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From nearly-zero energy buildings to net-zero energy districts

Lessons learned from existing EU projects

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Executive summary

The transition of Europe's neighbourhoods to net-zero energy districts is underway.

The implementation of the EU 2020 energy and climate targets triggered the transformation of Europe's neighbourhoods to net-zero energy districts. Frontrunner municipalities have set ambitious targets to reduce their energy demand and to increase the share of their energy supply from local renewable energy sources. European municipalities set their energy targets in different ways and the timeline to meet the agreed target at a local level varies from one municipality to another.

Hvar, the remote Croatian Island, as well as the municipality of Val-de-Ruz, in Switzerland, have set a target to be self-sufficient. However, the former aims at meeting its self-sufficiency target to be 20% by 2020 while the latter aims to be totally self-sufficient by 2030. Similarly, the municipality of Helsingor in Denmark aims for carbon neutrality by 2050 while Cloughjordan in Ireland aimed at building an eco-village in a rural area. Other municipalities such as Salzburg in Austria developed a 2050 smart city roadmap while Valby in Denmark set a renewable energy target and the municipality of Zaragoza in Spain developed and implemented a holistic bioclimatic design at neighbourhood level.

The definition of the target and the timeline to achieve the agreed target influence the selection of measures and sectors to consider. Importantly, making buildings highly energy efficient is a common component in each of the 61 identified European projects. However, in order to meet their energy targets, less than 50% of the identified projects considered both the renovation of existing buildings and the construction of new buildings to low-energy consumption standards. Additionally, data on the achieved energy consumption and the supply from renewables in the use phase as well as investment data were identified only for seven projects.

Municipalities consider the energy transition of their neighbourhoods as an opportunity to address their local socio-economic concerns.

Municipalities positively regard the holistic transition of their neighbourhood to net-zero energy districts. Building consensus around ambitious energy targets is easier if the energy transition complements other local projects and contributes to addressing local and regional socio-economic concerns, as shown by the seven case studies analysed in this report. The self-sufficiency target of Hvar project, in Croatia, addresses the concern that remote islands have regarding their reliance upon mainland energy supply, as well as having to deal with waste treatment locally. Similarly, the Cernier project (Val-de-Ruz in Switzerland) was about demonstrating that municipalities can be energy independent. Furthermore, the central objective of Lehen district in Salzburg was sustainable urban renewal aiming at improving the quality of life of the whole community while Valby municipality in Denmark aimed at improving its image, attracting young residents and becoming a green district. Zaragoza in Spain, Cloughjordan in Ireland and Helsingor-Helsingborg in Denmark/Sweden aimed at being showcase examples and laboratories for new urban planning and building design. The approach undertaken by these three projects has been a win-win approach from energy, visibility and exemplarity perspectives. Each of them is regarded as a best practice area and attracts tourists and experts to learn about the modern state-of-the-art efficient building and renewable energy supply practices.

Public finance (EU and national) has been instrumental in unleashing the transition to net-zero districts.

Identified projects have all benefited from receiving public finance. The municipalities usually leverage EU Finance, in the form of grants and/or loans, with national and local funds including such from private investors. In the identified projects, public finance allowed for the ambition of energy requirements to be increased, testing new technologies, building technical capacity, raising awareness and ensuring citizens' engagement in the energy transition. In Helsingør and Hvar, public finance allowed city councils to develop an ESCO model. In Salzburg, public finance allowed stakeholders to develop a "high-quality agreement" which defines the energy concept as well as the role and responsibilities of each stakeholder. In Valby and Zaragoza, public finance allowed for the involvement of researchers from universities and for documentation of the projects to be written up, enabling others to have access to lessons learned from practice and to better understand users' behaviour. Similarly, the use of public finance in Cloughjordan unleashed the Irish energy performance certificate database while in Helsingor-Helsinborg project public finance allowed for testing of prefabricated building elements, which is now a new construction practice imported to Denmark from Estonia.

Energy transition of Europe's neighbourhoods has led to the emergence of new actors and to setting innovative governance structures.

An important feature of the seven districts analysed in this report is the emergence of new actors and the innovative governance structures set by municipalities to ensure all necessary actors are involved and their roles as well as their responsibilities are well and clearly defined. The involvement of actors varies from one municipality to another; whether the developers involve the entire population, local businesses and investors in the energy transition of their neighbourhoods differs from project to project. The Centre of Urban Sustainability (CUS) in Zaragoza acts as a permanent exhibition as well as an interpretation centre to educate and disseminate projects' results to a wide range of people. Trainings and interventions provided in schools and universities around Valby project have been essential elements contributing to the success of this project. Similarly, Salzburg pioneered the "high-quality agreement" to engage multiple stakeholders and to ensure their full participation in the governance of the project. Sustainable Projects Ireland, a local NGO, had the responsibility of developing the eco-village of Cloughjordan, while municipalities of Helsingor and Helsinborg created a whole community approach by providing training on energy sustainability for janitors and SMEs. Overall, the role of these new actors in the design and the implementation phase of the identified projects is indisputable. However, the levels of engagement of these new actors in the use phase of each project are difficult to assess. Monitoring the level of engagement of different actors after the implementation of energy measures is an area to explore by social science researchers.

Modern technologies make the transition to net-zero energy districts a reality.

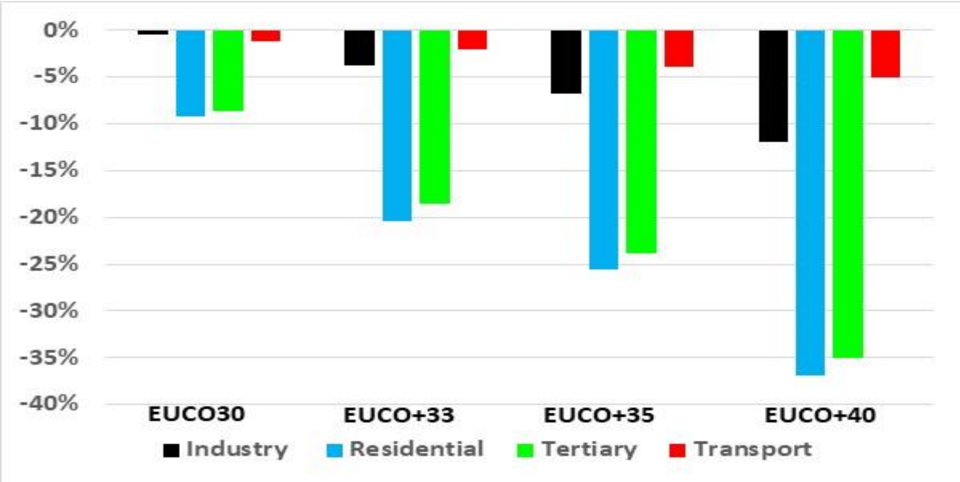
Modern technologies are pivotal in the energy transition. The use of modern technologies in the seven projects analysed in this report included i) the use of smart meters to monitor energy consumption, ii) the use of modern communication tools and social media platforms to raise awareness and to update stakeholders on the progress made in each project and in the case of the Danish example iii) the use of prefabricated building elements imported from Estonia to deliver on the high ambition of the project at an affordable cost. The latter is getting more attraction since Energiesprong project. In fact, the project used digitalisation technologies such as 3D-scanning and Building Information Models (BIM) to prefabricate off-site the buildings elements needed to renovate social housing, constructed in the sixties, to net-zero energy. Energiesprong was first implemented in the Netherlands and, more recently, EU funding allowed for the expansion of the practices to France and the United Kingdom (UK). The use of digitalisation technologies for renovation reduced on-site intervention to one week and helped deliver net-zero energy renovations. Furthermore, it is expected that scaling-up the use of digitalisation technologies in energy renovation would allow a sharp decrease of the cost of net-zero energy renovation making it affordable for all while improving the productivity of the construction industry. Moreover, the implementation of smart-meters, if well-combined with sensors, could be an opportunity for a better understanding of user's behaviour. Overall, modern technologies are expected to make the future of energy transition brighter.

Prologue

Introduction

The Clean Energy Package confirmed the pivotal role of buildings in meeting Europe's 2030 climate and energy targets. In fact, residential and tertiary buildings are expected to be the highest contributors to Europe's energy savings by 2030 (Figure 1). Grasping buildings' energy savings potential requires transforming Europe's building stock from being energy waster to being highly energy efficient and decarbonised as required by Article 2a of the 2018 recast of the Energy Performance of Buildings Directive (EPBD) [2].

Figure. 1. Projected savings potential in final energy consumption per sector in Europe by 2030



Key point: Buildings are expected to play a pivotal role in meeting the EU's energy targets and are the highest contributors to energy savings.

Source: PRIMES 2016 modelling results in [1].

Note: Energy savings potential is calculated as a difference between the final energy consumption in the baseline scenario which aims at 27% energy efficiency target in 2030 and in the scenarios with more ambitious 2030 energy efficiency targets (30%, 33%, 35% and 40%).

Improving energy efficiency and supplying with renewable energy sources both new and existing buildings are the two pillars of the decarbonisation of Europe's buildings. Literature suggests [3, 4] considering the neighbourhood or district scale to ensure this transformation will take place at the pace and with the level of quality needed to meet the Paris Agreement requirements [5].

The district approach allows considering energy interactions between each individual building and the broader energy system at local level. The system benefits and environmental gains from highly energy efficient buildings and local consumption of low carbon energy are currently being researched [6]. These issues have seen the concept of zero-energy districts gaining prominence in research and policy-making circles. However, studies on achieving zero energy target at the district level investigated decentralised scenarios for energy systems transition modelling [7], peer-to-peer energy trading analysis [8], or case-study analysis of city's Climate Action Plans [9]. Only few papers [3, 10, 11] focus on how buildings (new and existing ones) contribute to achieving the zero-energy target at the district level. This report aims at filling this gap by analysing the district approach to the renovation of existing buildings and the construction of new ones with the aim to achieve zero-energy at the neighbourhood level.

Methodology

The research has been carried out in stages. The first stage was to identify analytical frameworks in literature, allowing for analyses of a district approach to energy issues in the built environment. Peer-reviewed papers available on Science Direct and Google Scholar as well as grey reports, covering publications from 1992 to 2018 were reviewed. The keywords used for the selection of the papers included zero energy/zero carbon community, sustainable communities, urban/local energy governance, citizen engagement, local energy planning, local energy production and local energy transition. The analytical framework selected for the analysis identifies additional sustainability criteria used by local decision-makers and highlights the trade-offs considered between energy targets and other local sustainability priorities. A summary table of these criteria is provided in the following section.

The next step of the research was to browse the relevant European projects databases (Intelligent Energy Europe, CONCERTO, FP7, Covenant of Mayors) to identify case studies. In total, 61 initiatives aiming at reducing energy consumption and greenhouse gas emissions of the built environment at a local level were identified (Appendix). At this stage of research, a balance was kept between different geographical areas within Europe. However, most of the identified projects (almost 50%) are in western/continental Europe. Only a few cases (6) were identified in Eastern Europe, while sixteen cases from Northern Europe and ten from Southern Europe were found and investigated. The desk research has been complemented by information gathered at a workshop "From Nearly Zero Energy Buildings to Net Zero Energy Districts: Lessons learnt from existing projects" organised during the 2015 EUSEW.

The criterions for selecting the final seven case studies are described in this paragraph. Initially, projects were screened for clarity on energy achievements at the building level and the availability of monitored energy data for at least one year. The availability of investment data was another criterion considered for the selection of the case studies. Not all identified projects considered both the renovation of existing buildings and the construction of new ones at the same time, this was another important criterion in the selection process. The level of energy ambition varied from one project to another and played a role in guiding the final selection, based on the level of ambition. As, in fact, the 61 projects have a wide range of energy objectives, ranging from 10% energy savings target and 5% of local production of energy from renewable sources to more ambitious ones such as self-energy sufficiency and carbon neutrality targets (Appendix). At the end of this step, seven projects were considered for an in-depth analysis and 54 projects (Appendix) were eliminated from the in-depth analysis because they did not meet one of the criteria described above. A short description of each of the 54 projects as well as the reason for not considering them for the in-depth analysis is provided in the appendix. Finally, interviews were conducted with local actors involved in the seven case studies and our analysis were reviewed by selected local actors.

Analytical framework

Reducing energy consumption and greenhouse gas emissions are not the only drivers of existing zero-energy districts as illustrated by the variety of objectives and indicators considered by local actors (Table 1) to assess progress towards the agreed targets. In fact, zero-energy initiatives are driven either by urban renewal, the transformation of industrial and/or brown field areas into residential/mixed districts or the development of new settlements with strong sustainability outcomes for all residents [3, 10, 11].

The sustainability criteria considered by local actors (Table 1) are not equally targeted and/or assessed in all the existing zero-energy districts. However, their interactions with energy and greenhouse gas targets have been instrumental in the trade-offs decided by local authorities in achieving initial energy or carbon targets. The framework considered for the analysis of the seven selected case studies and the indicators identified contribute to framing climate mitigation pathways within the broader sustainability targets which are today grouped under the United Nations framework for the 2030 agenda for sustainable development [12].

Table. 1. Analytical framework for analysing zero-energy districts

Theme	Target	Objective	Indicator
Energy-water-waste nexus	Triple net zero (energy/carbon, water and waste)	Net zero energy/carbon	- Energy consumption and greenhouse gas emissions of the community
		Net zero waste	- % of waste recycled on-site and nearby - Quantity of waste produced per activity and per inhabitant
		Net zero water	- % of water re-used on site - Water consumption per activity and per inhabitant
Governance	Empowering local actors and citizens	Engagement of local actors and citizens	- % of inhabitants involved in the projects of the neighbourhood - % of citizens trained on environmental behaviour - % of citizens, environmental-friendly
Social equity	Functional and social mixing	-Affordability of the neighbourhood	- % of social housing - % of middle-class housing - % of privately-owned houses - % of population with support from the municipality to access cultural and sport activities
		Neighbourhood diversity	- % of m^2 of offices, % of m^2 of shops, % of m^2 dedicated to SMEs, % of m^2 for social, cultural and sport activities
		-Inter generational diversity	- % of each housing type (1 bedroom, 2, 3…)
Economic efficiency	Cost-effectiveness of the project	Contribution of the project to the local economy	- % of the project financed by the municipal budget - % of the project contribution to the municipal budget - Number of sustainable jobs created locally and % of unskilled ones
Conservation *(continued)*	Resource preservation	Reducing urban sprawl	- Number of inhabitants per m^2
		Ensuring the continuity of existing biodiversity and promoting new ones	- Ratio of green space (built areas/green areas) - Number of green spots - Number of species preserved - Number of new species - Water surface per capita

Theme	Target	Objective	Indicator
Conservation *(continued)*	Resource preservation	Efficient use of raw materials	- % of re-used (from demolition) construction material - % of recycled construction material - % of certified material for health and environmental purposes - Embedded energy of the construction material used (J/tonnes) - % of low-GHG emission construction material - Travelling distance of each group of construction material (km/construction material)
Quality of life	Environmental friendly quality of life	Reducing pollution	- % of main pollutants in the air
		Eco-friendly mobility	- Average distance from each building to the closest public transport stop (m) - Number of parking places per dwellings - Number of parking places per m^2 for tertiary buildings - Number of m^2 per dwellings and m^2 of tertiary buildings dedicated for bikes - Number of parking places dedicated to car-pooling - Bike lines, pedestrian areas, garages for bikes - Number of km travelled by each occupant/user of the neighbourhood by different transport types
		Winter and summer thermal comfort	- Number of hours per year where the inside temperature is higher (summer) or lower (winter) than set point temperatures
		Digitalisation	- Number of inhabitants with internet access - Public access to internet
		Eliminating insecurity	- Number of complaints per year for thefts and personal attacks
		Growing food locally	- Number m^2 of vegetable garden per dwelling
		Making public facilities accessible to all including handicapped and old people	- Average distance from each building to major public facilities - Easy access for handicapped and old people

Key point: Energy transition at local level is framed in the broader sustainability context.

Source: [3]

Selected case studies

The seven case studies selected for in-depth analysis include the renovation of existing buildings as well as the construction of new ones. Energy targets and achievements of each project are summarised in Table 2 while detailed analysis of each case study is provided in part II of this report.

Table. 2. Selected case studies (energy targets and achievements)

Project	Overall target at a community level	Targets for energy demand reduction and supply with renewable	Energy achievements
Cernier, Val-de-Ruz (Switzerland)	Self-sufficiency by 2030	- Reducing energy demand of existing buildings by at least 70%. - Reducing energy demand of new buildings by at least 30% compared to national standard. - 90% electricity self-sufficiency. - 70% of heating self-sufficiency.	- Energy savings in renovated buildings reached on average more than 70%. - Energy demand in new buildings was on average 38% less than the current standard. - 22% of electricity self-sufficiency. - 84% of heating self-sufficiency.
Cloughjordan (Ireland)	Create a sustainable energy region	- Reduce the energy consumption in 400 existing buildings by 40%. - Develop an eco-village with 132 houses, reducing energy demand by 30% compared to national standard, with a minimum final energy of 77kWh/m^2/yr. - Renewable energy systems in existing buildings - to increase the renewable energy supply by 200% using wood pellets and solar systems.	- Renovation of 350 buildings leading to 3.5 MWh/yr of energy consumption reduction. - Increased production from renewable energy sources from 660 to 2,300 MWh/yr. - Average Energy Rating of completed new builds is 56.5kWh/m^2/yr, more than 20% better than the SERVE target of 70kWh/m^2 /yr. - Energy supplied by Ireland's first renewable energy district heating system. - The eco-village is heated entirely by renewable energy sources.
Helsingør/Helsingborg (Denmark/Sweden)	- Helsingborg: Carbon neutral municipality by 2030 and 100% renewable energy district heating by 2035. - Helsingor: Carbon neutrality by 2050.	Helsingborg: - Reducing total energy consumption per inhabitant by 4% by 2010 compared to 1990. - Reducing fossil fuels input to district heating and power systems by 20%. Helsingor: - Reduction of 30% of energy consumption for regulated loads in eco-houses.	- Energy savings in renovated buildings range between 24% and 54%. - Energy demand reduction in new buildings is at least 27% lower than the current standard. - Total energy savings of 35% from new and renovated buildings. - Renewable energy production of around 106.1 GWh/yr in 2012.

Hvar Island (Croatia)	Demonstrate the energetic self-sufficiency up to a quota of 20% until 2020.	- 20% energy from RES. - Increasing security of supply on the island by refurbishing and optimizing the energy consumption of the buildings in the private and public sector. - Ensuring buildings are brought to a lower energy consumption (20-30% reduction in final energy consumption).	- Heat demand reduction of renovated buildings is on average 63% . - Total energy demand of the new buildings is 38 kWh/m²/yr. - Compared to reference values: 638 MWh/yr of final energy savings for the renovation and 70 MWh/yr of final energy savings for the new buildings. - CO_2 reduction of 330 tonnes of CO_2/yr.
Stadtwerk (Austria)	- Salzberg region aims to become climate neutral, fossil fuel free and nearly energy independent by 2050. - Stadtwerk aims to be an energy optimised district used as an international model.	- Heat demand for new buildings at maximum 20 kWh/m².yr (which is 75% less than current standard). - Heat demand for renovated buildings at maximum 35 kWh/m².yr (which is 75% less than current standard). - High amount of renewable in heat supply.	- Solar energy now covers about 35% percent of the annual heat demand. - Reduction of 78% of energy from fossil fuels. - 40% reduction in energy use of all buildings, equating to 4,300 MWh/year of heat demand and 430 MWh/yr of electricity demand.
Valby (Denmark)	- Copenhagen, intends to be the first carbon neutral capital in the world by 2025. - Valby aims at 15% PV solar power by 2025 (compared to 2010).	-Energy saving: 2,156 MWh/yr (estimated, 107 electricity and 2,049 heating energy). -Energy from RES: 2,516 MWh/yr (estimated, 600 electricity, 1,916 heating energy). -Supply 15% of all electricity from 30 MWp photovoltaic solar power.	-Saved a total of 70% of energy from fossil fuels (MWh/yr). - Energy savings of all buildings equates to around 4,000 MWh/yr of heat demand and 1,000 MWh/yr of electricity demand. - 1198 kWp PV and 840 m² solar thermal collectors have been integrated. - 777 kWp PV solar plant for a waste water treatment plant. -Renovation of 288 housing units and 13.500 m² of public building. - 500 new built housing units in Copenhagen (40.000 m²).

Zaragoza (Spain)	In 2005, the "Strategy for Climate Change Mitigation and Improvement of Air Quality" aimed to reduce CO_2 emissions per person by 30% in the period 2005-2015.	-A bioclimatic approach of social housings, with high energy-efficiency criteria. - Energy saving: 70%. - Energy from RES: over 40%. - Achieving dramatic reductions in energy consumption, from a minimum of 39% to a maximum of 71% above current building standards. - Achieving dramatic increases in the supply of renewable energy, from a minimum of 40% to a maximum of 60% of the resultant energy demand.	-9,650 social housings built based on bioclimatic principles. -The community supplies over 40% of its energy demand from renewables. - New buildings have a heating consumption rate per dwelling between 20-25 kWh/m^2/yr while heating energy consumption of conventional dwellings is between 80-110 kWh/m^2/yr which is equivalent to a reduction of 75%. - For the renovated dwellings, the heating consumption rate achieved is between 50-60 kWh/m^2/yr which is equivalent to a reduction of 40%.

Key point: The ambition of the energy target at the district level influences the measures implemented at the building level.

Source: Compiled by the authors.

Conclusions and future research work

This report identified key factors that can be used to compare and draw lessons from zero energy projects implemented at a neighbourhood scale. First, there is a need for clear and comparable targets. The review highlighted the lack of consistent terminology and targets used when implementing the zero concept at local level. Second, the analysis showed that existing projects have benefitted from cross-sectoral planning which goes beyond energy issues to include other sustainability criteria. Importantly, analysis of existing zero-energy districts showed that existing projects recognise the value of citizen engagement and have invested in triggering this engagement and in building capacity. Despite this initial engagement, none of the identified projects provides evidence for a sustained and meaningful engagement of local residents. This suggests that more research and innovation is needed to better understand the role of citizens in making zero energy communities successful in the use phase.

Finally, the in-depth analysis of the seven case studies has shown some difficulties in implementing the zero-energy concept at the neighbourhood scale. Cloughjordan, Zaragoza, Hvar, Stadtwerk and Valby all experienced initial difficulties in investor confidence. Zero energy projects' initial investment costs may be higher as the measures being tackled go beyond business as usual measures which target "low hanging fruits".

A large-scale project will involve many actors, organisations and personnel, some of whom may leave, such as in the Helsingborg-Helsingor project that subsequently held the project back. Administration and project organisation must be handled in an organised manner, making sure time is allocated for this during the project timeline. Moreover, both Cernier and Hvar teach us that the size of the community matters in order to technically and administratively implement the project. Cernier was hindered due to a lack of administrative personnel able to support the project; conversely Hvar was hindered due to the lack of technical capacity on the island.

When designing a zero energy district it is important to look into local planning laws during project design phase, some designs may need to be checked, as was the case for the low-energy building renovations in Zaragoza. Strong political commitment can be gained using robust data. Zaragoza Municipality had a strong political commitment to sustainable development and the town planning laws were adapted to the needs of the project.

A few of the projects received resistance from inhabitants, namely Cernier and Stadtwerk. Change can often be frightening for people especially if it is happening to their own homes or to their views (in the case of a wind turbine farm in Cernier). The right information techniques need to be used to inform inhabitants and also local stakeholders (constructors, architects, home owners, real estate companies) of the benefits of new building technologies and energy systems.

However, despite the challenges identified, the achievements of the pioneer projects demonstrate the potential for the zero-energy approach at local level to help cities meet the 1.5°C target. The challenge is to scale-up such initiatives and to make them business as usual, especially when it comes to retrofitting existing buildings and infrastructures. The Paris Climate Agreement [5] offers a clear time frame and clear target. Its implementation represents an opportunity to accelerate this scaling-up and to achieve the radical transformation of energy systems attempted by the reviewed initiatives. The report highlighted these issues to show the additional research and policy support needed.

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Cases studies

The selected case studies were assessed looking at different aspects considered in the analytical framework (summarised in Table 1 of the prologue section) to assess zero-energy districts, including:

(a) The objectives of the project, it's main concept, including the overall objectives and targets of the ZED project in relation to energy and CO_2 savings based on the technologies adopted.

(b) The emergence of the project.

(c) The general context (national and regional energy and climate policies) in which the district is located, considering the political and economic context with a focus on energy efficiency and renewable energy policies.

(d) Major features of the project: successful ZED indicators, information on the main actors, the achievements or ambitions towards the zero-energy goal.

(e) Governance structure: how the project was developed as a successful ZED, by whom and how this helped the success of the ZED project.

(f) Energy consumption and reduction objectives: technical aspects, refurbishments, new buildings, integration of renewable energy sources and the main results of each intervention, when available.

(g) The financial and economic aspects of the project.

Lessons learned and legacy from each case study are summarised prior to providing the detailed analysis described above.

Case study 1: Cernier (Val-de-Ruz, Switzerland)

Lessons learned and Legacy

Incorporating and complementing existing projects in the region is key for the success of ambitious energy projects. Cernier project was designed to be complementary to existing projects within the community. Energy efficiency and renewable energy measures considered to meet the ambition level of the Cernier project were designed and integrated into the existing energy plans of the Cernier territory. The optimisation and prioritisation of energy measures in Cernier project was straightforward as a holistic approach to energy consumption and production was considered.

Ambitious projects lead by example. The Cernier project acts as a model for other cities in Switzerland and further afield. The project laid the foundations for a more advanced energy policy in the Val-de-Ruz municipality, which has developed a cadastre to facilitate the management of energy. The project has also been an opportunity to test a range of energy saving and energy producing technologies. Thus, setting a stage for these technologies to be implemented in the surrounding regions. Moreover, Cernier provides advice and recommendations on energy efficiency, renewable energy and information campaigns to interested districts.

The size of the community matters. It has an impact on the human resources, which could be allocated to the daily management and administration of ambitious energy projects. The project's organisational structure must, therefore, be accounted for during the planning and set up of projects to avoid delays in the implementation of energy measures.

Citizens' support to ambitious energy projects should be secured by local authorities prior to the start of the project to avoid delays in the implementation. The construction of Cernier's wind farm was delayed and investors couldn't ask for a construction permit until the land-use plan was accepted by the population of the Neuchâtel canton in 2014.

Awareness raising campaigns are an essential element in motivating homeowners in undertaking energy efficiency measures. Factual reports on energy savings and the socio-economic impacts of energy renovations, face-to-face meetings, and informational conferences are regarded as being instrumental when trying to build trust in homeowners taking part in an energy programme. Such actions are proved to be invaluable to the success of the Cernier project.

EU funding was instrumental in implementing ambitious energy measures. The ingenuity of the municipality of Val-de-Luz in setting a new structure also played an essential role in enabling the use of EU funds for the Cernier project. EU funding was leveraged with national grants and subsidies for energy renovation, energy efficiency for new buildings and energy production from renewable energy sources.

Objectives of Cernier project

The main objective of the Cernier project is to demonstrate that municipalities can be energy independent. The self-sufficiency objective is achieved by setting ambitious targets to reduce energy demand through the implementation of energy saving measures in existing infrastructures and the production of energy from renewable energy sources located within the territory of the municipality.

The energy sufficiency plan developed by the municipality of Val-de-Ruz, where Cernier project is located, was articulated around seven key pillars:

1. Renovation of existing buildings.
2. Development of a large district-heating network based on wood and biomass waste.
3. Production of renewable energy in buildings (heat pump, photovoltaic electricity, etc.).
4. Reduction of energy consumption by implementing energy efficiency measures and raising awareness of occupants using modern information tools.
5. Installation of a wind power turbine.
6. Optimisation of water sanitation system and power generation by micro-turbines.
7. Optimisation and energy management of street lighting.

Energy measures considered in the Cernier project were integrated into projects that were already planned within the Cernier territory, like the renovation of the school, the development of the district heating network and the cogeneration plant. To ensure the overall targets will be met, some changes occurred during the course of the project. In fact, larger-scale renovation projects of public buildings were considered instead of the renovation of privately-owned buildings as private owners couldn’t commit to deep energy renovation for financial reasons. Similarly, the installation of solar panels was favoured over the wind turbine due to the non-acceptance of the wind farm project by the population until 2014.

Emergence of the Cernier project

Cernier is a typical Swiss town, located in Neuchâtel canton, with a population of around 2,000 inhabitants and an area of 9.1 km^2. The main economic activities in the area are agriculture and forestry. In 2013, 15 municipalities, including Cernier, merged into one: the Val-de-Ruz. The latter developed an energy concept aiming to reach energy self-sufficiency by 2030 which made the region known for its progressive political will to promote renewable energy and energy efficiency.

The progressive approach of the newly established municipality was instrumental in securing EU-funding (CONCERTO project SOLUTION[1]) for the Cernier project with the aim to contribute to the self-sufficiency target of the municipality. The overall objective is to ensure energy demand is met with renewable energy produced locally, 70% for heating and 90% for electricity. Meeting this target required reducing energy demand of existing buildings by 70% compared to national standard through the renovation of existing residential and non-residential buildings (a total floor area of 13,000m^2), and setting ambitious targets for new buildings, 30% less energy consumption compared to legal standards.

([1]) The CONCERTO project SOLUTION objectives include i) demonstrating the feasibility of energy self-sufficiency for buildings, ii) developing of a replicable model of energy sustainability by 2015, iii) reducing CO_2 emissions and iv) mobilizing of private and public resources for the project implementation.

The EU-SOLUTION project has been widely accepted by the town's authorities and population, so far 70 homeowners have applied for the grants provided by SOLUTION. The objectives of the project are considered from the point of view of the original Cernier territory (inhabitants, area, consumption, etc.). The Cernier/Val-de-Ruz municipalities were involved in the project and are now included in the municipality of Val-de-Ruz. The approach taken by SOLUTION provides co-financing for energy measures and applies to all small and medium entities in Cernier, Figure CS1.1.

Figure CS1.1 Urban plan and Cernier project

Key point: Cernier projects were spread across the community.

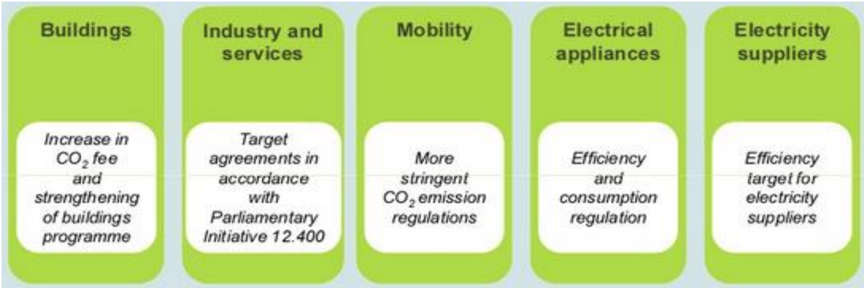
Source: SOLUTION CONCERTO, 2012.

The project covers the entire population and area of Cernier. The developments are based on a holistic range of measures, such as energy renovation of residential and public buildings, development of new low energy consumption buildings, production of renewable energy (solar thermal, PV, wood burners, geothermal heat pumps), a new district heating system, a wind turbine site, water and street-light optimisation and the use of smart meters to optimise energy consumption.

National and regional energy and climate policies

Switzerland's environmental targets include reducing GHG emissions by 20% by 2020 compared to 1990. This commitment aims to save 2.2 million tonnes of CO_2 emissions by implementing energy saving measures and increasing the share of renewable in the energy mix. The Swiss national energy programme puts emphasis on reducing energy consumption in key end-use sectors including buildings, industry, transport, appliances as well as in electricity supply (Figure CS1.2). Furthermore, Switzerland has planned to abandon nuclear power plants entirely by 2034.

Figure CS1.2 Key sectors of the Swiss National Energy Programme



Key point: The Swiss energy plan targets the main sectors of the economic activity.

Source: Swiss Federal Office of Energy, 2014.

A ten-year Swiss federal and cantonal "Building Programme" was launched in 2010 with the aim to support the energy transition of the Swiss building stock which uses roughly 40% of total Swiss energy demand and is responsible for the same share of its CO_2 emissions. Approximately 1.5 million of the total 3.5 dwellings in Switzerland need an energetic renovation. However, the annual renovation rate is about 1%. The "Building Programme" provides grants to people undertaking energy renovations (including funding for RES). The grant scheme is funded by a charge levied on heating oil. Since the launch of the programme, many homeowners have applied for a grant, circa 30,000 in 2010.

Furthermore, a new Swiss law on power supply allowed establishing an energy fund, the canton portion of the fund supports cost effective energy efficiency and renewable energy measures and the city portion supports energy efficient renovation measures. Cernier project became a leading financing model in Switzerland as it bundled funding from the energy fund with those from the European Commission and leveraged grants offered by the state.

CONCERTO, on behalf of the EC, allocated 2.8 million to the SOLUTION project in Cernier, intended to leverage national grants and subsidies for energy renovations, energy efficiency and renewable energy supply. Other funding sources that supported the actions taken in Cernier include ENERGIE, Swissgrid, grants from Programme Batiment and the canton.

Major features of Cernier project

The town of Cernier is a model for sustainable development and fulfils a number of ZED requirements (see Table 1 of the prologue section), such as social engagement, economic efficiency and reduced environmental impact. Some of the project's successful ZED indicators are discussed below.

Social engagement: A key aspect of the SOLUTION project was to involve the entire population of the town. This was deemed to be essential, as the reduction in energy demand has to come from the inhabitants. A number of concrete measures were established to change energy behaviour patterns and an information campaign was set up to get the message across to the citizens. The techniques used include the installation of smart meters (internet and smart phones (Figure CS1.3)) and technical advisor visits. A newsletter was initiated to provide informative material on the SOLUTION project. A regional festival was organised to provide the developers an opportunity to present the project to the public (distribution of flyers and a poster presentation. Building owners were informed of the benefits of SOLUTION project and advised on ways of integrating funding with federal and cantonal grants when renovating and/or installing renewable energy solutions in their buildings.

Figure CS1.3 Smart phone application to ensure citizens' engagement

Key point: The use of modern communication tools was instrumental in citizens' engagement.

Source: SOLUTION CONCERTO 2012.

Economic efficiency: The SOLUTION project has a direct impact on the image of the town, not only in surrounding areas, but also internationally. Most of the investment in the SOLUTION project (80%) went directly to local businesses for goods and services. Furthermore, skill development has been offered to the residents and businesses of Cernier through courses and information evenings.

Optimisation of water systems: Around 1000 m of water pipes have been renewed, saving roughly 57 MWh/year for Cernier.

Optimisation of street lighting systems: State-of-the-art lighting technologies have been installed leading to 48% of energy saving.

Governance structure

The project was initiated by PLANAIR, an engineering company who provides advice on energy and environmental issues and is supported by the municipality of Cernier/Val-de-Ruz. PLANAIR is the scientific and administrative coordinator of the SOLUTION project, responsible for the planning and design of the innovative energy solutions. The municipality acts as the public investor and is responsible for the supervision and the administration of the demonstration project. Finally, an external investor, CONTREN, is part of the management structure; they have also supervised the project given their extensive experience in the development of energy projects at the community level.

Under the SOLUTION scheme, three types of projects were developed:

Municipality projects, which include the development of the wind turbine farm, the district-heating network, public building renovations and water and lighting optimisation.

Individual projects which target home-owners and aim at renovating their dwellings including the installation of heating or electricity measures based on renewable energy and monitoring the effect of the installed measures.

Investor projects, which target the private portion in the district-heating network and cogeneration (electricity and heat) from waste.

Energy demand reduction and supply with renewable targets

I. Renovation of existing buildings

The objective of the project was to reduce energy consumption of each renovated building by at least 70%. Both residential and public buildings have been thermally renovated, equating to a total floor area of 13,000m^2 and a total energy savings of 2,435 MWh.yr for heating.

Described below, and summarised in Table CS1.1, are the energy consumptions of each renovated building, calculated weighted heating consumptions integrate the building's connection to the new biomass district heating and the fact that the energy supply rate is for 80% from renewable.

The renovated buildings in Cernier include:

1. Cernier Primary school (2,001 m^2), which was built in 1971 and has been renovated to the highest Swiss standards[2]. Every part of the building's envelope has been upgraded with high-level thermal insulation. Optimised lighting fixtures have been installed and the windows have been replaced by triple-glazed ones and fitted with an electric roller blind to ensure the building does not overheat. The heating consumption has been reduced from 238 kWh/m^2.yr to 52 kWh/m^2.yr, with a final total energy consumption of 61 kWh/m^2.yr. The school is connected to the district heating system, that is 80% renewable, therefore the weighted heating energy consumption is 35.5 kWh/m^2.yr.
2. Two family homes (329 m²) have been renovated, the total heating savings amount to 78 MWh/yr as described below:
    a. Fallet building is a 17th century farmhouse that has been converted into a residential building. The renovation works covered a full thermal renovation of the building envelope. The insulation was fitted inside the building to maintain the aesthetic historical heritage of the building. The heating requirements of the building are supplied using a heat pump. The renovation works reduced the building's heat consumption by 79%, from 336 kWh/m^2.yr to 58 kWh/m^2.yr. The weighted total annual average of the building is 40 kWh/m^2.yr (33 kWh/m^2.yr for heating).

1. Langel building is a family house that has undergone a full thermal envelope renovation. A wood pellet heating system has replaced the oil boiler. The renovation works reduced the building's heat consumption by 71%. The weighted total annual heat average of the building is 138 kWh/m^2.yr.
2. The Nursery school (1,028m²) was built in 1970 and has undergone a high-level energy renovation of the building envelope, as well as construction of an additional floor for a classroom. The lights in the building have been upgraded. The renovation works reduced the building's heat consumption by 85%, from 338 kWh/m^2/yr to 51 kWh/m^2.yr. The weighted total annual average of the building after being connected to the district heating system is 28.9 kWh/m^2.yr.
3. Temple Building – Fontainemelon (2,186m²) is a multi-family building of 26 flats built in 1966. The renovation focused on upgrading all parts of the building envelope. Taking renewable gains into account, the building has reduced the consumption by 70% and the weighted heating consumption is 45.9 kWh/m^2.yr.

3. High School - La Fontenelle (7,200m²) is a secondary school that consists of several building blocks (A to G). Blocks A to E have been renovated, focusing on upgrading the facades with double thermal fiberglass insulations and installing new triple glazed windows with a roller blind to ensure overheating does not occur. Building block E contains the swimming pool and has not been considered in the project since it was difficult to identify the share in heating needs for the swimming pool and the building itself. The building's lighting has been optimised. The renovation works reduced the building's heat consumption by 62%, from 233 kWh/m^2.yr to 44 kWh/m^2.yr (excluding building block E).

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[2] Swiss regulation for new building at the time of the project was 49.7 kWh/m^2/year

Table CS1.1 Energy consumption before and after renovation for each individual project

Project	Floor area (m^2)	Renovation year	Final energy consumption before renovation ($kWh/m^2.yr$)	Measured final energy consumption after renovation ($kWh/m^2.yr$)	Weighted energy consumption (heating and REs) ($kWh/m^2.yr$)	% of energy savings
Cernier primary school	2,001	2012	280	61	35.5	78%
Fallet family house	329	2011	336	70	33	79%
Langel family house		2014	468	197	131	58%
Nursery school	1,028	2010	338	51	28.9	85%
Appartment building (Fontainemelon)	2,186	2012	171	52	45.9	70%
La Fontenelle high school	7,200	2013	233	86	44	63%
Total	12,744		1,826	517	318	72%

Key point: Renovations in Cernier achieved an average of more than 70% energy saving which is equivalent to 1.525 GWhyr and 36 tonnes of CO_2.

Source: SOLUTION D2C2-5, 2014.

II. New buildings

Cernier project requires new buildings to be constructed according to the Minergie standards[3] and to have an energy consumption that is at least 30% less than a building constructed according to the Swiss building energy code [1].

A group of four new multi-family (5,148 m²) buildings have been erected as part of a cooperative: the Héliotropes. The flats have been constructed according to Minergie standards with a fully thermal envelope and energy savings of around 38.4% (Table CS1.2) compared to standard building constructions which is equivalent to 72 MWh.yr or 16.6 tonnes of annual CO_2 emissions. When taking into account renewable energy supplied by district heating, the weighted energy consumption is 21.9 kWh/m^2.yr.

Table CS1.2 Energy consumption of new buildings compared to legal standard

Project	Floor area (m²)	Construction year	Final energy consumption required in the legal standard (kWh/m².yr)	Calculated energy needs (kWh/m².yr)	Measured energy consumption (kWh/m².yr)	% reduction compared to legal standard
Les Heliotropes (Multi-Family building)	5,148	2014	45	37.1	27.7	38.4%

Key point: New buildings were able to achieve more than 38% reduction compared to standard levels.

Source: SOLUTION D2C2-5, 2014

III. Integration of renewable energy supply

Various renewable energy facilities have been installed in Cernier, some are linked directly to the buildings, additionally a district heating system and a wind farm supply energy to the town.

The renewable energy sources linked to the building include:

1. Solar thermal panels: Three projects were implemented using the SOLUTION support. Several others were installed without grants (surface area of 230m^2). The total surface area of the thermal panels is 32 m ^{2}, the heat output is 17.5 MWh/yr.
2. PV: 11 projects have been installed, providing a total power supply of 440 kWp and a production of 407 MWh$_{el}$/yr. Additional PV installations have been set up in Cernier without the SOLUTION funding.
3. 2 wood boilers with a thermal output of 158 kW.
4. A geothermal heat pump provides the old farmhouse with 15 MWh of energy per year.

The shared renewable energy sources include:

4. Biogas production and cogeneration has been operating since 2012, using pig manure and green waste, the biogas produced is used in a cogeneration plant for generating heat and electricity. The plant produces 859 MWh $_{el}$ and 739 MWh$_{th}$ annually, this is injected into the power grid and district-heating network.

[3] Minergie requirements for new multi-family dwellings are 38 kWh/m^2.yr (https://www.minergie.ch/)

5. District heating from biomass: 60% of the installed capacity is operational and heat production exceeds 14 million kWh per yr (more than 70% of the heat demand of Cernier).
6. Wind Turbine Farm is in the planning process and is expected to provide Cernier with around 70% (4,5000 MWh.yr) of the annual electricity needs. The wind farm will host 6 turbines with a power of 2MW.

Overall contribution of renewable to energy supply:

Cernier reached a 22% level of self-sufficiency in electrical production from the installation of the cogeneration and photovoltaic solar panels. The wind farm site (accepted in May 2014) will provide Cernier with an additional 70% of the electricity production necessary, making Cernier's target of 90% of electricity self-sufficiency achievable. Since 2017, the district-heating network is operational and supplies Cernier with 84% of its heat energy demand. The new district heating facility is co-managed by the municipality (10% of ownership) and a private investor through an exploitation company.

Financial and economic aspects of the project

As mentioned earlier, CONCERTO [4], on behalf of the EC, allocated 2.8 million to the SOLUTION project in Cernier, intended to leverage national grants and subsidies for energy renovations, energy efficiency and renewable energy supply. Other funding sources that supported the actions taken in Cernier include ENERGIE, Swissgrid, grants from Programme Batiment and the canton.

Table CS1.3 shows the different funding sources allocated to improved energy performance of building constructions and upgrades.

- New passive houses received a lump sum of 6,500 € for single family houses and 30€/m^2 for multi-family houses.
- Retrofitted buildings based on Minergie standards are granted an average amount per m2 (from SOLUTION, the Building Programme and the municipality).

Each project is subject to a special request for obtaining the municipal, federal and European subsidies. For the SOLUTION project, the support is also dependent on the exchange rate Euro - Swiss Franc. As shown in Table CS1.3, support from the SOLUTION project and local subsidies was based on the number of m^2 of heated floor area, while for the building programme, the support was based on the renovated surfaces (m^2 facades, m^2 of windows, etc.) contained. The support from the Canton applied only if the building is in line with the Minergie requirements (insulation but also type of heating).

Table CS1.3 Allocated funds to support energy efficiency measures in buildings

Funding source	Assigned amounts [€]				
Measures	Windows/doors	Façades	Roof	Ground floor	Attic floor
SOLUTION	25€/m² of gross heated floor area				
Programme Bâtiment4	40€/m²			15€/m²	
Canton	-40 €/m² of heated surface area if according to Minergie standard -50€/m² of gross floor area if according to Minergie-P standard				

Key point: Various funds were bundled to allow ambitious measures to be implemented.

Source: SOLUTION best practice guide for co-financing energy efficiency and large-scale renewables integration, 2012.

The SOLUTION project also supports the development of heat generating systems and renewable electricity linked to households [2] (Table CS1.4).

- Photovoltaic systems are granted a maximum lump sum of 1,300€/kWp (municipal level).
- Solar thermal systems are supported by a lump sum of 1,000€ for single-family houses and an average of 80€/ m^2 for multi-family houses.
- For automatic wood boilers (wood chips or pellets) it depends on their size; a new installation is financially supported with a minimum of 2,200€ (650€ + 70€/kW) and a replacement with 270€ + an average of 40€/kW.

Table CS1.4 Financing RE in buildings

Funding source	Heat Pumps	Wood	Solar PV	Solar thermal
SOLUTION	360€/kW_{el}	150€/kW_{th}	1100€/kW	100€/m²
Energie	1600€ if substitution of electricity	New >2000€ Substitution >6000e		>1000€
Swwi grid			0.25-0.4€/kWh	

Key point: Existing funding sources were bundled to allow for market uptake of renewables

Source: SOLUTION CONCERTO 2012

(7) To get the support of the building program, total investments should support at least CHF 3,000.

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Case study 2: Cloughjordan (North Tipperary, Ireland)

Lessons Learned and Legacy

The SERVE project made the region a best practice area for the implementation of a holistic approach to energy demand reduction and energy supply from local renewable energy sources. The set-up of an eco-village increased the attractiveness of the region to tourists and experts. Regular visits to the region are organised to learn about state-of-the-art energy efficient buildings and renewable energy practices.

Political will is an essential ingredient to set and achieve ambitious energy transition targets. The targets of the SERVE project were met and kept unchanged despite the severe economic crisis that hit Ireland just after the launch of the project. Many housing plots in the eco-village remained unsold for a while and the district-heating system did not break even until recent years.

The SERVE project created a norm for getting the vital message across to the contractors and municipality by stressing the importance of undertaking and investing in holistic and deep energy renovations rather than investing in "low hanging fruits" and individual measures. Although early challenges were faced in creating investors' confidence in the renovation projects.

A smart design of financial support to energy renovation could be a game-changer. The grants scheme associated with the SERVE renovation requires homeowners to think and act holistically. Financial support was provided mainly for the implementation of a collection of measures which maximise energy savings and limit the lock-in-effect.

The strategy for data collection applied during the SERVE monitoring process has fed the national analysis that drives the National Energy Agency's energy policy development. Data collection was made possible as an energy performance certificate, before and after renovation, was a pre-condition to access funding. This ensured mandatory monitoring was embedded into the project. This type of wide-scale monitoring programme had never been undertaken in Europe before. Ireland is now the front-runner in Europe for its online and open-sourced energy performance certificate database.

Successful local initiatives could set the ground for national energy policies and actions. Guidelines on appropriate integration of quality standards within the National Dwelling Energy Assessment Procedures were influenced by the SERVE Project.

The success of the SERVE project had a positive impact on policy-makers and industry. Based on the positive experiences of the workforce trained in the SERVE project, the Tipperary Energy Agency and North Tipperary Leader Partnership have undertaken another community housing retrofit scheme in Drumbane.

Objectives of Cloughjordan project

The main objective of the SERVE project was to showcase that energy optimisation of the building stock of whole communities and villages is more efficient than individual building measures through the demonstration of best practice examples of energy renovations, new eco-building constructions and state of the art renewable energy technologies. The project ran from 2007 to 2012. It aimed to cover a total of 635 buildings and to set new standards of energy performance design and renewable energy supply in rural Ireland.

The SERVE project has the following key objectives:

- Create a region in North Tipperary that is a leader in implementing sustainable energy measures.
- Reduce the energy consumption in 400 existing buildings by improving their energy performance through insulation and heating control measures.
- Develop an eco-village with 132 houses in Cloughjordan that showcases building energy efficient design, and which is supplied by Ireland's first renewable energy district heating system.
- Increase the use of renewable energy technologies by supporting the installation of renewable energy heating systems and demonstrating the use of electricity from micro-wind turbine sites.
- Use technical and socio-economic expertise from European Partners to monitor performance and impacts in the region and to disseminate the results widely.
- Provide training and information within the SERVE Region to stimulate further action in the field of sustainable energy.

The SERVE building standards used in Cloughjordan:

9. Refurbishments -to be in line with 2006 Building Regulations (40% reduction in energy use).
10. Renewable energy systems in existing buildings -to increase the renewable energy supply by 200% using wood pellets and solar systems.
11. New buildings in the Eco-Village of Cloughjordan - to have an energy performance that is 30% better than the 2006 Building Regulations (a minimum delivered energy rating of 77 $kWh/m^2.yr$).

Emergence of the Cloughjordan project

The SERVE region is located in North Tipperary. The region is set to be the frontrunner in sustainable energy practices in Ireland through the implementation of sustainable actions, such as energy upgrades for existing dwellings, installation of renewable heating systems including a district heating system and the development of an ecovillage of new buildings. Population distribution in the region shows that most of the inhabitants are based in very small settlements and villages. Only two divisions, Nenagh and Borrisokane, have more than 1,000 inhabitants. Therefore, the integration of sustainable energy practices focusing on rural development is integral to the success of the SERVE region.

In recent years, there has been an increase in population of 6.4%, compared to 2006. North Tipperary is experiencing an increased urbanisation and suburbanisation. Nenagh has experienced a population increase of 7,995 people. Inhabitants of the SERVE region, predominantly, live in owner-occupied homes (circa 80%). However, compared to the Irish average, more homeowners in the SERVE region own their houses outright (42% compared to the Irish average of 34%). This is beneficial to the SERVE project as owneroccupiers are more likely to invest in energy saving and renewable energy upgrades and equipment given that they can recover the costs of their investments. The construction period of buildings in the SERVE region generally reflects the Irish national construction periods. However, the pre-1919 housing is significantly higher in the SERVE region.

The SERVE project offered the area a comprehensive retrofitting scheme whilst integrating renewable energy, and an ecovillage of Cloughjordan. Households who did not benefit directly from the renovation grants have benefitted from the supply with renewable energy sources implemented such as the micro-wind turbines and PV panels.

Urban Plan of the SERVE project (monitored houses in the project)

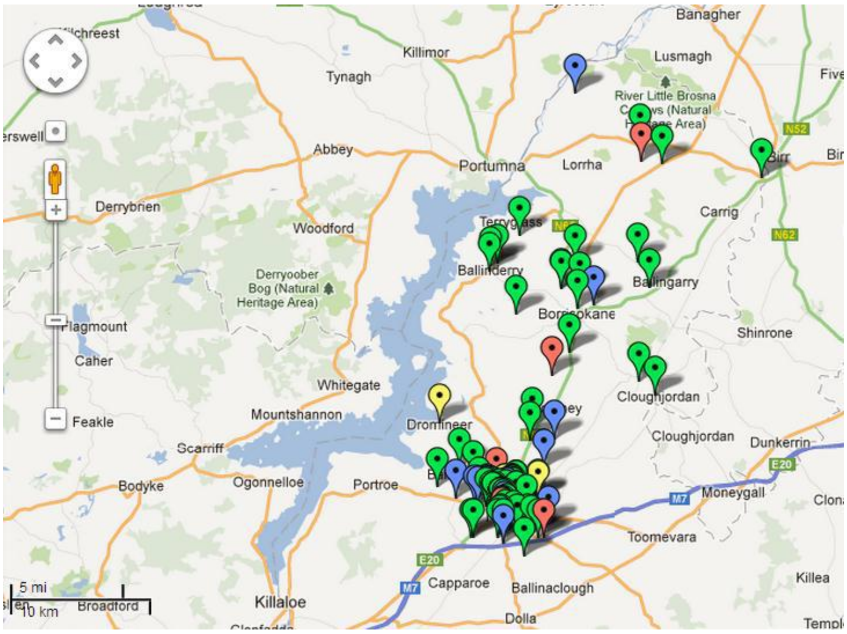
The geographical spread of the SERVE project is shown in Figure CS2.1. Most of the projects are situated in and around Nenagh which is the most densely populated area of the SERVE region.

The monitored houses were selected based on the possibility to arrange Internet connectively to the monitoring system. Therefore, the spread of houses that were monitored tended to be closer to the urban centre (Figure CS2.1).

The colours of the markers indicate the level of monitoring:

- Green - basic monitoring.
- Blue – disaggregated electricity monitoring.
- Yellow – solar energy production monitoring.
- Red - boiler efficiency monitoring.

Figure CS2.1. Geographical spread of monitored houses in the SERVE project.



Key point: Monitored households are spread across the SERVE region.

Source: SEAI-Report, 2010.

Cloughjordan

The Cloughjordan village, within the SERVE Region, is the location for Ireland's first eco-village, initiated in 2007. In the past, the town has suffered an aging population and population decline. It is surrounded by 50 acres of woodland and the community farm is an active producer of food for the region. Around 8,000 m^2 of new eco-buildings have been constructed in the town, created from inside the community, focusing on low embodied energy in the building materials and keeping energy efficiency as a key deliverable. The eco-village's heating and hot water is supplied by renewable energy sources including solar thermal systems and a wood chip district-heating system.

National and regional energy and climate policies

The Irish Government began to focus on energy renovation policies in 2008. This was driven by the EU 2020 energy and climate targets as well as the economic crisis that had hit Ireland, the possibilities and technical knowhow in building new, high energy performing buildings and the requirements imposed by EU targets such as the National Energy Efficiency Action Plan (NEEAP). The Minister of Communications, Energy and Natural Resources established a Home Insulation Scheme – the Home Energy Saving Scheme (HES Scheme) in 2008 which provides financial support to homeowners wishing to undertake an energy upgrade.

The Irish NEEAP has a target of saving 20% of energy within the residential sector by 2020 and a 33% reduction in public sector energy use. Achieving this target requires 1,000,000 Irish buildings to be renovated by 2020.

Ireland's predominant fuel for heating is oil and kerosene. This is likely to be the major fuel source in the foreseeable future. Given the rise of fossil fuel prices and the lack of natural gas availability, kerosene is becoming more expensive. The use of natural renewable energy for heating sources (wood and solar) should, therefore, be a feasible alternative in Ireland. It is regarded as an opportunity to safeguard energy consumption and security in the future for rural Ireland. Furthermore, low-income households tend to live in buildings with low energy performance which increase the share of the population facing energy poverty.

North Tipperary is a rural region in the Mid-West of Ireland that covers a total area of more than 600 km^2 and hosts a population of 12,000 people in 6,000 dwellings, of which 60% were constructed before 1981. The region is a rural area based on agriculture and more than two thirds of the inhabitants live in the open countryside and small towns and villages.

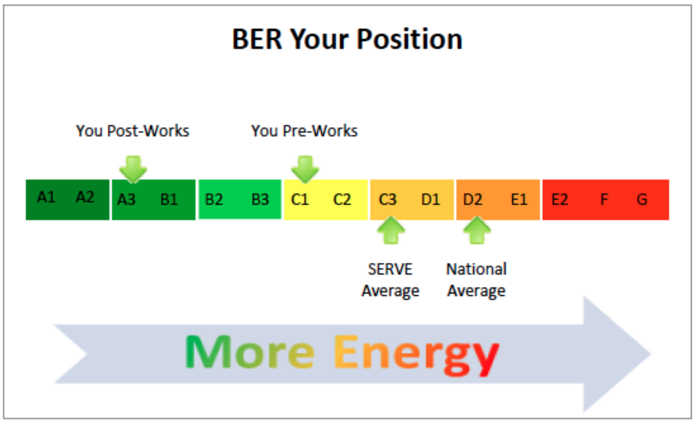
There is a limited use of renewable energy sources and around 60% of housing were originally built with poor insulation and have inefficient heating systems. North Tipperary is becoming a leader in the implementation of sustainable energy actions in Ireland. In 2007, the Sustainable Energy for the Rural Village Environment (SERVE) Project was initiated. The aim is to develop the region into a sustainable good practice district. An emphasis has been placed on upgrading the existing building stock, creating a new Eco village of Cloughjordan and focusing on the needs of the inhabitants as described in the following sections.

Major features of Cloughjordan project

The SERVE project in North Tipperary is a model for sustainable development and fulfils several ZED requirements, such as social engagement, economic efficiency and environmental impact. Some of the project's successful ZED indicators are discussed below.

> ***Social engagement:*** The SERVE project made strenuous efforts to engage with local citizens. The energy agency engaged with residents intensively, one-to-one. The initial step was an analysis by SERVE-trained assessors of the energy consumption of properties using "Building Energy Ratings" (BER) (Figure CS2.2). This allowed raising homeowners' awareness about energy consumption of their dwellings and the possible refurbishment measures that could be taken to improve their energy ratings. Other information dissemination projects took place, for example, in schools.

Figure CS2.2 BER performance indicator



Key point: The labelling system for the monitored helps demonstrate the impacts of the project compared to national standard.

Source: SEAI-Report, 2010.

Training and Education: Residents were given substantial support and encouragement to learn more about sustainable energy. The clarity offered by the BER ratings meant that energy performance and the impacts of improving energy performance of buildings could be easily understood. Construction workers were trained on-site. Training courses on high energy performance retrofits and low carbon technologies were provided. Funding to undertake accredited courses at the Tipperary Institute (now part of Limerick Institute of Technology) was made available. Moreover, there was collaboration with the two local schools. The effective communication campaigns increased the acceptance of the project.

Energy impacts: A total of 8 € million was invested in the project. This has resulted in an annual reduction of 5,000 MWh in energy consumption of homes. Moreover, renewable energy production in existing buildings has increased from 660 to 2,300 MWh.yr.

Political engagement: The experiences gained from the project have led to improved cooperation among the stakeholders. Important lessons have been learned which feed into national policy-making. Two reports by the Tipperary Energy Agency had a strong influence on methods of implementation of the Energy Performance of Buildings Directive and the National Home Energy Scheme. To date, Cloughjordan has Ireland's biggest solar thermal array and district heating network. There has been huge interest in the eco-village and it attracts, up to 300 visitors monthly, from tourists, school and university groups and those undertaking courses on sustainable construction and related themes. The "Irish Times" has ranked Cloughjordan among the top 10 places to live in Ireland and 60 new families have chosen to move there since the project.

Economic impacts: Around 25% of project activities were carried out by local companies, with the remainder also being based in Ireland, and employment in the region has gone up slightly. A specific aim of the SERVE project was the training of construction workers and energy advisors in low-energy retrofits. Contractors have been able to share the skills they have gained in similar projects and to benefit from new business opportunities. Between 10 and 20 new, permanent jobs have been created. In the eco-village, inhabitants have set up new businesses, including a bakery, a hostel, a picture framer, a café and several small internet-based companies. Local schools had been under threat of losing teachers but have now had to employ an additional new teacher each. The possibility of retaining the local train station, due for closure, has been proposed.

Monitoring and technical success factors: Reliable and effective monitoring was essential to the project and a condition for funding. To defray the costs of this, the SERVE project arranged co-funding with SEAI, who also require sound monitoring to meet their own objectives. The comprehensive monitoring in each house was new to Ireland. Domestic systems involved multiple meters for electricity, gas and renewables. Data was transmitted via broadband to data-base automatic capturing of consumption and logged in households. In addition, a graphical indicator, based on BER and colour-coded energy labelling (Figure CS2.2) was used to demonstrate average energy use within the SERVE project in comparison with national figures. This was a clear and interesting way of demonstrating the impacts of the project.

Institutional success factors: The new eco-village was integrated into an established village, with existing infrastructure, for example schools and transport, and close collaboration with Tipperary County Council. An NGO, Sustainable Projects Ireland Limited (SPIL) was established to develop the eco-village. Its involvement in the project was crucial. Residents signed up to the eco-charter which specifies that building design limit annual final energy use to 70kWh/m^2.yr (typically A3 BER) by using high levels of insulation and making use of renewable energy and passive solar gain. Reducing construction waste and using low embodied energy materials as well as minimising the use of potable water are also included in the eco-charter. Furthermore, residents agreed to use wood chip district heating supplemented by a solar thermal array. New buyers became part of the CONCERTO project as well as the ambitious eco-village project which involved community farming, permaculture principles, allotments, biodiversity measures, woodland management, live/work units, a small business centre and fibre optic cables for home working. Moreover, SERVE project used socio-economic and technical methods utilised by European partners for performance and impact monitoring and spreading of information. Professional training on sustainable energy was also increased in the region.

Socio-economic success factors: Following the SERVE project, case studies were undertaken to determine satisfaction with the project among householders and contractors. Six homeowner case studies were carried out, via questionnaire. The aim was to identify their motivation and issues they faced during the project. All households stated that their quality of life had improved, through lower costs, improved comfort and better environmental protection. Contractor case studies involved structured interviews related to level of engagement in the SERVE project, problems and impacts as well as homeowners' knowledge of RES and energy-efficient technology, the future of renewable energy sources and environmentally efficient residential building in Ireland and general satisfaction with the project. All contractors expressed satisfaction with the SERVE project. They were impressed with the positive impact on the local economy and awareness raising. Case studies were also arranged with local politicians to gauge their reaction to the project. Overall, a key result from the project was the increased level of expertise in sustainable construction.

Governance structure

The consortium of the SERVE project was funded under the EU-CONCERTO programme and lead by the Limerick Institute of Technology who acted as the overall scientific coordinator. Supporting the Limerick Institute in the implementation of the SERVE project were the North Tipperary County Council (leading the renovation work packages) and the Tipperary Energy Agency (providing technical knowledge and support).

The full list of the consortium members and a short description of their roles and responsibilities is described below:

1. Limerick Institute of Technology, IE, which was the lead partner in charge of the overall scientific co-ordination. The institute was involved in education and training, socio-economic research as well as project promotion and dissemination.
2. North Tipperary County Council, IE, which was leading the work packages on retrofitting and renewables in existing buildings as well as controlling the support of upgrades and renewable energy installations in existing buildings. The Council played a key role in disseminating information at local level.
3. Tipperary Energy Agency Ltd, IE, which has provided the technical knowledge in terms of retrofitting and renewables, including specific energy auditing of buildings and analysis of results from research programmes, quality inspection of the installations.
4. Sustainable Projects Ireland Ltd, IE, which is an NGO which had the overall responsibility for the development of the eco-village.
5. Renewable Energy Management Services Ltd, IE, which oversaw the design, installation and commissioning of the renewable energy solution for the heat requirements of the eco-village through a district heating network.
6. Energy Consulting Network, DK, which oversaw the monitoring aspects.
7. Senergy Econnect Ltd, UK, which conducted research into the electrical load characteristics of the Eco-village and evaluated the technical, economic and regulatory aspects of installing poly-generation.
8. CIRCA Group Europe Ltd, IE, which oversaw the administrative and contractual management of the project.
9. European Federation of Regions and Agencies for Energy & the Environment, BE, which oversaw the dissemination of the project outcomes to European partners.
10. Surface Power Technologies, IE, which implemented the micro renewable electricity solutions.
11. Ayuntamiento de El Franco, ES, which was an observer community.
12. North West Croatia Energy Agency REGEA, HR, which conducted the socioeconomic research.

Energy demand reduction and supply with renewables objectives

I. Renovation of existing buildings

The SERVE retrofitting objective was to complete a holistic renovation of buildings. The aim is to making energy savings in a cost-effective way. Therefore, SERVE funding was offered by the North Tipperary County Council, with its partner Tipperary Energy Agency, in the form of a Grant Scheme (Energy Efficiency and Renewable Energy) that could be received on the condition that mandatory holistic measures were taken and linked to the energy performance of the building before and after renovation.

Residential Buildings

The monitoring analysis indicates that the SERVE renovation targets have been met. Total energy savings of the buildings are in line with the 2006 Building Regulations. Energy consumption reduction was over 50% in the monitored 353 dwellings (Table CS2.1).

Table CS2.1. BER DEAP data

Number of dwellings analysed before and after renovation	353
Number of gross square meters	56,728
Number of heated square meters	50,650
Average BER figures before renovation	355.29 kWh/heated m².yr
Average BER figures after renovation	186.11 kWh/heated m².yr

Key point: On average, the 353 renovated buildings reduced their consumption by over 50%.

Source: SERVE CONCERTO, SERVE energy analysis, 2013.

Moreover, savings in the renovated buildings is 48% in fuel consumption and 38% in final energy net heating demand (Table CS2.2). The theoretical figures from the BER assessments provide an indication of the energy performance of buildings. However, actual energy savings will depend on the occupant behaviour. Therefore, 70 renovated dwellings were monitored to compare the results with the BER assessment. These 70 monitored dwellings give similar results to the BER assessments.

Table CS2.2. DEAP data (final energy) for all retrofitted residential buildings

	Before renovation			After renovation			Energy savings
	Main system	Secondary system	Total	Main system	Secondary system	Total	
Total final energy (kWh)	10,854,606	1,742,629	12,597,235	5,702,162	902,942	6,605,104	5,992,131
kWh/m².yr			222.06			166.44	106
kWh/heated m².yr			248.71			130.41	118
Total net heat demand (kWh.yr)			8,537,195			5,302,795	3,234,400
Heat demand/gross m².yr			150.49			93.48	51.01
Heat demand/heated m².yr			168.55			104.70	63.85
Tonnes CO_2.yr	2,952	474	3,426	1,551	246	1,797	1,629

Key point: On average, the renovated buildings reduced their final energy consumption by 48% and their net heat demand by 38%..

Source: SERVE CONCERTO, SERVE energy analysis, 2013.

Average final energy per floor area (m^2) of 37 of the monitored dwellings is close to the DEAP data and below the SERVE target (Table CS2.3).

Table CS2.3. Final fuel energy consumption according to DEAP and monitored data

DEAP data (after renovation)	Monitored oil consumption and secondary fuel	National benchmark	SERVE target
119	112	210	137

Key point: The final energy consumption per floor area of the 70 monitored dwellings is below SERVE targets.

Source: SERVE CONCERTO, SERVE energy analysis, 2013.

Out of the 57,000 m^2 of renovated buildings, around 23,000 kW of wood stoves have been introduced, many of which are used as secondary heating systems, 450 kW of biomass burners have been installed, and 450 m^2 of solar water heating systems have been installed. SERVE renovations have ensured that the buildings lie between energy ratings D1 (225 kWh/m^2.yr) and B1 (75 kWh/m^2.yr), most fall into the C1/B3 category, with a primary energy demand of 125-150 kWh/m^2.yr.

Non-Residential Buildings

Of the 11 renovated non-residential buildings, monitored data is available for 6. Energy saving vary, depending on the building and the measures taken. Total CO_2 savings of the 6 monitored buildings are:

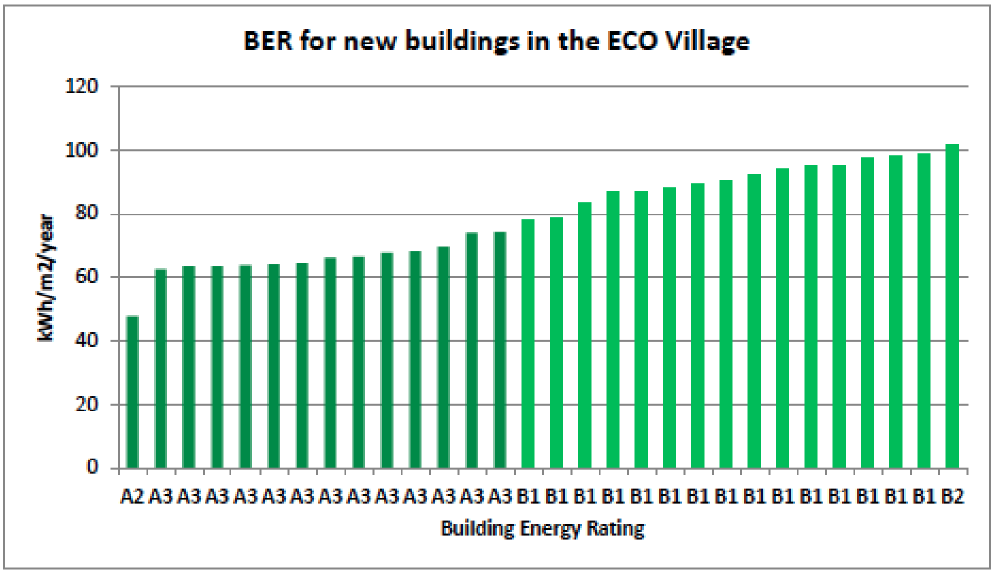
- Heat savings of 94% (742.5 tCO_2.yr).
- Electricity savings of 19% (28.5 tCO_2.yr).
- Total savings of 82% (771 tCO_2.yr).

II. New buildings

The Eco-village of Cloughjordan has constructed around 8,200 m^2 of new, high energy performing residential buildings, a community hostel of 588 m^2 and a Community Enterprise Centre of more than 500 m^2. Average energy performance of the residential buildings is 53 kWh/m^2.yr, 24% better than the SERVE targets of 70 kWh/m^2.yr.

BER assessments are available for 30 of the 50 new buildings; the figure below shows that the new buildings are rated between A2 and B2 (Figure CS2.3).

Figure CS2.3. BER rating of the first 30 eco-village buildings



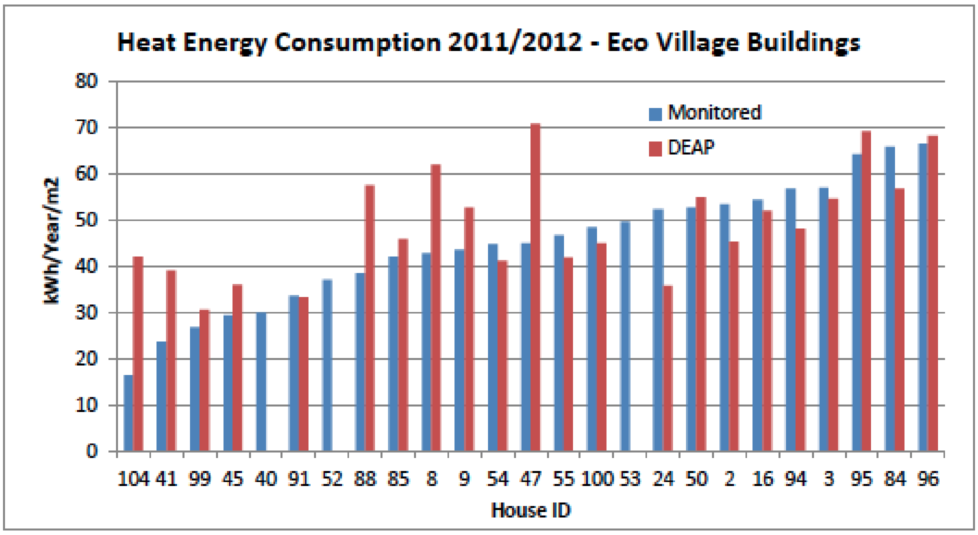
Key point: All new houses were rated between A2 and B2.

Source: SERVE CONCERTO, SERVE energy analysis, 2013

In 2011 and 2012, each of the monitored Eco-Dwelling's energy consumption in kWh was recorded monthly. The dwellings' heating and cooling degree-days were adjusted to data from the local weather stations. Data from the monitoring (Figure CS2.4) show that:

- The average consumption for 31 houses is approximately 8,109 kWh.yr.
- Energy consumption of each dwelling is below the 70 kWh/m^2.yr (SERVE target).
- The average heating energy consumption in 25 buildings is around 45 kWh/m^2.yr.
- The house with the lowest consumption (ID 104 in Fig CS2.4) is a passive house.

Figure CS2.4. Monitored heat consumption in 25 eco-village buildings



Key point: The heat energy consumption of the monitored dwellings are close to the DEAP datum.

Source: SERVE CONCERTO, SERVE energy analysis, 2013

III. Integration of renewable energy supply

A fundamental objective of the SERVE project is to increase the use of renewable energy sources in the region including wood biomass systems (replacing solid fuels), solar water thermal heating systems as well as the installation of micro-wind and PV systems in appropriate locations.

The objectives include the installation of 390 individual renewable energy systems:

- 260 wood biomass stoves.
- 30 wood biomass boilers.
- 400m^2 of solar water heating (flat plate and evacuated tube).
- 10 residential combined wind/PV systems.

By 2012, most of the renewable energy systems had been installed. The heating systems demonstrate the most efficient technology, meaning the oil-fired condensing boilers is 80% efficient and the wood stoves/boilers 60-90% efficient. The project planned the installation of 10 new wind/PV system is a hybrid; the turbine produces 450 W and the PV 300 W (in 10 prime locations). However, this aspect of the project was not successful, with only a limited number of micro-wind turbines being installed.

Moreover, the project planned to establish a new Green Electricity Purchasing Scheme, which would source 2000 MWh of electricity from green suppliers. The implementation of this scheme proved challenging due to regulatory issues. A communication campaign was, therefore, initiated where homeowner, businesses and public bodies were encouraged to purchase electricity from suppliers provide green electricity to the market. There was a considerable uptake in relation to this, but it was not monitored extensively. The use of heat from renewable sources has increased from 6% (660 MWh/year) to 300% (3,000 MWh/year); this is combined with demand reductions of up to 20%.

The final number of applications for renewable energy systems was 591, with 430 proceeding to complete works. Most of the targets have been met by at least 90%, except the wood boilers.

District Heating System: The Eco-Village of Cloughjordan has additionally implemented a new district heating system that covers the heating and DHW demand of the village. Two "Hertz" boilers of 500 kW each and a solar thermal array with 506 m² of floor area supply the system. The network's pipe that distributes the heat to each house is 2.2 km long and pipes are equipped with upgraded controls and a monitoring system. The output of the biomass boilers was measured at approximately 667,000 kWh between July 2011 and July 2012, out of which 85% was distributed to consumers, corresponding to 585,000 kWh. Additionally, another district heating system based on two 300 kW biomass boilers has been implemented at the "Gurteen Agricultural College" as part of the SERVE project.

Wood Biomass Stoves: The efficient wood biomass stoves' production ranges from 3kW to 14kW. By the end of the project, the implemented efficient stoves produced 2286 kW/m^2.

Wood Biomass Boilers: The National Greener Homes Scheme has enabled wood biomass boilers to gain prominence over the past three years. A recent study by the Mid-West regional authority states that a total of around 600 systems have been installed in the Mid-West and South Tipperary. Around 25 boilers, producing more than 450 kW/m^2 , have been installed in the SERVE region.

Solar Water Heating Systems: The SERVE region has installed around 460 m^2 of solar water heaters.

Wind/PV Systems: A 6kW wind turbine was installed at one location produced approximately 8MWh per annum.

Financial and economic aspects of the project

Both residential and non-residential building owners were offered a grant scheme, delivered by the North Tipperary County Council and the Tipperary Energy Agency, to upgrade their properties. The grants were provided if a set of measures are to be implemented when improving the energy performance of a property and not only one single measure. Moreover, the following requirements have to be met to benefit from the grant scheme:

- A BER was required before and after the building upgrades.
- The building must be in the SERVE Region.
- The building must have been built before 2006.

Additional criteria applied for non-residential buildings include:

- The building must be at least 100 m^2 and must have a minimum annual heating expenditure of €1,000.
- Upgrading works identified must result in at least 40% reduction in energy use.
- Buildings and proposed works must possess planning permission, especially in cases of protected structures and houses in Architectural Conservation areas.

The grants scheme, like the project, ran in three phases. Two different types of grants were made available: Energy Efficiency Grants and Renewable Energy Grants. The schemes financed roughly 30% of the improvement costs or renewable measures. Around 350 residential and 11 non-residential buildings were involved in the schemes.

Energy Efficiency Grant Scheme: The most popular and active building improvements were related to insulation and heating systems. Homeowners were eligible to apply for the SERVE Energy Efficiency Grant Scheme as well as for the Sustainable Energy Authority Ireland's Home Energy Saving Scheme (HESS), providing the SERVE grantees achieved higher energy efficiency standards than the HESS alone.

> **Phase 1:** No mandatory measures were required to be provided with a SERVE Grant. Homeowners could choose the energy efficiency or renewable energy investment they wished to undertake. Grants were limited to 35% of the total costs, calculated as €48 per m^2 of the building's heated floor area.
>
> **Phase 2:** The set-up of the SERVE Energy Efficiency Grant that provides €1,000 for mandatory measures (attic insulation, wall insulation & heating controls) and additional one-off payments for further energy efficiency measures (windows & external wall insulation, novel low carbon insulation, flat roof/interior roof insulation, advanced heating controls, high efficiency boilers and cylinders, lighting controls and LEDS). Furthermore, at least two additional measures were required to be completed to receive the grant.

Renewable Energy Grants Scheme: The grants scheme for renewable energy sources followed a similar methodology to that of the Energy Efficiency Grant Scheme.

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Case study 3: Helsingør–Helsinborg (Denmark–Sweden)

Lessons learned and Legacy

Boundaries of a zero-energy/carbon community project could go beyond the administrative limits of a city/country. Opportunities to increase ambition and to reduce cost, especially for energy production, could raise from expanding the boundaries to a neighbouring local authority. Neighbouring municipalities located in neighbouring countries could team-up to achieve ambitious energy and climate targets.

Ambitious climate targets lead to strengthening energy requirements for buildings. Helsingor adopted a climate policy mandating the municipality to reduce CO_2 emissions to less than 1 tonne of CO_2 per inhabitant by 2030 and to become entirely carbon neutral by 2050. To ensure these commitments are met, the municipality is currently adopting stringent building energy performance requirements as well as PV requirements. Helsingborg has adopted an "Energy Strategy Plan" that sets out an energy vision for the city, with concrete energy saving measures for district heating and cooling, wind power, solar power, biogas production, energy use.

Training, capacity building and awareness raising are instrumental to build an ambitious community approach to the energy transition. Training of janitors and SMEs on energy sustainability has created a whole community approach to thinking and acting in a sustainable manner. The different events used to get the information across were well attended. The exhibition was attended by 1,500-2,500 visitors a day. Informational meetings and conferences had around 750 participants, and the Kulturavaerftet welcomed around 2,000 visitors. Further measures and materials include local press articles, pamphlets, posters, working material and action plans. Together these measures raised awareness and consequently saved energy in housing as well as in commercial and municipal buildings.

Beyond energy savings, the energy transition is about the daily life of people. The project's initiatives have improved the quality of life of inhabitants, contributing to local well-being and economic growth. Low energy buildings and new construction approaches in Helsingborghem became the norm. Making energy efficient buildings healthier enhances the acceptability of the energy transition.

Impacts of successful projects go beyond the life-time of individual projects and their location. Although the project ended in 2012, the successful deployment of energy measures has not stopped. The housing company, Helsingborghem, is currently building 300-400 low-energy buildings in Switzerland, using the experiences gained from the ECO-Life building projects. A follow-up project, ECO-Life (2010-2016), is underway. It addresses sustainable living in three European districts. The targets for the ECO-Life project are slightly more ambitious.

Objectives of Helsingør– Helsinborg project

The objectives of the Helsingør–Helsinborg community are to demonstrate an innovative and holistic energy savings approach, focusing on energy-efficient solutions, efficient technology and the integration of renewable energy sources in an optimized interaction. The key components of the approach include energy demand supplied by renewable energy sources, energy efficient renovations as well as efficient new buildings, poly-generation, integration of renewable energy sources connected to buildings and innovative metering. Moreover, the initiative has adopted whole community approach by providing training to SMEs and janitor corporations. The idea behind the project was to stimulate the energy efficiency market by renovating and building state-of-the-art eco-buildings. The urban plan of Helsingør–Helsinborg community (Figure CS3.1) includes the following demonstration projects:

1. 2 MW wind turbine.
2. 5 MW biomass boiler connected to district heating using woodchips.
3. Biogas production based on organic waste.
4. 140 m^2 solar collectors for domestic hot water production.
5. Up to 453 dwellings to be ECO-rehabilitated, in total 35,629 m^2 (>30% savings vs normal standard, energy consumption (all heat and electricity use) of about 100 kWh/m²/yr for refurbishment (65 kWh/m^2.yr for heating and 35 kWh/m^2.yr for electricity).
6. 350 new ECO-dwellings, in total 28,271 m^2, with extra insulation, low-energy windows, demand-controlled ventilation / heat recovery etc.

Figure CS3.1. Urban plan of Helsingør-Helsingborg Community.

Key point: The project is an integrated community approach spreading across two cities located in two neighbouring countries.

Source: ECO-City-project, 2015.

Emergence of the Helsingør–Helsinborg project

Helsingborg and Helsingør are ancient twin cities connected by a 20-minute boat ride over the narrowest part of a 4 km stretch of strait. Helsingborg has a population of 97,000 inhabitants and Helsingør has 46,000 inhabitants. Both towns have set ambitious environmental targets towards creating a more efficient and sustainable future and complying with the goals of the EU-funded CONCERTO ECO-City programme. Past environmental targets include:

- Helsingborg: reduce the total energy consumption per inhabitant by 4% by 2010, reference year 1990, whilst reducing fossil fuels input to the district heating and power system by 20%.
- Helsingør: realise a 30% reduction of energy consumption for heating, hot water, lighting, ventilation and cooling of new eco-houses.

Identified drivers for the ECO-City project include the ambitious climate and energy targets, a prior close relationship between the two cities and motivated and progressive utility companies. The Helsingborg and Helsingør ECO-City project is a holistic and integrated community approach to energy efficiency and a sustainable energy supply.

National and regional energy and climate policies

Øresund (with a population of 3.8 million) is the largest metropolitan region in Northern Europe, with a total area of 21,203 m^2 . The region connects Denmark and Sweden. The Swedish side covers an area of 11,369 km^2 and the Danish side an area of 9,834 km^2. Although a strait separates Denmark and Sweden, they are linked by the HH ferry route (Helsingør (Denmark) – Helsinborg (Sweden)). One of the busiest international car ferry routes with more than 70 daily departures between the narrowest point of Øresund between Helsingør and Helsingborg. The Øresund Bridge (16km long) also connects Copenhagen and Malmo using a "fixed link" that includes a motorway and a parallel railway line [8].

Øresund is an internationally competitive region, accounting for 26% of Denmark and Sweden's combined GDPs. However, the region has a history of industrial pollution and environmental degradation and a long-standing reputation of a polluted and unhealthy area. This history has been a key factor in the "clean-up" of the area, which is now characterised as one of the most dynamic and green regions in Europe. The identity of the district is marked by increased diversity, openness and accessibility and the different traditions and languages of the two countries results in creating a cultural identity and diversity in Øresund.

Several trends, such as "ecological modernisation" and green "branding", have greatly contributed to the development of the region over the past 15-years. Environmental efforts have been in place since early 1990s. These efforts are regarded not only as being valuable for the health and environment of the region but also as stimulating economic growth and cultural attractiveness. The Øresund region has developed an Environmental Programme which states that a healthy environment "is one of the most important preconditions for a positive and dynamic economic development" [9]. The region hosts many cities that are internationally considered as environmental frontrunners, such as Copenhagen and Malmo. Furthermore, the technical department of the university of Lund is one of the global leaders in the field of energy efficiency research and development. Overall, the twin cities of Helsingor and Helsinborg have both ambitious political will towards achieving a more energy efficient and sustainable future. Both towns have both been involved in the EU-CONCERTO funded project to demonstrate innovative and integrated energy concepts.

Major features of Helsingør– Helsinborg project

The twin town project is a model for sustainable development and fulfils several ZED requirements (see Prologue section), such as social equity, citizen engagement, economic efficiency and environmental impacts. Some of the project's successful ZED indicators are discussed below.

Training, skill development and awareness campaigns: Helsingør and Helsingborg have worked together to set up a strategic training event, involving energy efficiency stakeholders. The aim is to create a network and to initiate awareness campaigns to educate schools and citizens on energy saving measures. A significant effort was put into training activities, socio-economic monitoring and dissemination. Multiple training programmes and events have been set up to educate and train all members of society on energy efficiency and energy saving measures. Local janitors and municipal staff members as well as politicians have been involved in the energy plan project. Workshops were set up to increase their knowledge and understanding of energy issues. Subsequently, this spurred the politicians to increase the weighting of energy and climate issues in the local agenda.

Citizen engagement: Between 2007 and 2009, an information campaign was launched to inform all citizens about the project and how to save energy. The campaign took the form of a 45-day long exhibition that occurred once a year during which pamphlets and flyers were handed out to the citizens. Additional measures included seven meetings on urban planning and environmental issues and the ECO-City conference for inhabitants and associations. Moreover, metering system were used to increase citizens' awareness about their own energy use in residential buildings and schools. The metering was also used to track progress in energy reductions. A new type of "comfort metering" system has been implemented in some new municipal council buildings. Users were able to visualise on a screen the monitoring of their energy consumption. The system also covers safety aspects such as fire alarms, burglar alarms and locking systems.

High market players' involvement: Stakeholders involved in the implementation of the project met up for planned and regular reporting meetings to ensure the flow and timeline of the project was on track (utilities, the university, energy consultants, waste companies and the local municipality). An important success factor of the project was the level of motivation and enthusiasm shown by market actors towards the ambitions and the implementation of the project's energy saving measures.

Cultural building: The city farm was renovated into an energy cultural centre used for education on sustainability aspects. It hosts a series of outbuildings and displays for training activities for pupils. The centre hosts, on average, 2 field trips per week.

Setting new standards: Helsingborgshem, the social housing company, has adopted the new low energy building and renovation standards achieved by the ECO-City project.

Governance structure

The project was initiated by COWI and supported by the two municipalities. The business model required the involvement of several local stakeholders working in sustainability. The partners of the project included COWI (project coordinator), Helsingborg city (municipality), Elsinore (municipality), Öresundskraft (utility), Energy Centre, Helsingborgs Hem (municipal housing company), NSR (regional waste management company), Supply Elsinore and Lund University.

Regular meetings were organised under the leadership of COWI. Modern communication tools were used during the meetings. Transparent and open discussions were key in the success of the implementation of the project.

Energy demand reduction and supply with renewable objectives

I. Renovation of existing buildings

The ECO-City project has undertaken the renovation of 600 buildings, with a floor area of around 60,000m^2, out of which 450 were residential buildings, with a floor area of 350,000 m^2, and the remainder were commercial and public buildings, including offices, schools and institutions as described below.

1. Grydemoseskolen, Eco-rehabilitation in Helsingør of a public school of 11,196 m^2. The renovation work included the conversion from natural gas to biomass district-heating and the installation of 144 m^2 of clay PV panels.
2. Prøvestenen, ECO-rehabilitation in Helsingør of an office building of 9,615 m^2. The renovation of the building included a new extension with high-tech-lighting, a control ventilation system and natural ventilation in individual areas.
3. Kulturværftet, ECO-rehabilitation in Helsingør of a cultural institution of 13,000 m^2. The work included the renovation of the old shipyard buildings with low energy lighting and effective dimming, A-labelled pumps and fans, high heat recovery ventilation and 35 m^2 of solar cells on the roof.
4. Parkkvarteret, ECO-rehabilitation in Helsingborg of multi-level dwellings of 3,114 m^2 equivalent to 61 apartments. The 9-storey brickwork building was fully renovated including glazing of balconies, ventilation system with heat recovery, water-saving fixtures and interior insulation.
5. Stattena (block 1), ECO-rehabilitation in Helsingborg of an apartment block of 5,600 m^2. Special ECO-technologies were used including ventilation with heat recovery and insulation of gables.
6. Hamilton, ECO-rehabilitation in Helsingborg of an apartment block of 17,250 m^2. The 140 apartments were renovated with air heating, 230 kW heat pump and energy efficient windows.
7. Vandtårnet, ECO-rehabilitation in Helsingborg of Student apartments of 2.525 m^2. Renovation of dormitory building and installation of 315 m^2 of PV-panel.

Energy savings achieved are summarised in Table CS3.1.

Table CS3.1. Measured final energy consumption of renovated buildings

Final energy consumption (kWh/m².yr)	Standard practice	CONCERTO estimates	Measured consumption	Energy savings
Grydempseskolen	169	119	102	40%
Provestenen	164	111	98	40%
Kulturavaerftet	224	195	159	29%
Parkkvarteret	220	147	100	54%
Stattena	220	147	168	24%
Hamilton	220	137	119	46%

Key point: Energy consumption reduction in renovated buildings ranges between 24 to 54%.

Source: Compiled by the authors.

II. New buildings

Around 300 new eco-dwellings have been constructed with a total floor area of 28,000 m^2 as described below:

1. Maria Park in Helsingborg is a new ECO-dwelling of 6,420 m2 and 64 apartments. The newly built apartments have an optimal use of passive solar, minimal thermal bridges, efficient insulation and high heat-recovery ventilation.
2. Maria Sofia 1-2, 3-4 in Helsingborg are new ECO-light dwellings. 1-2 is a multi-family building of 69 apartments equivalent to 7,098 m2 while the 3-4 is a multi-family building of 130 apartments equivalent to 11,842 m2. The newly built apartments used plaster roof cassettes with increased insulation and a highly efficient ventilation system.
3. Fronten in Helsingborg is a new ECO-dwelling of 5,491 m2 and 50 apartments. The elderly housing in the 14-storey house was made with large concrete elements and a 39-kW heat pump connected to a district-heating network.
4. Portalen in Helsingborg is a new ECO-dwelling of 11,073 m2 and 106 apartments. The multi-family building is a prefabricated concrete building with information technology, 113 m^2 of solar cells and 37 kW heat pump connected to the district heating network.
5. Laröd Östra (phase 1+2) in Helsingborg are two new ECO-dwellings with 1,388 m^2 and 6,544 m^2. In total, 88 apartments were built with optimal use of passive solar, minimal thermal bridges, better insulation, demand-controlled ventilation and highly efficient heat recovery on ventilation.
6. Björka Ödåkra in Helsingborg are new passive houses of 4,003 m^2 and 36 apartments. The two-storey houses are semi-detached and designed as low-energy homes with solar power and connection to district heating.

Energy savings achieved, compared to standard practice, in the newly constructed buildings under the ECO-City project are summarised in Table CS3.2.

Table CS3.2. Measured final energy consumption of new buildings

Final energy consumption (kWh/m².yr)	Standard practice	CONCERTO target	Measured consumption	Energy savings
Maria Park	197	147	144	27%
Maria Sofia 1&2	197	147	117	41%
Maria Sofia 3&4	197	134	104	47%
Fronten	197	113	79	60%
Portalen	197	113	101	49%
Larod Ostra	197	134	107	46%
Bjorka Odakra	197	134	103	48%

Key point: Final energy consumption is lower than standard practices by at least 27%.

Source: Compiled by the authors.

III. Integration of renewable energy supply

Several renewable energy sources have been installed in the Helsingør-Helsingborg community including:

1. 2 MW wind turbine farm.
2. 5,5 MW biomass boiler, energy based on woodchips.

3. Biogas generation plant from waste.
4. 140 m^2 of solar collectors for domestic hot water.
5. PV plants.

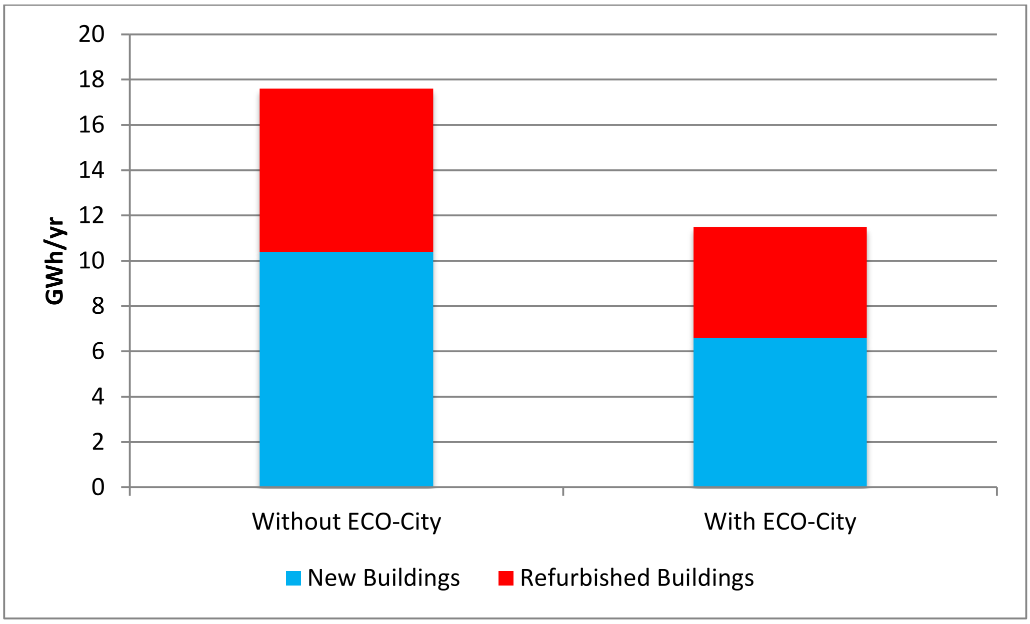
The shared renewable energy sources include:

1. The biogas plant in Helsingborg with a rated capacity of 45 GWh.yr. The plant uses a mixture of material including slaughter house waste, pig manure, pressed household waste, food industry waste, fatty waste, potato peel water and excess sludge.
2. The woodchip biomass boiler in Helsingør with an installed thermal capacity of 5,5 MW. It is estimated to produce around 35,000 MWh.yr.
3. The photovoltaic system with a total area of 148 m^2 and has been installed with a peak supply of 22.5 kW.
4. Medium-sized PV plants with a total area of 134 m^2 have been installed at the Public Swimming Bath and Kulturværftet in 2011.

In total, the project has a RES production of around 106.1 GWh.yr.

The overall reduction in energy consumption in the community is 35% as shown in Figure CS3.2.

Figure CS3.2. Energy consumption of ECO-city buildings compared to standard practices

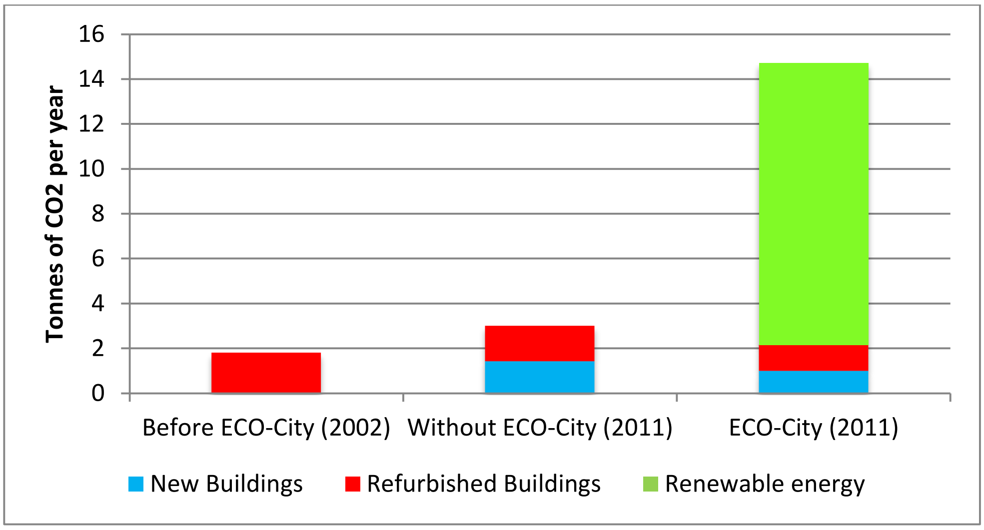


Key point: ECO-city buildings reduced annual energy consumption by 35%.

Source: ECO-City CONCERTO, Coordinators Meeting, 2012.

Energy consumption reduction had a positive impact on CO_2 emissions reduction. In fact, CO_2 emissions from buildings have been reduced by around 1,000 tonnes of CO_2.yr. Moreover, the supply with renewable energy sources has increased the reduction in CO_2 emissions by 12,500 tonnes/yr as shown in Figure CS3.4.

Figure CS3.3. ECO-city CO2 emissions reduction per year



Key point: Combining efficiency and renewable increase CO_2 emissions reduction at local level.

Source: ECO-City CONCERTO, Coordinators Meeting, 2012.

Financial and economic aspects of the project

The average payback period for all the demonstration measures undertaken in the community is 12 years for a total investment of €7 Million, before EU-funding. The two cities used different business investment models. The city council of Helsingør used an ESCO model, whereby the investment was financed by up-front loans.

The eligible cost per floor area of eco-buildings in the Eco-City project were:

- Refurbished apartment buildings: 32 €/m^2.
- Refurbished public buildings: 43 €/m^2.
- New residential building: 50 €/m^2.

The eligible cost for each renewable energy system per floor area or kW is:

- Biomass: 293 €/kW.
- Biogas: 786 €/ kW.
- Wind: 940 €/kW.
- Solar Collectors: 400 €/m^2.

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Case study 4: Hvar Island (Dalmatian coast, Croatia)

Lessons learned and Legacy

Combining energy efficiency measures with supply from renewable energy sources available locally make the self-sufficiency target of European remote islands reachable. Using resources that are indigenous to the region allow the self-sufficiency target to be sustainably viable. Solar thermal collectors, small and large-scale photovoltaic installations and solar cooling allow grasping the solar potential of remote islands. Other renewable energy sources available locally include kitchen and agricultural waste which could be used for biogas production.

The ambitious target of self-sufficiency encouraged the emergence of new stakeholders. Environmental organisations such as LAG Hvar and ECO Hvar have been launched to tackle and support local awareness and capacity building on sustainability issues. The island of Hvar had limited expertise on energy efficiency and large-scale photovoltaic operation prior to the project. The project allowed training local architects, installation companies as well as construction companies on energy-efficient building techniques.

The triggering effect of the project in developing and implementing ambitious energy efficiency and renewable measures has increased significantly decarbonisation activities in the island and in its surrounding. The technical energy performing building and renewable energy projects implemented in Hvar act as local benchmarks for best practice energy efficiency and renewable energy programmes. The lessons learned from the renovation of public buildings (the schools and nurseries) are being replicated to cover other public buildings. The Country of Split-Dalmatia is replicating these solutions to efficiently renovate their total 240 public buildings in the region.

The implementation of the renewable energy plants and the infrastructure that supports the supply of the produced energy act as an example for future projects on the island and can be further developed to cover more buildings. The mix of measures undertaken by the project ensures better security of supply with a solid infrastructure that is essential for the self-sufficiency target of the island.

Up-front securing of investments is needed to ensure project implementation is successful. Some of the proposed measures, such as solar cooling, could not be implemented since there were no interested investors to implement such a system. The primary targets for such systems were large heating/cooling energy consumers (such as hotels, apartment complexes, etc.), which were highly affected by the financial crisis and have significantly decreased their investments.

Objectives of Hvar project

The overall objective of Hvar Island is to demonstrate energy self-sufficiency, up to a quota of 20% by 2020, is feasible in a remote island. Energy efficiency improvements of buildings and low carbon technologies including photovoltaic panels, solar thermal and energetic use of biomass have been deployed to meet the self-sufficiency target.

The main achievements of the project include:

- 11 refurbished buildings.
- 4 new eco-buildings.
- 9 PV systems with an energy production of 45 MWh.yr[5].
- 39 solar thermal systems with an energy production of 150 MWh_{th}.yr.
- 1 biogas plant with an energy production of 200 MWh_{th}.yr and 150 MWh_{el}.yr[6].

One of the biggest opportunities and main objectives of the project is to increase security of supply on the island by refurbishing and optimizing the energy consumption of the buildings in the private and public sectors. It is assumed that the energy consumption will increase driven by the expected economic growth of the island. Therefore, another key objective is to exploit the renewable energy resources available locally.

The objectives of the SOLUTION project including setting-up guidelines for high-performance buildings (targeting a 20-30% reduction in consumption compared to national standard), to encourage consumer engagement, trigger behaviour changes surrounding energy use and, to increase public awareness of the positive impacts of energy efficiency and renewable energy. Finally, an important goal of the project was to develop suitable contracting models (e.g. ESCO) to overcome the up-front investment barrier.

The specific measures were chosen based on a previous assessment of Hvar needs, opportunities and available renewable, as well as waste resources. Since CONCERTO SOLUTION was the first and a one of a kind projects in Croatia, in a remote community, it was important to implement novel technologies. At the same time, proposed solutions had to be practical enough to ensure effective demonstration and implementation of planned measures and technologies.

Emergence of the Hvar project

Hvar Island is part of Split-Dalmatia County. It is located approximately 40 km offshore from the Dalmatian coast. Its total area is 297 km^2, making Hvar the fourth-biggest island in Croatia (72 km long and differs in width, the widest part reaching 10 km). The permanent population of Hvar is around 11,000. However, the population of the island doubles between April and September.

The island, being a remote community that imports most of its food, water and energy, has many related issues that hinder economic development. However, a report undertaken by the University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, claims the island can become 100% renewable and self-sufficient based on the abundance of natural resources (solar energy and biomass). According to this study;

[5] None of the plants implemented in SOLUTION project have the eligible producer status; eight out of nine systems are off-grid systems. The system on School in Svirče is connected to the grid but has a normal tariff setting according to the contract signed with HEP.

[6] The biogas plant included in SOLUTION project is located in the industrial area "Rake" and all appropriate location and spatial plans have already been enacted (a so-called dot-change was done).

the island's 47 GWh energy demand can be met by 2030 by local energy production by implementing energy efficiency measures and the installation of energy efficient devices. In 2009, Hvar was accepted as one of the four CONCERTO Solution communities to demonstrate the feasibility of the concept of self-sufficiency, aiming to make its energy supply 20% self-sufficient by 2020. The CONCERTO SOLUTION project covers the island as a demonstration zone and has undertaken projects in the main municipalities: Stari Grad, Hvar, Jelsa and Sućuraj. It is worth noting that the island has a high number of sunny days as well as olive oil and vinery production. The main economic activity of the island is tourism which increases energy consumption in summer time.

The SOLUTION project in Hvar covers the whole island including the renovation of both private and public buildings, the construction of new eco-buildings and the installation of renewable energy technologies. The icons with the blue sun highlight the areas where solar technologies have been installed, these systems have been co-financed with SOLUTION budget, many additional RE & EE projects have been implemented since the SOLUTION project ended. The red buildings represent building projects and the blue lightning bolt highlights the location of the biogas CHP (Figure CS4.1).

Figure CS4.1. Urban Plan of Hvar SOLUTION Project.

Key point: The energy projects cover the whole island of Hvar.

Source: SOLUTION-CONCERTO, 2015.

National and regional energy and climate policies

Croatia, like most Balkan countries, is dependent on substantial imports to meet its energy demand (more than 50% of its final consumption is imported). Due to Croatia's vulnerability to energy price volatilities, an essential environmental objective is to ensure a secure and reliable regional energy supply. The Croatian 2020 development strategy has three basic objectives: 1) increasing security of energy supply, 2) developing a competitive energy system and 3) ensuring sustainable energy sector development. The Strategy sets out specific sector targets that will support a movement towards becoming self-sufficient in future years, by 2020 Croatia will:

- Decrease greenhouse gas emissions by 20% compared to 1990.
- Increase the share of renewable energy by 20% in annual gross energy consumption of the country.
- Cover 10% of energy consumption in the transport sector using renewable energy sources.
- Decrease final energy consumption by 9% by 2016.

Furthermore, since 1992, Croatia has become more environmentally aware and has developed several energy and carbon policies including: i) the Declaration on Environmental Protection (1992 –mandating all new policies and actions to be drawn up with respect to environmental protection), ii) the Regulation on the Establishment of the Croatian Environment Agency (2002 –collection of environmental data to monitor, evaluate and use when developing future policies) and, iii) Environment Protection and Energy Efficiency Fund (EPEEF) (2003 –a fund was set up to provide financial support to prepare, develop and implement various programmes and projects in the fields of environmental protection, waste management, energy efficiency and renewable energy).

Croatian Islands

The Croatian islands have an insecure energy supply due to their fragile energy infrastructure and weak connections to the mainland. Most Croatian islands rely heavily on fossil fuel imports from the mainland, and grid failures and electricity outages are common occurrences, especially during the peak summer loads. An obvious solution to this is provided by the readily available renewable energy sources that could stabilise energy supply and demand. By exploiting the abundant source of renewable energy provided by the sun and other natural resources, the islands could become self-sufficient and sustainable.

Major features of Hvar project

The island of Hvar is a model for sustainable development and fulfils several ZED requirements (see Prologue section), such as social engagement, economic efficiency and environmental impact. Some of the project's successful ZED indicators are discussed below.

Social engagement through support groups: The historical lack of awareness of the inhabitants on issues such as a lack of energy policy, poor human resources, the present crisis and the island's dependence on the central government did not helped improve the island's economic conditions. However, with the birth of the LAG Hvar and the support from the SOLUTION project, social awareness is increasing, and a commonly accepted vision is now in place: securing an energy supply by increasing the energy efficiency and renewable energy on the island. Additionally, ECO-Hvar, a non-for-profit organisation, was launched in 2013 to improve the wellbeing of the environment, people and animals on the island.

Private sector engagement opportunities: The SOLUTION project undertook a study to investigate the available resources that could be developed as a business model for ESCO companies in the future. The study found various favourable conditions that would enable a successful ESCO market on the island and in the surrounding region. These include: very favourable climate conditions, large number of hotels/apartment houses and larger touristic capacities, large scope of possible services and high potential for achieving self-sufficiency energy initiatives already present on the island. The highlighted opportunities for the ESCO model success include, energy efficiency measures in buildings (public and private), public lighting projects, solar thermal projects, wind turbine farms, waste resource development, tidal power projects, solar cooling projects and island energy infrastructure. The study acts as a stepping-stone from a baseline assessment of an ESCO model to the adoption of ESCO initiatives in Hvar.

Economic opportunities: The SOLUTION project has hosted several workshops and events to inform local entrepreneurs about the business opportunities in energy renovation and renewable energy installations. The entrepreneurs were interested in the deployment of such measures and viewed them to boost local business, green tourism and ensure sustainable development on the island.

Improvement of energy system: As the island's energy infrastructure is weak and underdeveloped, the SOLUTION project used a mixed collection of measures to reduce demand, increase supply and consequently improve the renewable energy infrastructure. Owing to these efforts, the energy system of the island improved, and a positive impact was felt on the island.

Local standards and guidelines: The technical standards set by the SOLUTION project acts as a new guideline for the use of locally available resources to exploit renewable and energy efficiency developments on the island of Hvar. The state-of-the-art technical measures undertaken by the project demonstrate a route towards and provide a technical roadmap for the island to become self-efficient.

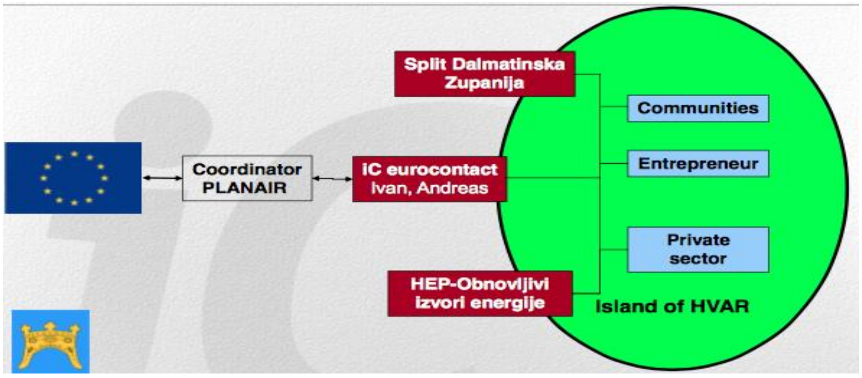
Governance structure

The EU in partnership with PLANAIR (an engineering company who provide advice on energy and environmental issues) initiated the SOLUTION project in Hvar. The project was open to both public and private investors which means that both levels of Island administration could be included in the project (Split-Dalmatia County and Municipalities on the island), as well as private companies and individual investors.

PLANAIR is the scientific and administrative coordinator of the SOLUTION project, responsible for the planning and the design of the innovative energy solutions. PLANAIR was supported by at least three organisations (Figure CS4.2) including:

- iC Eurocontact (iC artprojekt from 2011) - experts in the fields of mechanical engineering, electric engineering, water engineering, geography/urban and transport planning, energy management and HVAC engineering as well as environmental engineering.
- HEP – a renewable energy company owned by the Republic of Croatia. HEP-Obnovljivi izvori energije" is the company within the HEP corporation responsible for RES projects.
- The Split Dalmatian County

Figure CS4.2. Hvar project Organisation.



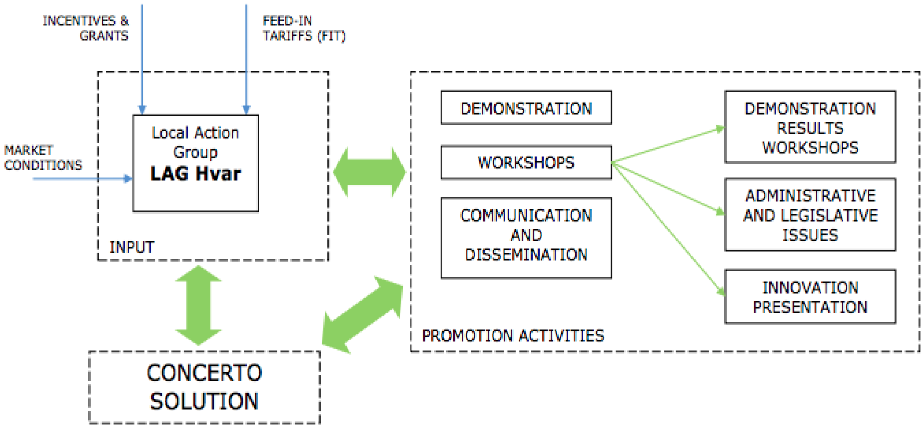
Key point: The organisation of the coordination team includes public, local and private investors.

Source: SOLUTION-CONCERTO, 2012

The CONCERTO SOLUTION project coordination team has approached many relevant stakeholders to ensure their participation, including SMEs, regional authorities, local authorities and citizens (Figure CS4.2). Both regional and local authorities have provided their full support on the project activities, seeing them as viable and essential ways of increasing the security of supply on the island.

Moreover, a Local Action Group (LAG), which is dedicated to ensuring sustainable development on the island, supports the Solution initiative (Figure CS4.3). LAG Hvar is an association that consists of representatives from the island's four municipalities, whose goal is to gather as many stakeholders as possible into one association to promote energy efficiency and renewable energy development. SOLUTION and LAG Hvar have undertaken many demonstration activities to increase consumer awareness and behavioural change as shown in Figure CS4.3.

Figure CS4.3 Hvar project coordination team and activities



Key point: Raising awareness and educating stakeholders on sustainable energy solutions was an important component of the SOLUTION project.

Source: SOLUTION-CONCERTO, 2012

LAG and the SOLUTION team organised workshops and seminars for stakeholders to gain a deeper understanding of socio-economic benefits and renewable energy resource exploitation.

Private companies were involved in the project in the form of investors. SOLUTION provided a framework for private companies to implement energy efficiency measures in their buildings or to install any of the renewable energy technologies included in SOLUTION project.

Energy demand reduction and supply with renewable targets

I. Renovation of existing buildings

Over the lifetime of the project, 11 buildings were refurbished, with a total floor area of 8,506 m^2. The typical measures used to improve energy performance of the buildings include thermal insulation, replacement of old heating and cooling systems and, replacement of windows and doors.

The section below describes the efficiency measures implemented in existing buildings and Table CS4.1 provides a summary of energy savings achieved in each renovated building.

1. Damjanić: 2 dwellings, with a total floor area of 118 m2, were refurbished in 2012. The family houses underwent a thermal renovation of the façade, the windows and doors and the heating systems were upgraded. The overall energy savings amount to approximately 61%.
2. Planjar: 2 dwellings, with a total floor area of 493 m^2, were refurbished in 2013. The buildings underwent a total thermal renovation of the façade, the windows

and doors and the heating energy carriers were upgraded. The overall energy savings amount to approximately 68%.

13. Tomić: 2 dwellings, with a total floor area of 232 m^2, were refurbished in 2013. The buildings underwent a total thermal renovation of the façade, the windows and doors and the heating energy carriers were upgraded. The overall energy savings amount to approximately 74%.
14. Fortuna: 10 dwellings, with a total floor area of 1,044 m^2, were refurbished in 2013. The buildings undertook a thermal renovation of the façade, the windows and doors. The overall energy savings amount to approximately 34%.
15. Matković: 2 dwellings, with a total floor area of 365 m^2, were refurbished in 2013. The buildings underwent a thermal renovation of the façade, the windows and doors. The overall energy savings amount to approximately 44%.
16. School in Jelsa, with a total floor area of 1,701 m^2, was refurbished in 2013. The building underwent a thermal renovation of the building envelope, including the outside walls and the roof, as well as replacement of windows and doors. The heating system was also improved. The overall energy savings amount to approximately 70%.
17. School Stari Grad, with a total floor area of 1,398 m^2, was refurbished in 2013. The building underwent a thermal renovation of the building envelope in the inside of the building as the façade is culturally protected. The overall energy savings amount to approximately 75%.
18. School Hvar, with a total floor area of 1,480 m^2, was refurbished in 2013. The building underwent a thermal renovation of the building envelope including the windows and doors. The overall energy savings amount to approximately 80%.
19. Kindergarten Hvar: The nursery of Hvar, with a total floor area of 869 m^2, was refurbished in 2013. The building underwent a thermal renovation of the building envelope including the windows and doors. The overall energy savings amount to approximately 59%.
20. The kindergarten in Svirče: The nursery of Svirče, with a total floor area of 461 m^2, was refurbished in 2013. The building underwent a thermal renovation of the building envelope including the windows and doors. The heating system and the SHW have been supported with a solar thermal system. The building has also been equipped with a heat pump, a 23 kW PV system and an energy monitoring system. The overall energy savings related to the facade refurbishment amount to approximately 72%.
21. School Sućuraj (A. Anđelinović): The school of Sućuraj, with a total floor area of 407 m^2, was refurbished in 2013. The building underwent a thermal renovation of the building envelope and the windows and doors were replaced. The overall energy savings related to the facade refurbishment amount to approximately 74%.

Table CS4.1. Heat demand before and after renovation of each project

Project	Ownership	Floor area (m²)	Date of renovation	Heat demand before renovation (kWh/m².yr)	Heat demand after renovation (kWh/m².yr)	Energy savings
Damjanic	Private	117	2011	119	46	61%
Planjar	Private	439	2013	156	49	69%
Tomic	Private	232	2013	191	48	75%
Fortuna	Private	1044	2013	54	36	35%
Matkovic	Private	356	2013	83	46	45%
School Jelsa	Public	1701	2013	150	45	70%
School Stari Grad	Public	1398	2013	89	22	75%
School Hvar	Public	1480	2013	96	19	80%
Kindergarten Hvar	Public	869	2013	83	33	
Kindergarten Svirce	Public	462	2013	158	45	72%
School Sucuraj	Public	408	2013	150	39	74%
Total		8506				68%

Key point: Total heat demand saving of the refurbished buildings range between 35% and 80%.

Source: SOLUTION-CONCERTO, 2012.

II. New buildings

CONCERTO funding contributed to the construction of four new buildings, with a total floor area of 3,168 m^2 , described below. Energy savings achieved in each building are summarised in Table CS4.2.

1. Tudor: The Tudor residential building, with a total floor area of 367 m2, was constructed in 2012. Implementation of thermal protection measures ensured the building's heating demand reduced by 70% compared to Hvar standard regulation.

22. Knezovic: The Knezovic residential building, with a total floor area of 304 m2, was constructed in 2013. Implementation of thermal protection measures ensured the building's heating demand reduced by 63% compared to Hvar standard regulation.

23. Prkic: The Prkic residential building, with a total floor area of 175 m2, was constructed in 2013. Implementation of thermal protection measures ensured the building's heating demand reduced by 54% compared to Hvar standard regulation.

24. Travelling terminal Stari Grad: The terminal at Stari Grad, with a total floor area of 2,312 m2, was constructed in 2013. Implementation of thermal protection measures ensured the building's heating demand reduced by 32% compared to Hvar standard regulation.

Table CS4.2. Heat demand in new buildings compared to standard requirements

Project	Ownership	Floor area (m^2)	Date of construction	Heat demand based on current standard ($kWh/m^2.yr$)	Heat demand of the project ($kWh/m^2.yr$)	Energy savings
Tudor	Private	376	2012	71	21	71%
Knezovic	Private	304	2013	94	35	63%
Prkic	Private	175	2013	76	35	54%
Travelling terminal Stari Grad	Private	2312	2013	63	43	32%
Total		3167		76	34	55%

Key point: Heat demand reductions compared to standard practice range from 32% to 71% in new buildings.

Source: SOLUTION-CONCERTO, 2012.

III. Integration of renewable energy supply

The island's goal of becoming 20% self-sufficient by 2020 largely depends on their renewable energy supply meeting the demands of the four municipalities and rural areas. The island has already developed several renewable energy systems including PV plants, solar thermal modules, biomass production and a biogas plant.

1. Biogas plant in Svirče with an energy production of 200 MWh_{th}/year and 150 MWh_{el}/year. Hvar is a home to large amounts of locally available bio-waste resources, primarily from olive oil and wine production. The biogas plant installed is a mobile plant consisting of 4 containers, 3 fermenters and a technical container with a CHP unit, mechanical equipment and an automatic control system for remote control. The fermentation plant uses a certain portion of the heat generated, but not all of it. The plant uses the heat for maintaining the process (fermenters have floor heating systems installed in order to maintain the necessary temperatures when necessary). Also, a heat rejection system was set up. The plant is still in the material testing phase to determine the most appropriate waste mix (olive processing waste, grape processing waste, kitchen waste, structure material, etc.) for maximizing energy production. While the plant is tested, all necessary steps to connect the plant to the electricity grid are undertaken in cooperation with HEP and Split-Dalmatia County. The CHP unit will have a power capacity of 28 kW_{el} and 57 kW_{th}. If more bio-waste is made available on the island, the plant could increase its capacity by adding more fermenters.

25. 39 Solar thermal projects: with energy production of 150 MWh_{th}.yr have been installed on Hvar. They are becoming increasingly popular, as they are the cheapest technological solution to exploiting renewable energy and have a short payback period. Out of the total 39 installed units, 34 are flat plate collectors and 5 are vacuum tube collectors. The solar thermal projects cover a total area of 218 m^2 and the energy production is distributed accordingly to the four municipalities:
    - City of Hvar – 34.178,81 kWh.yr.
    - City of Stari Grad – 25.614,38 kWh.yr.
    - Municipality of Jelsa – 63.850,65 kWh.yr.
    - Municipality of Sućuraj – 25.025,30 kWh.yr.

Both public and private bodies use the solar thermal energy – ranging from public users to hotels, apartment and camps, as well as private users. The 39 units save approximately 64% of the total energy used for domestic hot water (total demand in the buildings with installations is 233 MWh/yr). The carbon savings of the thermal projects are roughly 95 tonnes of CO_2/yr and according to the average for all projects implemented on the island are 0,44 tonnes of CO_2/m^2/yr. The average cost of reducing carbon emissions by deploying a solar thermal system on the island is 1,357 €/tonne of CO_2.

2. 9 PV projects of a total system area of 212 m² and with energy production of 45 MWh/yr with a total area of 211 m2 have been installed on the island. The PV systems are feasible on the island due to the favourable weather conditions. The PV projects were implemented across the island. The 9 units saved approximately 44,91 MWh of electricity (saved/generated), corresponding to a total CO_2 emission savings of approximately 8,38 tonnes of CO_2/yr. The average cost of the PV projects on the island is 3.247,11 €/kW.

Financial and economic aspects of the project

The EU-SOLUTION project awards grant up to 50% of the investment for implemented projects. The sources of funding used to finance the investments in Hvar include:

- Special Purpose Funds – Fund for Environment Protection and Energy Efficiency, Fund for Regional Development - works based on "Calls for application".
    - LPG & solar applications in public buildings on islands.
    - LPG & solar applications in private buildings on islands.
    - Clean technology fabrication facilities: This grant covered 60% of the maximum amount of investment:
        - Public users: up to 60% grants.
        - Private users: up to 40% loan with 0% interest rate, 2 years grace period and 5 years payment period.
- Budgets – national, local and regional authorities (Counties, Cities).
- Incentives – State support for RES technology production; tariff system for energy production from RES and Cogeneration.
- HBOR - Croatian Bank for Reconstruction and Development –supporting feasibility studies and renewable energy development costs with credits that are turned into grants when the projects are realized.
- Different international financing institutions: such as GEF or EIB are supporting renewable energy developments and energy efficiency projects by granting energy audits and feasibility studies and providing financing through Bank Owned Credit lines.
- EU programmes – FP7, IEE, IPA.

Renewable energy – economic aspects

The incentives and grants played a key role in motivating the citizens and developers of Hvar to install renewable energy technologies. The SOLUTION grants triggered additional financing (Table CS4.3) including:

- The Croatian Environmental Protection and Energy Efficiency Fund changed the schemes during the project period: grants can now be obtained for energy efficiency measures (thermal insulation of envelope, replacement of the heating system, replacement of lighting, etc.) and renewables (solar thermal systems, PV systems, etc.) in the case of both public bodies and private investors (individuals and companies).

- Municipality of Jelsa – co-financing of equipment and installation costs for 50 households, 45% of total costs with maximum applicable amount per household determined.
- Municipality of Sućuraj, co-financing of equipment and installation costs, 40% of total costs with maximum applicable amount per household determined.
- Feed-in Tariffs for Renewable Energy Sources of rated power lower than 1 MW.

Table CS4.3. Co-financing opportunities for renewable provided by EU-SOLUTION

	SOLUTION	Municipality of Jelsa	Municipality of Sucuraj	Split-dalmatia county
€/m²	250	N/A	N/A	N/A
Max grant (% of investment w/o VAT)	50%	-	-	-
Maximum grant (% of investment including VAT)	40%	40%	40%	45%
Maximum grant (€)	No limit related to m²	1.579	1.579	1.579
Total average grant (€/m²)	199,66	385,13	385,13	385,13

Key point: EU-SOLUTION funds were bundled with national and local ones.

Source: SOLUTION, Deliverable 2Hv4.4, WP 2Hv.4, 2014.

The SOLUTION grants are linked to the installed area of collectors; the local/state co-financing programmes are related to an average system calculation, whereby a previously described average solar thermal system costs around 3,947.4 €. The main limitations to the state funding are the limit of 1,579 € per project.

PV installation costs: taken from an average of the 9 implemented projects, the cost per kW for the installed systems is approximately 3.247,11 €/kWh, on average, one m^2 of PV systems generates 1,34 MWh/yr and the total cost for production of 1 MWh is approximately 2.407,10 €.

Approximately 29% of total energy demand for SHW can be met with a single m^2 of collector area, it is necessary to install approximately 1,47 m^2 of solar collectors to save 1 MWh of energy, the total cost removing the CO_2 emissions through application of solar thermal collectors amounts to 1.357,82 €/tonnes of CO_2.

Buildings –economic aspects

The average building refurbishment investment costs per square meter for private buildings in Hvar was 120,87 €/m^2. However, there were differences in amounts of refurbishment investment per projects. For example, the largest refurbishment investment cost was 250 €/m^2 in total, whereas the least expensive additional energy efficiency measures investment cost was 59,04 €/m^2. Public buildings that undertook renovations had very similar costs per floor area, with average cost of 0,35 €/m^2. Newly built private houses have average cost of 12,80 (€/m^2) / (MWh/yr), while refurbished private buildings have average cost of 8,71 (€/m^2) / (MWh/yr).

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Case study 5: Stadtwerk, Salzburg, Austria

Lessons learned and Legacy

Urban revitalisation, aiming at improving quality of life and well-being in a neighbourhood, could trigger the implementation of a sustainable energy model. The driving force behind the realisation of the Lehen district was the urban renewal of Stadtwerk area and the availability of funding to upgrade urban services in the neighbourhood. The revamping of the city and the desire to modernise a community allowed for a holistic energy plan to be enacted. Integrating renewable energy sources (solar energy in an urban district heating system) with a sustainable urban development plan with new and renovated buildings. Ambitious targets for the energy performance of the buildings were used as the basis to ensure the area would have a high share of renewable energy, both for heat and electricity demand.

The planning process, with an allocated steering committee and working groups, enabled an organised approach to the holistic urban renewal of the Lehen district. The funding allowed for a group of relevant institutions and personnel to develop and sign a "high-quality agreement" that defined the energy concept of the project and the roles and responsibilities of the main stakeholders. The steering committee and the high-quality agreement have been instrumental in the successful implementation of the energy concept developed by the working groups.

The term "sustainable" has been the central objective of the district, and by concentrating on important issues, such as quality of life, the whole community has benefitted. The sustainable renewal development project of Stadtwerk has been conducted and planned in a holistic manner. Some aspects include high energy performing new buildings, energy renovations and the use of solar energy within an existing district heating system.

Making from each challenge an opportunity towards sustainable development is the best way to overcome barriers to ambitious energy measures. The area of Stadtwerk is densely populated, consisting of multi-city apartments from the 50s-70s that needed renovation. The area faced several social challenges over the past years meaning business parks were abandoned and shopping areas were closed. Due to its central location, the opening of a new train station and critical conditions, the developers decided to improve the quality of life by developing a district that focuses on sustainability.

Replicating and expanding success stories. The municipality of Salzburg has been motivated by the success of the pilot sustainability project in Lehen. A stakeholder process was launched, between 2009 and 2012, to devise a plan for a "Smart City Salzburg" 2050. The process involved housing associations, NGOs, utilities, research institutes and consultants. Twenty-five sub goals were defined in the city council's master plan, 2012. One of them focusing on the development of CO_2 neutral districts. The finalised plan for Salzburg has both short and long-term targets, with the main objectives being based on buildings, energy networks, other urban supply and disposal systems, mobility, communication and information and city and urban regional systems.

Objectives of Stadtwerk project

The primary goal of the Stadtwerk project is to sustainably revitalise the area. The aim is to improve quality of life and well-being in the neighbourhood. Improvement in environment, energy and social life were deemed to be the key conditions for success. The project's main criteria concerning the energy performance of the district include [4]:

- Low-energy standards for new buildings and as economically as possible for renovations.
- High rate of renewable energy supply for the whole area (new buildings and renovations).
- Energy-efficient components in the public electrical applications (especially pumps and lighting).

Moreover, focus was on the energy supply concept of the district, which was optimised by integrating renewable energy sources to the existing district heating system (based on a large share of industrial waste heat resources). The targets of the district were achieved by optimising the energy performance of buildings and by using energy efficient technologies.

The project developers set specific energy performance targets for energy efficiency and renewable energy including:

- Heat demand for new buildings: 20 kWh/m^2/yr (75% below national standard).
- Heat demand for existing buildings: 35 kWh/m^2/yr (75% below national standard).
- High amount of renewable energy in the heat supply system (2,525 kW$_{therm}$ solar thermal collectors and connection to biomass district heating of 50 kW$_{el}$).

Local (micro) district heat (65/35°C) with 2,000 m^2 solar collectors, central storage tank of 200m^3 and electrical heat pump resulting in a solar fraction higher than 30%.

The overall idea was to develop an energy supply system with a high share of renewables, 30% was required by the EU-CONCERTO programme. SOLUTION replicability had highest priority and so the use of the existing district heating supplied by a high share of solar energy was the privileged option. Research focused on the use of heat pumps for increasing the efficiency of solar collectors. Simulations were made to define optimized parameters for a whole system approach (collector field, storage capacity, heat-net-temperatures, heat pump size).

Great challenges were faced with the undefined heat demand of existing building stock in the planning phase (the decision to renovate was made a couple of years later). This required a modular thinking for a whole system approach. Financial issues were not part of the simulations but were an important issue in the realization phase. On one hand, there were limited costs in social housing (technical solutions must be replicable) and national and European funding was necessary for implementation.

Emergence of the Stadtwerk project

Lehen is a district in Salzburg with the highest number of citizens and is situated close to the city centre. Most of the buildings in the area were constructed between the 1950s and 1970s out of which 85% are residential buildings (Table CS5.1).

Table CS5.1 Key statistics of Lehen project

Total area	155,00 m²
Owners	Social and commercial housing associations, city of Salzburg
Existing buildings	50,000m²
Number of dwellings	623
Average age of existing buildings	60-70 years
Type of buildings	85% residential and 15% non-residential
New buildings	105,000m²
Number of dwellings	550
Type of buildings	80% residential and 20% non-residential

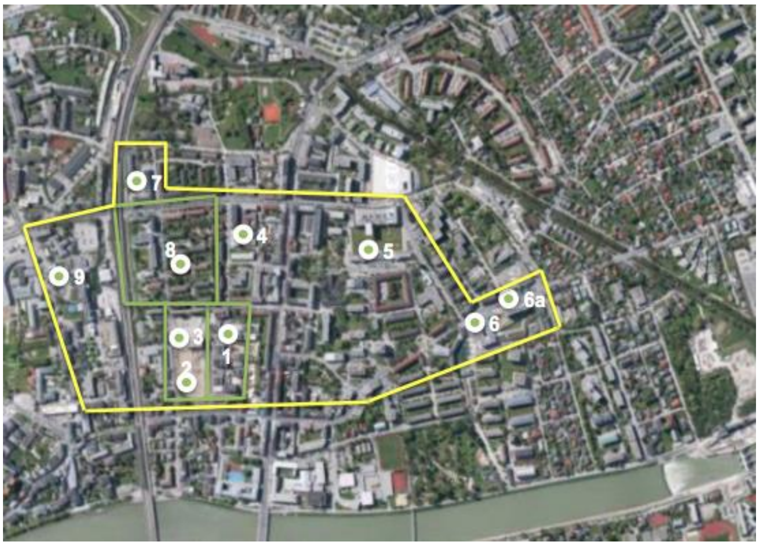
Key point: Lehen district is dominated by residential buildings.

Source: Strasser, Dorfinger, Mahler, 2012

Lehen's renewal project is located on a site where the old football stadium and utility companies were based. The motivation behind the project was based on improving the districts attractiveness. The energy efficiency initiative came from the Salzburg municipality who was involved in the development plan. The ambitious building standards and low carbon heat supply was discussed and started in parallel with the actual project of Stadtwerk. Discussions with relevant Stakeholders of Lehen followed and finally a financial contribution from the EU-funding programme of CONCERTO led to the decision to launch energy efficiency project.

The demolished area prompted the municipality to take a leading role in constructing a new high energy performing residential and commercial area, accommodating a municipal library, shops, a kindergarten, a student's hostel, cafes, an office, a centre for the elderly and 48 subsidized apartments. Furthermore, the surrounding existing social housing building stock is included in the project and has undergone thermal renovation. The new building project covers an area of 105,000 m^2, accommodating 550 dwellings and the renovated area covers 50,000 m^2 with 623 dwellings (Figure CS5.1).

Figure CS5.1. Urban Plan of Stadtwerk and CONCERTO projects



Project	New/ retrofit	Use
1) Stadtwerk Lehen residential part	N	housing
2) Stadtwerk commercial part solar	N	office
3) Stadtwerk Lehen high raised building	R	office
4) Esshaver strasse	N	housing
5) Neue Mitte Lehen solar plant	N	housing
6) Parklife senior residence	N	old-age home
6a) Parklife Apartments	N	housing
7) Kuenburgstraße	R	housing
8) Strubergasse	R	housing
9) PV hospital	N	hospital

Key point: The plan of Lehen shows the concentrated area targeted by the developers.

Source: CONCERTO, Green Solar Cities, 2013.

National and regional energy and climate policies

Austria's "Energy Strategy 2020" includes specific targets regarding the supply with renewable energy sources:

- Overall target: 34% of share of energy generated from renewable sources in gross final energy consumption.
- Heating and cooling: 33% of heat consumption met by renewable sources.
- Electricity: 71% of electricity demand met by electricity generated from renewable energy sources.
- Transport: 11.5% of energy demand met by renewable energy sources.

The strategy for realising these targets is three-fold and includes increasing energy efficiency, promoting and intensifying renewable energy and guaranteeing energy supply for the long term.

Salzburg

Salzburg is an Austrian city that sits along the German border with a population of roughly 150,000 inhabitants. Salzburg's local government has been active in promoting sustainable development and is a member of the European Green Cities Network (EGCN). The city of Salzburg has recently decided to join the European Energy Award.

Salzburg has a large repertoire of emission and energy saving initiatives for environmental protection. A "Smart City" roadmap 2050 has been generated by the municipality. The roadmap has set targets and established a vision for the development into a "Smart City", using district heating and by restructuring the energy supply. In 1998, a development plan was established by the city that included quantified sustainability targets, including goals for improving building performance and renewable energy use [8]. The development plan is coordinated by the municipality and the regional utilities and is based on the optimisation of the existing district heating system. Salzburg is part of the European Green Cities project and has a local strategy that focuses on optimising ecological footprint of buildings while providing a high level of comfort. Part of the strategy uses thermal solar and district heating from industrial waste and biomass. Salzburg has also developed strategies for urban living quarters, such as "A Smart Grid Model Region" which provides a detailed mapping of buildings and heating demand alongside a pilot project for sustainable urban development in Stadtwerk.

Major features of Stadtwerk project

The district of Lehen is a model for sustainable development and fulfils several ZED requirements (see Table 1 of the Prologue section), such as social equity, economic efficiency, environmental impact and citizen engagement. Some of the project's successful ZED indicators are discussed below.

Quality of life: Lehen has used the existing infrastructure to develop new facilities and meeting points for citizens. The general quality of life of the inhabitants has been improved in many ways. The buildings' thermal indoor climate has been improved and, hence, direct comfort and health benefits are seen. Meeting points, green spaces, cultural activities and buildings, shops and a library have been developed by the project for the citizens.

Social equity: Large social housing areas have been constructed and renovated in the neighbourhood. The social centre in the new construction area which organises activities for the elderly and the disabled people from the surrounding districts. The centre offers affordable meals and social activities, and a gym for "70 plus" citizens has been furnished with special equipment.

Citizens' engagement: The development team ensured the residents were integrated into the improvement process by organising information campaigns and ensuring that they were made aware of plans. These measures included leaflets, press releases and a book with a description of changes in the district. The tenants of the new energy apartments are offered personal training on their high-quality equipment. Additionally, a free consulting hotline has been developed to help residents with any technical or usage concerns.

Interactive citizen engagement using a monitoring system: The social housing project's monitoring scheme includes an "Energy Traffic Light" system (Figure CS5.2) that allows a screen visualisation showing the tenants' relationship with their energy demands and share of renewable supply.

Figure CS5.2. "Energy Traffic Light" system.

Key point: The traffic light system provides an interactive way for tenants to understand changes in their energy demand and the share of renewable in their supply.

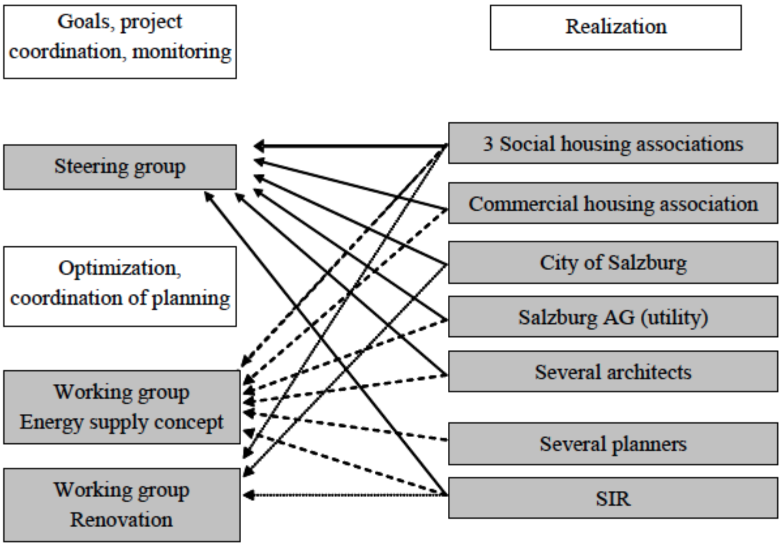
Source: Smartcities, 2015.

Economic efficiency: Skills development was part of the CONCERTO project in Lehen. Workshops were set up to educate local builders and planners on specific building issues, such as air ventilation, renovation and passive houses. The CONCERTO project team also provided public conferences and excursions to educate the workforce on issues such as, technical energy solutions and urban planning and city development towards CO_2 neutrality. The building projects in Lehen have also provided jobs in local companies.

Governance structure

Public and private companies supported the municipality of Salzburg's Stadtwerk plan. Moreover, the EU-CONCERTO funding triggered coordinated action among the project partners. The project developers, the City of Salzburg, several social housing associations and Energy Company Salzburg AG [4] signed a "high-quality agreement" guaranteeing coordinated cooperation and including thermal standards for the buildings and the energy concept requirements [4]. A steering committee and technical working groups were established (Figure CS5.3). EU-CONCERTO, Building of Tomorrow-Programme (BMVIT) and Land Salzburg (Stadtwerk, Salzburg) provided the funding for the Stadtwerk project.

Figure CS5.3. Governance and organisation of Lehen project



Key point: A high-quality agreement was signed by the stakeholders involved in the project.

Source: SIR Salzburger Institut für Raumordnung und Wohnen, 2011.

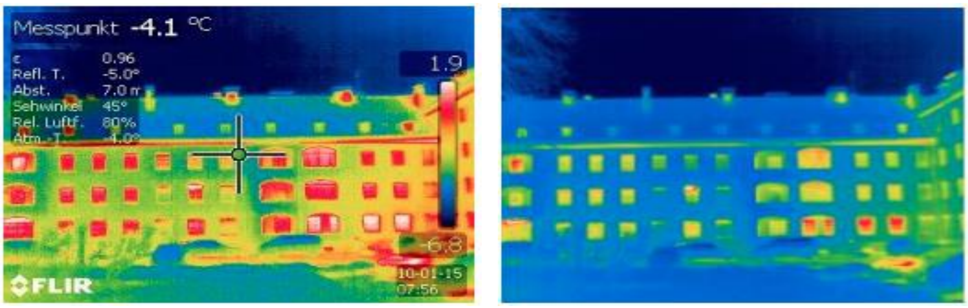
Energy demand reduction and supply with renewable targets

I. Renovation of existing buildings

The objective of the project was to reduce energy consumption and to integrate the use of renewable energy sources to satisfy the heating and electricity demand of the renovated buildings:

1. Stadtwerk Office Prisma is a high-rise office building that was built in the late 60s. It was renovated with advanced technology, internal insulation and a controlled ventilation system to achieve optimum comfort levels and a low energy standard renovation [7].
2. Kuenburggasse is a 45-apartment building with a gross floor area of 4,568 m^2. It was refurbished and connected to the district-heating network. The buildings underwent a high-quality thermal renovation (Figure CS5.4) and an air ventilation system was installed.
3. Strubergasse is a 285-apartment building which have been thermally renovated. 11 houses were demolished and will be replaced by new homes.

Figure CS5.4. Thermographic exposures (before and after renovation)



Key point: The uniform colour on the facade demonstrates the continuous insulating quality.

Source: CONCERTO II, Green Solar Cities, 2013

II. New buildings

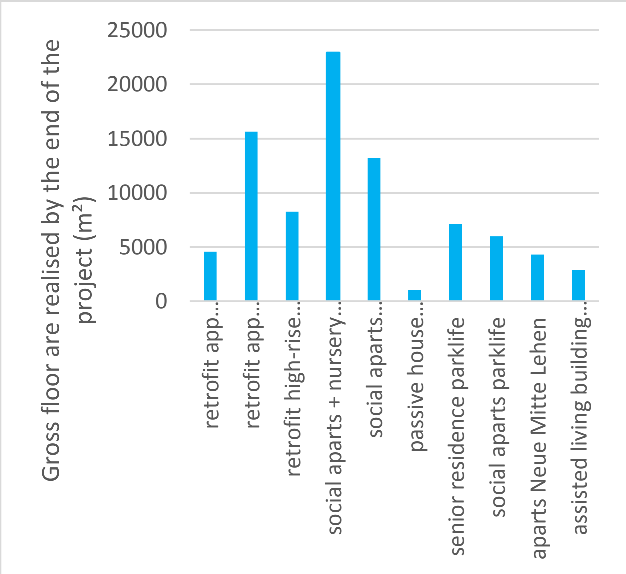
Every new building is connected to the municipal district-heating network covering the remaining energy demand of the buildings not supplied by the solar energy installations.

1. Stadtwerk residential area of 36,117 m^2 floor area comprising of 287 apartments, a kindergarten and a student dormitory (Figure CS5.5). Buildings have a very low energy demand and have been linked with the new district-heating network and a cold air ventilation system with heat recovery has been installed.
2. Esshaver Straße is a low energy building comprising of 12 dwellings, designed to passive house standards (measured thermal consumption annual average is 38.2 kWh/m2.yr). The technologies used to minimise the energy demand include 3-pane glazing, 36 cm thick thermal insulation, 37 m² of solar thermal collectors (for DHW and support of the low-temperature heating) and a mechanical ventilation system with heat recovery [1] [4].
3. "Neue Mitte Lehen" is a new building complex accommodating 48 flats, a new library, a centre for the elderly, a café and a bar. The complex integrates district heating with a solar thermal plant (140 m2) and a buffer tank (30,000 litres).
4. Parklife is a new building which includes a senior day-care centre of 90 rooms, a senior residence of 32 apartments and an apartment block of 56 flats. The buildings have been built according to ambitious energy standards that target the building envelope with humidity steered air ventilation to optimise energy performance. District heating and solar thermal collectors on the roofs supply the buildings' energy demands for domestic hot water and heating purposes.
5. PV Hospital is a new hospital building has been constructed with a 30kWp PV plant located on the roof.

The CONCERTO Monitoring Report of Salzburg indicates that a 78% reduction in fossil fuel consumption between the start of the project in 2007 and 2013[7]. Over the 6 years of the CONCERTO project, the buildings have saved 40% of energy use per year through low-energy design technologies and improved building envelopes. The total energy savings of all buildings equates to around 4,300 MWh.yr of heat demand (Figure CS5.6) and 430 MWh.yr of electricity demand (Figure CS5.7). Additionally, a total area of 2,700 m^2 of solar thermal systems and 50 kWp of photovoltaic panels has been installed [7].

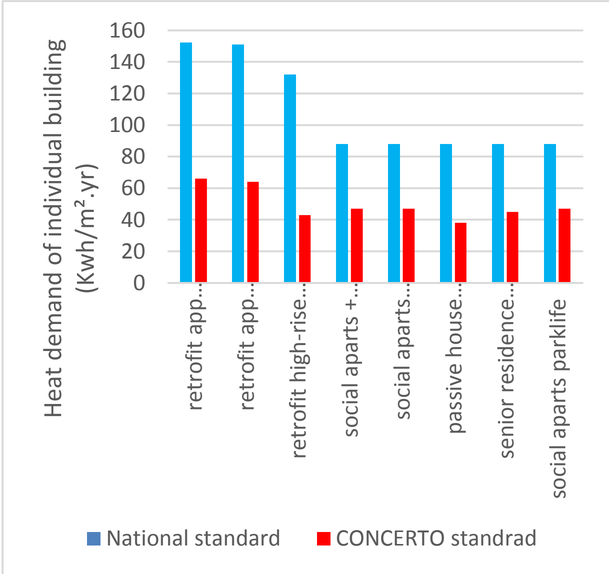
[7] CONCERTO, Green Solar Cities, 2014.

Figure CS5.5. Gross floor area of individual buildings included in the project (m²)



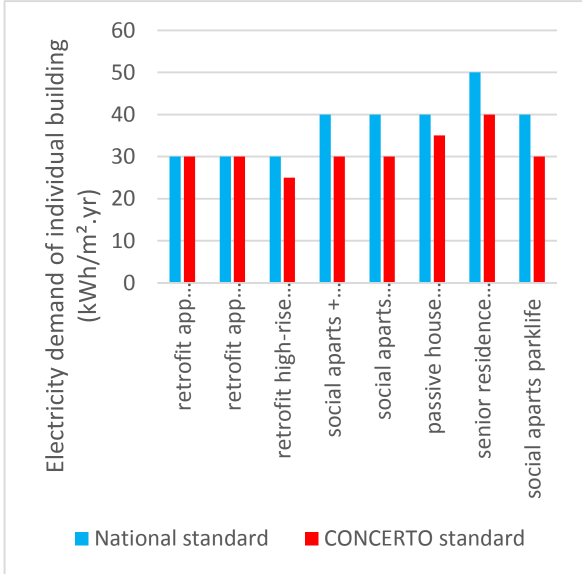
Key point: Total gross floor area of 86,000 m² was included in the Lehen project.

Figure CS5.6. Heat demand of individual buildings (KWh/m². yr)



Key point: Heat demand reduction range from 41 kWh/m².yr to 81 kWh/m².yr

Figure CS5.7. Electricity demand of individual buildings (kWh/m².yr)



Key point: Electricity demand reduction range from 5 kWh.m².yr to 10 kWh/m².yr

Source: CONCERTO, Green Solar Cities, 2014.

III. Integration of renewable energy supply

Stadtwerk's renewable energy supply plan integrates solar energy into the existing district heating network including:

1. Solar collector fields on buildings of 2000 m^2 yields and more than 400 kWh/m^2.yr
2. PV systems, peak power of PV systems ranges from 8 to 30 kWp. The sum of all PV systems results in about 40 MWh/year savings of electricity (with assumed solar gains of 800 kWh.yr).
3. Individual solar thermal systems, the size of collector area range from 38 to 963 m^2, the sum of all solar thermal systems results in about 950 MWh/year savings of heat (with assumed solar gains of 350 kWh/m^2.yr).
4. Micro-network grid distributes the solar energy (together, the district heating system with heat pump and solar thermal system results in about 740 MWh.yr savings of heat (compared to a conventional district heating system).
5. Central storage buffer tank (200,000 litre).
6. Electric heat pump to increase the efficiency of the solar heating system.
7. Heat distribution with low-temperature micro-net (65/35.C).
8. Back-up district heating 50% based on biomass.
9. Solar fraction higher than 30%.

Most of the Stadtwerk buildings (new and renovated) have a very low energy demand and have been connected to the new district-heating network that integrates 2,000 m^2 of solar collectors and a 200,000 litres buffer tank with an integrated solar-heat pump. Increased solar fraction was achieved by installing heat pumps that increase the efficiency of the solar collectors. A micro-network grid distributes the solar energy to the new and existing buildings. The system provides the area with 30% of its demand, and the district heating system supplies the remaining demand. Around 50% of the district heating system is based on biomass. The specific solar yield is more than 400 kWh/m^2/yr and is designed to save 200 tonnes of CO_2/year. The hydraulic scheme's main components include i) solar collector, ii) storage tank, iii) heat pump and iv) micro-grid.

Financial and economic aspects of the project

A high level of political commitment and cooperation between the municipality, the region and the housing associations, using societal discount rate for loans, has ensured that the project was delivered.

Total investment in the project was €107.6 million out of which €1.6 million was provided by CONCERTO funding.

Significant finance was invested in the Stadtwerk solar district as shown below:

- 2.047 m² solar collectors, the solar system investment, including storage, was 1,105,000/2.047 = 540 € / m².
- The heat pump and buffer storage cost a total of €215,000.
- The district heating and micro-grid set up cost €350,000.
- The energy management system and monitoring equipment required €86,000.
- The additional design costs were 8.6 % of the complete package.

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Case study 6: Valby, Copenhagen, Denmark

Lessons learned and Legacy
Ambitious national/regional energy targets lead to ambitious implementation at local level. Valby's commitment to introducing the use of renewable PV solar systems stems from the PV implementation plan (2000) that aims to implement a minimum of 15% PV solar power by 2025. By 2013, around 4 MWp of photovoltaic capacity had been established acting as a key milestone to the realisation of the Danish renewable energy targets. The CONCERTO Green Solar City set out to support the city of Copenhagen's ambitious energy and climate targets by demonstrating the feasibility of renewable solar energy to supply building demand in a focused area. The project has supported knowledge and awareness of energy matters to the district. Furthermore, at a qualified estimate, 500 people have been employed on the projects, averaging 10 people for each project. Leading by example. Since 2004, the introduction of large-scale building integrated photovoltaics in Valby has been extended to cover the whole of Copenhagen by creating the Solar City Copenhagen association. The association has been very active since then. Concurrently, several new buildings and housing renovation projects in the EU-CONCERTO area in Valby have improved their energy frame values between 30% to 79% compared to standard practice. The green image of a neighbourhood is likely to attract new residents. Valby has improved its image and has become a "green" district recognised for its utilisation of low energy solutions and PV installation. The neighbourhood has become a more integrated part of the City of Copenhagen, where young people are keen to live. Hosting international events could contribute to raising awareness on sustainable energy solutions. The COP 15 meeting that was held in Copenhagen was beneficial to raising awareness of these issues and helped to create a "buzz" around energy and the environment. Several 'green" social networks were created by the citizens of Valby. The focus was on issues such as low energy measures and renewables and energy and environment with the aim of improving social integration and employment. Stakeholders were brought together to collaborate on innovative and fun ideas to improve the environment and social wellbeing of the area. Bringing successful practices implemented at neighbourhood level to the national debate on energy renovation. Two of the key project staff are members of an initiative set up by the Danish Ministry on Climate on energy renovation. The initiative holds group discussions on devising a strategy for the climate-friendly renovation of the Danish building stock 2013-2050.

Objectives of Valby project

The primary aim of the Valby PV implementation plan, begun in 2000, is to supply a minimum of 15% of electricity from photovoltaic solar power by the year 2025. The project was developed by the local council of Valby and was supported by the City of Copenhagen and the Danish Energy Agency. In Valby, the public municipalities, and the government of Denmark support the project, as they wish to demonstrate that Denmark can use solar energy to help realise its clean energy and environmental targets with solar energy. As the PV market has not yet reached full market penetration, the project aimed to build innovation in solar energy. The project was realised with the support from the building owners, social housing departments and developers in Valby.

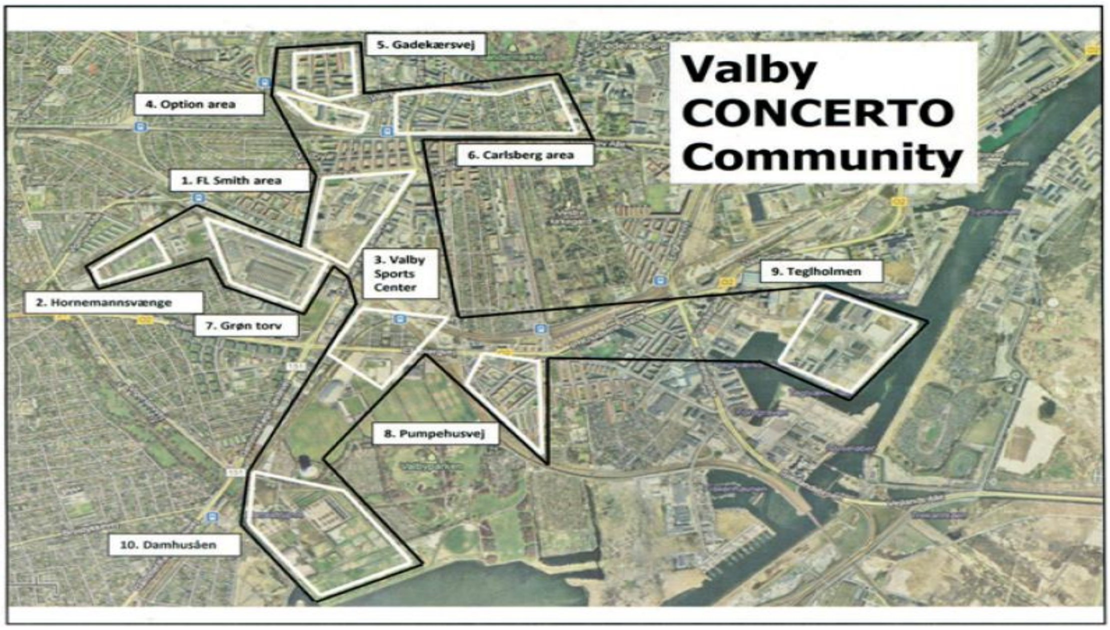
The Green Solar Cities CONCERTO project adopts a holistic approach, with energy efficient construction and installations in buildings designed to produce a comfortable indoor climate combined with the use of optimised energy supply systems and supply with renewable energy sources. Moreover, there is a focus on clear performance documentation to enable lessons to be learned from practice. The aims of the project are:

- Improved energy performance:
    - 288 housing units and 13,500 m^2 of public buildings have been retrofitted by thermal improvement of the building envelope and implementation of integrated renewable energy sources. Total final consumption is 46 kwh/m^2/yr.
    - 50,000 m^2 of new, high energy performing buildings have been constructed.
    - 70% of energy from fossil fuels (MWh/yr) has been saved between the start of the project and 2013.
- Increased use of renewable energy
    - 1,198 kWp PV and 840 m^2 solar thermal collectors have been installed in the new-built and renovated CONCERTO buildings.
- Reduction of greenhouse gases and pollution emissions.
- Enhancement of the competitiveness of the European industry.
- Reduction of the environmental impacts of associated products and services.
- Improvement in the quality of life.
- Implementation of solar cities.

Emergence of the Valby project

The number of inhabitants of the city of Copenhagen is 445,000 citizens, out of which one tenth live in the Valby district and 4,000 are directly involved in the CONCERTO demonstration projects in nine different areas (Figure CS6.1). The intention was to influence energy standards and the use of renewables in anticipated new construction and refurbishment in the residential, commercial and public sectors through the realisation of demonstration project. Valby aims to supply 15% of its electricity from the 30 MWp photovoltaic solar power to be installed by 2025. The objective is to increase the share of decentralised renewable energy systems integrated to buildings rather than large-scale plants.

Figure CS6.1. Urban Plan of Valby



Key point: Showing the CONCERTO demonstration projects.

Source: Green Solar Cities, 2011.

National and regional energy and climate policies

The Danish Parliament has the world-leading vision of complete independence from fossil fuels by 2050. It has introduced wide-ranging measures to achieve this goal and to significantly reduce carbon emissions. In 2011, the "Energy Strategy 2050" was launched, further bolstered by the "Energy Agreement" in 2012. These actions aim at strengthening energy efficiency and at reducing the use of fossil fuels by the energy industry (of 33% by 2020) through the increasing of the share of renewable energy supply of electricity (60% from wind, biomass and biogas by 2020 and 100% from renewables by 2035).

Copenhagen

Likewise, Denmark's capital, the City of Copenhagen, intends to be the first carbon neutral capital in the world by 2025. The city of Copenhagen has adopted the Copenhagen Climate Plan to this end, implementing a range of strategies which combine growth, development and raised quality of life with a reduction of 1.16 million tonnes of CO_2 emissions. An interim objective is that CO_2 emissions are reduced by a minimum of 20% by 2015, compared to 2005. Strong local support for this ambitious goal, which includes extensive retrofitting of buildings, reorganisation of the energy supply and change in transport habits, is essential. In the EU-CONCERTO project, Green Solar Cities, EU funding has been used to install photovoltaic systems in the Valby district of Copenhagen.

Major features of Valby project

The district of Valby is a model for sustainable development and fulfils several ZED requirements (see Table 1 of the Prologue section), such as social equity, economic efficiency, environmental impact and citizens' engagement. Some of the project's successful ZED indicators are discussed below.

> ***Environment group and green identity***: Valby's Local Committee has established a voluntary, open to all, citizens' group which works with the

committee, taking responsibility for local environmental activity in the context of regional initiatives. The Environment Group has formulated a practical framework for the Committee's work in future years to realise its vision that Valby be a town where inhabitants can live and work sustainably and that Valby's green and open environment is preserved and strengthened.
The Local Committee collaborates with Copenhagen Municipality and Valby citizens to achieve ambitious plans for sustainability. Initiatives to reduce energy consumption have targeted homeowners, tenants and businesses. Guidance is provided to help those who live and work in Valby to lower their footprints and initiate new green projects. In 2009, the COP 15 meeting was held in Copenhagen and triggered a general change in attitude, creating a buzz, developing community networks and contacting hard-to-reach sections of society. A Facebook group, focussing on low energy measures and renewables, was set up. A network among immigrants in social housing areas was established, to inform them about energy and environment and to promote social integration and employment. Two low energy renovation projects were set up in the frequently challenging sectors of co-operative housing and private rental. The visionary CONCERTO projects in Valby have given the town a positive reputation for its utilisation of low energy solutions and PV. Importantly, knowledge and awareness of the district has increased, Valby has become increasingly integrated into the City of Copenhagen and is a place where young people want to live. Furthermore, Danish authorities have been learning about the financing of low energy measures and the points system from Austrian partners.

Social equity: New and high-energy performing buildings (50,000 m^2) have been constructed in Valby. The Langgadhus centre for the elderly (8,723 m^2) consists of 68 dwellings, plus service areas, with 59 connected social housing units (100m^2 each). This building's heating is supported by 200 m^2 of solar thermal collectors. In the Karensminde area, 36 low energy prefabricated buildings have been constructed to provide "affordable housing for normal income families". At Dronning Ingrids Plejehjem, a development with 132 dwellings for elderly people, triple glazed windows and 60 m^2 of solar thermal collectors were instaleed on the roof. In addition, the new Water Culture House, a public indoor swimming pool, is supplied by district heating and a photovoltaic system.

Skill development: An estimated skilled workforce of 500 is required to undertake Valby's energy measures. The Valby Campus of the Copenhagen Business Academy offers a 2-year Environmental Management course for students interested in working in environmental issues. CONCERTO has supported the first prefabricated dwelling business in Denmark in Valby, this is expected to be a profitable new line of business. Permanent new jobs have been created in a Heat Recovery Ventilation company.

Governance structure

The vision of the project was created by the local council of Valby, Copenhagen Energy (the utility at that time), The Urban Renewal Company Copenhagen and CENERGIA and was supported by the city of Copenhagen. Later, the project was further supported by the EU CONCERTO programme. At that time, the group of stakeholders were called "the Valby Group". This was developed into the Solar City Copenhagen which is today known as the Solar City of Denmark.

The Valby PV plan places great emphasis on the continuous involvement of local groups and organisations. During the project, special Research and Technical Development theme groups were established. Two key personnel from Green Solar Cities, the initiator and technical coordinator, Peder Vejsig Pedersen, and the administrative coordinator, Jakob Klint, instigated the plan in 2000. In addition to his role in Green Solar Cities, Pedersen is Director of the energy Specialist Company, CENERGIA, and Chairman of the

Danish Association of Sustainable Cities and Buildings (FBBB). Jakob Klint was Project Leader at the Copenhagen Urban Renewal Company that is now Kuben Management.

Energy demand reduction and supply with renewable targets

I. Renovation of existing buildings

The Hornemannsvænge estate in Valby consists of six blocks (total area of 22,230 m^2), and 288 dwellings (16,580 m^2) and was given a low energy retrofit between 2011 and 2013. A solar energy combined heat and power solution, using both PV and solar thermal energy, is supplemented by energy from Copenhagen's large combined heat and power plants. The roofs have been renewed and installed with 14 kW (100 m^2) PV and 100 m^2 solar thermal systems. In addition, following a pilot project in one dwelling, a ventilation system with heat recovery was installed in all apartments. Final energy consumption is 46 kWh/m^2/yr.

II. New buildings

Traditional commercial activities in the southern district of Copenhagen Harbour have mostly disappeared or moved, this has made space for new office buildings and residential areas. In Valby, 50,000 m^2 of new, high energy performing buildings have been constructed.

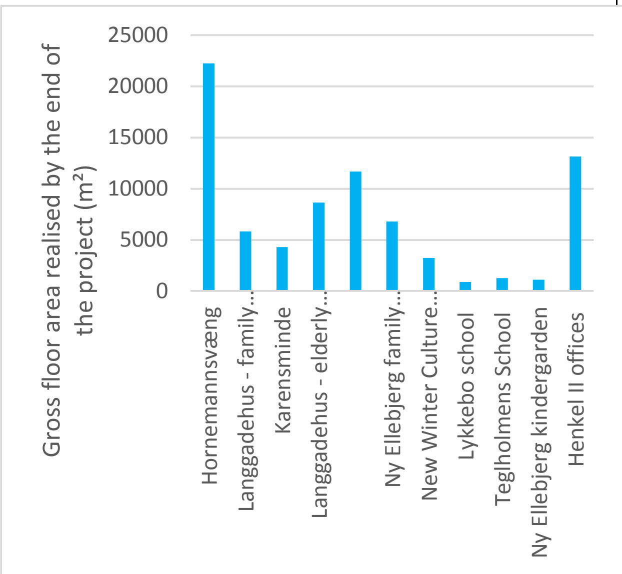
1. New dwellings at Karensminde: In the Karensminde neighbourhood of Valby, the first dwellings of an ambitious affordable social housing programme were constructed in 2008. The aim was to build 5,000 affordable homes in Copenhagen. Initiated by Ms Ritt Bjerregaard, the former Mayor of Copenhagen, and supported by CONCERTO, the programme is now being run by the KAB housing association and is spreading out over the whole Denmark. The project consists of the construction of 36 apartments and one common house, with an area of 4,300 m^2, using prefabricated room-sized modules made in Estonia. Lightweight prefabricated housing is a technology relatively new to Denmark. This solution enabled construction costs to be kept low. In addition, there were energy benefits. Construction to the low energy class 2 standard of the Danish building code (25% better than required) plus improvement to reach CONCERTO standard (30% better) and homes are heated by district heating. In Spring 2010, the buildings were equipped with photovoltaic systems (30 kWpeak in total). Subsequent monitoring has indicated that the buildings are meeting their energy class. In fact, final energy consumption of these dwellings is below 60 kWh/m².yr.

31. New Dwellings in Ny Ellebjerg: The Ny Ellebjerg development consists of 52 units of shared family social housing for people with physical and mental impairments (6,800 m^2), 30 housing units for elderly people plus a kindergarten, catering for 5 groups (1,100 m^2). The project has been designed by Vandkunsten Architects, in collaboration with KAB housing association, to construct a low energy Class 1 housing area. The developed balanced building concept will be used for rooftops dwellings. An optimized connection to the district heating network is considered, including the use of solar heating and a focus on low electricity use for ventilation and other purposes with integrated survey. Final energy consumption of these buildings is below 40 kWh/m².yr.

32. New-build elderly in Langgadehus: Langgadehus, completed in 2011, a centre for the elderly, which incorporates service areas and 68 apartments on the ground and first floor. 59 family-sized (100 m^2) units of social housing have also been constructed on the second and third floors (total 14,466 m^2). The prefabricated rooftop apartments have been built according to the Energibo carbon neutral rooftop concept and the building is supplied with 200 m^2 of solar heating. Final energy consumption of these buildings is around 93 kWh/m².yr.

33. New-build elderly in Dronning Ingrids Plejehjem: Dronning Ingrids Plejehjem is a new facility for elderly people comprising of 110 apartments with connected service facilities and a total area 11,671 m^2. CONCERTO project has led to the installation of triple glazing windows and improved insulation. As hot water consumption in the building is expected to be high, 60 m^2 of thermal solar collectors have been set up on the roof. Final energy consumption of these buildings was at 44 kWh/m².yr.
34. Teglholmens skole/Sydhavn skolen (School): Teglholmens School is intended as the primary school for the new developments and existing urban areas of Valby. Construction began in 2011 but was interrupted just before completion, by a fire in November 2012. This has resulted in only the kindergarten and some sport facilities (1,260 m^2) being included in the CONCERTO project (originally 10,500 m^2). It was anticipated that the building would be ready for use in summer 2014. The building's energy performance is Low Energy Class 2015 with a final energy consumption of 38.9 kWh/m²/yr.
35. Lykkebo skole (School): The new sport facility (896 m^2) was an extension added to an existing school, Lykkeboskole, which was completed January 2011. The building is low energy class 2 and to CONCERTO standard. A 3.8 kWp PV installation was integrated on the roof. Final energy consumption of the school is 92 kWh/m²/yr.
36. Henkel II (Building A): These offices will be in two large old industrial buildings undergoing substantial retrofitting with high overall savings targets. The total area is 13,149 m^2 but only 6,840m^2 is included in the CONCERTO project. However, the remaining parts of the buildings are being renovated to CONCERTO principles. There has been an extensive use of green roofs, together with a ground coupled heat pump connected to air conditioning. Final energy consumption is 26.7 kWh/m²/yr.
37. The Water Culture House in Valby Sports Park: The Water Culture House (3,230 m^2) is a low energy performance indoor swimming facility with state-of-the-art building design and water treatment technology. Air and water temperature are at least 28 degree Celsius to achieve optimum comfort for users. It has found favour with Valby families for both the quality of the building and its facilities since its launch in March 2012. The building's electricity supply is complemented by a 19.1 kWp PV system and heat comes from the district-heating network. A monitoring programme has been operating since its opening. Final energy consumption is 34 kWh/m²/yr.

The CONCERTO Monitoring Report of Valby shows that a total of 70% of energy from fossil fuels (MWh/yr) has been saved between the start of the project and 2013. The total energy savings of all buildings equates to around 4,000 MWh/yr of heat demand and 1,000 MWh/yr of electricity demand as shown in the figures below.

<table>
<tr><th>Figure CS6.2. Gross floor area of each individual buildings</th><th>Figure CS6.3. Heat demand of individual buildings</th><th>Figure CS6.4. Electricity demand of individual buildings</th></tr>
<tr><td>
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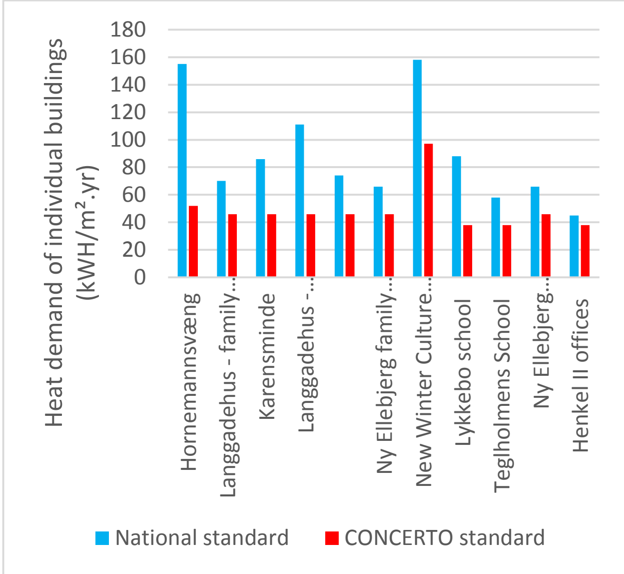
<td>
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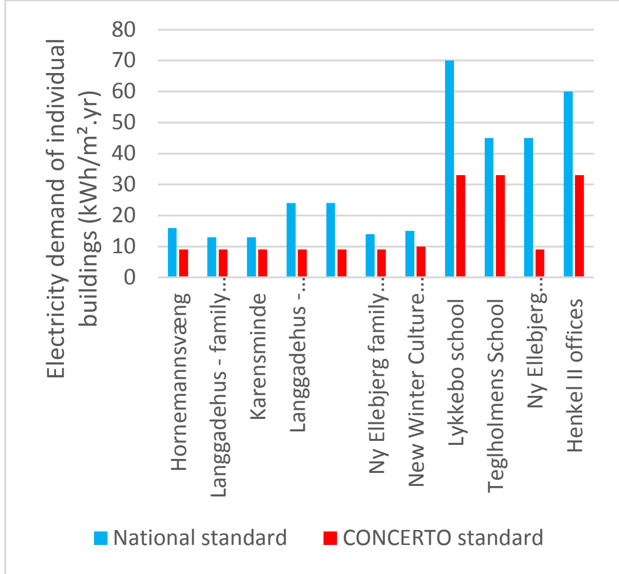
<td>
</td></tr>
<tr><td>Key point: A total gross floor area of 79,000 m² was included in the CONCERTO project.</td><td>Key point: Heat demand reduction range from 7 kWh/m².yr to 103 kWh/m².yr</td><td>Key point: Electricity demand reduction range from 4 kWh/m².yr to 37 kWh/m².yr</td></tr>
<tr><td colspan="3">Source: CONCERTO, Green Solar Cities, 2014</td></tr>
</table>

III. Integration of renewable energy supply

By 2013, around 4 MWp of photovoltaic capacity had been provided. Since 2004, the aim of introducing large-scale building-integrated photovoltaics was extended to cover all of Copenhagen, through the creation of the Solar City Copenhagen association. Since then, the association has been extremely active. At the same time, several new buildings and housing renovation projects in the EU-CONCERTO area in Valby have improved their energy frame values between 30% and 79% compared to normal practice.

- PV plan: The Valby PV plan (Figure CS6.5) aims to provide 15% of electricity from solar energy by 2025. The work on BIPV (building-integrated PV) demonstration projects in the Copenhagen area began in 1992, with EU support for the 'PV in Valby' project. In 2000, a PV plan for the entire district of Valby was launched, in cooperation with the Urban Renewal Copenhagen company, the local electricity company, Copenhagen Energy, and the municipality of Copenhagen.

Figure CS6.5. PV plan for the district of Valby.

Key point: PV plants are located in every area of Valby

Source: Green Solar Cities Publishable Final Activities Report 2007 – 2014.

38. Damhusåen photovoltaic plant: As part of the renewable energy contribution in Valby, a large 777 kWp PV solar plant for a wastewater treatment plant has been installed, the largest PV system in the Nordic countries. The PV plant is situated on top of a former 20,000 m² wastewater sludge deposit. The system occupies an area of approximately 14,000 m² of secured landfill with a built-in liner below the grass. This land would have been otherwise unusable for many years due to pollution from wastewater residues. An area of about 10,000 m² is required for the 3,500 m² of PV-modules. They are installed with a 45-degree slope and at a specified distance between PV rows to avoid mutual shading. The PV system supplements biogas-based electricity production to provide almost 50% of annual electricity demand through renewables. Electricity production is calculated at 850 kWh/kWp, it is anticipated that a total of 425,000 kWh will be produced annually.

39. Stakhaven PV: Photovoltaic panels have been installed in 8 housing blocks owned by the FSB housing association. PV is used in combination with asphalt layer roofs to provide for domestic electricity use. A total of 69.1kWp have been installed, oriented South-Southwest at a 15-degree slope. Electricity production is 63,000 kWh/yr.
40. Lyshøjgård PV: A/B Lyshøjgård was completed in spring 2013. The architects combined PV with new red tile roofs and extra roof insulation (200 mm). The plant size is 73,500 m² producing 62,000 kWh/yr.
41. Valby Sports Hall area PV: On the roof of the old Valby Sports Hall, the Copenhagen PV Cooperative has installed 22 kWp PV modules. The PV electricity is sold to Copenhagen Energy/ DONG Energy in a special solar stock exchange feed-in tariff scheme and is recorded every month. All photovoltaics are oriented South with a slope of 30 degrees.
42. Valby Citizen Centre PV: 12 kWp PV have been installed on the roof and gable. In addition to this CONCERTO action, PV has also been implemented along a pathway in combination with lighting savings.
43. Sjaeloer Railway Station PV: Sjaeloer is the first station in Copenhagen where PV modules supply energy for platform LED lightning. An on-going process of renovation of all the railway stations is likely to repeat this energy optimisation of lighting and PV integration on platform roofs. The total size of PV is 18 kWp.
44. Roofs of buildings: Several buildings in Valby have adopted different PV approaches. At Karensminde, 30 kWp PV was implemented on low cost housing. At Hornemanns Vænge, the housing retrofit has included the use of 60 m² PV and 60 m² solar thermal collectors for each of 6 housing blocks. At Langgadehus, a 200 m² solar thermal system has been introduced. Photovoltaics have been integrated in balconies in Folehaven.
45. Small scale PV installations: 30 installations have been implemented with a total installed capacity of 40,7 kW PV.
46. BIPV (Building Integrated PV): In 2011, BIPV was installed in 90 apartments, with 45 kWp PV (approximately 360 m^2). This was the first BIPV installation in Copenhagen to be permitted where it was visible from street level. This change in policy arose from the recognition of the importance of Copenhagen's climate plan objective, CO_2 neutrality by year 2025. Due to the location of the apartments near the "City lakes" and the busy "Fredensgade", the project involved intense and detailed dialogue with the chief architect's office in Copenhagen. The PV system consists of 28 kWp PV on sloping roof areas and 17 kWp PV on the flat roof.

Financial and economic aspects of the project

The Valby PV Implementation Plan and the Solar City Copenhagen co-operative have been supported by the Municipality of Copenhagen since 2000. Supplemental funding has been obtained from the EU and the Danish Energy Agency. In the Green Solar Cities EU CONCERTO project, Kuben Urban Renewal, Denmark acted as administrative co-ordinator, CENERGIA (DK) as technical co-ordinator and European Green Cities (DK) were responsible for the dissemination of information.

The support from the EU for the development of eco-buildings was 21 €/m^2 and 1,600 €/kWp PV. During the project period, 2007-2013, the installation price of PV decreased dramatically, which enabled the project team to raise the amount of the installed effect. The total eligible cost of eco-buildings and renewables systems of the project was around €5.128 Million out of which €5 million was a direct EU support to the project.

For each building project there were individual negotiations. For the large refurbishment projects in Valby, EU support was able to make the expenditure on renewables and low energy measures a good investment with a short payback period of 10-years (excluding EU-funding) and 7-years (including EU-funding).

The combination of PV, solar power and ventilation with heat recovery lead a kind of energy performance contract with the tenants and an agreement on the investment. Small PV panel projects were implemented through collaboration between DONG Energy (the power supplier) and Green Valby (the local Agenda 21 office). Green Valby performed the marketing to the citizens of Valby and DONG Energy installed equipment and guaranteed performance. They were able to market panels to residents at an economic price. Energy savings and related costs in Valby is based on 2006/2010 Danish energy regulations and is as follows; total saved electricity was 644 MWh which was equivalent to € 146,188, while total saved heat was 5,839 MWh which is equivalent to €280,272.

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Case study 7: Zaragoza (Aragon, Spain)

Lessons learned and Legacy

Setting new construction standards based on bioclimatic design principles. The RENAISSANCE project showcases examples of new bioclimatic building design. It has been successful in showing how energy savings can be achieved in social houses without increasing the cost if bioclimatic design principles are considered at the design stage of the project. The final outcomes of the new bioclimatic buildings and the efficient renovations can be used as a model for replicable and affordable projects, boosting the economy in a region.

Socio-economics research help the developers understand what residents think of innovative techniques, the habits that people have and the habits that should be adopted when thinking of bioclimatic design. The robust data obtained from the research allowed building trust in developers and policy makers. Additionally, the knowledge gained surrounding the importance of behaviour patterns spurred an information and awareness raising campaign that informed the local inhabitants of the importance of energy savings and provided solutions and advice on how to save energy in the household. The information gained from the monitoring systems, with over 200 control points, enabled the evaluation of different architectural solutions to better plan and future-proof high-energy performing buildings in Zaragoza.

The project was able to develop a comprehensive R&D programme that addressed all phases of the construction process from planning, design, construction to operation and maintenance. The activities carried out over the lifetime of the project have provided good case examples of how innovative ideas can strengthen the capacity of the workforce and stakeholders. The importance of data. The R&D undertaken by the project was a key success factor.

Political will and scientific evidence based on robust data could remove legal barriers. One of the barriers faced by the project developers was the old planning law that hindered the development of energy efficient buildings. Robust data obtained from monitoring studies and the commitment shown by the public and private companies as well as the political will of local authorities have allowed changing the town-planning rules.

The project supported policy developments in the region. New Building Energy standards based on the success of the bioclimatic buildings have been developed. Furthermore, a new social acceptance of this type of construction has been felt and the neighbourhoods are developing "greener" mentalities. Moreover, a new local by-law has been set to the project's building standards and Zaragoza has developed a new legal regulation tool to ensure all new and renovated buildings adhere to the energy saving, energy efficiency and renewable energy guidelines.

Successful projects boost support to sustainable development in the construction sector. Following on the project's success, several amendments to municipal laws were signed to support energy renovations and renewable energy, with a focus on low-income and vulnerable families. The municipality became a frontrunner in bioclimatic design.

Objectives of Zaragoza project

The EU-funded RENAISSANCE project in Zaragoza has triggered new bioclimatic construction activities and demonstration projects based on energy efficient design and energy savings. The fundamental goal of the project is to promote the adoption of high-performing bioclimatic buildings as standard practice and to research and develop mechanisms for this that are attractive to public authorities, public and private investors and are practical and replicable for constructors and the workforce. The aim is to have an impact on the overall energy demand of the neighbourhood. The project has been carried out in two districts of Zaragoza with complementary approaches:

- Valdespartera district is an ancient military precinct in the suburbs that has been transformed into a new bioclimatic neighbourhood with 9,650 social housings.
- The "Picarral" neighbourhood was planned in the 1940's during the rural-urban migration with very poor-quality construction. This area involves the renovation of social housing buildings and a public school.

The municipality expects the demonstration activities to provide evidence-based solutions and benefits to promote more sustainable and feasible building and renewable construction in Zaragoza that can be applied further afield. The objectives are threefold:

- Rational Use of Energy (RUE): The two communities ("Picarral" and Valdespartera) collectively aim to achieve reductions in energy consumption, from a minimum of 39% to a maximum of 71% above current building standards, through innovative urban planning, building design, specification and management practices.
- Use of Renewable Energy Systems (RES): The two communities collectively aim to achieve increases in the supply of renewable energy, from a minimum of 40% to a maximum of 60% of the resultant energy demand, for heating, cooling and power, based on the implementation of cost-effective biomass, solar and wind generation systems.
- The environmental impact of the energy supply for communities will be reduced by an integrated approach to energy management involving innovative management practices and advanced energy services to achieve energy efficiency increases and reductions in installation/operating/maintenance costs.

Emergence of the Zaragoza project

The RENAISSANCE project was set up to promote the adoption of high energy performance criteria for new and existing buildings and to increase the use of renewable energy, both to show that building innovation and significant savings are technically achievable in the semi-arid climate of Zaragoza. An important aspect of the project was the comprehensive showcase programme for Research and Technical Development (RTD) and dissemination of activities. Moreover, research was carried out on energy performance monitoring, socio-economic studies and software design in order to ensure the building districts are constructed in a holistic manner whilst integrating renewable energy systems on a neighbourhood scale. The project has been carried out in two districts of Zaragoza with complementary approaches:

- Valdespartera district is an ancient military precinct in the suburbs that has been transformed into a new bioclimatic neighbourhood with 9,650 social housings. In Valdespartera, specific actions have been taken to develop 616 bioclimatic apartments, with a total floor area of 64,027 m2. Moreover, an interpretation centre on urban sustainability (CUS) has been built. The neighbourhood was designed to follow a bioclimatic and sustainable urban design plan. The participation of public institutions, such as the municipality, has been key to the success of the district. The municipality initially prompted the idea of the eco-neighbourhood to adhere to their sustainable development commitments and created the institute, "Ecociudad Valdespartera Zaragoza", which is responsible for the management, design and construction of the neighbourhood. Renewable energy is integrated into the neighbourhood on selected and appropriate buildings. A total of 654 m^2 solar thermal panels for DHW has been installed on the apartment buildings and a 45kW geothermal and reversible wastewater heat pump has been installed on the CUS and integrated with a biomass boiler of 37kW.

- The "Picarral" neighbourhood was planned in the 1940's during the rural-urban migration with very poor-quality construction. This area involves the renovation of social housing buildings and a public school. The working class mainly occupies the "El Picarral" neighbourhood. This pilot project involves the bioclimatic refurbishment of 70 social residential buildings and a public school. This area was the first of its kind in Spain and hence, attracted public attention. The municipality, Ayuntamiento de Zaragoza, led the work. The integration of renewable energy sources played a role in reducing fossil fuel energy consumption of this neighbourhood, an 18 kWp photovoltaic system has been installed on the roof of the public school, Cándido Domingo. Additionally, 240 m^2 of PV panels have been installed on the roofs of the renovated social dwellings.

National and regional energy and climate policies

Zaragoza (Saragossa in English) is the fifth largest city of Spain. It is situated in the northern part of Spain located on the banks of the river Ebro. It is the capital city of the Zaragoza province and has a population of more than 700,000 inhabitants covering an area of 1,062 km^2. The city has a long history, famous for its folklore, and hosts some historical landmarks and is UNESCO World Heritage Sites. In recent years, it hosted a world fair on water and sustainable development in 2008 and was a candidate for the European Capital of Culture in 2012.

The Municipality of Zaragoza is recognised as a source of exemplary energy efficiency and energy savings in the region thanks to its successful implementation of a bio-climatically designed (double orientation, solar collectors, social housing area in the Parque Goya neighbourhood (see Box CS7.1). The energy policy of the municipality has set 2010-2020 targets of reaching a 24% reduction in energy consumption and a 35% increase in renewable energy in order to realise CO_2 savings of 24%.

Box CS7.1. Bioclimatic criteria adopted to Zaragoza Mediterranean microclimate

The urban plan was designed according to the Zaragoza climate and the building design techniques following a "right to the sun" methodology that optimises the distance between buildings and specifies a maximum building height. Zaragoza is situated in a particular microclimate in the Mediterranean climatic zone, with cold winters, hot summers, and a very strong wind called "Cierzo". Thus, the buildings needed to be designed for both seasons, with high insulation levels (compared to the rest of Spain) and a particular relationship with the sun. The design of the buildings, streets and vegetation was part of the city's urban plan and sustainable as well as energy efficiency regulations were imposed on the promoters and developers by the city plan, the "planeamiento".

Buildings: The mandatory building regulations included considering double orientation, double carpentry in the north façade and more insulation, south façade with galleries to benefit from the sun, more renewable resources (solar panels) for general installations of the building. Large glazed surface areas were South-facing (around 35 or 40%) to ensure the buildings gain heat from the sun during the winter months and overhangs for sun shading were implemented to reduce heat in the summer months. Overhangs were efficient for the Southern façade. However, the West facade faced some difficulties with high summers temperatures at 17:00 with the low sun in the West). In order to overcome the overheat sun protection such as lattice works was installed. Double frame and single frame windows of A3 standard (air-tightness) were used for the windows in the North and West as protection from the strong North-western wind.

Vegetation: deciduous trees were used to benefit from the sun in winter and protect in summer.

Street design was used to protect the buildings from the wind and streets were designed to provide access to garages inside the blocks designed in a sinuous way to avoid speeding.

A key contributor to the change in the strategy of energy administration in Zaragoza is the EU-funded RENAISSANCE project that has triggered new bioclimatic construction activities and demonstration projects based on energy efficient design and energy savings. Moreover, the Zaragoza Municipal Housing Society (SMZV) undertook a "Retrofit studies and proposals of 21 urban complexes of Zaragoza" that explains the benefits of energy renovations for social and environmental wellbeing. This resulted in financial grants being provided to SMZV to undertake social renovation projects in communities of Zaragoza.

Zaragoza faces numerous challenges to securing its energy targets, such as limits for feeding in wind power due to grid balance issues, inefficient design and maintenance of old buildings combined with excessive use of heating leading to excessive losses (46.3 %) etc. To promote energy efficiency and undertake successful renovation actions to reduce energy consumption, a number of amendments to municipal orders were made to support the implementation of the RENAISSANCE project and other energy saving programmes including:

1. Several ancient laws were reformed, such as the "Horizontal Ownership Law", the "Urban Development Legislation" and the "Urban Renting Law".
2. 2 Legal capabilities of local authorities were reinforced to allow them to impose renovation works in some of the districts in need of renovation.

Major features of Zaragoza project

The holistic bioclimatic design of the neighbourhood in Zaragoza is a model for sustainable development and fulfils several ZED requirements, such as social engagement, economic efficiency and environmental impact (see Table 1 of the prologue section). Some of the project's successful ZED indicators are discussed below.

Social engagement and public demonstration: To be able to speak to the community as well as public and private stakeholders about the benefits of renewable energy and energy efficiency, several awareness-raising campaigns and activities have been set up by the project. Some of these include: several workshops per year targeting different stakeholders, creation of a website to motivate citizens to get involved in the project, a good practice poster designed and put up in the neighbourhoods, media articles were published, and social networks were created. Additionally, the emblematic building centre on urban sustainability was constructed and acts as a permanent exhibition and interpretation centre to educate and disseminate the results of the project to a wide range of people. The centre exists to showcase the measures taken in the other building projects, these are made visible using displays and cut sections of the building.

Training and education: The project focussed on strengthening the capacity and skills of the stakeholders involved during each stage of the building process. Training days and advanced technical support was provided by efficiency building experts. The training was offered in several ways using workshops and hands-on, onsite training. Additional training included interventions in primary and secondary schools, courses for university students, master students, unemployed graduates, teachers and civil servants.

Bio-climatic design: The Valdespartera Ecocity is the first urban project in Spain to focus its holistic design and construction methods on bioclimatic criteria. A study was undertaken by the University of Zaragoza to review the project and verify the Kyoto bioclimatic criteria. The area has achieved an unmatched environmental balance (household consumption ratios of 0.06 kWh compared with the Spanish average of 0.11 kWh) by optimizing the use of resources such as water, energy, waste and lighting and making the best use of public spaces and efficient technology. The buildings designed were rectangular and south facing to optimise solar gains and cross ventilation. Furthermore, the spacing between buildings was designed to allow for inner cross-ventilation and to avoid the region's cold and dry wind ("cierzo"). The gardens and streets are set up to promote safe and quiet areas and the vegetation regulates the local microclimate (trees allow the sun to heat up the area during the winter periods and are used as solar radiation barriers in the summer). New Building energy standards based on the success of the bioclimatic buildings were developed. Furthermore, new social acceptance of this type of construction has been felt and the neighbourhoods are developing "greener" mentalities. Moreover, a new local by-law has been set to implement the project's building standards. Zaragoza has developed a new legal regulation tool to ensure all new and renovated buildings adhere to the energy saving, energy efficiency and renewable energy guidelines.

The monitoring campaign: A vast monitoring campaign was linked to the R&D of the neighbourhoods to investigate consumer behaviour and techniques of the building design process. The objective of the monitoring campaign was to provide adequate training and information to the inhabitants of the bioclimatic buildings to ensure the full energy savings potentials of the buildings are realised. Over 200 real-time monitoring systems were installed in apartments, providing aggregated information on building groups and allowing the evaluation of energy system performance as well as construction problems linked to improper consumer behaviour. The findings of the study helped improving the construction of the buildings and were disseminated by creating an online system to provide user specific recommendations to avoid energy consuming behaviours.

Governance structure

The actors and organisers of the project include:

- Project coordination – *HESPUL.*
- Political leadership- *Zaragoza Ayuntamiento.*
- Urban Planners and Developers - *Ecociudad Zaragoza* and *Zaragoza Vivienda.*
- Technical experts & energy providers - *Universidad Zaragoza*, *URBIC*, *CENER* and *ENDESA*.

The national team leader of the project is the Zaragoza City Council who is supported by the University of Zaragoza, the local coordinator. They are responsible for the successful management of the project and have an influence on all stakeholders across all realms of the municipality, with the commitment of the Mayor, and are well placed to ensure that the demonstration potential of the project is achieved and disseminated. Polytechnical Center (UZ) undertakes the monitoring efforts, to attain user and household data in Picarral and Valdespartera neighbourhoods. Ecocity Valdespartera and the Centre for Sustainable Urbanism are responsible for the urban development of the project. The technical experts undertake the engineering of the project.

The participation of private companies such as URBIC, CENER and ENDESA, enabled the development of commercially innovative and feasible solutions. The experience the private institutions have in energy design and management has been crucial to the success of the project, such successes include UBRIC set up and an ESCO, and has played an important role in the design phase of the building systems and ENDESA's experience and technical solutions have contributed to successful management of the gas and electricity consumption of the neighbourhood.

Energy demand reduction and supply with renewable targets

Eco-ciudad Valdespartera has monitored the bioclimatic buildings in the two neighbourhoods and consumption rate figures have been collected (Table CS7.1). The data obtained shows positive results:

- The new Eco-Cuidad buildings in Valdespartera have a heating consumption rate per dwelling between 20-25 kWh/m^2/yr; whereas in conventional dwellings in Zaragoza, the rate is between 80-110 kWh/m^2/yr- a reduction of 75% has been achieved.
- In the rehabilitated dwellings in El Picarral, the heating consumption rate obtained is between 50-60 kWh/m^2/yr, a reduction of 40% has been achieved.

Table CS7.1. Final energy consumption compared to standard practices

	Standard practices			RENAISSANCE projects			Energy savings		
Energy consumption (kWh/m².yr)	Heating	Electricity	Total	Heating	Electricity	Total	Heating	Electricity	Total
New buildings (616)	120	80	200	55	47	102	54%	41%	49%
Renovated buildings (70)	120	80	200	65	62	127	46%	23%	37%

Key point: Final average energy consumption.

Source: JRC, 2015.

Similarly, the share of renewable energy supply increased in the buildings included in the project as shown in Table CS7.2.

Table CS7.2. Share of renewables and breakdown of thermal energy consumption

Energy consumption (kWh/m².yr)	New buildings	Renovated buildings	Renovated school	Interpretation centre
Heating	25	52	51.5	79
Domestic hot water	9.5	14	-	-
Cooling	11	1.4	13.9	61
Share of renewable energy	64%	70% (solar thermal for hot water)	40% (electricity)	90%

Key point: The project's buildings all receive a large share of their thermal energy consumption from renewables.

Source: RENAISSANCE, 2012.

I. Renovation of existing buildings

Renovated buildings include:

1. El Picarral: A total of 70 of the planned 196 dwellings (7,700 m^2) have been refurbished. The public school has also been renovated and has reduced consumption by around 43%. The average CO_2 savings of the 70 dwellings is 3.3 tonnes of CO_2/m^2, with a total of around 231 tonnes of CO_2/m^2. The remaining

dwellings could not be renovated due to the financial constraints in Spain, and consequently on the developers, during the economic crisis of 2009. However, the results of the 70 renovated dwellings have been positive and the buildings have moved from very poor energy rating (E and G) to higher, more efficient energy performances (B and C), achieving significant energy consumption reduction and better thermal comfort for the inhabitants.

49. The Picarral Social Dwellings: Anzanigo and General Yague are the social housing dwellings, built between 1945 and 1960, which have been gradually renovated with the aim of demonstrating rational use of energy in buildings. Measures implemented included thermal insulation on the exterior walls (EPS layer externally), thermal insulation on the roof (EPS layer externally), installation of a second window externally of each existing one, installation of elevators in courtyards, improvement of sound insulation of facades, repair of the sewerage network and the plumbing system as well as upgrade of domestic hot water system, heating system, power plants (smaller individual heating plants were replaced by few centralised plants) and telecommunication network. Moreover, solar thermal panels to preheat water (providing 70% of DHW demands) were installed. Overall, the renovation of 70 dwellings has been a successful demonstration for the homes in Picarral and replication of these measures is foreseen in other districts of Zaragoza.

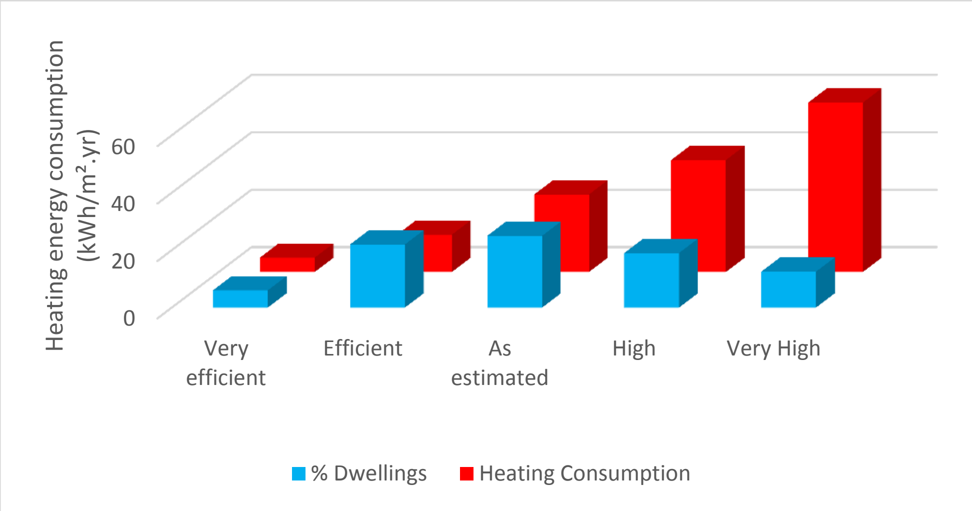
2. Cándido Domingo: has a floor area of 6,000 m^2. The school has been thermally renovated and a PV array of 18 kWp has been installed on the roof, accounting for 40% of the building's consumption and an energy reduction of 52% has been obtained.

II. New buildings

The Valdespartera Eco-district is a "a full-scale sustainability laboratory," explains Noelia Olona, Technical Area Manager of Ecocity Valdespartera Zaragoza. The eco-city is an exemplary concept of bioclimatic design through three main principles: urban planning, architecture and a suitable construction system. The city includes management networks to comply with bioclimatic criteria. According to Noelai Oloma the technical details of the nine management networks include "the drinking water network that collects its supply from various municipal deposits, a watering network supplied by the Imperial Canal, which is separate from the drinking water supply in order to prevent contamination of the subsoil with chlorine, and two sanitation networks, one for rainwater and another for sewage, differentiated in order to take advantage of rainwater for watering purposes. Moreover, a network was also designed to collect the level of energy consumption in homes, monitored by the University of Zaragoza, which analyses whether the energy saving targets defined in the initial plan are being reached, a network for the common facilities of electricity and gas, including its own substation built thanks to an agreement with Endesa, a network with the weather station to collect environmental information and contextualise it with other city systems such as watering, street lighting network and pneumatic waste collection network."

The RENAISSANCE project covered the new bioclimatic residential apartments. Over four plots of land, 616 bioclimatic apartments have been constructed in Valdespartera. The University of Zaragoza conducted the project and the results show that the buildings meet the electrical and heating consumption criteria, but that consumer behaviour can greatly affect the energy consumption. The figure below shows a graph of the heating consumption in kWh/m^2/yr of the dwellings next to the % of dwellings in the performance categories. It can be seen in that the majority of the newly built dwellings heating consumption remains under 25 kWh/m^2/year. However, if the inhabitants do not act efficiently, it is possible for the highly energy performing constructed dwellings to have a high-energy consumption of around 60 kWh/m^2/yr.

Figure CS7.1 Heating consumption and share of dwellings per performance category



Key point: Heating consumption of the majority of the newly built dwellings is below 25 kWh/m^2/yr.

Source: RENAISSANCE, 2012.

The technical measures used in the bioclimatic apartment blocks include:

- 40-50% more insulation than required by national building standards.
- Thermally efficient windows (k < 2 W/ m^{2}k).
- Passive elements for direct and indirect solar gain (> 40% of openings facing south and > 60% with glazed solar spaces).
- Solar protection (overhangs, canopies, blinds, etc.).
- Efficient lighting in communal areas based on efficient lighting and zoned time and/or presence control.
- Centralised space heating and cooling systems for each block or group of blocks using low temperature, gas fired modulating boilers with impulse temperature control related to exterior temperature.
- Hot water distribution networks (space heating and domestic hot water, DHW) with more insulation than required by building regulations, correct hydraulic and thermostatic regulation and individual metering for each home.
- Pre-installation of cooling in one of the plots using high efficiency installations and a distribution network compatible with the heating network (note: design to permit possible conversion to use of solar absorption cooling in the future)
- Solar thermal collector to meet 60% of the annual energy demand for DHW heating.
- Design for predominance of cross ventilation.
- Communal gardens with abundance of large deciduous trees (providing summer shade, allowing winter solar gains), water laminas, fountains and sprays (for evaporative cooling).

The Exhibition Centre, named “CUS Centro de Urbanismo Sostenible”: The sustainable urban planning centre has a total floor area of 1,543 m² and opened in June 2010. The building acts as a showcase for high energy performing buildings, this goes beyond current practices to demonstrate what a high energy performing building is. The technical renewable and energy efficiency measures of the building include:

- Highly-efficient building envelope
- Efficient cooling system
- Installation of a biomass boiler
- A geothermal and reversible water-water heat pump
- Solar/biomass absorption cooling to be linked to a wind generator

III. Integration of renewable energy supply

Renewable energy sources are a vital part of the demonstration project and have been included, whenever feasible, in the building construction and renovation, and supplies over 40% of the energy demand. The selected renewable energy sources have been chosen based on the needs of the buildings. The renewable energy technologies include:

- 654 m^2 of solar thermal panels for DHW have been integrated into the bioclimatic building project in Valdespartera buildings (reaching a total amount of 9, 000 m^2 in the neighbourhood).
- Polygeneration involving a 37 kW biomass boiler, and a 45 kW geothermal and reversible water-water heat pump has been installed as well as 37 kWp of photovoltaic systems in the interpretation centre.
- A collective energy efficient gas heat pump for cooling and heating integrated in the public school Cándido Domingo and an 18 kWp photovoltaic system has been installed on the roof.
- Photovoltaic panels and 240 m^{2}solar thermal panels have been integrated in the Picarral buildings.

Financial and economic aspects of the project

The overall RENAISSANCE project received €8.5 Million in total of out which €3.8 Million by EU-CONCERTO funding went to the city of Zaragoza. Several financial groups contributed to the RENAISSANCE project in Zaragoza. Alongside EU funding, the Municipality funded a large proportion of the work. Additional funding came from the private sector in the form of an ESCO contract. The Municipality set up two municipal companies to overlook the development; ECOCIUDAD Valdespartera Zaragoza and Zaragoza Vivienda. ECOCIUDAD is a joint venture funded in as PPP.

Total costs of the new buildings and renovations:

- Valdespartera - new buildings cost 2,805,233.28€ for 64,027.85 m^2= 43.8€/m^2.
- Anzánigo renovation of flats cost 86,350.88€ for 1,731.3 m^2= 49.3 €/m^2.
- Yagüe renovation of flats cost 327,540.94€ for 4,047.2 m^2= 80.9 €/m^2.
- Valdespartera new builds -654 m^2 solar panels cost 625,740.85€ = 956.8 €/m^2.
- Anzánigo renovation - 23,4 m^2 of solar panels cost 43,561.76€ = 1861.6€/m^2.
- Yagüe renovations - 52,14 m^2 of solar panels cost 87,190.48€ = 1672€/m^2.
- Candido Domingo School renovation cost 114.013,67€ cost for the facade, subcontracting and municipal costs of 52,869.06 € where spent in WP 3.3.2 in the roof and the electric system.

Homeowners undertaking a RENAISSANCE renovation were eligible to receive grants from the EU but also from national and regional funds. Considering the project was targeting social housing, the inhabitants had limited funding available. However, if, they met the minimum required resource brackets they were able to receive the proposed intervention, meaning that residents only needed to provide around 25% of the total renovation costs, which is around 6,000-10,000€. This sum was financed using private loans. Unfortunately, due to the financial crisis, some projects had to be cancelled due to a lack of available funding, dissuading investors to invest.

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Appendix: List of identified projects not considered for in-depth analysis

Project	Targets	Measures	Reasons for non-inclusion in Section I	References
Høje-Taastrup (Gammelsø Denmark)	• CO_2 neutral community. • Urban regeneration.	• Construction of 40 (total 4,573 m²) new dwellings built according to passive house standard. • Construction of 70 energy-class "A+" dwellings (total 7,000 m²) and a school, institution and administration offices (total 8,000 m²). • Solar thermal collectors. • A wind turbine of 0.85 MW. • 320 m² of photovoltaic panels. • Installation of decentralized heat pumps in various buildings.	• New buildings only. • Monitoring data was not available during time of analysis.	• http://www.ecolife-project.eu/index.html • http://www.CONCERTO.eu/CONCERTO/environmentaltechnologies/technologies-renew-technologies/technologies-renewable-technologies-seach-by-site/tech-sites-eco-life-hoje-taastrup.html
Hedebygade, Vesterbro (Copenhagen, Denmark)	• Reducing heating demand by at least 25%. • Reducing water consumption by at least 20%. • Urban renewal.	• 350 apartments (six-storey blocks) • Solutions to increase daylight • Integration of photovoltaic panels to existing buildings.	• Neighbourhood approach not identified.	• http://www.cardiff.ac.uk/archi/programmes/cost8/case/holistic/hedebygade.html • http://www.worldhabitatawards.org/winners-and-finalists/project-details.cfm?lang=00&theProjectID=153
Hillerød (Denmark)	• Zero CO_2 community. • Energy consumption of new buildings reduced by at least 25% compared to current standard.	• Construction of over 78,000m² eco-housing (50 Energy Class 1 dwellings, 670 Eco dwellings). • Renovation of city hall and part of the conference centre. • Fully integrated energy supply structure combining different RES solutions (wind energy, PV, heat pumps and low-energy district lighting).	• The focus of the project was mainly new buildings. • No monitoring data for the renovated buildings was available.	• https://smartcities-infosystem.eu/scis-projects/demo-sites/sorcer-site-hiller%C3%B8d
Stenlose (Egedal, Denmark)	• Strengthen the energy requirements for a new settlement. • Constructed with a heating energy consumption and an overall primary energy consumption better than it is required for a low energy class 1 building according to the Danish Building regulation from 2008 (BR08)	• Construction of 400 new buildings, a kindergarten and an activity centre for the elderly	• The focus of the project was mainly new buildings. • Other Danish projects with more holistic approaches	• http://CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-class1-stenlose.html

Eco-Viikki (Helsinki, Finland)	• CO_2 emissions will be cut at least by 20% in relation to conventional building and consumption of pure water by more than 20% • Aims to be an ecologically sustainable development including aims for cutting energy use	• Construction of a large residential area adjacent to the Science Park. • Conservation of the local environment and culture	• New buildings only	• http://www.secureproject.org/download/18.360a0d56117c51a2d30800078421/1350483402683/Viikki_Finland.pdf • www.energy-cities.eu/db/helsinki_579_en.pdf • http://www.cardiff.ac.uk/archi/research/cost8/case/holistic/viikki.html
Lapua (Ostrobothnia, Finland)	• 75% energy self-sufficiency by 2015.	• Overall a gross floor area of 5983 m² was newly constructed and the total refurbished area was 3174 m^2 • Local district heating provided by biogas polygeneration, boilers and heat pumps. • Wind power. • Effective energy management. • Remote control systems. • Improved consumer behaviour.	• Renovations did not meet set targets • Only two renovations were undertaken	• http://www.CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-solution-lapua.html • http://www.solution-CONCERTO.org/communities/lapua/content-49/gis-72/article/low-temperature-disctrict-heating?lang=en
Sannegårdshamnen, Backa Röd (Gothenburg, Sweden)	• A long-term target of the city of Gothenburg of 2tonnes of CO_2 emissions per person by 2050 • An intermediate target to reduce CO_2 emissions by 40% in 2020 compared to those in 1990.	• Construction of 116 apartments in passive buildings in 2008 in Sannegårdshamnen (using 25 kWh/m^2 energy for heating) • Energy efficient refurbishment of 16 apartments in Backa Röd in 2009 (reduction in annual energy consumption from 180 kWh/m^2 to 60 kWh/m^2)	• The holistic approach at a neighbourhood level was not identified. • Meeting CO_2 emissions reduction target is based more on the supply of heat using the district heating system then on reducing energy demand.	• http://celsiuscity.eu/Demonstrator/city-of-gothenburg/ • http://gmv.gu.se/digitalAssets/1522/1522775_sustainable-development---comparison-of-four-cities--corrected-report.pdf
Växjö *(Sweden)*	• Fossil fuel free by 2030.	• Construction of new eco-buildings with 31% energy savings compared to standard. • Construction of around 400 energy efficient apartments • Construction of a pre-school with a photovoltaic plant • Use of an absorption cooling system	• New buildings only • Approximately 95% of energy savings are expected to come from the use of RES heating	• http://www.upv.es/contenidos/CAMUNISO/info/U0677597.pdf
Falkenberg (Sweden)	• 25% reduction in final energy consumption • 100% of electricity from renewable sources	• Full-scale integration of innovative solar air systems • Energy checks for 10-20% of private housing • Energy renovation of 30 single-family homes and 180 apartments with monitoring • Construction of 120 apartments in seven passive buildings • Five wind turbines	• Energy savings targets were not met. • The average overall energy consumption was 165 kWh/m².yr.	• http://www.CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-energy-in-minds-falkenberg.html • http://www.upv.es/contenidos/CAMUNISO/info/U0677597.pdf

Hammarby (Sweden)	• Closed-looped urban metabolism aiming at sustainable neighbourhood. • Unified infrastructure of energy, water and waste • Urban-scaled density • Preservation/restoration of existing natural systems • Progressive construction and housing policies	• Construction of 1000 dwellings • Integration of photovoltaics to buildings and infrastructure. • Use of solar thermal. • Wind power. • Use of biogas for public transport. • Optimisation of waste and water management systems.	• New buildings only.	• http://www.aeg7.com/assets/publications/hammarby%20sjostad.pdf
Augustenborg and Bo01 (Malmö, Sweden)	• Carbon-neutral by 2020 • 100% supply with renewable energy by 2030. • Urban regeneration.	• Renovation of 1,600 apartments. • Re-use of construction material to reduce their carbon footprint. • Construction of new buildings	• The focus of the renovation work was more on the re-use of construction material and rain water than on the building envelope.	• http://www.dac.dk/en/dac-cities/sustainable-cities/all-cases/master-plan/malmo-bo01---an-ecological-city-of-tomorrow/. • http://www.westminster.ac.uk/?a=119909 • http://policytransfer.metropolis.org/case-studies/city-of-tomorrow
Ostra Sala backe (Uppsala, Sweden)	• Energy planning towards net-zero energy district.	• Construction of 2,500 new apartments • Innovative integration of energy technology. • Monitoring and analysis.	• New buildings only. • Monitoring data was not available during time of analysis.	• http://www.eusew.eu/upload/events/4599_20861_eu%20sustainable%20energy%20week_kilkis.pdf
Linero (Lund, Sweden)	• Reducing energy demand of existing buildings by at least 31% • Supply with renewables of at least 71% of the energy needs.	• Energy renovation of 16 apartments	• Monitoring data was not available during time of analysis.	• http://www.cityfied.eu/Demo-Sites/Lund/Lund.kl
Trondheim (Norway)	• Reducing CO_2 emissions by 20% in 2010 compared to 1990. • Integrated energy supply/demand community approach.	• Renovation of a block and a row of housing were renovated to 150 – 160 kWh/$m^{2.}$ • Installation of 750kW biomass fuelled boilers • Installation of solar collectors (265m^2) • Implementation of polygeneration, 6MWth energy conversion central, with 3 MW absorption cooling and district heating from waste.	• Energy savings achieved after renovation were less ambitious than in other North European projects.	• http://www.ecocity-project.eu/ProjectResults.html
Zlin (Moravia, Czech Republic)	• Lowering fossil fuel consumption of buildings in eco village • New buildings to be close to passive house, 60 - 90% of the heat energy from buildings is provided from renewable sources	• Refurbishment of 12 single-family houses and 120 apartments. • Construction of new low-energy housing. • Increasing RES energy supply, mainly through solar energy and biomass. • Reconstruction of district heating system. • Information and education campaigns	• Monitoring data was not available during time of analysis.	• http://www.CONCERTO.eu/CONCERTO/environmentaltechnologies/technologies-renew-technologies/technologies-renewable-technologies-seach-by-site/tech-sites-energy-in-minds-zlin.html?infolvl=0

Solanova (Dunaújváros, Hungary)	• Solar-supported, integrated eco-efficient renovation of large residential buildings and heat-supply-systems.	• Renovation of one solar block of flats. • Heat consumption was reduced from 220 kWh/m^2.yr to 20kWh/m^2.yr.	• The focus was on one building and not on the district.	• http://envsci.ceu.edu/sites/envsci.ceu.hu/files/attachment/project/550/tirado-herrero-urge-vorsatztrapped-heat14-march-2011a.pdf • http://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2005c/Panel_2/2136hermelink/paper
Mórahalom (Szeged, Hungary)	• Up to 14% of heat demand reduction. • Up to 21% final energy consumption reduction. • Up to 68% supply of energy with solar collector systems. • Up to 77% of hot water produced with solar systems.	• Renovation of public buildings (cultural centre, school, gymnasium and a kindergarten/day-care complex). • Wall insulation. • Replacement of windows and doors. • Solar collector systems • Geothermal energy.	• The project has not been implemented.	• http://geothermalcommunities.eu/downloads • http://CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-geocom-morahalom.html
Szentendre (Hungary)	• Up to 40% energy savings compared to current standard for new buildings. • Up to 10% of energy savings for retrofitted buildings.	• Renovation of residential blocks, offices, a kindergarten. • Building a new research centre. • Use of recycled material for insulation. • Upgrading of windows. • PV shading devices. • Microgrid for renewable energy production.	• Lack of ambition of energy renovation target.	• http://CONCERTO.eu/CONCERTO/environmental-technologies/technologies-renew-technologies/technologies-renewable-technologies-seach-by-site/tech-sites-pimes-szentendre.html
Óbuda-Békásmegyer (Budapest, Hungary)	• Up to 50% reduction in heat consumption.	• Complete insulation package for five buildings (900 flats) at above national requirements for new buildings. • Replacement of windows. • Renovation of heating system infrastructure. • Solar energy systems installed on roofs (1.500 m^2) • Separation of domestic hot water from heating systems.	• Monitoring data was not available during time of analysis.	• http://envsci.ceu.edu/sites/envsci.ceu.hu/files/attachment/project/550/tirado-herrero-urge-vorsatztrapped-heat14-march-2011a.pd)f • http://www.CONCERTO-staccato.eu/projects/obuda-budapest.html
Galanta (Slovakia)	• The focus is the exploration of the possibilities lying in the use of geothermal energy • Demonstrating best available technologies in the use of geothermal energy combined with innovative energy-efficiency measures and the integration of other renewable energy sources	• Retrofit of three 8-floor residential buildings (32 apartments) and a school. Installation of PV systems, 2.1kWp on residential buildings and 4.6 kWp on school.	• Data on the renovated buildings were not available when the projects were being analysed.	• http://geothermalcommunities.eu/downloads • http://www.CONCERTO.eu/CONCERTO/environmentaltechnologies/technologies-renew-technologies/technologies-renewable-technologies-seach-by-site/tech-sites-geocom-galanta.html

Hartberg (Austria)	• Self-sufficiency target by 2015. • 70% energy savings in new buildings compared to current standard.	• Construction of new commercial buildings to passive house standard. • Decentralised district heating systems and polygeneration. • Large-scale implementation of small/medium RES applications • Symbiotic integration of novel electricity storage units. • Improvements of investment framework. • Innovative integration aspects of renewables.	• The size of the project; too small compared to Lehen project included in Section I.	• https://smartcities-infosystem.eu/scis-projects/demo-sites/solution-site-hartberg
Weiz-Gleisdorf (Austria)	• Up to 24% energy savings. • Up to 30% supply with RES.	• Retrofit of 35,000m^2 of housing, public, private and commercial buildings. • Construction of 13,000m^2 of low energy homes.	• Monitoring data was not available during time of analysis.	• http://www.CONCERTO.eu/CONCERTO/environmentaltechnologies/technologies-renew-technologies/technologies-renewable-technologies-seach-by-site/tech-sites-energy-in-minds-weiz-gleisdorf.html • http://CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-energy-in-minds-weiz-gleisdorf.html
Mödling (Austria)	• 50% reduction of greenhouse gas emissions (GHG) by 2010 compared to those of 1990.	• Insulation of social housing and kindergartens. • Replacement of windows in social housing and kindergartens. • Connection to district heating network of social housing and kindergartens. • Construction of police department at eco-building standard. • Construction of commercial building "Sol 4" to passive-house standard. • Installation of photovoltaic systems, with total power of 48.22 kWp and producing 46.8 MWh per year.	• Project less district oriented.	• http://www.CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-holistic-moedling.html
Venning, Kortrijk (Belgium)	• CO_2 neutral eco-Village	• Renovation of 276 social housing units to the BREEAM energy performance certificate excellent rating. • Installation of low temperature district heating network, supplied by 1 MW woodchip boiler, connected to all buildings. • Installation of 10 kW biofuel cogeneration unit producing auxiliary electricity for the system (pumps, control and monitoring equipment). Heat from cogeneration unit is fed into the district heating network.	• Monitoring data was not available during time of analysis.	• http://www.ecolife-project.eu/TheProjectKortrijk.html

Confluence (Lyon, France)	• Up to 77% energy savings. • Up to 80% supply with RES for heat.	• Construction of around 75,000 m² of new buildings.	• New buildings only.	• http://www.CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-RENAISSANCE-lyon.html
Ajaccio (France)	• Approximate energy savings of 20% by: • Increasing energy efficiency of buildings constructed in the sixties • Renovating buildings in Ajaccio's historic centre	• Installation of double-glazing windows with thermo-coating in a total of 250 buildings including 50 buildings in the historical centre. • Implementation of energy efficiency measures in 565 apartments. • Construction of two High Environmental Quality new buildings, one with 15 apartments and one public service office building.	• Monitoring data was not available during time of analysis.	• http://CONCERTO.eu/CONCERTO/environmental-technologies/technologies-renew-technologies/technologies-renewable-technologies-seach-by-site/tech-sites-crrescendo-ajaccio.html
De Bonne (Grenoble, France)	• Reduction of CO_2 emissions by 14% by 2014 (compared to 2005). • Reduction of energy consumption per inhabitant by 2014. • Share of renewable energy increased to 14% of all energy consumed.	• 900 low energy consumption (50 $kWh/m^2.yr$) apartments • France's first positive energy office building.	• New buildings mainly.	• http://www.energy-cities.eu/IMG/pdf/37_from_buildings_to_smart_cities_grenoble_xavier-normand.pdf
Franklin (Mulhouse, France)	• Achieving 50 kWh/m².yr of primary energy consumption for renovated buildings	• Renovated 40 particularly run-down terraced townhouses of between two to four storeys.	• The district approach was not considered.	• http://www.eneff-stadt.info/fileadmin/media/Projektbilder/Internationale_Projekte/Dokumente_IEA_Annex_51/Suntask_B_final_repo_2013_01.pdf
San de Senart (Paris, France)	• Up to 54% final energy consumption reduction.	• Renovation of social housing.	• Monitoring data was not available during time of analysis..	• http://www.crrescendo.net/pdf/FinalcRRescendoReport.pdf
Kronsberg (Hannover, Germany)	• 60% CO_2 emissions reduction compared to 1990. • Conservation of species. • Reducing the use of private cars.	• Construction of 90 passive '1 Litre Houses' reducing the cost efficiency ratio of space heating to 15 – 20 $kWh/m^2.yr$ and making impressive reductions in energy requirements for appliances and hot water. • Savings on heating, hot water and electricity.	• New buildings only.	• http://www.ecoenergy-bg.net/Success_Guide/part2/hanover_566_en.pdf

Weilerbach (Germany)	• 100% of energy demand supplied with RES.	• Construction of 80 energy efficient homes. • Retrofitting of 100 homes. • Partial retrofitting of 200 homes. • Installation of 50 biomass boilers (total 826 kW). • Installation of 124 solar thermal systems (total 890 kW). • Installation of two solar air collector systems which heat up the supply air of mechanical ventilation systems. • Implementation of four small district-heating networks, based on biomass and connecting-up to four buildings.	• Monitored data on renovated buildings not available.	• http://CONCERTO.eu/CONCERTO/environmental-technologies/technologies-renew-technologies/technologies-renewable-technologies-seach-by-site/tech-sites-sems-weilerbach.html • http://www.stoffstrom.org/fileadmin/userdaten/dokumente/Veroeffentlichungen/ZE-Broschuere/ZE_Broschuere_01_29_2014.pdf
Vauban District (Freiburg, Germany)	• A sustainable model district. • Primary energy consumption of 65 kWh/m².yr for new buildings. • Minimum of 100 units with "passive house" (15 kWh/m2a) or "plus energy" standard • Planning for an additional 100 plus energy houses (houses which produce more energy than they need).	• All houses are built to a low-energy consumption standard, with 100 units designed to the Passivhaus ultra-low energy building standard, housing 5,000 residents • SUSI (4) wall and roof insulation. • Construction of 6 student settlements with wall and roof insulation. • DIVA roof insulation. • Haus 037 Roof insulation.	• Mainly new buildings. • Monitored data on the renovated buildings not available during analysis.	• http://www.vauban.de/en/topics/history/276-an-introduction-to-vauban-district • https://www.freiburg.de/pb/site/Freiburg/get/340683/Umweltpolitik_engl.pdf • http://vbn.aau.dk/files/52797783/report_UPM1_change_through_eco_neighbourhoods.pdf • http://eclink.org/media/filer_public/8e/4f/8e4fcca2-cbad-489a-a5b7-ba54b79d6741/casecud01vauban.pdf
Rieselfeld (Freiburg, Germany)	• Low-energy construction standard, district heating networks fed by a combined heat and power plant, integration of RES, rain water use	• 4,200 new low energy consumption residential buildings. • District heating network powered by a combined heat and power plant (CHP). • Decentralized solar energy system. • Storm water management	• New buildings only.	• http://transportation.org.il/sites/default/files/pirsum/rieselfeld_en_2007.pdf • http://www.its.berkeley.edu/sites/default/files/publications/UCB/2010/VWP/UCB-ITS-VWP-2010-7.pdf
Weingarten (Freiburg, Germany)	• To reduce the actual demand for energy consumption of the district by 30% and to propose a sustainable model for energy urban renovation	• Renovation of 840 flats housing (installation of new windows, thermal insulation, redevelopment of entrances) • Building social networks. • Neighbourhood improvement • Establishment of a sense of environmental responsibility	• Monitoring data was not available during time of analysis..	• http://www.energy-cities.eu/db/freiburg3_579_en.pdf • https://www.mdpi.com/1996-1073/9/5/365/htm
Neckarsulum (Germany)	• Up to 30% reduction in final energy consumption.	• Retrofitting of four single-family houses. • Around 3,000 single retrofit measures taken (eg retrofitting outside walls, roofs or window replacements). • Constructed 11,000 m² of new buildings	• Monitoring data of renovated buildings not available.	• http://CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-energy-in-minds-neckarsulm.html

Scharnhauser Park (Ostfildern, Germany)	• UP to 38% of energy savings. • Up to 80% of energy demand supplied with RES.	• New homes and offices for 35,000 residents. • Wood-fired cogeneration plant delivering electricity and heating.	• New buildings only.	• http://www.CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-polycity-ostfildern.html
Dundalk (Ireland)	• 20% renewable heat. • 20% renewable electricity. • 40% improvement in energy efficiency of selected buildings.	• Retrofitting of over 300 homes to meet energy efficiency requirements. • Planning a biomass district heating system for residential and commercial buildings.	• Monitoring data was not available during time of analysis.	• http://CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-holistic-dundalk.html • http://www.seai.ie/SEC/The-Communities/Dundalk_2020/#sthash.xegtBStc.dpuf
Redange (Luxemburg)	• 100% of RES.	• Retrofitting of 17 buildings (municipal and private, 3,400 m² in total). • Planned refurbishment of dwellings and administrative buildings. • Planning of regional biomass project (four biogas combined heat and power plants to be fuelled by domestic and agricultural waste as well as energy crops).	• Monitoring data was not available during time of analysis.	• http://CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-sems-redange.html
Poptahof (Delft, Netherlands)	• To emit 15% less CO_2 by 2012. • To raise the share of renewable energy to 5% of total consumption compared to 1990. • To use 15% less energy through renovations.	• Renovation of 100 residential buildings (thermal envelope). • Construction of 58 new eco-dwelling.	• Energy consumption target of renovated buildings was not ambitious compared to projects included in Section I.	• http://CONCERTO.eu/CONCERTO/environmental-technologies/technologies-renew-technologies/technologies-renewable-technologies-seach-by-site/tech-sites-sesac-delft.html
Heerlen (Netherlands)	• 50% – 100% CO_2 reduction. • 60% increase in RES energy supply in comparison with national practice.	• Construction of new buildings and renovations in two demonstration sites.	• Lack of data and detailed information on the project.	• http://CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-remining-lowex-heerlen.html
Apeldoorn (Netherlands)	• Carbon neutral by 2020.	• Construction of 31,000 new housing units to highest energy standard. • Renovation of 20 houses to 'energy neutral" level.	• No data and information available on the renovated houses.	• http://www.ehpa.org/media/newsletter/newsletters-2012/?eID=dam_frontend_push&docID=548 • http://CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-sorcer-apeldoorn.html
EVA-Lanxmeer (Netherlands)	• Maximum energy consumption per home set at 40 GJ per annum (50% of standard house).	• Housing development of 240 houses and apartments. • Heat recovery units (ventilation). • Solar water heaters. • District heating system.	• New buildings only.	• http://www.mimoa.eu/projects/Netherlands/Culemborg/Wilgenhoven%20Eva%20Lanxmeer%20-%20Culemborg/

Almere (Netherlands)	• Aiming to realise 48% energy savings at the end of the project • Almere Solar Island combined with conventional district heating aims to cut CO_2-emissions by 50%	• Construction of 1,710 eco-homes, commercial and public buildings • Construction of 589 "Solar Homes", constructed from wood, with low energy demand, an optimized use of daylight and solar powered energy supply from solar panels • Planning of around 100 passive houses . • District heating supplies heat to all new dwellings.	• New buildings only.	• http://www.CONCERTO.eu/CONCERTO/environmentaltechnologies/technologies-renew-technologies/technologies-renewable-technologies-seach-by-site/tech-sites-crrescendo-almere.html • http://www.upv.es/contenidos/CAMUNISO/info/U0677597.pdf
Lambeth (London, UK)	• To reduce CO2 emissions from our corporate buildings and street lighting by 20% by 2021	• Renovation of 3 tower blocks and 6 schools. • Installation of solar thermal and solar photovoltaic technologies on schools. • Training and development of professionals in the sustainable buildings sector. • Creation of a suite of learning resources for local residents • Energy audits and advice for local businesses.	• Individual building approach and not district approach.	• http://www.CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-ecostiler-lambeth.html
***Milton* Keynes** (UK)	• City aims to achieve zero carbon growth	• Construction of 3 office buildings and 445 residential units to raised sustainability levels. • High performance standards applied for insulation and air tightness. • CHP plant serving commercial and residential buildings.	• New buildings only.	• http://CONCERTO.eu/CONCERTO/environmental-technologies/technologies-renew-technologies/technologies-renewable-technologies-seach-by-site/tech-sites-crrescendo-milton-keynes.html
BedZed (London, UK)	• Z² (Zero carbon and Zero waste)	• Construction of 82 mixed tenure residential buildings. • Construction of 18 live/work workspaces. • On-site facilities incorporating innovative approaches to energy conservation and sustainability. • Integrated approach (water, waste, energy). • Building construction using thermally massive materials that store heat during warm conditions and release heat at cooler times.	• New buildings only.	• http://www.peabody.org.uk/about-us/sustainability/case-study-bedzed • http://www.hkip.org.hk/plcc/download/UK.pdf • http://webarchive.nationalarchives.gov.uk/20110118095356/http:/www.cabe.org.uk/case-studies/bedzed
ONE Brighton (UK)	• 70% less carbon emissions than standard UK home.	• Complex of 172 apartments plus offices, community space and café in two multi-storey blocks • Provided 54 affordable new homes • Using the ten One Planet Living principles • 67% reduction in operational carbon emissions compared to the UK's existing housing stock	• New buildings only.	• http://www.bioregional.com/wp-content/uploads/2014/10/One-Brighton-Impact-Report.pdf

Arquata (Turin, Italy)	• Aimed at promoting integrated energy systems based on distributed generation • Approx. energy saving: 46%	• Refurbishment of 30 council buildings. • Erection of PV modules on the roofs of social housing buildings and on façades of the building. • Realisation of green areas. • Creation of common spaces dedicated to social activities. • Social and occupational development. • Improvement of mobility. • Creation of small commercial spaces.	• Monitoring data was not available during time of analysis.	• http://www.CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-polycity-turin.html
Al Piano (Alessandria, Italy)	• aimed at demonstrating the economic and social benefits in investing in energy saving and renewable energy in urban regeneration. • The new building settlement of CONCERTO AL Piano has a zero fossil fuel objective • The renovation of 300 existing dwellings, with energy consumption reductions up to 50%	• Refurbishment of 300 social housing units. • Retrofitting of additional buildings. • Construction of a 104 dwelling eco-village fuelled by polygeneration and solar energy, featuring sheltered housing for the elderly, a health centre and kindergarten. • Design workshops to develop a renewable energy network and urban transformation. • Utilisation of a combination of biomass and solar power. • Monitoring. • Promotion to encourage community participation.	• Monitoring data was not available during time of analysis.	• http://CONCERTO-al-piano.eu/project.htm
Montieri (Tuscany, Italy)	• Integration of geothermal district heating combined with energy efficiency measures on buildings and the integration of other renewable energy sources • Refurbishments, photovoltaic and solar thermal installations were additional measures	• Retrofitting of selected dwellings (20% out of total) by using integrated approaches and techniques • Connection of 425 dwellings to the district heating system. • Implementation of a highly innovative geothermal district heating system using high-enthalpy fluid. • Installation of RES Integration PV panels system to serve as the main power source of the renewed public lighting system. • Installation of solar thermal collectors to serve as primary heating and DHW source for dwellings.	• Monitoring data was not available during time of analysis.	• http://geothermalcommunities.eu/downloads

Tudela (Navarra, Spain)	• To connect and balance the energy supply and demand side through an intelligent energy management system • Set a reference for new standards to prevail in the community both in retrofitting, new buildings and energy supply	• Retrofitting of 56 dwellings in 3 buildings, constructed '50s to '70s, (5,565 m^2). • Construction of a new neighbourhood. • Use of sustainable building materials. • Implementation of advanced monitoring and demand-supply system in new buildings. • Installation of renewable energy systems in the Queiles Neighbourhood.	• Monitoring data was more readily available for the chosen Spanish case study.	• http://CONCERTO.eu/CONCERTO/component/content/article/13-sites-articles/122-sites-RENAISSANCE-zaragoza-es.html • http://www.ecocity-project.eu/PDF/Final%20report%20of%20all%20realized%20monitoring%20and%20evaluation%20studies.pdf
Cerdanyola del Vallès, (Barcelona, Spain)	• Aims to become a model of sustainable growth • Green corridor with approximate energy savings of 55% and energy from RES of 33%	• Almost 2,000,000 m2 of buildings are being constructed over the next decade • Low energy construction measures • Natural ventilation solutions • Building envelope optimisation	• New buildings only.	• http://www.CONCERTO.eu/CONCERTO/environmentaltechnologies/technologies-renew-technologies/technologies-renewable-technologies-seach-by-site/tech-sites-polycity-cerdanyola-del-valles.html
Viladecans (Spain)	• To ensure that future development is more structured than the developments of the past, and that more streamlined energy approaches can be integrated into communities economically and efficiently • 30% energy savings upon completion of the CONCERTO measures	• Five public buildings have been either newly built or significantly refurbished. • Installation of 6 kWp PV system (36 kW) and solar thermal system (191 m^2) on each of five public buildings • Installation of PV installations on industrial and office roofs and public gardens (306 kW). • Installation of a total of 342 kW PV for community use	• Project has changed due to financial problems.	• http://www.CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-crrescendo-viladecans.html
Vitoria-Gasteiz (Spain)	• objective is to become a carbon-neutral zone, with an interim goal of cutting emissions by half by 2050 (2009). • Has clear strategy to become greener, promoting energy efficiency, renewable energy, low carbon mobility and smart infrastructures • Aims to reduce its energy consumption by rationalizing energy use and promoting the use of more efficient technologies such as district heating and micro-cogeneration, as well as greater energy efficiency in new and refurbished buildings	• New energy efficient dwellings, harnessing renewable energy. • Subsidized energy efficient dwellings, harnessing renewable energy. • Solar technology. • Advanced energy distribution. • Encouraging community participation in the improvement of quality of life and reduction of environmental impact.	• New buildings only.	• http://www.CONCERTO.eu/CONCERTO/CONCERTO-sites-a-projects/sites-con-sites/sites-con-sites-search-by-name/sites-pimes-vitoria-gasteiz.html • https://smartencity.eu/about/lighthouse-cities/vitoria-gasteiz-spain/

List of abbreviations and definitions

ATC	Advanced Technology Centre
BIPV	Building Integrated Photovoltaics
BMVIT	Building of Tomorrow-Programme
CHP	Combined Heat and Power
CO_2	Carbon dioxide
COP	Conference of the Parties
CUS	Centre on Urban Sustainability
DHW	Domestic Hot Water
EE	Energy Efficiency
EGCN	European Green Cities Network
EPBD	Energy Performance of Buildings Directive
EPS	Expanded Polystyrene
ESCO	Energy Service Company
EU	European Union
FBBB	Danish Association of Sustainable Cities and Buildings
HBOR	Croatian Bank for Reconstruction and Development
HEP	Obnovljivi Izvori Energije
iC	Eurocontact
ICT	Information and Communications technology
IEA	International Energy Agency
ISES	International Solar Energy Society
Km	Kilometre
kWp	Kilowattpeak
kW	Kilowatt
LAG	Local Action Group
LPG	Liquefied Petroleum Gas
m^2	meters squared
MW	Megawatt

MWh	Megawatt hour
MWp	Megawatt peak
MWth	Megawatt thermal
N/A	Not Applicable
nZEB	Nearly Zero-Energy Buildings
nZED	Net Zero Energy Districts
PPP	Public-Private Partnership
PV	Photovoltaics
R&D	Research and Development
Re	Renewable Energy
RES	Renewable Energy Sources
RTD	Research and Technical Development
RUE	Rational Use of Energy
SIR	Salzburger Institut für Raumordnung und Wohnen
SME	Small and Medium sized Enterprises
SMZV	Zaragoza Municipal Housing Society
UNESCO	United Nations Educational, Scientific and Cultural Organization
VAT	Value Added Tax

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