled. To supply higher amount of money for deeper drills it can be raised 4-5 times during the following years. The greatness of necessary investments fro research and competition of exploitation hot water wealth are not possible without special government support that is to say without treatment of geothermal energy as energetic with special social significance. Successive use of thermal water energy requires, first of all, change of try attitude towards this kind of energy and solution of the legal regulation from this area in the Republic, and in that way the economic condition with thermal waters will reach higher level. This particularly affects hydro geothermal appearances with temperature to 45°S which haven't been used as a source of energy. Whether is necessary to form special legal regulation or use of geothermal energy, which will define all problematic aspects of geologic researches and use of specific energetic resource.

Future researches in the RM should be directed in registered regions where are indications for increased terrestrial thermal yield such as Kratovo-Zletovo's volcano region, Vardar zone and Serbian-Macedonian massif.

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VIII. BIOGRAPHY

Dusan Nikolovski (1947) was born in Jurumleri, Skopje, Macedonia, on May 27, 1947. He graduated from the Mining-geological faculty, Belgrade at section of underground exploitation. He was promoted as a doctor of technical science in Mining-geological faculty, Stip, in 1997.

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Croatia´s RES potential for Decentralized Power Production

D. R. Schneider, M. Ban, N. Duić, Ž. Bogdan

Abstract-- **Although Croatia is almost completely electrified there are regions in which there is no electricity network or the network capacity is insufficient. Often those areas include regions of special state care (underdeveloped, impaired in war, deficient in population), islands, and mountainous area. But, in the same time, those regions are areas with good renewable energy potential. Since the decentralized generation covers a broad range of technologies, including many renewable technologies that provide small-scale power at sites close to users, the idea presented in this paper was to identify the areas in Croatia (not only geographical but also the one of potential use) where the decentralized energy generation that exploits RES could be applied. The DEG potential of wind, hydro, solar PV, geothermal and biomass power facilities is estimated by calculating their capacities and energy capabilities on regional basis. Also RES cost – supply curve for 2010 is given.**

***Index Terms*—Distributed energy generation, DEG, Decentralized Power Production, Renewable energy sources, RES, Wind, Biomass, Geothermal, Solar, Hydro**

I. INTRODUCTION

IN view of the fact that Croatia´s import of fossil fuels and electric energy is growing every year and that its energy consumption increases (predicted increase of approximately 0.5 TWh annually [1]) while the available surpluses in nearer surroundings decrease, so the exploitation of available energy sources is becoming the precondition of future development. Croatian power system is now stretched to the limit of generation capacity and the construction of new facilities is an imperative. Although Croatia Power Company (HEP) has plans to build new power plants the dynamics of new capacity increase is rather slow. Presently only one (in last decade) power plant is being built (hydro power plant Lešće of 40 MW / 90 GWh). Since this is not nearly enough to satisfy demand, the Republic of Croatia considers also the construction of facilities based on distributed and/or renewable energy sources. The RES technologies whether exploit wind, hydro or solar power, geothermal heat, biomass and waste materials, have benefits of providing small-scale power at sites close to users, energy resources diversification, decreased fossil fuel use and reduced per unit GHG emission.

This work was carried out as a part of ADEG "Advanced Decentralized Energy Generation Systems in Western Balkans" project, financed by the European Commission through INCO programme of 6th FRAMEWORK PROGRAMME [2].

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However, construction and utilization of dispersed energy sources should not suppress the significance of the conventional sources on maintaining the integrity of power system. In line with numerous advantages; the decentralized[1] production is characterized by its limitation of not being able to follow the daily power consumption diagram. Wind power and photovoltaic system production depends on the meteorological conditions, whereas the electric energy production in the cogeneration facilities is determined by the local heat requirements. As a result of the increased share of dispersed sources having fluctuating production, an increased reserve power of the system along with an adequate development of centralized sources, which will have to pay more attention to the stability of supply, will be required.

Liberalization of the electric energy market is currently not showing results according to which it has been initiated. It was envisaged to bring competition into the energy market with the real energy prices formation. Instead, the worldwide practice has shown that liberalization does not stimulate investments into the production capacities nor into the new technologies and therefore causes the prolongation of existing trends and results in reduction of the reserve power of the system. Only the bigger producers are able to withstand such environment - they engulf the smaller ones and due to their market-share they dictate the market conditions. On the other side, reduced energy supply on the market raises the redemption prices, occurring along with the current fossil fuels prices increase at the world market.

The upgrading of product energy system possibilities range from modernization and expansion of the existing facilities, construction new thermo- and hydro- power plants, to the implementation of renewable and distributed power plants in a greater proportion into the power and heat system of Croatia and its regions. It is not about selecting only one potential, but more about the smart utilization of all of them.

This paper focuses exactly on that segment of decentralized energy production based on RES.

II. DEG POTENTIAL BASED ON RES

Since the decentralized energy generation (DEG) covers a broad range of technologies, including many renewable technologies that provide small-scale power at sites close to users, the idea was to identify the areas in Croatia (not only geographical but also the one of potential use) where the

[1]Decentralized power production includes distributed generation plus big wind power plants, which by definition do not belong into distributed energy generation.

decentralized energy generation that exploits renewable energy sources could be applied.

Even though Croatia is almost completely electrified there are regions in which there is no electricity network or the network capacity is insufficient. Often such areas include regions of special state care (underdeveloped, impaired in war, lowered in population), islands, and mountainous area. These regions could be identified analyzing data such as electricity consumption, distance from the electricity network, population density, GDP per capita, number of rural dwellings etc. what was done in ADEG project [2].

Luckily, those regions have often a good renewable energy potential. RES potential of Croatia includes windpower, hydropower, solar power, geothermal and biomass resources as it could be seen for solar PV power (Fig. 1) and wind power (Fig. 2).

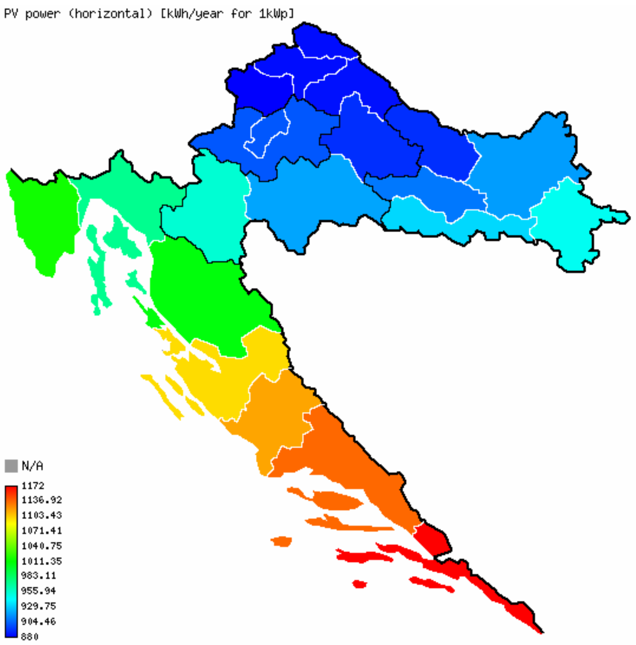

Fig. 1. Horizontal PV power (kWh/ year).

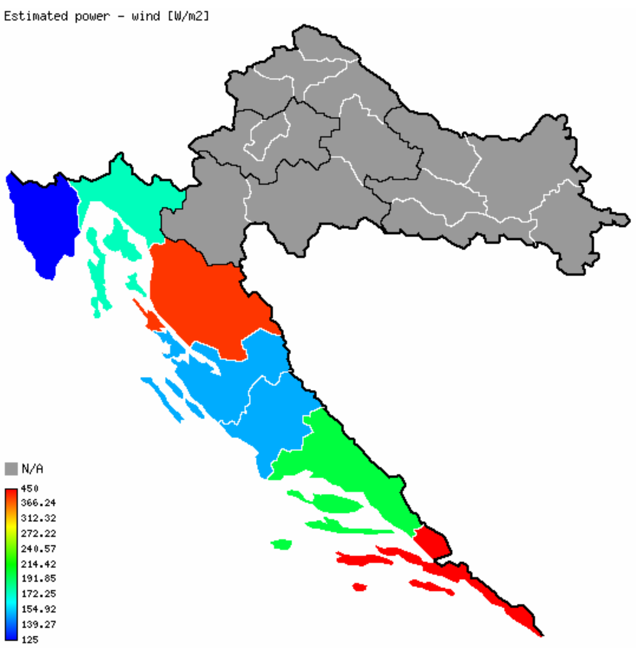

Fig. 2. Estimated wind power (W/m^2).

Note that values on these maps are given on regional basis (NUTS 3 statistical classifications[2]). According to the NUTS classification, the counties (cro. *županije*) of Republic of Croatia could be considered as NUTS 3 regions (thin lines), while NUTS 2 classification has just to be defined. Last proposal of division of Croatia on four regions includes Central, Eastern, Adriatic Croatia and Zagreb region (black thick lines) as it could be seen from the Fig. 3.

Fig. 3. NUTS categorization of counties and regions (proposed).

Islands and coastal area along Adriatic Sea in Republic of Croatia, have excellent solar and wind potential [3]-[6]. Great number of sunny hours with solar irradiation that exceeds 1450 kWh/m^2 annually [3] and average wind speed velocities above 4-5 m/s represent potential for production of energy that cannot be ignored.

Although the wind atlas of Croatia still does not exists there is strong interest for building wind farms especially on locations along Adriatic Sea, what could be seen from the Fig. 4 and Table I that represent the maximum potential load capacity[3] given on NUTS III level. Since the NUTS 3 level is not very suitable for energy planning in wider region (e.g. South East Europe) the load capacity is given on both levels (NUTS 2 and 3) as well as energy capability[4] (Table II). These parameters (load capacity and energy capability) consider all possible resources, even projects of low confidence (10-20%) that could be developed, but difficulties could be expected in terms of permitting and access. In comparison to RES cost – supply curve (Fig. 7) that considers only medium confidence resources, the maximum load capacity and energy capability (Tables I and

[2]Nomenclature of Territorial Units for Statistics, established by Eurostat.

[3]The maximum capacity that could be produced continuously for a prolonged period of operation under representative climatic conditions.

[4]The maximum potential energy produced under the most favorable conditions. Furthermore, the resource availability takes no account of electricity transmission and distribution constraints, which will be considered in the next part of the project.

II) take into account all levels cumulatively (low confidence resource available includes both the high and medium confidence bands).

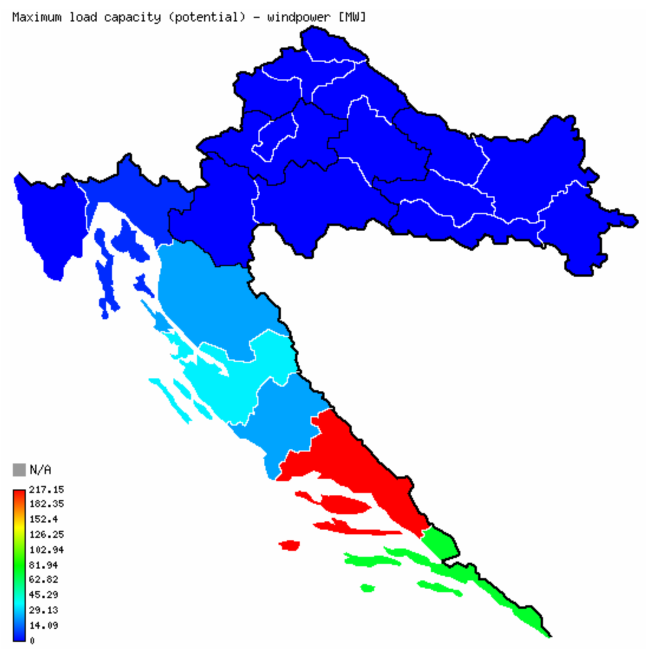

Fig. 4. Maximum load capacity of potential wind farms (MW), given on NUTS III level.

Calculated potential of wind units for electricity generation is technical and does not take into consideration recent decision of the Croatian government to ban construction and planning of all new wind power plants (together with quarries, warehouses, factories etc.) on locations that are on islands and less than 1000 m from the sea (the projects that in the moment of the proclamation of the decree had already obtained the location permits are excluded). The act was explained as a measure of protection of Croatian coastal area. That unfortunately includes some of the best locations on Croatian islands and along the Adriatic coast.

Despite good solar potential it is not likely that big solar power plants will be built in following years in Croatia due to high cost of these facilities (the graph representing RES cost – supply curve for 2010 shown on Fig. 7 does not contain data for big solar thermal power plants or PV due to high costs of such facilities that exceed chosen upper cost limit). Except certain number of households and other buildings that use PV systems, application of the photovoltaics will be reserved for isolated areas and specific purposes like telecommunication base stations, meteorological stations, lighthouses, road signs, public lightning, different autonomous monitoring systems (pollutant emission monitoring, forest fire protection, technical protection of individual facilities etc.).

TABLE I
MAXIMUM LOAD CAPACITY OF POTENTIAL FACILITIES (MW)

No	County (NUTS III)	Hydro	Small hydro	Windpower	PV	Biomass	Geothermal
I	Zagrebačka	39.00	0.80	0	0.007	6.00	0
II	Krapinsko-zagorska	0	0	0	0	2.00	0
III	Sisačko-moslavačka	0	0	0	0	0	0
IV	Karlovačka	40.00	0.52	0	0	8.00	1.67
V	Varaždinska	0	0	0	0	2.00	29.37
VI	Koprivničko-križevačka	140.00	0	0	0	5.00	1.88
VII	Bjelovarsko-bilogorska	0	0	0	0	1.50	13.07
VIII	Primorsko-goranska	0	6.77	6.00	0.047	30.50	0
IX	Ličko-senjska	383.00	0.19	23.00	0.047	7.50	0
X	Virovitičko-podravska	0	0	0	0	0	0
XI	Požeško-slavonska	0	1.39	0	0	2.00	0
XII	Brodsko-posavska	0	0	0	0	4.00	0
XIII	Zadarska	0	6.58	34.95	0.056	0	0
XIV	Osječko-baranjska	0	0	0	0	32.00	0
XV	Šibensko-kninska	0	7.86	23.10	0.056	0	0
XVI	Vukovarsko-srijemska	0	0	0	0	3.00	1.88
XVII	Splitsko-dalmatinska	0	2.96	217.15	0.113	4.00	0
XVIII	Istarska	0	0	0	0.047	3.00	0
XIX	Dubrovačko-neretvanska	63.00	2.21	74.00	0.056	1.00	0
XX	Međimurska	0	0	0	0.007	0	0
XXI	City of Zagreb	44.00	0	0	0.007	0	0
	Total	**709.00**	**29.26**	**378.20**	**0.444**	**111.50**	**47.87**

On the contrary, thermal solar systems for production of hot water will be used extensively due to their good economy. For the time being the main obstacle to wider usage of solar domestic water heating systems is nonexistence of the legislation that promotes and subsidizes the use of renewable energy systems as it is the case in other European countries. Newly established Environmental Protection and Energy Efficiency Fund of Republic of Croatia [7] periodically (at the present) announces public tenders for RES projects, including solar thermal collectors, but this mechanism is mainly reserved for companies and units of local self-government while the similar invitation has not yet been issued for physical persons (households).

TABLE II
ENERGY CAPABILITY OF POTENTIAL FACILITIES (GWH)

Region (NUTS II)	Hydro	Small hydro	Wind power	PV	Bio-mass	Geo-thermal
Central Croatia	744	3	0	0.008	78	362
Zagreb region	400	5	0	0.015	24	0
Eastern Croatia	0	7	0	0.000	202	15
Adriatic Croatia	735	143	785	0.450	218	0
Total	**1879**	**158**	**785**	**0.473**	**522**	**377**

Use of biomass is favorable in low plains of Pannonian Basin - Slavonia region in Croatia (agricultural residues [8], e.g. sunflower, soybean, rapeseed and beans (Table III), but also fruit and olive residues) and in mountainous forested regions (and partially in plains) of Primorsko-Goranska, Ličko-Senjska, Karlovačka and some other counties (forest residues and wood waste from wood processing industry, Table III). Such biomass could be used for the purpose of district heating and, in lower scale, electricity production (in cogenerations).

Energy potential is considerable (given in Tables I and II and on the maps in Figs. 5) especially in respect to relatively low costs comparable to those of wind power production (Fig. 7). But unlike the wind farms, power production from the biomass will have higher social benefits in terms of increased employment of local workforce and additional activities for farmers producing row material.

TABLE III
AGRICULTURAL AND WOODY BIOMASS POTENTIAL

Region (NUTS II)	Forest area ha	Wood assortment production m^3/year	Sun-flower t	Soy-bean t	Rape-seed t	Beans t
Central Croatia	464291	2527255	15	1346	2137	2696
Zagreb region	38669	173077	0	182	321	862
Eastern Croatia	357400	1803571	11104	8746	4807	1906
Adriatic Croatia	1131178	1564827	1	14	51	433
Total	**1991537**	**6068730**	**11120**	**10288**	**7316**	**5897**

The review of biomass potential would not be complete without considering the waste (municipal solid waste, sewer sludge, landfill gas, solid and liquid manures from livestock farms and abattoirs) whose energy potential is at the present time practically unused. The Republic of Croatia is currently making efforts to establish its waste management system, which among other things foresees energy usage of that part of the waste, which could not be recycled or used in other ways. It can be concluded that importance of this sector will grow in near future. Total biomass (plus waste) technical potential is estimated to be between 50 and 80 PJ in 2030.

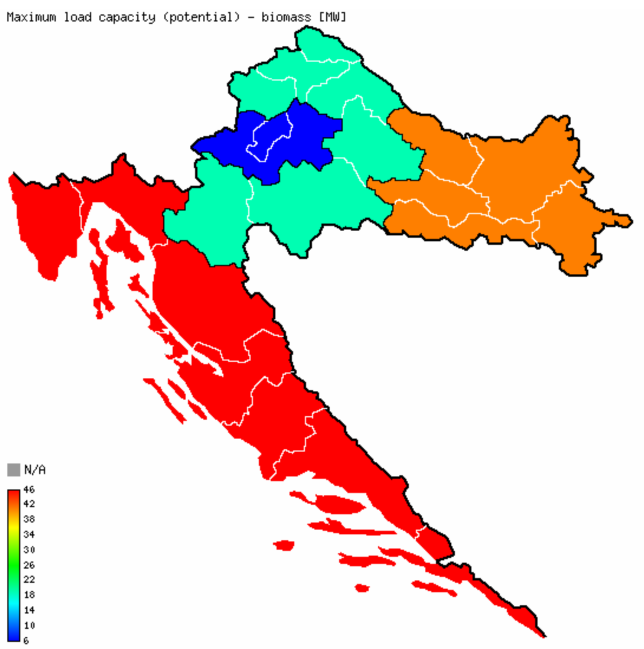

Fig. 5. Maximum load capacity of potential biomass facilities (MW), given on NUTS II level.

Hydro potential (big and small[5] power plants, Tables I and II) is traditionally the most exploited renewable energy resource (the share of electric hydro power generation capacity in Croatia is 51% of the total installed capacity [9]-[10]). The big hydro power plants, although belonging to centralized power generation, are included in the tables as the referent renewable technology, for the purpose of cost comparison. It is not surprising that the cost of electricity production for the big hydro power plants is the lowest of all RES, while the same does not stand for the small hydro power plants which, depending on the specific case, could exhibit substantial costs.

One part of hydro potential suitable for construction of big hydro power plants is permanently lost due to urban, environmental and economic limits. Even small hydro power plant projects in Croatia are confronted to strong public resistance due to increased environmental consciousness. Therefore, the quite significant total potential of small hydro power plants, given by the maximal load capacity and energy capability, will have to be revised.

The Republic of Croatia has a geothermal gradient of 0.049 °C/m (in Pannonian Basin), what is more than the European average (0.03 °C/m) [11]. Potential production of electricity, although not very likely in near future, would be profitable at only five (up to now) discovered locations with the temperature of hot water/steam above 120 °C, shown in the Fig. 6 and Tables I and II. Heat energy from other wells (with lower temperatures) could be used for heating purposes or in horticulture and agriculture industry (heating of greenhouses, drying and pasteurization of agricultural products) and for balneological and recreational purposes (spas and sport centers), for what it is traditionally

[5]Small hydro power plants are of size less than 10 MW.

exploited.

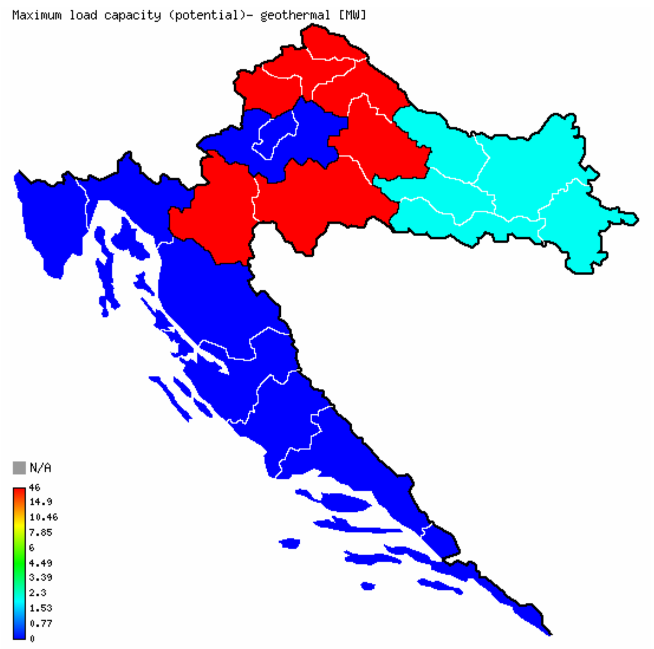

Fig. 6. Maximum load capacity of potential geothermal facilities (MW), given on NUTS II level.

III. RES Cost – Supply Curve

The resource availability and plant cost projection was combined to form electricity cost supply curve (Fig. 7). For cost projection, an estimation of electricity cost for existing facilities was used while for resource availability, the technological status, existing commitments on RES development and bearable fuel costs were considered.

The costs were estimated based on different publicly available sources. Published data was used plus consultations with a number of experts in the cases where information was unpublished. Nevertheless, the uncertainty in estimations is probably high (medium confidence level is declared). Medium confidence represents an intermediate resource estimate, for the most part a median estimate of uptake. Except achievable development rate the well proven resources of high confidence, assessed as readily able to be permitted and developed, were also taken into account.

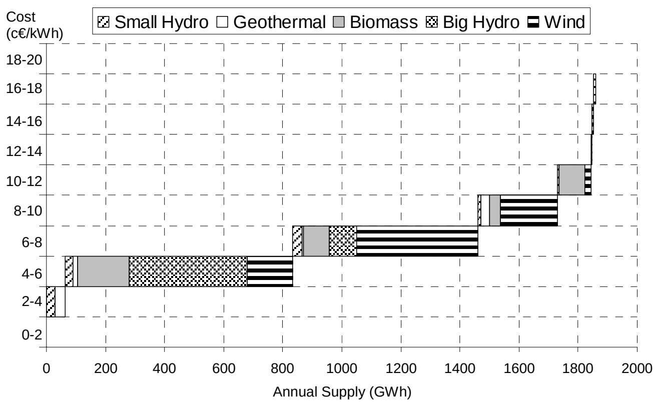

Fig. 7. RES cost – supply curve for 2010 (GWh).

The RES Electricity cost – supply curve was calculated on a basis of all planned/potential projects available. This histogram combines cost of electricity (Eurocent/kWh) with energy produced (annual GWh) from a specific energy source (solar, wind, biomass, geothermal and hydro). The technologies included in this analysis were considered as proven or commercial. The plant costs used are levelized unit costs for each project life. For every particular project the unit cost was derived by taking the present value of costs, i.e. capital, operation and maintenance, depreciation (including tax benefits of depreciation), fuel (where applicable), and it was divided by the present value of the kWh generated over the lifetime of the project. No revenue stream was included in this calculation. Various discount rates were used depending on the project and investor (e.g. discount rate for projects of the big companies like HEP and INA, which have access to favorable financial instruments, is 8% while the discount rate for projects financed with the loans given by commercial banks is almost 12%).

The current use of RES power generation systems was subtracted from the total assessed resource to obtain potential uptake by 2010 over and above the current usage (in 2005).

The facilities having costs above given specific threshold of 20 c€/kWh were omitted from the curves. That includes solar PV and some of the small hydro power plants. Then the potential projects were put in tight bands (of 2 c€/kWh) in the histograms depending on their energy supply costs, from the least to the most expensive one.

Not taking into account big hydro power plants, the second most attractive renewable resource in 2010 will be biomass, with 173 GWh electricity supply in the 4-6 c€/kWh cost band and 210 GWh in higher bands. For biomass plants, as for all other renewable technologies, energy production cost depend more on capital cost than it is the case for fossil fuel plants, where fuel has the biggest importance.

The most wind resource will be available in 2010 in the 6-8 c€/kWh cost band. As this technology is maturing resulting in progressive decrease of costs, some more resource will be also available in the cost band of 4-6 c€/kWh.

Some of the small hydro power plants exhibit the energy supply costs comparable (and even lower) to those of wind and biomass plants (88 GWh in 2-8 c€/kWh cost bands) but their availability is very limited since most hydro potential is already exploited while other available potential is subjected to strong environmental constraints. There were also 11 small hydro power plant projects that are not taken into account due to their substantial costs, which are higher than threshold value of 20 c€/kWh.

The power production costs of geothermal power plants are relatively low, comparing to other renewable sources, but its potential energy supply is not substantial due to low temperature energy of considered geothermal wells. The most probable geothermal power plant in Croatia, on locality Velika Ciglena (4.36 MW_e/34.32 GWh that could be increased to 13.1 MW_e/102.97 GWh in 2016) has the highest temperature of 170°C although the measured temperature at the surface is significantly lower. It should not exclude the possibility that some of these potential projects will be converted to heat generation facilities that will serve for space heating and in balneological/recreational purposes.

IV. Conclusion

The DEG based on RES in Republic of Croatia could find its niche most easily for users that will produce electricity for their needs and for users located in remote rural areas where there is no electricity network or the network capacity is insufficient (off-grid applications). The users (most likely small companies) that produce heat and/or electric energy for itself (like agriculture, wood and food processing industry) thus could control and reduce their costs of energy and achieve some sort of energy independence (e.g. applying cogeneration plant that uses biomass). They could also be grid-connected, islanded (off-grid) or embedded (in which case the extra generation could be sold to retailer). Examples of potential application of DEG based on RES in Croatia include: Hotels and apartment houses, restaurants, auto-camps, nautical marinas, sports and entertainment centers, mountain houses/chalets, also some facilities in rural and hunting tourism - in general all tourist facilities that are situated in remote isolated areas on islands and in mountains where there is no possibility of network connection or it would be too expensive to connect it or it is not permitted by environmental laws (e.g. in national parks and nature reserves); Cooling facilities for temporary storage of fish, meat etc., field ambulances (for electrical medical appliances and cooling of medicines), electrical fences for livestock ranching, autonomous electrical livestock/game feeders and water-troughs, for lightning and operation of agricultural facilities, hatcheries; Irrigation in deltas of rivers, water desalinization on islands; Telecommunication (base) stations, meteorological stations, lighthouses, road signs, public lightning, different autonomous monitoring systems (pollutant emission monitoring, forest fire protection, technical protection of individual facilities etc.); Households (permanent and weekend settlements) in isolated and rural areas (mountainous and coastal/island regions); Saw mills situated near small rivers where power from small hydro power plants could be produced; Hybrid combination of solar systems or wind turbines with LPG or diesel aggregates could help solve the problem of energy infrastructure on islands and other remote locations (region of Adriatic Croatia). Moreover, that could start development of traditional island activities with the engagement of local resources and workforce in accordance with the strategic development of Croatian islands [12]-[14], which in turn could result in slowdown of islands depopulation.

From all DEG systems based on RES analyzed as the most profitable ones show, now already technologically mature, wind power systems that are becoming commercially profitable in Croatia (particularly the big wind power plants with new feed-in tariffs) and also the biomass power plants. Comparison of the RES cost-supply curve with present situation shows that in 2010 more energy capability will be available at lower costs. Excluding the big centralized hydro power plants, the prevailing RES type in 2010 will be wind and biomass power. Despite having higher initial (capital) costs then wind power plants, biomass plants exhibit comparable energy supply costs. Further one, the power production from the biomass should be examined in wider social context of encouraging local employment and development of local business activities, particularly in rural areas, which finally contributes to their sustainable development.

If the external costs connected with global climate change and local pollution are included into electricity costs from conventional sources, which could reach almost 5.4 c€/kWh (for coal power plants, externalities included [15]-[16]), than the production of electricity from renewable sources becomes quite attractive because the utilization of these resources could help Croatia to fulfill Kyoto Protocol requirements, with the condition that the adequate incentives are provided. The annual energy supply of 1281 GWh from RES in 2010 (excluding the big hydro power plants) is also in concordance with the energy strategy of Republic of Croatia, where it is suggested that the minimal share of total electricity consumption coming from RES in 2010 should be 5.8% (or 1100 GWh/a).

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VI. Biographies

Daniel R. Schneider was born in 1967 in Zagreb, Croatia. He graduated from the Mechanical Engineering at the Faculty of Mechanical Engineering and Naval Architecture (FAMENA), University of Zagreb in 1993, and studied as postgraduate at FAMENA and Imperial College (UK). In 1993 he became a research assistant at the Power Engineering Department of FAMENA. Dr.sc. Schneider defended his PhD thesis in 2002 at FAMENA. In 2003 he was promoted to an Assistant Professor. He lectures at undergraduate and doctoral study at FAMENA and also at postgraduate study „Sustainable Energy Engineering" – International Master of Science Programme (FAMENA & KTH, Sweden). He is involved in many EU projects in the framework of programs as LIFE; FP6 etc. He is an author or co-author of 34 published papers.

Electricity from renewable sources - a new opportunity for companies from SEE

A. Špec, G. Škerbinek

Abstract – **Modern society is facing rapid electricity demand growth. Environmental problems are part of almost all serious discussions regarding electricity. Import dependency of European countries is rising, too.**

One of the solutions is to provide incentives to the use of electricity produced from renewable sources (RES-E). Electricity produced from renewables has many well known advantages. Countries from South Eastern Europe (SEE) have opportunity to become more active in the green certificate market. Tradable green certificates and Guarantees of Origin are well known and are used all over the EU. Tradable green certificates are commercially based confirmation papers which are agreed between parties. Guarantees of Origin are part of EU legislation and they are recognized in all member states.

Index Terms—**Tradable green certificates, RECS certificates, Guarantees of Origin, Renewable sources, South-Eastern Europe**

I. Introduction

ENERGY consumption is increasing with the development of society, despite essential improvement of technological procedures and efficiency measures. The development brings us new energy consuming devices which are accessible to an increasing number of customers.

Increasing of electricity demand requires new production facilities in the whole system. The biggest negative influence on environment occurs at the electricity production side.

Renewable sources (RES) are the best known solution for electricity production with minimum influence on environment. European directive on the promotion of electricity produced from renewable energy sources in the internal electricity market [1] requires from all member states to prepare their action plans on promotion of electricity from RES (RES-E). The directive also brings a clear definition which energy sources may be treated as renewable.

In a fully liberalized market electricity from RES is often uncompetitive, mostly because of high production prices. Nevertheless, the EU countries are trying to achieve higher share of electricity produced from RES, as required by the Directive [1]. To achieve this, they are using different types of support mechanisms. Well known and used are feed-in tariffs, tenders, quota obligations and fiscal incentives.

With tradable green certificates (TGCs) and guaranties of origin (GoOs), producers provide evidences that electricity was really produced from RES. The addition value of RES-E due to environmentally friendly production is formed on the certificate market. Certificate markets are a big opportunity for countries from South Eastern Europe (SEE), because they have a large potential for electricity production from RES.

II. Tradable green certificates and guaranties of origin

One of the most interesting tools for stimulating RES-E are tradable green certificates. A TGC represent an additional value of electricity due to its production in an environmentally friendlier way in comparison with the conventional way of production. This additional value can be traded in the certificate market.

A. Tradable Green Certificates and Certificate Market

A TGC represents an evidence that electricity was produced from RES. TGCs by themselves do not represent incentive for the use of RES-E. They should only be considered as a tool for achieving a transparent support system. Some possibilities of their use in supporting RES-E are given in the next chapter.

The main idea in TGCs is that the added value they represent is traded in a separate certificate market that is fully independent from the electricity market. This concept is shown illustrated in Fig. 1.

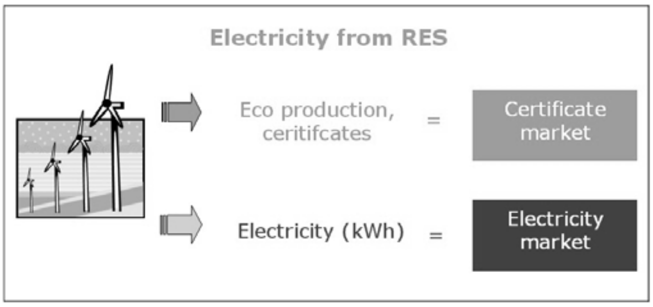

Fig. 1. Certificate and electricity market

From the illustration it is evident that electricity and certificates representing environmental benefits are fully separated and traded separately. At the end of the supply chain they should both end up at customers to satisfy their energy needs (electricity) and environmental requirements (certificates).

Electricity from renewable sources – a new opportunity for companies from SEE

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B. *RECS Certificates*

The best known TGCs are RECS (Renewable Energy Certificate System) certificates. RECS is a well organised certificate system with participants from 20 countries from Europe and other continents. The main characteristic of the system is that it contains many instruments for preventing any forms of fraud, such as multiple issuing, multiple selling or multiple counting of certificates. Certificates of this system are also widely recognised in many countries, especially in Europe.

The system was set up on the basis of idea that arose during the REALM workshop in 1998 in the Netherlands. The main initiators of the project of establishing RECS system were market players who saw their commercial opportunity in selling additional value of RES-E to the interested customers. In 2001 the system started its trial operation. It has been in normal commercial operation since the beginning of 2002.

The RECS system is organised regionally in domains with the main rules of the system being the same for all domains. Domains in most cases correspond with the borders of independent states, although it is not necessary. The main organisation in a certain domain is the Issuing Body (IB). It is an independent organisation that issues certificates and takes care of the whole RECS system in its domain. Issuing Bodies are usually TSOs, regulatory authorities or some other organisations independent from generation, trade and supply of electricity. IB also names some important supporting agents in the system, such as Production Registrars and Auditing Body. It is also responsible for setting up the Central Registration Database (CRD) of certificates. Having a central register of certificates is one of the basic prerequisites for prevention of multiple issuing and multiple selling of certificates. A RECS certificate is in fact nothing but an adequate electronic record in the CRD. The IB is obliged to specify all the domain specific features of RECS system in the document entitled Domain Protocol.

A RES-E generator who wishes to request issuing of RECS certificates for its generated electricity has to fulfil some basic requirements. Firstly, the generator has to fill-in Renewable Energy Declaration (RED), which includes some basic information about the RES-E production device. This declaration should be verified by the Production Registrar, who during a site visits checks the authenticity of the data from the RED. After this the verified RED data are entered into the CRD. Every producer who wishes to the data on the production devices into the database also has to pay an annual fee for the use of the database.

The producer who fulfils all the above conditions can request issuing of RECS certificates for electricity generated in the past period. This period is in principle the previous month, although it is possible to issue certificates for all electricity that has been generated since the date of verification of RED. Certificates are issued on the basis of readings of meters that measure generation of production devices. The correctness of meter readings sent to the IB is regularly checked by the Auditing Body. The certificates are issued in a standard form; each certificate represents 1 MWh of electricity generated from renewable sources.

Issuing of RECS certificates in fact means entering the adequate number of issued certificates into the CRD. The producer also pays for issuing of each certificate on the basis of the published tariff. The producer, to whom RECS certificates have been issued, can sell them to any interested party. Each transfer of ownership should be confirmed by the IB, which transfers the certificates in the CRG from the seller's to the buyer's account. This transfer can also be done between CRDs of different domains with different IBs.

When the final buyer wishes to use the certificate, for instance for meeting the RES-E quota obligation, the certificate is redeemed and thus used. After the redemption it is impossible to use the certificate for any more purposes. The redemption of certificates is also confirmed by the IB who transfers redeemed certificates into the register of redeemed certificates in the database from where it is impossible to move them to any other account in the CRD of its own domain of to any other CRD.

The participants in the RECS system are active in two separate international organisations. Traders and other stakeholders are members of the organisation RECS International. All Issuing Bodies of the RECS system are members of the Association of Issuing Bodies (AIB). Both organisations closely co-operate in further developing not only the RECS system but also other forms of electricity certification. AIB is also responsible for laying down the main rules of the RECS system, which are brought by the document called PRO (Principles and Rules of Operation) [2]. The General Meeting of AIB must also approve each Domain Protocol before it comes into force.

RECS system has been operating in Slovenia since 2004 with the Energy Agency acting as Issuing Body.

C. *Guaranties of Origin (GoO)*

Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market [1] requires from member states to establish a system of Guarantees of Origin (GoO) for electricity produced from RES. The directive itself does not bring many requested details the system of GoO in the EU Member States must fulfil. The directive does not require central database of GoOs, neither does it require MS to introduce redeeming of GoOs. From the directive text it is even unclear whether GoOs should be electronic or paper documents. The only fact, which was found very confusing when the EU Member States started to design their own GoO system, was the explicit request that GoOs should be clearly distinguished from TGCs. The Directive only requires that GoOs should contain information on energy source from which electricity was produced, date of production and in case of hydroelectric installations, their capacity. The directive also doesn't say anything about measures to prevent fraudulent behaviour of market players. But it does require that GoOs should be mutually recognised by all EU Member States.

In spite of very ambiguous definition of the Directive many EU Member States introduced GoO systems that contain most of advantages of RECS system. These advantages include Central Registration Database and redemption of GoOs. Such systems have been introduced mostly in those Member States that have a clear vision about the use of GoOs. Another Member States which only wanted to implement provisions of the Directive [1] in the easiest was without thinking what they will be used for.

The Association AIB has also been active in the attempts to transfer the experiences gained in operation of RECS system into the GoO system. These efforts have led to establishing of EECS (European Energy Certification System) system. This system enables issuing of Guarantees of Origin on the basis of the uniform standard which facilitates transfer of GoOs and their recognition by another EU Member States. The EECS system is designed as an open system and it will be possible to expand it with other types of certificates or GoOs (e.g. disclosure certificates, CHP GoOs, etc.).

The area of GoO is in Slovenia regulated by the Energy Act [3] and by the Governmental Ordinance [4]. Both acts implement not only the RES-E Directive [1] but also the CHP Directive [5]. The GoO Issuing Body for Slovenia is Energy Agency of the Republic of Slovenia. The Slovenian GoO system is a pure certificate system based on Central Registration Database, in which GoOs are just another form of certificates. The main difference between the systems of Slovenian GoOs and RECS is that the former system is defined and made obligatory by the national legislation, while the latter represent only an entrepreneurial initiative of an international group of market players.

III. Use of Tradable Green Certificates and Guarantees of Origin

Taking into account the abovementioned fact that in most of the EU countries there's no essential difference between GoOs and TGCs, it can be concluded that they can be used for exactly the same purposes. The main purpose of both TGCs and GoOs is to provide evidence to the customer that electricity supplied to him/her was indeed produced in the way claimed by the supplier. This can encompass both primary source of electricity (e.g. hydro, wind, solar, etc.) and generation technology (e.g. CHP). Below there are some examples of their practical use:

- **Green electricity products** – suppliers offer electricity from renewable sources to the market. The price of this electricity is by rule higher than the price of usual "grey" electricity. Such electricity is usually sold under a specific trademark. Since electricity suppliers are usually not able to bring electricity from a specific power plant, such as small hydro PP, to their customers through a direct line, they acquire the adequate number of TGCs or GoOs from this power plant or another power plant of the same type. At the end of the year the suppliers redeem the exact number of TGCs or GoOs that correspond to the quantity of electricity the buyers of individual green electricity product consumed in the past year. The suppliers can also require issuing of special paper certificates of redemption, which are used to provide an additional proof to the customers that electricity supplied to them was really produced from renewables and that all benefits rising from such kind of production really belong only to them. Green electricity products represent a part of voluntary electricity market, a market to which the players enter on fully voluntary basis, usually due to their environmental awareness. This is so until the state intervenes, e.g. by prescribing obligatory quotas of electricity from renewables (RES-E) or enabling tax reductions for customers buying green electricity products. In such a case the customers are no longer driven only by their environmental awareness but by other factors, too. They make it difficult to clearly distinguish between obligatory and voluntary market.
- **Obligatory fuel mix disclosure** – in addition to green electricity products that represent a fully commercial activity of electricity suppliers in the market, there is also a general obligation of all suppliers in the European internal electricity market to publish their fuel mix of the preceding year on the issued electricity bills. This area is in Slovenia regulated by the general act [6], issued by the Energy Agency on the basis of provisions of the Directive on Internal Electricity Market [7]. The suppliers are obliged to publish their overall fuel mix comprising both green electricity products and the remaining "grey" electricity. The suppliers can use redeemed TGCs or GoOs as evidences of renewable share of their fuel mix portfolios. Central Registration Database of GoOs can also be used as a central national registry of RES-E for the purpose of fuel mix disclosure. In such case the suppliers can on their electricity bills specify only the shares of RES-E that correspond to the number of GoOs redeemed on their account.
- **Monitoring the fulfilment of prescribed RES-E quotas** – the state authorities can prescribe minimum quotas that have to be fulfilled by individual suppliers. The suppliers have to substitute the missing quantities of RES-E by buying adequate number of TGCs or GoOs. This creates a certificate market in which a market price is formed on the basis of relation between supply and demand. Such mechanism can fully or partly replace the existing non market based support mechanisms, such as the current Slovenian feed-in tariff mechanism.
- **Meeting of national indicative targets of RES-E** – the countries that have surplus of electricity generated from renewables with regard to their national indicative targets as defined in the Directive [1], can export their surpluses to be counted towards meeting the importing country's target. Guarantees of origin can be used for this purpose only if the exporting country accepts explicitly, and states on a guarantee of origin, that it will not use the specified amount of renewable electricity to meet its own target [8]. Since these indicative targets will only have to be met in 2010, there have been no such transfers of GoOs so far.
- **Implementation of certificate based RES-E support systems** – in some European countries there are special RES-E support systems established that are based on GoOs. Such systems are distinguished from the purely market based support systems based on

prescribed quotas for suppliers. They are systems where the holders of TGCs or GoOs submit their certificates to the authorised organisation which redeems them and pays the certificate holders the value of RES-E support on the basis of redeemed quantities and known prices of each redeemed kWh of certificates or GoOs. Advantage of such system is that it prevents double selling of additional environmental benefits from generation facilities that are eligible to receiving support. In a support system like the current Slovenian feed-in tariff system, the generators receive payment of feed-in tariffs and are at the same time eligible to requesting GoOs for the same quantity of electricity generated. This enables them to sell such GoOs and thus receiving double support, the first arising from the feed-in tariffs and the second by selling GoOs in the market. A developed market with aware market players can limit selling of such GoOs, if they are properly earmarked that electricity for which they have been issued has already received support. Market players in such market will avoid buying earmarked GoOs or will pay lower price for them. If the market is not adequately developed, the generators can benefit from unaware market players. This shortcoming can be avoided by paying the support only after the adequate number of GoOs has been presented to the authority and redeemed.

IV. Possible use of RECS certificates in the SEE countries

The area of SEE is very rich in RES-E. In Croatia, Bosnia & Herzegovina and Serbia & Montenegro the share of renewables in the total national generation structure ranges between 30 and 60 %. The vast majority of these percentages represents electricity from large hydropower plants. It should be stressed again at this point that, according to the Directive [1] and the rules of RECS system, electricity from large HPPs is renewable and therefore eligible to be certified by RECS certificates or GoOs. Other countries from the region, especially Romania and Albania, have significant portion of RES-E generation, too.

On 25 October 2005 the countries of South East Europe signed in Athens the Treaty establishing the Energy Community. According to Article 20 of the Treaty, it is up to each Contracting Party when it will implement the Directive [1]. This means that at this moment it is not yet possible to predict when the SEE countries will start issuing Guarantees of Origin in line with the provisions of the directive. Since the markets in this part of Europe are mostly still in the phase of their development, it is not realistic to expect voluntary markets to develop there before the actual start of issuing of GoO.

The best opportunity at the moment for the SEE countries seems to join RECS system as soon as possible and to sell RECS certificates to the markets with adequate demand. RECS systems established in their countries would in the period until their full integration into the European Internal Electricity Market enable them to earn some money by selling certificates and at the same time to gradually develop their own voluntary RES-E markets. According to the experiences from the West European countries it is expected that the voluntary markets will not develop very quickly. Nevertheless, the most important is that it will start developing and the initial volumes of trade in these markets will really be of secondary importance.

On the other hand, it is not to expect that the importing markets of these certificates will be reluctant to recognise RECS certificates from SEE countries. It should be stressed once again that system of RECS certificates is a very reliable system with almost no possibilities of fraudulent behaviour. The fact that these countries will for a certain time not yet have their own GoO systems in place will be an additional argument for recognition of RECS certificates in the countries that otherwise require only GoOs as a proof of greenness of electricity they import from the EU countries with their GoO systems already in place.

SEE countries can start establishing their own RECS system by naming Issuing Bodies in their territories. These IBs will then have to find all necessary supporting agents, such as Production Registrars and Auditing Bodies. The IBs will also have to establish their CRD or sign a contract with one of the existing database providers. All the details of the new system will have to be written down in the Domain Protocol for this domain. In the meantime the IB will have to apply for the membership in AIB. Only after becoming a full AIB member and after the approval of the Domain Protocol by the AIB General Meeting the RECS system in a new country can begin its operation. According to the Slovenian experiences this process takes at least one year.

Another option that offers faster and cheaper solution is integration of new RECS countries into existing RECS domains. This means that a SEE country that wishes to start participating in the RECS system can join one of the existing domains. The IB of this domain will only have to modify its Domain Protocol and ask for its approval at the AIB General Meeting. This process is much faster than establishing its own domain and can be completed in a few months. This would not mean anything new for the organisation of RECS domains, since in some EU countries it is already the case that one RECS domain with on IB covers more than one country. One of such examples is Belgian Issuing Body which issues RECS certificates and prepares Domain Protocol for the domain comprising Belgium and Luxembourg. Joining an existing domain, such as Slovenia, with already established and functioning IB seems reasonable for SEE countries also due to the fact that their participation in the RECS system will most probably be a solution only for transition period until their full implementation of the Directive [1].

V. Conclusions

The area of electricity from renewable sources is very important for SEE countries, especially due to very suitable generation structure in the region. It will help establishing environmental awareness through gradual development of green electricity market in these countries and at the same time enable companies in these countries to earn by selling RECS certificates to the markets in EU. This will also contribute to progressive integration of SEE electricity market into the internal electricity market of the EU.

VI. References:

[1] Directive 2001/77/EC of the European Parliament and of the Council of 27 September 2001 on the promotion of electricity produced from renewable energy sources in the internal electricity market

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Renewable Energy in Western China – Part II: Support Policy

Xu Xiangyang, Su Zhengmin, Andrej F. Gubina

Abstract-- **This paper is the second in a two-part series that present an overview of the development in the renewable energy sources (RES) in the West Region of China. In the first part, we present the RES potentials of Western China, and in the second part, we propose some recommendations for RES policy development for the region, based on the European Union experience and international best practice.**

In this paper, we analyze two cases based on Tibet and Sichuan provinces located in West Region of China (WRC). We identify various barriers that hinder RES development in WRC. Based on examples from EU experience we propose policy measures to stimulate RES development in WRC and present some instruments for its implementation.

Index Terms— **biomass, China, EU, geothermal, renewable energy sources, solar, support policy, wind.**

I. RES and EU Experience

THE European Union now imports 50 % of its energy needs, while in 25 years, the share is forecast to rise to 70 %. Coupled with the increasing share of fossil fuel, this situation makes EU vulnerable economically, politically and with regard to the environment. To follow-up on its commitment to reduce its dependency on fossil fuel imports, as highlighted in the Commission's Green Paper on Security of Energy Supply [1], and to reduce greenhouse gas emissions, a joint strategy for promotion of renewable energy sources (RES) in EU has been set up.

As an attractive option to diversify the EU's energy supply, RES are available locally, they bring environmental benefits and they contribute to employment and the competitiveness of the European industry. Support for renewable energy is needed as long as technologies are still developing and market prices for non-renewable energy do not reflect their full costs to society due to subsidies and external costs. By the year 2010, the EU set the goal to double the share of renewable energy in national gross energy consumption to 12 % (White Paper "Energy for the future", [2]) and to provide 21 % of the electricity from RES (RES-E), [3].

The EU Member States have set up national targets for the consumption of RES-E and they can choose their preferred support mechanism. The different mechanisms used in Member States have met mixed success in promoting the consumption of RES-E according to the national indicative targets, including cost effectiveness, cost efficiency, compatibility with the internal market, and the ability to develop different technologies.

European experience shows that to increase the share of renewables in each sector of the energy system, a comprehensive regulatory framework has to be set up. The main objectives were:

- Removal of economic barriers to the development of RES by introducing financial support mechanisms and promotion schemes, and
- Mitigation of non-economic barriers such as administrative barriers, market imperfections, technical obstacles and grid restrictions.

In deployment of RES-E, two aspects are important: sufficient financial support and the reduction of barriers to RES development.

II. Barriers to RES Development in China

In this chapter we investigate some issues that are perceived as barriers to development of renewable energy in China. We focus on West Region of China, as it has the highest potential for RES development.

A. Poverty Economy and Low Purchase Power in WRC

Compared to East Region and Middle Region of China, West Region of China (WRC) is the poorest region of China. Most people in WRC live in the countryside, where there are unfavorable conditions for economic development and energy consumption. The GDP value per capita was only 5,006 RMB in year 2001, amounting to 66.4 % of the average GDP of China and 40 % of the East Region of China. Of 23 million people in China that don't have access to electricity, half of them live in WRC, mostly in the provinces of Yunnan, Sichuan, GuangXi and Chongqin. Their residence is usually far from electricity grid, and their electricity load is small and dispersed. In the mountain area of WRC, the construction fee of extending electricity grid is much higher than the other provinces of China. Lack of access to electricity severely restricts the activities of the population and prevents economic development, keeping the inhabitants too poor to afford electricity.

B. Investment Costs of Renewable Energy Projects

Of nearly 30 million people who can't access electricity in China, most of them live in WRC, especially in Yunnan, Sichuan, Guangxi and Chongqing. The areas rich with renewable energy sources are usually the ones in which the inhabitants do not have access to electricity. However, the

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cost of RES is usually much higher than the cost of conventional energy. When compared to a coal power plant of comparable size, in China the investment costs for a hydropower plant are 1.2 times higher, for a biomass power plant 1.5 times higher, for a wind power 1.7 times higher, and for a solar (Photovoltaics) are 11-18 times higher.

In China, national development of technology is preferred to technology import. The development of renewable energy technology is much more expensive than development of conventional energy technology and requires a long development cycle as well as a big amount of financial investment. The lack of technical standards in the field of RES is also an important barrier to RES development.

In the absence of electricity market, clear rules for free third party access, electricity company that enables RES generators to connect to the grid and purchases the electricity from them can dictate the prices at will. Usually the price of electricity is too low even for large wind projects, including some CDM projects. Even after China issued the "Renewable Energy Act" [4], this phenomenon still persists [5]. In WRC, small scale power generation technique and solar photovoltaics power generation technique should be listed as the first priority to RES technology development.

Obviously, there is a big gap between the demand for electricity and the purchase ability in no-electricity area of WRC. The high cost of renewable energy and few users that could afford it restrained the development of RES. At the same time, the small size of the market is also preventing the cost of renewable technology to decrease, completing the vicious circle.

C. Management issues

In China, influenced by conventional ideas, the renewable energy was classified as rural energy or regional energy for quite a long time. To stimulate the development of renewable energy was considered as a method to increase poor farmers' welfare and to improve the underdevelopment of countryside in China. This management method caused the renewable energy policy to deviate from conventional energy policy. In China, the renewable energy projects were operated and managed by different governmental sectors. For example, small scale hydropower projects are governed by Ministry of Water Resources or local governments. On the other hand, while the commercial utilization of solar energy is operated and managed by companies, the light utilization projects of solar energy are managed and operated by specific offices in different Ministry or departments, such as National Development and Reform Commission, State Economic and Trade Commission, Ministry of Science and Technology, and Ministry of Agriculture. The situation is similar in wind power generation projects. While micro- and small scale wind power facilities are in the hands of the commercial companies, large scale wind power projects belong to national and local governments. In biomass and biogas projects, the National Development and Reform Commission approve projects, Ministry of Agriculture manages them, and the State Economic and Trade Commission oversees them. There is no uniform administration department, so it is difficult to operate. As the main development region for renewable energy is in the countryside, this administration method is bringing inadequate results.

D. Financing Problems

Western Region is the most underdeveloped region of China. Due to low energy prices, the rate of return on investment is very low, decreasing the investment interest from local government, industry groups and private. In most WRC, the initial investment for renewable energy is higher than conventional energy projects. At the same time, the investment methods and financing channels are rudimentary. For renewable energy projects there is no equal investment system, which is customary to conventional energy projects. Due to difficult financial situation in WRC, caused by low income, creditworthiness and self-financing ability of farmers, the RES projects are lagging behind.

E. Market Environment

Although there are rich RES resources in WRC, there are also big gaps between the supply and the demand side in RES market of WRC. On the supply side, the investors of RES projects focus only on private profits without raising awareness of RES in general public to establish stable renewable energy market. On the demand side, the renewable energy belonged to "rural energy" for quite a long time, having the stigma of backwardness. Both sides lack support in national policies, lack of stable financial sources and virtually non-existent marketing.

III. Proposed RES Support Policy for WRC

A. RES Support Policies in EU

A number of different instruments are being used in EU member countries to support the development of RES, [6]. The most important ones are mentioned below:

Investment incentives: establish an incentive for the development of renewable energy projects as a percentage over total cost, or as an amount of Euros per installed KW. The levels of these incentives are usually technology-specific and may vary significantly between regions.

Feed-in tariffs (FITs): are generation based fixed price incentives that usually take the form of either a total price for renewable production, or an additional premium on top of the electricity market price paid to RES-E producers. A specific price is normally set for several years that must be paid by electricity companies to domestic RES-E producers. The additional costs of these schemes are paid by suppliers in proportion to their sales volume and are usually passed through to the consumers.

Production tax incentives are generation-based price-driven mechanism that work through payment exemptions of electricity taxes applied to all producers.

Tendering systems can either be investment focused or generation-based, but in both cases they are capacity-driven mechanisms. The state places a series of tenders for the supply of renewable electricity, which is then supplied on a contract basis at the price resulting from the tender. The additional costs generated by the purchase of renewable electricity are passed on to the end-consumer of electricity through a specific levy. Pure tendering procedures existed in two Member States (Ireland and France). However, France has recently changed its system to a FIT combined with tendering system, and Ireland has just announced a similar move.

Quota obligations based on Tradable Green Certificates (TGCs) are generation-based capacity driven instruments. These instruments are usually implemented through government defined targets and obligations on consumers or suppliers of electricity. Renewable electricity is sold on the market at the market prices. To finance the additional cost of producing green electricity, and to ensure that the desired green electricity is generated, all consumers (or in some countries producers) are obliged to purchase a certain number of TGCs from RES-E producers according to a fixed percentage, or **quota**, of their total electricity consumption/production. Since producers/consumers wish to buy these TGCs as cheaply as possible, a secondary market of certificates develops where renewable electricity producers compete with one another to sell green certificates.

Policies are interdependent, and need to adapt to the continuously changing market environment. The following issues impact the success of the EU directives:

- Enlargement of the EU: new opportunities for the exploitation of RES (esp. bioenergy).
- Interaction with other objectives and policies, e.g. environmental policies,
- Completion of internal EU energy market [7], in which free consumer choice fosters enhanced competition. In addition to that, possibilities exist to distinguish green products from conventional power supplies. RES-E impact is enhanced by required disclosure of fuel mix and environmental impact.
- Interaction with the Common Agricultural Policy (CAP reform) [8], which is a highly important element of a consistent RES support strategy.
- The establishment of a carbon market - greenhouse gas Emissions Trading Scheme [8], affecting the economic value of investment in RES-E.

The European Commission proposed a process of optimizing of national economic mechanisms and removal of administrative and grid barriers. EU Member States shall optimize and improve the success of their support schemes by enacting the following measures [10], [11]:

Increase of legislative stability and reducing investment risk. Since one of the main concerns with national support schemes is their stop-and-go nature of a system, such instability in the system creates high investment risks, resulting in higher costs for consumers. Thus, the long-run stability and reliability of support system is needed to reduce the perceived risks. Reducing investment risk and increasing liquidity to minimize unnecessary market risk is an important issue, notably in the green certificate market. Increased liquidity could improve the option of long term contracts and will give a clearer market price.

Reduction of administrative barriers, including the streamlining of administrative procedures for access support schemes should minimize the burden on consumers. Clear guidelines, one-stop authorization agencies, the establishment of pre-planning mechanisms and lighter procedures are concrete proposals to Member States in addition to the full implementation of the RES Directive.

Review of grid issues and the transparency of connection conditions. Transmission reinforcements need to be planned and developed in advance based on the fully transparent and non-discriminatory principles of cost bearing and sharing. The necessary grid infrastructure development should be undertaken to accommodate the further development of renewable electricity generation. The costs associated with grid infrastructure development should normally be covered by grid operators. Finally, the pricing for electricity throughout the electricity network should be fair and transparent, taking into account the benefits of embedded generation.

Encouraging technology diversity. Some support schemes tend to support only the strongest of the renewable technologies in terms of cost competitiveness. A good overall support policy for renewable electricity should preferably cover different renewable technologies. For instance, offshore wind energy would usually not be developed if it came under the same financial framework as onshore wind power. Such schemes could therefore be complemented with other support instruments, in order to diversify the technological development.

IV. Instruments Recommendation for WRC

China should take the international experience as a reference to promote renewable energy development. The steps to set up RES support policy that need to be investigated include setting of the goals of renewable energy development strategy, definition of methods, financial instruments and activities for RES promotion, definition of responsibilities, setup of a process for monitoring and evaluation of progress towards targets, and policy review/improvement process. The policy needs to be implemented in state regulations and national laws.

In this chapter we investigate RES potentials of two WRC provinces, Tibet and Sichuan, Fig. 1. They share some common traits, but are different in many ways, so the policies for RES support need to adequately reflect this.

Fig. 1 Chinese provinces

A. Financing Channels for RES Projects in Tibet

Qinghai-Tibet altiplano is the source of the main big rivers of East Asia and South Asia. There are 365 rivers with the total amount of water resources of more than 660 billion m^3. Due to the abundance of water resources in Tibet and its high position, the theoretical hydropower resource reserves are estimated close to 200 GW, the annual power generation amount can reach 1,760 TWh, and the technically exploitable hydro potential is estimated at 116 GW, about 30 % those of China [12].

Tibet is also in the leading position of geothermal application in China. The total installed capacity of geothermal power plants in Tibet is 28 MW. In Yang Bajing power plant, the installed capacity is 25.18 MW. Besides Yang Bajing geothermal field, there are three other proved geothermal fields.

Tibet is one of the richest solar energy regions in the world. The annual sunlight hours are between 1600-3400 hours. The number of days with more than 6 hours of sunlight per day is between 275-330. The total annual irradiance amount is 7 GJ/m2. West Tibet and North Tibet locate in rich solar energy regions, occupying 2/3 of Tibet area.

In the future years, hydropower, geothermal energy and solar energy projects constitute the main renewable construction projects of Tibet. The complex geological features and difficult transport conditions for fossil fuel increased the costs of conventional energy projects and decreased the gap between the construction costs of RES and conventional energy sources. This is why RES projects have better opportunities in Tibet, [12].

For solar photovoltaic projects and wind power projects, government investment is the main channel of financing for Tibet. Because of its dispersed nature, wind power and photovoltaic projects are more economical than construction of diesel oil power plant and extending electricity grid. There are a few banks and industry enterprises would like to invest in such projects.

For geothermal thermal projects, biomass projects and wind projects, the CDM (Clean Development Mechanism) should be introduced and used in Tibet. The geothermal energy has been widely used for heating, vegetable growing, recreational facilities, health protection and tourist industry. Still, the market potentials for geothermal applications are far from exhausted. Based on these applications, geothermal CDM projects can be shaped and can get financial investment from international markets.

Wind power projects and biomass projects in Tibet also have a possibility to become CDM projects, because the methodology for wind power generation project have been approved by the Executive Board of United Nations. Compare to other CDM project, wind projects can get approved more easily, so China has considerable experience with registration of wind CDM projects.

Tibet also has a lot of storage grain. The storage grain is an ideal resource to covert into ethanol. This can provide fuel for transportation and to substitute the petroleum consumption in Tibet. China has mature techniques for grain conversion to ethanol. This project can avoid CH_4 emissions from uncontrolled burning and decay of the storage grain. Beside the storage grain, there are big lands in Tibet, which can grow grain for energy purpose.

B. Financing Channels for RES Projects in Sichuan

Sichuan province is located in Sichuan basin of China. It is a big province of China with rich natural resources and large population. The total area is 485,000 km^2, the population in Sichuan province was 87.5 Million by the end of 2005, which ranks the third biggest population province of China. It is the biggest population province of WRC. Sichuan province is the first province in China to practice reform policy. The economy growth is fast, the annual GDP growth was 8.8 % in “Ninth Five-Year-Period”. In year 2005, the GDP of Sichuan was 738.51 billion RMB, which ranks the 9^{th} of main land of China and the 1^{st} of WRC.

Sichuan is a big energy production and consumption province. Besides rich renewable energy resources, Sichuan also has many coal resources, petroleum and natural gas resources. The exploitable energy amount is 27.492 billion tce. Among them, the hydropower energy is 8.57 GW, covering about 22.63 % of total amount in China. Biomass resources are abundant; there are 42.12 Million tons of straw and stalks, firewood 11.89 Million tons, human and animal waste 31.48 Million tons produced every year. Solar energy, wind resources and geothermal resources are rich too. The theoretical reserves of hydropower in Sichuan are 142.76 GW and the theoretical power generation amount is 1,250.6 TWh per year, the second biggest reserves in China (after Tibet).

Hydropower resources of Sichuan are suitable for small scale power stations below 25 MW. It was estimated that there are 1600 sets of exportable small power stations. The established Er Tan power station is the biggest hydropower station of China constructed in 20^{th} century with the installed capacity of 3.30 GW.Up to now, only 10 % of total hydropower resources have been exploited, far below the average utilization level of China.

Wind resources are distributed in West Altiplano Mountain area, influenced by monsoon of Qinghai-Tibet Altiplano and monsoon of East Asia. Part of the Altiplano regions of Ganzi state and Liangshan state of Sichuan are wind utilization region. The annual effective wind density is more than $100W/m^2$, the annual number of utilization hours is between 3000-5000 hours.

Firewood is the conventional energy in the rural place of Sichuan province. The total exploitable potential of firewood is 12.03 Million tons, equivalent to 6.97 Mtce. Straw and stalks are mainly distributed in Sichuan basin and hill region, the theoretical reserve is 51.22 Million tons, equivalent to 25.00 Mtce, with the exploitable amount of 24.20 Mtce.

Usually, the human and animal waste in rural of Sichuan is used as fertilizer; only in pasturing area, it is directly used as fuel. The theoretical reserve of excrements of human and animal waste in Sichuan is 47 Million tons, which equivalent to 22.35 Mtce, with the exploitable amount of 14.50 Mtce.

While Sichuan has rich geothermal resources, the geothermal resources are distributed widely, but not evenly. According to statistical data, the utilized geothermal resources amount to 30 % of total geothermal resources. It is mainly used as hot water in industry and agriculture production, travel and recuperation purposes.

Unlike Tibet, Sichuan has good economy background. Sichuan has too much energy resources, the conventional energy is abounded, such as coal, petroleum, natural gas. In Sichuan, it is cheap to access various energy resources. The consequence is too much energy-related pollutant emissions. There is big gap of construction fee between renewable energy projects and conventional energy projects, posing the difficulty to develop RES projects in Sichuan. The profitability calculation of RES project in Sichuan should take into account of the return of investment for renewable energy projects as well as for capital operations.

The following instruments are recommended to be used in Sichuan for stimulating RES projects:

Small scale hydropower projects are the first priority to develop in Sichuan. The government should provide investment subsidies and low interest loans. Tax reduction and exemption policy are proposed, in combination with tendering systems.

In **wind projects**, tendering systems will be used to decrease the price of electricity. In addition, subsidies, tax reduction and exemption policy will be used. The society would share the total cost of RES projects

For **biomass projects**, tax reduction is proposed, coupled with favourable pricing for the construction materials used in the RES projects and low interest loan for biomass projects.

In addition to national support schemes, CDM will be promoted to be used in various renewable energy projects.

V. Conclusion

Energy services are a fundamental human need and are thus indispensable for human well-being. Inadequate access to electricity is closely linked to a range of social concerns, including reduced economic and social opportunities contributing to poverty, poor health, and reduced educational attainment, particularly for women. National government should make efforts to reduce the gap between WRC and East Region of China and let more people to access electricity. In the paper, we have analyzed the potentials of West Region of China for RES, the international experience with RES support policies, and proposed some instruments and measures that could be successful in promotion of RES in West Region of China.

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VII. Biographies

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Techno-economic characteristics of wind energy use

V. Bukarica, M. Božičević Vrhovčak, Ž. Tomšić, R. Pašičko

***Abstract*-- Among all renewable energy sources, wind energy use has increased most rapidly over the last decade. The aim of this paper was to give a comprehensive overview and explanation of technical, economic and environmental characteristics of wind energy use. Technical guidelines for designing wind power installations taking into account the wind speed properties of a given location are presented. Factors influencing the amount and quality of electricity produced are thoroughly discussed. Since wind is an intermittent energy source, it can cause certain problems in overall power system operation, which need to be treated with special care. The paper also gives guidelines for economic evaluation of wind power projects. Although often claimed differently, wind energy use has also some adverse environmental impacts, which named in the paper. The current and future role of wind energy in total energy supply in Croatia is discussed and some interesting examples for wind power installations are given.**

***Index Terms* — Croatia, technology, economics, environment, EU, wind**

I. Introduction

ENERGY sector is now days facing two major challenges – ensuring security of energy supply and mitigation of adverse environmental impacts. The enhanced use of renewable energy sources (RES) is for sure significant part of the solution for both of these problems. Thus, their increased use is one of the baselines of the European Union's energy strategy. The objective of European Union for 2010 is to increase the share of RES to 12% of gross energy consumption and 21% of electricity production [1].

Among various RES types, the special role plays wind energy due to its prominent and fast penetration into power system. Namely, the installed world capacities have grown in time period 1993-2005 from 2.900 MW to 57.837 MW which correspond to an annual average growth rate of 28,4% through the last ten years [2] as it can be seen in Fig. 1. The EU target of 40 GW of wind turbine installations by 2010 has already been reached - in 2005 installed capacity has reached 40.455,4 MW. According to the newest estimates, wind energy origin electricity production has reached 69,5 TWh in 2005, which corresponds to a little over 2% of total EU electricity production [2]. The EU share in total world installed wind power capacities at the end of 2005 was equal to 70,6% and the share in market for generating equipment was equal to 60,3%.

The Republic of Croatia has also recognized the significance of RES use. According to the latest proposals, minimal renewable energy target in Croatia will be set to 1100 GWh or 5,8 % of electricity consumed in 2010. Among all RES that are abundant in Croatia, the largest interest currently is in wind energy use. Assessed wind potential is significant – 400 MW installed capacities and 800 GWh per year electricity production are results from analyses of 29 locations [3].

Due to very fast technology development and increased penetration into power systems, it is important to understand all aspects of wind energy use.

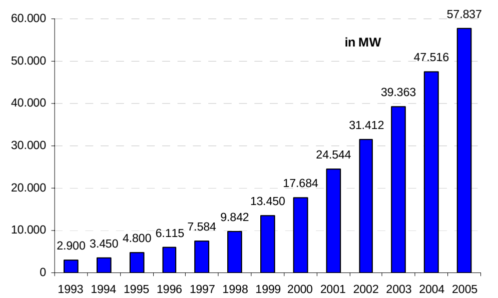

Fig. 1. Total wind power installed in the world since 1993

II. Technical Characteristics of Wind Energy Use

A. Wind Characteristics

Wind is intermittent energy source. Stochastic nature of wind can be very well described with probability density functions. It is very important for the wind industry to be able to describe the variation of wind speeds in order to optimize the turbine design, to minimize generating costs, and to maximize income from electricity generation. Long-term distribution of observed wind speeds conforms well to the well-known Weibull probability density function. Preparation of wind power project must thus primarily include measurement of wind speeds and directions. Usually measurements are performed at 10 m height above the ground and results are then extrapolated to the heights relevant for wind turbine placement (usually 50 m or above).

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B. Wind Turbine Characteristics

A wind turbine turns the kinetic energy of the wind into mechanical energy. Wind passes over the blades exerting a turning force. The rotating blades turn a shaft inside the nacelle, which goes into a gearbox. The gearbox increases the rotation speed for the generator, which uses magnetic fields to convert the rotational energy into electrical energy

It is very well known fact that the wind power *P* is proportional with the cube of the wind velocity *v*:

$$P = \frac{1}{2}\rho A v^3 \quad (1)$$

However, due to various losses the maximal usable wind power is equal to 59% of the theoretical value, which is known as a Betz coefficient. In the reality wind turbine efficiency is approximately 40%.

There are several aspects considered at turbine design [4]:

- orientation of axes (vertical or horizontal),
- number of blades and
- types of rotor power regulation (pitch or stall).

All modern turbines have horizontal axes, so this aspect will not be addressed in much more details.

Most modern wind turbines are three-bladed designs with the rotor position maintained upwind. Two-bladed and one-bladed wind turbine designs have the advantage of saving the cost of one or two rotor blade and lower turbine weight. However, they require higher rotational speed to yield the same energy output. This is a disadvantage both in regard to noise and visual intrusion.

There are two principal means of limiting rotor power in high operational wind speeds - stall regulation and pitch regulation. Stall regulated machines require speed regulation. As wind speed increases, providing the rotor speed is held constant, flow angles over the blade sections become steeper. The blades become increasingly stalled and this limits power to acceptable levels without any additional active control. For this to work, the speed of the rotor must be held essentially constant, which is achieved through the connection of the electric generator to the grid. Briefly, a stall regulated wind turbine will run at approximately constant speed in high wind, not producing excessive power and yet achieving this without any change to rotor geometry. Pitch regulation involves turning the blades about their long axis (pitching the blades) to regulate the power extracted by the rotor. In contrast to stall regulation, pitch regulation requires changes to rotor geometry. This involves an active control system to sense blade position, measure output power and instruct appropriate changes of blade pitch. The objective of pitch regulation is similar to stall regulation, namely to regulate output power in high operational wind speeds. For pitch and stall, costs are quite similar for each design type, but pitch regulation offers potentially better output power quality and pitch regulation with independent operation of each pitch actuator allows the rotor to be regarded as two independent braking systems for certification purposes.

The latest developments of wind turbine technology are directed towards turbines with higher rated power especially for off-shore applications, larger rotor diameter, development of new materials for lower blades mass, increased "grid friendliness" (variable speed drive) and off-shore applications.

C. Electricity Production from Wind Energy

Annual amount of produced electricity should be calculated according to expected wind characteristics. Total electricity produced from wind turbine E_T in specific time period *T* depends on the wind velocities *v* and is determined by the following equation:

$$E_T = T\int_0^{\infty} P_v\, p(v)\,dv \quad (2),$$

where P_v denotes wind turbine power at wind velocity *v* and *p(v)* is Weibull wind velocity probability distribution function.

Apart from windiness of the site, the amount of electricity produced from a wind turbine depends also on wind turbine availability, which denotes the capability to operate when the wind is blowing and is typically 98% or above and on the way the turbines are arranged (the ideal position for a wind turbine generator is a smooth hill top, with a flat clear fetch, at least in the prevailing wind direction).

The energy production is calculated based on the power curve of a selected wind turbine and on an average wind speed at hub height for the proposed site. The typical power curve is shown in Fig. 2. The calculation should also include losses of energy transformation as well as wind potential assessment uncertainty factor (usually 10%).

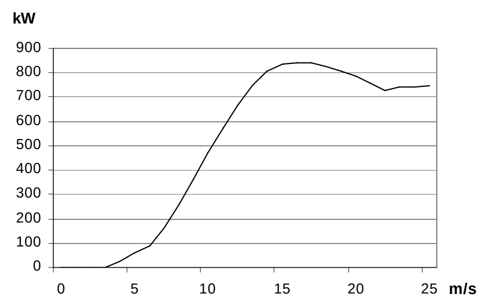

Fig. 2. Typical wind turbine power curve

D. Electric Generators Concepts

Apart from stochastic nature of energy carrier, what distinguishes wind power plants from conventional once is a power source, i.e. electricity generator. There are three types of wind turbine-generators couplings:

- constant-speed turbine coupled with squirrel-cage induction generator,
- variable speed-wind turbine coupled doubly fed (wound rotor) induction generator and
- variable speed-wind turbine coupled with direct drive synchronous generator.

A squirrel cage induction generator is an asynchronous machine, composed of a squirrel cage rotor and a stator with three distributed windings directly coupled to the grid. The wind turbine rotor is coupled to the generator through a gearbox. Substantially this is a constant speed wind turbine because the power converted from the wind is limited by designing the turbine rotor in such a way that its efficiency decreases in high wind speed. This kind of generators always consumes reactive power and is not able to control and regulate the voltage level. Hence capacitors close to these generators are necessary to avoid a voltage decrease. The concept is shown in Fig. 3.

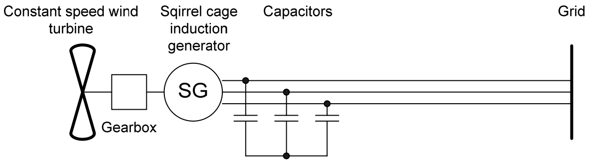

Fig. 3. Squirrel-cage induction generator system

Doubly fed induction generators are the most widely used for units above 1 MW. Wind turbine is coupled with doubly fed induction generator, which has a wound rotor with the windings being externally accessible via slip rings. The wind turbine rotor is coupled to the generator through a gearbox in the same way of the constant speed generator. The rotor current is regulated using power electronics, allowing the generator to operate over a relatively large speed range. A doubly fed induction generator's rotor is connected to the grid through a back-to-back voltage source converter. The concept is shown in Fig. 4. This concept enables to use variable speed wind turbine and to adjust its mechanical speed to the wind speed, which allows turbine operation at the aerodynamically optimal point for a certain wind speed range. Variable speed operation allows higher efficiency in generating system.

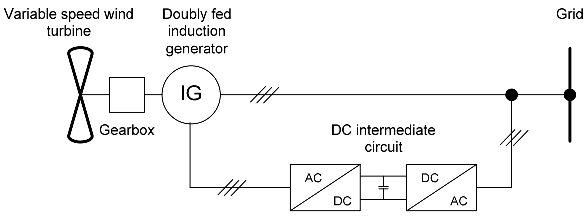

Fig. 4. Doubly fed induction generator (DFIG) system

Direct drive synchronous generator is completely decoupled from the grid by a power electronics converter connected to the stator winding, as shown in Fig. 5. The converter is composed by a voltage source converter on the grid side and a diode rectifier (or a voltage source converter) on the generator side. The direct drive generator is excited by an excitation winding or permanent magnets. In direct drive synchronous generator system, turbine and generator shafts are coupled directly, without gearbox. This allows variable speed operation over a wide range. Generator used in such systems is high-pole synchronous generator designed for low speed. Due to high number of poles this generators are quite large. The solution is found in direct drive concept but with single stage gear box with low ratio. Hence, the required number of poles is lower and generator is smaller.

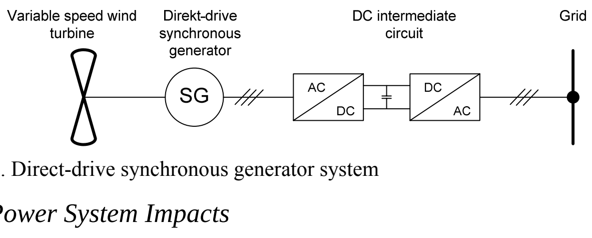

Fig. 5. Direct-drive synchronous generator system

E. Power System Impacts

The wind power characteristics are reflected in a different interaction with power system [5]. There is a distinction between local and system-wide impacts.

Local impacts occur at each turbine or farm and are largely independent of the overall wind power penetration level in the system as a whole. They include following aspects:

- branch flows and node voltages,
- protection schemes, fault currents, and switchgear ratings and
- power quality: harmonic distortion and flicker.

The local impact is highly dependant on the electricity generating system used within the wind power plant. For example, squirrel-cage induction generators do not affect node voltages since they have a fixed relation between rotor speed, active power, reactive power, and terminal voltage. On the other hand, variable speed turbines have, at least theoretically, the capability of varying reactive power to affect their terminal voltage. Also, squirrel-cage induction generators contribute to the fault currents, while in systems with power electronics, due to its sensitivity, this might not be the case. Harmonic distortion are an issue when power electronics is involved, while for constant-speed wind turbines based on directly grid-coupled asynchronous generators harmonics are not the issue. Flicker could be a consequence of wind fluctuating nature, which is directly translated into output power fluctuations in the case of constant speed turbines, while in general, no flicker problems occur with variable-speed turbines, because in these turbines wind speed fluctuations are not directly translated to output power fluctuations.

Unlike local impacts, system-wide impacts are impacts that affect the behavior of the system as a whole. They include following aspects:

- power system dynamics and stability,
- reactive power and voltage control and
- frequency control and load following/dispatch of conventional units.

Important requirement that is imposed to wind generators is the ability to maintain stability during normally occurring power system disturbances. Premature tripping of numerous wind generators due to local disturbances can be a risk for stability of whole system. It is especially the case for systems with high concentration of wind generating facilities. The impact on the dynamics and stability of a power system is strongly dependant on the wind turbine - generator concepts and every system should be analyzed by it self in order to simulate the fault ride-through ability. For example, during a fault, squirrel-cage generators accelerate due to the unbalance between mechanical power extracted from the wind and electrical power supplied to the grid. When the voltage does not return quickly enough, the wind turbines continue to accelerate and to consume large amounts of reactive power. This eventually leads to voltage and rotor-speed instability. On the other hand, sensitivity of power electronics in variable-speed wind turbines can cause instability in power system operation, especially those with high wind power penetration. Thus, system operators are now days prescribing that wind turbines must be able to withstand voltage drops of certain magnitudes and durations, in order to prevent the disconnection of a large amount of wind power at a fault. In order to meet these requirements, manufacturers of variable-speed wind turbines are implementing solutions to reduce the sensitivity of variable-speed wind turbines to grid voltage drops.

The impact of wind power on reactive power generation and voltage control originates first from the fact that not all wind turbines are capable of varying their reactive power out-put. However, two other things have to be considered. First, wind power cannot be very flexibly located when compared to conventional generation, so the voltage control aspect can not be as easily considered as in case of conventional generation. Second, wind turbines are relatively weakly coupled to the system because their output voltage is rather low and because they are often erected at distant locations, which further reduces their contribution towards voltage control.

Wind power hardly ever contributes to primary frequency regulation, due to intermittent nature of the prime mover. Further, the variability of the wind on the longer term (15 minutes to hours) tends to complicate the load following with the conventional units that remain in the system, as the demand curve to be matched by these units (which equals the system load minus the wind power generation) is far less smooth than would be the case without wind power. This heavily affects the dispatch of the conventional generators. The impact of wind power on frequency control and load following becomes more severe the higher the wind power penetration level is.

In order to find the best control and operating strategies that will power system stability, detailed analysis with simulation models for every specific system should be carried out.

III. Economic Characteristics of Wind Energy Use

Economics of wind power projects (WPP) should be evaluated in the same way as any other investment. Economic analyses of investment projects are based on the progress of future cash flows during the lifetime of the project and evaluation of project cost effectiveness using various profitability indicators, like payback period, net present value and/or internal rate of return.

The main parameters governing wind power project economics include the following [6]:

- Investment costs;
- Operation and Maintenance (O&M) costs;
- Electricity production/average wind speed;
- Turbine lifetime (lifetime of the project);
- Discount rate.

First two items denote the most important WPP expenditures, while the third denotes WPP revenues.

A. Wind Power Project Expenditures

The largest share in WPP costs are attributed to the investment or initial costs. They most usually include costs for preparing a feasibility study (preparation works at the micro-location like measurement of wind velocity and direction, geological assessment, etc.), performing the project development functions (power purchase agreement, permits and approvals, land rights issues, etc.), completing the necessary engineering (electrical, mechanical and civil design, tendering documentation and contracting), purchasing and installing the energy equipment, the balance of plant (wind turbine(s) foundations(s) and erection, road construction, transmission line, additional substations, transportation costs) and costs for any other miscellaneous items. The energy equipment and balance of plant are the two cost categories showing the strongest dependence on the number of wind turbines that make up the wind farm. Hence, the larger the wind farm, the more relative weight these two categories represent. Table I suggests typical ranges of relative costs.

TABLE I
Relative Investment (Initial) Costs of Wind Power Plant [7]

Cost category	Large Wind Farm (%)	Small Wind Farm (%)
Feasibility Study	<2	1-7
Development	1-8	4-10
Engineering	1-8	1-5
Energy Equipment	67-80	47-71
Balance of Plant	17-26	13-22
Miscellaneous	1-4	2-15

Annual O&M costs usually include land lease, property taxes, insurance premium, transmission line maintenance, parts and labor, travel and accommodation and general and administrative expenses.

Two more things should be included in WPP expenditures: cost of capital and depreciation. Costs of capital strongly depend on the way the project is financed, i.e. the structure and dynamics of the financial means use and terms of their use (debt ratio, debt term and debt interests). Depreciation of material assets is the reduction in value of an asset by the end of its lifetime.

B. Wind Power Project Revenues

The most important WPP revenues come from electrify sales. They are strongly dependant on the amount of the produced electricity and its price. Wind origin electricity price depends on the electricity production price in the power system, on the legislative framework and on the electricity market organization. In fully liberalized electricity market, electricity could be soled in the prompt market or on the basis of bilateral agreements. The price will depend on the daily load diagram. In every hour, the average electricity price is dictated by the most expensive power production unit in the system. However, in the most European countries, renewable sources are eligible producers with guaranteed favorable purchase price for the total amount of electricity production. This price is either guaranteed in its full amount or prescribed as a price cap on the electricity market price. In the most countries, feed-in tariffs are prescribed for every renewable source and it is aimed to guarantee feasibility of the RES project. Sensitivity analyses of economic evaluation results strongly emphasize the importance of incentive electricity purchase price for overall cost effectiveness of WPP.

C. Specific costs and electricity production costs

According to usual initial (investment) costs, specific costs per installed kW of wind power plant can be calculated. The cost per kW typically varies from approximately 900 €/kW to 1.150 €/kW.

The calculated costs per kWh wind power as a function of the wind regime at the chosen sites are shown in Fig. 6. As shown, the cost ranges from approximately 6-8 c€/kWh at sites with low average wind speeds to approximately 4-5 c€/kWh at windy coastal locations. The electricity purchase price is crucial for WPP cost effectives.

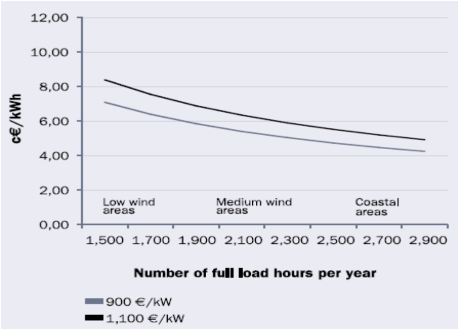

Fig. 6. Calculated costs per kWh produced using wind power

IV. Environmental Characteristics of Wind Energy Use

As all power production facilities, wind turbines have environmental impacts, which include noise, visual impacts, atmospheric emissions during the materials processing and components production, birds' mortality and electromagnetic interference [8].

Noise from wind turbines can be of mechanical and aerodynamic origin. Aerodynamic noise is caused by interaction of the turbine blades with the surrounding air. Mechanical noise is due to the moving parts in the nacelle and it is transmitted to the environment both directly through the air and via the rest of the structure, including the tower [9]. The noise problem is the most emphasized wind turbine environmental impact. However, modern turbines are seldom heard at distances further than 300 m as background noise from wind in trees, for example, will be higher.

The impact of wind turbines on visual amenity is the most controversial and difficult to quantify. In general, concern over visual impact is highest in areas of special importance and beauty and it is clear that care should be taken in the sitting and design of the turbines in other areas. Techniques for assessing visual impacts exist and are used within the planning process for wind power plants.

Although there are no direct emissions to the atmosphere caused by wind turbine operation, emissions from non-operational phases of the life cycle do exist. It has been shown that atmospheric emissions from the wind fuel cycle are insignificant in comparison to those from fossil fuels [9].

The major potential impact of wind turbines on birds are collision in flight with turbines and behavioral disturbance from blade avoidance. Although numerous studies show that birds rarely collide with rotor blades this is an issue sometimes raised.

The electromagnetic signals may be reflected from the turbine blades, so that a nearby receiver picks up both a direct and reflected signal. Interference occurs because the reflected signal is both delayed (due to difference in path length) and Doppler shifted (due to the blade motion). However these problems can be minimized by careful sitting of a wind facility.

V. Wind Energy Status in Croatia

Renewable energy sources have already quite large share in total energy production and total energy supply in Croatia, which is a consequence of the large share of hydro power. When it comes to electricity production, 51% of installed capacities are in hydro power plants. Apart from hydro power, there is very small share of other renewables in electricity production, as shown in Table II. In 2004 the share of RES excluding large hydro power plants was equal to approximately 0,8% of total electricity consumed.

TABLE II
INSTALLED RES CAPACITIES AND ELECTRICITY PRODUCTION IN CROATIA IN 2004 [11]

Type of RES	Installed power capacity	Electricity production
Sun	12,74 kW	12,63 MWh
Wind	5,95 MW	1,96 GWh
Biomass	0	4 GWh
Small hydro	26,7 MW	126,3 GWh
Geothermal	0	0
TOTAL	32,663 MW	132,27 GWh

However, according to the Strategy of energy sector development [12], renewables will gain more significant role in Croatian energy supply and their increased use is one of the most important strategic goals of Croatian energy policy. The Strategy considers three different scenarios all characterized by the increase of RES use from approximately 75 PJ in year 2000 to 100 PJ (business-as-usual scenario), 130 PJ (moderate scenario) and 160 PJ (distinctively ecological scenario) in year 2030.

Wind potential assessed within the national wind energy program ENWIND in 29 locations equals to about 400 MW and electricity production capacity equals to 800 GWh per year [4]. These potentials can be exploited in Croatia in one of the following ways:

- On-grid installations (wind farms);
- Off-grid installations (hybrid systems);
- Water pumping, desalinization and irrigation installations.

The most usually considered applications are central-grid electricity generation facilities – wind farms. Currently there is only one wind power plant in operation in Croatia – a 5,95 MW wind park at the island of Pag for which a power purchase agreement has been signed by the investor and the Croatian power utility. A similar agreement has been signed for a wind power plant Krtolin near Šibenik which is yet to be constructed with a planned capacity of 5 MW as well as a wind power plant near Obrovac with a capacity of about 10 MW. The interest for wind potentials exploitation comes mainly form foreign investors. However, one good example can be found within Croatian industry. Namely, Končar Group, the leading electric industry in Croatia, has a strategic goal to wider their activities to wind power. Since Končar already produces all necessary electric equipment like generators and switchgear, they have decided also to develop own wind turbine concept. It is expected that the first wind turbine prototype will be erected by the end of September 2006. In this way the completely domestic product will be developed. These aspects of RES use – creating new employment opportunities and strengthening domestic industry – are extremely important and socially beneficial, but still not emphasized strongly enough. The significant work, especially measurements ad mapping of wind potentials, has been done within ENWIND program. The program has also suggested a pilot project of 6,3 MW wind power plant Stupišće on the island of Vis. Thorough analysis of that proposed project has shown that crucial for project liquidity and profitability is properly defined (guaranteed) electricity purchase price. The lack of complete regulatory framework for RES use in Croatia is exactly the main barrier to increased RES penetration into Croatian power system!

Off-grid installations are applicable in remote areas, especially islands. However, all inhabited Croatian islands are connected to the mainland electric grid and there are no plans for an energy autonomous island. However, there are some proposed projects for autonomous tourist settlements. For example, hybrid energy system for tourist settlement on the island of Brač would include a photovoltaic solar power plant and a wind power plant for electricity production and solar thermal collectors for thermal energy production. The excess electricity would be used for hydrogen production and for sea water desalinization [10]. These kinds of demonstration projects could contribute to the technology development, but also to the increased attractiveness of tourist settlements, improved island economy and revering the project of island depopulation.

According to analyses performed within ENWIND program, in Croatia wind energy can also be successfully used in water pumping systems and production of drinking water. This is especially case for Dalmatian Background and Adriatic islands, where agricultural activities are limited due to adverse hydrological conditions. With wind power irrigation system it is possible to accumulate water surpluses from winter period and to use accumulated water in dry summer season. For islands irrigation systems it is possible to obtain sufficient amounts of water thorough reverse-osmosis desalinization process, in which wind power will be used for necessary electricity production. In ENWIND program, the suggestion for pilot project on the island of Vis is suggested. Vis has its own water resources that are not sufficient for current demand in summertime and that are far from sufficient for any serious agricultural activity. This kind of wind powered irrigation system will ensure both drinking water supply for town Komiža and irrigation of cultivated areas.

VI. Concluding Remarks

The aim of this paper was to highlight technical, economic and environmental characteristics of wind energy use. Wind energy is a renewable energy source that has encountered the highest growth in the past decade. The wind power technology development is very dynamic and directed towards larger machines, off-shore applications, improved operational and control strategies and reliable wind forecasting methods. This strong technology development has also led to a fall of around 20% in generation costs, enabling in that way wind power to compete with alternative forms of electricity generation, in some countries even without requiring any special support. However, in most of the countries, included Croatia, wind origin electricity generation is still not competitive with conventional electricity generation and needs financial support provided by proper legislative and regulative framework. The lack of it can be freely marked as the most important obstacle to higher wind and renewables in general use in Croatia as well as in whole Western Balkans region.

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VIII. Biographies

Vesna Bukarica was born in Osijek, Croatia, on September 26, 1977. She graduated from the Faculty of Electrical Engineering and Computing, University of Zagreb in 2001. She acquired her M.Sc. title from the same faculty in 2006.

Her employment experience included Ekonerg, Končar – Power Plant and Electric Traction Engineering and the Faculty of Electrical Engineering and Computing, where she is currently employed. Her fields of professional interest include energy efficiency, environmental impact of electricity generation and renewable energy sources.

Maja Božičević Vrhovčak was born in Zagreb, in 1972. In 1996 she graduated at the Faculty of Electrical Engineering and Computing, University of Zagreb. She defended the Master's thesis in 2000, and her Ph. D. thesis in 2005.

Since 1996 she has been employed at the Faculty of Electrical Engineering and Computing as a junior researcher. Her fields of professional interest include environmental impact of electricity generation and renewable energy sources.

She is a member of several professional associations.

Željko Tomšić was born in Vrbovec, Croatia, on July 27, 1957. He graduated from the Faculty of Electrical Engineering and Computing, University of Zagreb in 1981. He acquired his M.Sc. title in 1990. and Ph.D title in 2001, from the same faculty.

Except Faculty of Electrical Engineering and Computing, he is currently employed on a position of Assistant minister for Energy and Mining in Ministry of Economy, Labour and Entrepreneurship.

His fields of professional interest include power system planning, impact assessment of power plants, environmental protection in power system, energy management, energy conservation and energy auditing in industry.

He is president of supervisory boards for both HEP and JANAF, and member of various professional societies.

Robert Pašičko was born in Koprivnica, Croatia, on May 22, 1979. He graduated from the Faculty of Electrical Engineering and Computing, University of Zagreb in 2003.

During his study he attained two summer trainings abroad. His employment experience includes Exor – power department, and the Faculty of Electrical Engineering and Computing, where he is currently employed. His fields of professional interest include emissions trading, renewable energy sources and environmental impact of electricity generation.

Potential for PV application in the mountainous and highlands regions of Croatia

Uros V. Desnica, Dunja Desnica-Frankovic and Mario Rakic

Abstract-- **The potential for wider application of photovoltaics to satisfy basic electricity needs in off-grid mountainous locations in Croatia was analyzed. The performance and costs of a small PV off-grid system is analyzed by detailed and realistic computer simulations. It has been found that, by using existing subsidies and incentives for RES offered to these areas (up to 80% off from commercial prices), the cost of a PV system of 1 kWp could be decreased below 1600 €, which would mean price of electricity of about 0.31 €/kWh during the warranty lifetime of PV modules (20 y). Satisfying basic needs for electricity by PV would open new opportunities for sustainable socio-economic development in isolated rural regions of Croatia**.

***Index Terms*—Computer simulation, Croatia, mountain regions, highlands, off-grid, photovoltaic, PV, RES, solar electricity, solar energy**

I. Introduction

Croatia is a small Mediterranean country (in total 56.610 km^2) [1] but with considerable variations in topological and climatic conditions. According to geographical characteristics, Croatia is usually divided into 3 parts [2]: Pannonian, low-laying area in the northern and eastern part; Mediterranean coastal region, and highlands area, stretching parallel to the coast, along and behind the coastal mountain wall. Regarding the height, 21.0% of total Croatian territory is mountainous; higher than 500 m above the sea level; additional 25.6% is between 200-500 m above the sea level.

The main reason for the dramatic variation of climatic conditions is an unbroken chain of mountains stretching all along and parallel to the coast, separating the narrow coastal regions with typical Mediterranean climate, from inlands, which have a continental climate with less sun and harsher winters. As a consequence, the average yearly global radiation on the horizontal plane varies considerably (Table I), ranging from approx. 1100 kWh/m^2 year in some parts of inlands up to over 1600 kWh/m^2 year in southern part of the Adriatic coast and islands. Table I gives daily average values for few characteristic parts of Croatia.

Great potential of exploiting solar energy is evident for the coastal region, where the intensity of solar radiation in summer months is very high and coincides nicely with the strongly increased demand for both electricity and domestic hot water due to tourism.

TABLE I

A comparison of global solar radiation (10-y. averages) at horizontal planes for different parts of Croatia.

location/region in Croatia	yearly average kWh/m^2 day	July, kWh/m^2 day	January kWh/m^2 day
Croatian coast, south	4.2-4.4	6.6-7.0	1.7-1.8
Croatian coast, middle	3.4-4.2	6.0-6.6	1.2-1.7
Coast, north and continental flat	3.3-3.4	5.8-6.1	0.9-1.2
Zagreb (inlands, flat)	3.2	5.7	0.9
Inlands, mountains	3.3-3.9	5.8-6.6	1.1-1.6

However, what is less obvious, is that solar energy has a great prospective in continental, mountainous areas as well. Within EU FP6 Program RISE we have studied the technical, economical and socio-economical aspects of using photovoltaic (PV) conversion to supply with electricity isolated, off-grid location in such highlands locations in Croatia. In this paper, we are presenting a summary of these results.

II. Continental mountainous areas

A. General

Croatian highlands and mountainous areas are very different both from maritime and plane-inland areas, in practically every aspect. These are remote and often hardly accessible regions, generally sparsely populated, with population of less than 20 inhabitants/km^2, often only few, if any. Croatia as a hole, is not densely populated (averaging 85 inhab./km^2, comparing to 102/km^2 in Europe, 190/km^2 in Italy, 119/km^2 in Hungary, etc.) [2], but the population distribution is even more unfavorable. The whole regions are under populated and exposed to depopulation, the rural areas especially highlands, are almost emptied. This is hardly unexpected, since these are generally the poorest areas in Croatia, with no or very little industry, no enterprise nor economic development. Many of these scattered mountain locations were never connected to the grid at all.

These areas were also among the hardest hit during the latest war events (1991-1995). Devastation of houses and properties by the war did additional damage, so that many of these people live on the verge of existence. At many locations, part of the existing grid was destroyed during the latest war. Furthermore, part of the pre-war Croatian grid infrastructure near the border with Bosnia and Herzegovina (BIH) used to be connected and supplied from BiH. As after the war BiH become a separate, independent state, it is not likely that this part of the grid will be repaired in any foreseeable future.

However, slowly but surely, things are changing. Many of the numbered drawbacks are now becoming an

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advantage. Due to remoteness and low population density, along with beautiful, pristine nature, these regions are becoming an oasis in the polluted Europe, hungry for fresh air, clean spring water and ecologically grown food. Thus, the prospects of eco tourism and sustainable development are growing strong. In that respect, renewable energy sources could play an important role. RES applications are ideal for remote areas with low population density, rough and woody terrain where the gridlines are difficult to set and even more difficult to maintain. So the prospects of RES distributed locally and in prospective connected as microgrids [3] is an inviting and economically viable option.

Within the EU funded project RISE, we tried to tackle the existing se barriers to the wider scale application of renewable energy sources and especially in community-based projects, since for Croatia, overcoming mentioned barriers and giving communities a clear role and involvement in managing and planning their energy future and policy will have crucial role in increasing share of renewable energy sources. The use of success stories and/or demonstration projects is clearly essential to making real the vision of sustainability.

B. Applied methodology

In a study of application potential for photovoltaics for electricity production at isolated places, in the mountainous and highlands regions, the following methodology was applied:

1) Potential locations, candidates for study cases, were identified in Lika region, in counties Korenica and Donji Lapac. The main criterion in the selection process was that the locations were not connected to national grid, that the cost for grid installation is most probably too high to be economically feasible, and that the proposed design would have high replication potential for other off-grid locations.

2) Initial contacts with potential users have been established as well as with local authorities and utilities representatives. These locations were visited and technical specifics of selected locations were determined.

3) Priorities of electricity needs of inhabitants at selected sites were established. Detailed estimates of the expected electricity consumption (power demand) were determined based on the most important needs and daily habits.

4) Two types of systems to satisfy these electricity needs were designed and analyzed in detalis: a stand-alone PV system (consisting of PV panels, battery, inverter, charge controller, etc) or PV-diesel hybrid system.

5) Global radiation data on the inclined, specifically oriented surface were calculated using Meteonorm, a professional computer program [4]. Output data were prepared to be compatible with both PVSYST and RETScreen computer simulation programs.

6) PVSYST – a specific, specialized professional program [5] for simulations of PV or PV-genset hybrid systems, was used to analyze quantitatively and in detail selected PV-based systems and to optimize and assess all technical aspects of the system design. In addition, RETScreen [6], a standardized and integrated RES project-analysis-software was used for pre-feasibility, quantitative economic analysis of various PV systems. Our newly assembled Database of various Input data concerning PV solar systems and system components that are available at the Croatian market enabled realistic simulations for optimizing size/price ratio of RES systems.

III. Selection of potential locations

Long list of potential sites for RES applications in Lika region was obtained from local authorities and local dispatcher company. The visited and analyzed sites are listed in the Table II. The most interesting information, cost for grid instillation, obtained from the dispatcher company, is given in the fifth column.

TABLE II
Analyzed continental locations with number of households, inhabitants and cost for grid installation.

No.	Location	No. of houses	No. of inhabitants	Cost for grid installation
1	Busevic	1	3	120 000 €
2	Homoljac	1	3	42 500 €
3	Vujinove Glave	6	20	178 000 €
4	Corkova Uvala	1	Visiting scientists	N/A
5	Grabusic	1	3	100 000 €
6	Uvalica	1	2	170 000 €
7	Melinovac	1	1	160 000 €

Three different types of locations were taken into account: a) locations in the war-ravaged areas, still experiencing the consequences of war, like Bušević, Homoljac, Melinovac…; b) locations within the National Parks and Nature Park areas, that due to preservation and environmental reasons are not suitable for grid-connections, like Uvalica, Ćorkova Uvala, Bigina Poljana; c) locations that due to remoteness never had electricity, like Grabušić, which has been permanently occupied, or Vujinove Glave, occupied only during summertime.

Common characteristics of the visited locations is that: a) the number of inhabitants in the household would increase very soon should they get at least basic electricity, and b) that in the close neighborhood some houses would be soon repopulated if these elementary needs are satisfied.

Although we have concentrated in our analysis on the location #1 as a study case, very similar rationale applies to the other listed locations, as well as a great number of other similar ones. A number of potential locations are found within the Nature Park Velebit Mountain or the National Park Plitvice Lakes, consisting of a complex of sixteen cascading lakes, declared by UNESCO as the World's natural inheritance. Classical grid connected installations are quite inappropriate solutions since they interfere with the park integrity, require drastic cuts in woodland, scare wild animals, are expensive for maintenance, etc.. *Ćorkova Uvala* is an interesting location in the remotest part of the Plitvice Lakes NP. The Park Authorities would like to use it as a center for scientists and environmentalists investigating the Park area.

Our study case, Busevic village, is located on the rolling hills at the highlands near the Una river, close to the Croatian border with BiH. Administratively the village belongs to the not very prosperous Donji Lapac County. Prior to the last War in the region, the village comprised 65 households, now only seven are inhabited periodically. Villagers come mostly during the summer time, in an effort of restoring their property and repairing the demolished houses. Many are planning on returning permanently if the living conditions in the village would improve.

Only one house has been inhabited permanently for the last three years. The house was rebuilt by the authorities. The 220V AC installations in the house were provided with renovation. It is a simple and small single-level building, presently occupied by three persons. Their only occupation has been agriculture and goats rising. Providing refrigerating facilities, they would like to start cheese production and diversification of other products. For all these activities a supply of at least some electricity is indispensable.

After a thorough analysis of first priority needs and daily habits for such typical household, a power demand curves were constructed, and presented in Fig.1.

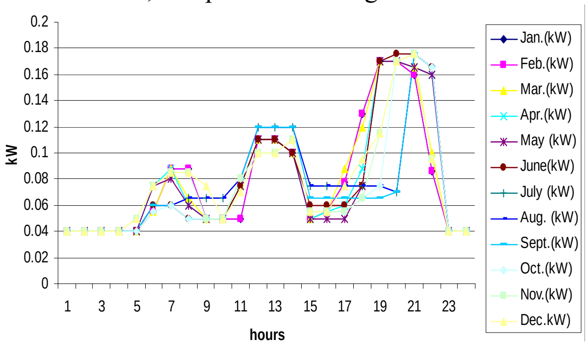

Fig.1: Graphical presentation of the estimated first priority loads, given as averaged monthly values in hourly time intervals.

First priority electricity load consists of several light-bulbs, a freezer, a water-pump and some small appliance, like cellular phone charger or similar. Expected electricity load data were organized in a standardized way, as averaged monthly values given in hourly time intervals.

IV. Technical aspects

A. *Solar radiation and climatic data*

For any location the reliable knowledge of global (total) solar irradiation is essential for the evaluation of solar potential and for the prediction of the performance of any solar-based device. In fact, values of both components of global radiation on horizontal planes– direct component (H_Bh) and diffuse component (H_Dh) need to be known, since for real, inclined receiving plane (say, roof) the diffuse component remains unchanged while the density of direct component can be increased by proper inclination and orientation. Generally, the long-term data (10-year average or longer) are necessary, but the number of meteorological stations in Croatia having such data is quite small. In this work, we have used *Meteonorm* computer program whose predictions of global radiation on horizontal planes at locations far away from measuring station are very reliable (to be presented elsewhere).

Monthly average of global radiation on horizontal surfaces (GlobHor) in kWh/m^2 per month, for one of the locations (Busevic), is shown in Fig. 2 as sum of Direct component (H_Bh) and Diffuse component (H_Dh) of solar radiation. Note that direct (beam) solar irradiation prevails in summer and diffuse irradiation in winter months.

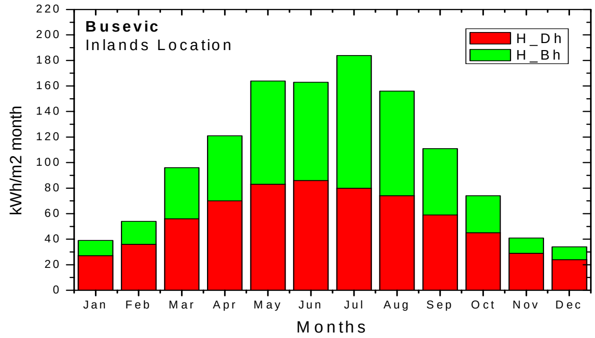

Fig. 2 Basic solar data for a representative mountain location

B. *Simulation of technical performance and economics of a solar PV-based system*

In this section, we present results of computer simulations for a stand-alone PV system (consisting of PV panels, battery, inverter, charge controller, etc) or for a PV-genset hybrid system. Sizing of system components depends, of course, on the expected load. Two loads (and than two sizes of PV- systems) are analyzed. First priority electricity load, labeled L1, consists of several light-bulbs (11 W each), a freezer (150 W), a water-pump (75 W) and some small appliance, like cell phone charger and radio, totaling about 1.7- 1.9 kWh/day, or 677 kWh/year. Total monthly load is about 60 kWh/month. Load estimates are based on priorities from the interview with household members, and on the assumed normal size higher quality appliances (class A). If very energy efficient, but also more expensive and not always readily available (class A+) appliances would be used, L1 would be lower, or the same L1 would include also some additional appliance (like TV), but that will not affect seasonal variation of the load.

C. *Basic PV-based solar system*

The PV-produced power is still relatively expensive and must not be wasted. Therefore, to minimize surpluses and waste, the PV system was dimensioned to completely satisfy basic electricity needs only when the solar supply is highest, i.e. during summer months. That implicates that electricity needs at other seasons will be covered only partly. We have performed a number of simulations with different loads, sizes and types of all elements of the PV system, and some examples are shown here. In the first example, a basic PV 500 Wp system (Wp denotes peak-watt, which is defined as the energy produced under standard conditions, i.e. 1000 W/m^2 of solar radiation at 25^o C) includes an array of high efficiency (13.3%) monocrystalline silicon modules with total surface area of 3.8 m^2, and a set of batteries of total capacity 400 Ah.

The analysis of seasonal variation has shown that L1 is pretty constant throughout the year: while the expected consumption of light-bulbs will be higher in winter months (shorter days) the electricity consumption of a freezer will be lower (smaller temperature difference between freezer set temperature and air temperature in the surroundings, especially if the freezer is placed (as expected and also recommended) in unheated part of the house. Hence, some seasonal imbalance between the load L1 (approximately constant) and PV supply is unavoidable, which will be obviously larger in summer than in the winter part of the year (Fig. 3).

Problem of the yearly imbalance of solar energy supply can be reduced by appropriate inclination of the plane with PV modules. Fig. 3 shows the available solar energy for different tilts of this PV system.

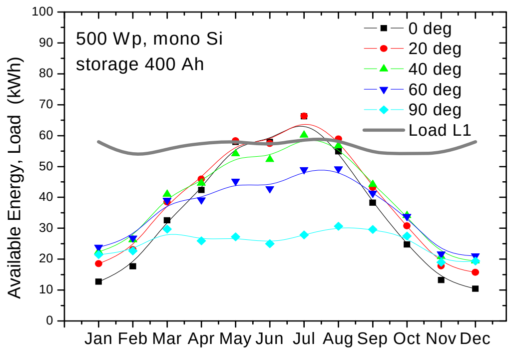

Fig.3: Available energy after all losses of the system have been subtracted, in dependence of the inclination slope of the solar panels. Values relate to the 500 Wp mono-Si plus 500 Ah battery system at the location Busevic.

Although tilting increases available solar energy by about a factor of 2 in winter months in comparison with energy on the horizontal plane, it is clear that tilting cannot solve the yearly imbalance completely. The effect is aggravated by the fact that percentage of diffuse radiation is high (Fig.2), so the effect of tilting, which affects only the direct component of global radiation, is strongly reduced. Inclination toward south up to 30-40^o increases both the total yearly irradiation per m^2, and (especially) irradiation in winter months. For even larger tilts the sum of solar energy throughout the year decreases again (for tilt 90^o , it is 1/3 lower than for the optimal tilt.).

Hence, tilt of 40^o was selected as optimal, especially since it also coincide to the tilt of the roof. Results of detailed calculations for the 500 Wp system for tilt 40^o toward the South are shown in Fig. 4. The following entities were analyzed: theoretically maximal energy form PV array (Edelivered), energy really available (Eavailable) after all expected losses are taken into account (efficiency and thermal coefficient of efficiency for the selected PV modules, PV-array losses, battery charging losses and system losses) and energy which, (for a given PV system load, and solar delivered energy), is not utilized (Eunused) for whichever reason, for example battery is full, etc. The Euser, the energy actually used by the consumers, and Emissing, the energy which user will not get from the solar system; are calculated and compared with the first priority load (Load L1) for each month of the typical year.

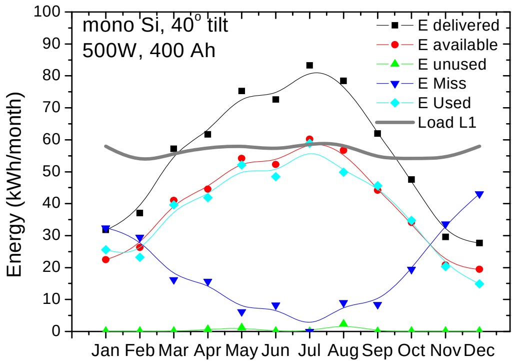

Fig.4: Delivered, available and used solar energy at Busevic location, for a small (0.5 kWp) PV system , together with first priority load, L1

The economic analysis of this specific basic system and the price of PV-produced energy is calculated based on the actual commercial prices in Croatia: 5,74 €/Wp, for PV module (5 pieces of 100 Wp modules, high-priced but also high quality and high efficiency module, having 20 year warranty), 177 €/100 Ah battery (4 needed) and additional 600 € for frame (support) of modules, regulator, inverter, setting, wiring and system integration. Calculations of performance and economics using RETscreen simulation program gave slightly more favorable (within 10 %) but essentially the same results.

The needed investment amounts in total to 4128 € for this basic system. If the purchase of the system is based on the fully commercial basis, over the lifetime of the modules (loan 8% over 20 year), taking into account the replacement of batteries every 6 years and 1% for maintenance/year, the total yearly cost (all taxes and expenses included) is 538 €/year. Energy cost per each solar produced and used kWh (476 kWh/year) is 1.13 €/kWh. All these prices are, of course, quite high. Still, when we compare the investment into basic PV system with the price of bringing the grid to this (or any other remote location, like those given in Table II) it is obvious that such investment pays off, even in worst case, i.e. on fully commercial bases. It is so not only for a single remote house, but also for the cluster of houses in some remote village. The prices can be somewhat lower if lower quality (and lower efficiency) PV modules are used, but then the area of modules needed for the same nominal power is higher (for amorphous Si solar modules about 2.5x larger area would be needed), and the system is less durable. Some reduction of price can be also obtained by reducing the size of the storage, although not more than 30% since then the battery-full loses start to increase considerably

The financial aspects become much more attractive if some incentives can be obtained – and that is possible up to a very high percentage. According to the Croatian *Law about regions of special governmental care, LRSG* [7], both counties *Donji Lapac* and *Plitvicka Jezera* belong to the first category (as well as territories within 15 km from the Croatian border, etc)., and have a number of privileges. For the considered case, the most interesting is the financial support that local (regional) communities can obtain from the *Fond for the ecological protection and energy efficiency* (ZOFU, [8]) for activities and projects related to protection of environment and renewable energy sources (Article 3). According to the Article 23 of the same document, the communities from the First category of *LRSG* are eligible for subsidies up to 80% of the investment. (Communities from the whole mountain/ highlands. region are entitled to 60% subsidies). Furthermore, Croatian Bank for rebuilding and development (HBOR, [8]) provides help by financing such projects with just 4% interest on the loan [9], and in combination with ZOFU the interest can be lowered to 2%. If indeed investor (local community or local electricity provider) succeeds in paying just 20% of the investment, then the investment into basic 500 Wp PV system becomes only 826 €, the total yearly cost 169 € (monthly bill of just 14€) and energy cost of solar electricity 0.35 €/kWh, which looks much more attractive.

The problem that remains is the missing part of the electricity load (about 1/3 of total, primarily in few winter months) which is not covered by PV solar. Sizing the PV system to satisfy the load throughout the year is out of question: such PV system would be about 2.5x larger (and as much costlier) and the percentage of unused energy would be enormous 43% (in comparison with 2% in the 500 W basic system). One option is to accept that in one part of the year the supply will be inadequate. The other option is to add a small back-up diesel genset to the basic PV system. The simulation showed that the addition of a 2 kW diesel genset could cover all missing load. It would add to the investment cost about 30€/year, and would spend about 200 liters of diesel per year.

D. *Larger solar PV system*

The other analyzed load, L2, estimated to be L2 = 1100 kWh/year was obtained when the electricity consumption of some additional household appliances is included, i.e. added to the basic needs (L1). These appliances were in interviews declared as important but not essential. They include TV, the refrigerator, some additional small appliances, and possibly a milking machine and a washing machine (the later ones if all above appliances would be of A+ class).
The analysis of seasonal variation of L2 group (Fig. 5) of electrical appliances has shown somewhat different distribution throughout the year than L1, which was basically uniform (Fig. 4). The consumption of some appliances from the group L2 (TV, washing machine..) are also expected to be essentially constant throughout the year, but some other (and larger) appliances (the refrigerator, milking machine...) are expected to have larger consumption in the summer part of the year. Hence, L2 is expected to be somewhat preferentially distributed in summer part of the year.

Simulations had shown that a PV system having peak power 1 kWp (7.5 m^2 of the mono-Si modules), and 700 Ah battery storage would be adequate, i.e. using the same criteria for sizing: such system would fully satisfy load during the summer months, and partly during the rest of the year. The main results of simulations are shown in Fig. 5. Due to somewhat different yearly distribution of the L2 load, the yearly solar fraction coverage of L2 is higher (81%), the solar energy that consumer can use (Eused) is also relatively higher, and unused energy is very small (just 3% of Eavailable).

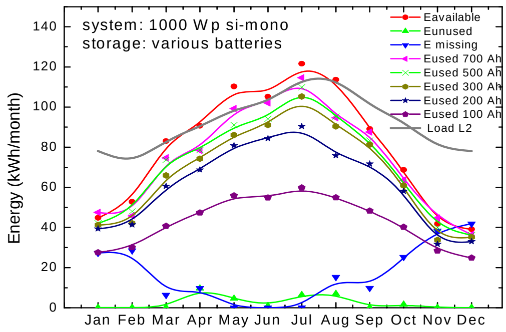

Fig.5: Delivered and used solar energy at Busevic location, larger load, larger system. The influence on Eused of reducing the storage capacity is also shown.

The price of this 1 kWp system and the price of the PV-produced energy is calculated in the analogous way as for basic system. For the realization of this 1 kWp system on the fully commercial basis (all taxes and expenses included) the investment would be 7879 €, the yearly cost over the warranted lifetime of modules would be is 1008 €/year, and the energy cost is 1.05 €/kWh (960 kWh/year). Again, if investor could benefit from subsidies and actually pay 20% of the full price, the actual price of investment, yearly cost and energy cost would be 1576 €, 302 €/year and 0.32 €/kWh, respectively.

Satisfying the part of the load L2 that is not covered by solar (19%) is much less critical if this larger PV system is used. First, that load (213 kWh/year, of which 42 kWh in the worst month, December) can be covered with a similarly small genset as in the case analyzed for basic PV system. More importantly, the 1kW PV system would practically cover basis needs (L1) throughout the year, so, with some inconvenience in few winter months, users could avoid genset altogether. One of advantages of PV is that devices are modular, so if a larger, say 2kWp system would be needed at some later time, it could be easily added later. It is important to say that if once in the future the remote user (or cluster of remote users, forming micro-grid) would be connected to the grid, the investment into PV would not be lost: for the user, the PV-system would continue to provide considerable savings in electricity, and for the grid provider, it would mean that lower installed power (and less expensive system to bring it to the user) would be needed.

V. Socio-Economic and Environmental Aspects

Environmental aspects: The proposed site in Busevic is a war-devastated location, 3 km away from the nearest local electricity network. The only feasible alternatives for the households are the diesel generator and RES. Given that the generator is environmentally unfriendly solution, the RES remain the most reasonable choice. Furthermore, since winds are not sufficiently strong in the area, nor the suitable hydropower sources exist nearby, a PV remains a good and environmentally favorable solution. The installation of PV is not polluting, has no negative impacts on the nature, and is in line with the new legal initiatives in Croatia regarding the wider incorporation of RES. Furthermore, PV system is additionally very welcomed in areas were grid-connections are discouraged due to nature-preservation policies or due to some specific environmental or some other reasons.

Economic aspects: According to the local utility representatives, in the remote mountainous areas an average electricity distribution is 1.2 consumers per square kilometer, and there are hundreds of places similar to our selected case study. Hence, the conventional grid-connected energy source cannot be expected in the foreseeable future. On the other hand, the introduction of the RES in the these remote communities would result in the people returning to the region, re-starting agriculture, possibly eco-, and cattle breeding, and contribute to the increase in the overall living and economic conditions. In addition, the development of a successful sector of renewable energy sources could in the long run contribute to diversification of energy production, decreased import of energy and significant reduction of the pollution from the energy sector. Furthermore, employment and all associated issues are today one of imperatives of the Croatian economic and social policy. Using RES provides new jobs openings, investment in rural areas, and retention of the income within local communities.

Social aspects: Migration to the neighboring cities or even abroad is the reality of the places like Busevic, which is especially the case with the younger population. However, the inhabitants in the visited households stated that if they would gain electricity, the other members of their family would return to live there. Hence, these cases are good examples how the introduction of electricity could help stop the depopulation. Not to underrate the fact that this RES incorporation would “spread news” to the neighboring communities and contribute to their environmental education. However, presently the level of knowledge, technological and practical, is quite low and an important part of the undertaking should concern the education as well. Only then, the wider introduction of RES and possible engagement of nearby local SME could be expected. Local administration seems to be very interested and eager to do, at local level, whatever is needed to help the realization of such projects.

VI. Conclusions

In this paper we have analyzed the potential for wider application of photovoltaics for electricity production in mountainous locations in Croatia. Being sparsely populated and with many houses/small communities distant from the grid lines these areas are good candidates for such application despite high prices of PV modules. The performance and costs of a small PV off-grid system is analyzed by detailed and realistic computer simulations. It has been found that, by using existing subsidies and incentives for RES offered to these areas (up to 80% off from commercial prices), the cost of a PV system for local communities should be below than 1600 € per 1 kWp, which would mean price of electricity of about 0.32 €/kWh during the warranty lifetime of PV modules (20 y). Satisfying basic needs for electricity by PV would open new opportunities for sustainable socio-economic development in isolated rural regions of Croatia.

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Feasibility Analysis of Wind-plant in the Region of Deliblatska Peščara (Serbia)

Ž. Đurišić, N. Rajaković, D. Mikičić, M. Bubnjević

Abstract--**The paper deals with the feasibility analysis of a wind-plant of installed power 3×2MW at the site Čibuk at the periphery of Deliblatska Peščara. Based on long term meteorological measurements, conventional measurements, analysis of roughness and orography of the terrain, using the software package WAsP, the wind potential at target location has been determined. For the selected type of wind-generator and actual wind conditions, annual electric energy production of perspective wind-plant has been estimated. For the calculated annual production, considering typical costs of wind-plant construction, costs of electric energy production have been evaluated. Sensitivity analysis of electric energy price versus rate of interest has been performed, as well as the analysis of annual production of the wind-plant depending on the height of the mast (where the wind-turbine is mounted).**

***Index Terms*--wind – plant, wind energy potential, wind-plant economy**

I. INTRODUCTION

AVAILABLE wind energy potential in Serbia varies greatly from one region to another, showing substantial differences even at small distances. The other characteristic of available wind potential space distribution in Serbia, which can be considered unusual, is that wind energy is more available in lower areas than in higher ones. This paradox can be explained with a fact that winds are usually *catabatic* and have higher speed in descent moving. Wind potential estimation given in wind atlas is not detailed enough to cover some local characteristics. These maps show rather high variability regarding power at short distances, especially in hilly and mountain areas.

Northeastern part of Serbia is characterized by a strong southeastern wind. This wind with descending component is stronger than ascending wind that arises simultaneously. The area affected by this local wind (*košava*) is surrounded by mountains from the south and east, and open towards north and west. *Košava* most often occurs during the colder period of the year. Warmer period of the year is dominated by western winds.

Meteorological network in Serbia provides continuous wind registering. Wind speed measurements are conducted at standard height of 10m. Anemometers are generally of older types with tape recording (anemographs), thereby making hourly average wind speed data mostly unavailable. In last two years, modern digital equipment with remote measurement reading of wind parameters has been installed at several measurement stations in Serbia.

This analysis distinguishes Vojvodina as a region of special interest. Custom wind measurements in this region are of particular importance because lowland terrain provides very reliable space extrapolation of measurements in a wide radius around the measurement mast (20 to 30km). Lowland terrain and relatively built-up electric energy network in Vojvodina are a precondition for low costs of connecting perspective wind-plants to electric energy system (EES). River Danube and road infrastructure allow cheap transport of wind-generators from countries of European Union and low building costs, which have significant impact on the economy of wind-generators [1]. Unlike mountain regions, Vojvodina has relatively low keraunic level [2], which is also a relevant factor in selecting location for a wind-plant, as atmospheric discharge is the frequent cause of wind-generator faults. These are the essential reasons for favoring Vojvodina as a perspective region for wind-plant construction.

Based on longtime wind measurements in hydro meteorological stations in Vojvodina, a conclusion can be made that there is a dominant southeastern direction of wind speed in target region. Particularly interesting is the region of south Banat where the wind of dominant direction also has dominant speed, which represents the basic quality for building wind-generators. This kind of wind rose is beneficial for building individual wind-generators as well as wind-plants with grouped wind-generator units, as the negative effect of leeward (*wake* effect) can be reduced using the space layout. Additionally, custom wind measurements have been performed in this region, also showing significant wind energy potential. Based on custom wind speed measurements, this paper analyses economic payoff of wind-plant construction at site Čibuk, at the periphery of Deliblatska Peščara.

II. COST STURCTURE FOR THE CONSTRUCTION OF WIND-PLANT

Wind-generators are nowadays being constructed in a wide range of power levels. Smaller wind-generator units (up to 200 kW) are mostly used for feeding isolated systems or for water pumping. Bigger wind-generator units are intended for network operation and are subject to this analysis.

Wind-generator construction costs can be divided into:

1) Investment costs (*capital costs)* – costs of purchase, transport, wind-generator construction and its connection to the network;

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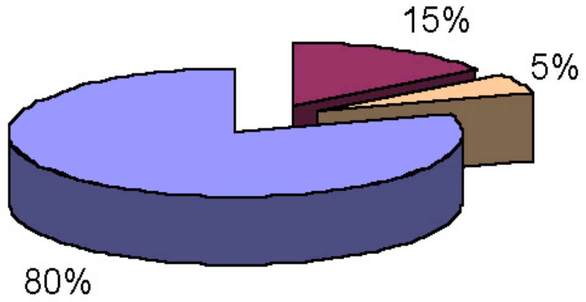
2) Production costs (*running costs*) – operational costs, repair, land renting etc;
3) Costs of financing.

A. *Investment costs*

Typical structure of investment costs for a contemporary wind-generator plant on land is depicted in Figure 1.



Costs of purchase and transport of wind-turbine, including mast and connection equipment (ex –work costs)

Construction costs
- building road and telecommunications infrastructure
- building works (foundation)
- connection to electric network
- other costs

Project development costs
- land
- measurements of wind parameters
- project documentation making
- insurance
- rate of interest in installation period
- administrative taxes

Fig 1. Typical costs structure for wind-plant construction

Costs structure in Figure 1 is based on experience of Denmark and Germany in constructing smaller wind-plants (power up to 8 MW) [1]. For specific projects, the share of individual elements of capital costs can considerably differ from typical values. Especially sensitive therein are the costs of building the access road and electric network. The access road must provide conveyance of the mast and wind-turbine, as well as building machines (primarily crane) for mounting the wind-generator. At some (mountain) sites, this can be a limiting factor regarding size (installed power), because for some sites it is impossible to provide an access road for heavy trucks and building machines. Making a wind-plant project, one should particularly consider the vicinity and capacity of regional electric network. Sites near the existing network significantly reduce the price of connecting the wind-generator to electric energy system (EES).

The structure of capital costs itself clearly indicates that bigger wind-plants reduce specific costs (costs by installed MW). Hence, to perform a precise analysis of construction costs for a wind-generator plant, cognition of all relevant parameters for specific location is required.

Purchase costs for a wind-turbine can be defined if wind-turbine type and power are specified, as well as mast height and means of transport. These costs can be expressed using the specific price per 1m^2 of wind-turbine (k):

$$ex - work \ \ costs = k \cdot (\frac{d^2 \pi}{4}) \quad [Euro] \ , \qquad (1)$$

where d represents the diameter of wind-turbine. The value of specific costs (k) gently grows with the increase of wind-turbine size, typically adhering to the characteristics given in Figure 2, [3]. It should be mentioned that the diagram in Figure 2 has been made according to experience in wind-turbines sale during 1998. More recent wind-turbines have remarkably lower specific costs (15 to 20%), while, due to technological progress, minimum of specific costs has moved towards greater wind-turbine surfaces (powers).

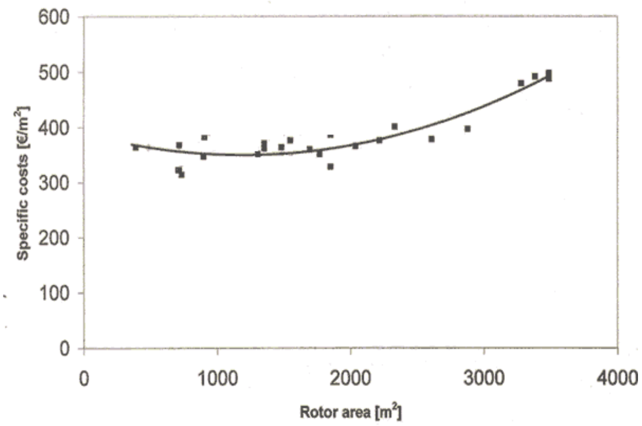


Fig. 2. Specific costs versus wind-turbine size

Ex-work costs comprise costs of purchase and transport of wind-turbine (entire equipment with mast), i.e. all costs not related to location.

B. *Operational costs*

As the wind energy is free of charge, production costs refer to costs of regular services, repairs and insurance of wind-generator. These costs may include land rent at the site where wind-generators are installed. Operational costs depend on wind conditions and usually are higher for mountain sites, also increasing with wind-generator ageing. These costs are usually taken into account as fixed annual costs per produced kWh. Typical values of operational costs for new wind-turbines (nominal power (0,5 ÷1,5) MW) are (0,6 ÷1) Euro-cent /kWh. During exploitation, maintenance and repair costs increase, so for turbines operating more than 10 years operational costs amount about (1.5÷2) Euro-cent /kWh.

C. *Costs of financing*

Costs of financing depend on national credit policy in a great deal. In countries of European Union, national Governments use different subventions, beneficial credits and tax privileges to stimulate investors in placing capital into construction of wind-generators. Additionally, in deregulated electric energy systems, such are the European, wind-generators are being favored in electric energy market. Such non-market principles are justified by present nonexistence of mechanisms for including ecology factor into the price of electric energy, which primarily relates to thermal plants. After including ecology into the price of electric energy, all subventions for wind-generators will be slowly revoked, but it is expected that in new pricing environment they will be more competitive in the market than all fossil sources [4].

III. WIND-PLANT ECONOMY

In order to comprehend payoff for constructing a wind-plant, it is also necessary to analyse elements affecting productivity of wind-generators, besides costs. Most important elements affecting productivity of wind-generators, i.e. the price of electric energy produced by the wind-generator, besides the defined costs, are also the following:

- annual average wind speed,
- wind-generator availability,
- wind-generator lifetime,
- amortization period,
- real rate of interest.

Annual average wind speed is the most important parameter that affects the price of electric energy produced by wind-generators. Considering typical histograms of wind speeds (wind duration curves), as well as efficiency of commercial wind-turbines, the amount of electric energy (E) per unit surface of wind-turbine annually produced by a wind-generator can be estimated, according to the following relation:

$$E = 3,2 \cdot v_{sr}^3 \quad [kWh / m^2 year], \qquad (2)$$

where v_{sr} refers to the annual average speed of wind-turbine at the level of wind-turbine axle altitude (mast height). Relation (2) represents a rough estimate and is applicable only if there are no custom wind measurements, but only data on annual average wind speed.

Wind-generator availability in range of working wind speeds (typically (3÷25) m/s) is high for modern wind-turbines, typically about 98%. Additionally, regular repairs of wind-generator can be planned in periods of weak wind (summer months).

Lifetime of a modern wind-turbine is 20 to 25 years and depends on the conditions of exploitation (wind turbulence, precipitation etc). Lifetime refers to main components of wind-generator, while replacing particular parts (oil in reducer, brake covers, different bearings and gears of the system for horizontal turning of wind-turbine etc) takes place periodically (3 or 5 years) and pertains to maintenance costs. General repair (substitution) of wind-turbine main bearings is commonly performed in the middle of wind-turbine's lifetime.

A. *Model for calculating electric energy production costs in a wind-plant*

Price calculation for electric energy produced by wind-generators is rather complex and must comprise all the elements affecting costs and productivity of wind-generator. Also, ecology should be comprehended, as a significant factor for pricing.

In this analysis, a simplified model shall be given for price calculation (production costs) of 1kWh electric energy produced by a wind-generator. Model is based on the following equation:

$$c = \frac{a \cdot I}{A \cdot E} + m \qquad (3)$$

where:
c – price per 1kWh produced electric energy (Euro/kWh),
a – annuity factor,
I – total investment per 1m^2 of wind-turbine rotor (Euro/m^2),
A – wind-generator availability (0÷1)
E – annual energy production per 1m^2 of rotor (kWh/m^2),
m – operational costs (Euro/kWh).

Annuity factor can be calculated according to the following relation:

$$a = \frac{i(1+i)^n}{(1+i)^n - 1}, \qquad (4)$$

where:
i - real rate of interest,
n - amortization period.

IV. ANALYSIS OF ECONOMIC VINDICATION OF WIND-PLANT CONSTRUCTION AT THE PERIPHERY OF DELIBLATSKA PEŠČARA

Target region of Deliblatska Peščara is characterized by a strong local southeastern wind. This wind with descending component is stronger than ascending wind that arises simultaneously. The area affected by this local wind (Košava), is surrounded by mountains from the south and east, and open towards north and west. Košava most often occurs during the colder period of the year. Warmer period of the year is dominated by western winds. Available wind energy in this period of the year is much smaller than during winter.

Based on available custom measurements conducted on anemometer mast of 40m height and using WAsP, a relatively good wind potential has been determined at a higher number of micro locations in target region. Wind is characterized by relatively stable streaming with occasional occurrence of squalls that rarely exceed 25m/s.

As a specific example, economy payoff of wind-plant construction at site Čibuk will be generally analysed. Figure 3 presents satellite snapshot of wider region around target location.

Subject to analysis was the construction of wind-plants with three turbines Enercon E-82, each of 2MW nominal power, so wind-plant installed power would be 6MW. Figure 4 illustrates wind energy potential and wind rose at micro location intended for constructing wind-turbines, assuming they are mounted on a mast 70m high.

Fig. 3. Satellite snapshot of wider region around target site Čibuk

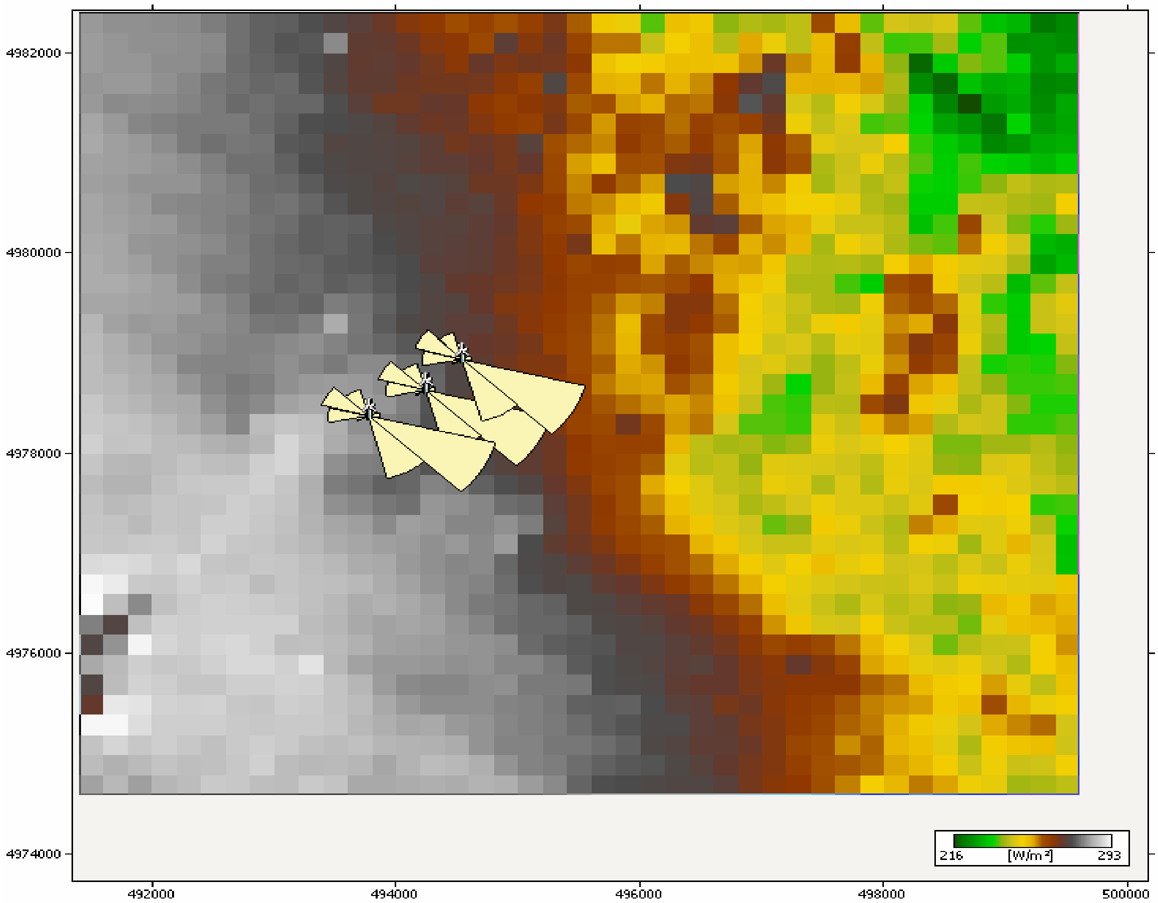


Fig. 4 Wind power potential and wind rose on potential plant micro locations

Table I shows wind energy potential for target location obtained on basis of measurements and application of software package WAsP.

TABLE I
WIND ENERGY POTENTIAL CALCULATED AT DIFFERENT HEIGHTS AT ČIBUK SITE

Height	Parameter	0.03 m
25.0 m	Weibull A [m/s] Weibull k Mean speed [m/s] Power density [W/m²]	5.8 1.88 5.11 166
50.0 m	Weibull A [m/s] Weibull k Mean speed [m/s] Power density [W/m²]	6.7 2.07 5.90 232
100.0 m	Weibull A [m/s] Weibull k Mean speed [m/s] Power density [W/m²]	7.9 2.19 6.99 366

Table II shows the analysis of wind-plant electric energy production if wind-turbines are put on masts with different heights, offered by the vendor of wind-generator E-82.

TABLE II
ANALYSIS OF ELECTRIC ENERGY PRODUCTION FOR A WIND-PLANT OF 6MW (3×2MW) POWER, IF WIND-TURBINES ARE PUT ON MASTS WITH DIFFERENT HEIGHTS.

Mast height of wind-generator E-82 [m]	Total annual production of electric energy [MWh/year]
70	15600
80	16600
90	17600

As price data for wind-turbine is not available, it will be estimated for this analysis based on technical data for E-82 turbine, relation (1) and diagram in Figure 2 (considering that the price is about 15% lower than shown):

$$ex-work\ costs = k\frac{d^2\pi}{4} = 300\cdot 5281 \approx 1\,580\,000\,Euro\cdot$$

Thus, total costs for wind-turbine with mast, conveyed to installation site, would be about 1 580 000 EUR per turbine, which yields the overall (total) amount for the whole plant:

$$ex-work\ cost(farm) = 3\cdot 1\,580\,000 = 4\,740\,000\,Euro\cdot$$

Ex-work costs make about 80% of overall wind-plant construction costs (Figure 1), so the overall (total) investment is:

$$I_{tot} = 1{,}25 \cdot 4\,740\,000 \approx 5\,900\,000 \text{ Euro}$$

Total expected annual production of the analysed wind-plant, considering *wake* effect and assuming the turbine has 100% availability, is shown in Table 2.

Expected capacity usage factor (τ) on yearly basis (if the wind-plant would be 100% available), for the case of mounting wind-turbine on an 80m high mast, would be:

$$\tau = \frac{16{,}6\cdot 10^6}{8756\cdot 6000}100 = 31{,}6\%\cdot$$

Hence, the expected equivalent work duration time of the wind-plant with nominal power on yearly basis would be about 2700 hours.

In order to estimate production costs per 1 kWh electric energy for analysed wind-plant, it is necessary to adopt a model for economic analysis. Based on the model given by relation (3), production costs estimate can be supplied if operational costs are taken into account as fixed costs per produced kWh. For these purposes, the following parameters will be presumed in this analysis:

amortization period - n = *25* years,
operational costs - m = *0,1* Euro cent/kWh/year ,
rate of interest - i varies from 2 to 8%,
availability - A =98%.

Figure 5 shows production costs for analysed wind-plant for different wind-turbine mast heights and different rates of interest.

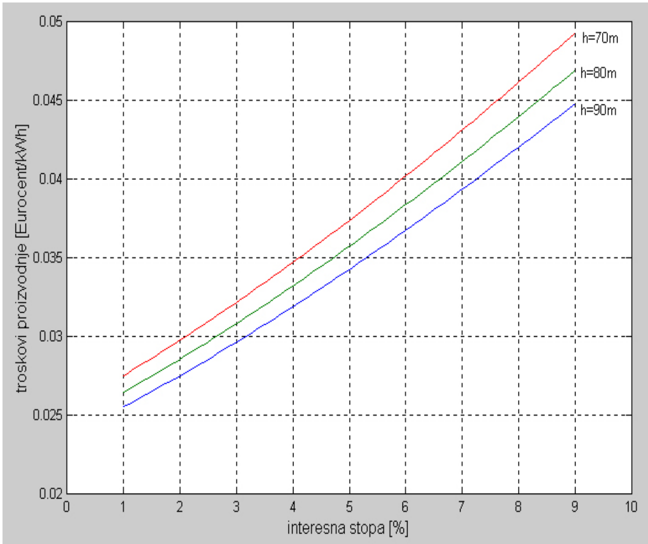


Fig. 5. Electric energy production costs for perspective wind-plant of 3×2MW power at site Čibuk

Preceding analysis presumes that investment costs, availability and maintenance costs do not vary depending on mast height. Actually, investment costs are slightly higher for turbines of higher altitude. Higher wind-turbines are more exposed to atmospheric discharge and stronger squalls, so this should be kept in mind for the final selection of mast height.

In order to obtain the price of electric energy that a consumer has to pay, it is also necessary to consider rate of profit, tax and costs of transfer and losses. It should be mentioned that wind-generators are usually connected to distribution network thus directly injecting energy into consumer nodes, which greatly reduces losses and practically does not occupy transport capacities, so the related costs are significantly lower compared to centralized production systems.

V. CONCLUSION

Based on experience of countries with developed wind-energetics, the paper shows typical costs structure for constructing wind-plants of installed power up to 8 MW. Using this analysis and determined wind potential, the economy of constructing a wind-plant of installed power 3×2MW at site Čibuk at the periphery of Deliblatska Peščara has been analysed. It has been determined that target location has a good wind potential with annual average speed of 6,4m/s calculated at 70m height above ground. Using software package WAsP, the annual production of perspective wind-plant has been determined, amounting 15600 MWh/year for the selected wind-turbine E-82 mounted on a mast 70m high. This productivity corresponds to capacity usage factor of 29,7%, which is above the average for locations in countries of European Union. Electric energy production costs in the subject wind-plant have been analysed as a function of rate of interest. For a real rate of interest (4 ÷ 6)%, production costs are about 3,5 to 4 Euro-cent/kWh. These costs can be significantly reduced if the turbine is put on a higher mast, where wind conditions are better, and if more convenient credit terms are provided.

For the analysed location, low costs of transport, connection to network and maintenance should be expected, due to an accessible terrain with built-up road infrastructure near a floating river and electric network.

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Target Site Rošijana for Demonstration of RES Application in Isolated Region

Miodrag Zlatanović, Oldja Marius, Jovan Vujić, Bojana Jakovljević and Mirko Stojković

Abstract--**Based on the existing meteorological wind data, terrain and met stations modeling and RISE Project objectives several possible target areas for the case study of wind power exploitation were preliminary selected: Vršac, Dolovo, Vlasina, Kopaonik, Bjelasica and Zlatibor. As the most attractive candidate sites** Vlasina lake **and** Deliblatska Peščara **reserve were analyzed in details.**

The sustainable use of Deliblatska Peščara **reserve is a mandatory rule. The conservation and upgrading of sandy area special nature reserve include the protection measures regarding forestry policy, agricultural use, water resources management and sand exploitation. The development of urban infrastructure, tourism, hunting and water supply require energy sources which, concerning the ecology, should be of renewable nature. Using WAsP software and the existing data base the best location for mounting a 50 m height wind measuring must was selected in** Deliblatska Peščara **before looking for the final target site.**

Five kilometers far from the wind must location we discovered the old forestry service house *Rošijana* **which we found to meet all the project requirements as the target site looking from many aspects: environmental, economical, social, educational and energetic.**

***Index Terms*— renewable energy sources, wind power, target site for RES demonstration, wind potential of Deliblatska Peščara, eco house Rošijana, WAsP model**

I. Introduction

Taking into account all aspects of wind energy conversion in selecting the target sites for demonstration of applications in isolated regions, *the challenge* of possible matching of wind power sources with the rules of special eco regions energy supply prevailed. The one is Rošijana located in the plain region north of the Danube and the second one Vlasina in the east-south mountain region of Serbia. After more detailed analysis the decision was made to rebuild the old forestry service house ***Rošijana*** located in special nature reserve Deliblatska Peščara as the eco green house powered mostly by the wind energy. The wind climate in selected region was described as well as the plans for old forestry service house to be reconstrated as the first eco house in Deliblatska Peščara. Future eco house will consists of the following units: residential house, workshop house, mechanical house with the equipment for water supply, artesian well, water pull and the garden. Load identification is given as well as the discussion of environmental, economical, social, educational and energetic aspects.

This work has been performed within the EC funded RISE project (Contract number FP6-INCO2-509161).

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II. Vlasina Height

Target site **Vlasina height** is suited in southern Serbia and surrounded by the highest wooded Serbian mountain range after Mt. Kopaonik and very promising tourist site for the construction of ski lifts and opening ski runs for recreational and professional skiing. The Vlasina Jezero Lake is the most attractive part of the height, a true paradise for fishermen in summer and, in the future, for skate men in the winter. The surface temperature of the lake water during the sunny days of July and August is around 23 degrees Celsius, excellent for swimmers, while up to two meters thick lake ice in the winter is suitable to walk across or skate.

A known trademark mountain water Rosa is collected and directly bottled in the Vlasina height at the spring positioned at an altitude of 1550 m with the state of art pure ecological technology. This virgin nature is at a sufficient distance from larger urban areas and fully protected in ecological terms.

The floating islands on the Vlasina Jezero Lake are a unique natural phenomenon in the world grown by the nature during about 5000 years. On one of islands a colony of rare cormorants was discovered and protected by low. As the pearl of Vlasina height, Vlasina Jezero Lake is 12 km long and 3 km wide and surrounded by up to 1922 m above the see level mountain peaks.

To preserve the nature a facility for recycling waste water has been drown up. A future tourist complex with the capacity of 4000 beds, a ski center, a helicopter and tourist aircrafts airport, an artificial snow making equipment based on recycled water, as well as several recreational facilities were planned.

The energy supply of the future tourist center is based on renewables, mostly small hydropower installations.

Based on some climate data we preliminary selected Vlasina height as the target site in Serbia for the wind power case study. The site geographical location is given in Fig 1.

Fig. 1 Map of Vlasina Jezero Lake

III. SPECIAL NATURE RESERVE DELIBLATSKA PEŠČARA

The periphery of the special nature reserve **Deliblatska Peščara,** one of the last Pannonian Sand-Dunes, was also considered as the target zone. In the Pleistocene, the Danube and Carpathian rivers deposited alluvia which were later wind-blown to form 100-500 m long dunes oriented NW-SE with maximum elevation of some 200 m. The most valuable of the **Deliblatska Peščara** landscape is the biological potential with specific ecosystem and relating biodiversity. The vegetation includes specific combination (*Festucetum vaginatae deliblaticum*) developed only in this **Peščara** and some rare plants like orchid species, *Iris pumula* and *Paeonia tenuifolia*. The ecosystem complex includes fauna with endemic species like *Tentyria frywaldskyi*, the most important locality in Europe of some reptiles and one of the most important Bird Areas for bird of prey. Vast areas around the Danube are important for waterfowl during spring and autumn migration, while the **Deliblatska Peščara** represents the only remaining Pannonian Plain habitat of *Canus lupus*.

The sustainable use of **Deliblatska Peščara** reserve is a mandatory rule. The conservation and upgrading of sandy area special nature reserve include the protection measures regarding forestry policy, agricultural use, water resources management and sand exploitation. The development of urban infrastructure, tourism, hunting and water supply require energy sources which, concerning the ecology, should be of renewable nature. In the past the wind energy was the origin of aeolian accumulation and the sandy areas appearance which movement was powered also by blowing wind. We proposed the wind energy to be used for electricity production and water supply of the nature reserve **Deliblatska Peščara** by constructing the wind turbines at the target site in upstream periphery region of **Deliblatska Peščara.** The maps show the approximate geographical position of **Deliblatska Peščara** with indicated preliminary proposed target area (Fig. 2)

The mean year wind velocity at 50 m height is close to 6 m/s and the energy density higher than 220 W/m^2 [1]. The number of windy days is between 128 and 115 days per year.

Fig. 2 Position of Dolovo site relative to **Deliblatska Peščara**

An extensive research of the exact position of the target location for the demonstration of wind energy application was performed during the summer and early autumn 2005. Nearly 30 trips were made to visit the potential locations, to make photos and get the insight in the local citizen experience with the wind. As the most attractive we found the places around both sides of the river Danube were some specialized measurements of the wind potential are in course. Nearby the Danube canyon Djerdap, the measurements are made at three places using the wind musts up to 60 m in height. In Dolovo the first year of measurements terminated 19th of October 2005.

The conclusion was drown that we have to made a serious wind potential analysis by using met station data and the most advanced software to select the best place for mounting the wind tower with velocity, temperature and pressure sensors and to find a nearby location as a definitive target site for studying the performance of a renewable wind energy based system in an isolated rural region.

IV. PREDICTED WIND CLIMATE IN DELIBLATSKA PEŠČARA

The analysis using WAsP software developed by RISO Institute from Denmark included the detailed wind energy potential investigations of Dolovo, Kuštilj, Straža, Vršački breg and Zagajičko brdo as the candidate sites for wind must installation.

The photographs given below illustrate the terrain configuration at the location Zagajičko brdo [2]. An overall aerial photo is given in Figure 3 which shows the view approximately from the east south-east. The position for mounting the wind must is in central top part of the photo.

Fig. 3 Aerial photo of Zagajičko brdo

Figure 4 shows the pyramid for geological identification at the contour of the hill to the right of the wood. The planned must position is 70 m far from that place.

Fig.4 The place called pyramid at Zagajičko brdo

Inside the valley bellow the pyramid few objects with the old artesian well are located without the connection to the grid, but it is not possible to make any disturbance due to very strict nature reserve region rules (Fig. 5).

Fig. 5 Artesian well at Zagajičko brdo

V. Target site Rošijana

The best results for positioning the wind must were obtained for the location **Zagajičko brdo.** Ten years meteorological data from the stations Rimski Šančevi, Veliko Gradište, Kikinda and Beograd were used, the topographical maps of Deliblatska Peščara, satellite and aerial photographs, roughness data from 1:25000 maps and terrain data obtained by the inspection of met stations and some locations. It was found that the met station Banatski Karlovac is the most relevant for wind potential prediction of special nature reserve (SNR) Deliblatska Peščara. We found the data for the year 1999 the most valuable and complete so we performed the wind analysis for this year. The met station Banatski Karlovac was modeled and 3D terrain maps were made around the station and specified locations.

The position of the met station and location Zagajičko brdo is given in Fig. 6 with the wind roses at both places. The predominant wind influenced the terrain configuration in the past.

Figure 6. illustrates the wind climate at Banatski Karlovac location. The distance between this met station and the target site Zagajičko brdo is 17 km indicating the same wind climate at both places. From the existing data bases and terrain and met station modeling the wind potential at the site Zagajičko brdo was predicted at 50 m height above the ground. The met station is positioned at the elevation of 90 m above the see level, while Zagajičko brdo is the highest point in SNR Deliblatska Peščara 251 m above the see level. The wind climate calculation predicted about 5.7 m/s wind velocity (Fig.7), while local wind velocity as high as nearly 7 m/s was estimated (Fig 8), making Zagajičko brdo to be the best position for wind measurements and its surroundings suitable for the target site.

As the next step we were looking for the target site for the case study in the area considered taking into account the main goals of the project FP6 RISE INCO-509161.

At approximatelly 5 km distance from Zagajičko brdo inside SNR Deliblatska Peščara we discovered the old forestry service house ***Rošijana*** which we found to meet all the project requirements as the target site looking from many aspects: environmental, economical, social, educational and energetic.

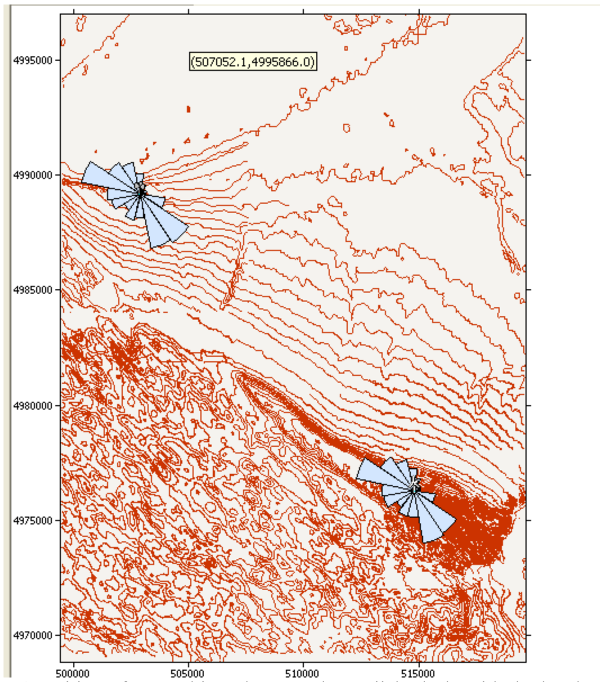
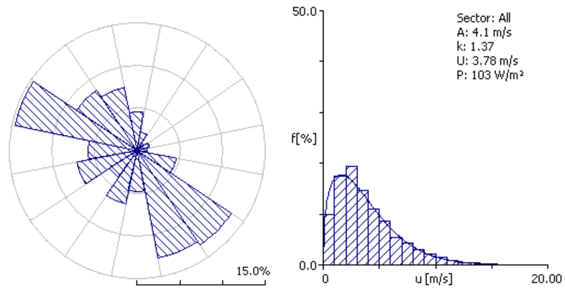
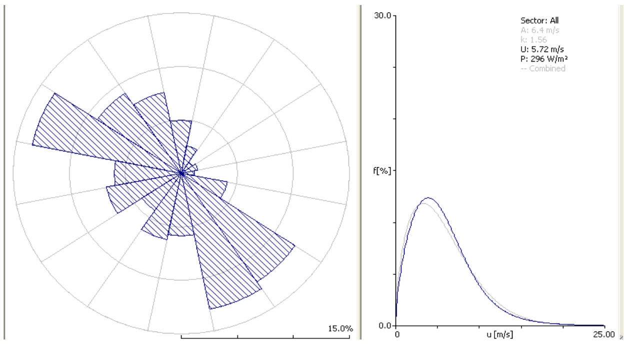


Fig. 6 Position of Banatski Karlovac and Zagajičko brdo with the local wind roses



a)



b)

Fig. 7 The predominant wind roses and Weibull distribution curves for a) Banatski Karlovac b) Zagajičko brdo

The position of ***Rošijana*** is given on the topographic map in Fig. 8. Four objects were drawn positioned close to the road towards Zagajičko brdo. The view of Rošijana objects is shown in Fig. 9.

The schematic view of the object bases is presented in Fig.10. Since no new buildings are allowed in the special nature reserve, Rošijana is planned to be reconstrated as the first eco house in Deliblatska Peščara. All aspects are to be included: new recyclable materials, waste water treatment, energy efficiency, sustainable development, a variety of renewable energy sources, explanation of flora and fauna of nature reserve, demonstration of scientific results, research activities tourism and more.

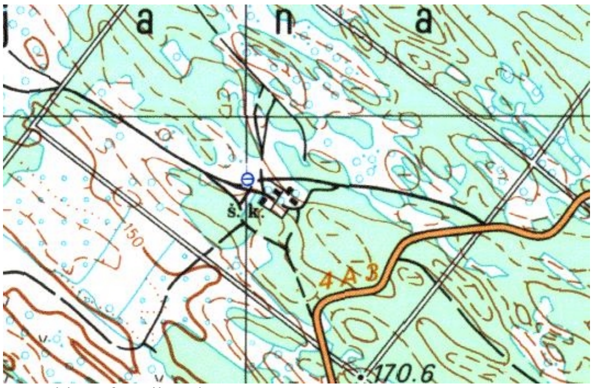


Fig. 8 Position of Rošijana house

Future eco house will consists of the following units: residential house, workshop house, mechanical house with the equipment for water supply, artesian well, water pull and the garden.

VI. Load Identification

Rošijana is planned for all over the year activities. It has the place for the resident family of about four members responsible for maintenance and operation. Two principle groups of visitors are considered: hunters and other groups. The other group includes schoolboys, tourists, researchers, nature organization, visitors and experts from outside countries and all other people interested in visiting the largest sandy area in Europe and its surroundings with nearby river Danube, Djerdap canyon and large hydropower station.

The electric load of Rošijana house was calculated taking into account the following planned data:

Fig. 9 Rošijana site

- The hunting season lasts from 1st. of May to 14th of February with the highest season in December and January. Maximum 8 poeple are planned to be in the house, but this number is in average 3 depending on the season and the day of the week.
- Special two week camps are mostly organized in July and August with about twenty poeple.
- The education lessons will be organized in principle from Jun to September.
- All energy needs were calculated based on the above eco house activities. The expected position of the wind turbine with respect to the houses is given in Fig. 11.

(a) Electricity needs

The load data for each month are given in the tables bellow, as well as the daily load distribution.
The daily data contained in the tables are graphically illustrated in Fig. 12, while monthly energy distribution is presented in Fig. 13.

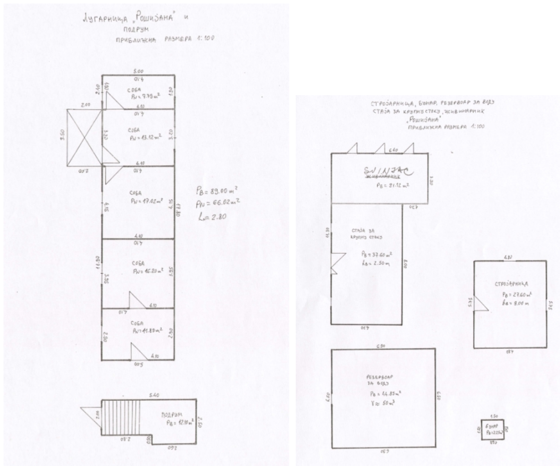


Fig .10 The basis of the objects at Rošijana site

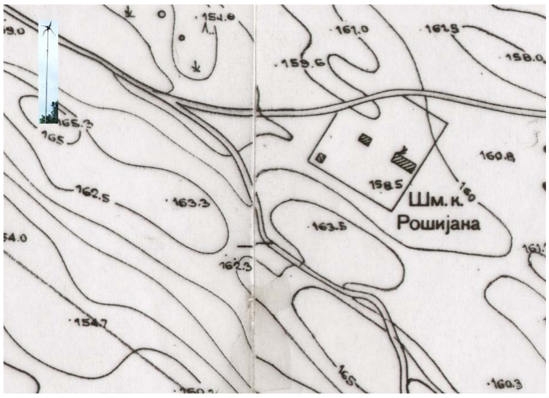


Fig. 11.Position of the wind turbine in Rošijana complex

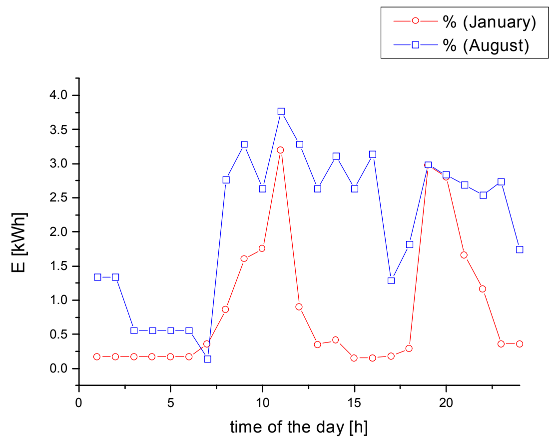


Fig. 12 Daily energy load distribution

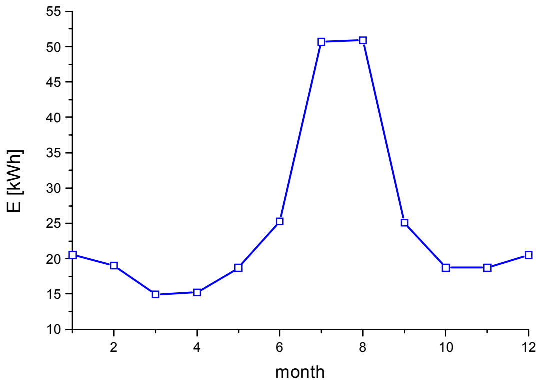


Fig. 13 Monthly energy load distribution

b) Heat energy needs

The biomass is supposed to be the dominant heat source based on large amount of biomass in the SNR.

In addition, solar heating is used and a small amount of electricity for security reason and for air conditioning.

VII. OTHER ASPECTS

A. Environmental aspects

The eco house Rošijana is supposed to meet the most critical rules of environment protection which are mandatory in special nature reserve Deliblatska Peščara. The possibility of designing of an ecology compatible renewable energy source will be demonstrated.

B. Economic aspects

Green house Rošijana is expected to play an important role in economic development of the region located east of Deliblatska Peščara. From the beguining of this project tenth of consulting and manufacruting companies from the field of wind energy applcation visited the municipality of Vršac and Bela Crkva looking for contracts to construct the wind farms. Promoting the idea of a clean efficient energy source Rošijana is to help the near future change of the region economy towards an important wind energy center.

C. Social aspects

Haw to explain to people having to change their own job and to go to the wind related activities that the wind is not the enemy? Rošijana education center will be busy by this job!

VIII. CONCLUSIONS

In Serbia, a rural area called Rošijana, located inside the special nature reserve Delibaltska Peščara which is the largest sand dune region in Europe, was considered as the target site for designing an eco green house powered by RES. This eco house Rošijana is supposed to meet the most critical rules of environment protection which are mandatory in special nature reserve. The conservation and upgrading of sandy area special nature reserve include the protection measures regarding forestry policy, agricultural use, water resources management and sand exploitation. The development of urban infrastructure, tourism, hunting and water supply require energy sources, which, concerning the ecology should be of renewable nature. In the past the wind energy was the origin of aeolian accumulation and the sandy areas appearance which movement was powered also by blowing wind. By constructing a wind turbine the wind energy will be used for the electricity production and water supply helping all the activities in special nature reserve and promoting the sustainable use of RES, energy efficiency, new recyclable material application and WWT. Based on regional wind climate the municipalities surrounding the nature reserve are expected to change their economy towards electricity production from wind. Rošijana eco house is planned to be the center of enormous importance for the demonstration of RES use, dissemination of related knowledge and the education of people that has to change their own job and to go to the wind related activities. Some project related research activities will also be performed in Rošijana house. The selected site is of primary importance concerning the main project objectives and the results dissemination.

IX. ACKNOWLEDGMENT

The authors wish to thank the RISE partners for their contributions and the EC for partially funding this project. The valuable contribution of Mr. Veljko Zlatanović, Mr. Mihajlo Tomašević and Mr. Zoran Begenišić is greatly acknowledged.

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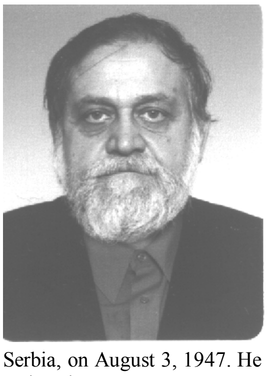

Miodrag Zlatanović was born in Belgrade, Serbia, on August 3, 1947. He graduated and finished PhD thesis at Belgrade University.

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Testing of Internet Wind Data for Regional Wind Climate Assessment at Deliblatska Peščara site

Miodrag Zlatanović

***Abstract*-- The experiments were performed in order to evaluate the relevance of the existing meteorological data for the assessment of the wind potential of Serbia.**

The wind potential in the northern part of Serbia at the periphery of sand dunes region Deliblatska peščara was calculated from the wind velocity measured at 20 m, 30 m, and 40 m heights above the ground and compared by the wind data at 10 m height obtained from nearby located metrological station number 13180 and from wind data collected at the internet site http://meteo.infospace.ru. The met station data were used in original form with wind velocity discretisation 0.1 m/s and in rounded-off 1 m/s discretisation form. The detailed comparison of wind data evolution during March 2005 was made illustrating the validity of the meteorological station and internet data as compared to more precise wind mast measurements.

***Index Terms*— renewable energy sources, wind power, wind potential of Deliblatska Peščara, WAsP model, wind rose, wind frequency, wind measurement**

I. Introduction

THE planning of wind potential resources exploitation usually starts with a rough estimation of wind availability based on the corresponding wind atlas estimation. In the absence of the wind atlas of Serbia and Montenegro we tried to analyze the existing meteorological data from the met stations to identify the regions suitable for the wind power exploitation. Several papers were published by different authors and institutions related to the regional wind potential but no one publication is suitable for identifying the all relevant windy regions in Serbia since several of existing met stations were located at the sites not exposed to predominant wind [1]-[3]. The study prepared for the Electrical Company of Serbia is probably the most valuable one [1]. It contains the wind velocity map of Serbia obtained by analyzing ten years met data of about 30 met stations.

In this paper we report the results of wind resources prediction in Deliblatska Peščara, the region in the northern part of Serbia, which is exposed to predominant southeast wind košava.

This work has been performed within the EC funded RISE project (Contract number FP6-INCO2-509161).

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II. Met station locations

The region of South Banat in northern part of Serbia is known as a windy area with predominant wind from southeast direction, called Košava, which is especially present during late autumn, winter and early spring, but is of lower intensity during summer period. The land is predominantly flat with few hilly terrains and only one mountain at the Serbian-Romanian border located at the east part of the area. The sandy dunes area at the west part of South Banat region is a Special Nature Reserve – Deliblatska Peščara - in which the construction of large wind farms is forbidden by the low.

Fig. 1 contains the map of Serbia with the principal met station locations from which the synoptic data of interest for wind resources predictions are available. The central and southern parts of Serbia include some mountain regions in which the wind resources prediction is difficult due to non-convenient locations of the met stations. The relevant met stations for wind climate assessment in predominantly flat South Banat are Banatski Karlovac and Vršac indicated in Fig. 2, but also Veliko Gradište station located over Danube river may contain very useful data.

Fig. 1. Principal met station locations in Serbia

The wind mast 40 m in height was installed at the location Humka Nagula nearby village Dolovo (Fig. 2) while 50 m tall wind tower is to be positioned at the Zagajičko brdo site. In near future two additional wind masts with the wind measuring system are planned to be mounted: the one 40 m height mast close to the airport met station Vršac and the second one 50 m tall on the location in direction Straža – Kuštilj, which is a long escarpment visible on Fig. 2 as the orographic configuration starting from Zagajičko brdo towards the region south of mountain Vršac.

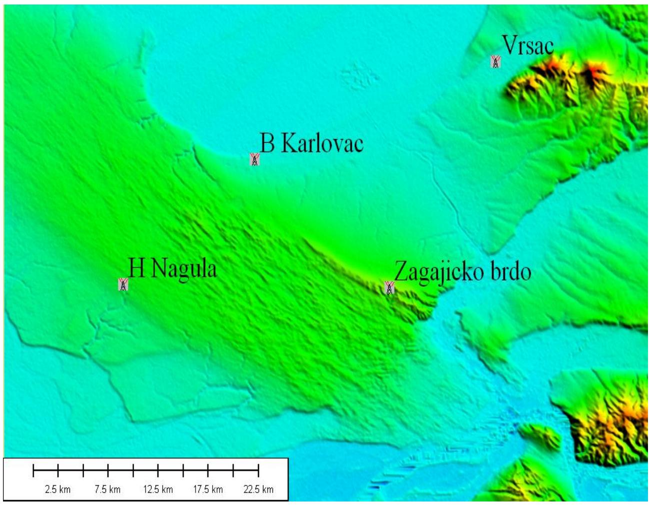

Fig. 2. Position of met stations in Južni Banat

As it can be seen from the satellite vector map on Fig. 2, close to Vršac Mountain there is an elevated region oriented southeast – northwest which is mentioned above – Special Nature Reserve Deliblatska Peščara. The predominant wind during the centuries put the fingerprint in the sand allowing for predominant wind direction changes to be identified by today measurements, since during the last century the movement of the dunes was stopped by the forest and tries cultivation.

In order to validate predicted wind resources in Deliblatska Peščara based on the met data from Banatski Karlovac station, the comparison was made with the measured wind speed at 17 km distance located wind mast in Dolovo. In 2003 year, the company Helimax from Canada started the project for assessment of wind resources in South Banat and the wind station Dolovo was a part of the agreement between municipality of Pančevo and Helimax Company.

III. Measuring site s description and terrain modeling

The met station Banatski Karlovac is located at the position 45^0 03' N 21^0 02' E at the elevation of 86 m. a.s.l. Since the station was established the data were collected in an analogue form. The instruments were periodically calibrated but the error for low wind velocity measurement may exceed 3%. The anemometer is mounted onto the rough of the house so that the influence of the met station object has to be taken into consideration (Fig. 3). We modeled the met station using the polar map in which the influence of the met station itself was included as an obstacle. The polar roughness diagram with 12 sectors was prepared based on topographical map given in Fig. 4 which also contains the objects (obstacles) and vegetation. The station is located at the periphery of the village Banatski Karlovac and is 800 m far from the next village Nikolinci. Both the objects and vegetation are modeled by the sector with different roughness length.

Fig. 3. Met Station Banatski Karlovac

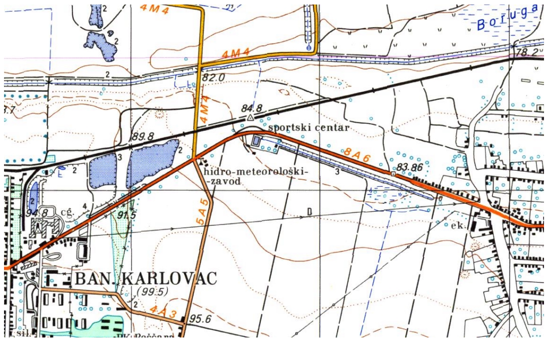

Fig. 4.Map around Banatski Karlovac met station

Dolovo site is located at 145 m height a.s.l. in slightly hilly region with the roughness which could be represented by the length of 3 cm. The region is exposed to all wind directions so that there is no influence of obstacles on the wind direction rose. The southwest wind acceleration is taken into account by orographic map.

At the position 44^0 56' N 20^0 53' E the NRG company 40 m tall mast was mounted equipped with 3 anemometers, wind direction measuring system and thermometer. The electronics for data handling was assembled at about 8 m height, together with the acu station for supplying the sensors and electronics as well as the signal light at the top of tower. The wind velocity is measured at 20 m, 30 m and 40 m heights. The picture of the measuring tower is given in Fig. 5.

Fig. 5 Wind mast at Dolovo

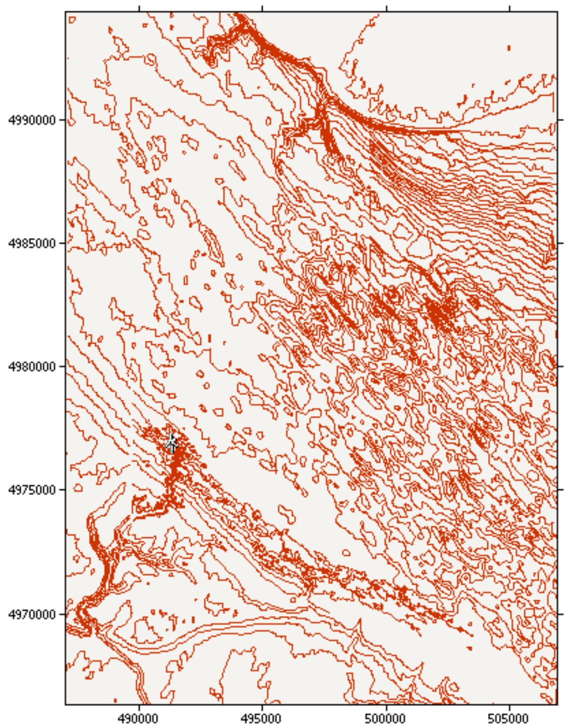

Fig. 6 Humka Nagula region vector map

The orographic database is completed by combining the orography map and the satellite vector map. 3D terrain configuration is 3-second satellite vector map, while around the sites more detailed 3D maps were obtained from 1:25000 topography maps.

It is very attractive today to use the satellite remote sensing also for wind velocity data, but still some additional terrain data are needed for wind resources prediction at the selected sites [4].

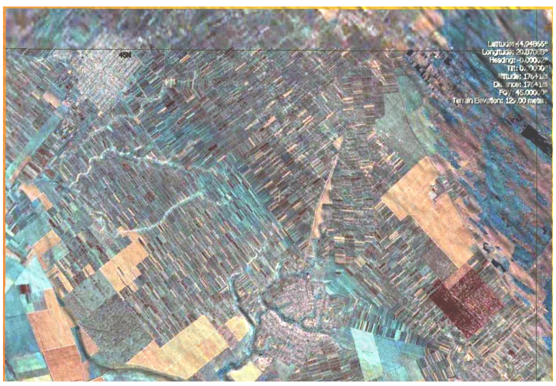

Fig. 7 Satellite photo of Humka Nagula (Dolovo) site

Combining the topographical 1:25000 map, satellite photos and the terrain inspection at the sites the roughness data were obtained. The obstacles around the met station Banatski Karlovac were included in the roughness rose. The vector orography map and satellite photos at Dolovo site are illustrated in Figs. 6 and 7 respectively.

IV. Results and Doscussion

A. Databases

The wind speed data are available from different sources but most data originated from international synoptic network for weather and similar purposes tracking. On different internet web site addresses the met station data were collected and we tried to evaluate such databases.

The reference data were taken from Helimax Company and municipality Pančevo wind station at Dolovo which were collected during March 2005. Since synoptic data used for comparison were given in the integer form, i.e. rounded-off without decimal digit, a large error is made at low wind velocity. As a consequence a windy month such as March 2005 was used as the reference.

Second database was obtained as hourly averaged wind speed with one decimal digit collected every hour during the Year 1997 at Banatski Karlovac met station. This database is called 1997 B. Karlovac.

TABLE I

March 2005 self prediction at measurement sites

Wind mast data 40 m March 2005			
	Weibull fit	**Combined**	**Discrepancy**
Mean wind speed	6.11 m/s	6.14 m/s	0.40%
Mean power density	218 W/m²	218 W/m²	0.01%
Met station data at 10 m March 2005			
Mean wind speed	4.15 m/s	4.20 m/s	1.21%
Mean power density	103 W/m²	103 W/m²	0.01%

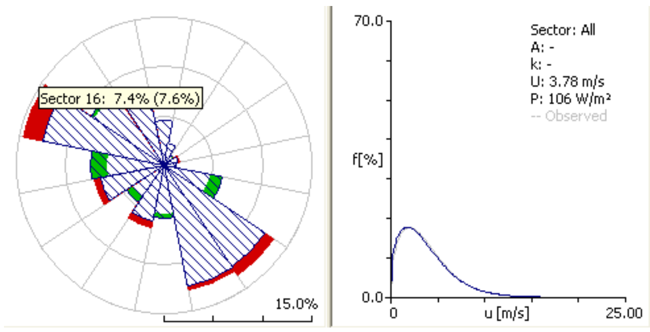

Fig. 8 Self-tests of wind data from Banatski Karlovac met station 1997 year

As the third data base, hourly averaged synoptic data base with the rounded-off wind velocity values collected during March 2005 at Banatski Karlovac station was considered.

The additional scarce data base for the station Banatski Karlovac with rounded-off velocity taken every three hours was obtained at the internet web sites **http://meteo.infospace.ru**.

For the calculation of wind atlas WAsP program version 8.2 was used and model consistency was tested by the self-testing procedure which calculates the wind velocity at the location of the measuring station itself. The results were illustrated in Table I and Fig. 8.

B. Predicted resources for 1997 Year

The met station data collected during 1997 year at 10 m height mast at Banatski Karlovac were used to predict the wind resources at Dolovo site. Fig. 9 illustrates the observed annual wind climate for the region. The corresponding Veibull distribution and wind rose are also given.

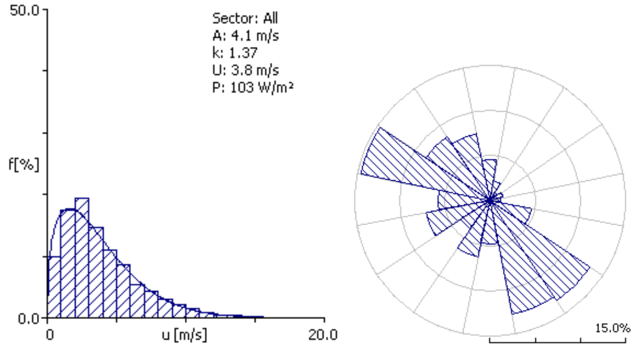

Fig. 9 Observed wind climate at the met station Banatski Karlovac, 10 m mast 1997

TABLE II
PREDICTED DELIBLATSKA PEŠČARA REGION MEAN WIND SPEED AT 40 M FROM MET STATION BANATSKI KARLOVAC DATA (1997)

Variable	Mean	Min	Max
Weibull-A	6.1 m/s	5.6 m/s	6.4 m/s
Weibull-k	1.54	1.51	1.57
Mean speed	5.51 m/s	5.05 m/s	5.80 m/s
Power density	267 W/m²	201 W/m²	311 W/m²
RIX	0.0%	0.0%	0.6%
Elevation	134.9 m	75.0 m	177.4 m

Table II summarizes the predicted wind resources at the Deliblatska Peščara region, for 1997 year 40 m above the ground.

It is interesting to compare this results with the annual averaged wind velocity obtained from data collected at Dolovo mast station from October 2004 to October 2005. The predicted mean speed for the year 1997 was 5.51 m/s. while measured wind speed during 2004-2005 year at the wind mast was 5.45 m/s.

V. PREDICTED AND MEASURED WIND DATA DURING MARCH 2005

The wind data taken during March 2005 at Banatski Karlovac met station containing wind speed in rounded-off form and the data from simultaneous measurements at Dolovo mast station were used to predict the mean wind characteristics over Deliblatska Peščara region shown on the map in Fig. 6. The results are summarized in Table III and Table IV. The mean speed obtained from met station data differ 6.6% from the reference data measured at Dolovo. The mean power density difference is 8.8%, which is inside acceptable limit taking into account the power dependence on the speed and wind direction rose.

The original 1997 year wind database with velocity discretisation 0.1 m/s and the same database with rounded-off velocities with 1 m/s discretisation gave non-important difference in prediction of the regional wind climate in Deliblatska Peščara. The difference between predicted values of mean velocity and power density was less than 2%.

TABLE III
PREDICTED WIND AT DELIBLATSKA PEŠČARA FROM MET STATION DATA-MARCH 2005

Variable	Mean	Min	Max
Weibull-A	6.3 m/s	5.9 m/s	6.7 m/s
Weibull-k	1.86	1.81	1.91
Mean speed	5.61 m/s	5.20 m/s	5.92 m/s
Power density	223 W/m²	172 W/m²	260 W/m²
RIX	0.0%	0.0%	0.6%
Elevation	134.9 m	75.0 m	177.4 m

TABLE IV
PREDICTED WIND AT DELIBLATSKA PEŠČARA FROM MAST STATION DATA-MARCH 2005

Variable	Mean	Min	Max
Weibull-A	6.8 m/s	6.2 m/s	7.1 m/s
Weibull-k	2.58	2.49	2.69
Mean speed	6.01 m/s	5.52 m/s	6.33 m/s
Power density	205 W/m²	155 W/m²	238 W/m²
RIX	0.0%	0.0%	0.6%
Elevation	134.9 m	75.0 m	177.4 m

It is interesting to validate the internet met data for wind energy potential assessment. From met station Banatski Karlovac the wind velocity data at the internet site http://meteo.infospace.ru were given non-regularly for each third hour in rounded-off form with 1 m/s discretisation. Figure 10 gives the comparison of wind rose and frequency distribution of velocity obtained from original met station data regularly recorded each hour and synoptic data from the same station collected at the internet web site. Besides much less data on internet, no large difference in wind rose, mean velocity and power density was found. The data were summarized in Table V. Actually, the internet wind database contains the values extracted from the met station base taken predominantly each third hour.

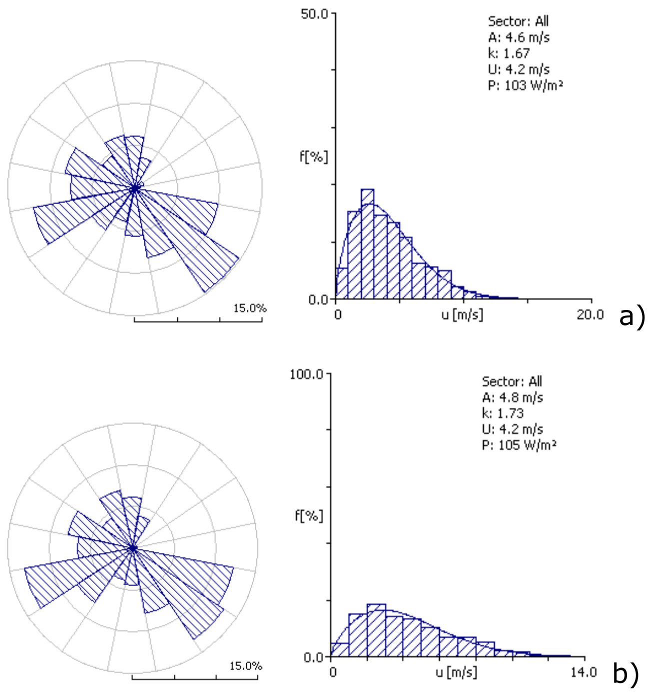

Fig. 10 Wind rose and frequency distribution obtained from a) original met station data and b) scarce data recorded at the internet site http://meteo.infospace.ru

The internet data were used as the input in WAsP program to predict the wind characteristics at the position of wind measuring mast located approximately 17 km far from the met station. It was found that the mean velocity can be predicted reasonably well, while the error occurs in predicting wind power density at 40 m anemometer position- 253 W/m^2 was predicted, while 216 W/m^2 calculated from the measurements. There is a large difference in wind rose as seen from Fig. 11 which contributes to large power density difference. The prediction may be improved by more precise siting which includes topographic elements, as well as data from additional met stations to account for more complex flow.

TABLE V
MEAN VALUES FROM MET STATION DATA AND FROM WEB SITE (MARCH 2005)

Original met station data	Unit	Measured	Weibull-fit	Discrepancy
Mean wind speed	m/s	4.17	4.15	0.49%
Mean power density	W/m²	101.16	103.02	1.85%
http://meteo.infospace.ru	**Unit**	**Measured**	**Weibull-fit**	**Discrepancy**
Mean wind speed	m/s	4.26	4.24	0.30%
Mean power density	W/m²	103.37	105.30	1.87%

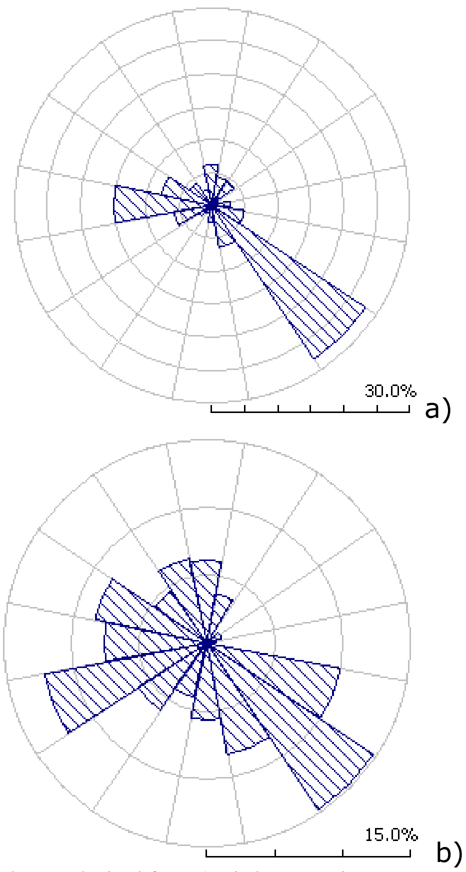

Fig. 11 Wind roses obtained from a) wind mast station measurements and b) from web site data

VI. CONCLUSIONS

The regional wind climate assessment requires wind data bases from the regional met stations, while for siting of wind energy potential the measurements at higher elevations than standard 10 m height met station instruments are needed.

The possibility of wind climate prediction in Deliblatska Peščara region in North Serbia using scarce met data from internet address http://meteo.infospace.ru was tested. The testing was performed for relatively windy month March 2005 year. It was found that rounded-off originally hourly averaged data taken each hour at the met station Banatski Karlovac gave satisfactory results compared to more precise 0.1 m/s discretised wind velocity values from the same data base. Relatively scarce hourly averaged data taken each third hour with rounded–off 1 m/s discretisation wind velocity were used to predict wind climate of Deliblatska Peščara. This procedure was found satisfactory regarding the mean wind velocity, but less effective concerning wind rose. For wind energy potential assessment at selected site both, more precise modeling based on roughness, orography and obstacles data, as well as more improved wind data base are required.

VII. ACKNOWLEDGMENT

The authors wish to thank the RISE partners for their contributions and the EC for partially funding this project. Thanks are due to Helimax Company and Municipality Pančevo for measuring data at Dolovo site. The valuable contribution of Mrs. Bojana Jakovljević, Mrs. Zlatica Popov, Mr. Veljko Zlatanović and Mr. Mirko Stojkanović is greatly acknowledged.

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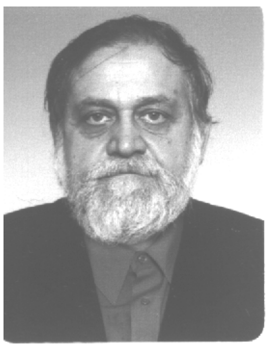

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Economic and Environmental evaluation of Large Solar Water Heating System installed in Macedonian Sheepfold

N. Bitrak, M. Todorovski, N. Markovska

***Abstract*— In this paper, we present a case study for a large solar water heating system installed at a remote location. The location, as well as the solar energy potential have been identified in the RISE Project (FP6 call for Western Balkans) dealing with renewables for isolated systems. We have evaluated the main economical and environmental parameters using the RETScreen software for a certain system selected from its database. The results have shown that even for this case when the avoided costs for heating energy (diesel oil) are pretty high, the payback period is longer then 10 years mainly due high investment costs and no grants. On the other hand, such system is a win-win measure for GHG abatement and it can greatly improve the quality of life at the location and contribute to a much better cheese production process. This in turn will produce higher incomes and better social situation in the region. All of the results are a valuable input for the further work under the other packages in the RISE Project.**

***Index Terms*— hot-water solar system, cost estimation, renewable energy sources, RETScreen**

I. Introduction

The solar irradiation in Macedonia is amongst the highest in Europe. The average solar radiation is about 3.8 kWh/m^2/day which is 30% higher then the value in many European countries. This promising solar energy potential is considered in the set of renewable energy sources (RES), which are investigated in the FP6 Project "Renewables for Isolated Systems – Energy Supply and Waste Water Treatment (RISE)".

According to the radiation measurements performed by the National Institute of Hydro-meteorology, the average daily solar radiation varies between 3.4 kWh/m^2 in the Northern part of Macedonia (Skopje) and 4.2 kWh/m^2 in the South Western part (Bitola). Under the conditions of the geographic belt where the meteorological stations are located, the total annual solar radiation varies from a minimum of 1,250 kWh/m^2 in Northern part of Macedonia to a maximum of 1,530 kWh/m^2 in the South Western part which leads to an average annual solar radiation of 1,385 kWh/m^2.

Although the geographic position of Macedonia and its climate provide favorable conditions for the successful development of solar energy, the low electricity prices and non-available investments are the main barriers to the large-scale dissemination of solar technology. However, ever increasing oil prices, as well as the expected introduction of a new electricity tariff system with prices close to the European electricity prices will change the economic situation of solar installations to a better position offering a shorter payback period.

This work has been performed within the EC funded RISE project (FP6-INCO-509161). The authors want to thank the EC for partially funding this project.

II. Study Case

A. Methodology

Under the RISE Project, several software tools for evaluation of renewable energy technologies (RET) have been studied (HOMER, HYBRID2 and RETScreen) [1]. For the evaluation of solar water heating system at one of the locations considered in the RISE Project, the RETScreen software package was found most suitable. RETScreen provides many results concerning the economic and environmental performances which are valuable input for the further work (e.g. Work Package 4) under the RISE Project.

The RETScreen International Renewable Energy Project Analysis Software [2, 3] is a unique decision support tool developed with the contribution of numerous experts from government, industry, and academia. The software, provided free-of-charge, can be used world-wide to evaluate the energy production, life-cycle costs and greenhouse gas emission reductions for various types of renewable energy technologies. The software also includes product, cost and weather databases; and a detailed online user manual. RETScreen is dedicated to the preparation of pre-feasibility studies. It uses international product data from great number of suppliers, as well as international weather data from many monitoring stations. In addition, RETScreen evaluates the greenhouse gas emissions reduction for various renewable energy technologies.

The RETScreen Solar Water Heating Project Model can be used to evaluate solar water heating projects. There are three basic applications that can be evaluated with the RETScreen software: Domestic hot water; Industrial process heat; and Swimming pools (indoor and outdoor).

Six worksheets (*Energy Model, Solar Resource and Heating Load Calculation (SR&HLC), Cost Analysis, Greenhouse Gas Emission Reduction Analysis (GHG Analysis), Financial Summary* and *Sensitivity and Risk Analysis (Sensitivity)*) are provided in the Solar Water Heating Project Workbook file. The *SR&HLC* worksheet is used to calculate the monthly energy load required to heat water to the desired temperature. This worksheet also calculates the annual solar radiation on the tilted collector array for any array orientation, using monthly values of solar radiation on a horizontal surface. The annual performance of a solar water heating system with a storage tank is dependent on system characteristics, solar radiation available, ambient air temperature and on heating load characteristics. The RETScreen SWH Project Model has been designed to help the user define the hot water needs, integrating a Water Heating Load Calculation section in the *SR&HLC* worksheet. To help the user characterize a SWH system before evaluating its cost and energy performance, some values are suggested for component sizing (e.g. number of collectors). Suggested or estimated values are based on input parameters and can be used as a first step in the analysis and are not necessarily the optimum values.

In the final worksheet "Financial Summary", numerous financial indicators are provided to help support decisions (e.g. internal rate of return, simple pay back, net present value, etc.). The results are then presented in a simple project cash flows graph for presentation to key decision-makers. The Financial Summary worksheet also allows the user to perform a tax analysis and a Clean Development Mechanism (CDM) type analysis for the individual project.

The *Sensitivity* worksheet is provided to help the user estimate the sensitivity of important financial indicators in relation to key technical and financial parameters. In general, the user works from top-down for each of the worksheets. This process can be repeated several times in order to help optimize the design of the solar water heating project from an energy use and cost standpoint.

RETScreen has three families of input parameters: site conditions, system characteristics, and financial parameters; while the main outputs are the annual energy balance, project costs and savings, yearly cash flows and financial feasibility.

The performance of service hot water systems with storage is estimated with the *f*-Chart method. The purpose of the method is to calculate *f*, the fraction of the hot water load that is provided by the solar heating system (solar fraction). Once *f* is calculated, the amount of renewable energy that displaces conventional energy for water heating can be determined. The method enables the calculation of the monthly amount of energy delivered by hot water systems with storage, given monthly values of incident solar radiation, ambient temperature and load.

Comparison of the RETScreen model predictions to results of hourly simulation programs and to monitored data shows that the accuracy of the RETScreen Solar Water Heating Project Model is excellent in regards to the preparation of pre-feasibility studies, particularly given the fact that RETScreen only requires 12 points of data (monthly average daily radiation on horizontal surface) versus 8,760 points of data for most hourly simulation models.

B. Location

In this paper, we have selected the sheepfold “Fezlievo Bacilo” as a location where a large solar water heating system will be installed. This location was identified in the RISE Project [4], following the priorities of the specific call under the FP6 dedicated to the Western Balkan countries:

- A possibility to supply the locations by small low cost RES
- Economic and social benefits for the local community
- The access to relevant information and availability of data about the location

“Fezlievo Bachilo” is located near the Albanian border on altitude of about 1950 m in the National Park Mavrovo, which is a well preserved entity of a vast ecological, economical and tourist significance.

It is populated only during the wormer part of the year, from May till October, when the sheep are brought to the lower parts to spend the summer. There are about 3000 sheep at the site and 10 employees. This remote location is with no electricity supply, and it is even without the diesel generator which was used before the crisis of 2001.

There are two smaller objects there. The first one is used for the employees (staff room); while in the other one the cheese production equipment is placed. They have need for electricity as well as hot water of at least 2000 littres daily (60˚C) for cheese production and hygienic purposes.

The site has quite good potential for RES exploitation, being situated in a small valley, exposed to the sun and protected from winds.

So far no systematic measurements of the solar radiation have been conducted on the location. However, applying some well-known interpolation methods (METEONORM software [5]), the underlying parameters can be calculated, and conclusions on the solar energy potential can be derived. The METEONORM software, calculates the hourly values for the whole year for all solar radiation and meteorological data. From the METEONORM output, for each month, the hourly values of the global solar radiation are calculated as an average over the set of hourly values from all days from the given month. The same procedure was applied on the set of hourly data for the air temperature, relative humidity and wind speed, so that the corresponding monthly average values have been obtained. These data, presented in Table I, are the essential input for the simulating software tools employed when sizing and determining the performances of the solar system in the given conditions.

TABLE I.
INPUT DATA FOR THE MODEL OF SWH SYSTEM FOR THE LOCATION “FEZLIEVO BACHILO”
(M.A.D- MONTHLY AVERAGE DAILY)

Month	Fraction (0-1)	M.A.D.rad. on horizontal surface (kWh/m²/d)	M.A. tem. (°C)	M.A.relative humidity (%)	M.A.Wind (m/s)
Jan.	0.00	1.99	-2.1	79.0	3.8
Feb.	0.00	2.70	-1.3	78.0	3.7
Mar.	0.00	3.54	1.3	74.0	3.9
Apr.	0.00	4.49	5.8	71.0	3.8
May	0.25	5.13	10.5	71.0	3.4
Jun.	1.00	5.22	13.7	71.0	3.3
July	1.00	5.93	16.2	67.0	3.3
Aug.	1.00	5.46	16.2	69.0	3.1
Sep.	0.25	3.93	12.9	73.0	3.3
Oct.	0.00	2.94	8.2	75.0	3.4
Nov.	0.00	1.94	4.0	77.0	3.7
Dec.	0.00	1.45	0.0	80.0	3.7

The calculated value for the annual solar radiation amounts to 1,368 kWh/m^2. This value is approximately the same as the county‘s average leading to the conclusion of favorability of the site for solar installations. Graphical presentation of the hourly distribution of global solar radiation over the year is given in Figure 1.

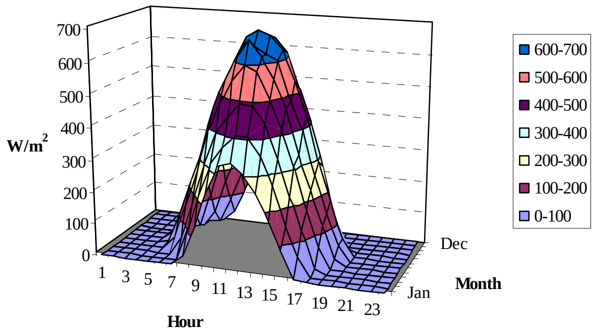

Fig. 1. Hourly Distribution of Global Solar Radiation

C. Large Solar Water Heating System

As for the large hot-water solar system, the financial evaluations are performed with solar collector “Sunlight 2500 R – T” produced by “Austria Email”. In this case the system has a storage tank of 2,631 litters and collector area of 13×2.4 m^2, i.e. 13 such collectors are required. The system is a pump system with a pumping power of 10 W per m^2 of collector area. A PV panel or the existing diesel generator will be used to supply electricity for the pump. It is assumed that such system can supply the needs for hot water of the sheepfold and it will be used for 7 days per week. The detailed data for this system are presented in the tables II, III and IV.

The investment cost of such system is estimated at 9,867 € which includes the equipment costs, transportation and installation. The operational and maintenance costs are estimated at 55 € per year, which is about 0.6 % of the investment costs. In addition, periodic costs of 500 € every 10 years for valves and fittings are considered. The project lifetime is 30 years.

TABLE II.
HOT-WATER SOLAR COLLECTOR CHARACTERISTICS

Solar Collector		
Collector type	-	Glazed
Solar water heating collector manufacturer		Austria Email
Solar water heating collector model		Sunlight 2500 -T
Gross area of one collector	m²	2.53
Aperture area of one collector	m²	2.40
Fr (tau alpha) coefficient	-	0.72
Fr UL coefficient	(W/m²) / °C	4.15
Suggested number of collectors		13
Number of collectors		13
Total gross collector area	m²	32.9

TABLE III.
HOT-WATER STORAGE CHACTERISTICS

Storage		
Ratio of storage capacity to coll. area	L/m²	80.0
Storage capacity	L	2,631

TABLE IV.

BALANCE OF SYSTEM

Balance of System		
Heat exchanger/antifreeze protection	yes/no	Yes
Heat exchanger effectiveness	%	80%
Suggested pipe diameter	mm	19
Pipe diameter	mm	38
Pumping power per collector area	W/m²	10
Piping and solar tank losses	%	1%
Losses due to snow and/or dirt	%	3%
Horz. dist. from mech. room to collector	m	10
floor from mech. room to collector	-	0

It is assumed that a large hot-water system will be installed on a Sheepfold where diesel oil is used for hot water production. The efficiency of the base case diesel boiler is set to 80% and the cost of the fuel is assumed to be 0.7 €/*l* (Table V).

TABLE V.
BASE CASE (DIESEL GENERATOR)

Base Case Water Heating System		
Heating fuel type	-	Diesel(#2 oil)-L
Water heating system seasonal efficiency	%	80%

D. Economic Evaluation

RETScreen uses the following five financial criteria for the economic evaluation of the projects: internal rate of return, net present value, year-to-positive cash flow, simple payback, and profitability index.

The following financial parameters were used in the analysis:

TABLE VI.
FNANCIAL PRAMETERS

Avoided cost of heating energy	€/L	0.70
Energy cost escalation rate	%	3.0
Inflation	%	2.0
Discount rate	%	8.0
Project life	yr	30
Incentives/Grants	€	1,500

Using the solar radiation and meteorological data, the RETScreen software calculates the annual energy production, as well as the solar fraction which are given in Table VII.

TABLE VII.
ANNUAL ENERGY PRODUCTION FOR A SWH

Specific yield	kWh/m²	247
System efficiency	%	64%
Solar fraction	%	43%
Renewable energy delivered	MWh	8.12
Renewable energy delivered	GJ	29.22

The financial feasibility of the project is presented in Table VIII, while the cumulative cash flows are presented in Figure II.

TABLE VIII.

THE FINANCIAL FEASIBILITY FOR THE SWH

Pre-tax IRR and ROI	%	8.7
After-tax IRR and ROI	%	8.7
Simple Payback	yr	13.8
Year-to-positive cash flow	yr	12.1
Net Present Value - NPV	€	667
Annual Life Cycle Savings	€	59
Benefit-Cost (B-C) ratio	/	1.07

Since the main economic indicators are depending on many systems' characteristics, such as the renewable energy delivered, initial costs and avoided cost of heating energy it is useful to perform a sensitivity analysis which will give valuable information about the project viability under different conditions. In Table IX and X, we give the results of the sensitivity analysis on the internal rate of return. The gray cells in the table are indicating an unviable project for a threshold for IRR of 7.4 %.

TABLE IX.
IRR SENSITIVITY ANALYSIS ON THE RENEWABLE ENERGY DELIVERED

Renewable energy delivered (MWh)		**Avoided cost of heating energy (€/litter)**				
		0.56	0.63	**0.70**	0.77	0.84
		-20%	-10%	0%	10%	20%
6.49	-20%	4.3%	5.4%	6.4%	7.4%	8.3%
7.30	-10%	5.4%	6.5%	7.6%	8.6%	9.6%
8.12	0%	6.4%	7.6%	**8.7%**	9.8%	10.8%
8.93	10%	7.4%	8.6%	9.8%	10.9%	12.0%
9.74	20%	8.3%	9.6%	10.8%	12.0%	13.1%

TABLE X.
IRR SENSITIVITY ANALYSIS ON THE INITIAL COSTS

Initial costs (€)		**Avoided cost of heating energy (€/kWh)**				
		0.5600	0.6300	**0.7000**	0.7700	0.8400
		-20%	-10%	0%	10%	20%
7,89	-20%	8.8%	10.2%	11.5%	12.8%	14.0%
8,88	-10%	7.5%	8.8%	10.0%	11.1%	12.2%
9,87	0%	6.4%	7.6%	**8.7%**	9.8%	10.8%
10,85	10%	5.5%	6.6%	7.7%	8.7%	9.6%
11,84	20%	4.7%	5.8%	6.8%	7.8%	8.7%

From the above tables, one can see that the project may not be attractive only in cases when the avoided costs of diesel oil are low in a combination with low renewable energy output and/or high initial costs. Bearing in mind the climate conditions in Macedonia, the level of the energy output will not be the main limiting barrier and even smaller barrier would be the price of diesel oil which is now pretty high and comparable to the European level prices. So that, we may conclude that the only uncertain parameter which may affect the IRR index is the initial cost.

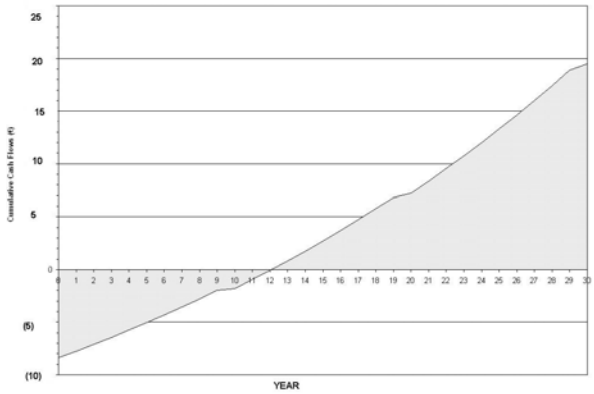

Fig. 2. Cumulative cash flows for the hot-water solar system

E. Environmental Evaluation

The RETScreen CO_2-eq emission factor for the diesel oil is 0.336 t CO_2/MWh, which is taken from the revised IPCC Guidelines for National Greenhouse Gas Inventories. By a multiplication of the renewable energy delivered (8.12 MWh) and the CO_2-eq emission factor (0.336 t/MWh), we get that the large hot-water solar system saves 2.73 tones CO_2-eq emissions annually.

TABLE XI.
GHG REDUCTION

Average GHG reduction	t CO_2/yr	2.48
Renewable energy delivered	MWh/yr	8.12
GHG emission reduction cost	€/t_{CO2}	-24

III. CONCLUSION

The economic indicators for large hot-water systems are attractive since in this case the avoided costs of heating energy (diesel oil) are pretty high. But even in this case, the payback period is longer then 10 years mainly due high investment costs and no grants.

The sensitivity analysis for this case has shown that any variation in the renewable energy delivered, initial costs and avoided cost of heating energy by a ±20% will not change the economic indicators in such a manner that the project may become unviable if it was viable before.

On the other hand, such system is a win-win measure for GHG abatement, since the emission reduction costs are negative meaning that the project saves certain amount of emissions, saving at a same time considerable fuel costs.

In addition, this project will greatly improve the quality of life at the location and will contribute to a much better cheese production process. This in turn will produce higher incomes and better social situation in the region.

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V. BIOGRAPHIES

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Estimation of Costs for Implementation of a PV System in an Isolated Region

A. Krkoleva, V. Borozan

***Abstract* —The estimation of costs for implementation of a small PV system are performed for a target location which was selected in the framework of Renewables for Isolated Systems-Energy Supply and Waste Water Treatment (RISE) Project. As input for the estimation, data collected from project participants were used. The estimation was made using RETScreen which is a software application with features that enabled determining the possible initial costs for the system which could be installed at the location. When performing the analysis it was assumed that the proposed PV system would allow replacement of a diesel aggregate or avoid grid extension. The results of the analysis show the cumulative cash flows for both assumed cases.**

***Index Terms*— cost estimation, photovoltaic system, renewable energy sources, RETScreen**

I. Introduction

THE investigation of possibilities offered by renewable energy sources (RES) for energy supply in isolated regions is the objective of the FP6 Project, Renewables for Isolated Systems-Energy Supply and Waste Water Treatment. The project goals are being achieved by investigating low-cost innovative RES technologies and by developing decision support and operational tools for wide implementation of RES in isolated regions. Later on, these tools should be applied to selected study cases in different parts of the West Balkan countries, comprising remote regions which are not connected to the electrical grid and physical islands.

This paper aims to show the preliminary estimation of the costs associated with the implementation of RES technology solution at one of the selected sites in Macedonia. As the project has not yet achieved the final stage, a suitable software application can be used to estimate these costs. For this purpose, in the future phases of the project, the tools developed by the project participants are expected to be used.

There are several software packages which include modules for optimization of the design of renewable energy sources for electricity in isolated regions, among which are: HOMER, HYBRID2 and RETScreen [1]. In HOMER and RETScreen the economical part is much more detailed than the technical part, while, on the contrary, HYBRID2 is much more technical than economical model.

HOMER [2] is a micropower optimization model that simplifies the task of evaluating designs both of off-grid and grid-connected systems for variety of systems. HOMER has been developed by the National Renewable Energy Laboratory (NREL) of the U.S. Department of Energy (DoE). HOMER models micropower systems with single or multiple power sources: photovoltaics, wind turbines, biomass power, run-of-river hydro, diesel and other reciprocating engines, cogeneration, microturbines, batteries, grid, fuel cells and electrolyzers. HOMER finds the least cost combination of components that meet electrical and thermal loads. It simulates thousands of system configurations, optimizes the lifecycle cost, and generates results of sensitivity analysis on most inputs. It is primarily an economic model and can be used to compare different combinations of component sizes and quantities, and to explore how variations in resource availability and system costs affect the cost of installing and operating different system designs. Some important technical constraints, including bus voltage levels, intra-hour performance of components, and complex diesel generator dispatch strategies are beyond the scope of this model.

HYBRID2 is a combined probabilistic/time series computer model for the simulation and analysis of hybrid power system performance. HYBRID2 is a joint project between the University of Massachusetts and NREL. It features a graphical user interface where the user can easily define the components of the system, the input data, the control strategy, and the economic parameters based on Windows. HYBRID2 was designed to study a wide variety of hybrid power systems. The hybrid systems may include three types of electrical loads, multiple wind turbines of different types, photovoltaics, multiple diesel generators, battery storage, and four types of power conversion devices. Systems can be modeled on the AC, DC or both buses. A variety of different control strategies/options may be implemented which incorporate detailed diesel dispatch as well as interactions between diesel gensets and batteries. An economic analysis tool is also included that calculates the economic worth of the project using many economic and performance parameters. The economic analysis that is completed by HYBRID2 was designed only to provide a reasonable estimate of system cash flow and an even comparison to an all-diesel power system alternative. Due to the complex nature of project economics, HYBRID2 was not intended to conduct a complete economic analysis.

RETScreen [3] is standardized and integrated renewable energy project analysis software. This tool provides a common platform for both decision-support and capacity-building purposes. RETScreen can be used worldwide to evaluate the energy production, life-cycle costs and greenhouse gas emissions reduction for various renewable energy technologies. RETScreen is dedicated to the preparation of pre-feasibility studies and is made available free-of-charge by the Government of Canada through

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Natural Resources Canada's CANMET Energy Diversification Research Laboratory (CEDRL).

RETScreen uses international product data from 1000 suppliers. It also uses international weather data from 1000 ground monitoring stations and also from satellite derived NASA Surface Meteorology and Solar Energy Data Set. RETScreen includes the following eight technology modules that are working independently (not linked): Wind Energy, Small Hydro, Photovoltaic, Solar Air Heating, Biomass Heating, Solar Water Heating, Passive Solar Heating, and Ground-Source Heat Pump Project Analysis.

In this case, RETScreen is used as it enables performing basic cost estimation, but it also has features which allow defining the technical characteristics of the RES system that would be applied at the selected site.

II. Study case Fezlievo Bacilo

AMONG the selected sites for application of RES technologies is the sheepfold Fezlievo Bacilo. It is a remote location with no electricity supply, situated in the western part of the country. The location is actually situated in the National Park Mavrovo which is a well preserved entity of ecological, economic and tourist significance, well known not only in the country, but also in the Balkans and Europe. The region covers the southern parts of Shara Mountain, a whole massif of the mountains Korab and Desat and parts of Bistra and Vlajnica. The region actually grasps the most beautiful relief of the country. There are as many as 52 peaks with an altitude higher than 2000 m. The National Park comprises 36 villages in four local regions. The village settlements are composed of old often deserted houses, occasional reconstructed village houses in the typical Mijak architecture but there are also a number of settlements with weekend cottages, modern hotels and tourist facilities all situated around Mavrovo Lake. The inhabitants are Macedonians, muslimised Macedonians and Albanians who earn their living by sheep breeding and agriculture where possible.

All of the suggested locations for RISE in Macedonia are actually situated in this part of the country. The basic information for the particular site is given in Table I.

Table I
General information about the selected location-sheepfold Fezlievo Bacilo

Location: Sheepfold Fezlievo Bacilo	latitude	41˚47’9”
	longitude	20˚35’41”
	altitude	1950 m
GSM/GPRS		available
Number of employees		10
Number of sheep		3000

Different types of data were gathered prior any planning of possible RES application. The collected data refers to solar radiation, wind speed, hydrology, meteorology, production of biogas, load identification etc. Data examination showed that the location has quite good perspectives for RES exploitation especially if solar and biogas potential could be used. As RETScreen doesn’t comprise technology module for electricity or heat production from biogas, the appropriate analysis for this kind of RES application are omitted.

Before collecting the data for the location, it was expected wind potential to be better. The provided data showed average annual wind speed of 3.5 m/s, which would not allow installing cost-effective wind application for electricity production at the particular location. Though no actual measurements were undertaken, the wind speed projections were made using software application and were compared with the results provided in the ongoing study for creating a wind map for Macedonia. Both sources showed similar results for average wind speed for the target location.

A. *Photovoltaic Project Analysis Model*

There are three basic Photovoltaic (PV) applications that can be evaluated with RETScreen [4]:

- On-grid applications, which cover both central-grid and isolated-grid systems;
- Off-grid applications, which include both stand-alone (PV-battery) systems and hybrid (PV-battery-generator) systems; and
- Water pumping applications, which include PV-pump systems.

The sheepfold is a remote location, with no grid connection, so the option for off-grid application is used.

The RETScreen Photovoltaic Project Model has three families of input parameters:

- Site conditions, which include project location, latitude of project location, annual solar radiation (tilted surface), annual average temperature;
- System characteristics, which include application type, nominal PV array power, PV module type, nominal PV module efficiency, slope of PV array, inverter capacity and average inverter efficiency (if inverter exists), battery data (if battery exits), load data (for off-grid applications); and
- Financial parameters, which include initial project costs (feasibility study, development, engineering, PV equipment, transportation, system installation), annual costs (property taxes/insurance, operation and maintenance), annual savings or income (energy savings/income, capacity savings/income, greenhouse gas reduction income) and parameters for the economic evaluation of the project (energy cost escalation rate, inflation, discount rate, project life, debt interest rate, debt term).

The photovoltaic energy model flow chart for off-grid applications is shown on figure 1.

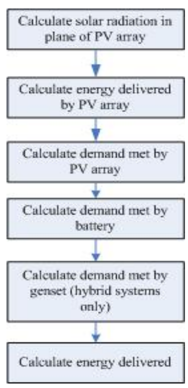

Fig. 1. The photovoltaic energy model flow chart for off-grid applications

As shown in figure 1, based on the values of input parameters and using appropriate formulas, the model calculates the energy delivered by the system. As it is an estimation tool, the software offers two types of analyses: pre-feasibility, less detailed, requiring lower accuracy information and feasibility analyses, which are more detailed and need higher accuracy information. As one of the project tasks in RISE is completing a pre-feasibility study for the target locations, this is the type of analysis that would be performed.

B. Load Identification

The load assessment was needed in order to be able to size the PV system that would supply electricity at the site and to select the appropriate equipment.

The small settlement is inhabited from May till October, so the system should provide electricity only during these months of the year. Tables with data for the appliances that would be used if electricity was available at site and the frequency of their use were made for all the months when there is activity at the sheepfold.

The data was assembled according the requirements made from the employees who work at the sheepfold. Table II shows data for a typical day in May. The highlighted rows in the table show the loads with higher priority.

TABLE II
LOAD IDENTIFICATION AT THE TARGET LOCATION

Appliance	Size (W)	Timing	Hours per week	Days per week
Light bulb 1	18	05-06 19-23	5	7
Light bulb 2	12	19-24	4	7
Refrigerator	300	0-24	12	7
Milk pasteurization machine	3000	16-21	5	7
TV/Radio	40	20-22	2	7

According to these data and by examination of the daily activities performed at the sheepfold, the projection of the daily load curve was made as shown in figure 2.

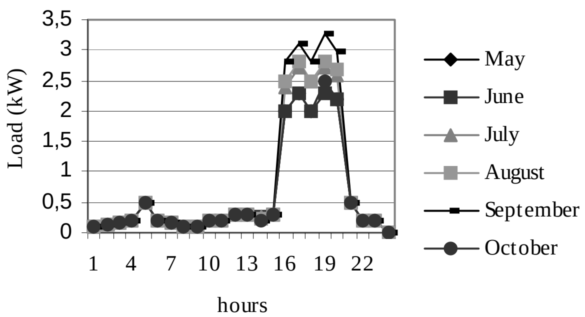

Fig. 2. Daily load curve for an average day during the months when the sheepfold is inhabited

The system would be expected to provide energy not only when exposed to sun, but also during the night hours, so energy storage device would be required. In this case the solution considers simple battery system which should be able to meet the load demand for two days starting from a state of full charge and using batteries only.

C. Solar radiation data

After identifying the loads, the next step was to collect data for the solar radiation at the location. Using the data for the monthly average daily radiation on a horizontal surface, the software is able to calculate the monthly average daily solar radiation in the plane of the projected PV array. The orientation of the PV modules is a very important design consideration for optimal energy collection. Best overall energy collection on an annual basis is generally obtained with south-facing collector having a tilt at an angle with the horizontal of approximately 90% of the latitude of the site [5]. For the particular location, the slope of the array is projected to be 36˚. The monthly average daily solar radiation data for horizontal surface and for the PV array plane are given in figure 3.

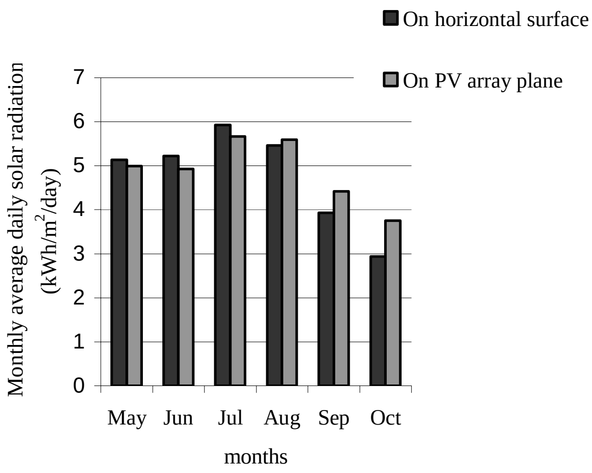

Fig. 3. Monthly average daily solar radiation at selected location

D. Description of the PV system

The load identification and the solar radiation are the basic data needed to choose the appropriate PV array. The software application offers a variety of PV products which could be used for different applications. For the purpose of this estimation, the modules with mono-Si cells are chosen. Being the most common PV modules in use today, the prices offered for this PV module type are supposed to be lower than other module types. It is obvious that the selection of the PV module type for a certain application depends on a number of factors including: price from suppliers, product availability, warranties, efficiencies, etc. The nominal module efficiency in this case, based on the information given by the producer is 11,1% .

In order to be able to provide for 100% load in the worst day of the month, the PV array should have nominal power of 6,96 kWp. As this is the worst case considered, it is possible to choose lower nominal power for the array, which would still satisfy consumer's needs. For this case, an array with nominal power of 6,02 kWp is chosen.

For the proper operation of the PV array, an array controller is needed. It is used to interface the PV array to the rest of the system. The Maximum Power Point Tracker is a type of controller that could be used at the particular application. It enables maintaining of the operational voltage of the array at a value that maximizes the array output. For more complex systems, the controller could be combined with other electronic devices with the purpose of better system performance.

The chosen PV array would have an array area of 54,2 m^2 and would consist of 43 modules. Because there is enough space at the sheepfold, the size of the array is not limited by the available land area. The roofs of the two small houses could be also used for mounting the PV array, which in that case could be divided in two separate parts, but bearing in mind that the size of the array should not exceed approximately half of the roof area. Where the PV arrays would be installed is important when calculating the costs of the supporting array equipment.

As stated before, the battery should have two days of anatomy, which should provide reasonable availability for the system. The battery that could be used for this application would be with nominal voltage of 24V and efficiency of 85%. The nominal battery voltage has no influence on the energy predictions of the model used by the software application. The use of additional diesel machine is not taken in consideration because it was assumed that the batteries would be able to provide enough reserve for the system.

E. Cost analysis and financial summary

Using this software application, the initial costs for the installation can be estimated. To perform these cost analyses, data for possible prices referring to energy equipment, balance of equipment, and miscellaneous are needed. The compilation of these data for Macedonia was especially difficult as the penetration of PV equipment on the market is quite low, so hardly any reference values exist. The basic energy equipment in this case includes the PV modules, while the balance of equipment includes the module support structure, the inverter, the batteries as well as the other electrical equipment. The costs for system installation and transport are also considered when the initial costs are calculated. The initial costs for the pre-feasibility study were calculated using average market prices [6] for all equipment which could be installed on site. The costs for preparing and developing the pre-feasibility study at this stage were not considered.

When performing cost analyses, it is important to stress out what conventional sources would be replaced with the proposed PV system. Two possible cases for the selected target location were analyzed:

- replacement of a diesel aggregate; and
- avoiding grid extension.

1) Replacement of a Diesel Aggregate,

When replacing a base system, which in this case is a diesel aggregate, with a PV system, the specific fuel consumption needed to provide given amount of electrical energy is directly related to the avoided cost of energy. The calculations were made assuming that the avoided cost of energy is 0,7 €/L (approx. 2,6 €/gal). These values, including the renewable energy delivered by the system are used by the software to calculate the annual energy savings. Several economic parameters like: energy cost escalation rate, inflation, discount rate etc are used by the model to obtain the cumulative cash flow for the proposed project. The calculations started assuming energy escalation rate of 5%, inflation rate of 1% and discount rate of 8%. The project life should span over 30 years.

The cumulative cash flow for a PV system which replaces a diesel aggregate is shown on figure 4.

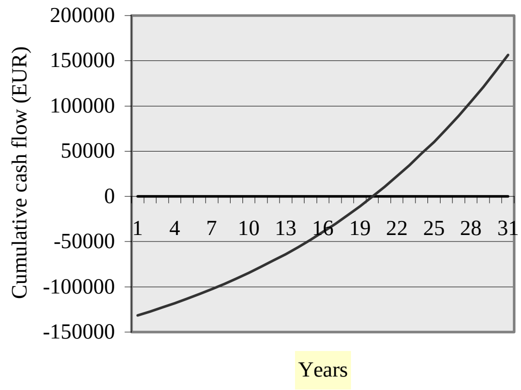

Fig. 4. Cumulative cash flow when PV system replaces a diesel aggregate

The cash flow analysis shows that the positive cash flow would be achieved after more than nineteen years. The model calculates the number of years to positive (cumulative) cash flow, which represents the length of time that it takes to recoup the initial investment out of the project cash flows generated. The year-to-positive cash flow considers project cash flows following the first year as well as the leverage (level of debt) of the project, which makes it a better time indicator of the project merits than the simple payback.

In this case further sensitivity analysis was performed because of the uncertainty of the used economical parameters, especially concerning the avoided costs of energy. The years-to-positive cash flow for the different assumed values for the avoided and initial costs are shown in figure 5. The changes of the avoided cost of energy and initial costs were made with 10% step change. The sensitivity analyses show that the change of fuel price would certainly affect the year to positive cash flow. Bearing in mind the big changes in fuel prices in the last two years, it becomes hard to predict how they would change in future

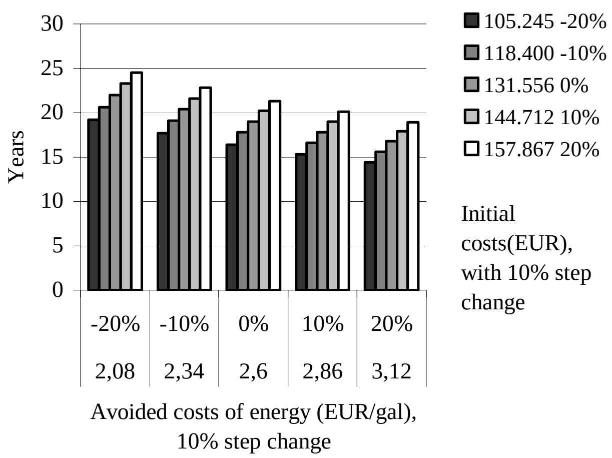

Fig. 5. Sensitivity analysis graph showing the year-to-positive cash flow when the avoided costs of energy and the initial costs are changed with 10% step change

Sensitivity analysis performed with 10% step change of the avoided costs of energy and annual costs is shown on figure 6.

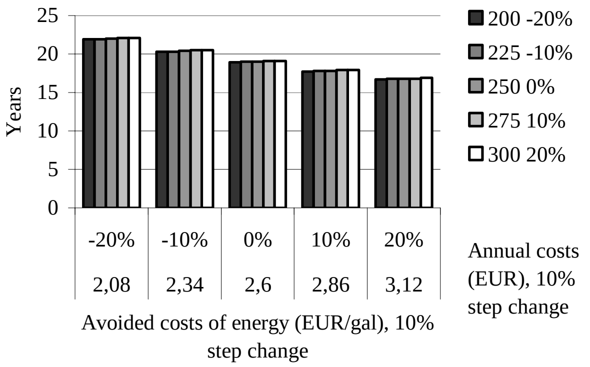

Fig. 6. Sensitivity analysis graph showing the year-to-positive cash flow when the avoided costs of energy and the annual costs are changed with 10% step change

2) Avoiding Grid Extension

When avoiding grid extension, similar analysis have been performed, assuming that the avoided cost of energy would be 0,05 €/kWh. The other parameters have been kept the same. The cumulative cash flow is shown on figure 7.

The cumulative cash flow shows that even after 30 years, year-to-positive cash flow would not be achieved. The analysis did not take in consideration any promoting measures for RES. The avoided cost of energy was set to the actual electricity price, but changes in electricity price should be expected.

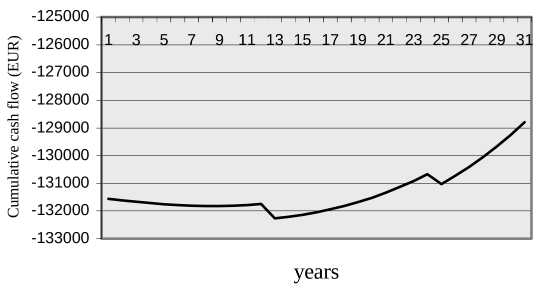

Fig. 7. Cumulative cash flow when grid extension is avoided

If the price of electricity is set higher, the year-positive-cash flow would be achieved sooner. The figure 8 shows the cumulative cash flow, assuming electricity price of 0,5 €/kWh, which is 10 times higher than the starting point.

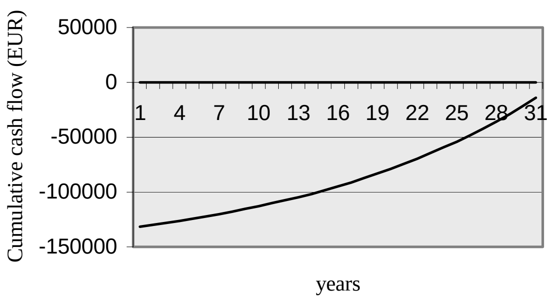

Fig. 8. Cumulative cash flow when grid extension is avoided when higher prices of electricity are taken in consideration

Even with this price, the year-to-positive cash flow would be achieved after the thirtieth project year. After applying sensitivity analysis to the second case, the prices for which the year-to-positive cash flow is obtained were determined. Figure 9 shows the year-to-positive cash flow assuming different values for avoided costs for energy.

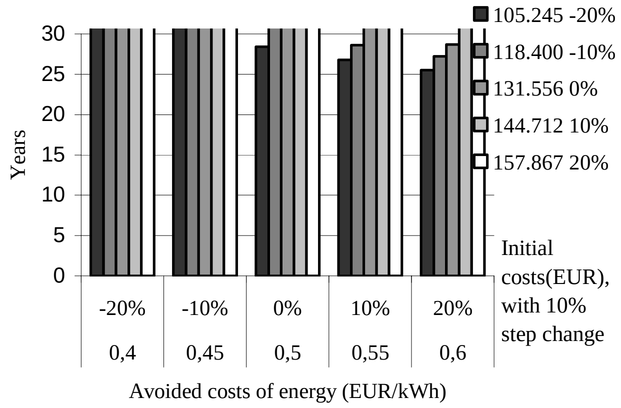

Fig. 9. Sensitivity analysis graph showing the year-to-positive cash flow when the avoided costs of energy and the initial costs are changed with 10% step change

Sensitivity analysis was carried out changing the avoided costs of energy and annual costs, again with step change of 10% and the results are given in figure 10.

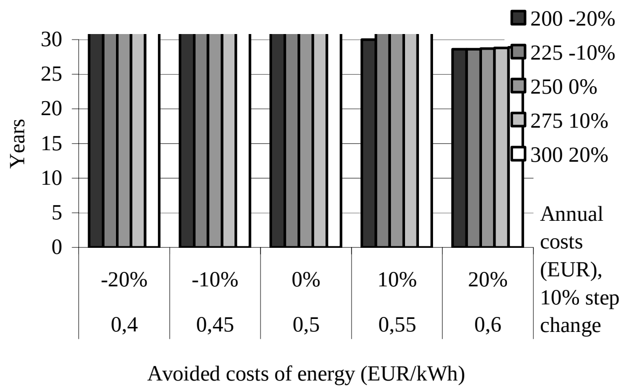

Fig. 10. Sensitivity analysis graph showing the year-to-positive cash flow when the avoided costs of energy and the annual costs are changed with 10% step change

The cumulative cash flow analysis were made considering the electricity grid as base system and assuming that the avoided costs for energy would be equal to the electricity price that the consumer would have to pay if the location was connected to the electricity grid. Further analysis should be made in order to estimate the costs for building and maintaining a distribution line to the location and compare them to the costs for building and maintaining the small PV system.

III. Conclusion

The estimation of costs for RES applications to isolated regions can be made using different software applications. The analyses in this paper were done with RETScreen, which is a software package with more detailed economic model. Only basic analyses were performed, not taking in consideration any supportive measures for RES technologies. The results showed the possible initial costs for the proposed PV system and the cumulative cash flows for the project.

It is important to stress out that the study case analyzed in this paper is selected from the proposed target locations in RISE Project. It is a remote location with no electricity supply. As it is a sheep-breading facility, the electricity supply would affect the quality of the cheese production process which is a main source of income for the employees of the company. The better product quality would make it more competitive in the market and would have impact to the local economy. Though these benefits were not taken in consideration when these analyses were made, they should be when deeper analyses for project evaluation are performed. The socio-economic benefits of RES project would have impact on overall evaluation of the project feasibility.

IV. Acknowledgment

The authors gratefully acknowledge the contributions of all RISE Project Partners: ICCS/NTUA, MEPSO, ICEIM-MANU, BIG, SOLTECH, IES, IRB, INESC Porto, ARMINES, UM, ULJ, UB, UTU and UKIM.

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VI. Biographies

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EXPLORATION OF WIND ENERGY POTENTIAL IN REPUBLIC OF MACEDONIA

Vladimir Dimcev, Krste Najdenkoski, Vlatko Stoilkov

Abstract-- In Macedonia there is no accurate knowledge of country's wind resources and it is a major barrier for any possible development of the utilization of wind power. The available wind speed information in Macedonia originates from the national network of meteorological stations. The paper explains latest developments considering exploration of Macedonian wind resources. A Wind Atlas of Macedonia was created in 2005. Four complete measurement stations were provided, which will be installed in May/June, 2006. After installations of the stations, the planned measurement campaign will start for 12 -15 months.

Index Terms—*wind energy, wind atlas, measurement of wind parameters*

I. Introduction

In last 15-20 years the wind energy exploitations faced dramatic development world-wide. The target set by EU commission for 10% wind generation penetration in overall electricity production in European Union by the 2010 now it seems feasible, and this goal will be reached even earlier. In Macedonia few dedicated professors from Faculty of Electrical Engineering (FEE) in Skopje started to push the idea that investigation of country wind resources is something that should be done as soon as possible. In fact the first step for wind farms development is to determine accurately the wind resources and potential wind energy production of a future wind farms in selected candidate sites. Unfortunately in Macedonia there is no accurate knowledge of country's wind resources and it is a major barrier for any possible development of the utilization of wind power. The available wind speed information in Macedonia originates from the national network of meteorological stations, which - as in the rest of the world – used alone are not sufficient for accurate wind resource assessment.

This situation was inspiration to make strategic plan for investigation of wind resources and potential and possible development of wind farms in the near future. The plan is consisting of three main phases: preparation of wind atlas which is numerical modeling based on geophysical and meteorological inputs, conducting of measurement campaign on the most promising sites defined from the atlas and preparation of feasibility studies as basis for possible erection of wind farms.

The first phase was conducted by ESM (the former Electric Power Company of Macedonia) and Wind Atlas was prepared by AWS Truewind Company from U.S.A in May and June, 2005. The second phase, now underway, is measurement campaign of wind parameters on selected sites. This phase is sponsored by Norwegian Ministry of Foreign Affairs throw Kjeller Vindtehnikk (KVT) from Norway with active participation of FEE and ELEM.

The four complete measurement stations with sensors, data loggers and musts were provided (April, 2006). The height of towers is 50 meters. This phase will last between 12 and 15 months.

II. Wind Energy Atlas

The Wind Atlases are based on numerical modeling of the large-scale climatology of the atmosphere. The inputs for modeling are typically taken from global databases: the wind field could be taken from the NCEP/NCAR database, the land-use from the GLCC data base of USGS (United States Geological Survey) and the height information of the country from the SRTM30 database by NGA (National Geospatial-Intelligence Agency) and NASA. This information is validated with all other available information (e.g. maps, satellite images, etc.).

In our case the medium scale modeling has been made to resolve atmospheric phenomenon on scales down to the order of 10's of kilometers. The model enables an understanding of the overall wind resource to such an extend that informed choices can be made for setting up measuring campaigns on selected sites. This wind atlas represents the mean of winds modeled in the medium scale class simulations after adjustment to specific standard surface conditions, uniform roughness and level terrain.

A. Description of the model

The wind resource modeling is mesoscale-microscale approach. This approach combines a numerical weather model capable of simulating large-scale wind patterns with a microscale wind flow model which respects the local surface and terrain conditions. The mapping of wind resources over large regions is with greater accuracy than has been possible in the past. Mesoscale-microscale modeling can greatly reduce the time and cost to identify and evaluate the potential wind project sites.

The used model is MASS (Mesoscale Atmospheric Simulation System), a numerical weather model developed by MESO, Inc. The model simulates the fundamental physics of the atmosphere including conservation of mass,

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momentum and energy, as well as the moisture phases and it contains a turbulent kinetic energy module that accounts the effects of viscosity and thermal stability on wind shear. MASS is a dynamical model which creates great computational demands, especially when running at high resolution. Hence MASS is coupled to a simpler but much faster program, WindMap a mass-conserving wind flow model.

The MASS model uses a variety of online, global, geophysical and meteorological databases. The main meteorological input is a gridded historical weather data set produced by the US National Centers for Environmental Prediction (NCEP) and National Center for Atmospheric Research (NCAR). The data provide a snapshot of atmospheric condition around the world at all levels of the atmosphere in intervals of six hours. The other meteorological input is data from land surface measurements. The model determines the evolution of atmospheric conditions within the region based on the interactions among different elements in the atmosphere and between the atmosphere and the surface.

The main geophysical inputs are: elevation of the country from SRTM30 database, land cover from the global 1km MODIS (Moderate Resolution Imaging Spectroradiometer) data set, vegetation greenness (normalized differential vegetation index - NDVI), soil moisture.

AWS Truewind has created a distributed processing network consisting of 94 Pentium II processors with 3 terabytes memory storage to meet the model computing requirements. In other word a typical mesoscale project that would take two years (94 weeks) to run on a single processor with distributed network of processors can be completed in just one week.

The MASS model simulates weather conditions for 366 days and each simulation generates wind and other weather variables (temperature, pressure, moisture, turbulent kinetic energy and heat flux), in three dimensions throughout the model domain, the information is stored at hourly intervals. The results are input into WindMap program for the final mapping stage. The two main products are (1) color maps of mean wind speed and power density at various heights above ground and (2) data files containing wind speed and direction frequency distribution parameters. The maps and data can be compared with actual wind measurements, if any are available, and adjustments to the wind maps can be made.

The possible sources of errors in the wind modeling are: the finite grid scale of the simulations, errors in assumed surface properties, errors in the topographical and land cover data bases. The finite grid scale of the simulations results in a smoothing of terrain features like mountains and valleys and blurring the boundaries between different land types (for example shorelines). This can lead to underestimation or overestimation of wind speeds.

B. Wind maps

The Atlas is consisting of wind speed maps at four heights (40m, 60m, 80m and 100m) together with the ArcReader CD which allows user to obtain the "exact" wind speed and wind direction values at any point. The map of predicted wind speed at 80m is shown on Fig. 1. The map shows that the best wind resources in Macedonia is generally found along high mountain ridges, while lowlands and valleys are likely to have much lower average wind speeds. The predicted mean wind speed at 80m height on the ridge tops varies from 6,5m/s to 8,5m/s. Unfortunately the windiest areas are at elevations above than 2000m, which may be impractical for wind projects.

Sites of moderate to good wind resources exist at lower elevation, however. Perhaps the most important examples are the hills on either sides of the Vardar River between Demir Kapija and Gevgelija, where the predicted mean wind speed reaches 7 – 7,5m/s at 500 -800m above see level. The river valley forms a gap in the mountain range, through which the wind flow is concentrated under some weather conditions.

The surface roughness surrounding a site also plays a big role, open fields and bodies of water experience greater wind speeds than urban or forested areas. It should be clear that the predicted wind speed at any particular location by the Atlas may depart substantially from real values due to errors on surface roughness, land cover, etc.

C. Site selection

The analysis done throw MASS model identified 15 candidate sites for wind farms, which were selected and ranked on the base of predicted mean wind speed, wind plant size, turbine output, cost of energy, interconnection cost and other factors. A brief summary of parameters for each site is provided in Table 1. The predicted wind resource at each point on the map was combined with elevation and temperature data to estimate the net annual output of 1,5 MW turbine with a 77m rotor diameter and 80m hub height.

The GIS-based approach considered the factors like: the cost for new transmission lines for connection to existing electricity grid, the cost for new access roads, terrains with slope greater than 20% based on SRTM digital elevation model, the gross turbine output was reduced by 12% to account planned maintenance and outages. These factors were combined with the minimum output for wind farm of 25 MW to predict the cost of energy (COE).

The amount of land area required for a 25 MW wind farm project depends on the type of terrain, direction of the wind, and other factors. In the program were assumed two extreme cases: a broad valley or plain with a multi-directional wind resources and a narrow ridge with a nearly one-directional wind resource. The program interpolated between these two extremes depending on the shape of the site.

The selected 15 candidate sites have a potential plant capacity between 25 MW and 33 MW. The cost of energy (COE) for the sites range from \$0,07/kWh to \$0,094/kWh, assuming a 25MW plant capacity, 15% fixed charge rate and no subsides or other incentives for wind projects. The predicted mean wind speed ranges from 6,7 m/s to 8,4 m/s. These figures are within the normal range for commercial wind projects being developed today.

An AWS Truewind engineer together with ESM engineers carried out a field inspection of selected sites between May 29 and June 3, 2005. The purpose of the trip was to assess the accuracy of the data used in the site selection, to assess the suitability of mountain ridge for installation of meteorological masts and wind turbines, to check the quality of roads, any restricted areas such as military facilities or telecommunication towers and microwave links.

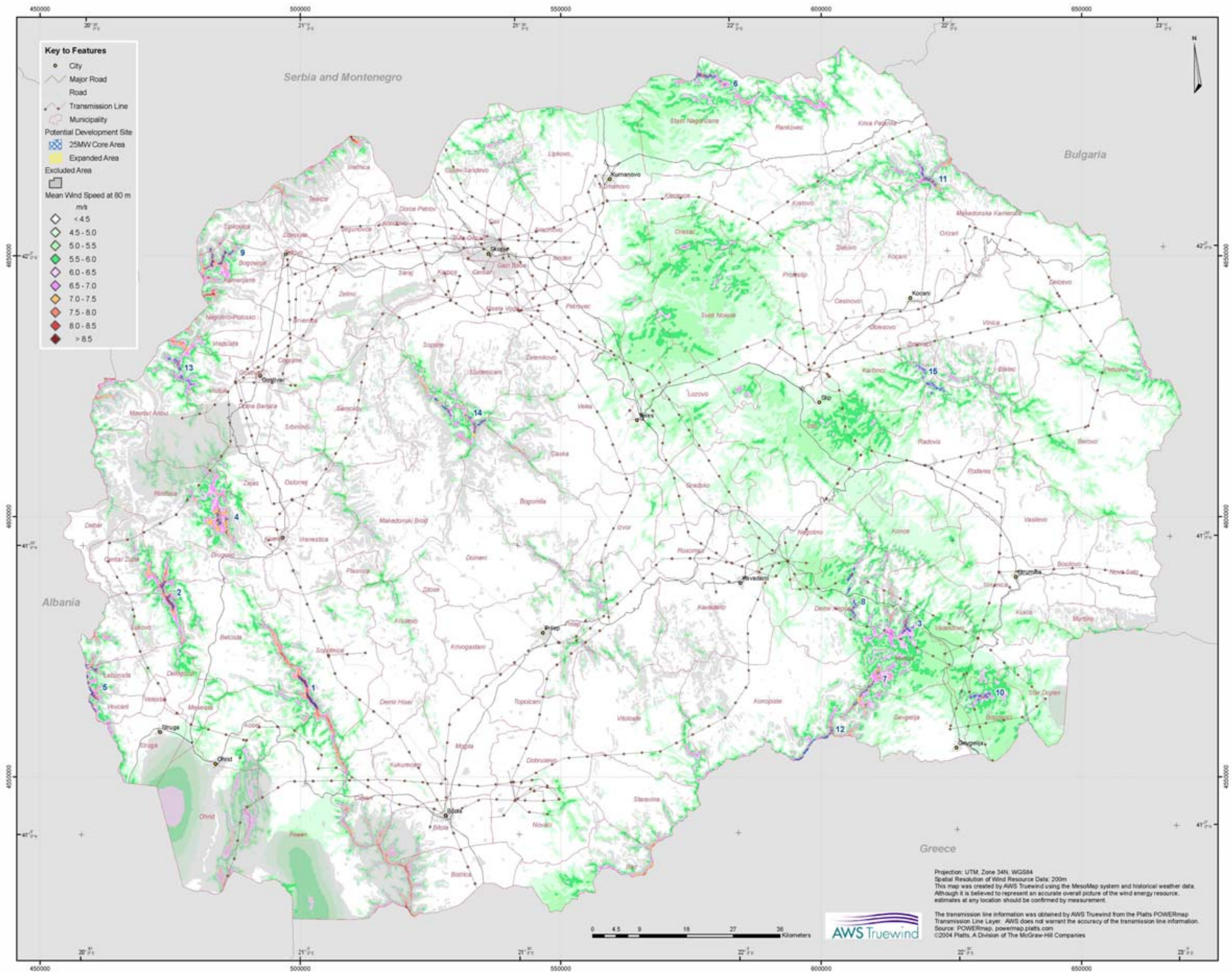

Fig. 1. Wind Resource of Macedonia - mean annual wind speed at 80 meters

After the site screening was completed and careful consideration of all obtained data by the Atlas were made, four sites are recommended for wind measurement campaign.

Site 7 - Kozuf Mountain has greatest potential for development of wind farm. It is large open grassland and the top of the ridgeline consists of gently rolling hills. The site elevation between 1300m to 1760m may produce problems during installation phase and maybe for maintenances of turbines.

Site 10 – Ranovec Mountain, Bogdanci, the ridge has 450-500m elevation and an east-west orientation in an area where the wind is predominantly from the southeast. The vegetation on the site is grass and low shrubs and the site is located between three 110kV lines linked into triangle. Maybe this site is most promising.

Site 16 – Sasavarlija, Stip the site was identified by ESM people. It is located several kilometers to the southeast from the town of Stip on highland with several dispersed hills and a maximum elevation of 996m. The predicted mean wind speed at 80 meters is 5,81 m/s with capacity factor of 22,44%.

Site 20 – Bogoslovec, Sveti Nikole the site was also identified by ESM people. The site is on short ridge of up to 750m elevation. The site has moderate winds of 6,0 – 7,0 m/s at 80 m according to the wind map and is estimated to have the potential to accommodate wind farm to 10 MW

TABLE 1
THE PREDICTED PARAMETERS OF 15 CHOSEN SITES BY MASS MODEL

General site data				25 MW Capacity				
ID	LON	LAT	Avg Elevation (m)	SPD 80m (m/s)	PWR 80m (W/m2)	AREA (km2)	DENS (MW/km2)	MW
1	21,02	41,25	1896	8,41	700	2,1	12	25
2	20,7	41,41	2079	7,97	502	2,1	12	25
3	22,39	41,35	566	7,35	482	2,2	11,5	24,9
4	20,82	41,54	1994	7,63	482	2,1	12	25
5	20,52	41,26	2088	7,85	690	2,1	12	25
6	21,95	42,31	1159	7,53	518	2,1	12	25
7	22,3	41,25	1453	7,45	581	2,1	12	25,4
8	22,27	41,4	641	6,96	370	2,2	12	26,4
9	20,81	42	2511	8,06	640	2,1	12	25,4
10	22,56	41,23	408	7,04	502	2,2	11,4	25
11	22,46	42,13	2003	7,3	488	2,1	12	25
12	22,18	41,15	1998	7,43	666	2,2	12	25,9
13	20,72	41,8	2134	7,13	413	2,1	12	25
14	21,38	41,72	2319	7,29	566	2,3	12	27,4
15	22,45	41,78	1577	6,68	384	2,2	12	25,9

III. MEASUREMENT CAMPAIGN

The objective of measurement campaign is to install, measure and analyze the wind parameters on four locations with promising potential of wind energy. The final goal is to obtain valid results for feasibility studies of wind energy potential on selected locations and final decision for building wind farms. This is the next phase, after the preparation of Wind Atlas, in overall scientific determination of regions and locations with promising wind energy potential. This initiative is perfectly fitted with governmental strategy for developing of renewable resources, as well as with the strategy of EU to develop renewable sources. The possible development of wind power plants in the near future will also have positive implication on the local economy.

The project is funded by Norwegian Ministry of Foreign Affairs throw Nord-Trondelag Elektrisitetsverk and Kjeller Vindteknikk also from Norway. In all phases of the project implementation (installation, commissioning, data acquisition, data analysis, etc.) professionals from FEE and ELEM are include.

A. Measurement equipment

For the realization of the measurement campaign four complete measurement stations are provided, which will be installed on 4 previously chosen sites. The height of the towers is 50m, this is a trade off between being as close possible to hub heights of today's wind turbines (80m or higher) and reducing cost of towers (lattice towers with that heights are expensive).

The measurements system is consisting of three anemometers, two wind direction vanes, thermometer. All sensors are by NRG Systems, USA and high quality anemometer on the top of the towers are made by RISO, Denmark. The wind speed sensors are calibrated according to the MEASNET standard with accuracy class of 0,1m/s, which is used by the wind industry in Europe. The wind direction is measured in two different heights for redundancy. Temperature is measured at 2 m, which is a meteorological standard.

In addition to sensors there are data loggers inside weather proof cabinets with communication capabilities over GSM line.

B. Data processing

All sensors are sampled every 2 seconds, average values, standard deviation, maximum and minimum values are saved every 10 minute, according IEC 61400-12. The data is stored on a data cards in the data loggers. The data loggers will send data once per day via GSM to dedicated computers. The measurements should continue at least 12 months, probably this period will be extended for few months.

The data will be processed and archived in a well-defined, systematic and consistent manner. All raw data received via remote communications will be archived monthly into a complete database. The raw files will be converted to engineering values (wind speed, wind direction, temperature) using appropriate software.

Incoming data will be checked regularly for any signs of equipment damage and/or malfunction. The completeness of the received data files will be analyzed weekly, and the data will be analyzed on a bi-weekly basis for errors and equipment failures. The need for accuracy is usually higher for wind energy projects than for weather forecasting. The analysis of data will be performed in close cooperation with the local meteorological office.

IV. Conclusion

The paper explains latest developments considering exploration of Macedonian wind resources. A Wind Atlas of Macedonia was created in 2005. The maps formed the basis for a GIS-based selection of 15 prospective sites where measurements should be done. Another five additional sites were proposed by ESM (now ELEM). From those 20 sites, after on sites visits four most promising sites were chosen for further measurement campaign.

Four complete measurement stations were provided, which will be installed in May/June, 2006. After installations of the stations, the planned measurement campaign will start for 12 -15 months. The final goal is to provide reliable results for feasibility studies of wind energy potential on selected locations and final decision for building wind farms.

V. Acknowledgment

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VII. Biographies

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