Project logo:

Priority logo:

Project No: **INCO – CT – 2004 – 509205**
Project acronym: **VBPC - RES**
Project title: **Virtual Balkan Power Centre for Advance of Renewable Energy Sources in Western Balkans**

Instrument: Coordination Action

Thematic priority: International Cooperation (INCO)

D5: 1st Summer School materials and conclusions

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Organization name:
Faculty for Electrical Engineering, University of Ljubljana

Revision:

Project co-founded by the European Commission within the Sixth Framework Programme (2002 – 2006)

Dissemination level

PU	Public

Virtual Balkan Power Centre
Renewable Energy Sources

Summer School 2005 Report

Bucharest, Romania 10-16 October 2005

Introduction

The traditional Balkan Power Summer School (BPSS) took place at University "Politehnica" in Bucharest, Romania, between 10.-16.10.2005. This year's student's event was part of the 6.FP project "The Virtual Balkan Power Center for Advance of Renewable Energy Sources in Western Balkans (VBPC-RES Project, INCO-CT-2004-509205)", co-funded by European Commission, and was co-organized by the University of Ljubljana, Faculty of Electrical Engineering, Ljubljana, Slovenia, Power Engineering Faculty from University "Politehnica" of Bucharest and ESTEC LC Bucharest. Ten students from Romania, Slovenia, Croatia and Serbia and Montenegro who qualified at the Balkan Power Student Contest 2004 were invited to participate in the BPSS. They met at "Politehnica" University to discuss Renewable Energy Sources, contemporary issues and technologies.

The lectures presented here had the main goal of involving students in problems related to Renewable Energy Sources (RES) in the region of Western Balkan. The countries in the Western Balkan region have great, but insufficiently exploited RES potential. The efficient use of RES could significantly contribute to security of supply within the region and in the wider neighbourhood. Special care should be devoted to innovative and viable solutions for electricity supply of underdeveloped areas and areas isolated due to war damage. Therefore this year's main topic of Summer School was the renewable energy sources in South – East Europe.

Academic program

A typical working day was divided to two lectures in the morning followed by lunch and free time. By dinner, two more hours of exercises were scheduled. Five international and two local lecturers prepared interesting lectures and exercises with focusing on RES problems, solutions and policies. While the BPSS was devoted primarily to policy and operational issues of RES as well as their potentials, photovoltaics (PV) and small hydro energy sources received their fair share of attention. The SS students were accommodated in the university's campus (a building used for guests and foreign students).

The academic programme was held by international and local lecturers, covering the following topics:

- wind energy - situation in Europe and Romania;
- solar energy;
- RES policies and their impact on trading with green electricity;
- green certificates, advantages and disadvantages of this system;

- the impact of distributed generation on medium voltage networks;
- aspects about micro hydropower plants.

In the first presentation of the BPSS, Dr. Andrej Gubina as representative of Faculty of Electrical Engineering, University of Ljubljana, presented RES Policy in Europe and other countries with special focus on Policy Instruments for the Promotion of RES and Recent Policy Developments. The following presentation of Dr. Dejan Paravan dealt with trading with green energy. Presentation included Green Certificate Trading, practical examples for Slovenia and Austria, RECS system, Feed-in tariffs and HSE's solution for promoting energy from renewals. Prof. Dr. Halilčević from Faculty of Electrical Engineering, University of Tuzla held a presentation with short intro to Sustainable Energy and focusing on energy of the sun, particularly photovoltaics and its possibilities. The lectures were complemented with appropriate accompanying exercises that were designed to give the students some hands-on experience and tools for practical problem solution. For example, in one exercise the owner of mountain hotel in Carpathian Mountains was able to calculate the necessary number of photovoltaic arrays to cover his demand for electricity. Romanian lecturers Prof. Dr. Tristu and Prof. Dr. Tânțăreanu have presented local problems and solution for RES and the impact of distributed generation on electric networks. Small hydro power plants were presented by Ms. Aleksandra Krkoleva from Faculty of Electrical Engineering, Ss. Cyril and Methodius University, Skopje, Republic of Macedonia, along with its problems and advantages. She finished her presentation with presenting RETScreen program for investment studies for RES project. The presentation of Ms. Elena Boskova of DMSG, Novi Sad, Serbia and Montenegro, dealt with the RES potentials of in European Union, and presented the analysis of their technical and economic potentials for the 25 member states of EU.

The lecturers were all very well informed and enthusiastic. The atmosphere was relaxed and still serious, so that everyone felt free to ask questions and debate the aspects that they were most interested in. The practical part of this event consisted in familiarizing the participants with software that calculates the economics of a power plant that uses an alternative source of energy. More than that, during the weekend trip, there has even been a real case study.

Participants

Participant	Country
• Vesna Bukarica	Croatia
• Florin Alexandru Ragea	Romania
• Ionut Burloiu	Romania
• Oana-Monica Gigica	Romania
• Cristian Pirvulescu	Romania

Maria Viziteu	Romania
Miloš Rakić	Serbia and Montenegro
Tomaž Oštir	Slovenia

Lecturers

a. International lecturers:

- UNI-LJ: Dr. Andrej Gubina
- UNTZ: Prof. Suad Halilčević
- UKIM. Aleksandra Krkoleva

b. Local lecturers:

- Assoc. Prof. Ion Tristiu,
- Ing Cristian Tantareanu, from ENERO – Romania

Cultural dimension and international bounding

Familiarizing the Balkan participants with elements of the Romanian culture was the task of EESTEC LC Bucharest. All of the activities were well organized and coordinated. The guests got to visit some of the most interesting parts of Bucharest and also a few of the most famous tourist objectives: The House of People, The Village Museum, The Traditional Costumes Museum (in the building of The House of People) and The Cotroceni Palace.

Also, the participants have started some nice friendships, exchanged contacts, and now they are keeping in touch.

This event was the prove of the good collaboration that exists between the Power Engineering Faculty, from University "Politehnica" of Bucharest and the Faculty of Electrical Engineering from Ljubljana and also the good communication between professors and students.

From this point of view, Maria Viziteu, member of the EESETC LC Bucharest, is thanking Professor Mircea Eremia and Professor Gubina, on behalf of the attending students, for maintaining the bonding alive.

Special Thank You

The Romanian organizing part is warmly thanking Senior Engineer Tantareanu from ENERO, for preparing the presentation with the situation of the wind power in Romania.

EESTEC would like to thank the partners TRANSELECTRICA and ELECTRICA that have substantially contributed with the financial support making the event possible.

Virtual Balkan Power Centre – Renewable Energy Sources

Summer School 2005

Bucharest, Romania 10-16 October 2005

RES Policy in Europe and other countries

Dr. Andrej Gubina
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University of Ljubljana, Faculty of Electrical Engineering
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Overview

- Introduction
- Policy Instruments for the Promotion of RES
  - – Main Instruments in the Sectors
    - Electricity, Heat and Transport
  - – Combining Several Support Schemes
  - – Success Stories and Key Barriers
- Recent Policy Developments

What is a RES policy?

- A plan of action for tackling issues related to energy supply, demand, development of energy related industry and trade and consequences of energy activities.

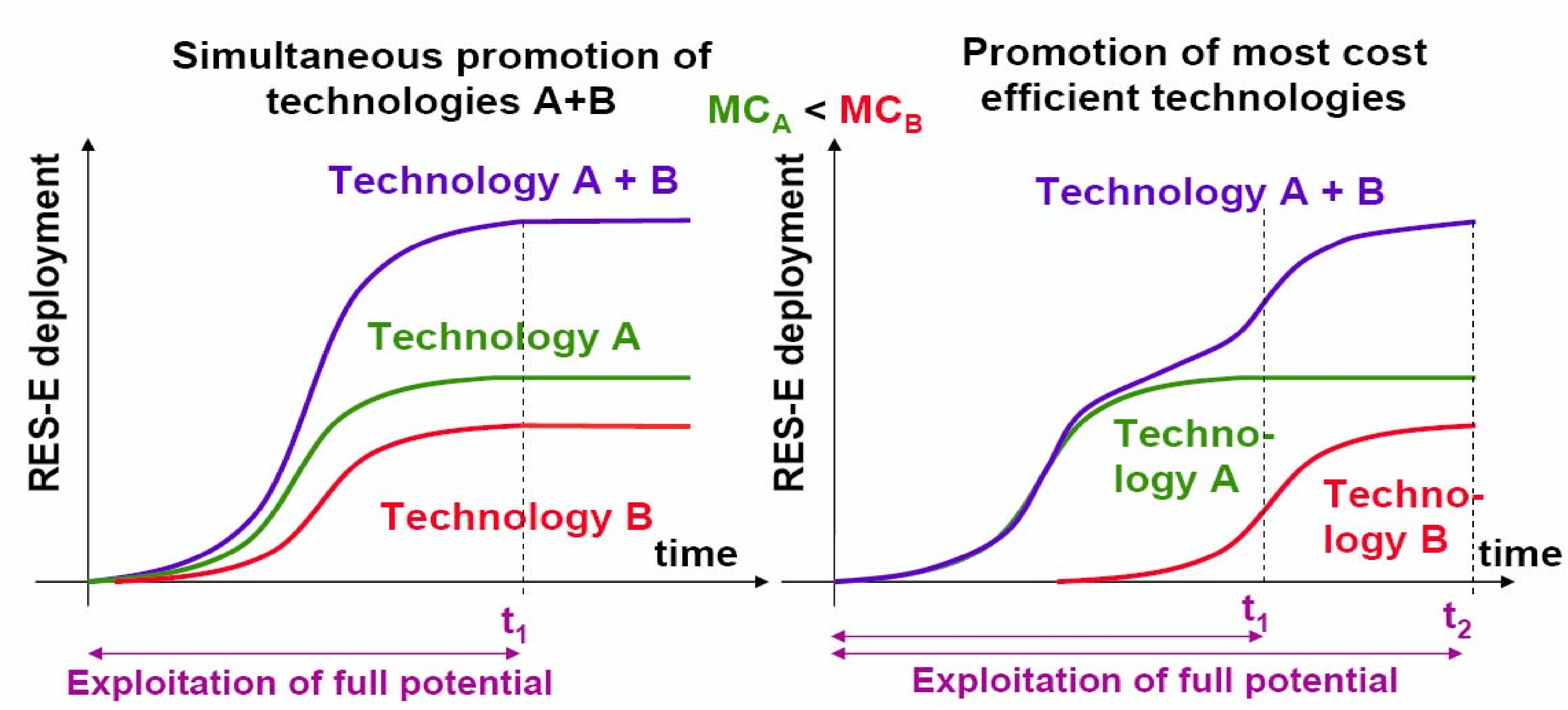
RES Policy

- A policy contains the following elements:
  - Statement of purpose
  - Clear and measurable goals:
    - E.g. % improvement, time schedule
  - Tools, methods and activities planned.
  - Responsibilities
  - Progress towards targets:
    - Process for monitoring and evaluation
  - Policy review/improvement process.

How to Set Up a Policy?

- Define the subject of the policy,
- Review state of the art,
- Define goals and specific targets to pursue,
- Select instruments, methods and activities,
- Delegate responsibilities,
- Set up clear guidelines based on experience,
- Define supporting bylaws to be adopted later,
- Set up process for periodic amendment and improvement of policy,
- Test it on small scale first, prepare rollout plan,
- Set deadlines for implementation.

Support of RES Technologies: Policy Choice



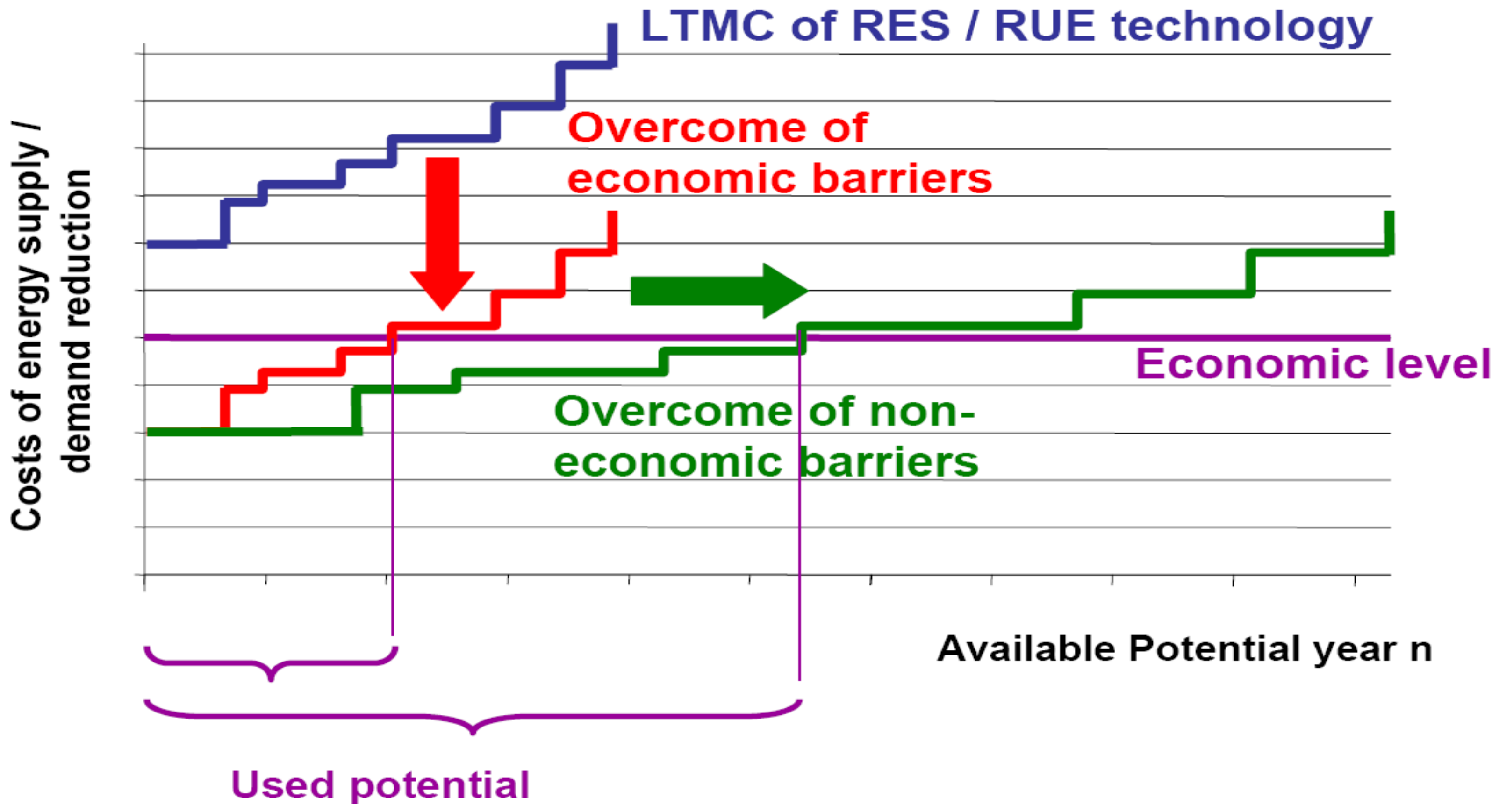
EU Policy Goals in RES

- Reach Environmental goals of EU – Kyoto Protocol
- Increase of security of supply
  - Decreasing the dependence on imported fuels and
  - Diversification of electricity generation sources
- Increase of social welfare
  - Creating new employment opportunities
  - Supporting social cohesion
- Contribution to the goal of the Lisbon process:
  - Sustainable economic growth
  - Improvement of the global competitiveness of the EU

Policy: Barriers to RES Growth

- Removal of economic barriers: introducing
  - Financial support mechanisms and
  - Promotion schemes,
- Mitigation of non-economic barriers:
  - Administrative barriers,
  - Market imperfections,
  - Technical obstacles and
  - Grid restrictions.

Policy: Barriers to RES Growth, 2



Policy Papers for RES Deployment

- 1997: White Paper "Energy for the future"
  - Target of share of RE in primary energy consumption: 6% in 1997 to 12% in 2010.
- 2000: Green paper on security of energy supply in Europe
- 2001/77/EC: RES-E Directive
  - EU-25 target of 21% share of RES-E in demand by 2010
  - Indicative targets for all 25 member states.
- 2001: Directive on the energy performance of buildings
  - Renewable heating applications support
- 2003/30/EC: Directive on the promotion of biofuels
  - Share of biofuels in total transport: 0,6% (2003) → 2% (2005), 5.75% (2010)
- 2003/96/EC: Energy taxation Directive
  - Several mid-term indicative targets and other requirements.

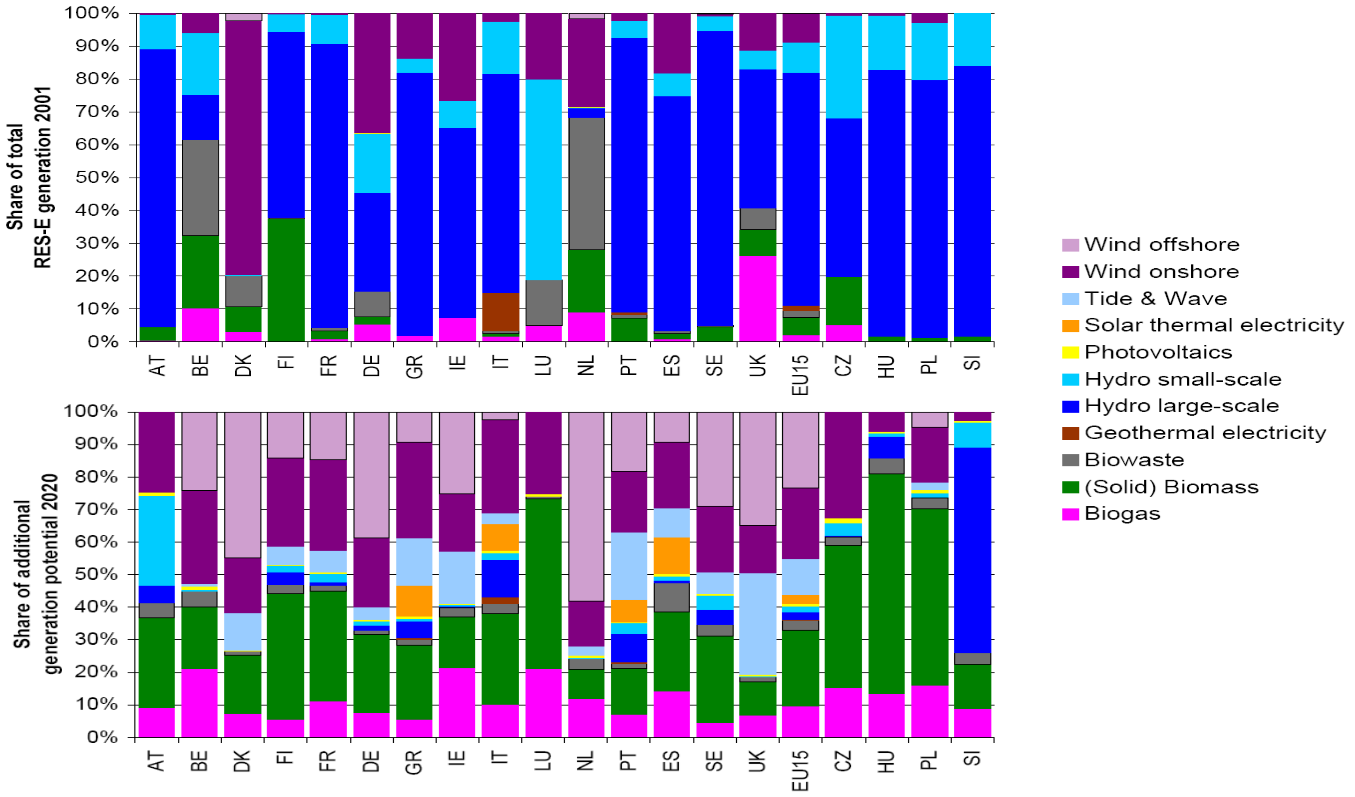
Indicative Targets for RES-E Consumption for EU-25 in 2010

EU-15	**Target (%)**	**EU-10**	**Target (%)**
Austria	78.1	Cyprus	6
Belgium	6.0	Czech Republic	8
Denmark	29.0	Estonia	5.1
Finland	31.5	Hungary	3.6
France	21.0	Latvia	49.3
Germany	12.5	Lithuania	7
Greece	20.1	Malta	5
Ireland	13.2	Poland	7.5
Italy	25.0	Slovak Republic	31
Luxembourg	5.7	Slovenia	33.6
Netherlands	9.0		
Portugal	39.0	**Total EU-15**	22
Spain	29.4	**Total EU-10**	11
Sweden	60.0	**Total EU-25**	21
United Kingdom	10.0		

Monitoring of RES Policy Measures

- What is the progress towards targets?
- Monitoring needs to focus on:
  - Is everybody on the same page?
    - Adoption of EU legislation into national legislation
    - Translation into national action plans and policy instruments
  - How do we measure performance?
    - Provision of framework to analyse the impacts of national policies
  - How successful are you?
    - Measurement of progress of the EU-25 states to the targeted deployment of RE.

RES-E: Achieved and additional Potential, 2001



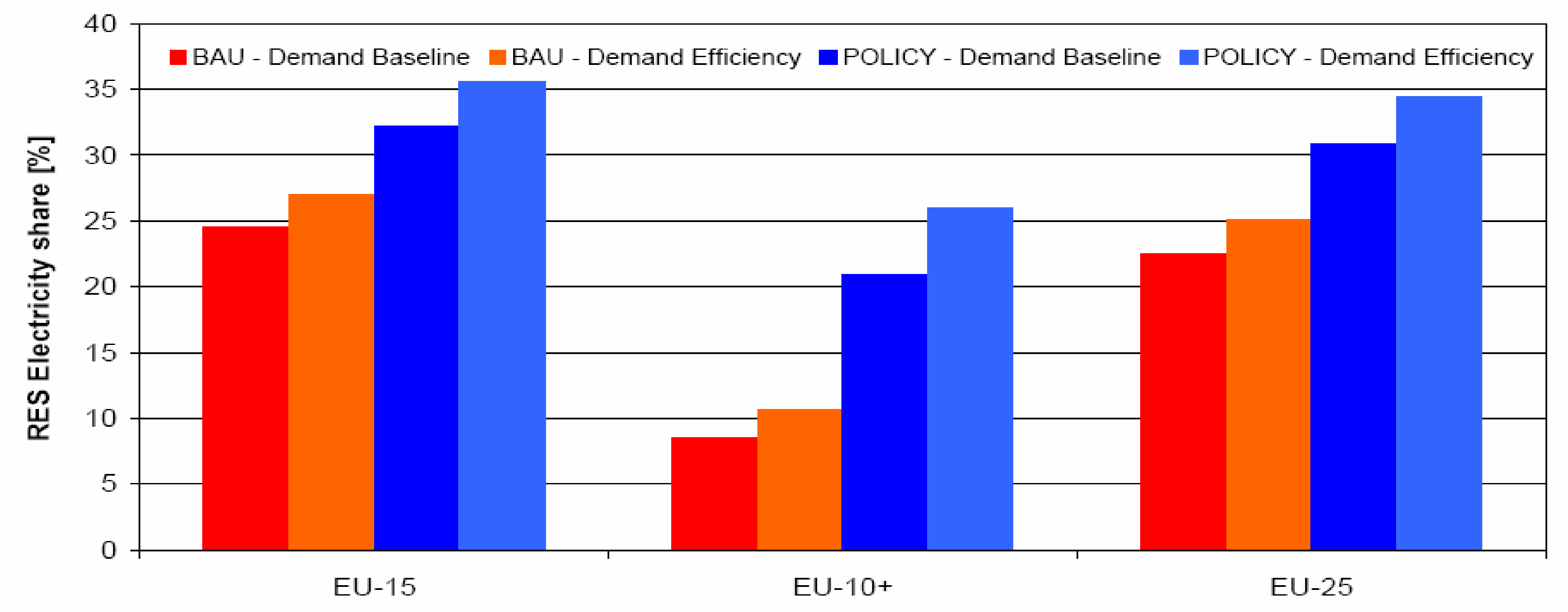
Interaction of Policies

- Policies must adapt to the changing market environment.
- Issues to impact Holy Three Directives (White Paper, RES-E Directive and Directive on Biofuels) :
  - EU Enlargement: new RES exploitation prospects (e.g bioenergy).
  - Interaction with other policies, e.g. environmental policies,
  - Completion of internal EU energy market,
    - Free consumer choice -> enhanced competition
    - Possibility to distinguish green products from conventional power.
    - Enhanced by required disclosure of fuel mix and environmental impact
  - Interaction with the Common Agricultural Policy (CAP reform)
    - The CAP is a highly important element of a consistent RES strategy.
  - The establishment of a carbon market – GHG emissions trading,
  - Affects the economic valuation of investment opportunities.

Monitoring of the policies - on national level (implementation!)

- Detailed analysis of existing national
  - RES objectives and Policies
  - Promotion schemes
  - Barriers
- Result: proposal for a strategy for 15 years ahead (2020)
- Scenarios for future evolution:
  - Business-as-usual (BAU): Present policies and barriers
  - Policy scenario (PS): Best practice national policies are selected
  - Both assume the technology learning effect and economies of scale
- Methods for forecasting of RES penetration
  - Model-based: explicit modeling of relationships
  - Econometric analyses: correlations on historical data
    - Best practice policy implementation and corresponding RES penetration

Share of RES-E production in 2020



Overview

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  - – Main Instruments in the Sectors
    - Electricity, Heat and Transport
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Main Instruments in the Sectors

- The main RES policies and measures in Europe are focusing on RES-E.
  - Choice of instruments has not been prescribed or harmonized in Europe
  - Each country adopted own unique set of promotion instruments.
- National RES goals:
  - Environment,
  - Security of supply,
  - Employment support for national (emerging) renewable industries.

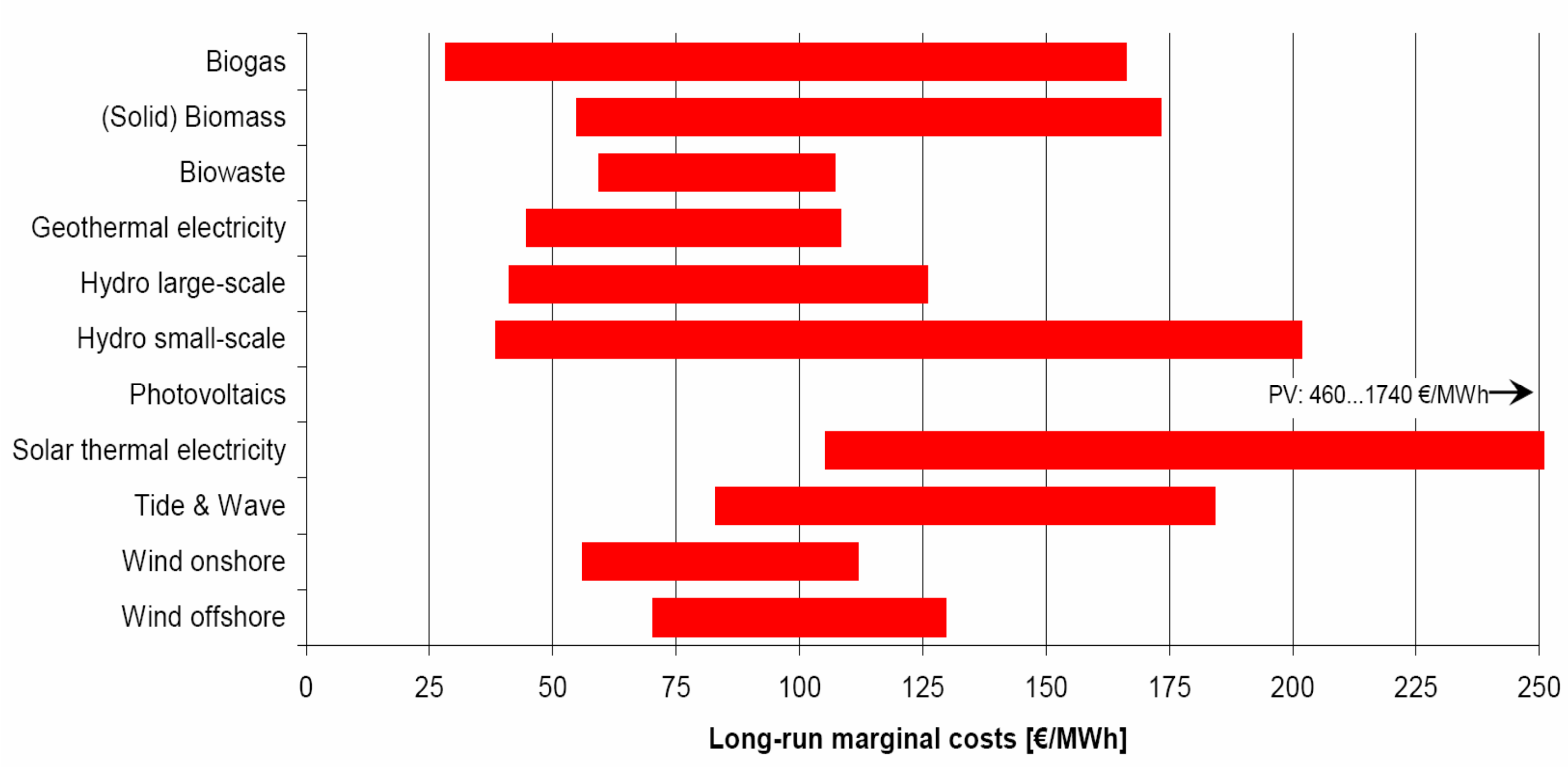
RES-E: Supporting Instruments

- Main instruments to support generation of RES-Electricity are:
  - Fixed feed-in tariffs,
  - Quota obligations,
  - Green certificate system,
  - Fiscal incentives,
  - Tender scheme.

Evaluation Criteria of Policy Instruments

- How do you know which instrument is the right one?
  - Effectiveness: quantitative goals, capacity or production
  - Market efficiency: price competition, min. of costs
  - Certainty for RES-E industry: system stable in the short/long term?
  - Cost effectiveness: costs per kWh of RES-E
  - Stakeholder support for the system
  - Equity: long-term sustainability os the system
    - fair distribution of costs and benefits of RES-E implementation over various stakeholders.

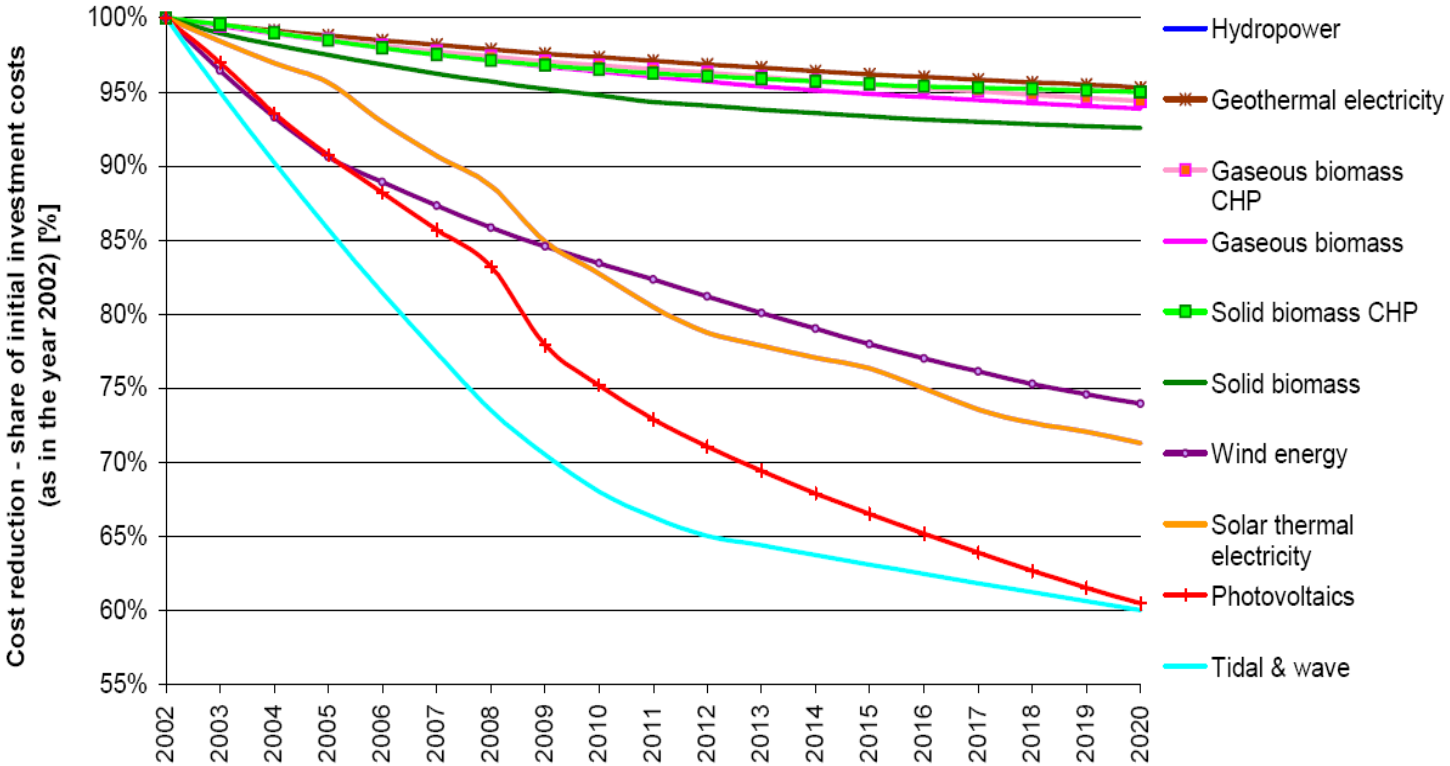
Long-term marginal gen. costs (2002) of RES-E technologies



RES-E: Fixed feed-in tariff system

- Main instrument for RES-E generation support in EU-25.
- Advantages:
  - Investors get longer-term certainty about receiving support,
    - Much lower investment risks of future return on investments
    - Significantly lower capital costs for RES investments
  - Lower costs for society.
    - Stepped tariffs reduce producer surplus (by limiting windfall profits)
    - A tariff can be reduced over time in line with technology learning.
  - Can be designed to promote a broad portfolio of RES technologies.
    - Early market diffusion of less mature technologies,
    - Higher dynamic efficiency (lower costs for society in the long term).
- Disadvantages:
  - FIT do not stimulate sufficient competition among RES generators
    - Does not bring down the costs of RES technology investments.
    - Generation costs for individual installations might be higher.
  - Relies on more government involvement than quota system.

Development of Investment Costs (BAU scenario)

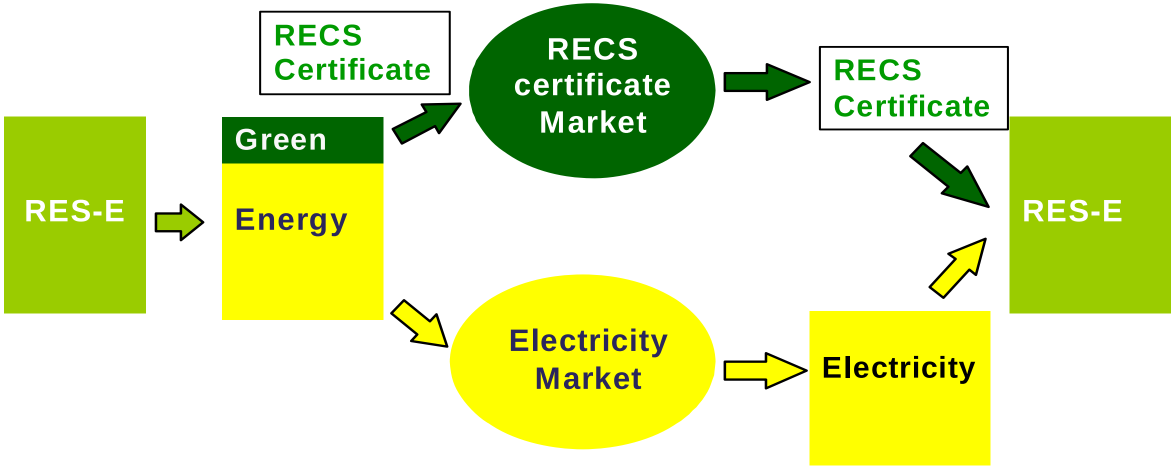


RES-E: Renewable Quota Obligations (RQO)

- RQO are relatively new, used in 5 of 25 EU states (BE, IT, SE, UK, PL).
- Impose minimum shares of renewables on
  - Consumers,
  - Suppliers or
  - Producers.
- The system is often combined with green certificate systems.
- Advantages:
  - Relies more on market forces and competitive policies than FIT
  - Provides a strong incentive for short-term technology cost reductions.
- Disadvantages:
  - Initial stage of development,
  - Complexity of the system,
  - Risk of supporting only lower-cost technologies.
  - Only works well when designed carefully.
- Basic concepts of RQO and FIT are gradually converging.

RES-E: Tradable Green Certificates (TGC)

- Also known as Tradable Renewable Certificates (TREC)
- Market-based instrument for transfer of production attributes or environmental quality of RES-E separately from electricity.
  - For each 1 MW of electricity 1 TGC is issued.
  - Buyer assures that RES-E is produced somewhere in Europe.



RES-E

RECS Certificate

Green

Energy

RECS certificate Market

Electricity Market

RECS Certificate

Electricity

RES-E

RES-E: Tradable Green Certificates (TGC), 2

- Several national and international systems exist, the main ones are
  - RECS certificates: www.recs.org
  - Guarantees of Origin (GoO): based on RES directive (2001/77/EC)
- Advantages:
  - Completely market based
  - Internationally supervised, standardized, universal
  - Can distinguish among supported technologies: the buyers decide!
  - Can be a foundation for green retail products
- Disadvantages:
  - Double counting can be an issue
  - Voluntary market alone is not sufficient to sustain trading.
  - Obligatory market is coupled with Quota obligations and works well.
- Certificate systems are becoming increasingly popular, linked to different support schemes:
  - UK, IT, SE (considering: CZ, PL): to Quota obligation
  - NL: to FIT / Tax exemption
  - BE: to FIT / Quota

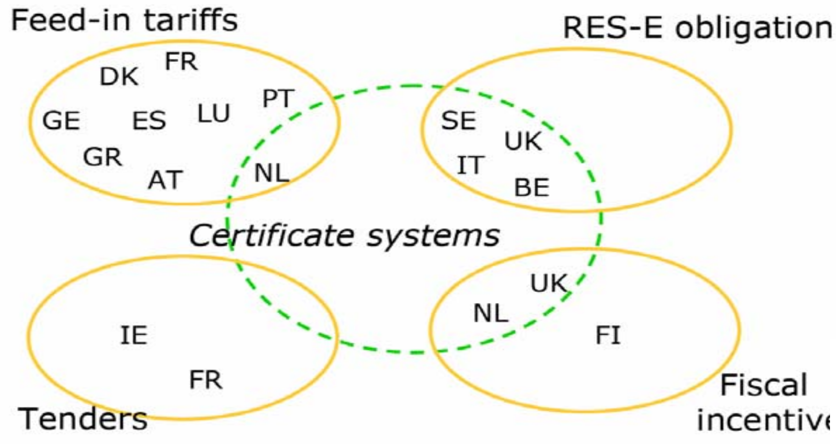
RES-E: Tax / Fiscal incentives

- Indirect financial support through taxes.
- Fiscal incentives are
  - Producer: tax exemption of CO2
  - User: reduced energy taxes.
- Advantages:
  - Convey direct message to final energy consumers about the added value of RES-E.
- Disadvantages:
  - No longer-term certainty about investments → increased investment risks.

RES-E: Tender scheme

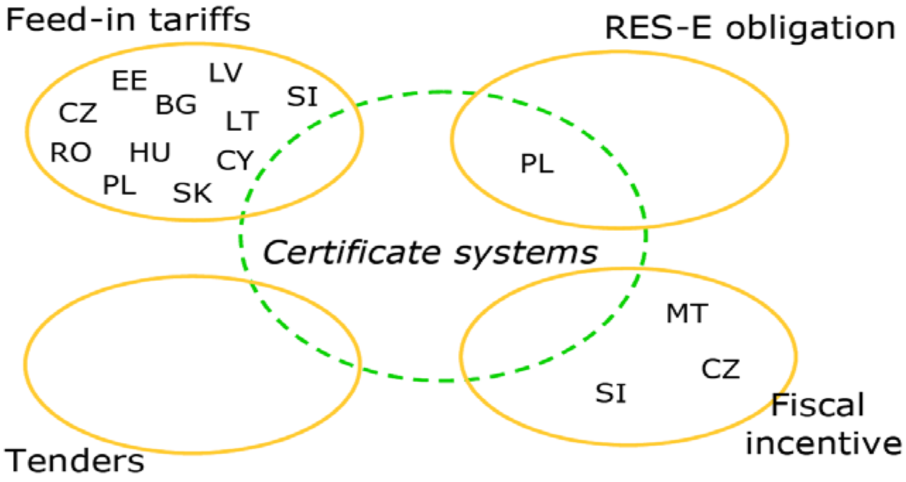
- Gov’t issues a tender for licenses for building RES-E generation.
- Tender scheme has been used in the UK and is still used in Ireland and France.
- Advantages:
  - Draws attention towards RES-E investment opportunities
  - Incorporates competitive element.
- Disadvantages:
  - Overall number of implemented projects very low,
  - Much lower penetration of renewables than anticipated.

RES-E: Overview of Renewable Electricity Support Systems



- EU-15

- EU-10

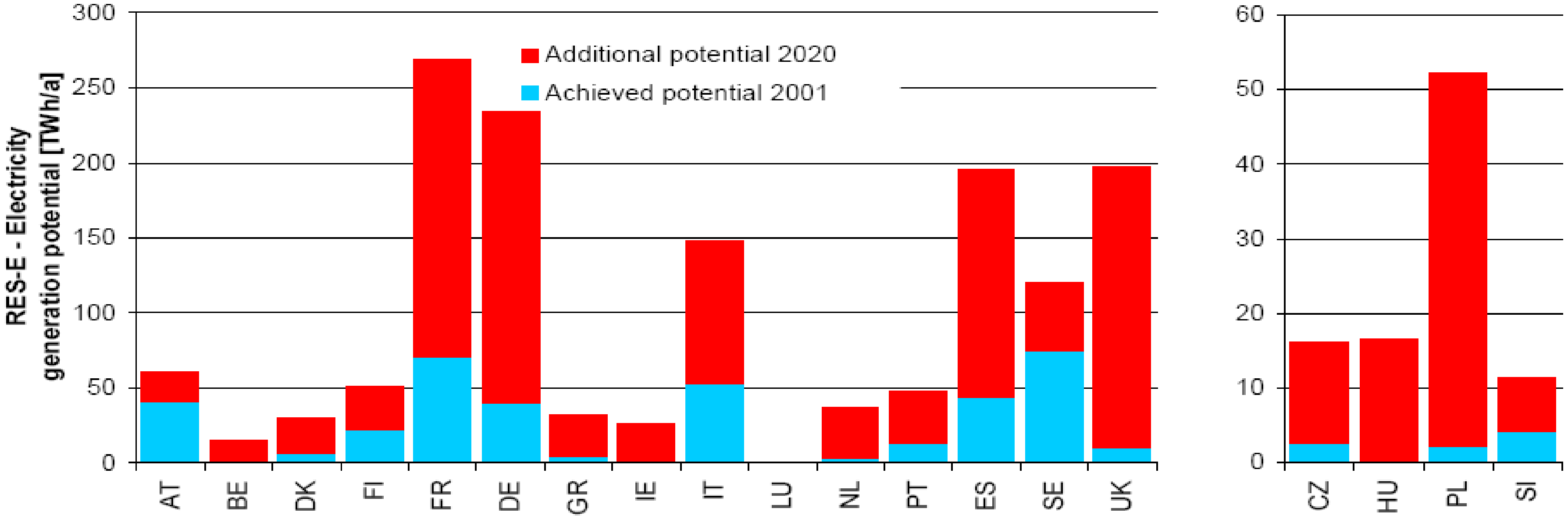


Status of the RES-E market

- RES-E continued to increase significantly in recent years.
  - Most countries are still behind targets.
- Wind: high growth rates are to continue offshore.
- Biomass: starts growing, but slowly in most countries.
  - large unexploited potentials in new member states
- PV: growing, constant high rates
  - DE: new FIT → accelerated growth!
- Active solar thermal el.: to grow by 15-20% annually
- Wave, Tidal: Significant growth in the medium term
- Geothermal: small growth.
- Hydro: small growth.
  - some remaining potential for refurbishments.
  - Large hydro: Most environmentally sustainable potential exploited

RES-E: 2001 vs. Potential in 2020

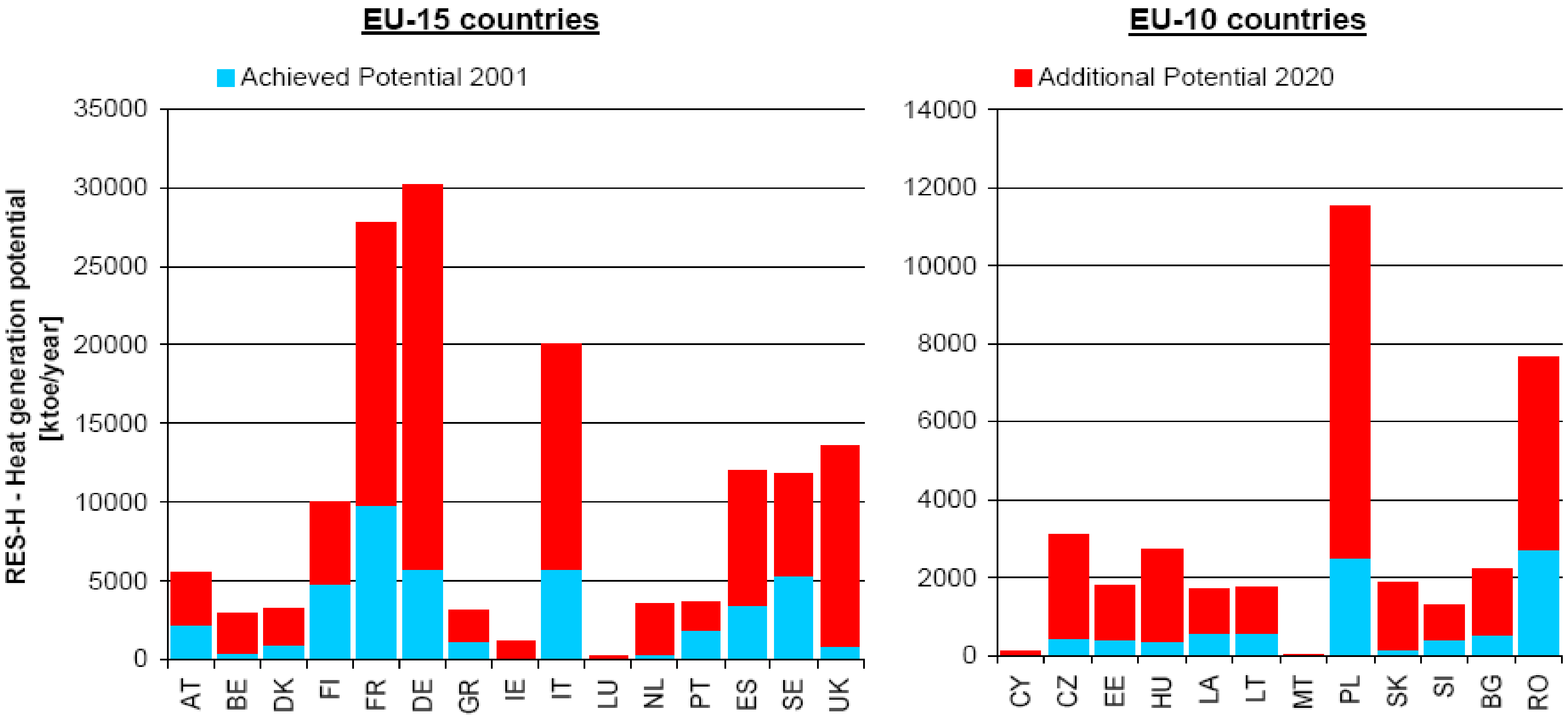
- Where can the RES-E generation potential evolve?



Instruments to Support RES Heat (RES-H)

- Europe: very few policy incentives for RES-H
- Mainly concentrated on selective, local support policies.
  - Local objectives: industrial support or employment opportunities
  - Mainly solar thermal panels and small scale biomass heating
  - DK: obligation scheme to support solar heating in large buildings
- First EU-wide policy:
  - Directive on the energy performance of buildings (EPBD), 2002.
  - Promoting selected RES-H technologies
- Efforts still required to build up European RES-H market
- Promotion of qualified, skilled manufacturers/importers,
  - Financial support mechanisms to close the price gap to natural gas,
  - Increasing awareness of users and knowledge of installers.

Heat: 2001 vs. Potential in 2020



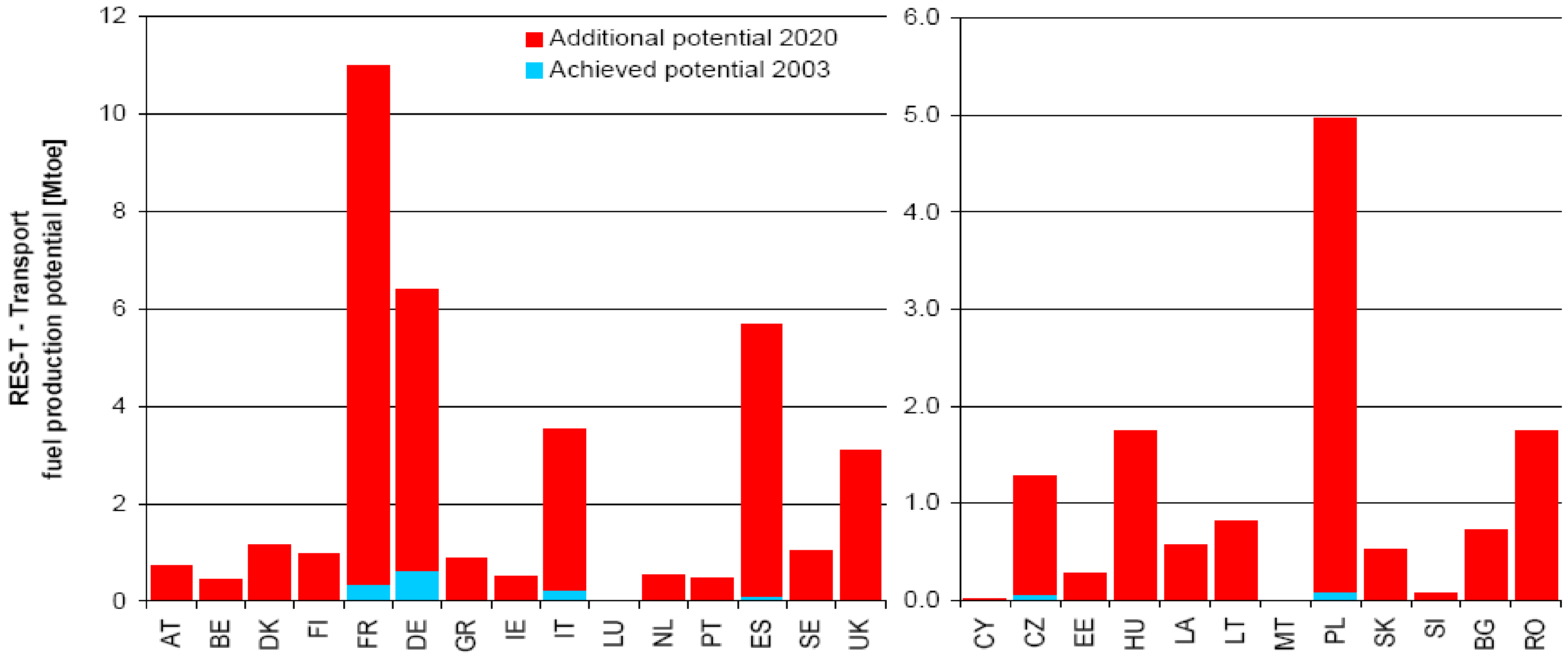
EU-15 countries

EU-10 countries

Instruments to Support Biofuels for Transport (RES-T)

- Biofuels: early stage of development on European market
- Directive on the promotion of biofuels (2001)
  - Share of biofuels in total transport:
    - 0,6% (2003) → 2% (2005), 5.75% (2010)
  - No common approach to promotion policies.
- EC: full tax exemptions for biofuels (biodiesel, bioethanol)
  - More competitive with conventional transport fuels.
  - Impressive growth: DE, FR, ES, IT
- Most countries still have no indicative national targets
  - Main instruments: compensation schemes and tax exemptions
  - Tax exemptions for biofuels very effective for good market position.
    - AT, CZ, DE, FR, IT, PL, ES, FI, SE
- Major biofuel production capacities: in DE, FR, IT, PL, CZ.

Biofuel: 2003 vs. Potential in 2020



Combining Support Schemes

- Measures need to be combined to be effective.
  - RES-E Directive - clear goal to combine measures.
  - Specific support instruments (FIT, Quotas etc.)
  - Capital subsidies, long-term policy and target setting
- Integrated policies:
  - Combine Rational use of energy (RUE) with RES supply.
  - Directive on the Energy Performance of Buildings
- RUE is combined with
  - decentralised energy production, preferably from RES

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Success stories and key barriers

- Specific instrument design or implementation
  - Not instrument type
- Alleviation of market barriers:
  - Political uncertainty:
    - Uncertain or unclear long-term institutional setting
  - Complex administrative systems
  - Grid connection rules and planning issues
  - Transparency of grid connection costs
  - Tender schemes: stop-start nature; uncertainty of winning a bid
- Social acceptance: biomass, large-scale wind.

Success factors

- DE: Combination of FIT + investment support
- UK: redistribution of ROQ buyout revenues,
- BE: high penalties for non-performance
- AT: mandatory disclosure of fuel mix
- Key factor:
  - clear and long-term institutional setting → good investor security.

Barriers

- Complex administrative systems: BE
  - Long lead times for actual project realisations
  - Higher investment uncertainty.
- Regional grid weaknesses : PT, ES, IT, IE.
  - Much RES-E planned and ready for construction,
  - Implementation delayed, expected grid connection problems.
- Political uncertainty: DK, AT, NL, FI, IT, SE
- Markets with high FIT (NL, PT) or strong investment climate (IE) but without long-term certainty →
  - Investors were reluctant
  - Higher equity/debt ratios or higher interest rates,
  - Lower RES penetration than expected from the level of financial support.

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Recent policy developments, RES-E

- Most significant changes, 2002 – 2004
  - AT, FR, NL, SI: new feed-in systems.
  - SE: introduced a renewables obligation for end users, linked to a TGC system.
  - IE: large tender rounds for wind energy issued.
  - ES: very attractive feed-in tariffs for solar thermal electricity generation introduced.
  - DK: changed most of its formerly successful schemes.

Recent policy developments

- RES targets
  - – RES-E: EU RES-E Directive: leading policy document for national target setting
    - October 2005, a Report on policies and measures
  - – RES-H: Few national selective targets
  - – RES-T: No clear national targets
- National policies are constantly evaluated, fine-tuned, and new sets of instruments arise.

SUSTAINABLE ENERGY

SE embraces a number of practicies, policies, and technologies which seek to provide us with the energy we need at the least financial, environmental, and social cost

Prof. Dr. Suad Halilčević

SUSTAINABLE ENERGY

We divide it into two major groups:

- Energy efficiency, and
- Renewable energy

ENERGY EFFICIENCY encompasses

- Demand-side management,
- Integrated resource planning,
- Generation, transmission, and distribution efficiency,
- End-use efficiency

RENEWABLE ENERGY includes

- Solar power,
- Biomass power
- Wind power,
- Hydro-electric generation,
- Goethermal power,
- Fuel cell,
- Hydrogen
- Tides

SUN

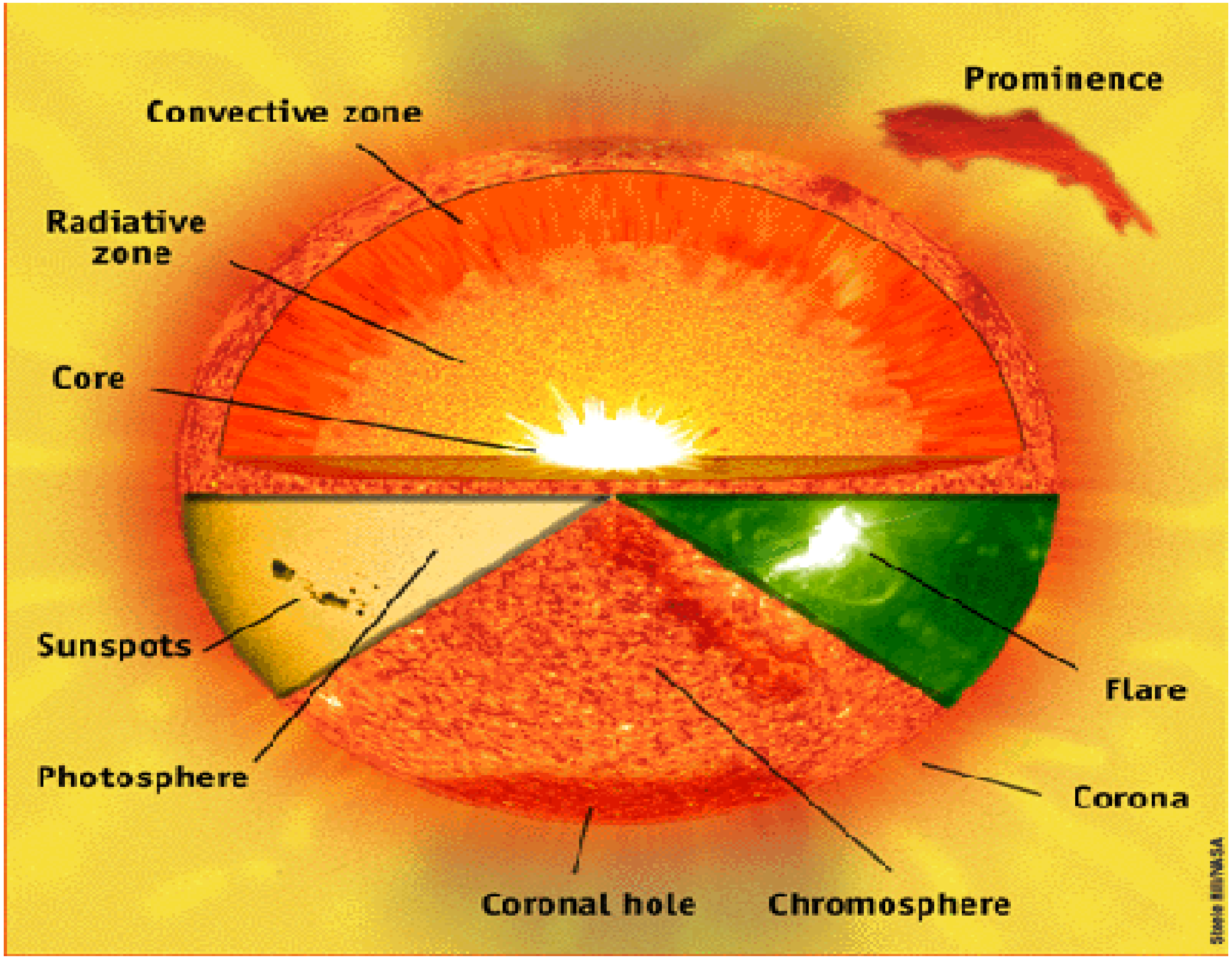
- The sun is made of gas and has no solid surface as Earth does. However, it still has a defined structure. The three major surface areas of the sun are shown in the upper half of the next figure:
- **Core**
- **Radiative Zone**
- **Convective Zone**

SUN

- The sun is a star, just like the other stars we see at night. The difference is distance -- the other stars we see are light years away, while our sun is only about 8 light minutes away (many thousands of times closer).
- Officially, the sun is classified as a G2 type star based on its temperature and the wavelengths or **spectrum** of light that it emits. The sun is an "average" star, merely one of billions of stars that orbit the center of our galaxy.

SUN

- The sun has "burned" for more than 4.5 billion years and will continue to do so for several billion more. It is a massive collection of gas, mostly hydrogen and helium. Because it is so massive, it has immense gravity, enough gravitational force to hold all of hydrogen and helium together (and to hold all of the planets in their orbits around the sun!).
- The sun does not "burn" like wood burns. Instead the sun is a gigantic nuclear reactor



Steele Hill/NASA

SUN

- Above the surface of the sun is its atmosphere, which consists of three parts as shown in the lower half of the previous figure:
- **Photosphere**
- **Chromosphere**
- **Corona** - extremely hot outermost layer extending outward from the chromosphere several million kilometers

SUN

- All of the major features of the sun can be explained by the nuclear reactions that make its energy, the magnetic fields that are caused by the movements of the gas, and the immense gravity.

Sun Facts

- **Average distance from Earth** = 150 million km
- **Radius** = 696.000 km
- **Mass** = 1.99 x 1030 kg (330.000 Earth masses)
- **Makeup (by mass)** = 74 percent hydrogen, 25 percent helium, 1 percent other elements
- **Average temperature** = 5,800 degrees Kelvin (surface), 15.5 million degrees Kelvin (core)
- **Average density** = 1.41 grams per cm3
- **Rotational period** = 25 days (center) to 35 days (poles)

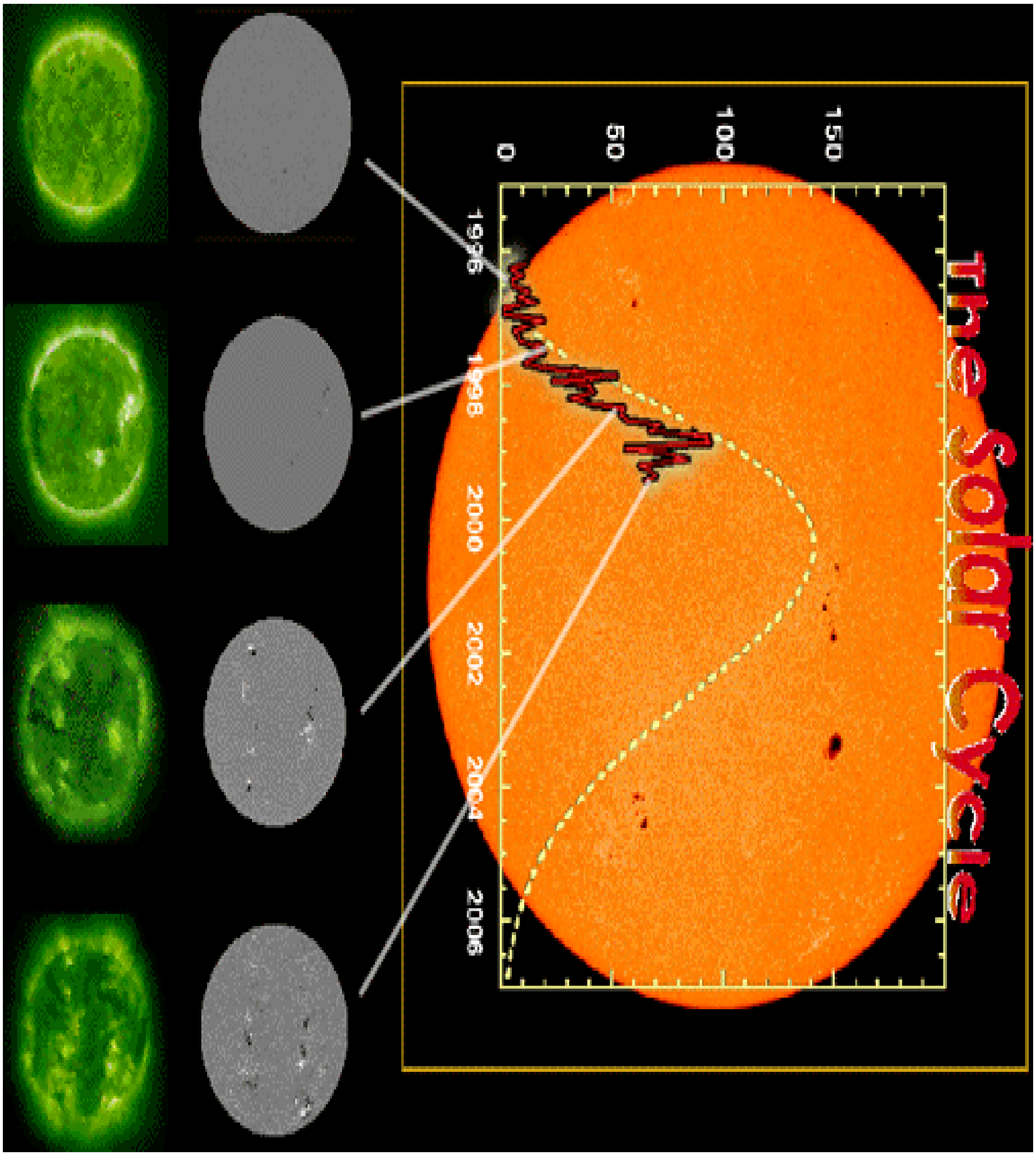
Sun Facts

- **Magnitude** = -26.8 (apparent), +4.8 (absolute) Apparent magnitude refers to a star's brightness in the sky from our vantage point on Earth. Absolute magnitude is the star's true brightness if all of the stars were the same distance from Earth. The lower the number, the brighter the star.

- **Distance from center of Milky Way** = 25,000 light-years

- **Orbital speed and period** = 230 kilometers per second and 200 million years

The sun's 11-year solar cycle as reflected by the number of sunspots recorded to date and projected (dotted line). Selected EIT 195 angstrom (green) and MDI magnetogram (gray) images are shown. In this cycle, the sun undergoes a period of activity (solar maximum) followed by a period of quiet (solar minimum). The rising level can be clearly seen in the comparison of EIT and MDI images.



Reactions on Sun

- The core starts from the center and extends to 25 percent of the sun's radius. Here, gravity pulls all of the mass inward and creates an intense pressure. The pressure is high enough to force atoms of hydrogen to come together in nuclear fusion reactions. Two atoms of hydrogen are combined to create helium-4 and energy in several steps:
- Two protons combine to form a deuterium (hydrogen atom with one neutron), a positron (similar to electron, but with a positive charge) and a neutrino
- A proton and a deuterium atom combine to form a helium-3 atom (two protons with one neutron) and a gamma ray.

- Two helium-3 atoms combine to form a helium-4 (two protons and two neutrons) and two protons.

Reactions on Sun

- These reactions account for 85 percent of the sun's energy. The remaining 15 percent comes from the following reactions:
- A helium-3 and a helium-4 combine to form a beryllium-7 (four protons and three neutrons) and a gamma ray.
- A beryllium-7 captures an electron to become lithium-7 (three protons and four neutrons) and a neutrino.
- The lithium-7 combines with a proton to form two helium-4 atoms.

Reactions on Sun

- The helium-4 atoms are less massive than the two hydrogen atoms that started the process, so the difference in mass was converted to energy as described by Einstein's theory of relativity (E=mc2). The energy is emitted in various forms of light:
- ultraviolet light,
- X-rays,
- visible light,
- infrared,
- Microwaves, and
- radio waves).

Reactions on Sun

- The sun also emits energized particles (neutrinos, protons) that make up the **solar wind**. This energy strikes Earth, where it warms the planet, drives our weather and provides energy for life. We are not harmed by most of the radiation or solar wind because the Earth's atmosphere protects us.

How much we get from the Sun

- On a bright, sunny day, the sun shines approximately 1,000 watts of energy per square meter of the planet's surface, and if we could collect all of that energy we could easily power our homes and offices for free.

PHOTOVOLTAICS

- Photovoltaics, as the word implies (photo = light, voltaic = electricity), convert sunlight directly into electricity. Once used almost exclusively in space, photovoltaics are used more and more in less exotic ways. They could even power your house.

- How do these devices work?

Photovoltaics

- Providing power for villages in developing countries is a fast-growing market for photovoltaics. The United Nations estimates that more than 2 million villages worldwide are without electric power for water supply, refrigeration, lighting, and other basic needs, and the cost of extending the utility grids is prohibitive, $23,000 to $46,000 per kilometer in 2000.

- A one kilowatt PV system* each month:
  - prevents 150 lbs. of coal from being mined
  - prevents 300 lbs. of CO2 from entering the atmosphere
  - keeps 105 gallons of water from being consumed
  - keeps NO and SO2 from being released into the environment

- * in Bosnia and Herzegovina, or an equivalent system that produces 150 kWh per month

Solar panels absorb energy to produce hydrogen at SunLine Transit Agency.

PHOTOVOLTAICS

- Photovoltaic (**PV**) cells are made of special materials called **semiconductors** such as silicon, which is currently the most commonly used. Basically, when light strikes the cell, a certain portion of it is absorbed within the semiconductor material. This means that the energy of the absorbed light is transferred to the semiconductor.

- The energy knocks electrons loose, allowing them to flow freely. PV cells also all have one or more electric fields that act to force electrons freed by light absorption to flow in a certain direction. This flow of electrons is a current, and by placing metal contacts on the top and bottom of the PV cell, we can draw that current off to use externally.

- This current, together with the cell's voltage (which is a result of its built-in electric field or fields), defines the power (or wattage) that the solar cell can produce.

Silicon

- Silicon has some special chemical properties, especially in its crystalline form. An atom of silicon has 14 electrons, arranged in three different shells.

- The first two shells, those closest to the center, are completely full. The outer shell, however, is only half full, having only four electrons. A silicon atom will always look for ways to fill up its last shell (which would like to have eight electrons).

- To do this, it will share electrons with four of its neighbor silicon atoms. It's like every atom holds hands with its neighbors, except that in this case, each atom has four hands joined to four neighbors. That's what forms the **crystalline structure**, and that structure turns out to be important to this type of PV cell.

Silicon

- We've now described pure, crystalline silicon. Pure silicon is a poor conductor of electricity because none of its electrons are free to move about, as electrons are in good conductors such as copper. Instead, the electrons are all locked in the crystalline structure. The silicon in a solar cell is modified slightly so that it will work as a solar cell.

Silicon in Solar Cells

- A solar cell has silicon with **impurities** -- other atoms mixed in with the silicon atoms, changing the way things work a bit. We usually think of impurities as something undesirable, but in our case, our cell wouldn't work without them.
- These impurities are actually put there on purpose. Consider silicon with an atom of phosphorous here and there, maybe one for every million silicon atoms. Phosphorous has five electrons in its outer shell, not four. It still bonds with its silicon neighbor atoms, but in a sense, the phosphorous has one electron that doesn't have anyone to hold hands with. It doesn't form part of a bond, but there is a positive proton in the phosphorous nucleus holding it in place.

Silicon in Solar Cells

- In to pure silicon we drop the impurities – for example phosphorous
- It is **doping**, to get more free electrons, more free carriers
- when doped with phosphorous, the resulting silicon is called **N-type** ("n" for negative) because of the prevalence of free electrons. N-type doped silicon is a much better conductor than pure silicon is.

Silicon in Solar Cells

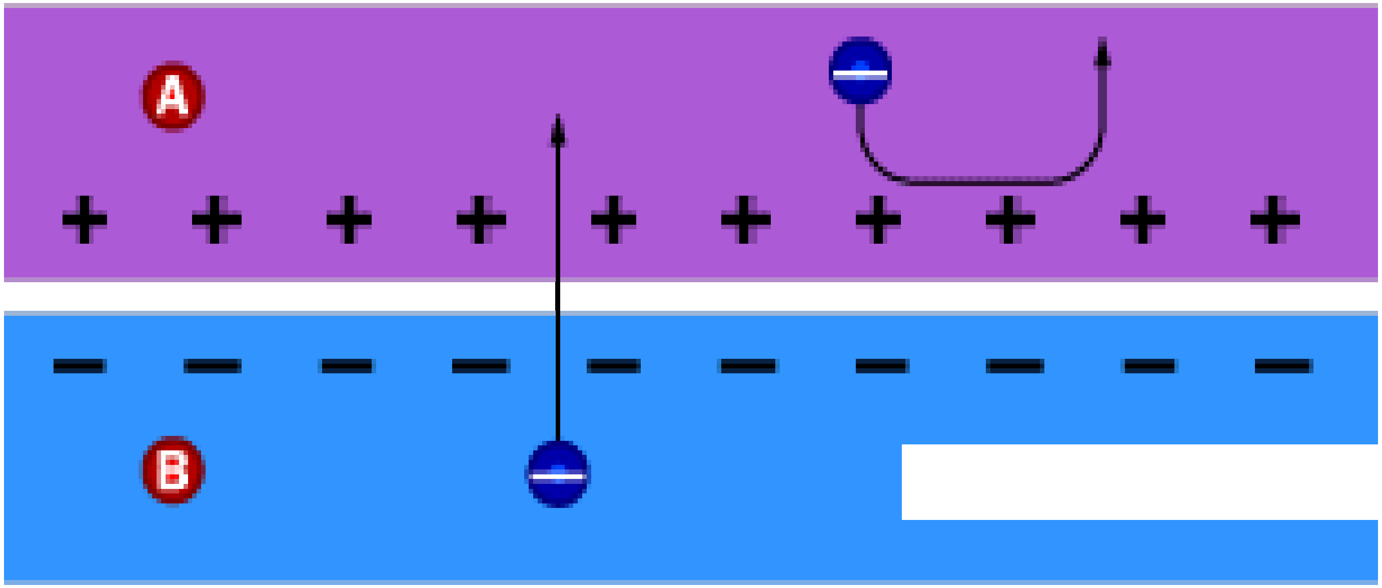
- Actually, only part of our solar cell is N-type.
- The other part is doped with boron, which has only three electrons in its outer shell instead of four, to become **P-type** silicon.
- Instead of having free electrons, P-type silicon ("p" for positive) has free holes. Holes really are just the absence of electrons, so they carry the opposite (positive) charge. They move around just like electrons do.

N-type Plus P-type Silicon

- The interesting part starts when you put N-type silicon together with P-type silicon.
- Every PV cell has at least one **electric field,** and this field forms when the N-type and P-type silicon are in contact.
- The free electrons in the N side, which have been looking all over for holes to fall into, see all the free holes on the P side, and there's a mad rush to fill them in.

N-type Plus P-type Silicon

- This electric field acts as a diode, allowing (and even pushing) electrons to flow from the P side to the N side, but not the other way around. It's like a hill -- electrons can easily go down the hill (to the N side), but can't climb it (to the P side).



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When Light Hits the Cell

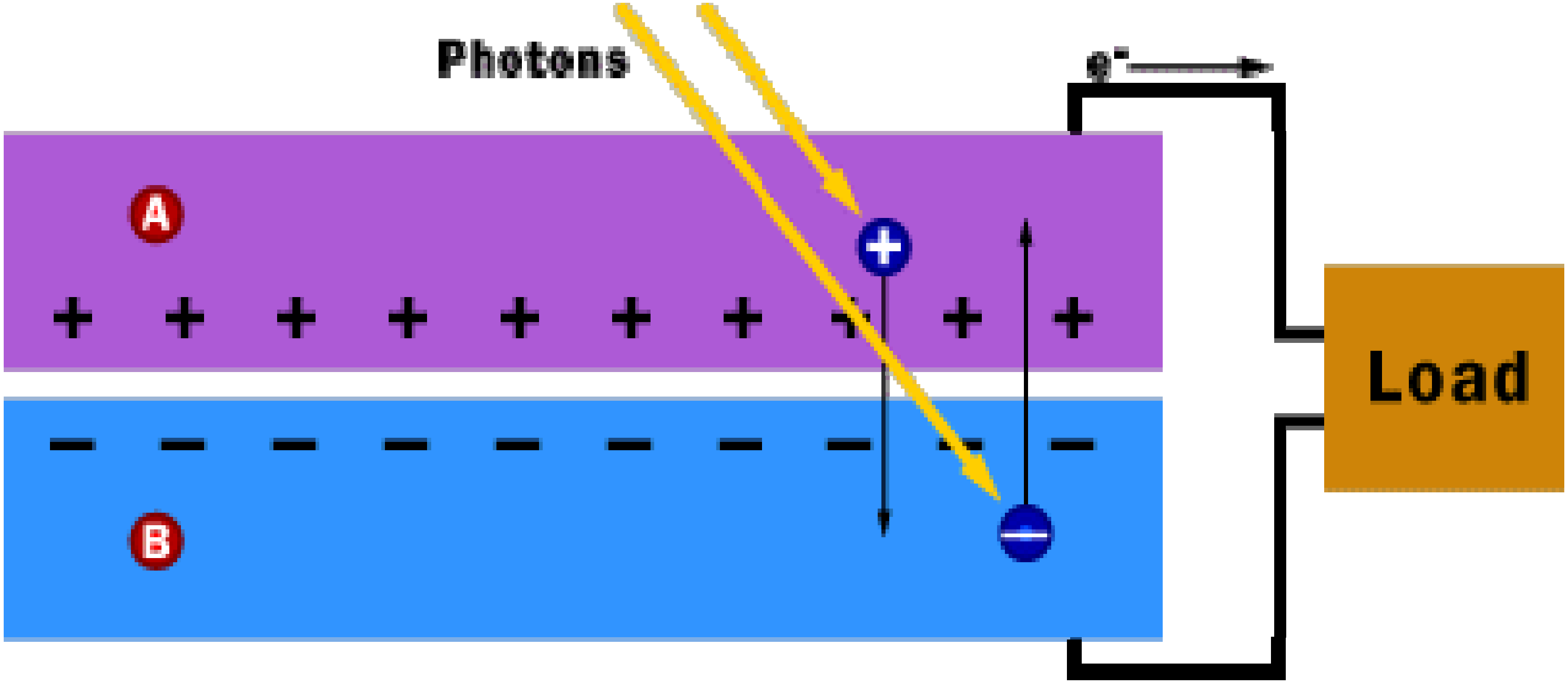
- When light, in the form of photons, hits our solar cell, its energy frees electron-hole pairs.

- Each photon with enough energy will normally free exactly one electron, and result in a free hole as well. If this happens close enough to the electric field, or if free electron and free hole happen to wander into its range of influence, the field will send the electron to the N side and the hole to the P side. This causes further disruption of electrical neutrality, and if we provide an external current path, electrons will flow through the path to their original side (the P side) to unite with holes that the electric field sent there, doing work for us along the way.

When Light Hits the Cell

- The electron flow provides the **current**, and the cell's electric field causes a **voltage**. With both current and voltage, we have **power**, which is the product of the two.

When Light Hits the Cell



How much sunlight energy does our PV cell absorb?

- Unfortunately, the most that our simple cell could absorb is around 25 percent, and more likely is **15 percent or less**.

Energy Loss

- Visible light is only part of the electromagnetic spectrum. Electromagnetic radiation is not monochromatic -- it is made up of a range of different wavelengths, and therefore energy levels.

Energy Loss

- Light can be separated into different wavelengths, and we can see them in the form of a rainbow. Since the light that hits our cell has photons of a wide range of energies, it turns out that some of them won't have enough energy to form an electron-hole pair. They'll simply pass through the cell as if it were transparent. Still other photons have too much energy. Only a certain amount of energy, measured in electron volts (eV) and defined by our cell material (about 1.1 eV for crystalline silicon), is required to knock an electron loose.

Energy Loss

- We call this the **band gap energy** of a material. If a photon has more energy than the required amount, then the extra energy is lost (unless a photon has twice the required energy, and can create more than one electron-hole pair, but this effect is not significant). These two effects alone account for the loss of around 70 percent of the radiation energy incident on our cell.

Energy Loss

- Why can't we choose a material with a really low band gap, so we can use more of the photons? Unfortunately, our band gap also determines the strength (voltage) of our electric field, and if it's too low, then what we make up in extra current (by absorbing more photons), we lose by having a small voltage. Remember that power is voltage times current. The optimal band gap, balancing these two effects, is around **1.4 eV** for a cell made from a single material.

Energy Loss

- We have other losses as well. Our electrons have to flow from one side of the cell to the other through an external circuit. We can cover the bottom with a metal, allowing for good conduction, but if we completely cover the top, then photons can't get through the opaque conductor and we lose all of our current (in some cells, transparent conductors are used on the top surface, but not in all). If we put our contacts only at the sides of our cell, then the electrons have to travel an extremely long distance (for an electron) to reach the contacts. Remember, silicon is a semiconductor -- it's not nearly as good as a metal for transporting current.

Energy Loss

- Its internal resistance (called **series resistance**) is fairly high, and high resistance means high losses. To minimize these losses, our cell is covered by a metallic contact grid that shortens the distance that electrons have to travel while covering only a small part of the cell surface. Even so, some photons are blocked by the grid, which can't be too small or else its own resistance will be too high.

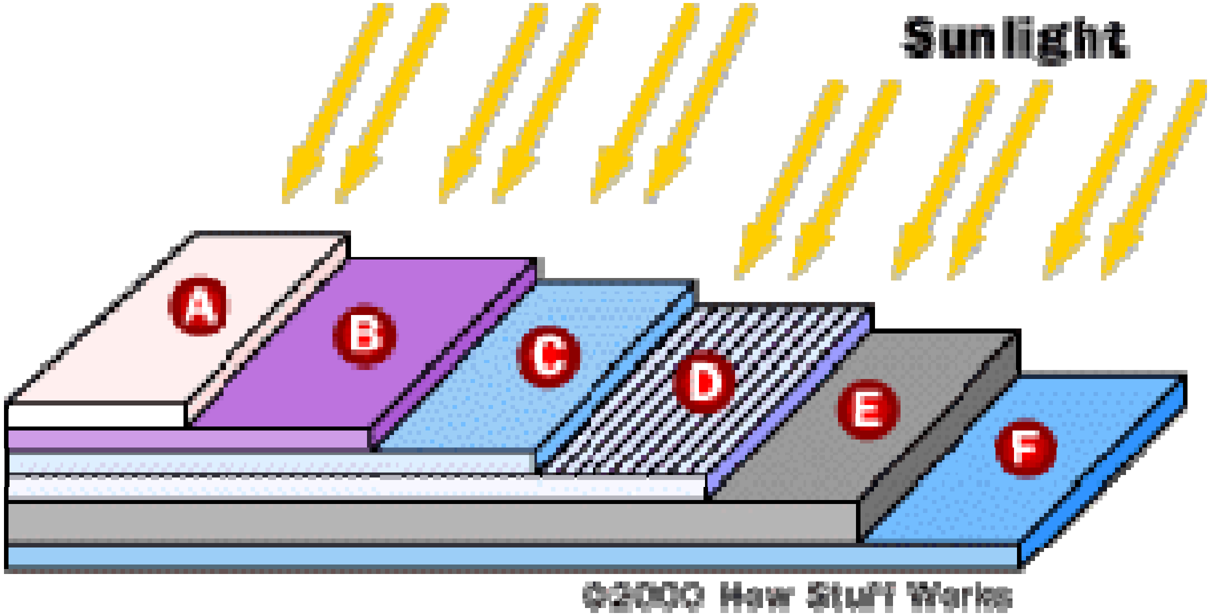
Finishing the Cell

- There are a few more steps left before we can really use our cell. Silicon happens to be a very shiny material, which means that it is very reflective. Photons that are reflected can't be used by the cell. For that reason, an **antireflective coating** is applied to the top of the cell to reduce reflection losses to less than 5 percent.

Finishing the Cell

- The final step is the **glass cover plate** that protects the cell from the elements. PV modules are made by connecting several cells (usually 36) in series and parallel to achieve useful levels of voltage and current, and putting them in a sturdy frame complete with a glass cover and positive and negative terminals on the back.

Finishing the Cell



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Basic structure of a generic silicon PV cell

- A Cover glass
- B Antireflective coating
- C Contact grid
- D N-type Si
- E P-type Si
- F Back contact

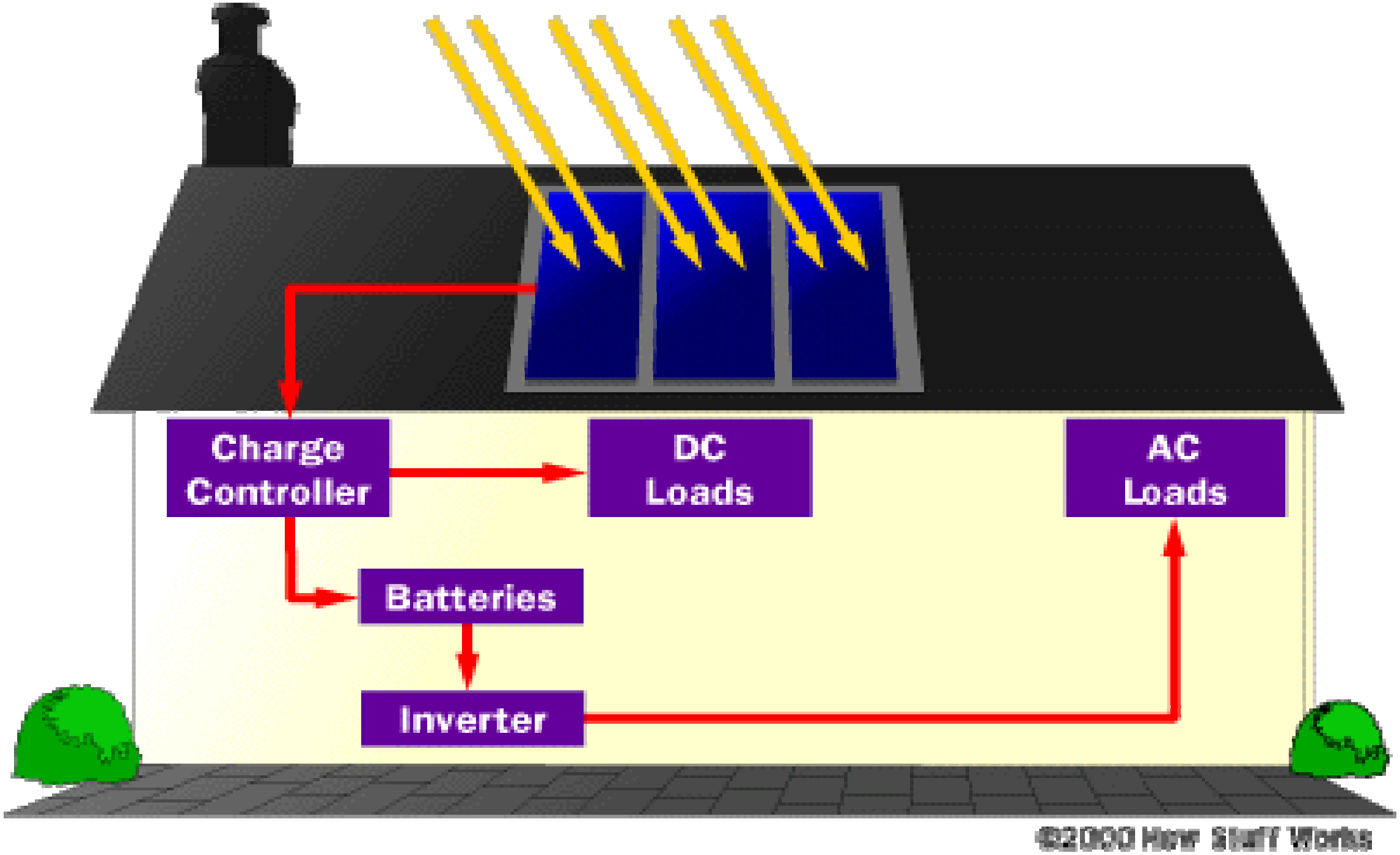
Other materials

- Amorphous silicon, which has no crystalline structure, is also used, again in an attempt to reduce production costs. Other materials used include gallium arsenide, copper indium diselenide and cadmium telluride. Since different materials have different band gaps, they seem to be "tuned" to different wavelengths, or photons of different energies.

Other materials

- One way **efficiency** has been improved is to use two or more layers of different materials with different band gaps. The higher band gap material is on the surface, absorbing high-energy photons while allowing lower-energy photons to be absorbed by the lower band gap material beneath. This technique can result in much higher efficiencies. Such cells, called **multi-junction cells**, can have more than one electric field.

Powering a House



Powering a House

- Throw in the mounting hardware, wiring, junction boxes, grounding equipment, overcurrent protection, DC and AC disconnects and other accessories and you have yourself a system.
- Electrical codes must be followed (there's a section in the National Electrical Code just for PV), and it's highly recommended that the installation be done by a licensed electrician who has experience with PV systems. Once installed, a PV system requires very little maintenance (especially if no batteries are used), and
- It will provide electricity cleanly and quietly for 20 years or more.

Costs

- Currently, an installed PV system will cost somewhere around 8 **euros per peak Watt**.

Costs

- Small home, and it is estimated that its 3.6-kW PV system covers about half of the total electricity needs (this system doesn't use batteries -- it's connected to the grid). Even so, at 8 euros per Watt, this installed system would cost you around 28.000 euros.

Possibilities

- 6.5 cm^2 of solar cells can generate about 70 milliwatts of electricity, and that it might be able to do this for about five hours a day on average (depending on latitude, average rainfall and other environmental factors).
- An 4,047 m^2, size solar panel in an hour, can produce about 440,000 watt-hours of electricity. In a five-hour day, it can produce 2.2-million watt-hours, and in a year it can produce about 800-million watt-hours of electricity.

How many solar cells would I need in order to provide all of the electricity that my house needs?

- The solar panel contains 4 cells, and each of them can produce 0.45 volts and 100 milliamps, or 45 milliwatts. With these solar cells you can generate 45 milliwatts in 6.45 square cm. For the sake of discussion, let's assume that a panel can generate 70 milliwatts per 6.45 square cm. To calculate how many square cm of solar panel you need for a house, you need to know:
- How much power the house consumes on average
- Where the house is located (so you can calculate mean solar days, average rainfall, etc.). This question is impossible to answer unless you have a specific location in mind. We'll assume that on an average day the solar panels generate their maximum power for 5 hours.

Calculation

- A "typical home" in Europe can use either electricity or gas to provide heat -- heat for the house, the hot water, the clothes dryer and the stove/oven. If you were to power a house with solar electricity, you would certainly use gas appliances because solar electricity is so expensive. This means that what you would be powering with solar electricity are things like **the refrigerator, the lights, the computer, the TV, stereo equipment, motors in things like furnace fans and the washer, etc**. Let's say that all of those things average out to 600 watts on average. Over the course of 24 hours, you need 600 watts * 24 hours = 14,400 watt-hours per day.

Calculation

- From our calculations and assumptions above, we know that a solar panel can generate 70 milliwatts per 6.45 square cm * 5 hours = 350 milliwatt hours per day. Therefore you need about 5.18 meters square. That would cost around 12.500 euros right now. Then, because the sun only shines part of the time, you would need to purchase a battery bank, an inverter, etc., and that often doubles the cost of the installation.

Conclusion

- The thing to remember, however, is that 100 watts per hour purchased from the power grid would only cost about 18 eurocents a day right now, or app. 68 euros a year. That's why you don't see many solar houses unless they are in very remote locations. When it only costs about 68 euros a year to purchase power from the grid, it is hard to justify spending thousands of dollars on a solar system.

Ways to use the Sun energy

- Passiv

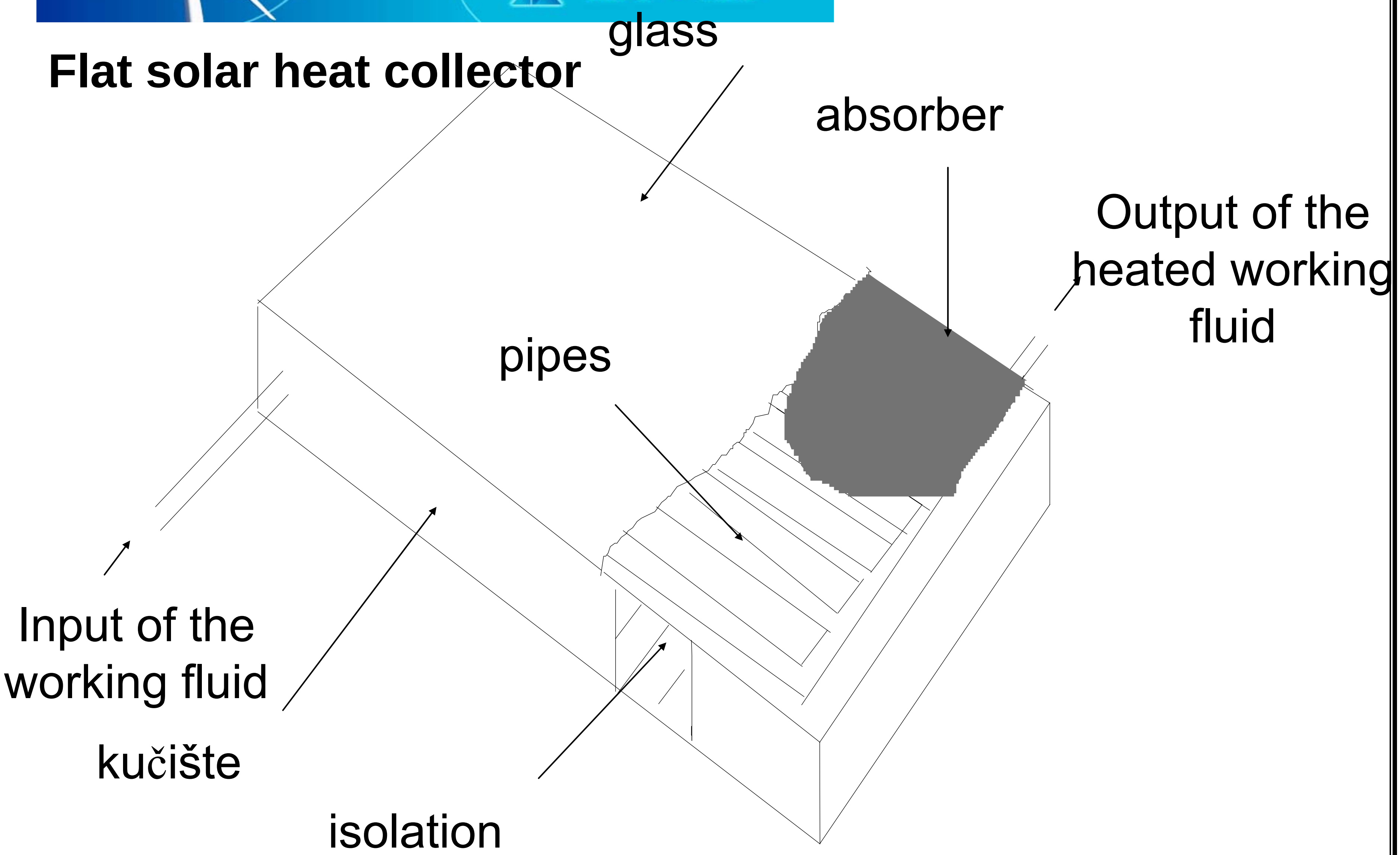
Thousands of years ago, the Anasazi Indians in Colorado incorporated passive solar design in their cliff dwellings.

This home's passive solar design features direct gain heating and clerestory windows for daylighting.

Heat solar collector (HSC)
The equipment intended to transform the solar energy in to the heat energy

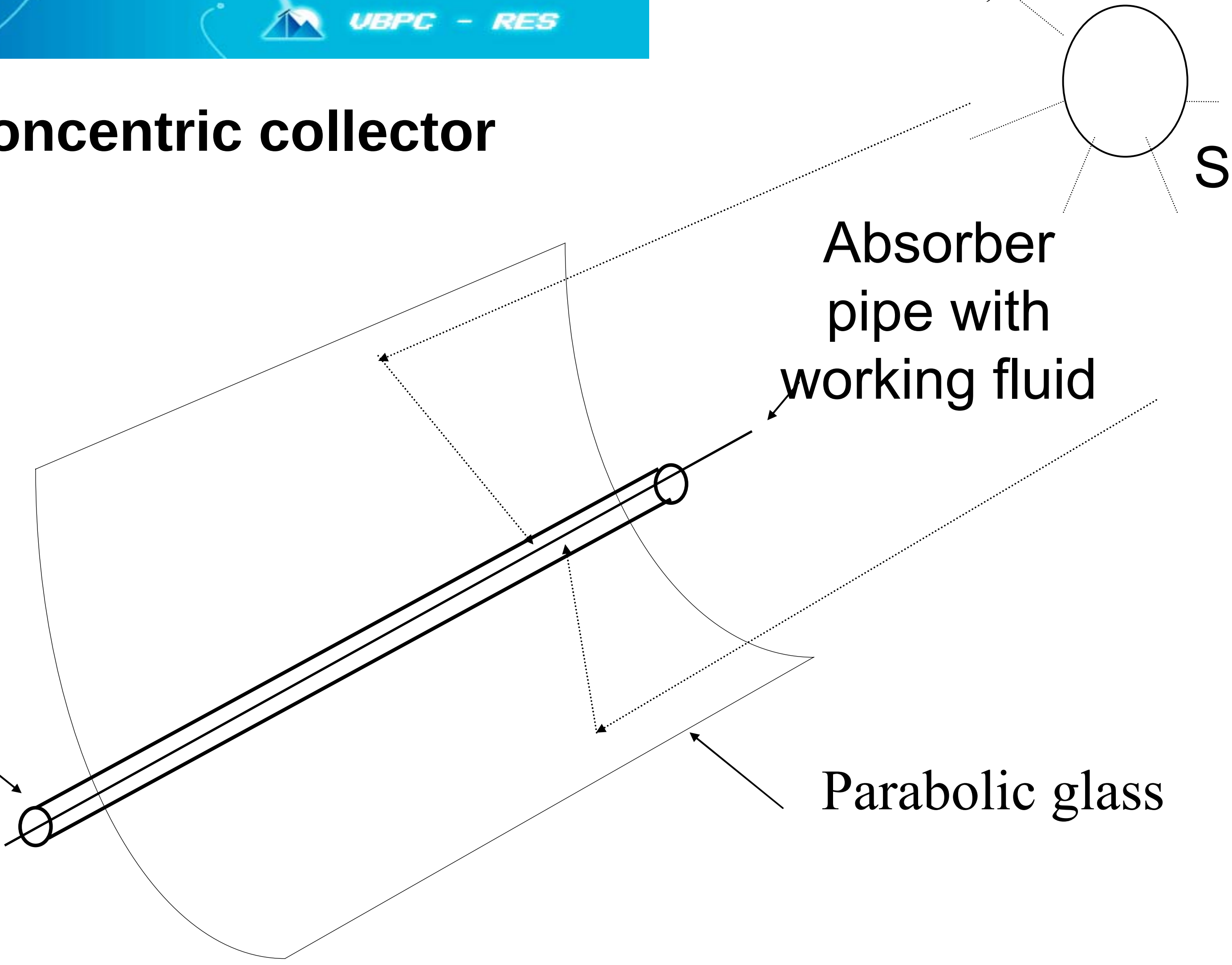
- There are three types of the HSC:
  a) flat collector,
  b) selective collector, and
  c) concentric collector.

Flat solar heat collector



The solar hot water system on this roof in Sarasota, Florida, can provide 40% to 50% of a family's hot water needs.

Parabolic concentric collector

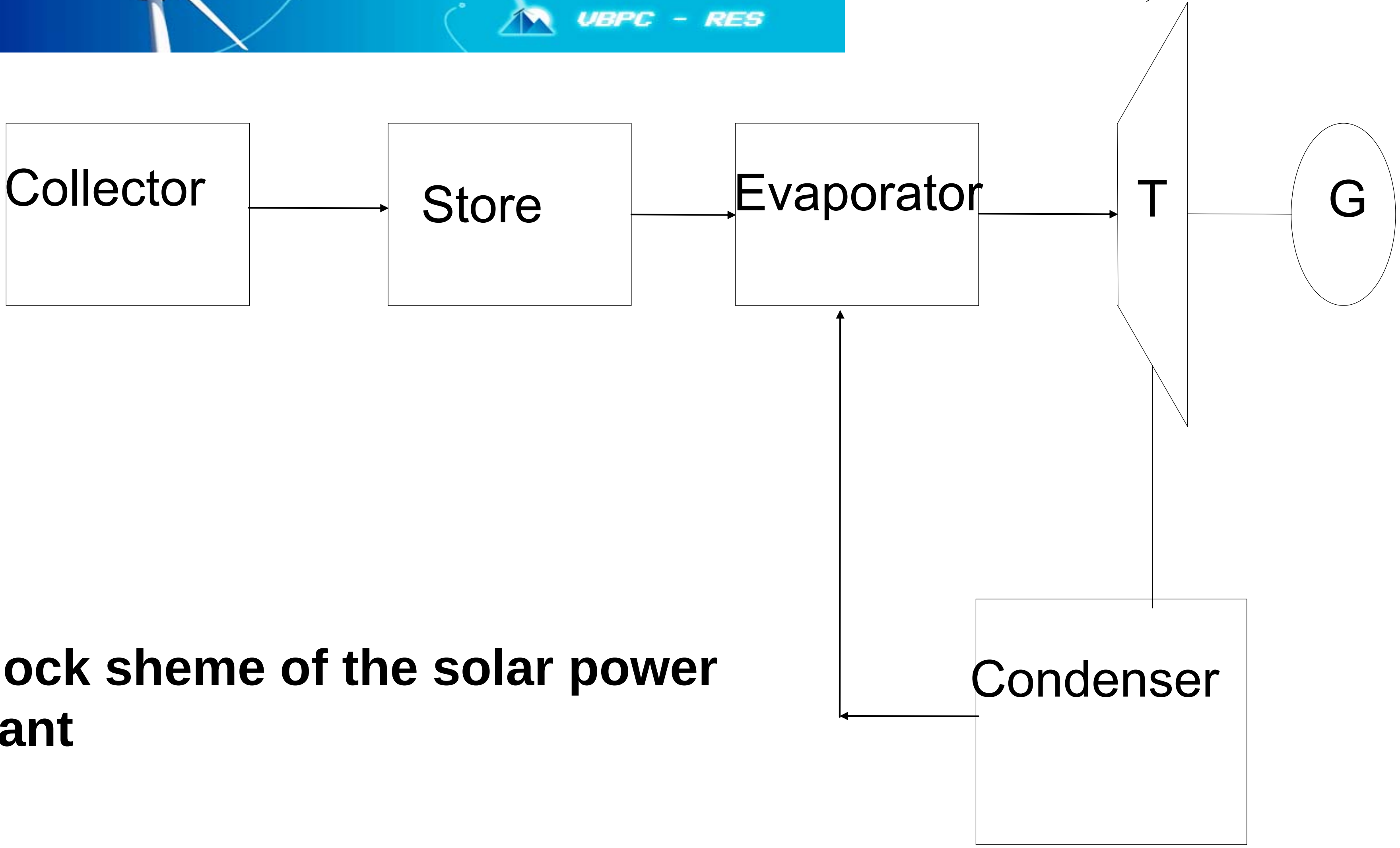


Sun

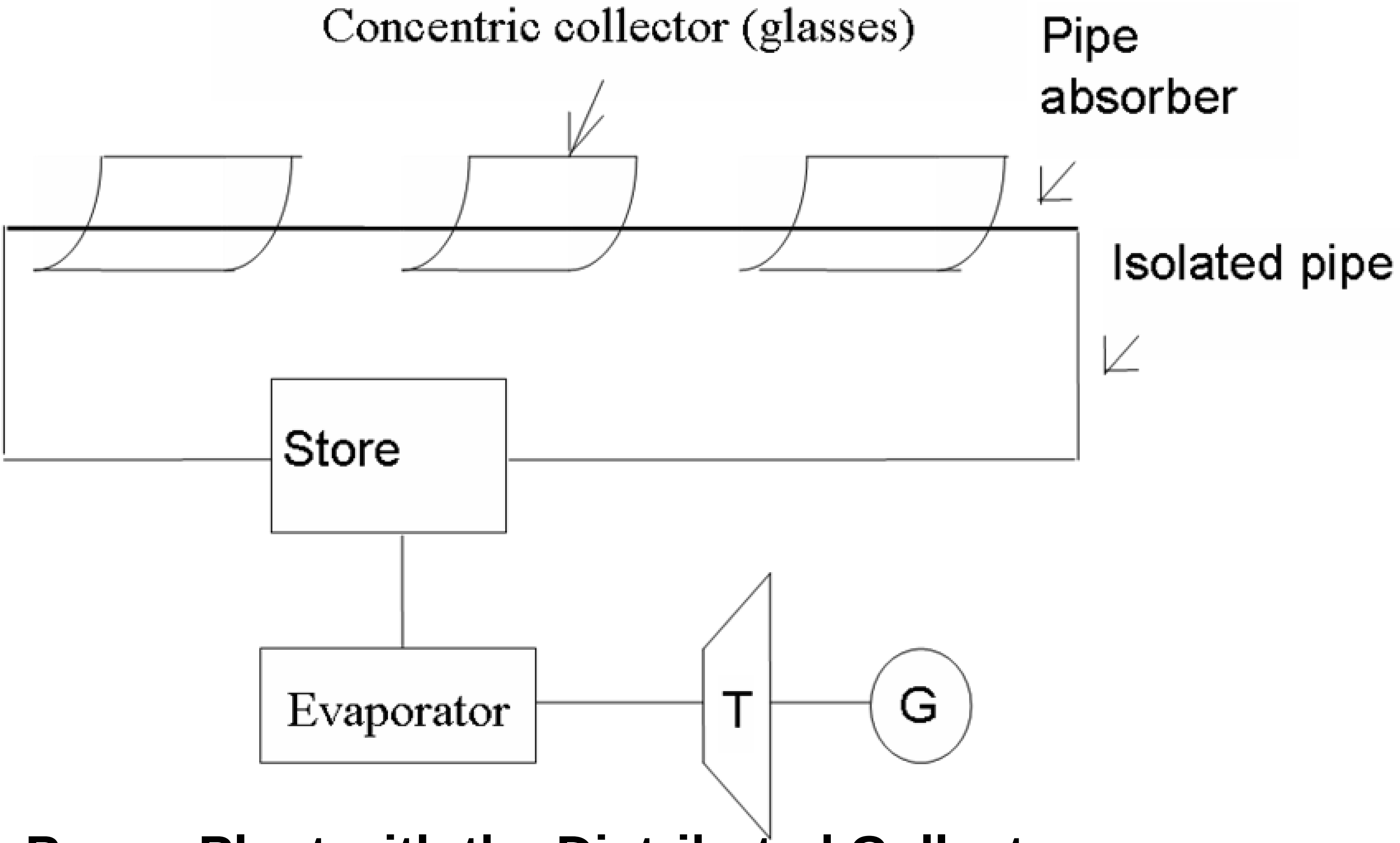
Absorber pipe with working fluid

Glass pipe

Parabolic glass



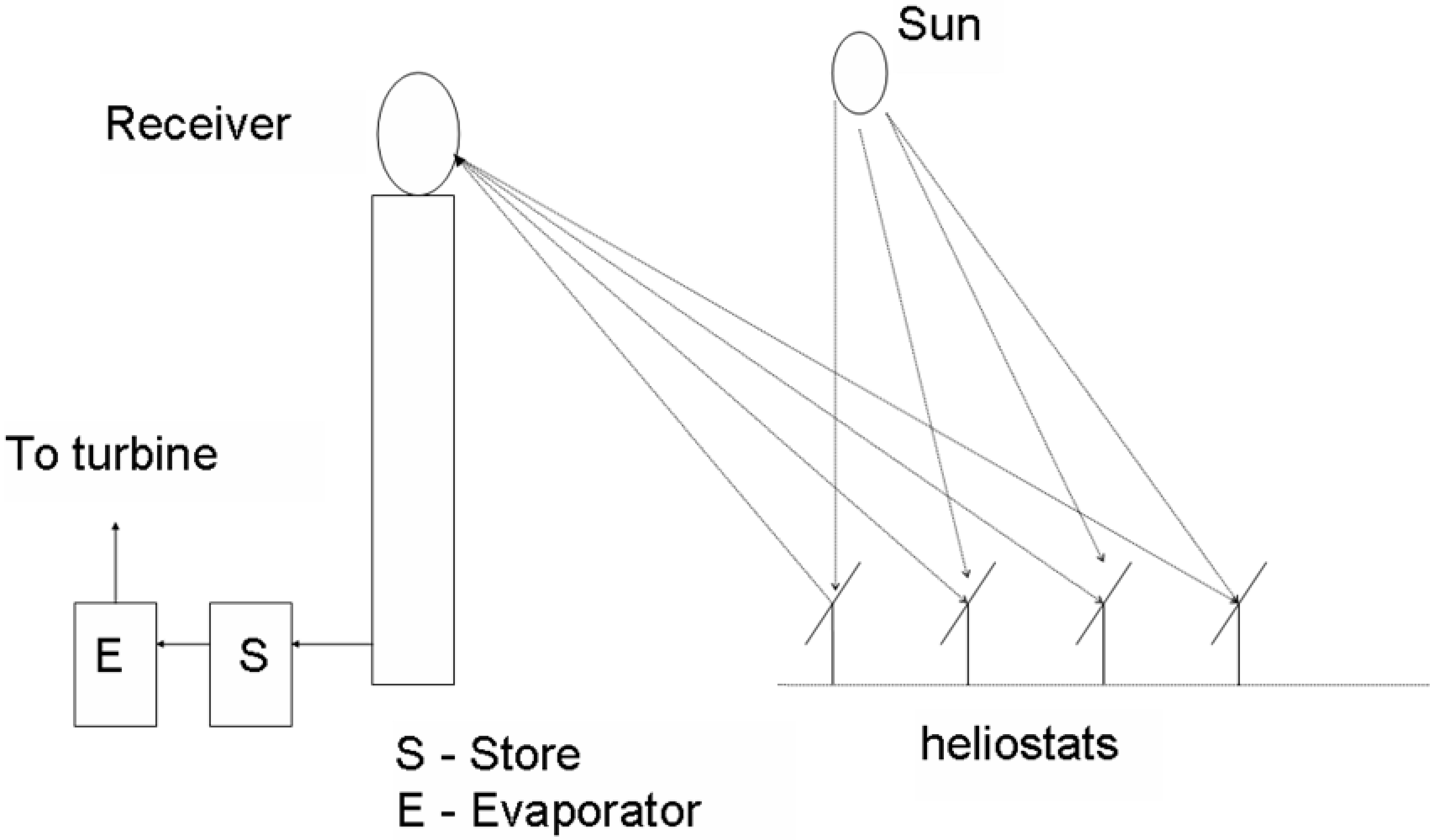
Block sheme of the solar power plant



Solar Power Plant with the Distributed Collectors

A 25-kilowatt Dish Stirling System catches its last rays of light at the end of the day.

Solar Power Plant with the Central Receiver



S - Store
E - Evaporator

There are several ways to store the solar energy :

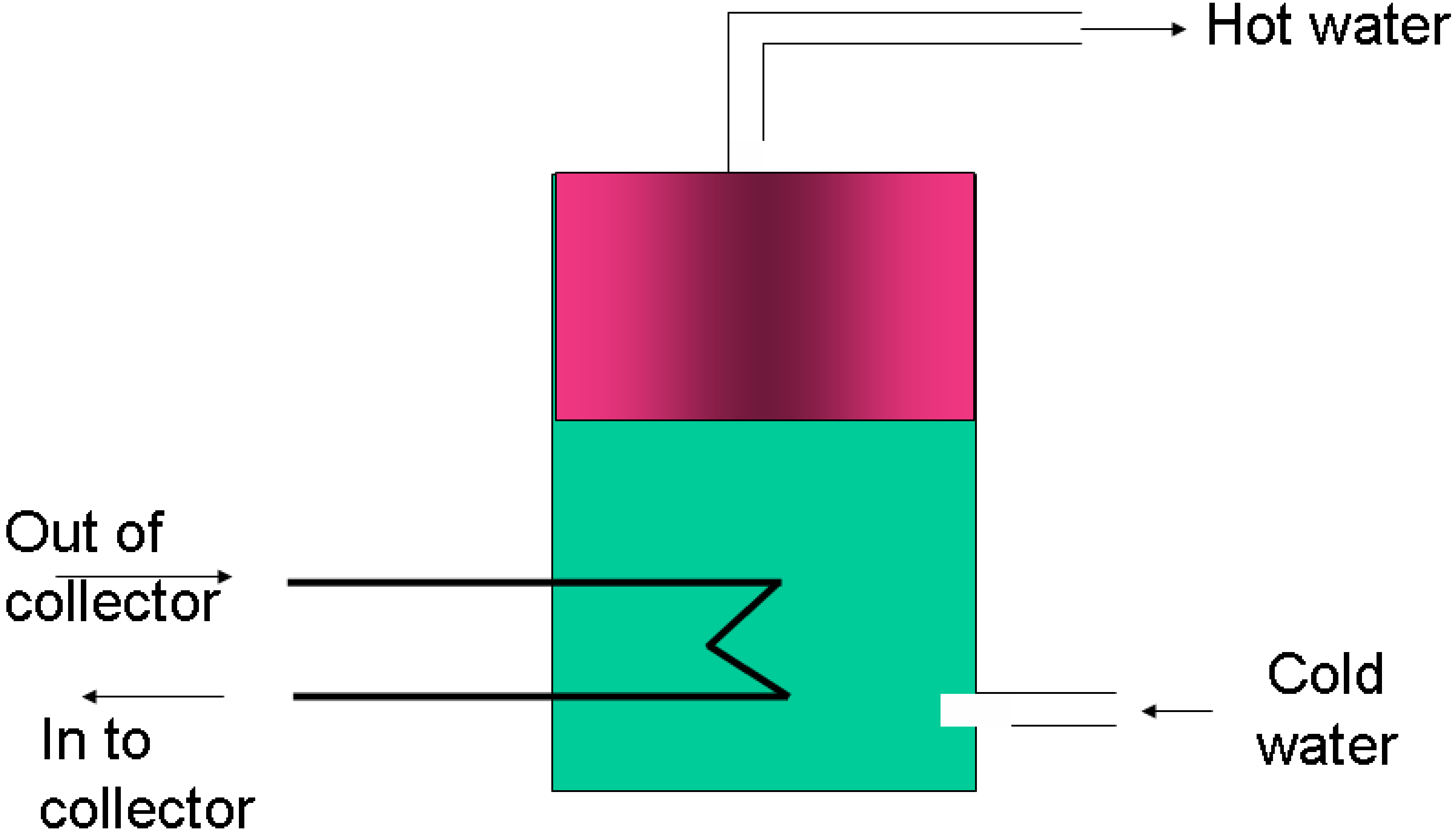
- heating (by heating the specifical materials, and by using the latent heat),
- chemical (reverse chemical reaction),
- thermo-chemical (heat capacity of the isolated volumes of water and land),
- mechanical (fly weel).

1 Storing by means of the heated materials

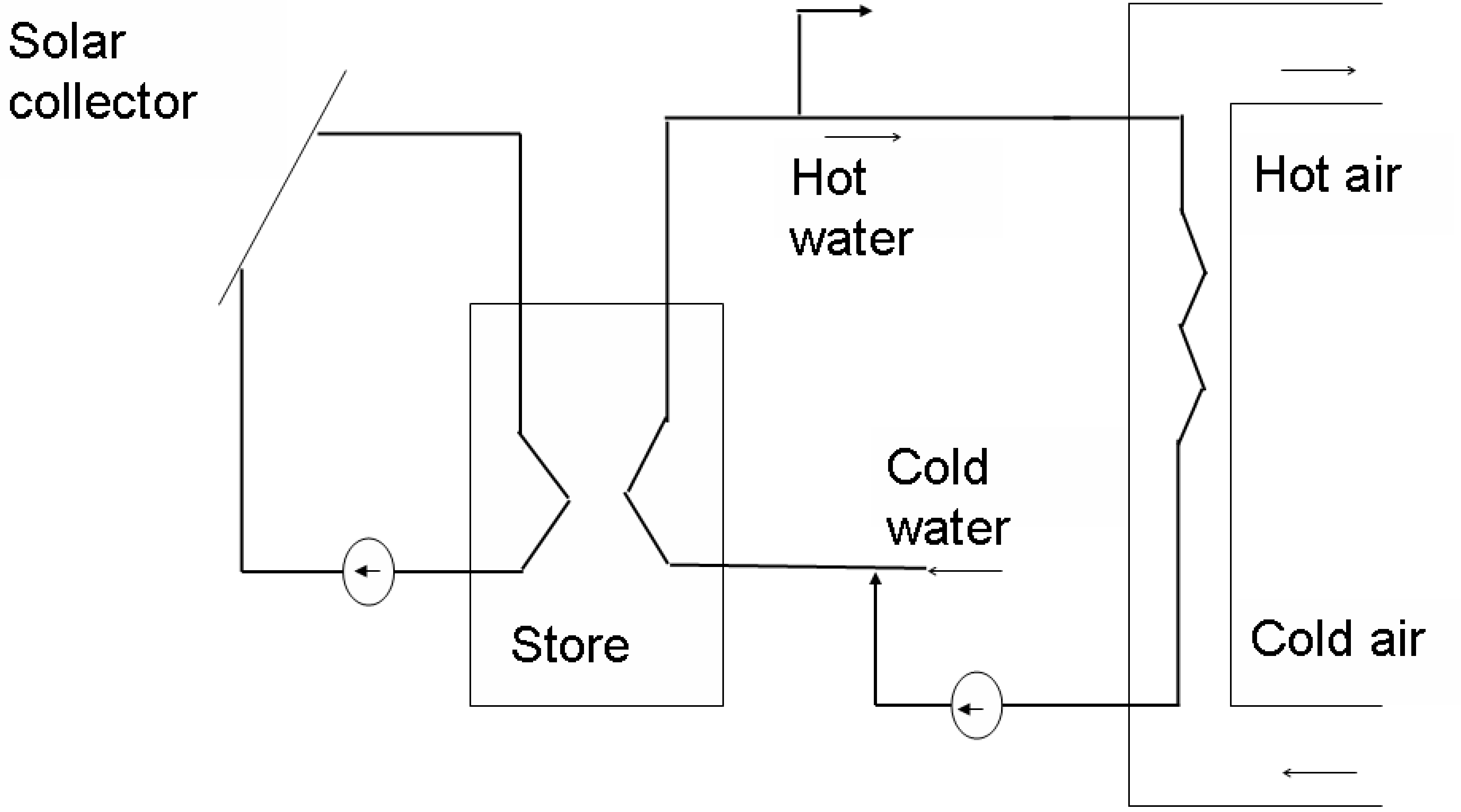
- gustoća (kg/m3),
- specific heat capacity (kJ/kgK),
- volumen heat capacity (J/m3K), and
- conducting (W/mK).

$$V = \frac{Q}{c \cdot \varphi \cdot \Delta T} \; (m^3)$$

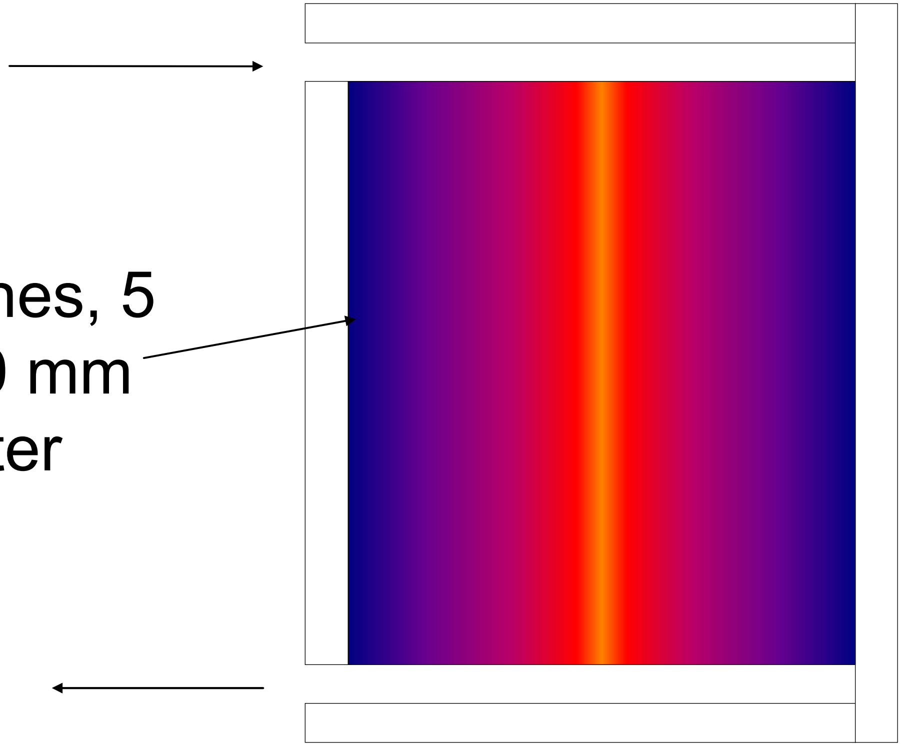
Needed volumen of materials to store the heat Q



Water Reservoar for the Storing of Sun Energy



Principal Scheme of Cogenerative Solar System

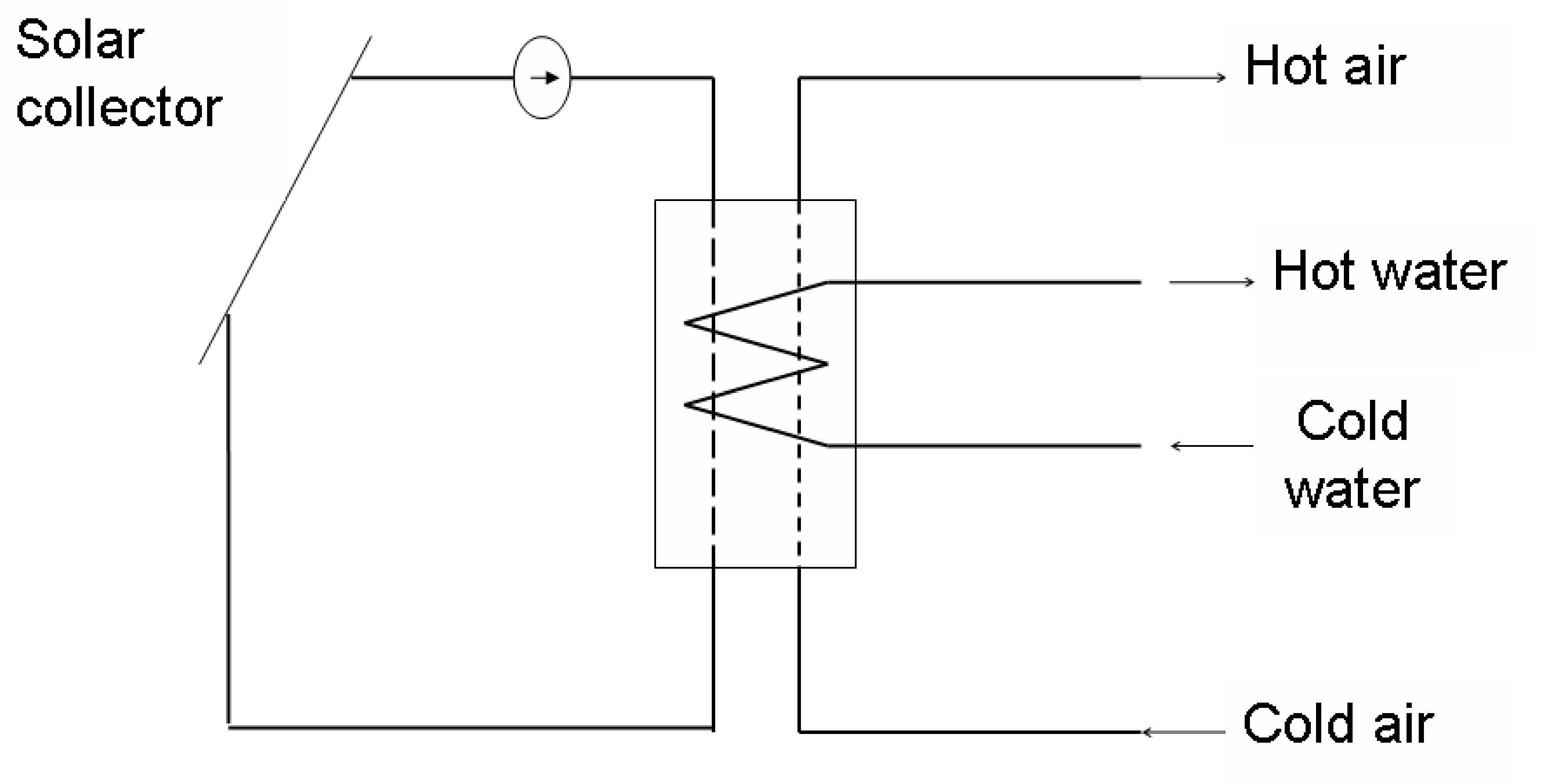


Hot air from collector

Small stones, 5 mm to 10 mm diameter

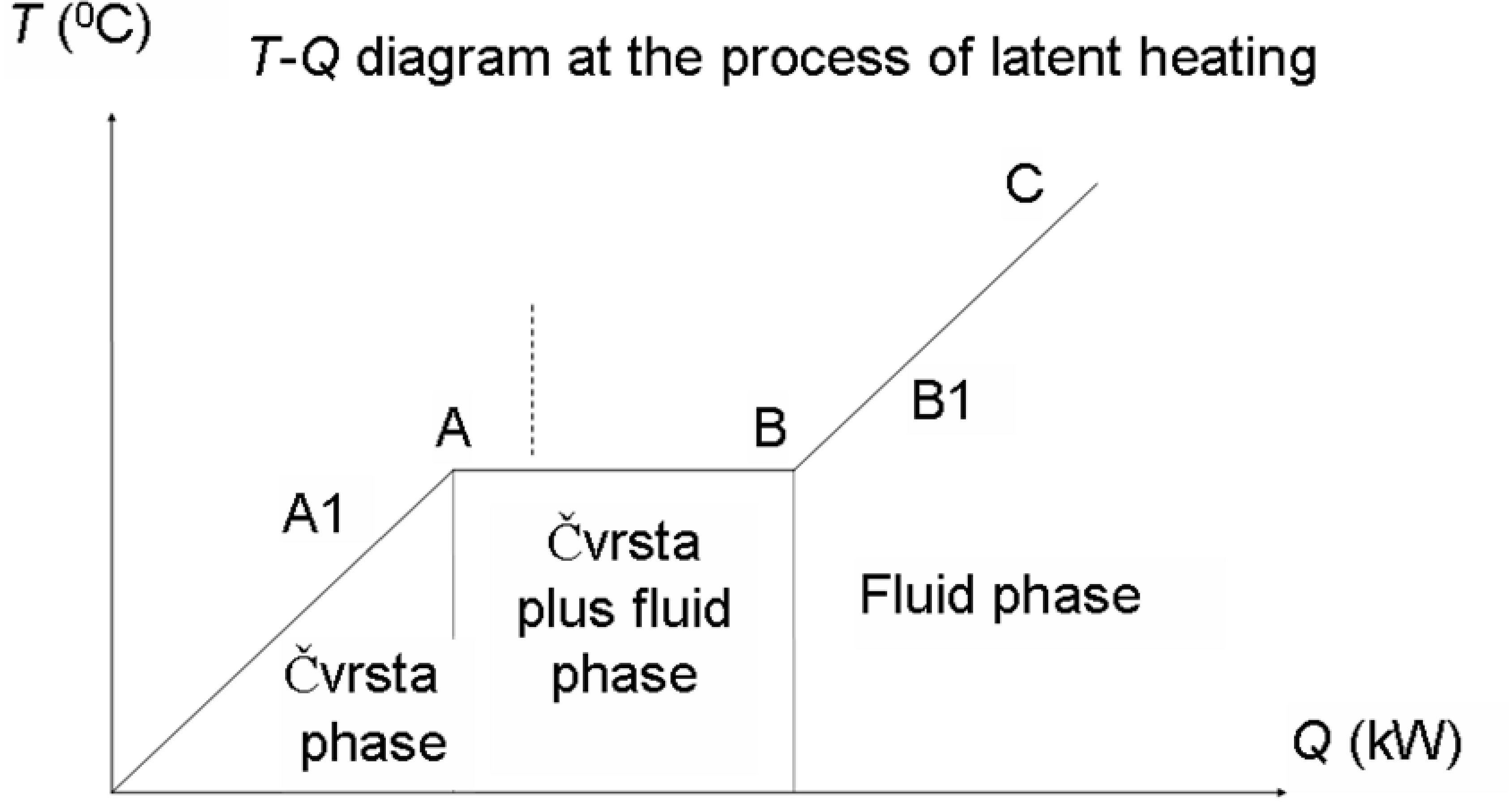
Cold air

Heat store with the stones as a store medium



Cogenerativ system for air and water heating with the stone heat store

2 Energy of Sun stored by means of the latent heat



The total amount of heat *Q* which is delivered to some material into well defined temperature interval :

$$Q = m \int_{T_{A1}}^{T_{A2}} c_1 \, dT + mL + \int_{T_B}^{T_{B1}} c_2 \, dT$$

m - material mass (kg),
c1 - specific heat capacity of the čvrstog state of material (kJ/kgK),
c2 - specific heat capacity of the fluid state of material (kJ/kgK),and
L – specific heat of transition, i.e. the heat necessary to transfer the stone state of material in to fluid state (kJ/kg).

Appropriate materials for latent heating

- Parafin, and
- Glauber's salt ($Na_2SO_4 10H_2O$).

For example:

To store 1 MJ of energy, in to temperature range of 20 ^{0}C, we need 3,1 kg Glauber salt.

For the same process, we need 12 kg of water or 60 kg of stones.

3 The Sun Energy storing by means of the reverse chemical reactions

- To melt one amount of salt we need the heat;
- To take out the heat stored into the melted salt we need the process of cooling – in that way we take the heat out
- For these processes the appropriate materials are sulphur acid - H2SO4, kalium-nitrogen salt - KNO3, sodium-nitrogen salt - NaNO3, sodium-sulfpur salt - Na2SO4

Past projects have included a 20 kilowatt building integrated photovoltaic system in Woody Creek, Colorado. The entire roof of a barn was covered in PV roof shingles.

Energy Facts

- **Energy Consumption**

Though accounting for only 5 percent of the world's population, Americans consume 26 percent of the world's energy. *(American Almanac)*

In 1997, U.S. residents consumed an average of 12,133 kilowatt-hours of electricity each, almost nine times greater than the average for the rest of the world. *(Grist Magazine)*

Worldwide, some 2 billion people are currently without electricity. *(U.S. Department of Energy)*

Total U.S. residential energy consumption is projected to increase 17 percent from 1995 - 2015. *(U.S. Energy Information Administration)*

- World energy consumption is expected to increase 40% to 50% by the year 2010, and the global mix of fuels--renewables (18%), nuclear (4%), and fossil (78%)--is projected to remain substantially the same as today; thus global carbon dioxide emissions would also increase 50% to 60%.

- Among industrialized and developing countries, Canada consumes per capita the most energy in the world, the United Sates ranks second, and Italy consumes the least among industrialized countries.

- Developing countries use 30% of global energy. Rapid population growth, combined with economic growth, will rapidly increase that percentage in the next 10 years.

- The World Bank estimates that investments of $1 trillion will be needed in this decade and upwards of $4 trillion during the next 30 years to meet developing countries' electricity needs alone.

- America uses about 15 times more energy per person than does the typical developing country.

- **Residential appliances**, including **heating and cooling equipment and water heaters**, consume **90% of all energy** used in the U.S. residential sector.

- The United States spends about $440 billion annually for energy. Energy costs U.S. consumers $200 billion and U.S. manufacturers $100 billion annually.

Global Warming

- Worldwide, 1995 was the warmest year since global temperatures were first kept in 1856. This supports the near consensus among climatologists that emissions of carbon dioxide and other gases are causing global warming. *(Chivilan and Epstein,* Boston Globe*)*

- On average, 16 million tons of carbon dioxide are emitted into the atmosphere every 24 hours by human use worldwide. *(U.S. Department of Energy)*

- Carbon emissions in North America reached 1,760 million metric tons in 1998, a 38 percent increase since 1970. They are expected to grow another 31 percent, to 2,314 million metric tons, by the year 2020.

- The United States is the world's largest single emitter of carbon dioxide, accounting for 23 percent of energy-related carbon emissions worldwide. *(U.S. Department of Energy)*
- An average of 23,000 pounds of carbon dioxide are emitted annually in each American home. *(U.S. Environmental Protection Agency)*
- The transportation sector consumed 35% of the nation's energy in 1990; this sector is 97% dependent on petroleum.
- Fossil fuels are depleted at a rate that is 100,000 times faster than they are formed.

Estimated electrical energy for 100.000 householders equipped with heat-solar collectors and photo-voltage panels is about 2000 GWh

- Reduction of NO_x for 4000 tons and SO_2 for 6000 tons

Health

- Approximately 30,000 lives are cut short in the U.S. each year due to pollution from electricity production. *(ABT Associates study)*
- About 81 tons of mercury are emitted into the atmosphere each year as a result of electric power generation. Mercury is the most toxic heavy metal in existence. *(U.S. Environmental Protection Agency)*
- Burning fossil fuels to produce energy releases carbon dioxide and other global-warming-causing gases into the atmosphere. Global warming will increase the incidence of infectious diseases (including equine encephalitis and Lyme disease), death from heat waves, blizzards, and floods, and species loss. *(Chivilan and Epstein,* Boston Globe, *April 10, 1997)*

Transportation

- The United States consumes about 17 million barrels of oil per day, of which nearly two-thirds is used for transportation.

- The United States imports more than seven million barrels of oil per day.

- While the world's population doubled between 1950 and 1996, the number of cars increased tenfold. Automobile congestion in the United States alone accounts for $100 billion in wasted fuel, lost productivity, and rising health costs. Still, analysts project that the world's fleet of cars will double in a mere 25 years. *(Worldwatch Institute)*

- Americans use a billion gallons of motor oil a year, 350 million gallons of which end up polluting the environment. *(Department of Energy and Maryland Energy Administration)*

Transportation

- A car that gets 20 miles per gallon (mpg) emits approximately 50 tons of global-warming-inducing carbon dioxide over its lifetime, while a 40-mpg car emits only 25 tons. Over the average lifetime of an American car (100,000 miles), a 40-mpg car will also save approximately $3,000 in fuel costs compared to a 20-mpg car. *(Natural Resources Defense Council)*

- The cars and trucks reaching the junkyards this year have higher gasoline mileage, on average, than the new ones rolling off dealers' lots, for the first time on record. *(Matt Wald,* The New York Times, *August 11, 2002)*

Renewables

- Only 7.5 percent of total U.S. energy consumption came from renewable sources in 1998. Of that total, 94 percent was from hydropower and biomass (trash and wood incinerators). *(U.S. Energy Information Administration)*
- For the 2 billion people without access to electricity, it would be cheaper to install solar panels than to extend the electrical grid. *(The Fund for Renewable Energy Everywhere)*
- Within 15 years, renewable energy could be generating enough electricity to power 40 million homes and offset 70 days of oil imports.

The impact of distributed generation on electric networks

Ion Tristiu – Associate Professor

POLITEHNICA University of Bucharest
Power Engineering Faculty
Electric Power Systems Department

Dispersed Generation

Principle: *generating locally in zones of consumption of quantities of electricity relatively weak in relation to the classic units of production (thermal, nuclear, hydraulic, etc.).*

Characteristics: - not centrally planned (by the utility);
- not centrally dispatched;
- normally smaller than 50-100 MW;
- usually connected to the distribution system.

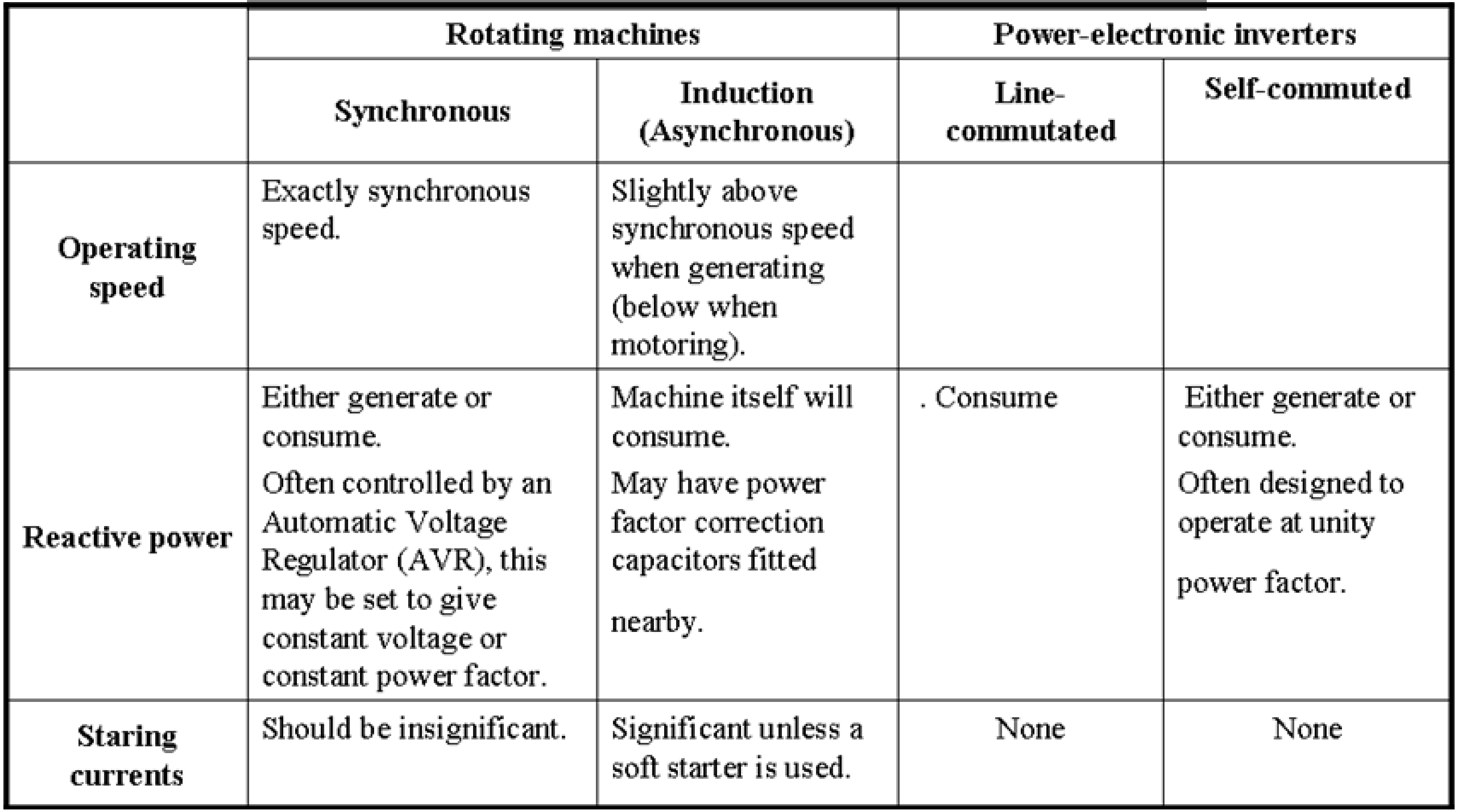
Embedded generation = Distributed generation = Dispersed generation

Advantages: ☺ **Reducing in gaseous emissions (mainly CO_2);**
☺ **Energy efficiency or rational use of energy;**
☺ **Deregulation or competition policy;**
☺ **Diversification of energy sources;**
☺ **Reduction of costs of electricity transmission;**
☺ **Improvement of quality indices of electricity (reliability, voltage level).**

Dispersed generation technologies

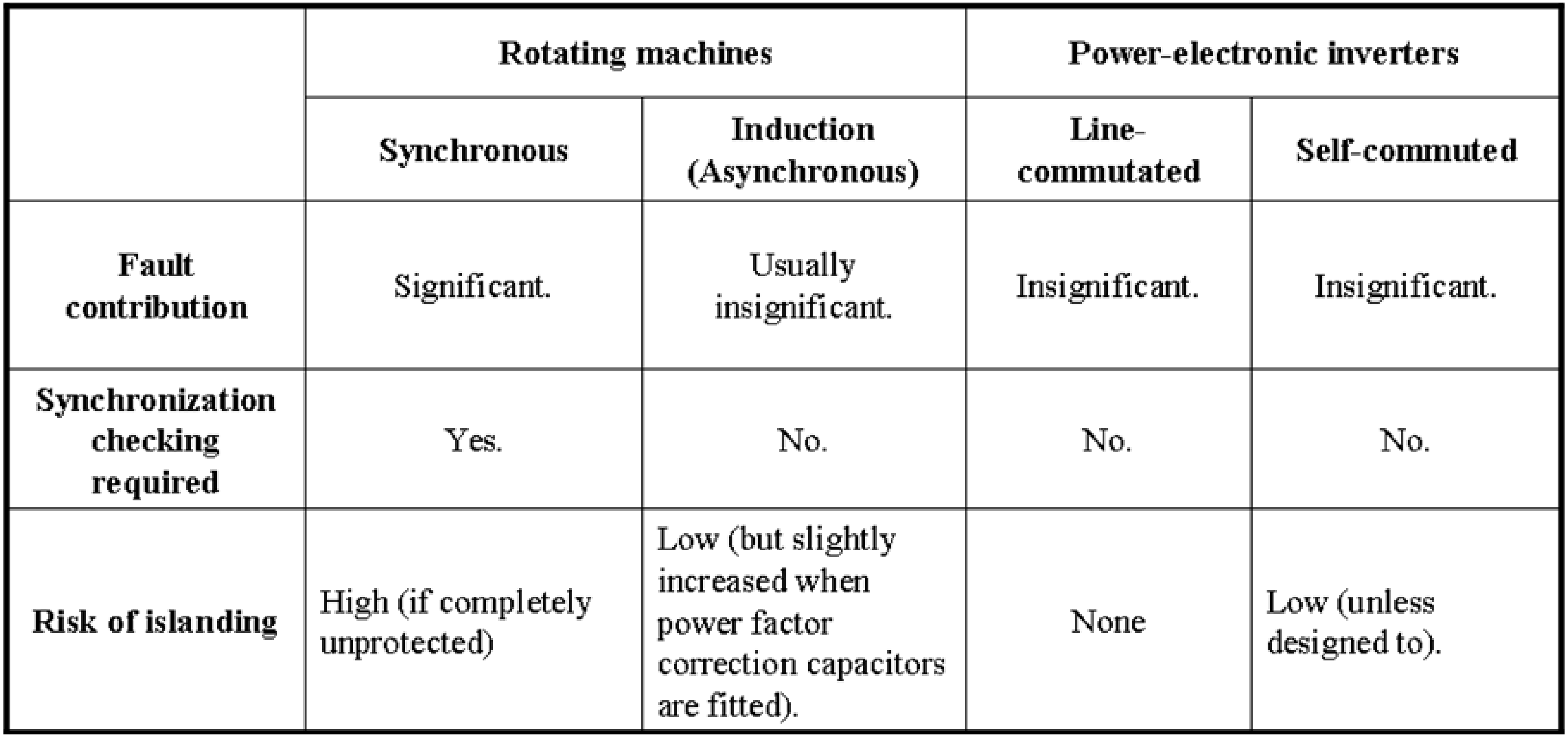
Technology	Energy sources	Supply reliability	Generator types
Combined heat and power	Fossil (coal, oil, natural gas) Renewable (biomass)	Good	Synchronous and asynchronous machines
Gas turbines	Fossil (natural gas)	Good	Synchronous and asynchronous machines
Diesel plants	Fossil (oil)	Good	Synchronous and asynchronous machines
Small-scale hydro-generation	Renewable (water energy)	Good	Synchronous and asynchronous machines
Wind turbines	Renewable (wind energy)	Weak	Asynchronous and synchronous machines
Solar photovoltaic	Renewable (direct solar energy)	Weak	Power electronic converters
Fuel cells	Renewable (wind energy)	Good	Power electronic converters

Generator types and characteristics (1)

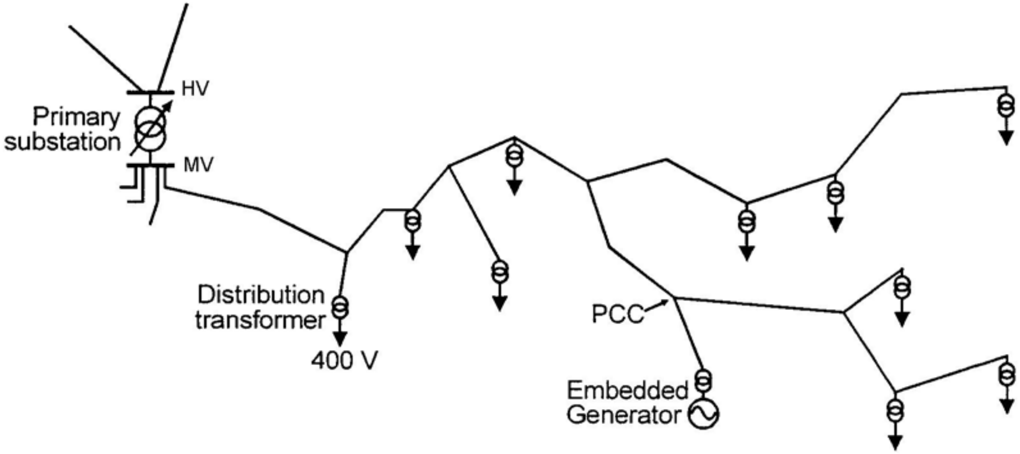


	Rotating machines		Power-electronic inverters	
	Synchronous	**Induction (Asynchronous)**	**Line-commutated**	**Self-commuted**
Operating speed	Exactly synchronous speed.	Slightly above synchronous speed when generating (below when motoring).		
Reactive power	Either generate or consume. Often controlled by an Automatic Voltage Regulator (AVR), this may be set to give constant voltage or constant power factor.	Machine itself will consume. May have power factor correction capacitors fitted nearby.	. Consume	Either generate or consume. Often designed to operate at unity power factor.
Staring currents	Should be insignificant.	Significant unless a soft starter is used.	None	None

Generator types and characteristics (2)



	Rotating machines		Power-electronic inverters	
	Synchronous	**Induction (Asynchronous)**	**Line-commutated**	**Self-commuted**
Fault contribution	Significant.	Usually insignificant.	Insignificant.	Insignificant.
Synchronization checking required	Yes.	No.	No.	No.
Risk of islanding	High (if completely unprotected)	Low (but slightly increased when power factor correction capacitors are fitted).	None	Low (unless designed to).



Point of Common Coupling

Problems:

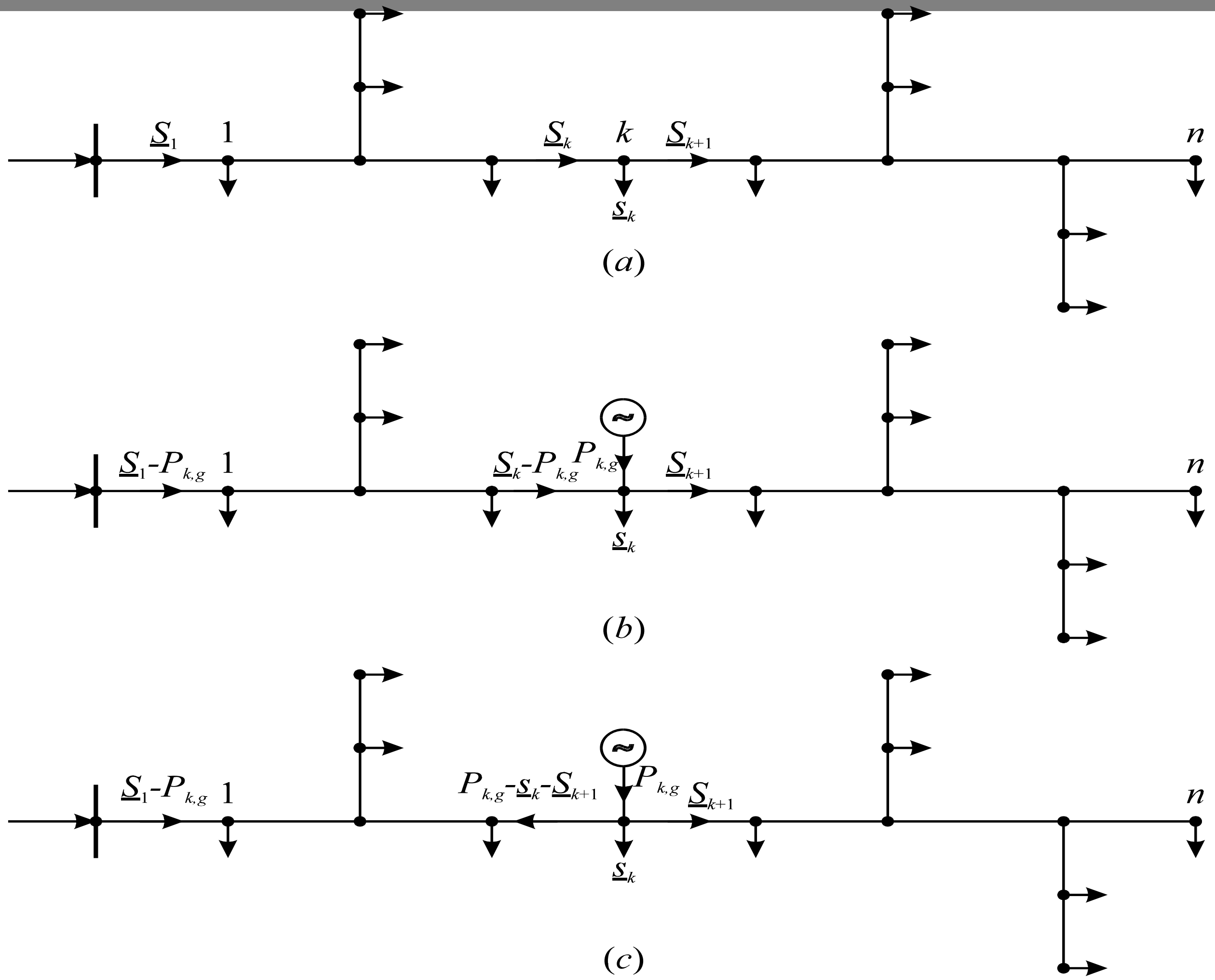
- **network losses;**
- **voltage effects;**
- **thermal limits;**
- **fault level;**
- **islanding;**
- **protection;**
- **power quality;**
- **stability.**

Power losses in distribution networks with DG

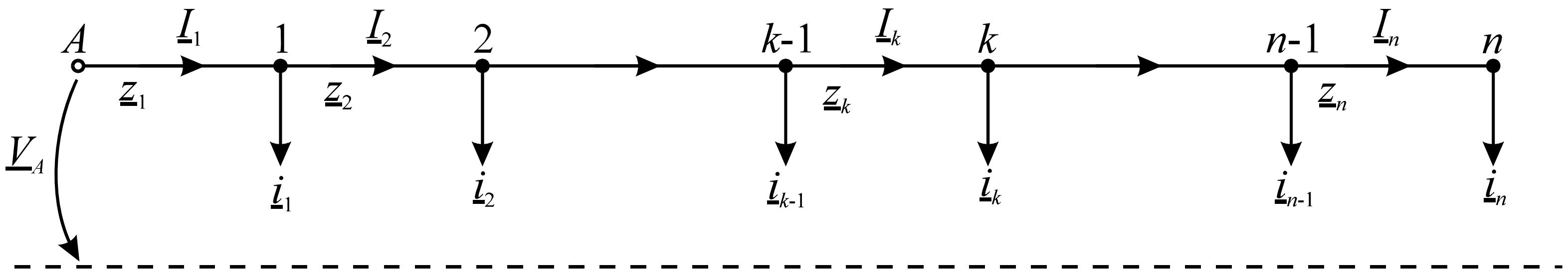
Problems:

- Power losses modification;
- Optimal location of dispersed generators;
- Voltage control and its impact on losses;
- Allocation of losses;
- Network reconfiguration.

Modification of power flow in distribution networks by introducing DG



Variation of power active losses in distribution network by introducing DG



$$\Delta \underline{i}_k = \Delta i_{ka} + j\Delta i_{kr}$$

$$\Delta\left(\Delta P\right) \overset{\text{Not}}{=} \delta P = 3\left[\left(\Delta i_{ka}^2 + \Delta i_{kr}^2\right)\sum_{i=1}^{k} r_i + 2\Delta i_{ka}\sum_{i=1}^{k} r_i I_{ia} + 2\Delta i_{kr}\sum_{i=1}^{k} r_i I_{ir}\right]$$

Optimal location of DGs for minimization of active power losses (1)

$$\Delta\left(\Delta P\right) \overset{\text{Not}}{=} \delta P = 3\left[\left(\Delta i_{ka}^{2} + \Delta i_{kr}^{2}\right)\sum_{i=1}^{k} r_i + 2\Delta i_{ka}\sum_{i=1}^{k} r_i I_{ia} + 2\Delta i_{kr}\sum_{i=1}^{k} r_i I_{ir}\right]$$

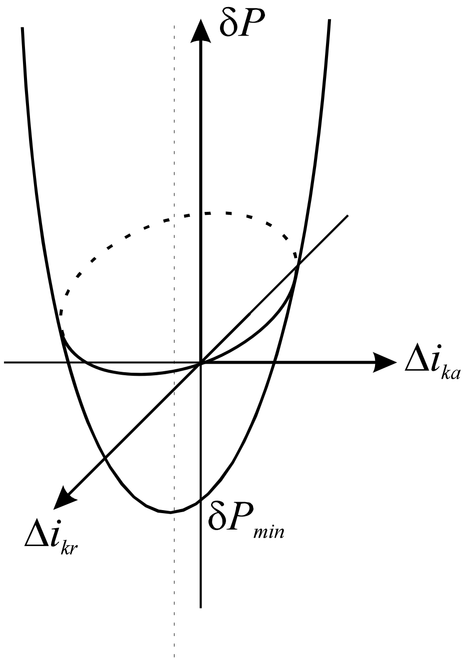
$$\Delta U_a \overset{\text{Not}}{=} \sum_{i=1}^{k} r_i I_{ia}; \quad \delta U_a \overset{\text{Not}}{=} \sum_{i=1}^{k} r_i I_{ir}$$

$$\delta P = 3\left[R\left(\Delta i_{ka}^{2} + \Delta i_{kr}^{2}\right) + 2\Delta i_{ka}\Delta U_a + 2\Delta i_{kr}\delta U_a\right]$$

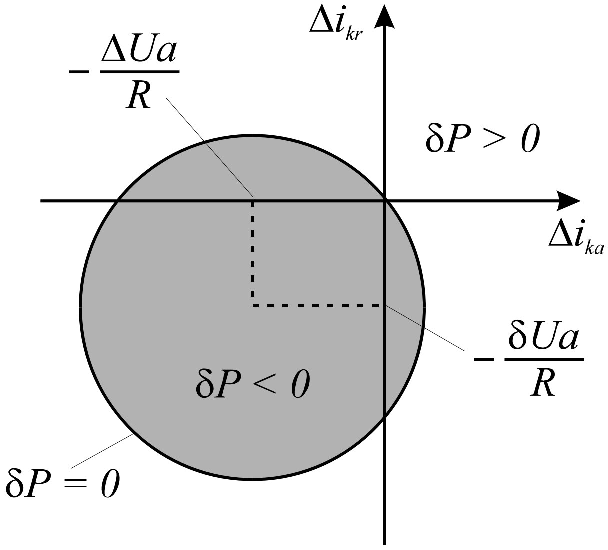
$$\delta P = 3\left[R\left(\Delta i_{ka} + \frac{\Delta U_a}{R}\right)^{2} + R\left(\Delta i_{kr} + \frac{\delta U_a}{R}\right)^{2} - \frac{\Delta U_a^{2} + \delta U_a^{2}}{R}\right]$$

Optimal location of DGs for minimization of active power losses (2)

$$\delta P = 3\left[R\left(\Delta i_{ka} + \frac{\Delta U_a}{R} \right)^2 + R\left(\Delta i_{kr} + \frac{\delta U_a}{R} \right)^2 - \frac{\Delta U_a^2 + \delta U_a^2}{R} \right]$$



a



b

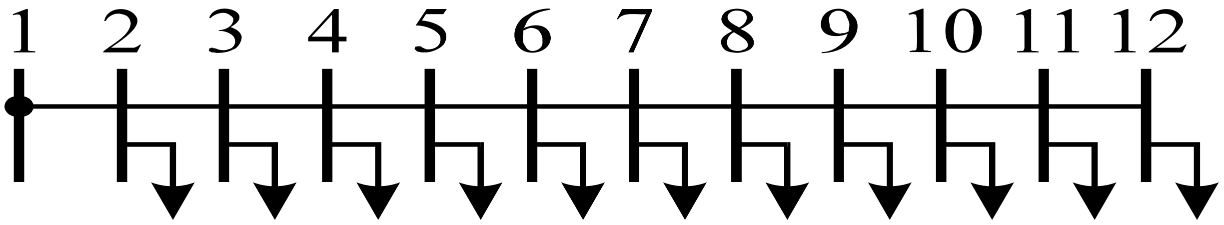
Optimal location of DGs for minimization of active power losses (3)

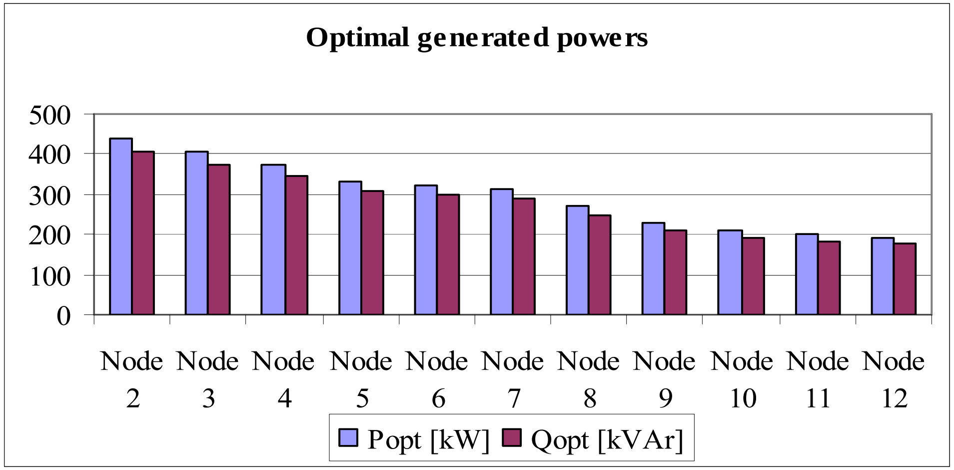
$$\begin{cases} \dfrac{\partial(\delta P_k)}{\partial(\Delta i_{ka})} = 0 \Rightarrow \Delta i_{ka} = -\dfrac{\Delta U_a}{R} = -\dfrac{\sum_{i=1}^{k} r_i I_{ia}}{\sum_{i=1}^{k} r_i} = I_{ka,g} \\[2em] \dfrac{\partial(\delta P_k)}{\partial(\Delta i_{kr})} = 0 \Rightarrow \Delta i_{kr} = -\dfrac{\delta U_a}{R} = -\dfrac{\sum_{i=1}^{k} r_i I_{ir}}{\sum_{i=1}^{k} r_i} = I_{kr,g} \end{cases}$$

$$\delta P_k = -3\frac{(\Delta U_a)^2 + (\delta U_a)^2}{R} = -3\frac{\left(\sum_{i=1}^{k} r_i I_{ia}\right)^2 + \left(\sum_{i=1}^{k} r_i I_{ir}\right)^2}{\sum_{i=1}^{k} r_i}$$

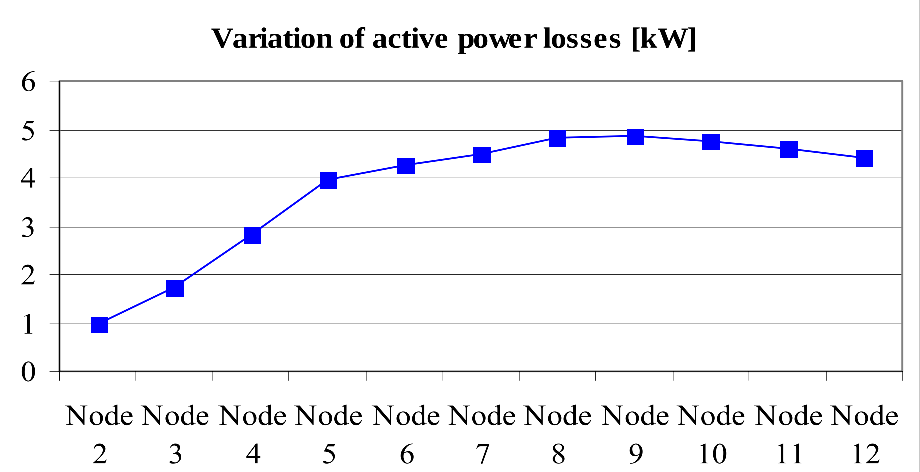
$$\frac{\delta P}{P_{k,g}} = \frac{\Delta P_{\text{inițial}} - \Delta P_{GD_k}}{P_{k,g}} = \frac{3\dfrac{\left(\sum_{i=1}^{k} r_i I_{ia}\right)^2}{\sum_{i=1}^{k} r_i}}{\sqrt{3}U_k I_{ka,g}} \cong \frac{3\dfrac{\left(\sum_{i=1}^{k} r_i I_{ia}\right)^2}{\sum_{i=1}^{k} r_i}}{\sqrt{3}U_{n,k}\dfrac{\sum_{i=1}^{k} r_i I_{ia}}{\sum_{i=1}^{k} r_i}} = \frac{\sqrt{3}}{U_{n,k}}\sum_{i=1}^{k} r_i I_{ia}$$

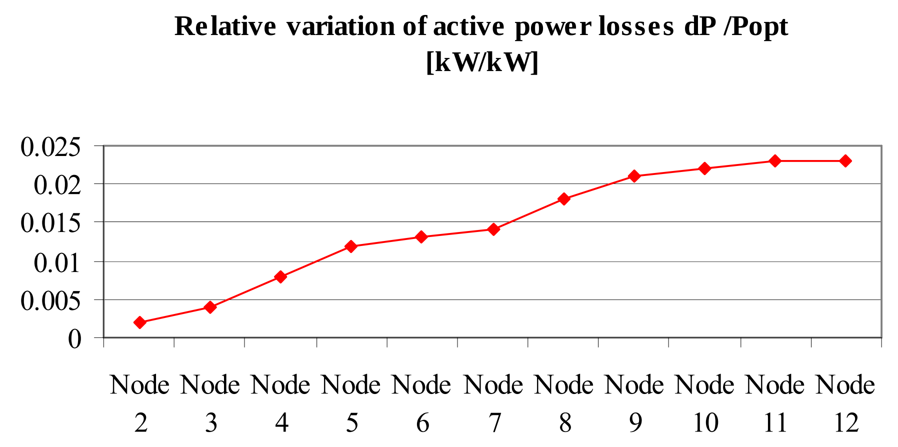
Case study


1
2
3
4
5
6
7
8
9
10
11
12

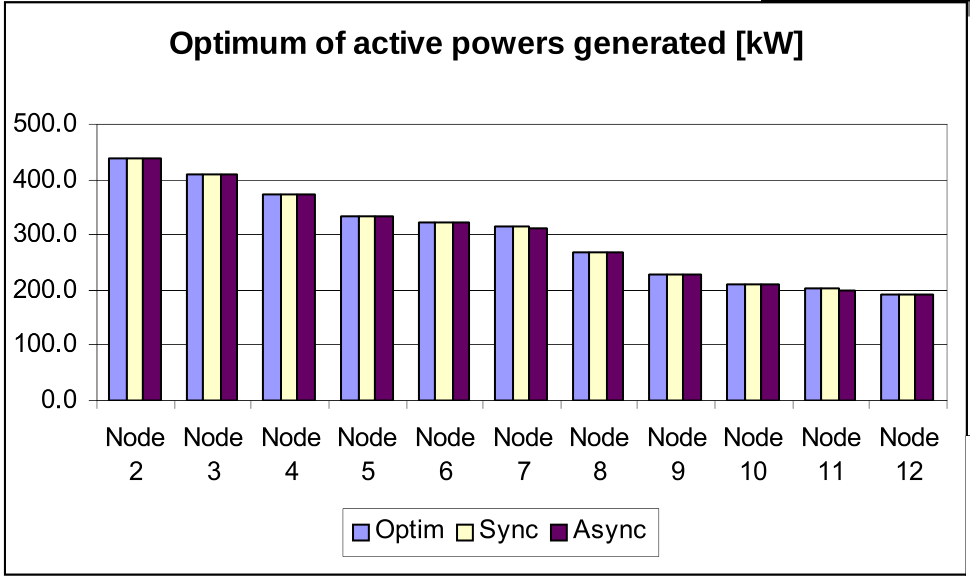

Optimal generated powers
500
400
300
200
100
0
Node 2
Node 3
Node 4
Node 5
Node 6
Node 7
Node 8
Node 9
Node 10
Node 11
Node 12
Popt [kW]
Qopt [kVAr]

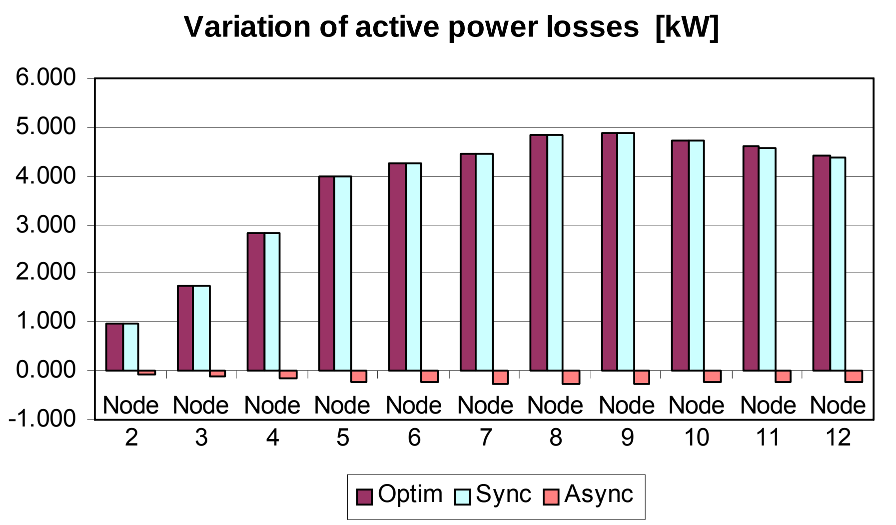
Case study


Variation of active power losses [kW]
6
5
4
3
2
1
0
Node 2
Node 3
Node 4
Node 5
Node 6
Node 7
Node 8
Node 9
Node 10
Node 11
Node 12

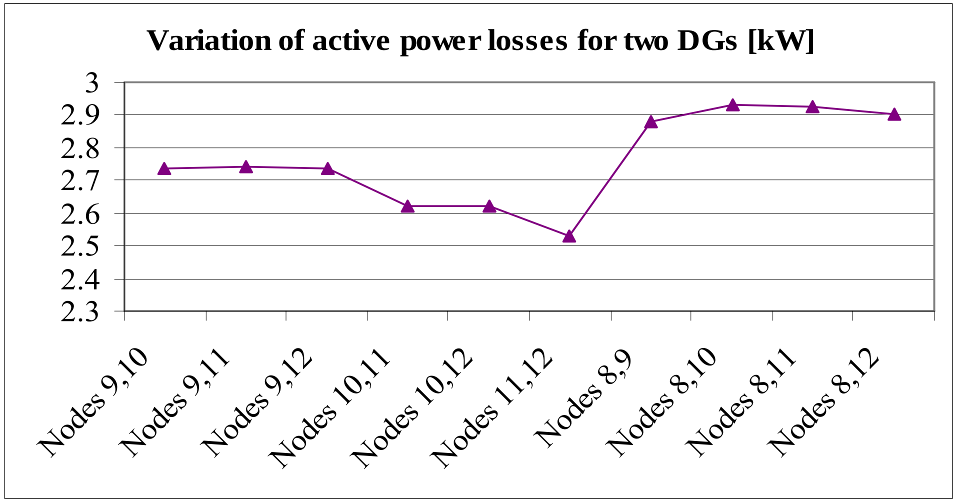

Relative variation of active power losses dP /Popt [kW/kW]
0.025
0.02
0.015
0.01
0.005
0
Node 2
Node 3
Node 4
Node 5
Node 6
Node 7
Node 8
Node 9
Node 10
Node 11
Node 12

Case study


Optimum of active powers generated [kW]
500.0
400.0
300.0
200.0
100.0
0.0
Node 2
Node 3
Node 4
Node 5
Node 6
Node 7
Node 8
Node 9
Node 10
Node 11
Node 12
Optim
Sync
Async

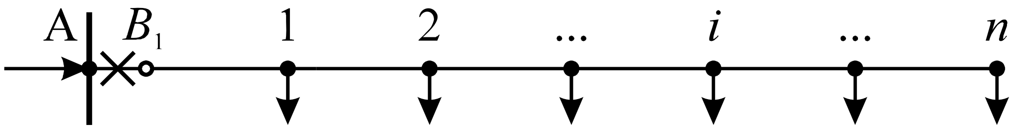

Variation of active power losses [kW]
6.000
5.000
4.000
3.000
2.000
1.000
0.000
-1.000
Node 2
Node 3
Node 4
Node 5
Node 6
Node 7
Node 8
Node 9
Node 10
Node 11
Node 12
Optim
Sync
Async

Case study

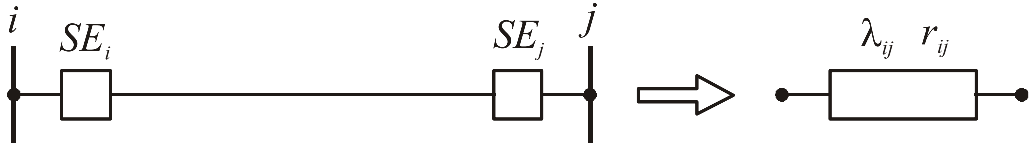

Variation of active power losses for two DGs [kW]
3
2.9
2.8
2.7
2.6
2.5
2.4
2.3
Nodes 9,10
Nodes 9,11
Nodes 9,12
Nodes 10,11
Nodes 10,12
Nodes 11,12
Nodes 8,9
Nodes 8,10
Nodes 8,11
Nodes 8,12

Distribution network without DGs (1)

Radial electrical network



Equivalent reliability parameters for a branch



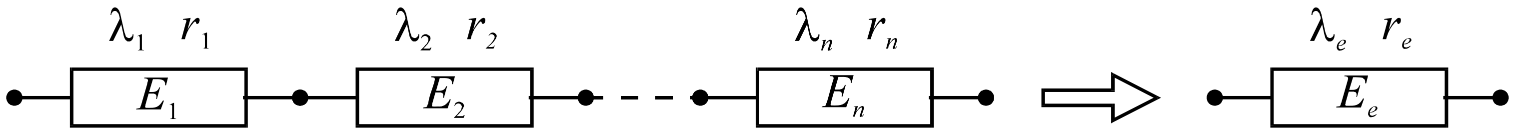
λ_{ij} *failure rate, expressed in failures per year (f/yr)*

r_{ij} *failure duration, expressed in hours*

$$\lambda_{ij} = \lambda_{SEi} + \lambda_{0ij} l_{ij} + \lambda_{SEj}; \qquad U_{ij} = \lambda_{SEi} r_{SEi} + \lambda_{0ij} l_{ij} r_{0ij} + \lambda_{SEj} r_{SEj}; \qquad r_{ij} = \frac{U_{ij}}{\lambda_{ij}}$$

Distribution network without DGs (2)

Reliability bloc diagram



$$\lambda_{ei} = \sum_{j \in Rep} \lambda_j + \sum_{j \in Isol} \lambda_j; \qquad U_{ei} = \sum_{j \in Rep} \lambda_j r_{j,rep} + \sum_{j \in Isol} \lambda_j r_{j,isol}; \qquad r_{ei} = \frac{U_{ei}}{\lambda_{ei}}$$

Energy not supplied

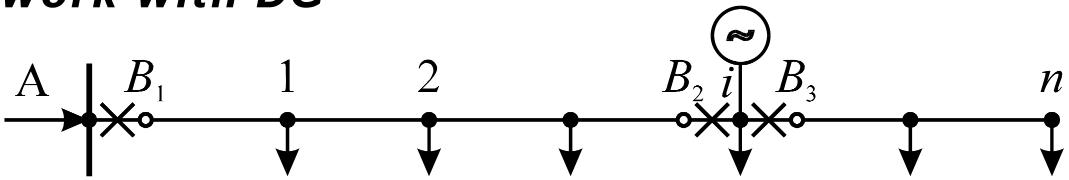
$$L_i = \lambda_{ei} r_{ei} \Delta L_i$$

Consumer Interruption Cost

$$IC_i = \lambda_{ei} \left[c_P \left(r_{ei} \right) + c_W \left(r_{ei} \right) r_{ei} \right] \Delta L_i$$

Distribution network with dispersed generators

Electrical network with DG



Interruption Cost

$$IC_i = \lambda_{ei}\left[c_P\left(r_{ei}\right) + c_W\left(r_{ei}\right) r_{ei}\right]\left(P_i - P_{G,i}\right) + \lambda_{ei}\left[c_P\left(r'_{ei}\right) + c_W\left(r'_{ei}\right) r'_{ei}\right] P_{G,i}$$

$$r'_{ei} = \left(1 - p_{DG,i}\right) r_{ei}$$

Mathematical model of the dispersed generators placement problem

A. Objective Function

$$\text{MIN}\left[CIC=\sum_{i=1}^{n} IC_i\right]$$

B. Constraints

1) Power Flow Equations

$$F_i\left(\mathbf{x},P_{G,k}\right)\quad i=1,2,\dots,n$$

2) Operational constraints

$$V_i^{\min}\le V_i\le V_i^{\max}$$

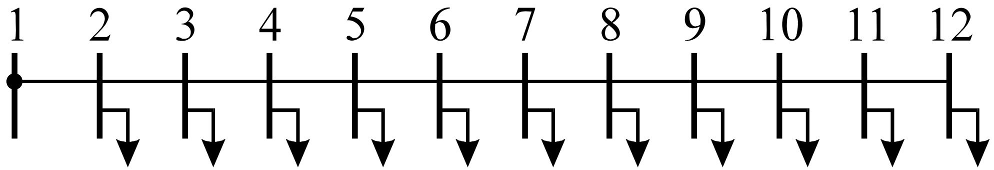
$$P_l\le P_l^{\max}$$

3) Constraints on the size and number of DGs

$$P_{G,k}^{\min}\le P_{G,k}\le P_{G,k}^{\max}$$

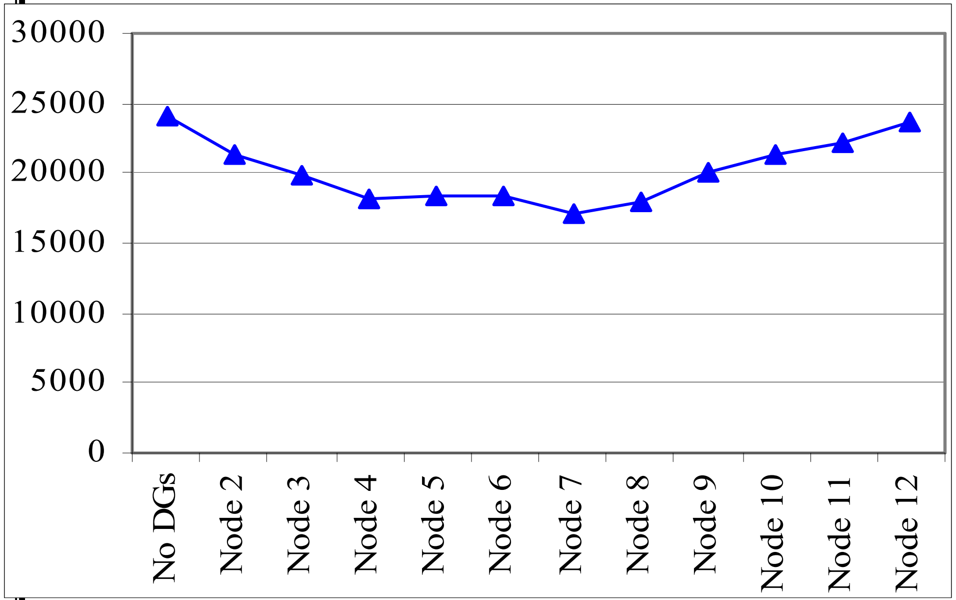
$$n_{DG}\le n_{DG}^{\max}$$

Case study

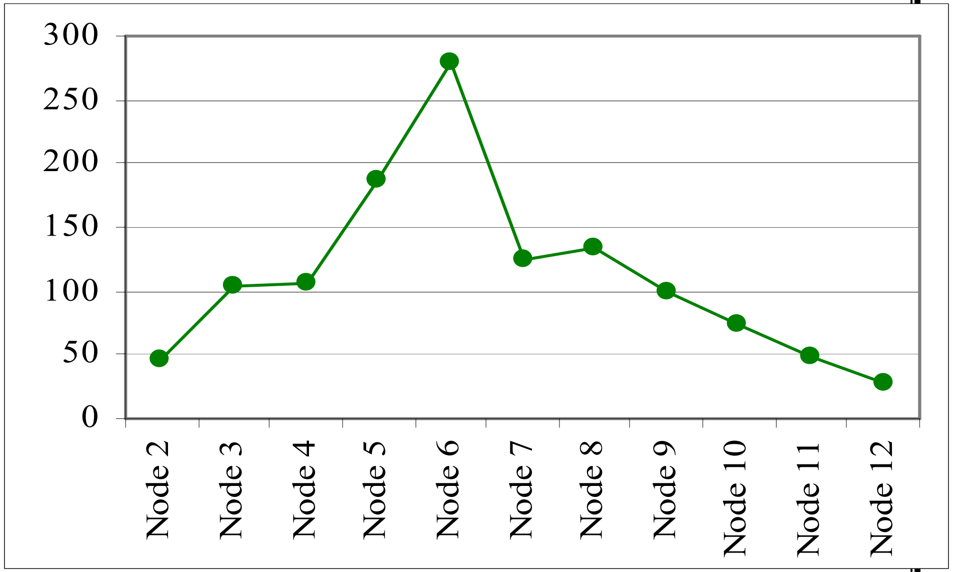


Introduction of one DG

CIC variation (Euros)



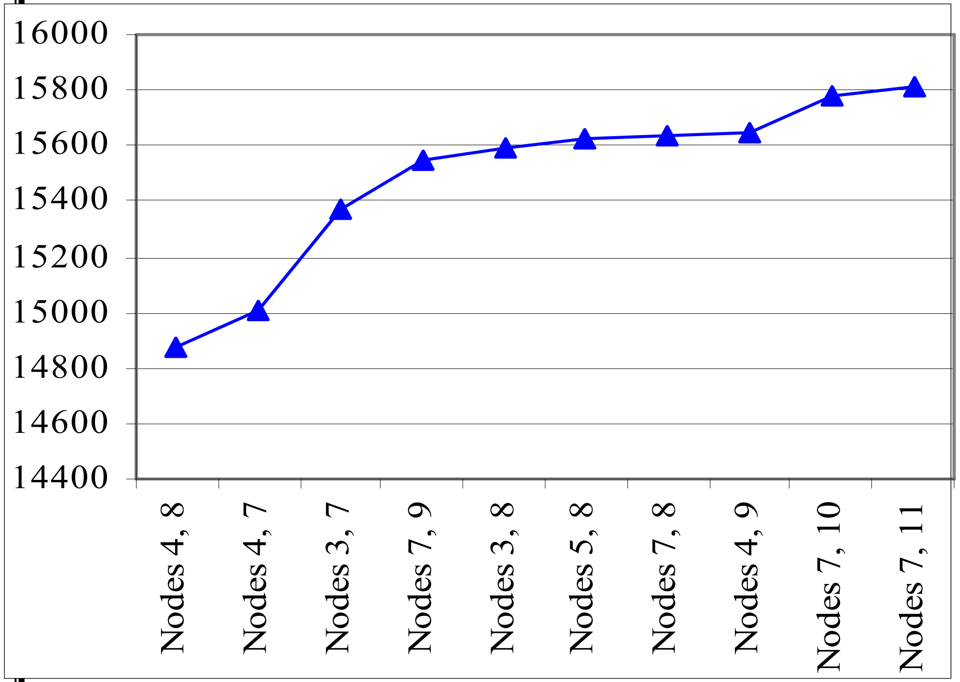
Generated active power benefit (Euros per kilowatt)



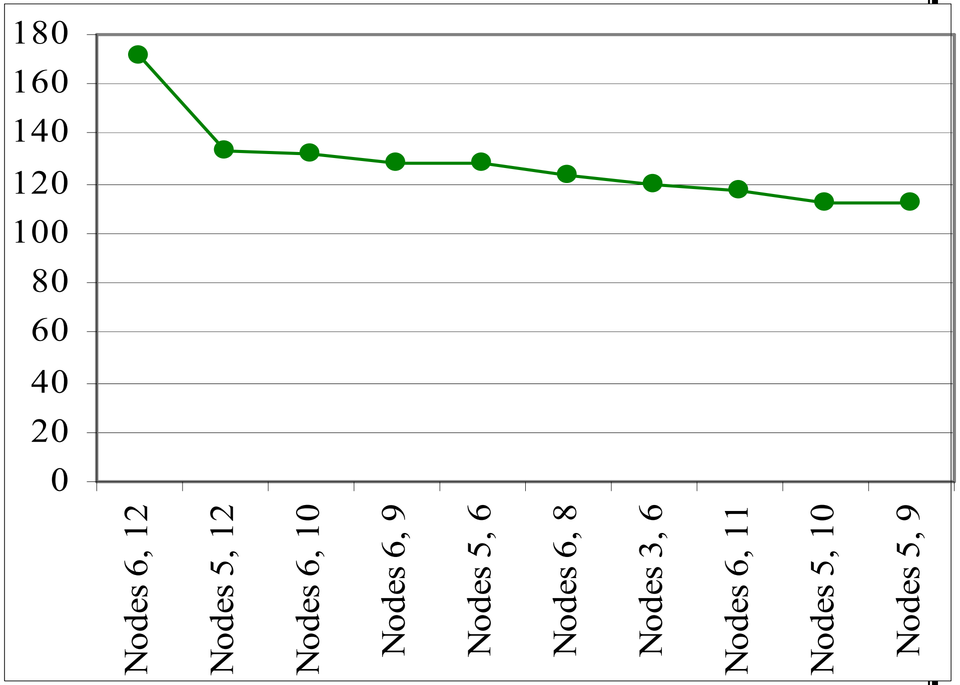
Case study

Introduction of two DGs

CIC variation (Euros)



Generated active power benefit (Euros per kilowatt)



Conclusions

- The introduction of dispersed generators ➔ improvement of the consumers supply safe

- Complex analysis of the optimal placement ➔power losses, investments, etc.

- The introduction of circuit breakers to separate the network area fed by a dispersed source contributes to the improvement of the consumers supply safe situated upstream to the circuit breaker location (between this place and the supplying node).

ISTRABENZ ENERGETSKI SISTEMI

TRADING GREEN ENERGY

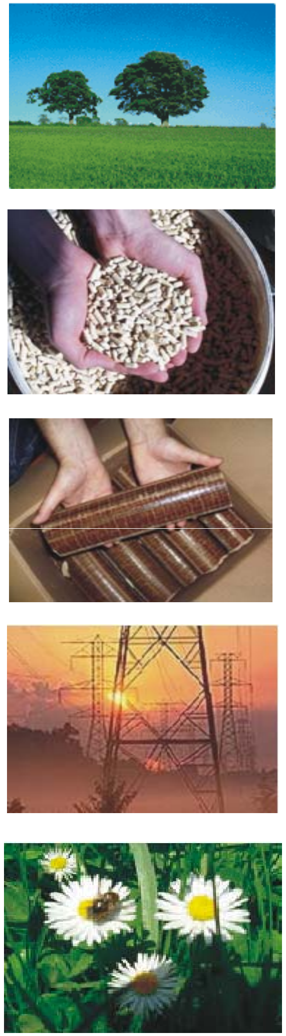
renewable support schemes

dr. Dejan Paravan, Istrabenz Energetski sistemi

dr. Andrej Gubina, University of Ljubljana

Outline

- Why RES?
- RES on market
- Certificate systems
- Feed-in tariffs
- Practical examples: Austria and Slovenia
- Harmonization of rules in EU
- Future perspectives
- Conclusions



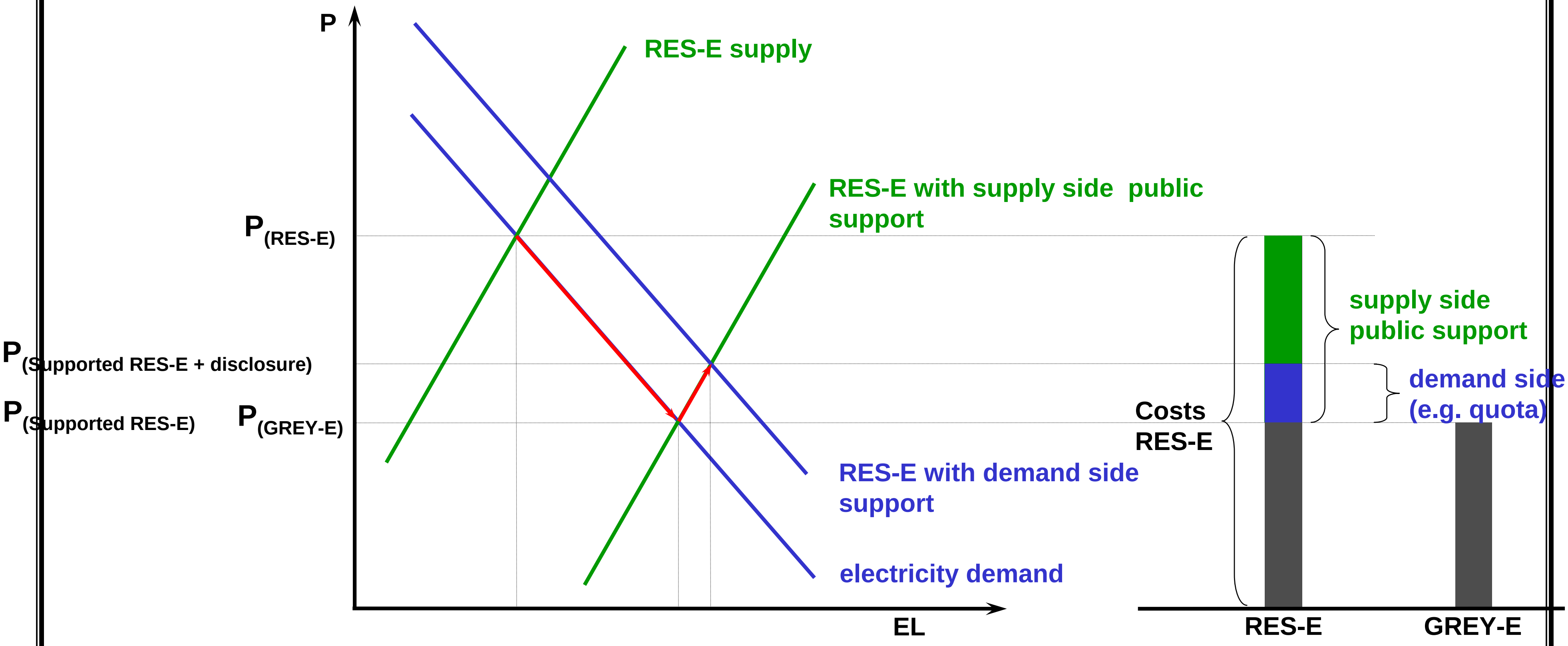
Advantages of RES$_E$

- The EU set down indicative targets for the production of electricity from renewable energy sources for all Member States, assuming the following advantages
    - environmental protection,
    - sustainable development,
    - increase in local employment,
    - positive impact on social cohesion,
    - contribution to security of supply and
    - meeting the Kyoto targets more quickly.

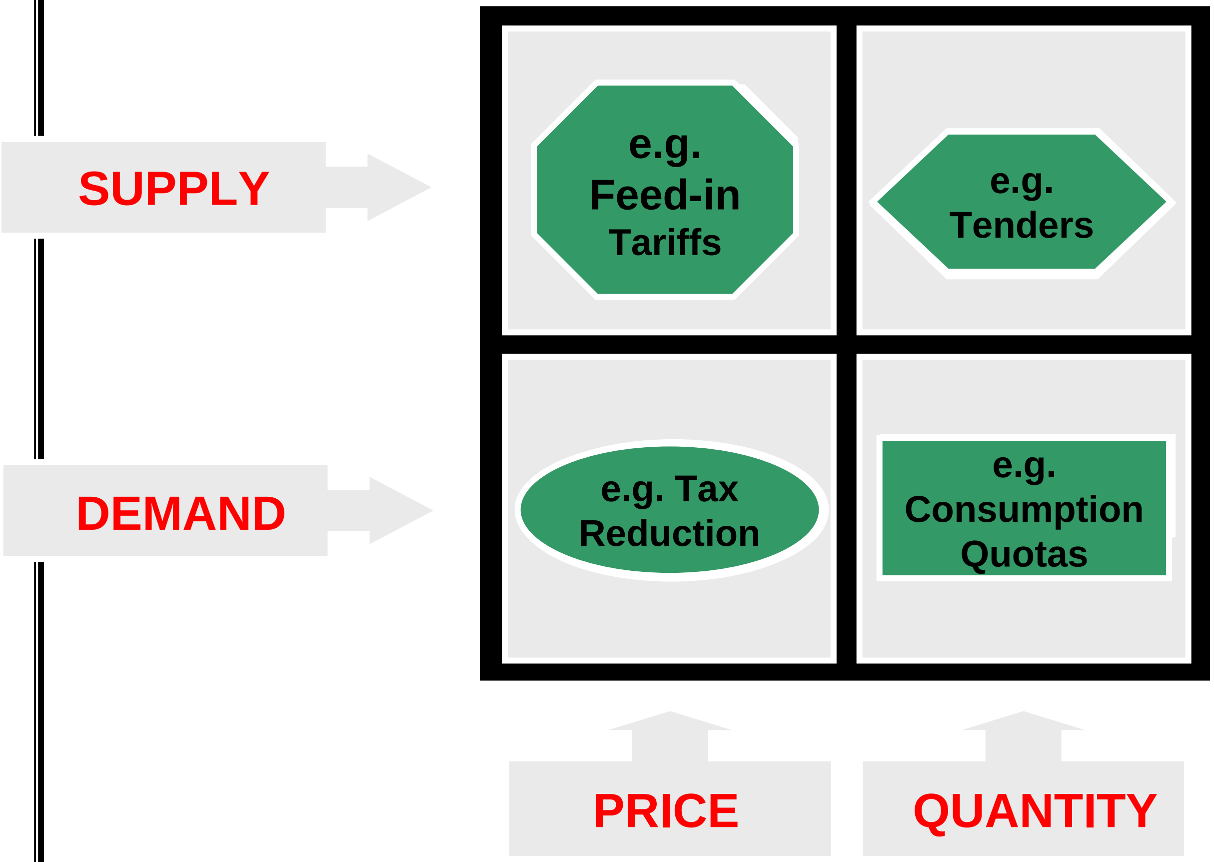
Market for Electricity from RES: RES-E

- Supply of RES-E:
  - 3 time/space separate levels
    - Physical flow of electrical energy
    - Financial contract on electricity supply
    - Financial contract on selling characteristics of energy
- Green certificates
  - Instrument for transfer of the information on production attributes of RES-E.
  - Project RECS - First international initiative for certificates
- Guarantees of Origin (GoO):
  - Dir. 2001/77/EC, Art. 5: GoO for each MWh RES-E
  - Slovenia: several bylaws in preparation.
    - Trading with GoO separated from trading with electricity.

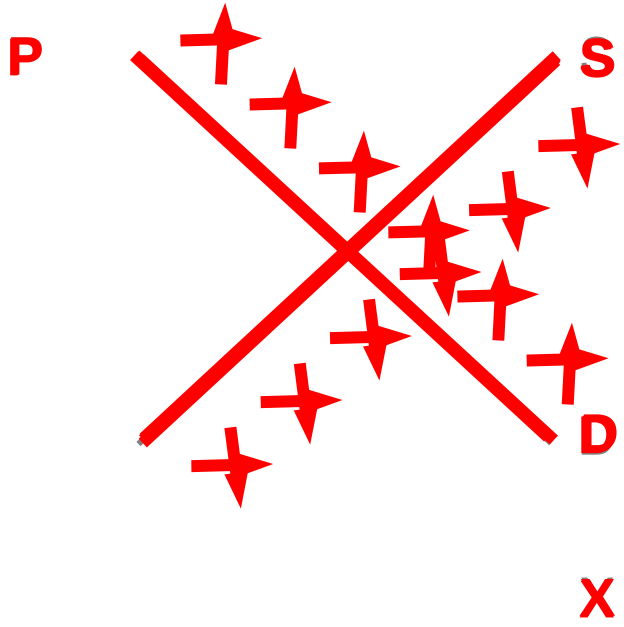
WHy RES-E market needs to be supported?



RES-E Support Systems



	PRICE	QUANTITY
SUPPLY	e.g. Feed-in Tariffs	e.g. Tenders
DEMAND	e.g. Tax Reduction	e.g. Consumption Quotas



The two major support systems

- Certificate system makes national and international trading possible, supports renewable energy production at the best and most productive sites

For mature markets

- Feed in tariffs, if fixed for a minimum period of at least the first 10-15 years of operation period, give interested investors a high economic security.

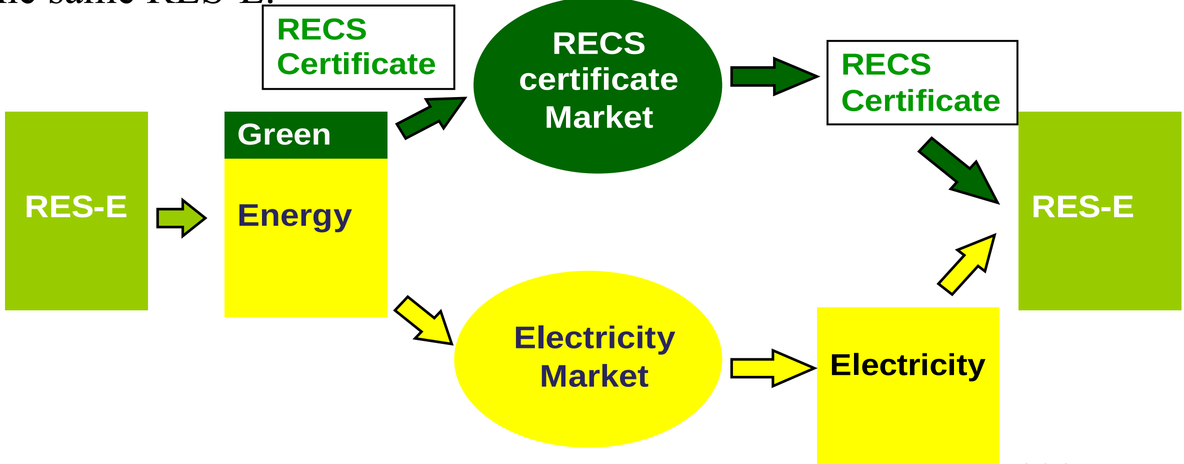
For emerging markets

RECS System

- RECS International
  - Largest international association of energy companies
  - Promotes international trading with green certificates
  - AIB (Association of Issuing Bodies) development and activity of RECS system:
- Slovenia: RECS is successful
  - Issuing Body in Slovenia: AGEN-RS.
  - Auditing Body: TÜV Sava Bayern, Germany
  - National and international sales of certificates

Green Certificates trade

- “Wholesale market” for RES-E
  - Buyer assures production of RES-E in Europe.
  - Trading with Certificates and energy is independent
    - Energy: traded for the future
    - Certificates: issued for the energy produced in the past
  - Green certificate
    - Internationally supervised origin of RES-E
    - No double-selling of the same RES-E.



RES-E

Green

Energy

RECS Certificate

RECS certificate Market

RECS Certificate

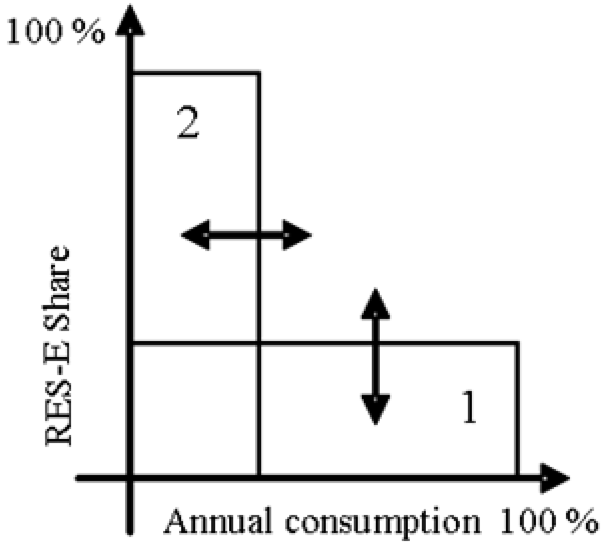
Electricity Market

Electricity

RES-E

Retail Market for RES-E

- RES-E end-products
  - Green Certificates used for quality assurance
  - Sales procedures differ in companies/countries
  - Suppliers can influence demand considerably
    - Structuring and marketing of RES-E end-products.
  - Energy labels used in RES-E products:
    - not harmonized nor comparable.
  - A comprehensive marketing communication with buyers is necessary.
- Two methods of RES-E
- products formation

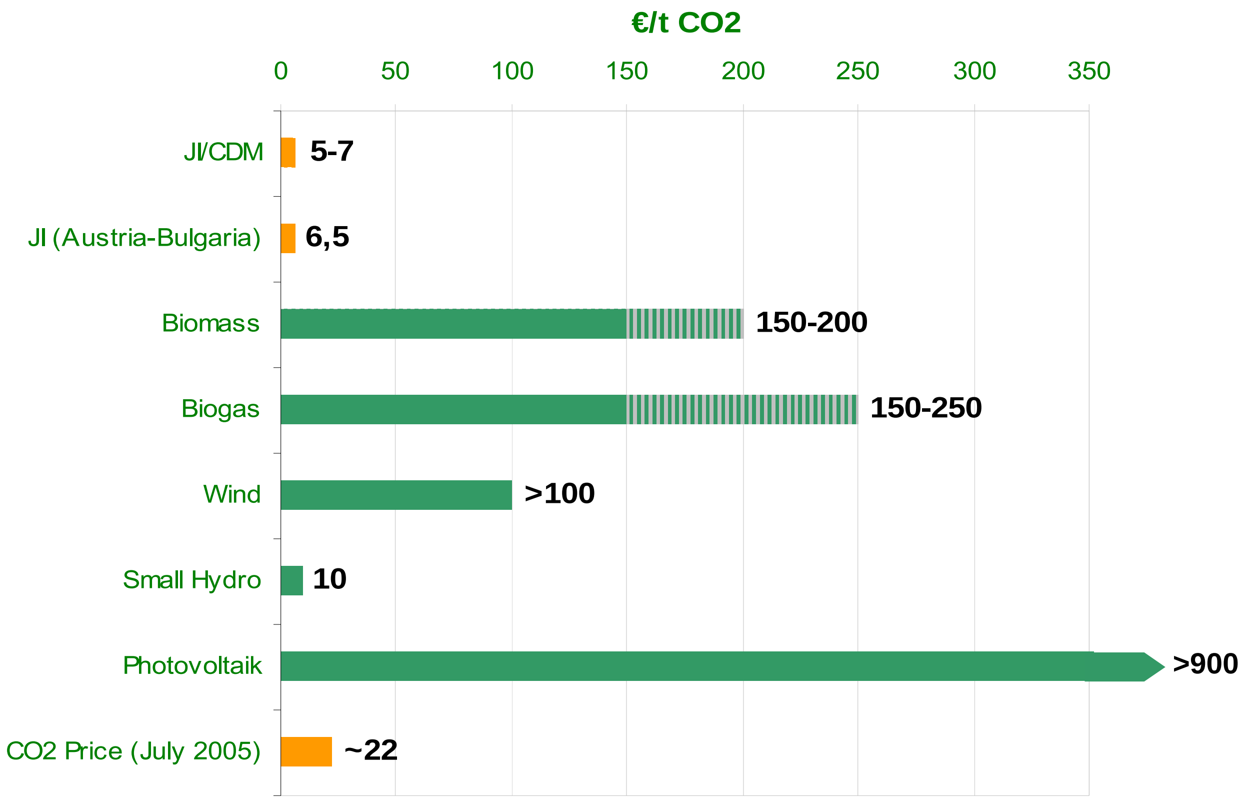


Subsidies create potential market distortions

– Economic theory states that subsidies in general have the potential to distort the market.

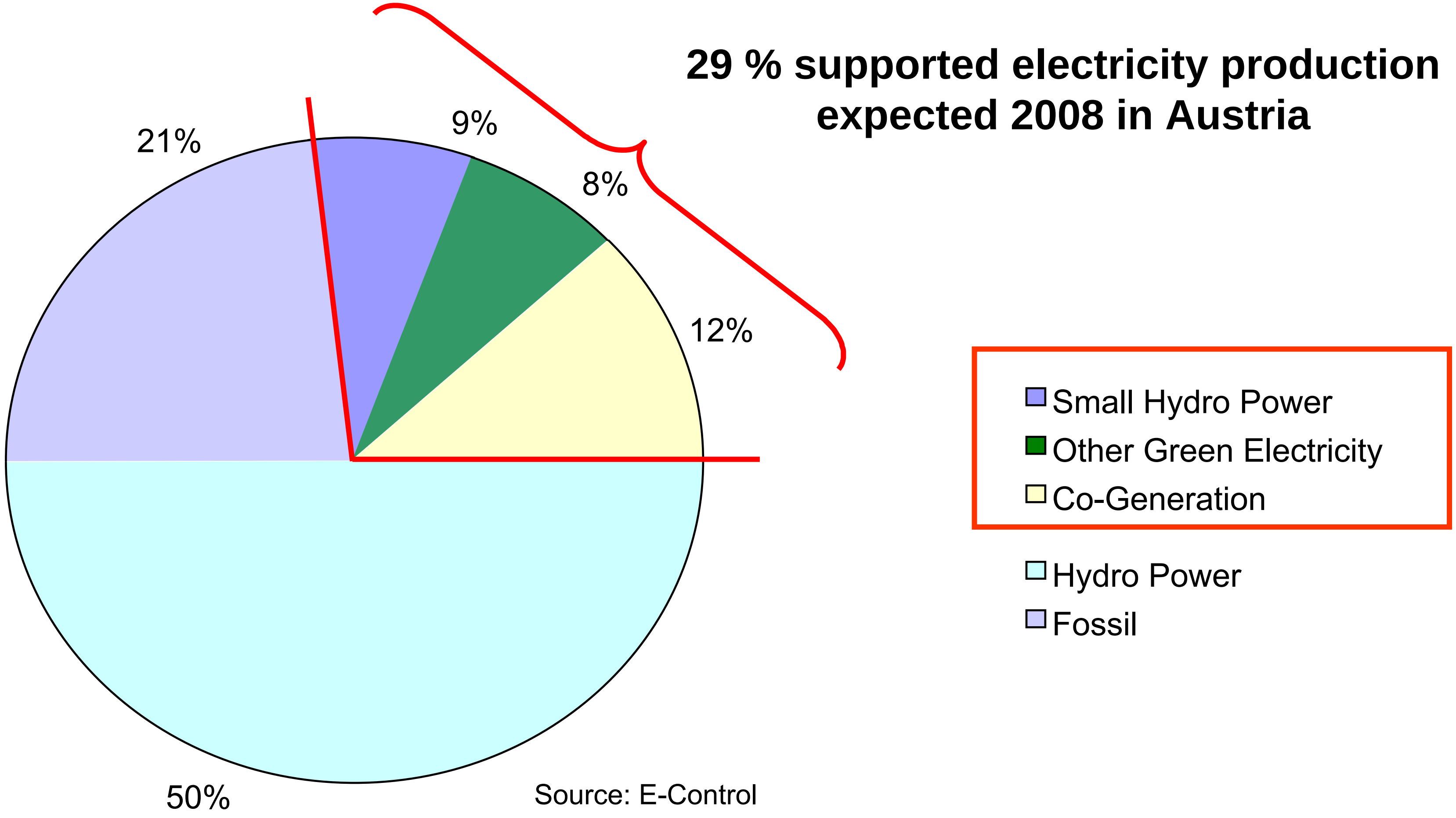
1. Additional costs are allocated differently to end consumers from one country to the other.
2. Different support levels create undue competitive advantages for some market participants.
3. Guaranteed support levels often lead to artificially high production costs, because power equipment producers align their prices to the support level.

CO_2 Reduction Costs – Flexible Mechanisms vs. RES_E in Austria



Source: E-Control

Supported Electricity in Austria



29 % supported electricity production expected 2008 in Austria

Source: E-Control

RES electricity generation in Slovenia

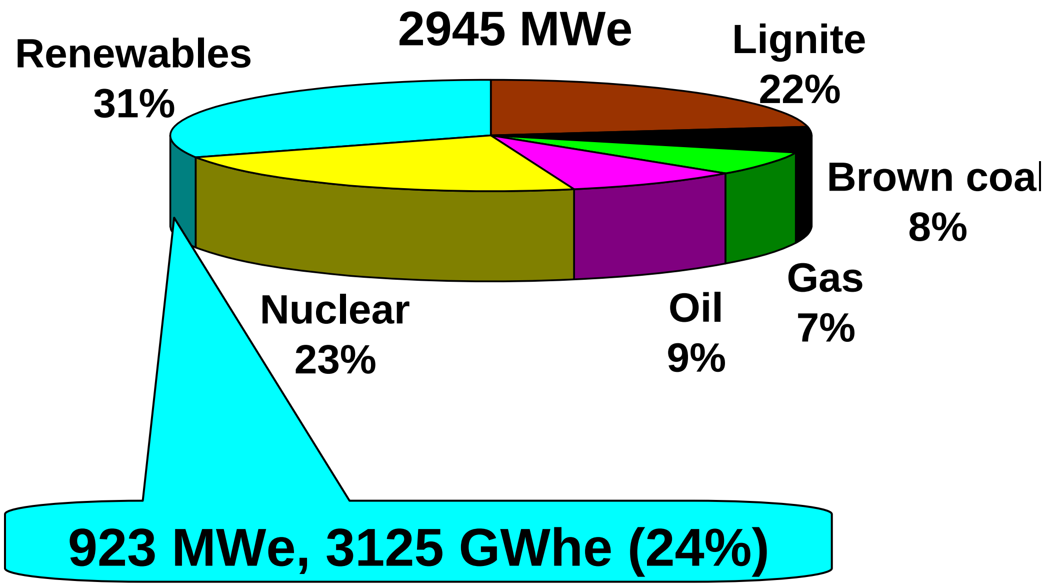
TOTAL Installed el. gener. capacity: ~ 3000 MW_e

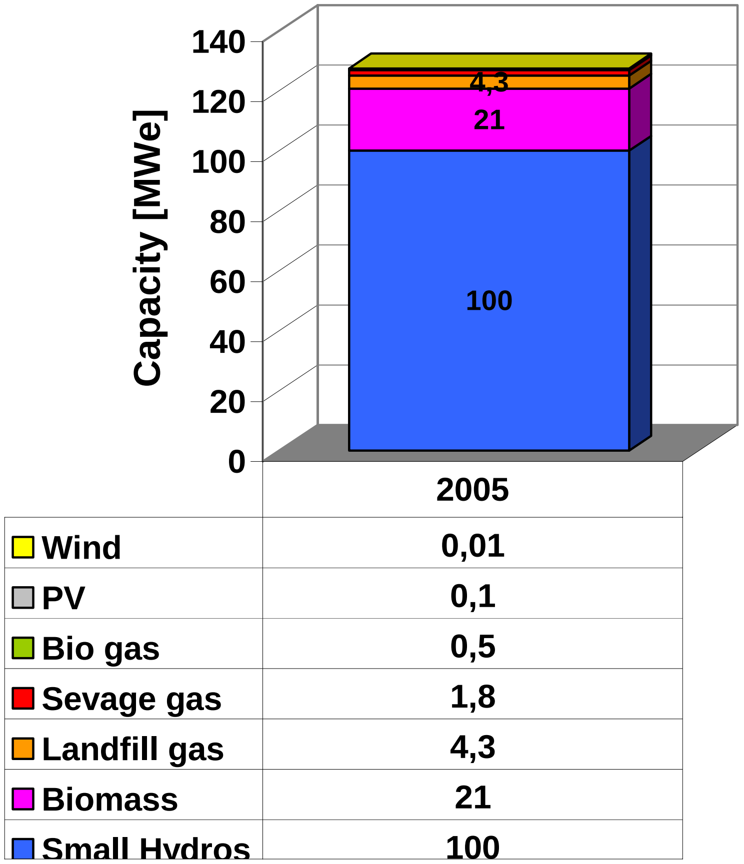
(50% of NPP owned by Croatia)

Installed capacity (<10 MW):

~ 127 MW_e

470 GWh (4%)





	2005
🟨 Wind	0,01
⬜ PV	0,1
🟩 Bio gas	0,5
🟥 Sevage gas	1,8
🟧 Landfill gas	4,3
🟪 Biomass	21
🟦 Small Hydros	100

SLOVENIA

Legal Framework for RES installations

- **Energy Act (1999, 2004)**
- **Status of “Qualified electricity producers” (QP):**
  - with above-average efficiency CHP (Yearly efficiency ≥ 78%)
  - **use of renewable energy sources (RES)**
  - **in a manner consistent with the protection of the environment**
- **Network system operators:**
  - responsible for the purchase of all electricity offered by QP at the price determined by the Government
  - obliged to conclude **long-term (10 years) feed-in contracts**.
  - payment of a premium for the independent el. sales of QP
  - all costs covered by the price for the use of networks.
- **Ministry for the Economy - responsible for QP policy:**
  - requirements for QP, setting and updating of feed in tariffs

Feed-in Tariffs (FIT) for QP

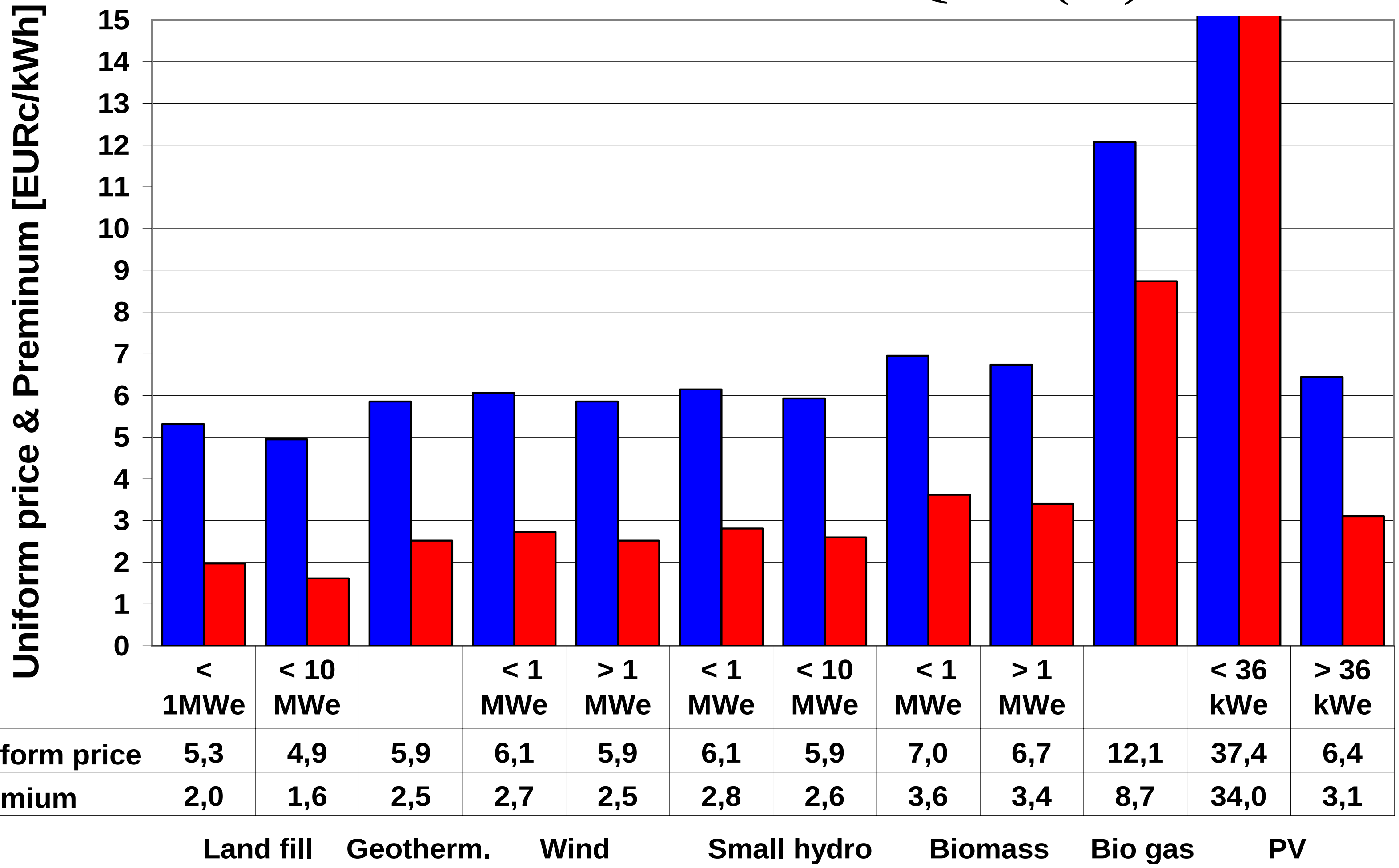
Market price
33 €/MWh

Premium

Feed in tariffs

- **Uniform price** or **binom tariff** (day/night, seasons)
- **<u>Premium</u> –** varied by technology and primary source:
    - **100%** for independent electricity sell
    - **30%** for own electricity use (without use of public network)
- **Reduction of FIT:**
    - **-5%** on transmission net., after 5 years, for each 10% invest. subsidy
    - **-10%** after 10 years of operation
- **Micro QP (<36kW)** – household tariff (two way counters)
- **FIT renewed once per year** (inflation)

Feed-in Tariffs for QP (2)



	< 1MWe	< 10 MWe		< 1 MWe	> 1 MWe	< 1 MWe	< 10 MWe	< 1 MWe	> 1 MWe		< 36 kWe	> 36 kWe
🟦 Uniform price	5,3	4,9	5,9	6,1	5,9	6,1	5,9	7,0	6,7	12,1	37,4	6,4
🟥 Premium	2,0	1,6	2,5	2,7	2,5	2,8	2,6	3,6	3,4	8,7	34,0	3,1
	Land fill		Geotherm.	Wind		Small hydro		Biomass		Bio gas	PV	

Subsidies and network costs

- **Subsidies and financing:**
  - **restricted investment subsidies:**
    - biomass, biogas, heat pumps and remote PV installations (yearly tenders).
  - **financing (up to 50%) feasibility studies and project documentation**
  - **Soft loans** (Environmental found of the RS)
- **Minimum costs of network prices for use of electricity from QP up to 1 MWe:**
  - **Consumers (even households eligible customers before 1.7.2007) pay the price for use of network reduced by:**
    - the network charge for the use of transmission network
    - supplement for preferential dispatch *(QP + Dom. coal protection)*

Certification

- **<u>RECS certification system:</u>**

RECS
Renewable Energy
Certificate System

  - Agency of energy (regulator) – designated certifier
  - **Holding Slovenske elektrarne – main trader**

- **<u>Guarantees of origin (2003/54/EC)</u>**
  - Decree drafted
  - Agency of energy (regulator) – issuing body

Green electricity market

EKOWATT

Modra energija
Obnovljivi viri sedanjosti in prihodnosti

ZELENA ENERGIJA

- **Private supply company created by owners of small hydro PP**
  - Small commercial customers and HH
  - **Huge problems with energy balancing !**
- **Holding Slovenske elektrarne**
  - ***Large hydro PP production***
  - All eligible customers (industry, services)
  - *Price supplement:* ***4 EUR/MWh***
  - ***2005: ~ 600 contracts, 25 GWh***
- **Distribution company Ljubljana**
  - **Own small hydro PP production**
  - Households
  - Very limited response (50 contracts)
  - Recent decrease of price (*price supplement:* **4 EUR/MWh)**

Modra energija
Obnovljivi viri sedanjosti in prihodnosti

Modra energija

- 2005: RES-E Market in Slovenia starts
  - Stimulation of RES-E development
  - Formation of the RES-E market
  - Sales of RES-E in Slovenia.
- Product : Modra Energija (Blue/Wise energy)
  - Registered Brand
  - Based on RECS certificates
  - HPPs involved – Renewable Energy Declaration.
- The price of ME: 1 SIT/kWh
  - Fixed surcharge to end-consumer electricity price
- Individual buyer can purchase
  - between 10 and 100 % share of ME

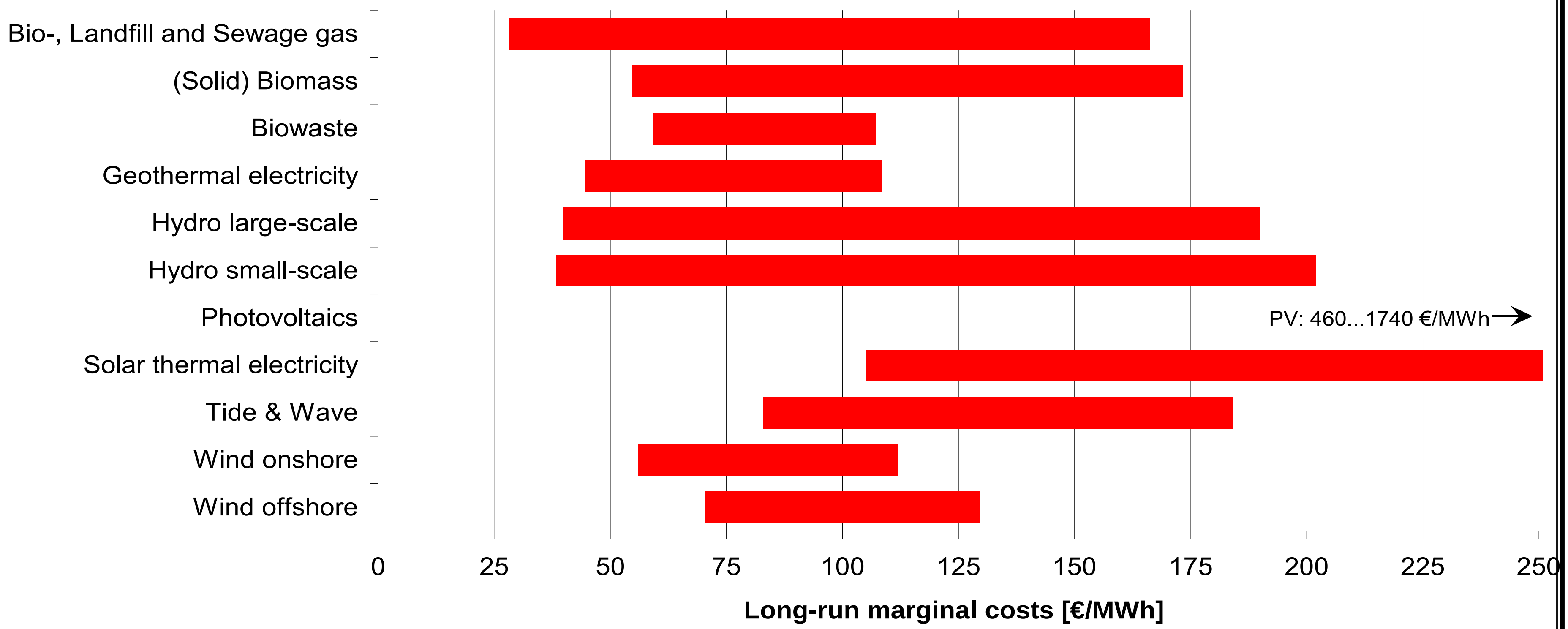
Modra energija
Obnovljivi viri sedanjosti in prihodnosti

Modra energija

- Modri sklad (*Blue Fund*)
  - Collects 60 % of the ME income
    - Financing of the projects that stimulate RES-E production
    - Development and reconstruction of RES-E production units
    - Research of RES.
- Consumers of ME – benefits
  - Listed on a dedicated web site of Modra energija
  - Improved visibility - high environmental awareness
  - Official certificate/diploma:
    - Lists the purchased quantity of RES-E in the calendar year.
  - Use of a special label in marketing of products and services.
- Sales of Modra energija
  - January 2005: sales begin
  - July 2005 : more than 720 companies, individuals on board
- RES-E Market in Slovenia: expected to grow

Napaja nas
Modra energija

Different Costs of RES-E in EU-15 (2003)

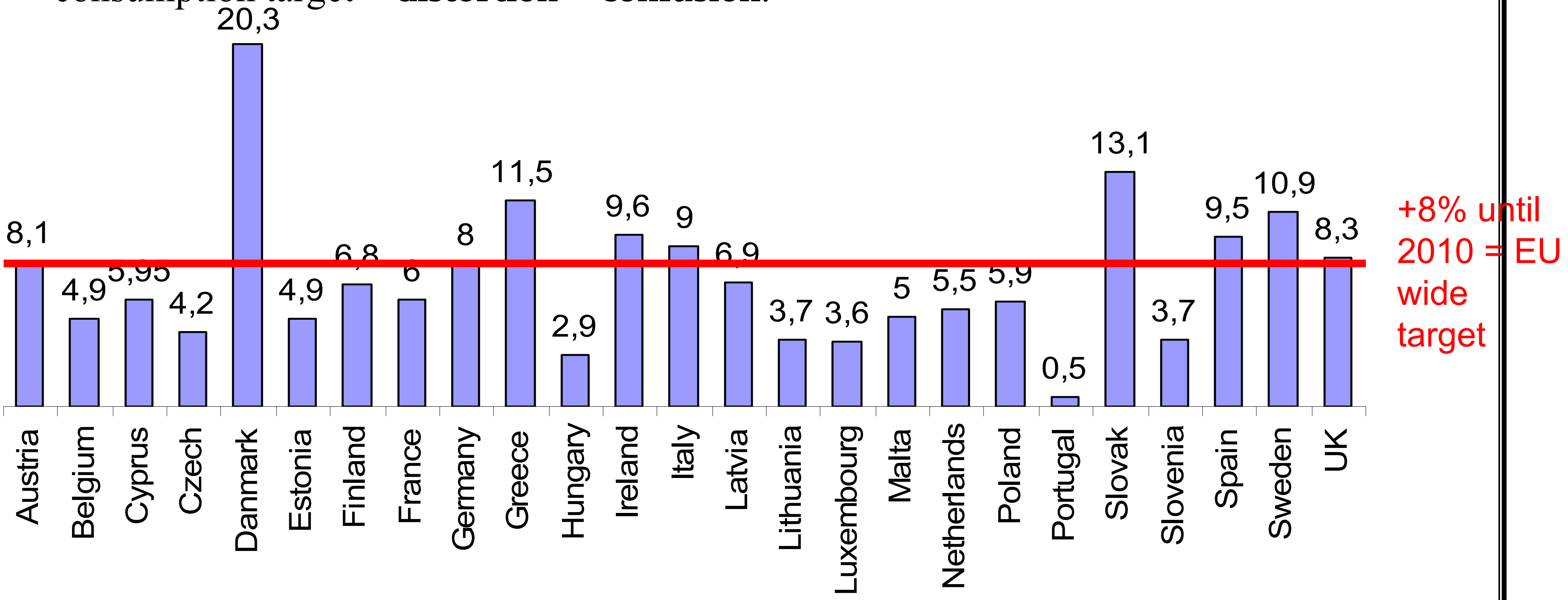


Support systems need to be harmonized!!!

- Green electricity support in Europe effects market distortions and cost-ineffectiveness
- Main problem: **no harmonised support system**
- A harmonised support system should fulfil the following standards:
  - reflecting the existing potentials of different energy sources within Europe,
  - enhancing competition between generators,
  - encouraging renewable electricity suppliers to improve operation performance and technological efficiency,
  - offering objective information to end consumers,
  - including additional costs and making them transparent and
  - introducing market based mechanisms.

Indicative targets of the RES$_E$ Directive

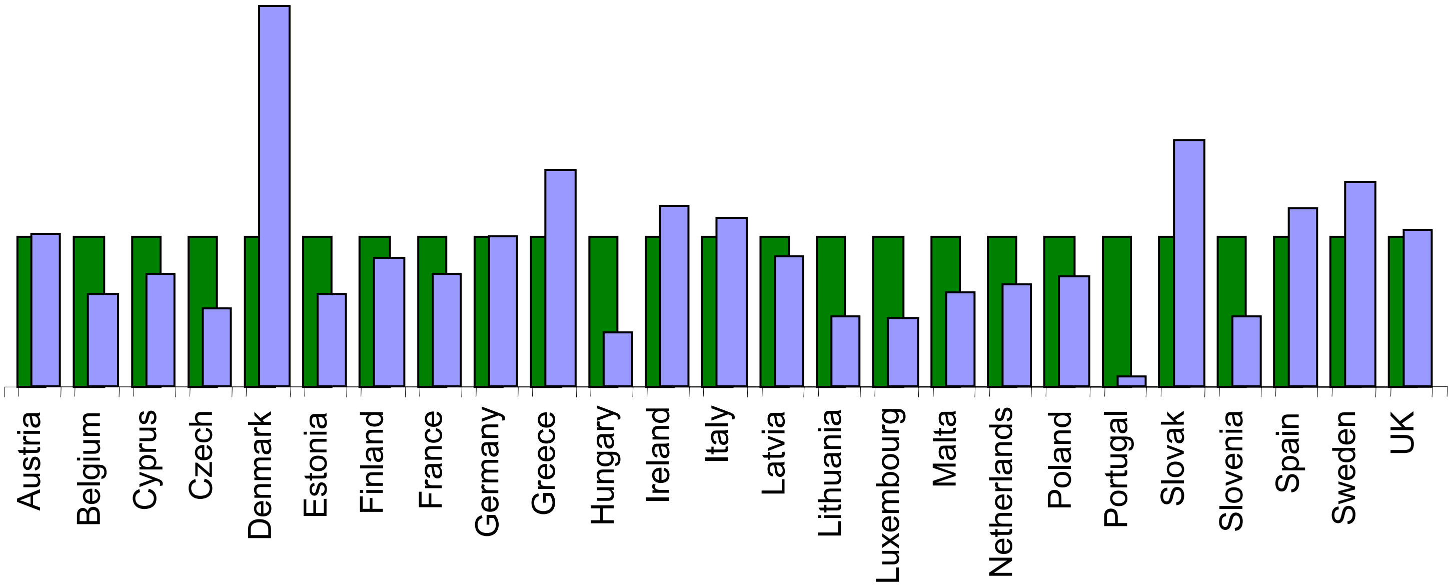
- Different indicative targets lead to an unbalanced burden sharing within the different Member States and the targets are designed as a production target but meant as a consumption target = **distortion + confusion**.



Increase of RES-E production from 1997 to 2010 in %

Possible solution: Pan-European certificate system

- Change from different national to an overall target
- Every end consumer within the geographical scope of the Internal Electricity Market has the same additional obligatory target
- Penalties need to be equal
- Penalties have to be paid into one single fund



Main barriers to the development of RES

- **Active or only declarative support** (whole energy sector)?
  - Acceptance of distributed generation?
- **Insufficient FIT for some technologies** (biomass, PV, micro units, etc)
  - expensive imported technologies – wider benefits to the economy?
- **Consistent and transparent spatial planning**
  - clear definition of potential investment area (exclusion of national parks, intact areas) to avoid conflicts of interests and speed up procedures.
- **Low electricity prices** (households, market uncertainty)
- **Bad project preparation:**
  - big environmental effects and low whole economy effects of RES projects
  - bad public communication – strong opposition (NGO, etc.)

Conflicts between targets of different EU Directives

KYOTO PROTOCOL

Same target, but no coordinated measures

IEM Directive

Emissions Trading Directive

(potential)

Market distortions

Linking Directive

RES-E Directive

Competing targets

CHP Directive

Security of Supply (Proposal)

Water Framework Directive

LCP Directive

IPPC Directive

Competing targets

CONCLUSIONS

- RES-E Market in Europe is quickly developing
- RES-E without incentives is not competitive on market
- 2 major support schemes
- Harmonization of EU RES market

References

- Balkan Power Conference 2005, International RES Seminar, 14.-16.9.2005, Sofia, Bulgaria
  - *"Current Experience with Renewable Support Schemes in Europe"*, D. Preinstorfer, E-control, Austria
  - *"Evaluation of Renewable Elecricity Policy in Slovenia"*, S. Merše, "Jožef Stefan" Institute, Slovenia
  - *"Renewable Markets and Green Certificates"*, Dr. A. Gubina, Universit of Ljubljana, Slovenia

Thank you for your attention!

SMALL HYDRO POWER PLANTS

Balkan Power Summer School

Aleksandra Krkoleva

What do small hydro systems provide?

- Electricity for:
  - Central-grids
  - Isolated-grids
  - Remote power supplies

…*but also*…

  - Reliability
  - Very low operating costs
  - Reduced exposure to energy price volatility

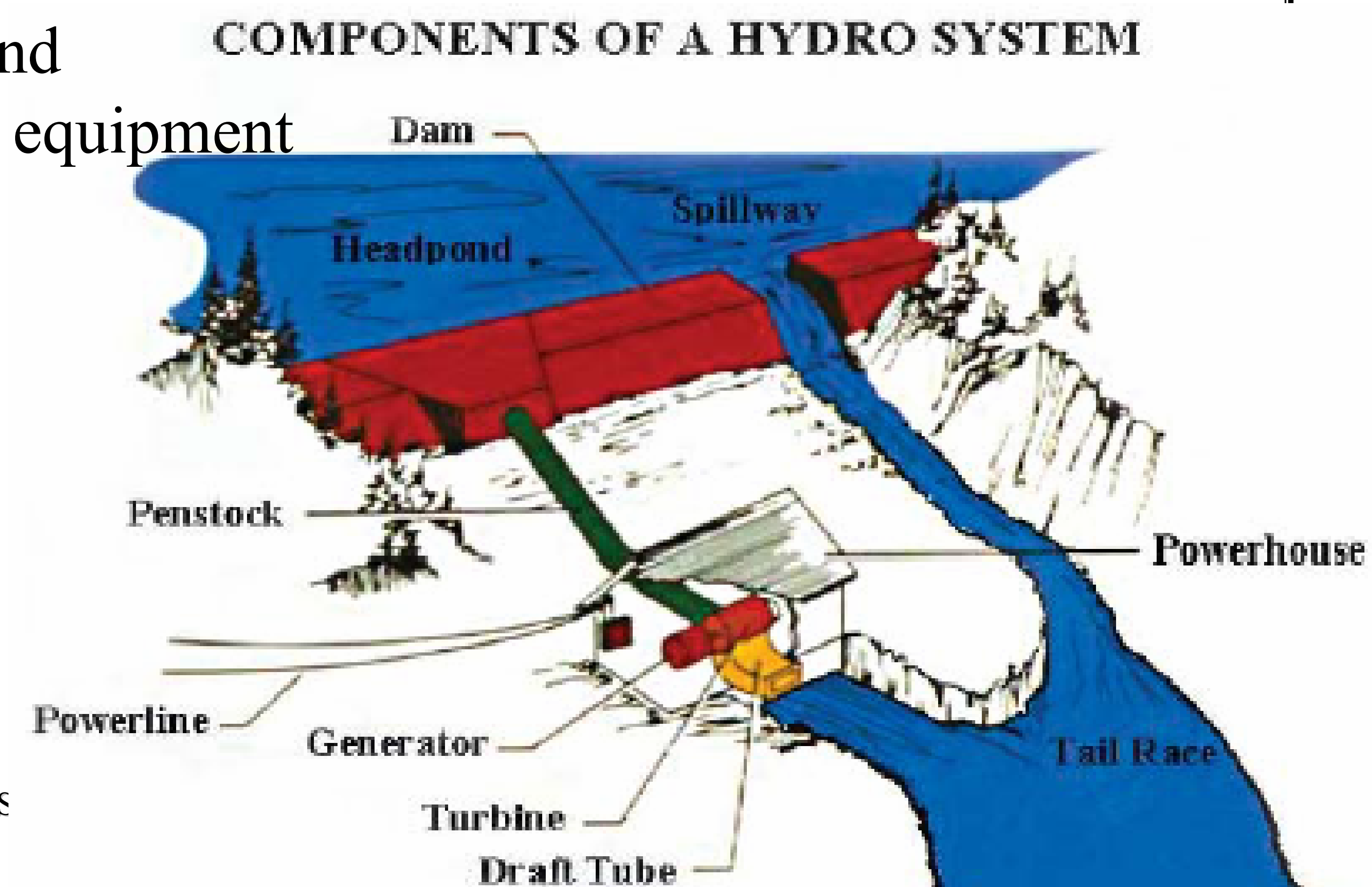
Small hydro

- No universally accepted definition

	Typical power
Small	1 to 50 MW
Mini	100 to 1000 kW
Micro	< 100 kW

Description of small hydro power plants (1)

- Civil works
- Electrical and mechanical equipment

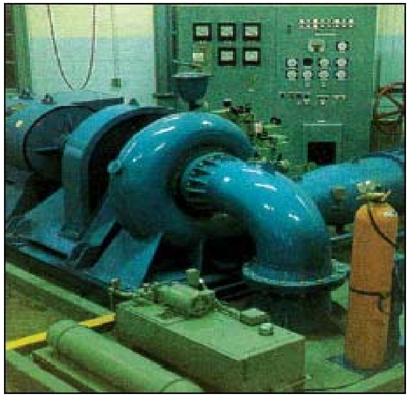


Description of small hydro power plants (2)

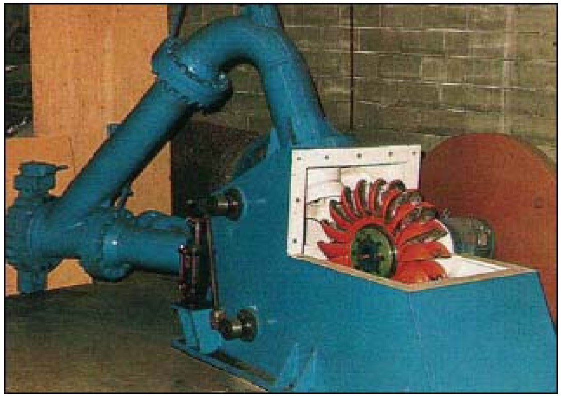
- Civil works typically account 60% of initial costs
  - – dam or diversion weir
  - – intake
    - trashracks, gate and entrance
  - – canal, tunnel and/or penstock
  - – entrance and exit of the turbine
    - valves and gates
  - – tailrace

Description of small hydro power plants (3)

- Electrical and mechanical equipment
  - Turbines-scaled down versions of turbines used in conventional HPP
    - Possible efficiency of 90%
    - Francis, fixed pitch propeler,Kaplan-for low to medium head applications
    - Pelton, Turgo, crossflow-for high head applications



Small Hydro power house
containing Francis turbine



Pelton turbine

Description of small hydro power plants (4)

- Generators
  - Synchronous
    - Can be operated in isolation
    - Suitable for stand-alone small hydro applications
  - Induction
    - Normally operated in conjunction with other generators
    - Best suited for small HPP providing electricity to large existing grid
- Other electrical and mechanical equipment

Small hydro project development (1)

- Development of small hydro projects takes from 2 to 5 years to complete
- The technical and financial viability of each potential small hydro project are very *site specific*
- Types of small hydro projects
  - Run of river development
  - Water storage development

Small hydro project development (2)

- Run of river-uses only the available water of the natural flow of the river
- The power fluctuates with the stream flow
- Best suited to provide energy for larger electricity system
- Can supply isolated area only if the minimum flow of the river is enough to meet peak requirements

Small hydro project development (3)

- Water storage system-store water in one or more reservoirs to provide power on demand
- Financial viability- better for isolated areas where energy value is higher
- Storage is limited to small water volumes
- Pumped storage systems

Environmental issues

- Small HPP can change:
  - Fish habitat
  - Site aesthetics
  - Recreational/navigational uses
- Impacts and environmental assessment requirements depend on site & type of project
  - Run-of-river at existing dam-relatively minor
  - Run-of-river at undeveloped site: dam/weir/diversion construction
  - Water storage developments: larger impacts that increase with scale of project

Hydro project engineering phases (1)

- Reconnaissance surveys and hydraulic studies:
  - map studies;
  - preliminary studies of flows and floods;
  - preliminary layout;
  - site visits;
  - costs estimates

Hydro project engineering phases (2)

- Pre-feasibility study:
  - site maping and geological investigations
  - preliminary layout based on materials known to be available;
  - preliminary project characteristics (installed capacity, type of project etc.);
  - cost estimate based on quantities;
  - identification of environmental impacts

Hydro project engineering phases (3)

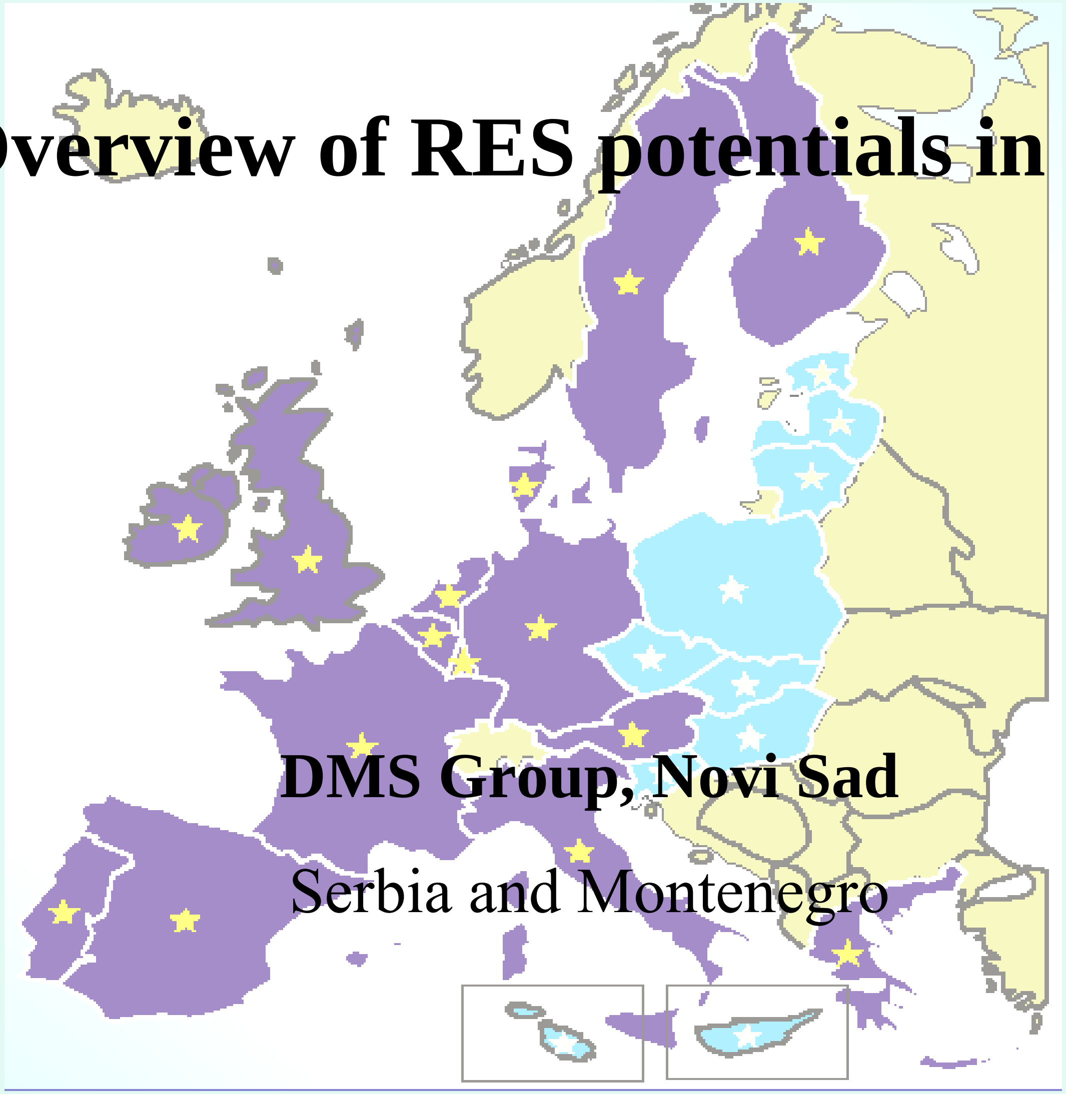
- Feasibility study:
  - major foundation investigation;
  - diversion estimation;
  - design and probable maximum floods;
  - determination of power potential for a range of dam heights and installed capacities for project optimisation;
  - design of all structures in sufficient detail;
  - determination of dewatering sequence and project schedule;
  - optimisation of project layout, water levels and components;
  - detailed cost estimate;
  - economic and financial evaluation of the project including assessment on the impact of existing electrical grid

Hydro project engineering phases (4)

- System planning and project engineering:
  - studies and final design of the transmission system;
  - integration of the transmission system;
  - integration of the project into the power network to determine precise operating mode;
  - tender drawings and specifications;
  - analysis of bids and detailed design of the project;
  - detailed design drawings and review of manufacturer’s equipment drawings

Thank you for the attention!

Overview of RES potentials in EU



Author(s):

DMS Group, Novi Sad

Serbia and Montenegro

Introduction

- Natural flows of renewable resources are immense in comparison with global energy use, this holds both from a theoretical and technical perspective
- However the level of their future use will primarily depend on the economic performance of technologies utilizing these flows
- analysis of renewable energy potentials performs detailed investigations in theoretical, physical, technological, environmental and economic aspects

Historical development of electricity generation from RES

- Electricity produced by renewable energy sources in the EU-15 countries amounted to 363 TWh in 2002, corresponding to a share of 13.4% of gross electricity consumption. The relevant figures for the EU-10 are 17.7 TWh and 5.6%, respectively.

- Wind energy is the RES-E source with the highest yearly growth rates of about 38% in electricity production over the last ten years. Especially in EU-15 countries, wind energy is predominant in recent portfolios of ‘new’ RES, whilst biomass is prominently represented in some of the new member states.

Methodology for the assessment of potentials

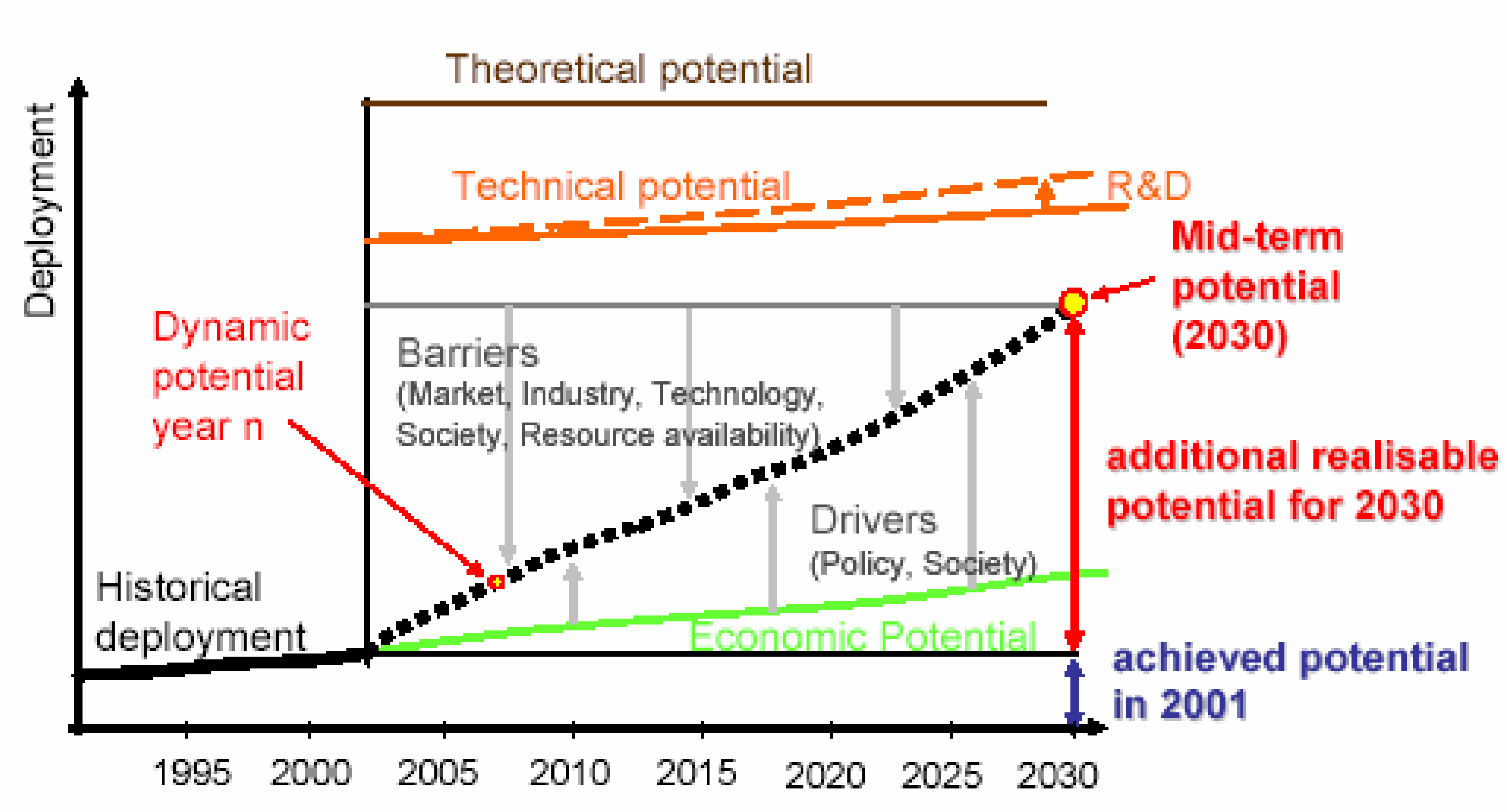
Definition of potential terms

Theoretical potential: general physical parameters have to be taken into account; the upper limit of what can be produced from a certain energy resource from a theoretical point-of-view, of course, based on current scientific knowledge;

Technical potential: technical boundary conditions are considered; dynamic context

Realizable potential: the maximal achievable potential assuming that all existing barriers can be overcome and all driving forces are active, general parameters are taken into account.

Mid-term potential: equal to the realizable potential in the year 2030.


Theoretical potential
Technical potential
R&D
Mid-term potential (2030)
Dynamic potential year n
Barriers
(Market, Industry, Technology, Society, Resource availability)
Drivers
(Policy, Society)
additional realisable potential for 2030
Economic Potential
Historical deployment
achieved potential in 2001
Deployment
1995
2000
2005
2010
2015
2020
2025
2030

More on approaches

- In most cases a ‘top-down’ approach seems suitable (e.g. for wind energy, photovoltaics)
- First step: the technical potential for one technology in one country for 2030 has to be derived by determining the total useable energy flow of a technology
- Second step: the midterm potential for the year 2030 is determined by taking into consideration the technical feasibility, social acceptance, planning aspects, growth rate of industry / market and market distortions
- The additional mid-term potential is determined by the mid-term potential minus existing penetration plus decommissioning of existing plants.

- For a few technologies, a ‘bottom-up’ approach would be the preferable option (e.g. for geothermal electricity), i.e. by looking at every single site (or band) where energy production seems possible and by considering various barriers and drivers in a dynamic context, the additional mid-term potential is derived. The accumulated value of each single band yields in the additional potential.

Photovoltaics

-Energy source characterized by a large potential, which can be realized from a technical point-of-view. The recommended approach for the assessment of the (additional) realizable mid-term potential is based on the following categorization of PV plant:

- PV on roofs (building integrated),
- PV on facades (building integration),
-PV on fields (no building integration).

Economic aspects are the main obstacles to tapping this potential.

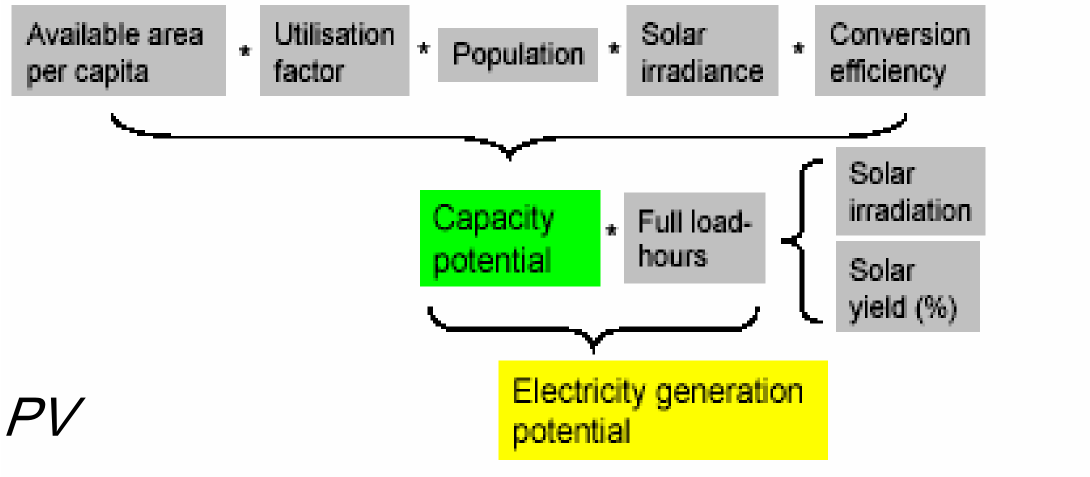
Annual Solar Energy Potential

Region	Minimum Exajoules	Maximum Exajoules
North America	181	7,410
Latin America and Caribbean	112	3,385
Western Europe	**25**	**914**
Central and Eastern Europe	**4**	**154**
Former Soviet Union	199	8,655
Middle East and North Africa	412	11,060
Sub-Saharan Africa	371	9,528
Pacific Asia	41	994
South Asia	38	1,339
Centrally planned Asia	115	4,135
Pacific OECD	72	2,263
TOTAL	**1,575**	**49,837**

Note: The minimum and maximum reflect different assumptions on annual clear sky irradiance, annual average sky clearance, and available land area.

1. Assessment of the *capacity potential*:

- *building integrated PV*



Available area per capita * Utilisation factor * Population * Solar irradiance * Conversion efficiency

Capacity potential * Full load-hours

Solar irradiation

Solar yield (%)

Electricity generation potential

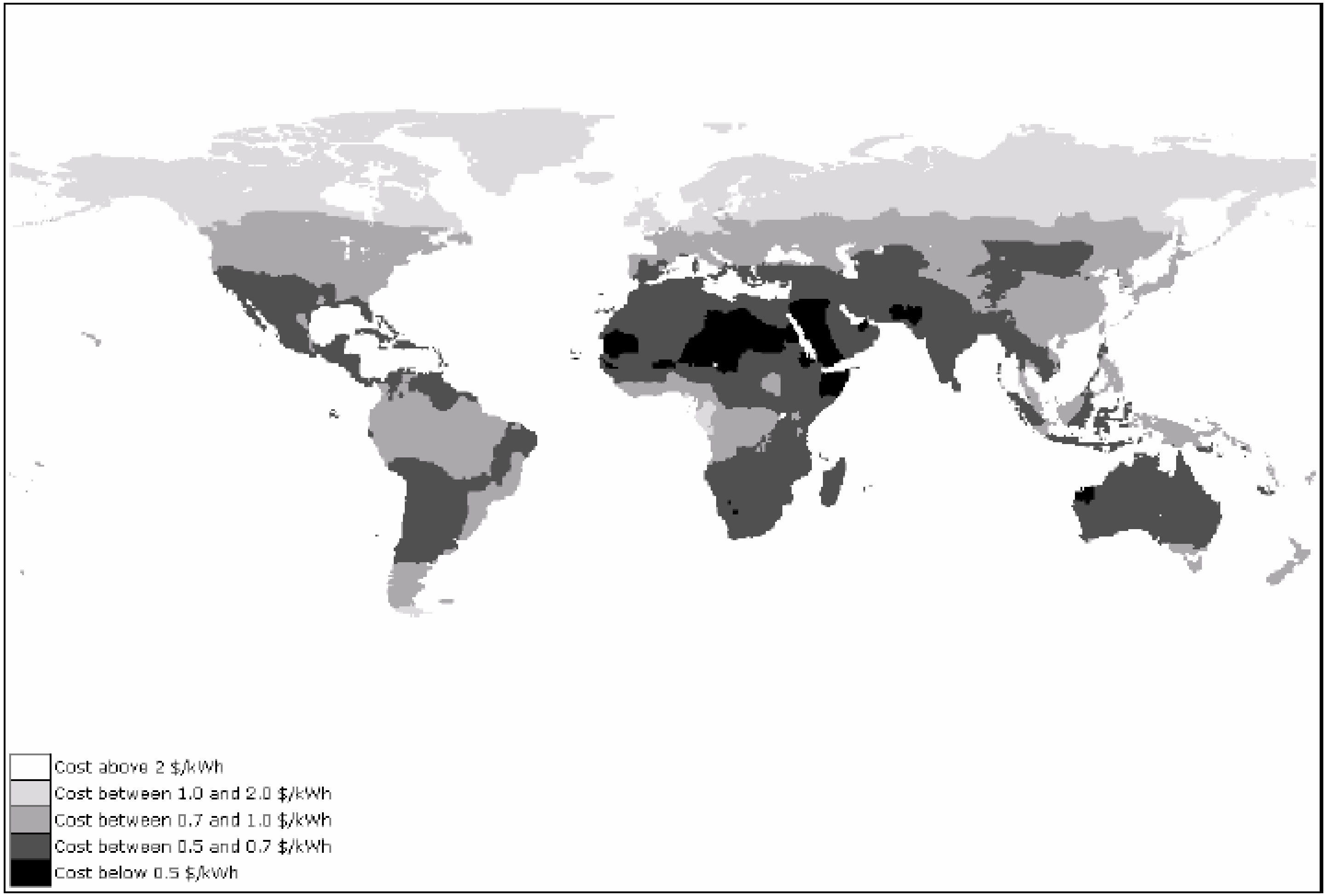
- *non-building integrated PV*

2. Total *primary energy potential =* equal to the electricity generation potential;

3. maximum achievable potential of electricity from PV is limited to 8% of expected gross electricity consumption in 2020

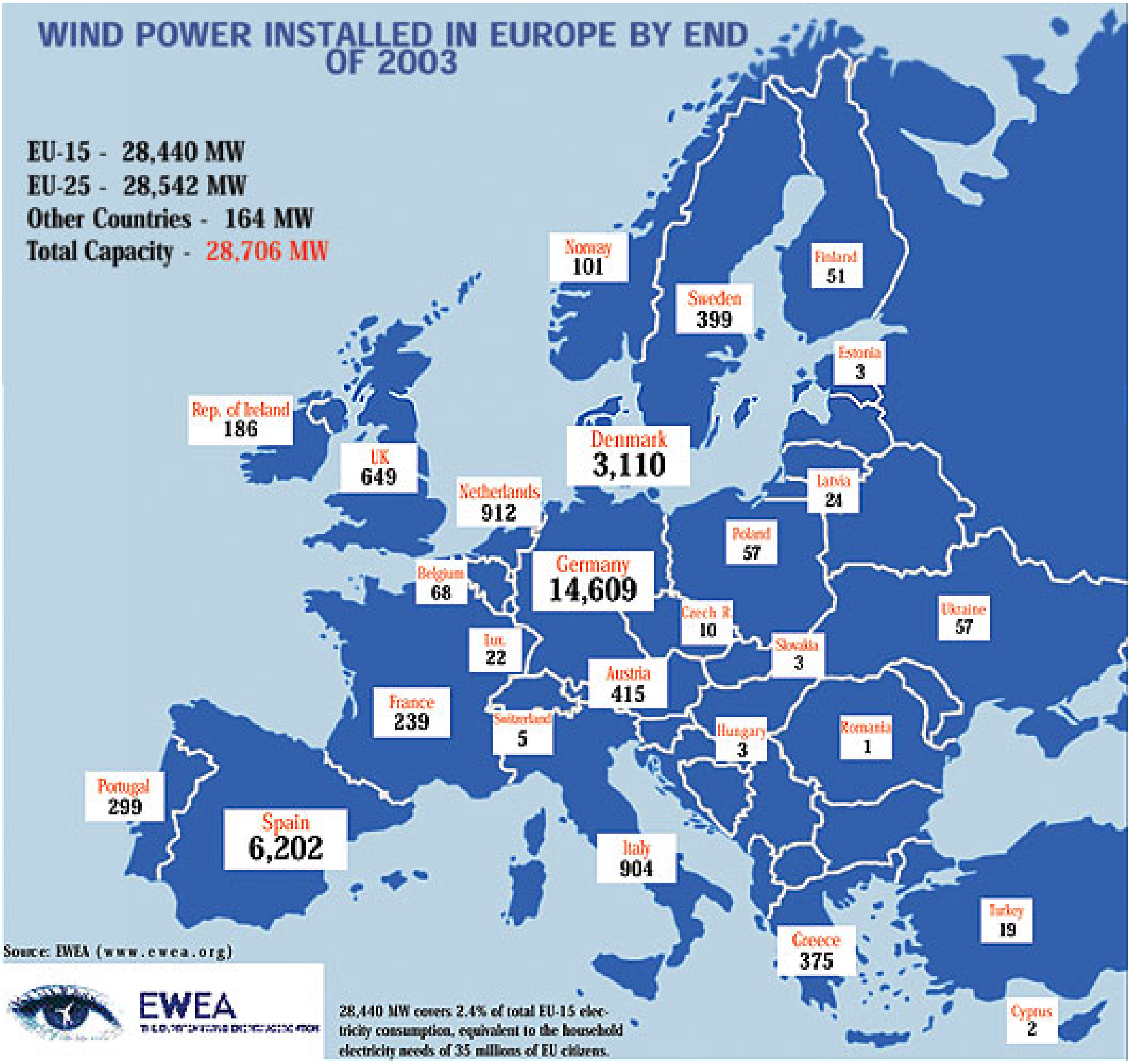
4. mid-term potential is calculated by subtraction of the already achieved potential

Geographical Distribution of Present Costs for Solar Electricity



Wind energy

- important factors include the percentage of land exposed to the wind resource and land-use and environmental restrictions
- amount of potential electricity that can be generated is dependent on several factors, including the spacing between wind turbines, the assumed efficiency of the machines, the turbine hub height, and the estimated energy losses
- electricity production from grid-connected wind turbines has been growing at an impressive rate of about 30 percent per year
- gradual growth in the unit size of commercial machines, from 30 kilowatts of generating capacity in the 1970s (rotor diameter 10 meters) to 5 megawatts (110 to 120 meters diameter) and more at present



WIND POWER INSTALLED IN EUROPE BY END OF 2003

EU-15 - 28,440 MW
EU-25 - 28,542 MW
Other Countries - 164 MW
Total Capacity - 28,706 MW

Source: EWEA (www.ewea.org)

28,440 MW covers 2.4% of total EU-15 electricity consumption, equivalent to the household electricity needs of 35 millions of EU citizens.

Wind offshore:

- overall technical potential for offshore wind energy seems to be huge in parts of Europe, especially in the North Sea
- realizable potentials: keeping in mind important ‘constrain indicators’ like e.g. ‘percentage of wind power on total electricity consumption’, ‘wind power (capacity) potential per capita’
- economic data: Area classes

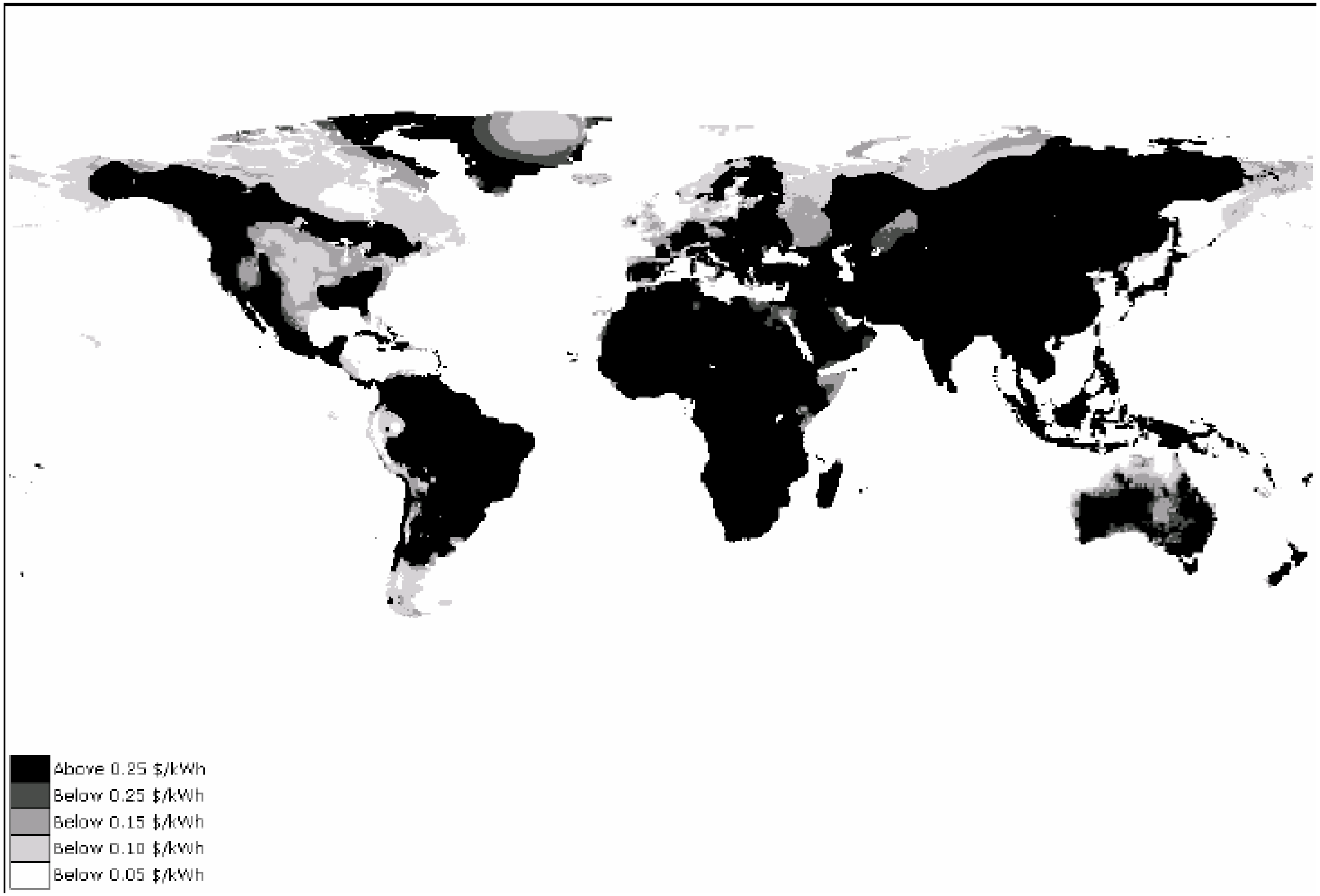
Wind onshore:

- technical potential for on-shore wind energy is high in various EU countries, namely France, UK – but several barriers have to be overcome, e.g. public acceptance, power grid constraints

- realizable potential: wind maps can be applied to the define areas characterized by certain ‘wind characteristics’

- electricity potential: calculations are based by appliance of a power curve for a common on-site turbine in size of 2 MW

Geographical Distribution of Present Costs for Wind Electricity



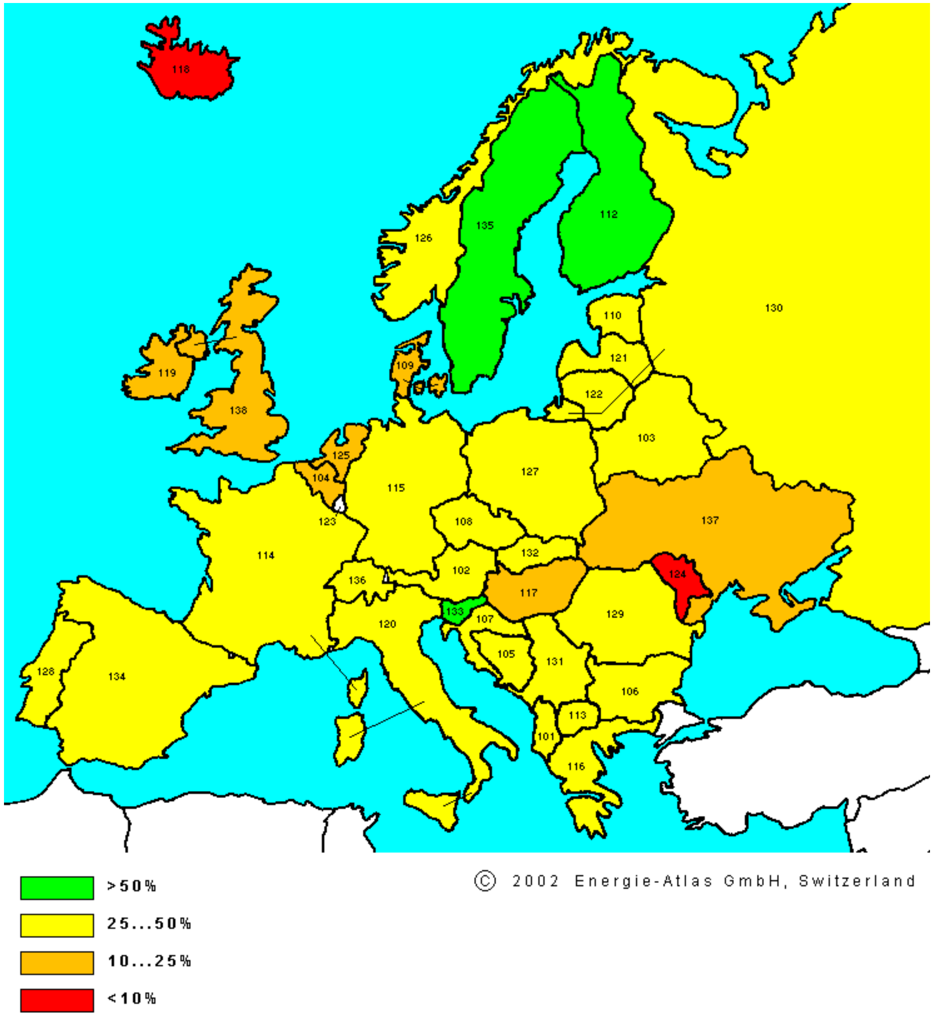
Biomass

•The present biomass contribution to the total world energy needs approaches 14 % (50 EJ/y on a total contribution of 406 EJ/y) and is essentially based on agro-forestry residues and natural forest

•An issue of availability but sustainable management, conversion, and delivery to the market in the form of modern and affordable energy services

- Gaseous Biomass: Biogas, Landfill gas, Sewage gas
- Solid biomass: Forestry products, Agricultural products, residues
- Benefit: storage
- Key technical challenges to be overcome in order for bio based industrial products to be cost-competitive are finding new technology and reducing the cost of technology for converting biomass into desired bio based industrial products

Productive forest area in relation to the total area of the country



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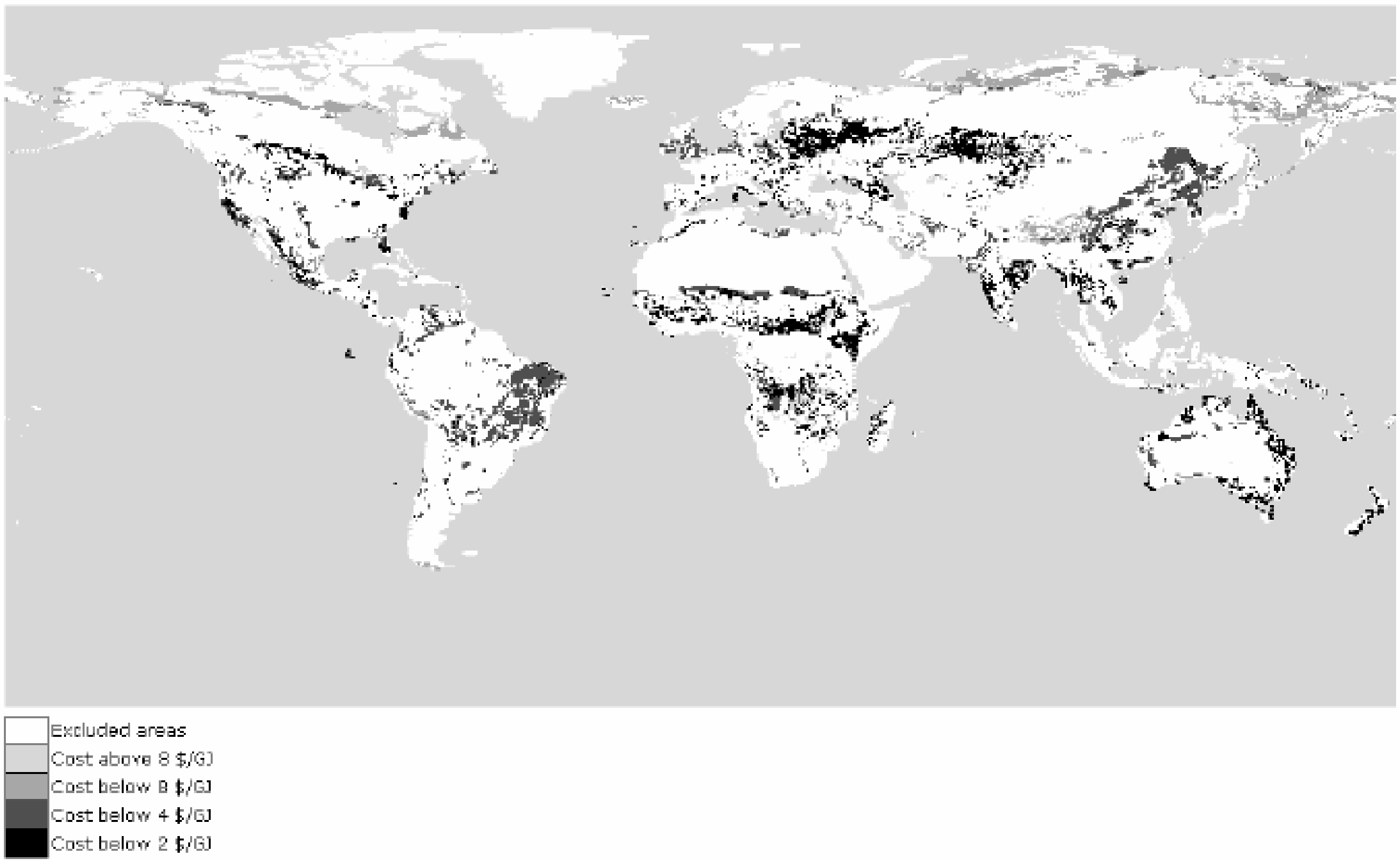
Geographical Distribution of Present Costs for Biomass Energy



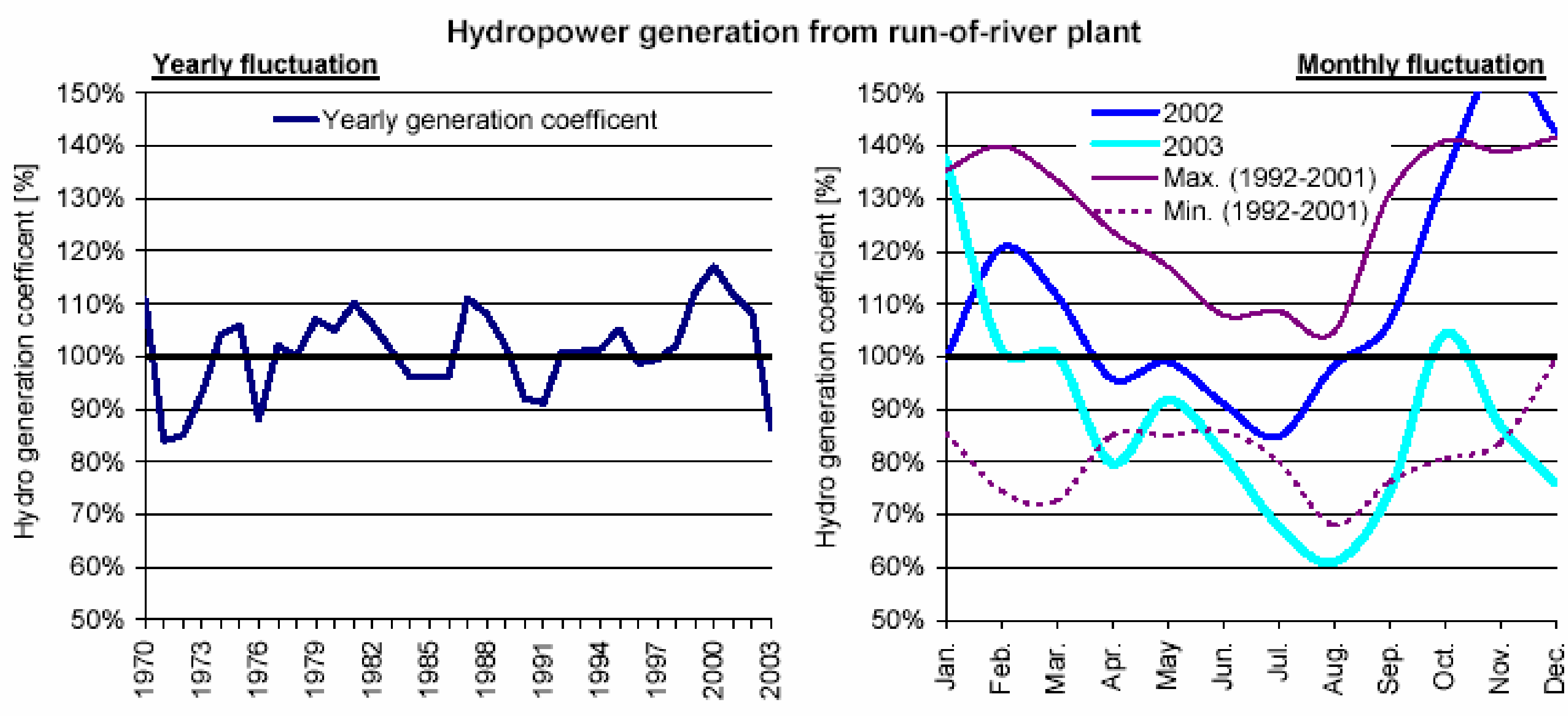
Hydropower

- mature technology: small-scale hydropower can expect further technical development
- requires detailed information on the local and geographical factors of runoff water: available head, flow volume per unit of time
- the most important impacts are the displacement of local communities, changes in fish amount and fish biodiversity, sedimentation, biodiversity perturbation, water quality standards, human health deterioration, and downstream impacts
- distinguish between the potential for new plant and the potential for upgrading or refurbishment of existing plant
- Large scale vs. small scale hydropower

The estimated hydropower potential and exploitation in EU

Countries	**Economical Feasible Potential (GWh/a)**	**Production from Hydro Plants (GWh/a)**	**Exploitation Ratio (%)**
Selected 15 EU Countries of which	390.000	320.000	82
Austria	50.000	38.000	76
France	72.000	70.000	97
Germany	25.000	25.000	100
Italy	55.000	52.000	95
Spain	40.000	35.000	88
Sweden	85.000	68.000	80
Selected non-EU countries of which	480.000	250.000	52
Romania	30.000	16.000	53
Switzerland	36.000	34.000	94
Turkey	120.000	40.000	33

Source: IEA, Eurostat, Hydropower & Dams and own interpolation/computations



Annual (left-hand side) and monthly (right-hand side) volatility of electricity generation from run-of-river hydropower plant in Austria generation from run-of-river hydropower plant in Austria

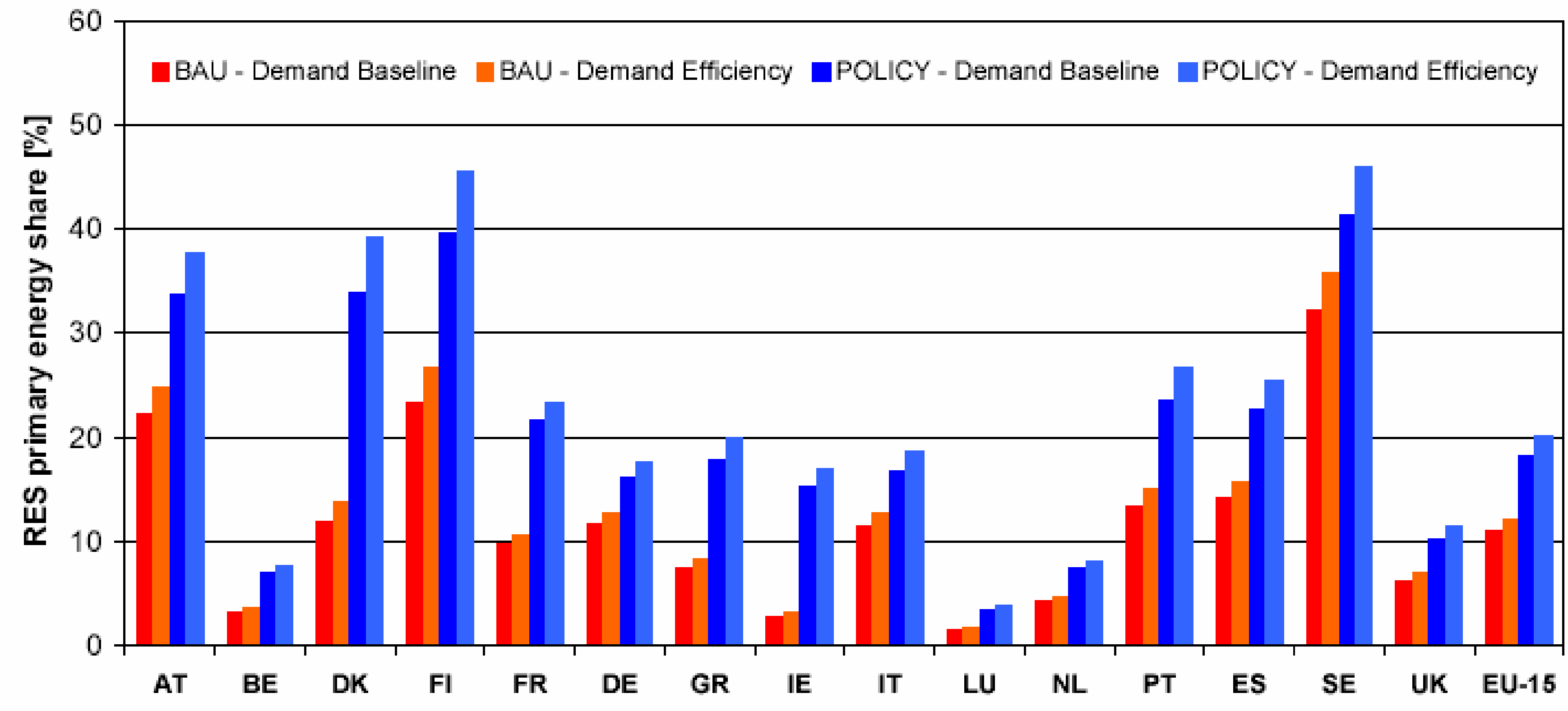
Energy: Total Primary Energy Supply

- Total Primary Energy Supply (TPES) measures the amount of primary energy demanded in an economy

- Expansion of the European Union added nearly 203 Million tonnes of oil equivalent (Mtoe) of energy demand:

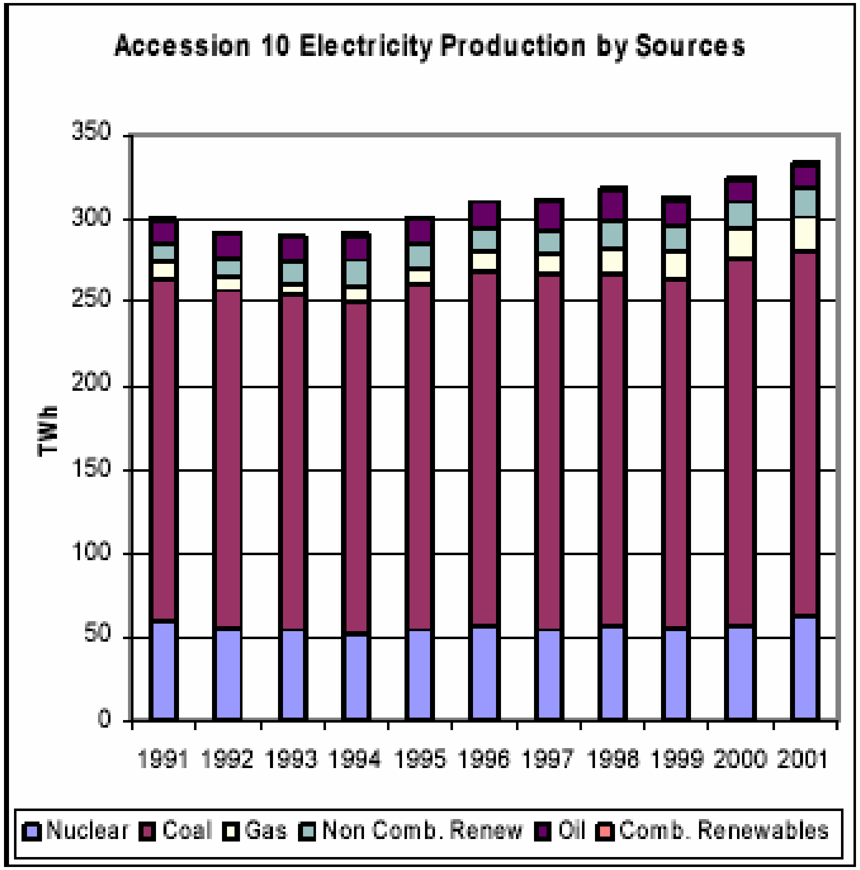
  Latvia, Lithuania and Estonia added over 17 Mtoe; Czech Republic, Hungary, Poland, Slovak Republic and Slovenia, added nearly 183 Mtoe; Cyprus and Malta added over 3 Mtoe.

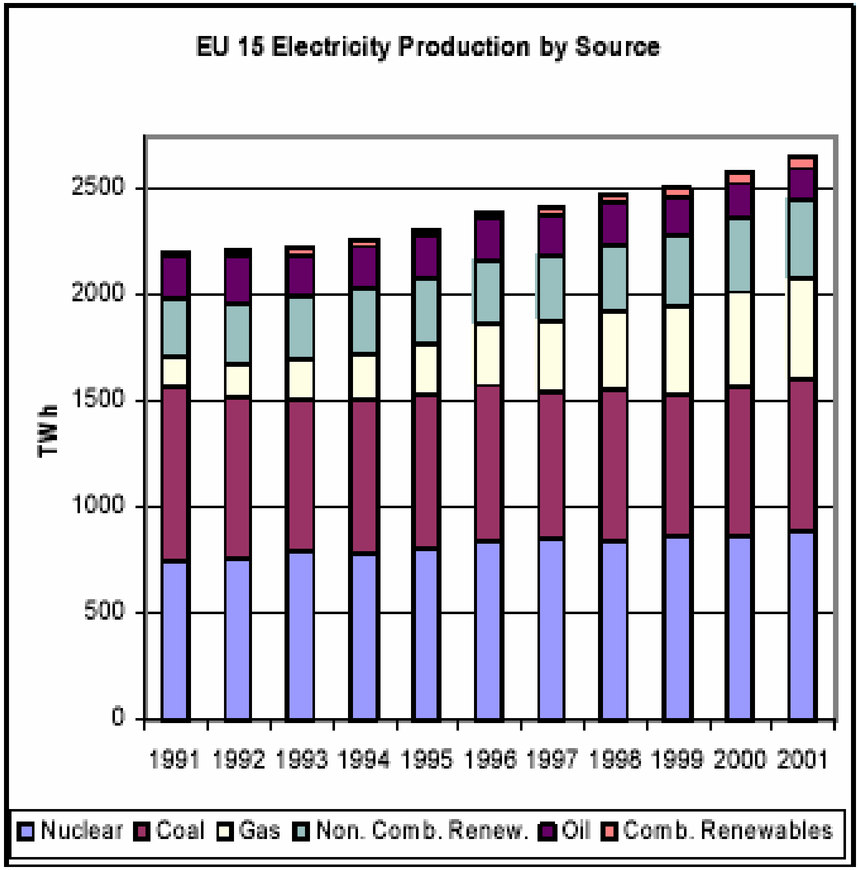
- The expansion to the European Union “25” raises EU TPES by 13.6%, from 1,495 Mtoe to over 1,981 Mtoe.



Share of RES primary energy in EU-15 member states in 2020

Electricity Production by Source





Comparison of Electricity Generation with Renewables:

In 2001, Accession 10 electricity generation with renewables reached nearly 18.5 tWh

•Electricity generation with renewables was 5.5% of total generation

• Renewables electricity generation is increasing at 4.4% annually since 1991.

•Only Latvia and Slovenia are currently over the EU 2010 target of 20%

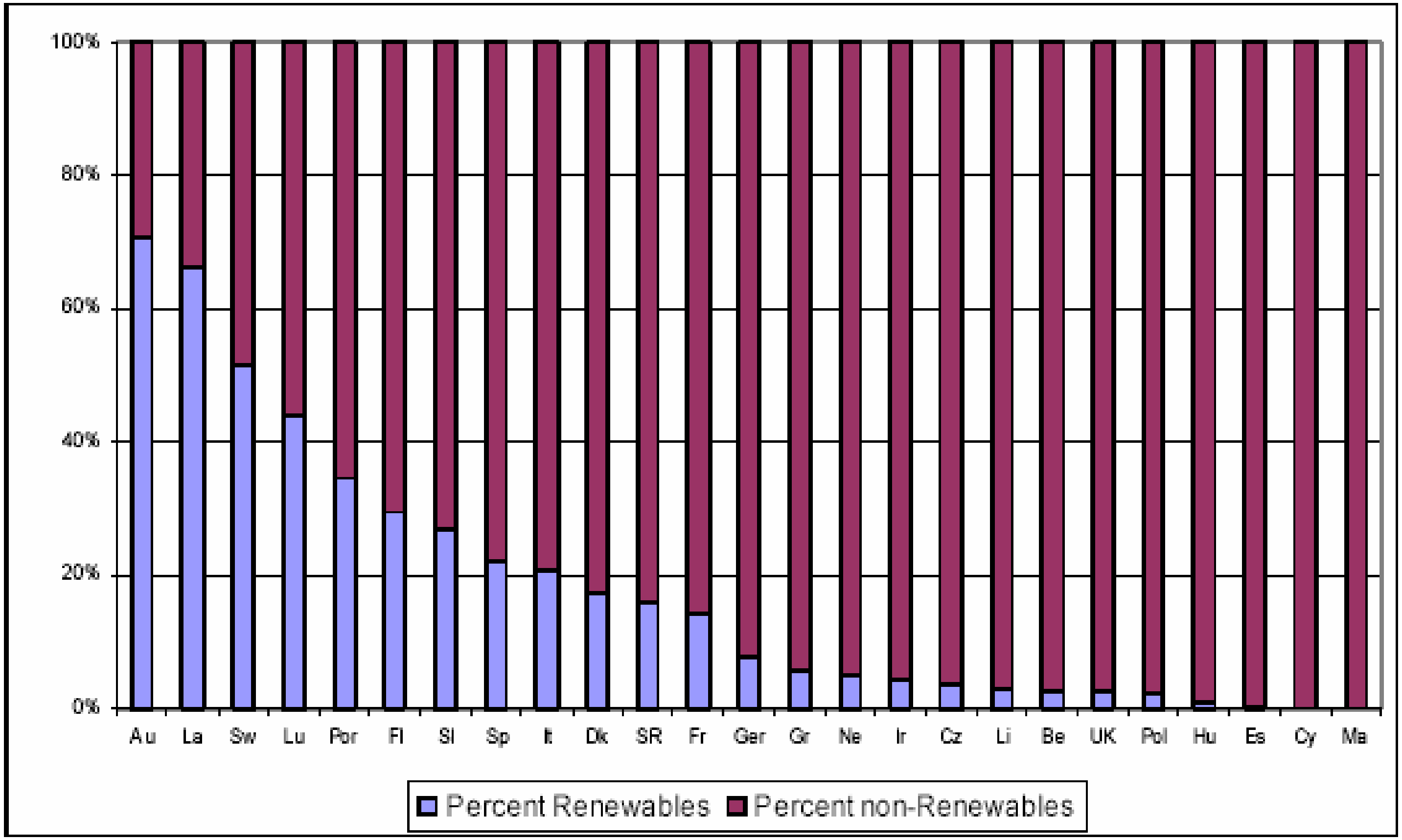
In 2001, EU 15 electricity generation with renewables was over 422.3 tWh

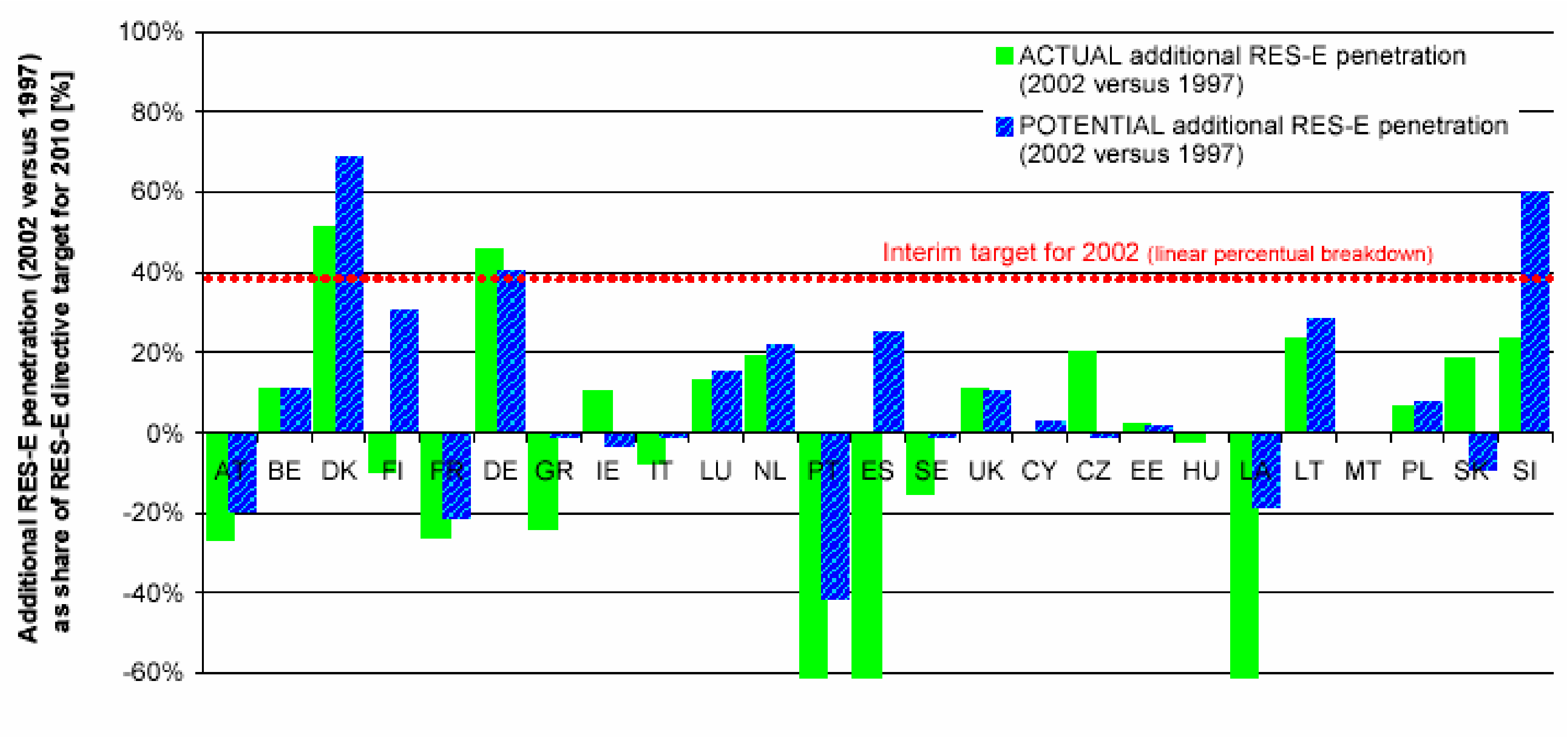
•Electricity generation with renewables was 15.9% of total generation

• Renewables electricity generation is increasing at 3.9% annually since 1991

•Austria, Sweden, Luxembourg, Portugal, Finland, Spain and Italy are currently over the EU target of 20%

Renewable Electricity Generation Targets





RES target achievement at country level: comparison of actual and potential additional RES-E penetration (2002 versus 1997)

Conclusions

- Renewable energy sources have the potential to make a large contribution to the sustainable energy future of the European Union. In particular they can help to reach the environmental goals of the EU - with regard to the commitments under the Kyoto Protocol - , increase the security of supply by mitigating the dependence on imported fuels
- Increase social welfare by creating new employment opportunities. Finally the development of renewable energy sources contributes to the goal of the Lisbon process to reach sustainable economic growth and to improve the competitiveness of the European Union on a global scale by creating lead markets for innovative technologies.
- The challenge of increasing the share of renewables in each sector of the energy system has been recognized by the European Union and translated into a comprehensive regulatory framework.
- The existing EU legislation needs to be adopted into national legal and policy measures of member states following the two main objectives of:
- the removal of economic barriers to the development of renewable energy sources by introducing financial support mechanisms and promotion schemes,
- the mitigation of non-economic barriers such as administrative barriers, market imperfections, technical obstacles and grid restrictions.