BUILDING SMART CITIES TOGETHER

SHARINGCITIES

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D3.1 Local Energy Production

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ACRONYM LIST

BEIS	Department for Business, Energy & Industrial Strategy
CIC	Community Interest Company
CHP	Combined heat and power
CO_2	Carbon Dioxide
CRC	Carbon Reduction Commitment
DER	Distributed Energy Resources
DHW	Domestic hot water
DSR	Demand Side Response
EAHP	Exhaust-air heat pump
EMS	Energy Management System
ERDF	European Regional Development Fund
ESCO	Energy service company
EST	Early stage technologies
EU	European Union
FAI	Innovation Support Fund
FEE	Energy Efficiency Fund
FiT	Feed-in Tariff
FREE	Regional Fund for Energy Efficiency
GHG	Greenhouse Gases
GSE	Energy Services Manager (Gestore Servizi Energetici)
KD	Knight Dragon
LED	Light-emitting diode
LEEF	London Energy Efficiency Fund
NOx	Nitrous oxides
nZEB	nearly Zero Energy Building
OFGEM	Office of Gas and Electricity Markets
PEAR	Regional Environment and Energy Program
PNAEE	National Energy Efficiency Action Plan
PNAER	National Renewable Energy Action Plan
PPA	Power Purchase Agreement
PV	Photovoltaic panel
RBG	Royal Borough of Greenwich
RES	Renewable Energy System
RET	Renewable-energy Technologies
SEAP	Sustainable Energy Action Plan
SEMS	Sustainable Energy Management System
SME	Small and Medium Enterprise
SOx	Sulfur Oxides
sqm	square meter (m^2)
UK	United Kingdom

EXECUTIVE SUMMARY

This report aims to share how the lighthouse cities from the Sharing Cities programme are dealing with local energy production. Cities and urban areas in general are currently facing significant challenges regarding climate change and efficient use of energy. In fact, energy efficiency is considered one of the main priorities supporting urban areas in this crucial transition towards decarbonisation. The focus has been mainly on making energy use more efficient, leading to the reduction of GHG emissions. In addition, there has been also a strong emphasis in recent decades on the acceleration of the development and market deployment of energy efficiency and low-carbon technology applications in the urban environment. Then, this is particularly challenging within a Smart Cities context, and crucial to ensure a safe, reliable, affordable and sustainable energy system.

In addition to the current vision and strategies of the three lighthouse cities of Sharing Cities regarding the local energy production, an extensive set of activities are expected to be performed during the programme. These include the deep retrofit of both public and private residential and services properties, integrated with the installation of low carbon energy sources (solar PV, water source heat pump), aiming to affect up to 15,000 citizens. The main goal is to increase local renewable energy generation, resulting in the reduction of energy costs and the decarbonisation of the local energy system. Additional benefits include more secure, stable decentralised generation and the implementation of demand side response applications. As a result, up to 6 MWh are expected to be saved each year, representing an overall reduction of 1,350 tonnes of CO_2 at overall level.

An important factor within this scope concerns the influence that European and National legislation and Local regulations have on the adoption of renewable technologies. Despite focusing on their promotion, the identification of the most suitable incentive schemes to renewable energy sources can be, by itself, a difficult task. This is mainly because the actual costs related to the implementation and operation of renewable technologies are often difficult to predict accurately. Therefore, understanding how to integrate conventional and renewable regulatory approaches is not straightforward, particularly considering long-term perspectives. With this in mind, an overview of both successes and failures of real life case studies that have occurred within the scope of RES implementation in the 3 lighthouse cities, is also presented.

Structurally, this report is organised into 5 main chapters as follows:

- Chapter 1 reviews the main European and National legislation and Local regulations influencing the adoption and promotion of local energy production in the 3 cities.
- Chapter 2 presents a brief description of the main policy instruments and technological tools that can be used to support the adoption of renewable energy sources.
- Chapter 3 reviews the current vision and strategies of the 3 cities within the local energy production context.
- Chapter 4 shares a group of practical success and failure case studies related to the adoption of renewable energy sources occurring in the 3 cities, as well as the main lessons learnt.
- Chapter 5 resumes the main activities related to energy production that are expected to be implemented in the 3 cities during the Sharing Cities programme.

INTRODUCTION

Cities, and urban areas in general, are facing significant challenges to meet the rising needs of their populations, while maintaining a healthy living environment and increase quality of life of their citizens. Accounting for more than half of the world's population, urbanization is expected to increase during the next decades, posing strong implications for urban management and governance. For this reason, strategic planning is seen as a key tool and one of the major priorities nowadays for urban areas.

Urban strategic planning is a difficult task. It has to take into account a broad set of factors and activities that compose the urban dynamics, including not only the land use or the management of public infrastructures and spaces, but also the ability to integrate complimentarily growth and development, industrialization, energy, water, sanitation, waste, transportation and telecommunication, among several others. Climate change is definitely another growing concern of great relevance nowadays. In this respect, urban areas are not only responsible for a considerable portion of the global anthropogenic greenhouse gases emissions but are also particularly vulnerable to its effects. Thus, local decision-making and strategic approaches have an important role to search for opportunities and pursue more sustainable pathways.

The type of initiatives assumed by cities within this context varies widely. Nevertheless, from a general perspective, it is possible to identify three main structural categories for these policy initiatives. These are: energy and climate planning and governance, specific mitigation policies and programs focused on reducing the local energy system's contribution to climate change, and adaptation efforts dealing with the consequences of climate change [1].

Thus, it becomes clear that the energy sector plays a critical role both within climate change mitigation and urban planning framework. However, the integration of a substantial amount of renewable energy sources in energy systems is one of the major challenges for electricity supply. In this respect, a complex range of factors is shaping how cities are currently dealing with energy demand and supply, while they account for about 65% of global energy demand and 70% of energy-related carbon dioxide emissions [2]. With an increase of population living in urbanized areas, a significant increase in energy demand is anticipated within these areas, meaning that the decoupling of energy production and consumption from the greenhouse gases (GHG) emissions is imperative.

Significant efforts have been made during the last decades to tackle this problem, with strong emphasis on the acceleration of the development and market deployment of energy efficiency and low-carbon technology applications in the urban environment. Regarding the use of low-carbon energy sources, including renewable energy technologies (RET), it has expanded rapidly in recent years. The reasons for this expansion are related to the decrease in costs related to these technologies, fossil fuels price volatility, and an increase in energy demand and environmental awareness amongst the public, which has led to various types of government policies and commitments. However, despite these government policies and commitments, a considerable portion of low-carbon energy technologies still have lower maturity levels – in particular when compared to traditional ones – meaning that public support schemes are still required to support deployment and attract the necessary increases in investment in technologies and infrastructure.

Energy efficiency is considered one of the main priorities supporting urban areas in this crucial transition. The rationale of this concept is clear and focus on making the use of energy more efficient, i.e. decrease the overall energy demand, leading to the reduction of GHG emissions. However, the benefits resulting from this ultimate goal are much broader and focusing on energy supply and demand alone is definitely reductive. At a higher level of implementation, it supports economic growth, enhances social development, advances environmental sustainability, ensures energy-system security and helps build prosperity.

Early investigations of these multiple benefits suggest that they are significant, however they are left out of most policy and programme evaluations for various reasons, including lack of relevant data and evaluation methods, estimation challenges and perceived credibility risk.

In the urban environment, buildings are on the front line of this issue, presenting the largest potential for savings. They are responsible for 40% of energy consumption and 36% of CO_2 emissions in the EU [3]. In addition to significantly improving the health and well-being of occupants, energy efficiency measures in buildings have also great economic advantage, in particular by reducing energy use for heating and/or cooling, electricity use for lighting, and lower the building maintenance requirements.

Nonetheless, the emphasis is on the integration of these two concepts, aiming for the promotion of adequate urban planning practices to create opportunities for both reducing energy consumption and supporting the integration of renewable energy systems (RES) and smart grid technologies in an urban context. As cities play a crucial role in driving global energy demand, this is a particular challenge within a Smart Cities context, and key to ensuring a safe, reliable, affordable and sustainable energy system.

1. ENERGY POLICIES

The European Union's energy policies are driven by three main objectives: securing reliable energy supplies; ensuring that energy providers operate in a liberal market to ensure affordable prices; and ensuring sustainable energy consumption, through the lowering of GHG emissions, pollution, and fossil fuel dependence [4]. With the EU currently importing over half its energy at a cost of €350 billion per year, the EU external dependence on energy is a particularly pressing issue to tackle through these objectives. Another important challenge includes the global demand, price variation and the scarcity of fossil fuels like crude oil, or gas. In addition, the use of these fossil fuels raise important environmental concerns, in particular related to global warming and air pollution, which is a significant concern for urban areas. To pursue these goals within a coherent long-term strategy, the EU has formulated targets for different time horizons, including 2020, 2030, and 2050. The 2020 Energy Strategy, which was put in force with the Renewable Energy Directive [5], defines the EU's energy priorities between 2010 and 2020. Its main aims at EU level are:

- reduce greenhouse gases by at least 20%;
- increase the share of renewable energy in the EU's energy mix to at least 20%;
- improve energy efficiency by at least 20%.

Considering these targets at EU level, the Directive specifies also national renewable energy targets for each country, considering its starting point and overall potential for renewables. These range from a low of 10% in Malta to a high of 49% in Sweden.

More recently, to ensure the achievement of these targets, in 2016, the Commission has released a package of draft legislative proposals to recast this Directive and to include the appropriate adaptations for necessary to accomplish its vision for 2030 [6,7]. The target defined for this horizon is of at least 27% renewables in the final energy consumption. The measures include draft proposals on electricity market design, renewables, and energy efficiency.

Concerning transport, biofuels and bioliquids are also supporting EU countries to meet their 10% renewables target in transport and mobility sector. In addition, the Renewable Energy Directive sets out biofuels sustainability criteria for all biofuels produced or consumed in the EU to ensure that they are produced in a sustainable and environmentally friendly manner.

In terms of RES for heating and cooling, the Ecodesign Directive [8] establishes a framework for the setting of Ecodesign requirements for energy-related products. Within this context it provides a consistent EU-wide rules for improving the environmental and energy performance of products, by defining minimum mandatory requirements for a comprehensive list of energy-related products, including air conditioners and comfort fans, air heating and cooling products, space and water heaters, high temperature process chillers and fan coil units, among others.

1.1. LONDON & UNITED KINGDOM

At UK national level, there exists policy and regulation which acts to either encourage and reward uptake of local and small-scale renewable energy generation; or to deter and penalise energy consumption of energy from high carbon emission sources.

An example of the former is the Feed-in-Tariff (FiT) scheme, a Government scheme under which anyone who installs or has installed an eligible system such as solar PV, wind turbines, hydro or micro CHP, can receive payments for the generated electricity and which goes back into the national grid.

An example of the latter is the Carbon Reduction Commitment (CRC) Energy Efficiency Scheme. This is a mandatory scheme, whereby large organisations are required to report on eligible energy consumption and purchase carbon allowances to cover the associated carbon dioxide emissions. The Royal Borough of Greenwich is required to participate in this scheme, noting emissions from energy consumed by its corporate buildings, and assets such as street lighting. In 2014/15 total CRC emissions reported were 17,884 tonnes of CO_2, at a cost to the Borough of £278,990.40. The current UK government has stated recently that the CRC scheme is to be abolished.

National policy also promotes indirectly the production of local renewable energy through regulations relating to the building sector. Current building regulations dictate that major new developments of housing above 10 units must deliver a 35% reduction in regulated carbon dioxide emissions beyond the 2013 building regulations. From October 2016, the Mayor of London's key policy document, 'The London Plan', enforces this regulation for London that goes beyond this 35% to apply a zero carbon standard to new residential buildings. This means that all major development must strive for 100% reduction beyond 2013 national Building Regulations, with a minimum target of 35% reduction. In case of the 100% target is not achieved, the remaining regulated carbon dioxide emissions are to be off-set through a cash in lieu contribution to the relevant Borough to be ring fenced and secure delivery of carbon dioxide savings elsewhere.

Prior to 2016, all major new housing developments were also to achieve against the Code for Sustainable Homes, which included targets on inclusion of renewable energy. However, this Code has now been abolished at national level.

The requirement that larger developments achieve an onsite reduction in carbon emissions of 35%, and previous targets specifically relating to renewables inclusion, have led- to many new housing developments utilising renewable energy technologies, particularly Solar PV. In the Royal Borough of Greenwich, the enforcement of these regulations through the planning process by the Council has resulted in over 35,000 m^2 (equivalent to 5 football pitches) of solar panels being installed on developments in the Borough since 2010, as well as the application of other renewables such as biomass, solar thermal and ground source heat pumps.

Regarding refurbishment of housing stocks, there is currently no regulation in the UK which dictates standards for the inclusion of renewables.

1.2. MILAN & ITALY

The European Renewable Energy Directive [5], currently under review in order to enforce the European target for 2030, sets for Italy a target for the share of energy from renewable sources, in gross final consumption, equal to the 17% for 2020.

According to the prescription of this Directive, the Italian Ministry for Economic Development, in 2010, delivered the "Italian National Renewable Energy Action Plan". The Plan, in order to ensure that global target of 17% is achieved by 2020, sets the targets for each sector. In general, these are: 17% for building heating and cooling, 26,4% for electricity and 10,1% for transports. The Plan also establishes a complete set of actions and measures to be implemented in order to achieve these targets.

In addition to the Italian National Renewable Energy Action Plan, the Legislative Decree no.28 of March 2011, defines the institutional, legal and financial framework, the mechanisms and the incentives necessary for the target's achievement.

In terms of incentives, the Ministerial Order no.28 of December 2012 (updated in February 2016) implements the provisions of the Legislative Decree n.28, by setting a system of capital grants, known as *Conto Termico*. The *Conto Termico* provides grants for deep energy retrofit of buildings and for the use of renewable energy sources and it is open to public bodies, private companies and citizens.

At the regional level, the regional targets were set by a Ministerial Order in March 2012 – the so called Burden Sharing Order. The target for Lombardia region, where Milan is located, is currently 11.3 % share of energy from renewable sources in gross final consumption by 2020.

The Official Strategic Act regarding energy at the Regional Level is the Regional Environment and Energy Program (PEAR - *Programma Energetico Ambientale Regionale*), approved in June 2015. This Program defines the energy strategy at the regional level, and includes, among its objectives, the target for renewable energy.

According to the PEAR, various instruments were adopted. Among them it is worth mentioning the FREE Fund (Regional Fund for Energy Efficiency), financed with European Regional Development Fund (ERDF), that provides grants to public bodies for the deep energy retrofit of their buildings. The incentives are partially granted as a capital grant and partially as a loan at a 0% rate.

1.3. LISBON & PORTUGAL

As the Lisbon policy scenario is characterized by the national framework, this section covers the Portuguese current transition state for renewable energy policies.

Energy efficiency and renewable energies have been the main trends of the Portuguese energy policy. The main aim of this policy strategy is to comply with low carbon targets and to reduce the imported energy dependence while maintaining appropriate supply security levels.

The promotion of renewable energy, based on feed-in-tariffs (FiD), is one of the reasons for the actual energy system economic unsustainability, known as the "tariff deficit" problem. This is currently leading to some stress in the energy sector, slowing or even blocking new public initiatives in support to investment.

In this context, considering that there is not a clear and sustainable viability, the private sector does not have great incentives to invest in innovative energy technologies. Despite this unfavorable environment for energy investment in Portugal, there are still ambitious energy policy goals and the private interest for investment has started growing, both for renewables, with new photovoltaic production plants, wind and hydro retrofit projects, as for energy efficiency.

As of 2010, the National Energy Strategy for 2020 (ENE 2020) laid out a commitment to invest in developing an energy research strategy, consistent with the energy policies and the broader national economic goals, as outlined by the Portuguese government in a specific National Regulation (RCM no. 29/2010). The ENE 2020 research and development (R&D) policies are aligned with the European policies for energy and climate change, engaging the main national support institutions in this area, such as FCT (Foundation for Science and Technology) and DGEG (Directorate-General for Energy and Geology). The ENE 2020 is based on five main pillars, as following:

1. Agenda for competitiveness, growth and energy and financial independence;
2. A commitment for renewable energies;
3. Promotion of energy efficiency;
4. Ensuring security of supply;
5. Economic and environmental sustainability;

More recently, in 2013 the Portuguese government defined the National Renewable Energy Action Plan (PNAER) and the National Energy Efficiency Action Plan (PNAEE), in compliance with the European targets for national level action plans, again considering the 2020 horizon for target completion. The former outlined the trajectories to introduce RES in three critical sectors: heating and cooling, electricity and transport. The later intends to foster energy efficiency in fields such as: transport, residential and services, industry, state and agriculture.

In addition, some public financial support instruments should also be accounted at this stage. One good example is the Innovation Support Fund (FAI), created in 2008, which supports innovation, technological development and investment in renewable energy and energy efficiency areas. FAI has supported the Mobi.E project, which created and continues to develop the first national electric mobility network, with thousands of EV charging stations spread across the country, as well as many other RES based electricity generation projects, as solar PV plants and floating offshore wind platforms, or additional energy efficiency projects in smart grids, transport and buildings. The Energy Efficiency Fund (FEE) is another financial support public instrument, created in 2010, which funds programs and measures within the scope of the PNAEE. Its main aims are then to encourage energy efficiency practices at citizen and company levels, raising awareness and promoting behavior change leading to an overall energy consumption reduction.

2. RENEWABLE ENERGY PROMOTING INSTRUMENTS

The European Union has taken on a leading role in the world regarding energy transition, by posing strong commitments and goal on renewable energy production, energy efficiency and reduction of GHG emissions. However, to be successful with its long-term vision a stable political framework is first and foremost required, as well as a well-tailored support system, financial, technical and administrative, to overcome the obstacles existing in distorted energy markets.

From a political and financial perspective, several types of instruments exist to support both the increase of installed capacity and technological scaling up. In general, the objectives of RES supporting policies is to promote deployment, as well as improve technology cost-competitiveness, create jobs, promote a sustainable level of RES production, and move towards a more sustainable, secure energy system. For this reason, despite some RET having become cost-competitive, one can say that political and financial instruments are set up to support economically the increase of RES market share and potentially the main driver for its success.

From a technological perspective, a wide range of different energy tools and models are available to support decision making on energy transition. These are diverse both in terms of the considered technologies and the objectives to fulfil, ranging from stand-alone RES applications, such as single-buildings, local communities, or single-projects, to multi-layer complex analysis of energy systems, from both electricity and heat points of view.

Considering this diversity, the next sections present a brief analysis of available political and financial instruments and energy tools and models.

2.1. POLICY INSTRUMENTS

According to the above-mentioned, it is clear that renewables are playing an increasingly important role in the energy supply systems. In addition to the technical issues previously referred, its production presents also challenges for regulators and policymakers. In this context, the identification of the most suitable incentive scheme to renewable energy sources can be, by itself, a difficult task, mainly because it is evolving rapidly, in terms of technological maturity, and the actual costs are often difficult to predict accurately. Then, understanding how to integrate conventional and renewable regulatory approaches is not straightforward, mostly considering long-term perspectives.

However, despite these constraints, some principles are common with respect to regulation of renewable energy production. Although they differ in significant ways, a number of regulatory instruments are commonly used to promote renewable energy production. Most of them involve distributed generation, meaning that technical specification such as the access to the grid, power quality, and several other issues, need to be clearly addressed by regulators in the design of the instruments. However, overall, all instruments entail financial commitments to potentially influence the success of RET market deployment, being the subsequent costs met through national budget, by specific green electricity consumers or shared among all electricity consumers.

In general, these instruments can be classified in two different typologies: the price-based and the quantity-based instruments. Although most of the current practices suggest that price-based instruments (e.g. feed-in tariff model) are more effective at reducing investor risk, there are evidences that quantity-based instruments (e.g. certificate trading models) can be less expensive in general terms. The rationale is that quantity-based instruments promote competition among available technologies, giving an advantage to more mature and consequently less expensive ones. Thus, despite an increasing number of countries being considering the trading model, the feed-in tariff is definitely the most applicable instrument in terms of installed capacity. From a future perspective, a mixture of both is expected.

To better understand these instruments, the next table presents a brief summary of the main ones currently in use to promote renewable energy sources.

Table 1 - Brief summary of the main policy instruments to promote renewable energy sources [9].

Instrument	Type	Description
Feed-in Tariff (FiT)	Price-based	Energy distribution utilities are obliged to purchase electricity generated from renewable sources meeting specified criteria. Typically, the costs of renewable energy tend to be higher and hence the generator is offered fixed minimum tariffs guaranteed over a relatively long period. This ensures that investors are guaranteed income that covers costs and additional return on capital sufficient to motivate investment. This tariff can be targeted to specific technologies or all renewable energy technologies. The additional costs can be met by additional energy cost of electricity or by taxpayers in general.
Net-metering	Price-based	It is a system whereby electricity produced in excess of the customer's load is sold back to the grid. The payment is normally at wholesale market rate and can be made for each kWh delivered to the system or credit when production equals own consumption. The underlying assumption in the latter case is the consumer saves the utility from adding capacity.
Quota system	Price-based	Under this system, the government mandates that a share of the generation or capacity must come from RES. The two main types of quota system are tendering system and obligations or certificates. Usually, the maximum prices per kWh are also set.

Instrument	Type	Description
Renewables Portfolio Standard	Price-based	It is a market mechanism where the share of renewables is mandated by the government, with credits provided for each kWh. Investors and generators make all decisions about how to comply, including: the type of renewable energy to acquire, which technologies to use, what renewable developers to do business with, what price to pay, and which contract terms to be agreed. In this case, the government's role is to certify credits, monitor compliance, and impose penalties if necessary.
Production subsidies	Quantity-based	In this system, the government provides subsidies for specific renewable technologies. However, the subsidies require the availability of substantial funds and a supporting system that would address the validation aspects as well as manage the funds. A credible accounting system would also have to be in place to ensure that funds are spent as per the goals of the program.
Tax credits and exemptions	Quantity-based	Tax credits and exemptions have largely been used to spur up growth of specific technologies with wind and PV being the most obvious. Although regulators would generally not have control over such funds, the agency might be given the responsibility for monitoring the cost-effectiveness of such programs. This ultimately means lost revenue to the governments.
Rebates	Quantity-based	In this system, refunds are provided to investors, based on a share of the cost of a generation technology, installation costs or fixed amount of money per KW installed. These are mainly administered by the utility and financed through extra charge per kWh consumed. Usually, the program operates well as long as the extra tariff charges meet the costs and are guaranteed over the longer term.
Government guaranteed loans	Quantity-based	It is a measure to support the normally high investment needed for RET compared to conventional technologies. The government enters into an agreement with financial institutions which in turn provide the loans at low interest rates and since the funding is fully guaranteed by the government. Generally, this approach has been largely used for small scale household systems.
Carbon Tax	Quantity-based	Tradable emission permits for electricity producers are used to encourage adoption of renewable energy and energy efficient technologies. The target is set nationally and producers are given a Carbon entitlement. Then, producers emitting more than their allowed amount are fined. Therefore, a monitoring and registration system is needed to validate the emissions reduced as well as retire permits at appropriate time. The cost of such carbon tax tends to be passed on to the consumer and this is often rationalised as the consumer pays principle.

Instrument	Type	Description
Standards and labeling systems	Quantity-based	Standards and labelling systems can facilitate keeping out low quality technologies. However, monitoring is necessary and enforcement is normally a major challenge. The fact that renewable energy power is available intermittently makes it crucial to have grid standards that differ from the conventional generation sources.
Government support to voluntary action	Quantity-based	In this system, utilities generate power from green sources and sell it at green tariffs or at premium rates to consumers. Governments support these efforts through implementing public awareness campaigns.
Targets	Quantity-based	The use of targets is an increasingly favoured mechanism for promoting renewables, often without penalties and applicable at the national level. Usually, targets are used in complement to previous instruments. For this reason, it is difficult to determine the level of success since the monitoring methods are also not always made public.

2.2. ENERGY TOOLS AND MODELS

Several discussion papers present reviews on the different available tools that can be used to analyse the integration of RES within energy systems. Perhaps, the most detailed review was made by Connolly, in 2009, that considered 68 different tools, from which 37 were analysed in detail [10]. According to the author, the aim was to provide background information and support the identification of most suitable energy tools to analyse the RES integration into various energy-systems under different objectives. As a main result, this paper concludes that all reviewed tools are highly dependent on the specific objectives of the analysis, and that there is not an ‘ideal‘ tool that addresses all issues related to RES integration.

The next table provides a summary of the identified tools, including their brief description and main target audience. Afterwards, a more detailed description is provided, resuming their main features and characteristics.

Table 2 – Brief review of energy models and tools.

Name	Description	Target users
AEOLIUS	Energy production dispatch simulation tool to analyse the impact of higher penetration rates of fluctuating energy.	Planners Power companies System operators
BALMOREL	Tool which supports modelling and analysis of the energy sector with emphasis on the electricity and the combined heat and power sectors.	Researchers Consultants Power companies
BCHP Screening Tool	Tool supporting the assessment the savings potential of combined cooling, heating, and power systems for commercial or institutional buildings.	Researchers Consultants Power companies
COMPOSE	Technological and economic energy-project tool to assess to energy projects in terms of intermittency, offering a realistic evaluation of the distribution of costs and benefits under uncertainty.	Financers Developers Promoters Researchers
EMCAS	Model to simulate the operational and economic impacts of various external events on the electricity sector.	Researchers Power companies System operators
EMINENT	Tool supporting the introduction of new energy technologies and new energy solutions into the market.	Financers Developers Promoters Researchers
Energy Efficiency Assessment	Method supporting cities on the identification of major energy efficiency issues, gaps, constraints and solutions	Planners Consultants Policy Makers
EnergyPLAN	Tool to assist in the design of national or regional energy planning strategies, by providing technical and economic analyses of implementing different energy systems and investments.	Planners Power companies

Name	Description	Target users
energyPRO	Tool for combined techno-economic design, analysis, and optimisation, of both fossil and bio-fuelled cogeneration and trigeneration projects.	Planners Consultants Researchers System operators
ENPEP-BALANCE	Market-based simulation tool to assess the demand for energy and the available resources and technologies.	Financers Power companies System operators
FROnT	Tool supporting decision making on heating and cooling systems, by assessing the competitiveness of renewable energy technologies, against traditional ones.	Residential consumers
GTMax	Model to provide utility companies with a simulation of the dispatch of electric generating units and the economic trade of energy.	Researchers Consultants Power companies
H2RES	Tool that simulates the integration of renewable energy into energy-systems.	Planners Consultants Researchers
HOMER	Micropower design tool to simulate and optimise stand-alone and grid-connected power systems.	Planners Power companies System operators
INFORSE	Energy balancing model for national energy-systems, providing support on the identification of potential use of renewable energy and identifying trends in energy efficiency, energy services and energy policies.	Planners Policy Makers
Invert	Simulation tool providing support to national energy-systems on the design of efficient promotion schemes for renewable and efficient energy technologies.	Planners Consultants Policy Makers Power companies
IRENA Project Navigator	Online platform aiming to support the development of complete lifecycle renewable energy projects by providing users with technical guidelines, knowledge products and tools.	Developers

Name	Description	Target users
LEAP	Tool to assess energy consumption, production, and resource extraction in all sectors of an economy.	Planners Power companies System operators
London Renewables Toolkit	Toolkit aiming to support the development of policies and strategies relating to renewable energy.	Planners Developers Consultants
MESSAGE	Tool used for the planning of medium to long-term energy-systems, analysing climate change policies, and developing scenarios for national or global regions.	Planners Policy Makers Power companies System operators
PRIMES	Tool to assess market solutions for energy supply and demand.	Consultants Power companies System operators
RAMSES	Tool of assess electricity and district heat production.	Planners Consultants Researchers System operators
Renewable.ninja	Online simulator that provides the hourly power output from wind and solar power plants located anywhere in the world.	Developers Researchers
REFINe	Web-based tool that supports on the identification and development of financial instruments to overcome renewable energy technologies risks and barriers.	Financers Planners Developers
Renewables Selector	Web-based tool aiming to provide support to general consumers on defining the most suitable renewable systems for households.	Residential consumers

Name	Description	Target users
RETScreen	Decision support tool aiming to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies	Planners Developers Consultants
SimREN	Tool to design models of energy management, adapted distribution systems, and energy supply and demand.	Planners Consultants Power companies System operators
SIVAEL	Tool supporting the electricity and district-heating systems simulation with start/stop and load distribution.	Consultants Power companies System operators
Solar potential map	Geo-referenced product based on photogrammetry techniques and specific algorithms for calculating solar energy production potential of buildings and other surfaces in urban areas.	Planners Policy Makers Consultants Residential consumers
System Advisor Model (SAM)	Model providing a performance and financial analysis to support decision making on renewable energy technologies for electricity generation.	Project managers Designers Developers Researchers
TRNSYS16	Tool supporting the simulation of the electricity and heat in an energy-system.	Planners Power companies System operators

AEOLIUS

The AEOLIUS tool aims to support the impact analysis of different penetration rates of fluctuating energy carriers such as wind or PV, on conventional energy systems. In general, it is an energy production dispatch simulation tool used to identify secured capacities and efficiency losses due to more frequent start-ups. It allows the simulation of the electricity system accounting all thermal-generation technologies as well as pumped-hydro-electric and compressed-air energy storage, wind, photovoltaic, and geothermal power. [11]

BALMOREL

BALMOREL is a model for analysing the electricity and combined heat and power sectors in an international perspective. It is highly versatile model, which can be modified according to specific requirements, suitable for analyses of supply security, flexible electricity demand, wind power development, development of electricity markets, market power, heat transmission and pricing, expansion of electricity transmission, markets for green certificates or emission trading and environmental policy evaluation [12].

BCHP SCREENING TOOL

The BCHP Screening Tool is a tool for assessing the economic potential of combined cooling, heating, and power (CHP) systems for commercial buildings. It contains a comprehensive equipment database including HVAC systems, electric generators, thermal storage systems, prototypical commercial buildings, climate data, and electric and gas utility rates. Together with a building energy use analysis tool (DOE2.1e) the database can be used to calculate heating, cooling, and electrical loads as well as monthly and annual utility costs. It is structured to perform parametric analyses between a baseline building, typically a conventional building without a CHP system, and up to 25 alternative scenarios with varying selections for building mechanical systems and operating schedules [13].

COMPOSE (Compare Options for Sustainable Energy)

The COMPOSE tool supports the evaluation the feasibility of a defined energy option in a defined energy-economic system-wide perspective using different methodology options. It aims to assess to which degree energy projects may support intermittency, while offering a realistic evaluation of the distribution of costs and benefits under uncertainty. Results include operational dispatch, economic costs, financial costs, fiscal costs, system-wide fuel consumption and CO2 emissions/cost-effectiveness, and metrics intermittency-friendliness and intermittency-volume as measures of smart performance.

In terms of CO2 emissions, COMPOSE offers the possibility of an assessment of an energy option's technical CO2 emissions taking into account the marginal producers of electricity and fuel in the respective markets. Any number of marginal producers of electricity and fuel can be selected for which the corresponding marginal production costs (calculated just as any other energy option) and the energy-economy system's spot market prices decides marginal CO2 impacts.

In terms of intermittency-friendliness and intermittency-volume, COMPOSE offers an innovative assessment of how well an electricity producer or consumer interacts with intermittent electricity supply, electricity markets, and other electricity demand in the energy system. [14]

EMCAS (Electricity Market Complex Adaptive System)

EMCAS is used to probe the possible operational and economic impacts of various external events on the electricity sector in an energy-system. EMCAS can simulate all costs, thermal generation, and renewable generation technologies, as well as various market operating rules established by a regulator agent. The rules can range from a conventional vertically integrated utility operating under rules established by a local public utility commission to a fully deregulated market operating under forward bidding procedures, such as some that are already in place. In addition, a random event generator allows for simulation of unexpected incidents, such as generator or transmission line outages [15].

EMINENT

The main goal of EMINENT tool is to support technology financers, developers and promoters, universities, and research centres, in the introduction of new energy technologies and new energy solutions into the market, in a faster way. The tool aims to support the assessment of a technology at financial, environmental, and energy levels, comparing it with other technologies that already exist in the market over a one year period.

As main feature, the EMINENT tool evaluates the performance and potential impact of early stage technologies (ESTs) in a pre-defined energy supply chain. To support this function, it comprises two different databases. One contains information on the number of consumers per sector, type of demand, typical quality of the energy required and the consumption and installed capacity per end-user, and a second database with the EST and with other already commercial technologies. This second database contains key information on new thermal generation, heat, and also other renewable technologies that are currently at lower stages of development [10].

ENERGY EFFICIENCY ASSESSMENT

From a city perspective, an Energy Efficiency Assessment supports a city on the identification of major energy efficiency issues, gaps, constraints and solutions. As a result, it yields practical recommendations for improving energy efficiency in one or multiple sectors, and a course of actions for the city government to prioritize policy interventions and investments across urban sectors. It generally includes the following four steps: (i) identification of energy efficiency gaps and potential solutions; (ii) evaluation of the cost and benefits of potential solutions; (iii) analysis of the barriers and constraints to implementing defined potential solutions; and (iv) recommending a course of actions based on energy efficiency goals, local capabilities, and available resources.

ENERGYPLAN

EnergyPLAN is a tool to assist on technical and economic analyses of the consequences of implementing different energy systems and investments in the design of national or regional energy planning strategies. It is based on a deterministic input/output model which uses expected demands, renewable energy sources, energy station capacities, costs and different regulation strategies emphasising the electricity production excess/deficit. By using these data, the tool provides energy balances and resulting annual productions, fuel consumption, import/export of electricity, and total costs including income from the exchange of electricity. The model is also able to analyse the influence of fluctuating renewable energy sources on the system as well as weekly and seasonal differences in electricity and heat demands and water inputs to large hydro power systems. [16]

ENERGYPRO

ENERGYPRO is a modelling tool for combined techno-economic analysis and optimisation of both cogeneration and trigeneration projects as well as other types of complex energy projects with a combined supply of electricity and thermal energy (steam, hot water or cooling) from multiple different energy producing units. Its main goal is to support the optimization of the operation to be made against fixed tariffs for electricity or against spot market prices, by providing the user with a detailed financial plan including the presentation of the operating results, monthly cash flows, income statements (P&L), balance sheets and key investment figures such as NPV, IRR and payback time. In addition, it also enables the user to calculate and produce a report for the several GHG emissions (CO_2, NOx, SO_2, etc.) [17].

ENPEP-BALANCE

ENPEP-BALANCE is a nonlinear equilibrium model that matches the demand for energy with available resources and technologies. By using a market-based simulation approach it determines the response of various segments of the energy system to changes in energy prices and demand levels. The model relies on a decentralized decision-making process in the energy sector and can be calibrated to the different preferences of energy users and suppliers. Basic input parameters include information on the energy system structure, base-year energy statistics including production, and consumption levels and prices, projected energy demand growth, and any technical and policy constraints [18].

FRONT

Resulting from a European funded project, the FROnT tool supports decision making on heating and cooling systems, by assessing the competitiveness of renewable energy technologies, against traditional ones. As an outcome, the tool provides a comparison of the constant cost of generating 1 kWh of heat/cold over the lifetime of the renewable energy technology and the Levelised Cost of Heating and Cooling of the conventional (non-renewable) system. Aiming to provide the profitability of replacing the conventional by a renewable system, the results consider three financial parameters: Net Present Value, Internal Rate of Return and Simple payback [19].

GTMAX (Generation and Transmission Maximisation Model)

GTMax aims to provide utility companies with a simulation of the dispatch of electric generating units and the economic trade of energy, using a network representation of the power grid. The objective of GTMax is to maximise the net revenues of power systems by finding a solution that increases income while keeping expenses at a minimum. The tool provides simulations of both the electricity sector and district heating networks. The generation and energy transactions serve electricity loads in different locations throughout a national or regional energy-system. All thermal, renewable and electric vehicles can be simulated by the model. [20]

When multiple systems are simulated, supports on the identification of utilities and projects that can successfully compete on the open market, solving simultaneously the maximisation objective for all hourly time steps during different time periods. In addition, the model can be also implemented in real-time operations with connections to SCADA systems [20].

H_2RES

The H2RES model is designed for balancing between hourly time series of water, electricity, heat and hydrogen demand, appropriate storages and supply (wind, solar, hydro, geothermal, biomass, fossil fuels or mainland grid). The main purpose of model is energy planning of islands and isolated regions which operate as stand alone systems but it can also serve as planning tool for single wind, hydro or solar power producer connected to bigger power system [21].

HOMER

HOMER is a simulation model suited for supporting the identification of viable systems considering different equipment and load combinations including wind turbines, PV arrays, run-of-river hydro power, biomass power, internal combustion engine generators, microturbines, fuel cells, batteries, and hydrogen storage, serving both electric and thermal loads. Also, all costs (including any pollution penalties) can be included, with exception for fuel handling costs and taxes [22].

INFORSE (International Network for Sustainable Energy)

The INFORSE is an energy balancing model for national energy-systems. It has been used to simulate the renewable energy potential production by 2050 for a number of countries including: Belarus, Bulgaria, Denmark, Latvia, Lithuania, Romania, Russia, Slovakia, Ukraine and the UK, as well as a 100% renewable energy-system for Denmark by 2030.

The model uses energy production, energy demand, energy trends and energy policies to provide an overview for the possible energy-development for a country or region. This is done by providing an energy balance for every decade simulated, illustrating the potential use of renewable energy and identifying trends in energy efficiency, energy services and energy policies. The economic perspective is also included in the model considering the overall energy cost and CO2 costs [23].

INVERT

The Invert simulation tool is primarily used to simulate national energy-systems and supports the design of efficient promotion schemes for renewable and efficient energy technologies. The tool focuses specifically the heat sector, by analysing the use of heat pumps, solar thermal and conventional heating systems, to support on the impact assessment of different promotion schemes, including feed-in tariffs, subsidies, soft loans, etc. The simulation can be run for up to a 25-year period, in 1-year time-steps and it accounts for all sectors of the energy system. The outputs include costs, unit productions, fuel consumption, mix of energy carriers, energy demands, and installed capacities of units required [24].

IRENA PROJECT NAVIGATOR

The IRENA Project Navigator is an online platform that walks developers through renewable project creation from initial conception to end results. It supports the development of renewable energy projects from inception up to operations by providing users with technical guidelines, knowledge products and tools that cover the complete lifecycle of a project. For this reason, the nine phases of renewables implementation are considered: Identification, Screening, Assessment, Selection, Predevelopment, Development, Execution, Operation and Decommission [25].

In addition, it offers practical resources such as financial models, checklists and evaluation forms to assist developers at different stages of the process. With these features, the platform supports its users in gathering strategic information, addressing risks, taking informed decisions and using resources efficiently towards successful project financing and implementation. It also contains written project proposal guidelines, an interactive project development tool to help project developers create a successful, bankable project and an interactive financial navigator which connects projects with funding opportunities. These three components are hosted on a Communication and Coordination Platform which enables interaction between the different tools and connects the various stakeholders (e.g. banks, donors, international organisations) to facilitate project financing and encourage the exchange of experiences and common problem solving.

LEAP (Long-range Energy Alternatives Planning)

The Long-range Energy Alternatives Planning System is a tool for energy policy analysis and climate change mitigation assessment. It is an integrated, scenario-based modelling tool that can be used to track energy consumption, production and resource extraction, to account for GHG emissions sources and sinks, and to analyse emissions of local and regional air pollutants, and short-lived climate pollutants (SLCPs) making it well-suited to studies of the climate co-benefits of local air pollution reduction. [26]

LONDON RENEWABLES TOOLKIT

This toolkit supports the development of policies and strategies relating to renewable energy use in London representing a Supplementary Planning Guidance to the London Plan on renewable energy. Overall aim is to show that renewable technologies are cost effective, easy to install and well suited to urban areas. It provides a detailed overview of the renewable energy technologies available and their appropriateness for different development types, and supports developers, their consultants and all planners to make informed decisions and navigate the planning process in a more easily perspective.

MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental Impact)

MESSAGE aims to support the design of long term energy supply strategies or test energy policy options by analysing cost optimal energy mixes, investment needs and other costs for new infrastructure, energy supply security, energy resource utilization, rate of introduction of new technologies (technology learning), and environmental constraints. On this purpose, it combines technologies and fuels to construct so-called ‘energy chains’, making it possible to map energy flows from resource extraction, beneficiation and energy conversion (supply side) to the, distribution and the provision of energy services (demand side). As a result, MESSAGE develops different scenarios through minimizing the total systems costs under certain imposed constraints, and presents the evolution of the energy system from the base year to the end of the time horizon [27].

PRIMES

The PRIMES energy model simulates the European energy system and markets on a country-by-country basis and across Europe for the entire energy system. The model provides projections of detailed energy balances, over the period from 2015 to 2050 in 5-years intervals, for demand and supply, CO_2 emissions, investment in demand and supply, energy technology penetration, prices and costs. It simulates demand and supply behaviour by agent (sector), based on microeconomic founded modelling which includes technical constraints, under different assumptions regarding economic development, emission and other policy constraints, technology change and other drivers [28].

RAMSES (RApid Multiprocessor Simulation of Electric power Systems)

RAMSES is a simulation tool of electricity and district heat production and governmental national energy forecasts. any number of electricity and district-heating areas. It considers the operation of the existing plants, as well as reinvestment in new plants if required.As results it presents the primary energy consumption, renewable energy penetration rates, and GHG emissions. It considers all costs and thermal-generation technologies within a national energy-system, as well as wind, hydro, PV, geothermal, heat pumps, pumped-hydroelectric energy storage, compressed-air energy storage, and battery energy storage. To carry out the simulation, it uses datasets such as a plant database, information on electrical energy consumption, district heating consumption, fuel prices, fuel properties, exchange capacity, taxes, quota prices, grants, environmental costs (i.e. CO2, SO2, NOX costs), etc. [10].

RENEWABLE.NINJA

Renewables.ninja is an online simulator that provides the hourly power output from wind and solar power plants located anywhere in the world. Based on 30 years of observed and modelled weather data, it predicts the wind speed likely to influence turbines and the sunlight likely to strike solar panels at any point on the Earth during a year. These figures are combined with manufacturer's specifications for wind turbines and solar panels to give an estimate of the power output that could be generated [29].

RENEWABLES ENERGY FINANCIAL INSTRUMENT TOOL (REFINE)

REFINe is an interactive web-based tool that supports on the identification or development of financial instruments to overcome renewable energy technologies risks and barriers. It aims to assist policymakers, mainly from low-income countries, in identifying how to apply financial instruments to support the scaling-up of commercially proven Renewable Energy Technologies [30].

RENEWABLES SELECTOR

Developed by Energy Saving Trust, this web-based tool aims to provide support to general consumers on defining which renewable systems may be suitable for households. Mainly targeted for UK residents, it estimates the energy bill savings considering the installation of renewable energy technologies and the different available energy schemes [31].

RETSCREEN

The RETScreen Clean Energy Project Analysis Software is a decision support tool aiming to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs). In practice, it provides a comparison between a baseline, typical considering the conventional technology or measure, and a proposed scenario, i.e. a clean energy technology. As a result, it is ultimately not concerned with the absolute figures, but rather the difference of the proposed scenario when compared with the baseline. From an economic perspective, the outcome is to determine whether or not the balance of costs and savings over the life of the project are financially attractive. For this purpose, the tool includes products, projects, hydrology and climate databases [32].

SIMREN (Simulation of Renewable Energy Networks)

SimREN is simulation tool supporting the calculation of energy supply and demand with a certain temporal resolution. At its basis, it uses independent and detailed tools for energy demand, energy management, adapted distribution systems, and energy supply. It is primarily used to study different energy-systems relying on renewable sources [33].

SIVAEL

SIVAEL is a simulation tool for the electricity sector and district-heating systems. It aims to optimise the energy-system to produce the most economical fuel combination by considering all costs except investment and fixed O&M costs. As a result, it presents a standard report for the simulation period and the possibility of analysing various different time periods. In general, it can be used to analyse the impacts of CHP and large-scale wind energy on the energy-systems, the environmental impacts of electricity and CHP generation, and to project the consumption of fossil fuels [34].

SOLAR POTENTIAL MAP

Usually, the solar potential map is a geo-referenced product produced based on photogrammetry techniques and on specific algorithm for calculating solar energy production potential, which currently serves as a tool to support the evaluation of the solar potential of buildings and other surfaces in urban areas. It is intended to be a starting point and help consumers on quantifying the potential benefits of investing in solar renewable energy technologies, by providing information on viability and irradiance data.

SYSTEM ADVISOR MODEL (SAM)

The System Advisor Model (SAM) aims to support decision making by assessing performance and financial characteristics of renewable energy technologies. It general aim is to support o decision making for people involved in the renewable energy industry. From the performance point of view its model makes performance predictions for grid-connected solar PV, concentrating solar power, wind, biomass and geothermal power systems. Its cash flow models are appropriate for distributed energy projects that buy and sell electricity at retail rates, and for power generation projects that sell power at a price negotiated through a power purchase agreement. The model calculates the cost of generating electricity based on information you provide about a project's location, installation and operating costs, type of financing, applicable tax credits and incentives, and system specifications [35].

TRNSYS16

TRNSYS is a transient systems simulation tool with a modular structure. By specifying the components that constitute the system and the manner in which they are connected, the user is able simulate the performance of the entire energy-system in terms of solar energy applications and prototype solar-thermal systems, thermal performance of buildings, hybrid PV–thermal solar system, renewable-energy penetration and even biological processes. Its library includes many of the components commonly found in thermal and electrical energy systems, as well as component routines to handle input of weather data or other time-dependent forcing functions and output of simulation results [36].

2.3. CHALLENGES FOR RENEWABLE ENERGY SOURCES INTEGRATION

As the climate change becomes an important overall issue, and bearing in mind the volatile prices of petroleum products, energy distribution grids are key for an efficient use of energy resources in today's cities. However, a set of complex challenges, such as age, pricing or the integration of renewable energy sources, are challenges that influence current decisions.

Currently, although in many places, continuity of service is not presently compromised, most of the electrical distribution infrastructures are almost at the limit of their capacity. The risks related with the use of an increasingly aging power grid are growing day by day, and significant challenges arise while cities are becoming "smarter", more efficient and more sustainable. Within this context, Smart Grids stand as a concept that's not only useful, but fundamental to achieve the proposed goals related to energy and energy services demand, as well as the environmental commitments established by the various nations.

According to the EU, a Smart Grid is an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety [37]. For this purpose, a Smart Grid includes the application of smart products and services together with intelligent monitoring, control, communication, and self-healing technologies. Therefore, the main difference of today's grids and smart grids is related to the capability to handle more complexity in an efficient and effective way. Currently, the main goals of EU smart grids are as follows [37]:

- To better facilitate the connection and operation of electricity generators;
- To allow consumers to play a part in optimising the operation of the system;
- To provide consumers with greater information and options for how they use their supply;
- To reduce the environmental impact of the whole electricity supply system;
- To maintain or even improve the existing high levels of system reliability, quality and security of supply;
- To maintain and improve the existing services efficiently;
- To foster market integration towards European integrated market.

Within this context, the cost reduction of renewable energy systems poses a variety of opportunities to address electricity generation. However, to achieve its widespread use, a substantial set of technological, economic and regulatory challenges need to be addressed.

From the technological perspective, the main challenge for grid operators is related to the uncertainty and variability of renewable energy generation. In the case of solar energy, and considering that the movement of the sun is very well understood, much of the variation in its energy output is highly predictable. However, an additional and less predictable source of variability is the presence of clouds that can limit generation for short periods of time. On the other hand, wind energy is less predictable, but still subject to certain patterns. Often, wind energy is more available in the winter or at night-time, when the wind blows stronger, posing additional challenges in some instances if the output corresponds to lower load levels. For this reason, it becomes clear that energy grids require a greater flexibility to accommodate supply variability and its relationship to generation levels and loads. This means that the whole energy supply system, from the generation to the user, needs to be perfectly integrated.

Nowadays, different options are available to address these integration challenges related to the additional variability of renewables, being variable in terms of viability considering the characteristics of the existing grid system. In general terms, and despite the role that ICT is increasingly playing in grid/network management, energy systems need to be more flexible. From the technological perspective, this flexibility can be achieved through the implementation of [38]:

- Advance forecasting – to support a reduction on the uncertainty and help grid operators to commit or de-commit generators more efficiently in order to accommodate changes and variable renewable energy generation.
- Operational practices – including infrastructure fast dispatch and larger balancing authority areas. Fast dispatch helps manage the variability while it reduces the need for regulating resources, improves efficiency, and provides access to a broader set of resources to balance the system, meaning that load and generation levels can be more closely matched, reducing the need for more expensive regulating reserves.
- Reserve management – reducing the overall reserve requirements can lead to substantial cost savings, for instance by placing limits on energy ramps to reduce the need for reserves and enable variable renewables to provide reserves or other ancillary services.
- Market design – by providing a more flexible market, in terms of tariffs, consumers are encouraged to change their consumption behaviours reflecting the availability of renewable energy in the grid.
- Demand response - it can be used to supply reserves and ancillary services as well as peak reduction, particularly in cases of fast ramps or extreme events.
- Flexible generation sources - the flexibility of generation sources in terms of their ramp rates, output control range, response accuracy as well as minimum run times and off times, start-up time, cycling cost, and minimum generation level, increases the flexibility of the grid.
- Digital and generation technologies - the commercialisation of battery technology in particular is driving innovation for EV’s, grid level storage, and a range of standalone and ‘combined renewable generation and storage’ business models.

In addition, a key role for network operators will be to connect distributed energy resources (DER’s), such as generation, storage and demand side response (DSR) to the local networks. If called upon at the right times, these DERs can help by providing flexibility to the local and national system at times of critical need (peak times). However, regulatory and feasibility barriers need to be also considered for their integration. Then new market platforms and more sophisticated price signals are currently needed to make this vision a reality.

From a regulatory perspective, diverse barriers arise mainly concerning the economic costs, the need of investment to improve current grids, and variability of incentives. In this respect, long-term horizons, as well as proper and stable regulatory and policy environment with appropriate incentives are critical to achieve the current defined policy goals regarding the integration of renewable energy sources. According to the World Economic Forum, the key regulatory barriers and challenges include [39]:

- Absence of long-term planning;
- Large number of relevant authorities;
- Need for better coordination between relevant authorities;
- Electricity market structures;
- Insufficient consideration of renewable energy in spatial planning;
- Complex permitting procedures and legal appeal process;
- Lack of stakeholder involvement in decision-making;
- Lack of experience among decision-makers;
- Complex grid connection procedures;

3. ENERGY PRODUCTION IN OUR CITIES

One of the main current challenges facing urban areas is the energy transition towards decarbonisation. While the amount of energy used by cities is rising, cities are impelled to shift towards energy production areas, using a majority of renewable energy sources, and also maximising energy efficiency and better management of energy demand [40].

In recent decades, cities have been promoting local initiatives and projects on sustainable energy, leading the issue of transition to a more efficient and secure energy outlook. From these initiatives and projects, it becomes clear that this transition encompasses not only technological challenges, but that societal, cultural, economic and environmental aspects need also to be considered. In fact, there is a clear implication of a more active role for citizens and communities to improve the outlook.

This is particularly relevant for energy efficiency initiatives, where consumers behaviours play a crucial role. However, improving energy efficiency, *per se*, does not necessarily translate into a direct reduction of GHG emissions. As cities are part of complex energy systems, managed at national or even international level, the implications should be seen at a higher scope. And the truth is that currently, at this scope, cities do not usually have a significant influence.

Therefore, the central topic on decoupling energy from decarbonisation is at its production level. Renewable Energy (RE) is a key solution within this context. Despite some disadvantages, as the reliability of supply and their lower levels maturity and efficiency, mainly when compared to traditional fossil fuel sources, the advantages both in terms of environmental and economic perspectives, clearly compensate.

In the UK, for instance, on June 7th power from wind, solar, hydro and wood pellet burning supplied over half (50.7%) of the UK's energy. However, the majority of the energy required and consumed is still derived from fossil fuel sources; which accounting for approximately 80% of the UK's energy supply in 2016 [4].

In 2015, Portugal was able to conduct an extraordinary 107-hour run with the electricity consumption in the country being fully covered by renewable (solar, wind and hydro power). Nevertheless, on a year basis, all renewable sources together still only represent 48% of the generated electricity.

In a more practical way, the next sections present the current state and the vision of Sharing Cities Lighthouse cities regarding renewable energy production.

LONDON – GREENWICH

VISION ON RENEWABLE ENERGY PRODUCTION

Greenwich's vision for the Borough is one that supports renewable energy technologies as a means of supplying energy with less associated carbon emissions and air pollution; and enables the generation of renewable energy on its own estate to displace traditional fossil fuel sources. This vision includes both renewably generated heat and electricity. With focus being on those renewable power sources geographically and readily available, and which can be applied in areas which the council has most influence over.

This vision and focus is present in Greenwich's delivery of the Sharing Cities programme. The project aims the generation of 1,539,817 kWh[1] a year of renewable electricity from Solar PV installations on estates; and explore renewable heat generation from a water source heat pump from the nearby River Thames which would provide space heating and hot water for 95 properties.

GOALS AND TARGETS

The Royal Borough of Greenwich has set out commitments to support renewable energy production in its *Greener Greenwich Strategy*, which includes the following strategic objectives:

- **Strategic Objective 1:** To encourage local, low carbon, and renewable energy uptake. This includes actions to remain committed to procuring its electricity from green sources, promoting the uptake of solar PV, and an aspiration to couple renewable energy production with technologies such as battery storage to improve and extend the potential renewable energy has to reduce greenhouse gas emissions, reduce energy costs and improve energy security.
- **Strategic Objective 2:** To support the development of district heat networks, and investigate their use on the Royal Borough's own buildings.
- **Strategic Objective 11:** Ensure that high environmental standards for new development are upheld; and that these include incorporation of energy efficiency and low carbon energy measures, sustainable waste and transport infrastructure. This includes actions to ensure all major new developments: achieve carbon savings; connect to, or provides for future connection to, district energy networks; and achieve on-site reduction in CO_2 emissions through the use of renewable energy.

STRATEGY

Greenwich's strategy to achieve the above targets follows a four-tiered approach as follows:

1. **Reduce energy demand** of housing stocks, ensuring more energy efficient buildings. This will involve initial improvements to the fabric of the buildings to minimise heat

[1] According to the current Building Energy Specification Table (BEST) developed for Sharing Cities

losses, including applying insulation and replacing or refurbishing windows. In addition, building services will be also improved, by changing to LED lighting, and implementing a lower temperature heating network.

2. **Maximise renewable energy contributions**, production and supply to housing estates through installing renewable energy generation in accordance with the above targets.
3. **Enable and maximise on site use of the renewable energy** produced through installing energy storage, both for electrical and heat generation.
4. **Develop and implement a Sustainable Energy Management System** (SEMS) which optimises the running of the renewable energy generating system (in particular the heat pump and network) according to certain principles and external factors such as energy efficiency, carbon targets, and energy prices.

EXPECTED IMPACTS

The key expected impacts of the above strategy, if fully implemented, include:

- Reduction in energy bills for the Council and for residents;
- Create low emission near zero carbon estates;
- Increased energy supply security;
- Elimination of on-site gas consumption for selected social housing locations and the consequent elimination of associated emissions, both carbon dioxide (CO_2), nitrous oxides (NOx) and sulphur oxides (SOx);
- 100% renewable heat supply at and a near zero carbon estate;
- Clean electricity being supplied to communal areas, and a consequent reduction of grid source electricity;

CURRENT SOURCES OF ENERGY

The buildings in Greenwich included as part of the Sharing Cities programme are currently supplied by electricity from the national grid, and each dwelling has its own private electricity supply. The majority of the energy at national grid level is still derived from fossil fuel as primary sources, which still accounts for approximately 80% of the UK's energy supply in 2016.

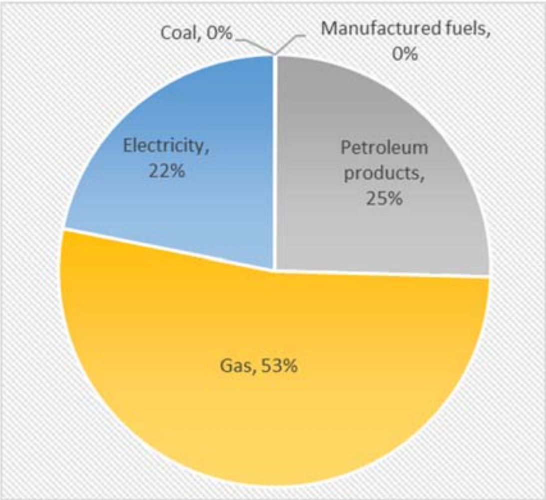

Figure 1 - Breakdown of energy consumption by source of energy in Greenwich, in 2014

Regarding heat, the current energy source is gas. This is used either in a gas fired communal heating system to supply space heating and hot water (e.g. Ernest Dence and Sam Manners estates), or to fuel individual boilers in each dwelling (e.g. Flamsteed Estate).

MILAN

VISION ON RENEWABLE ENERGY PRODUCTION

The Energy Policies of the City of Milan are designed within its Sustainable Energy Action Plan (SEAP). In the vision outlined in the SEAP, the renewable energy production is a component of a comprehensive approach, that tackles the theme "Sustainable energy" from four different perspectives: energy saving, renewable energy production, CO_2 emissions saving and air pollution reduction. Regarding renewable energy, in consideration of the city structure (dense) and of the available sources (presence of a wide, deep, multilayer aquifer), more emphasis is currently being putted on heat pumps, both air and water sourced, than on solar energy.

GOAL AND TARGETS

At Milan city level, there are not specific targets or goals for renewable energy production. Currently, there is only an estimation of the share of energy from renewable sources in gross final consumption that could be achieved with the implementation of the SEAP measures.

Therefore, according to the SEAP's projections, by 2020, the 3,3% of the total energy demand (mobility and transports included) could be covered by local renewable energy production. It is a conservative value, that takes into consideration only a partial exploitation of the total potential (and it does not include solar thermal, that needs to be further estimated).

STRATEGY

In Milan, there is not a strategy specifically targeted at renewable energy production. The issue is tackled with a framework focusing energy savings in buildings, which includes three main instruments:

- **Development Charges**: a reduction of development charges is granted for new and retrofitted buildings that respect specific criteria regarding energy efficiency and renewable energy, which are stricter than limits fixed by current legislation;
- **Building Code**: incentives (in terms of increased authorized volume) are granted for new buildings and deep retrofit, according to criteria that include specific requirements regarding local renewable energy production (besides energy efficiency requirements);
- **Funding**: Milan Municipality grants direct incentives for solar thermal, solar PV, solar cooling, water source and geothermal heat pumps in existing building. Incentives are granted through specific calls that include also incentives for deep energy retrofit;

EXPECTED IMPACTS

The expected impact is, as already mentioned, a 3,3% of the total energy demand covered with local renewable energy production by 2020. This is an estimation and the total potential is certainly higher. In addition, some of the mentioned grant and incentive instruments are being reviewed in order to improve their efficacy. In this respect, more ambitious policies are expected to be designed in the next years, in coherence with the European and global scenarios, in order to better exploit the renewable energy potential.

CURRENT SOURCES OF ENERGY

The majority of the energy used in Milan is derived from natural gas. However, this estimation does not include solar thermal and air and water source heat pumps, except for the ones of the district heating system. This refers to 55 GWh heat being produced from groundwater heat pumps and used in the district heating system - equivalent to the 0.5% of the total demand for building heating – and 13 GWh solar PV - equivalent to the 0.2% of the total electricity demand.

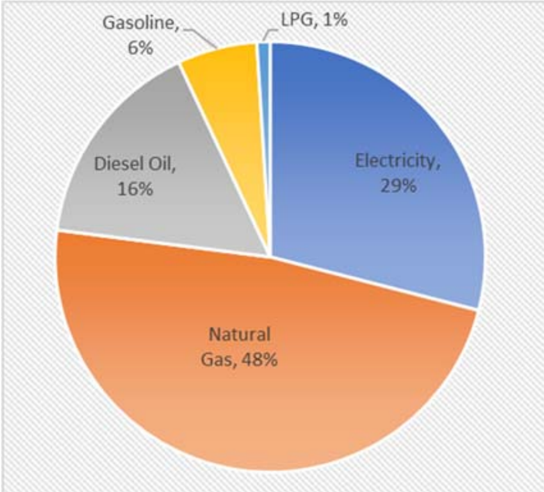

Figure 2 - Energy **b**reakdown by source of energy consumed in Milan, in 2014.

LISBON

VISION ON RENEWABLE ENERGY PRODUCTION

Lisbon considers essential to increase the production of renewable energy in the city as one of the main objectives with environmental relevance, but also to reduce the costs related to these technologies. With this in mind, the Municipality encourages all consumers on this purpose, both from public and private sectors, including the residential. In the Municipal domain, renewable production is currently focusing two main areas: buildings, promoting mostly self-consumption, and public transport fleet (now in direct dependence of the Municipality), promoting electric mobility with renewable origin.

GOAL AND TARGETS

The City of Lisbon has set the goal to be carbon neutral in 2050. In the scope of this goal, the Municipality intends to achieve a renewable production based on photovoltaic of 8 MW within the next 4 years. The produced energy will be used for self-consumption, in Municipal buildings, and to power electric buses that will be acquired during this period. The main aim of this initiative is to serve as a driving force for further public and private investment in this area, in order to achieve the currently defined sustainability goals, including the reduction of the city's energy intensity, to renewable energy production and saving and air pollution reduction.

In addition, according to the Sustainable Energy Action Plan (SEAP) defined for the Municipality, an annual primary energy consumption reduction rate is established for transports (by 1.49% per year) and residential and service buildings (by 2.11% per year).

STRATEGY

At the base of the Municipal strategy is the reduction of the city energy intensity. This is being translated into practice by conducting projects aiming the reduction of energy consumption, increasing energy efficiency and energy production from renewable sources. Within this scope, several projects have been already accomplished, resulting on a substantial increment of energy efficiency mainly in buildings, public lighting and traffic lights.

Form a more strategic perspective, the Municipality, with the support from Lisboa E-Nova, has also developed the Lisbon Solar Potential Map. Conceptually, this is an efficient awareness tool, both for local authorities, investors, companies and citizens, which allows the identification of the preferable areas to invest in solar technologies.

In addition, the Municipality intends to conduct a set of protocols with entities with high potential for renewable production, as well as support the investments in renewables in the residential sector.

EXPECTED IMPACTS

In the short term, it is intended that at least 20% of the electricity consumption in Municipal buildings will have a renewable source. The installation of a considerable amount of renewable energy technologies is currently in place, focusing in particular solar energy through the installation of PVs.

Regarding the mobility and transport sector, the Municipality is also converting its entire fleet, being already the national entity with the biggest national electric fleet, and supporting the local public transport companies on the acquisition of electric buses that will be supplied with renewable energy.

CURRENT SOURCES OF ENERGY

In 2014, electricity accounted for more than half of the total energy consumed in Lisbon, which is expected to continue during the following years. Evidently, most of the electricity consumed (98%) is dependent from the national electricity grid. However, during recent years, there has been an increase of the amount of the electricity produced locally. Despite still presenting a small contribution, the main local energy production sources are local cogeneration plants (2%), which use fuel and natural gas; miniproduction and microproduction plants (0.1%), which rely on photovoltaic energy and self-consumption from both renewable and non-renewable sources (0.08%).

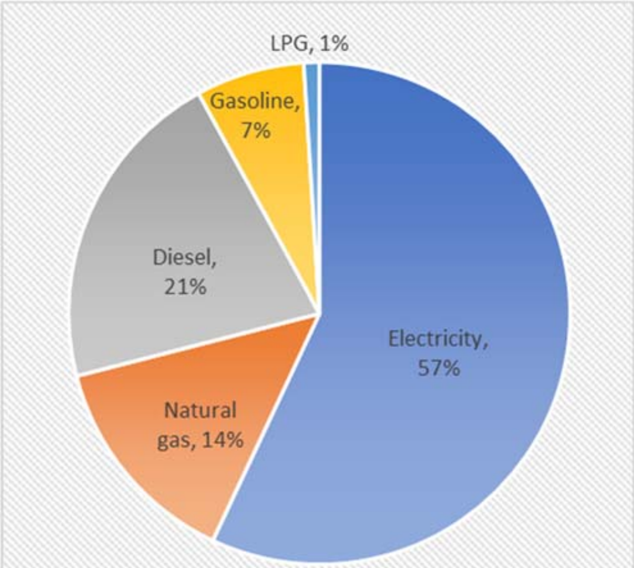

Figure 3 - Energy breakdown by source of energy consumed in Lisbon in 2014.

Regarding the consumption of diesel and gasoline, its combined share is also considerable, representing around 30% of the total energy consumed in Lisbon. Despite this smaller contribution, when compared to electricity, the impacts are significant in terms of CO2 eq. emissions, representing about 40% of the total GHG emissions in the city.

4. CASE STUDIES

Considering the above-mentioned challenges and barriers, a set of case studies are presented. These intend to show concrete situations, that have occurred within the scope of RES implementation in the 3 lighthouse cities of the Sharing Cities programme: Lisbon, London and Milan. Besides the description of the case study and the business model expected to implement, the main success and/or failure factors are discussed.

LONDON

2016

Total Costs

£50,000

CASE STUDY #1: COMMUNITY SOLAR SCHEME

Description

A solar installation project, involving installing solar panels across 40 different properties in RBG (and a total of 200 across 4 local authorities), funded by external finance and repaid via a power purchase agreement and tariffs under a 'rent-a-roof' scheme. The scheme was viable in the current low FiT environment, as a higher FiT rate was secured, before the reduction for a period of 12 months as long as the project was undertaken by a community organisation.

Business Model

An income from the FiT, Export Tariff and through paying for the electricity consumed on site via a Power Purchase Agreement (PPA) was to be directed to a Community Interest Company (CIC). The external funding, management cost, insurance, etc., was to be repaid from the CIC, with any surplus revenue to be used for energy efficiency projects in the community. The benefit of the scheme was to delivery renewable energy at low set up cost to the council and to provide a revenue that could be used over 20 years to support energy efficiency projects in the community.

Stakeholders involved and management structures

RBG was the owner of the buildings and customer of the electricity generated by the PV panels. Agility Eco was the company providing consultancy and co-ordinating the scheme and overseeing the procurement and installation of PV panels and the on-going maintenance of the panels. Geo Capita was the co-ordinator of finance and the registered owner of the CIC. OFGEM is the Government body that registers installations for FiT.

Main challenges and barriers

The project was initiated quickly as the legislation that allowed community organisations to register PV installations and secure the FiT for 12 months was being withdrawn. The scheme had 12 months from registering the properties with OFGEM as potential locations of solar installations to having the PVs commissioned and operational. After this time, the 12p/kW FiT secured would be reduced to 3.5p/kW in line with the governments reduction in the tariff.

Given the short period of time in which properties were selected, parameters that influenced the financial model had not been set. These include the size, output and cost of the installations (only confirmed once installers had tendered), finance rates and repayment structure, managing fees, maintenance fees. Given this uncertainty, the attractive outputs proposed in the financial model at the beginning of the project began to disappear as these inputs were resolved. There was also huge complexity in the way the community organisation and the lease & PPA agreements were to be set up. This created legal issues, which absorbed further time, creating greater pressures. In the end the scheme became unviable, with community benefits not to be available until the last 5 years of the 20-year lease.

CASE STUDY #2: GREENWICH PENINSULA ENERGY CENTRE

LONDON

2015-2017

Installed Power

9 MW

Pipework

10 km

Total Area

2,600 m^2

Total Costs

£18.3M

Description

During the planning phase of development, it was identified that a potential peninsula energy network could provide combined heat and power to over 15,000 dwellings and 3.5 million square feet of commercial space across Greenwich Peninsula.

Business Model

Energy (heat and electricity) is generated and sold to residents via a distribution network. Electricity is sold on the competitive market and heat (which is currently unregulated) is sold to residents and commercial premises connected via the network.

Stakeholders involved and management structures

To support the commercial case for the project, RBG applied for funding from the London Energy Efficiency Fund (LEEF), which would be used alongside private investment from the developers Knight Dragon (KD). For this reason, a funding agreement was put in place between RBG and KD.

The Network is owned and maintained by Pinnacle Power – a subsidiary of KD, and a customer facing company (Loka Energy) was established to manage billing and customer care.

RBG sits on the Governance Committee to monitor performance and management of the Network.

Main challenges and barriers

As main drivers, this project has intended to achieve the following:

- Implement a low carbon solution to energy provision for the peninsula development;
- Requirement to meet increasing energy demand and invest in new infrastructure;
- Avoid increase in pollution from local domestic boilers.

The main identified barriers were as following:

- Competing stakeholder objectives and loss of operational control for the council;
- Limited technical expertise and knowledge of heat networks in the UK market;
- Customer perception of single provider model;
- The necessary initial capital investment.

MILAN

2013-2016

Installed Power
20 kW

EAHP
32.1 kW
(thermal power)

7.62 kW
(total absorbed electric power)

District heating
600 kW
(thermal power of heat exchanger for heating)

300 kW
(thermal power of heat exchanger for DHW)

Total Area
10,961 m^2
(gross floor area)

132 m^2
(PV panels)

Total Costs
€ 154,000

CASE STUDY #3: VIA FELTRINELLI 16 – PUBLIC HOUSING

Description

The social housing building located in via Feltrinelli 16 was retrofitted within the EU GUGLE project, funded by the EU. The deep energy retrofit included envelope retrofit actions (calculated primary energy performance index from 299 to 34 kWh/m^2.year for heating). However, also important measures to increase the local share of renewables are included in the building retrofit. In particular, a PV system on the roof of the construction and an innovative heat recovery system on the exhaust air ducts (exhaust-air heat pump - EAHP) have been installed for the exploitation of Renewable Energy Sources (RES). In addition, the building has been connected to the city's district heating network for heating and domestic hot water.

Business Model

The project implementation was public financed by 100% (from Three Year Plan of Public Works). Regarding the energy renovation actions, additional EU funding was used via the FP7 research project EU-GUGLE (about 50.00 €/m2).

Stakeholders involved and management structures

The Municipality of Milan was the property owner, and has conducted the design and supervision of the interventions. Politecnico di Milano has provided scientific support, on energy and comfort monitoring. The construction company was selected by public tender. Unareti is the electricity supplier. GSE (Gestore Servizi Energetici) deals with exported energy produced on site. A2A Calore & Servizi is the district heating provider.

Main challenges and barriers

Several bureaucratic/administrative issues hindered the process to obtain the actual registration of the PV plant following the national accreditation procedure. First, it was necessary to register the PV system on the portals of different authorities (Terna-Gaudì portal, Unareti-Tica portal, GSE portal) to apply for the connection to the public electrical network and the pose of the bidirectional meter and to sign the agreement about the exchange on site and the convention to receive refunding. Second, the contract with GSE for refunding requires a maintenance agreement, to allow payment for the produced energy to the owner (Municipality). However, the Municipality outsourced the maintenance of public housing and their systems to an external contractor, and now it does not have control on specific systems anymore. It is thus not clear who should sign the contract with GSE, either the Municipality or the maintenance contractor.

MILAN

2010

Installed Power
6 kWp

Total Area

45 m^2
(PV panels)

Total Costs
€ 32,000

CASE STUDY #4: PHOTOVOLTAIC PLANT IN A RESIDENTIAL MULTI PROPERTY BUILDING – SAN DONATO MILANESE

Description

Installation of a PV system, in a residential building placed in San Donato Milanese (metropolitan city of Milan), for the partial coverage of the common electrical consumptions, which mainly consists on the lightning, an auxiliary heating device and the elevator. The PV plant, which has a power of 6kWp, to produce 6,500 kWh/year, was installed on the top floor of the building, using a support that allowed the tilt to maximize its exposure to the sun irradiation. The part of electricity produced but not consumed on the site is transferred through the grid-connection.

Business Model

The total cost of the implementation was totally covered with a very advantageous bank loan (1.5% of interest). This financing scheme was required by the owner's community and the payback time was expected to be around 10 years. It was also possible to benefit from the *Conto Energia*, a specific incentive for electricity produced by PV plants. The incentives, which are due to the owner's community for 20 years following the investment, consist of 0.4 €/kWh and are delivered for the totality of the electricity produced by the plant, whether it is used on-site or is delivered to the grid.

Today the owner community spends about 1,700 € per year for electricity in common spaces, being the savings from solar energy up to € 1.300 just for self-consumption. In 10 years the investment will be completed repaid.

Stakeholders involved and management structures

The idea was launched by the building administrator, who was, by the time, councillor of San Donato Municipality. Residents agreed to execute the works with a resounding majority, then expressed satisfaction for the economic benefits brought about by savings in the electric bill and for the incentives benefit. The "Teicos Group" company, which has put the new facility at disposal of the condominium with a "turnkey" system, took care of the execution of the works and the necessary permits.

Main challenges and barriers

Despite the costs of photovoltaics were higher than the current ones, by using the *Conto Energia* incentive it was possible to return the investment within 10 years, making the plant implementation economically advantageous. In addition, there were no bureaucratic obstacles to obtain permits and no malfunctions after 7 years from the installation of the plant. Moreover, from the environmental point of view, this intervention has allowed a saving in terms of estimated CO_2 emissions of 88 tons in 25 years, quantifiable in almost 5 hectares' tree-lined area.

Nevertheless, a similar installation it would not be economically viable, because actual legislation does not allow to use on site the energy produced and the fixed price for selling it to the grid is so low that it does not ensure the payback time of the investment. The actual legislation forces local PV energy production to be used for the legal entity who owns it or to be sold to the grid. In this case, being the legal entity a multi-property community, the energy can be used just in common parts of the buildings, whose consumption is very low.

CASE STUDY #5: PV INSTALLATION IN EXISTING PUBLIC BUILDINGS - MUNICIPALITY OF BUBBIANO

MILAN

2010

Installed Power
57.5 kWp

Total Area

125 m^2
(PV panels)

Total Costs
€ 245,214

Description

This case study is interesting for investigating synergies between public administrations and private companies and the influence of energy policies to the RES implementation. It concerns the installation of a PV system, in the Municipal Hall Building (40 sqm of PV panels) and New School Building (84,3 sqm of PV panels), for the coverage of the electrical consumption. The PV system has been completely integrated into the roof top and produces electricity which is used directly by the users in the 2 buildings. The part of electricity produced but not consumed on the site is transferred through the grid-connection.

Business Model

The municipality owned the grounds and the buildings' roof on which the PV system was installed. Bubbiano municipality granted the right to Teicos to install PV on public buildings and thus let the land property to the private company for 18 years. Teicos has designed, installed and managed the PV installation for 18 years. The total cost of the realization was totally funded by Teicos. GSE, the Energy Services Manager that promotes the development of renewable sources in Italy through the provision of incentives, has provided incentive rates to Teicos to pays the initial investment.

Stakeholders involved and management structures

The Municipality of Bubbiano benefits of the installation of PV system and its maintenance during 18 years. The energy produced covers the whole energy consumption of the two mentioned buildings. Teicos, a SME – ESCo, has invested in the realization of the PV system and contains the 95% of the incentive allocated by GSE. The payback time is 11 years; after that, the revenues are all a benefit for the ESCo. GSE, the Energy Services Manager, managed the RES incentives in Italy and verifies the installation projects and its annual production.

Main challenges and barriers

The Public Private Partnership was concluded to be a win-win solution. On one side, the municipality was enabled to use clean and renewable energy in its buildings, without incurring the costs for the investment and for the maintenance of the photovoltaic system. On the other side, the ESCo was able to invest in its own productive system (in this case the ESCo designs and installs itself the PV installation) and have a long-term program of income that can support further investments.

However, this is clearly only possible when the financial institution considers this operation as a project financing scheme, meaning that the risk-evaluation is done on the forecast project cash flow without considering all other activities of the company.

LISBON

2012-2014

Installed Power
2.8 MW

Total Area

18,368 m^2
(PV panels)

Total Costs
€ 4.6M

CASE STUDY #6: PV INSTALLATION IN LISBON UNIVERSITY

Description

This project aimed to connect four electricity production units, providing more than 2.8 MW of installed capacity, and producing 4.28 GWh per year, throughout Lisbon University. This consisted in placing 11,480 PV panels in the roofs of the University's Faculties, car parks and leisure areas. For the University, this project assumes a high importance internally and externally, being pioneer at the university level in Portugal and integrated in its Environmental Sustainability Plan.

Business Model

After registering and obtaining licenses for the construction and operation of photovoltaic plants under current national regulation, and through a public consultation procedure, the University signed a contract with Galp Power SA, which has implemented the project. The system is currently being exploited in two ways. Through the self-consumption the university is able to save on its energy bill, selling the surplus production to the grid, covering the investment made.

Stakeholders involved and management structures

University of Lisbon was the owner of the buildings and customer of the electricity generated by the PV panels. Galp Power SA was the technology provider and responsible for the system installation.

Main challenges and barriers

The model was based on the sharing of revenues obtained from the sale of electricity to the grid, providing the University with extraordinary financial resources, that are directly applicable in promoting and introducing measures that promote energy efficiency and rationalization of consumption in its buildings. Without this extra value, resulting from the existence of national FiT, and taking into account budgetary constraints, it would be rather difficult to introduce technological measures in order to achieve interesting energy efficiency values, as well as to support some projects developed by the university community in the field of energy and environmental efficiency.

From an environmental perspective, it is estimated that this project avoids the emission of 12,106 tonnes of CO_2 per year.

CASE STUDY #7: SOLAR THERMAL POWER STATION AT CAIXA GERAL DE DEPÓSITOS (CGD) HEADQUARTERS

LISBON

2008

Installed Power
1 GWh/year
(thermal energy)

Total Area
1,600 m^2

Total Costs
€ 1M

Description

The CGD headquarters solar thermal power station, in operation since 2008, is the largest installation of this type in Portugal and the largest in Europe with an absorption chiller. It consists of 158 solar collectors installed in 1,600 m^2 of the CGD building in Lisbon.

Business Model

The plant produces energy for the heating and cooling of water required by the centralized climate control system and the sanitary facilities. The energy savings achieved amount to more than 1 GWh per year, divided between water heating for kitchens and sanitary facilities, production and distribution of heat and cold through hot water tanks and an absorption chiller and the installation of complementary electronic speed variators for water pumps. This system has contribute to a significant decrease of CDG energy costs.

Stakeholders involved and management structures

CGD is the owner of the buildings and the main beneficiary of the solar thermal power station. EDP was the technological consultant and system provider.

Main challenges and barriers

With CGD's headquarters solar power plant, CGD saves more than 1 GWh of electricity, avoiding the emission of about 1 kg of CO_2 into the atmosphere in each minute of operation. In addition to its size, the project complexity was higher due to other innovative aspects. The use of absorption chiller technology, allowing the production and distribution of cold to the HVAC system, significantly increased the energy savings obtained from a conventional solar thermal system, and reinforced the demonstration of the interest of applying this type of system to large service buildings. Innovative solutions for architectural integration of the panels were also implemented. The plant has a detailed monitoring system of the energy produced, which allows to analyse, in real time, its performance.

4.1. MAIN LESSONS LEARNT

From a general perspective, there are important lessons that can be retrieved from both the above-mentioned case studies and the overall application RES in urban areas. These regard the three main phases of a RES project: planning and design, implementation and operation; as well as the policy/legislative approach used to promote RES. Regarding the later, it is clear that it presents a great value added for projects, by facilitating a more effective deployment, enhancing capacity building and empowering local economy and resources. However, it is also clear that different types of instruments lead to significant different success rates. A comprehensive analysis of these instruments is made later in this report.

Concerning the institutional aspects, it is important that roles and responsibilities within the implementation project are well defined. This means that the management structure needs to be aligned with project objectives and that expectation expressed by involved stakeholders are met. In this respect, expectations must be clearly defined and fulfilled to avoid de-motivation. To achieve this, the capabilities of involved stakeholders should be used as possible, in order to ensure the long-term reliability of the project.

Finally, the strong involvement and engagement of the users, the quality of the components, the compliance with regulation in force, as well as the operation services, including guaranty and maintenance, are all necessary to ensure a successful implementation of a project.

All in all, considering the above-mentioned case studies, the main lessons going forward are:

- To ensure simplicity wherever possible;
- To create as much certainty upfront as possible;
- To be clear about the project and understand its main drivers;
- To understand regulatory schemes and incentives;
- To undertake projects in-house, much of the income is taken up by the fees of consultants and lenders.

5. HOW ARE WE ADDRESSING THE LOCAL ENERGY PRODUCTION IN SHARING CITIES?

LONDON – GREENWICH

The Royal Borough of Greenwich (RBG) forms a distinct district in London, being one of London's 33 local authorities, and one of the six designated "growth" Boroughs of East London. Greenwich is undergoing significant growth which is placing pressure on public services and infrastructure including, mobility/congestion, energy demand and other urban services, and by pressure on public budgets and natural resources. Having already grown by 17% since 2001, the population of Greenwich is projected to grow 33% over the next ten years from 255,000 to 340,000 inhabitants – much of this is due to the availability of former industrial and utility brownfield sites. Moreover, Greenwich receives over 18 million foreign, national and local visitors each year, which generate € 1.4bn for the local economy, but also add additional pressures on service and resources.

Focusing the energy demand, in defining its scope as a demonstrator area for Sharing Cities, the following factors have been taken into consideration:

(i) complex urban challenges linked to significant economic and population growth, where solutions are scalable and transferable;

(ii) well established residential communities and businesses, alongside major new redevelopment schemes; and a significant inward and outward movement of employees and visitors;

(iii) strategic assets for low-carbon transformation in the H2020 timeframe (e.g. the Greenwich power station, its community, the emerging digital cluster in the Peninsula, with expertise in security, data integration and visualisation, mix of housing/retail/commercial buildings, and major visitor destination and multi-modal transport – ferries, tube, rail, bus).

From the building perspective, RBG owns 23,000 properties (around 25% of all housing in the Borough). Between 2004 and 2011 £282 million was spent bringing 98% of the stock up to the Decent Homes Standard. Over 50% of housing stock is owner occupied or private rented and in 2009 Building Research Establishment estimated that 10% of that stock was non-decent due to SAP ratings below 35. This group is supported with through the Energy Company Obligation, Green Deal and our Landlord Scheme. Nearly a quarter of the Royal borough's carbon emissions (over 35,000t CO_2 in 2013/14) are produced from corporate buildings. Seven municipal buildings will be retrofitted through the GLA's RE:FIT programme (energy performance contract model with guaranteed energy savings and payback period) and up to five schools are being sought for the RE:FIT Schools programme (adding SALIX funding and/or school reserves).

Within Sharing Cities, activities to be performed in Greenwich include the deep energy retrofit of 357 homes in 3 public housing developments (16 blocks), with a total of 25,274m^2. These interventions are also aiming to connect all retrofitted buildings to a low carbon energy heat network, being the heat supplied by a new 2MW river-source heat pump, for which 3.4M € are the expected costs. This heat pump will be backed up by the Greenwich Power Station, a low carbon Combined Heat and Power system with thermal storage, and PV/solar systems providing renewable power to each building. In fact, this will be London's first demonstration of renewable energy production (heat pump and solar PV) integrated with a heat network providing heat and power for deep retrofitted homes and EV charging.

MILAN

According to the current Italian legislation on the promotion of renewable energy and energy efficiency for buildings, the type of retrofit intervention foreseen for the public housing in Sharing Cities, is not requiring a minimum mandatory amount of energy provided via the exploitation of renewable sources. However, the design team committed to satisfy the obligations of renewables integration, as required by regulation, for major renovations and to reach the nearly Zero Energy Building (nZEB) certification. This intends to deliver a high-performance and lighthouse project able to inspire the future policies about public and social housing retrofits. In particular, the measures will include the installation of the following technologies:

- a PV system for the production of electricity (127 m^2 to be installed for an estimated total production of 19.8 MWh/yr);
- a solar thermal system integrating the domestic hot water (DHW) system (20 m^2 to be installed for an estimated total production of 9,000 kWh/yr);
- a high-performance centralized heating and DHW generation systems based on water-to-water heat pumps;

In addition, an Energy Management System (EMS), in combination with electric storage batteries (20 kWh), will contribute to maximize the building self-consumption of the PV generated energy, to satisfy common uses such as elevators and lighting, and (potentially) also heat pumps and mechanical ventilation.

The heating and DHW generation systems will use a water-to-water heat pump with ground water heat source, which allows relying on an almost constant temperature source throughout the year. The heat pump is expected to be modular and capable of operating at partial loads to maximize the efficiency based on the actual thermal loads.

Regarding private residential buildings, the local energy production is implemented through tailored solutions according to the buildings specifications: architecture, plant-system, actual energy consumptions (energy bills), etc.

During the co-design process the technologies listed below were proposed to cover specific energy end-uses:

Table 3 – Energy consumption key evaluated elements

Energy end-uses that can be covered by renewable energy sources	Available renewable energy technologies
electrical energy use for common uses	PV-systems
thermal energy use for DHW	thermal solar panels
thermal energy use for space heating	gas heat pump

Due to the national regulation, the PV-systems can be only installed for the common services (e.g. elevators, lighting, heat pumps, circulation pumps, etc.). In addition, the feasibility of their integration with the solar thermal system was evaluated considering two elements: technical feasibility assessment and authorization procedure.

The PV-systems sizing was conditioned by the analysis of the current electrical energy consumptions and the feasible integration type. The type of installation (on sloping roof/flat roof or on façade) has also conditioned the PV-systems sizing. In sloping roofs, the local regulation only allows the installation of the modules parallels to the roof. In flat roofs, the modules have to be installed on mounting structures at a certain distance between them, to avoid the self-shading.

Considering different "clusters" based on the buildings surface available for PV installation (in terms of available square meters), it is possible to analyse how the size affects the PV-production (see Figure 4). Cluster 1 is made up by all the buildings having available surfaces lower than 2,000 sqm. The average energy consumption of previous years is 6,804 kWh/y and it can be covered by PV-production over the 67%. Thanks to low common-services power consumption it was possible to have a high percentage of renewable energy. In Cluster 2 – which includes buildings with available surfaces between 2,000 and 3,000 sqm – the amount of PV production is higher than Cluster 1 but it covers only 60% of the total electrical needs – due to higher common energy usage. Cluster 3 includes all the buildings with available surface greater than 6,000 sqm; in this cluster 34% of energy consumption can be covered by PV-production. On average, more than 50% of electricity consumption could be covered by PV-production.

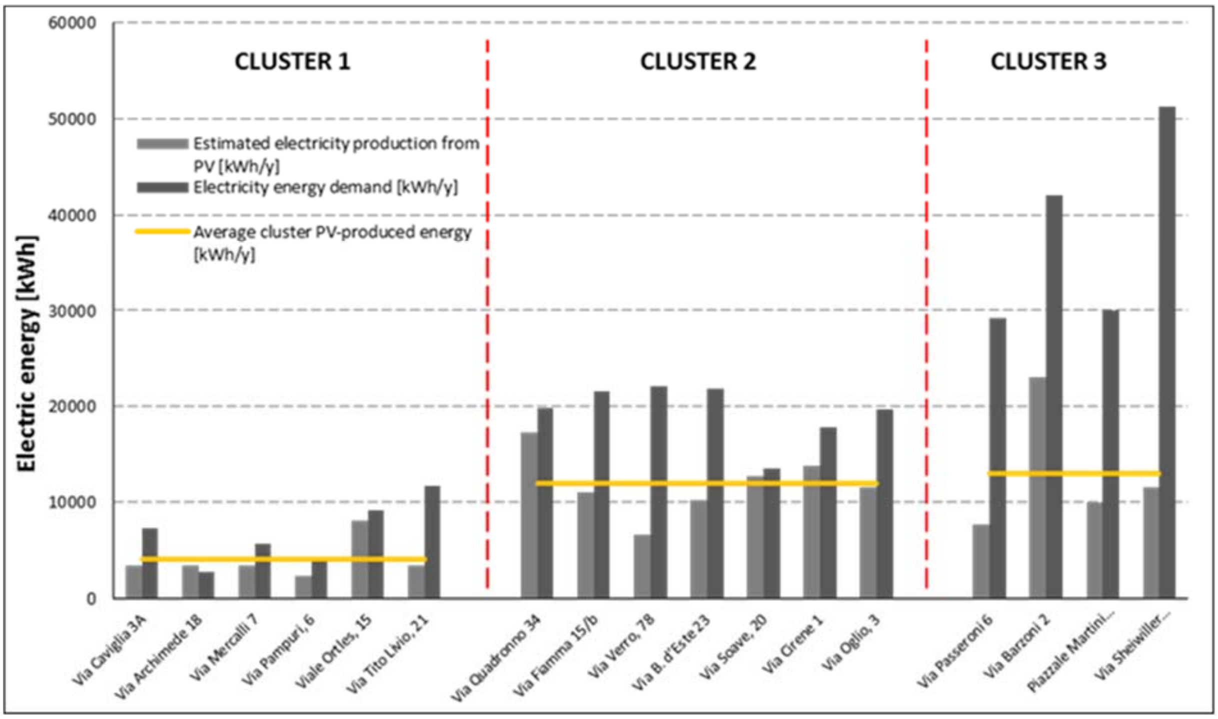

Figure 4 – Correlation between surface area of the selected buildings and estimated energy production

Moreover, for economic reasons, the adoption of electric storage batteries was also proposed by all owner's communities. The intention was to maximize the building self-consumption of the electricity generated by the PV system.

Regarding domestic hot water, it was addressed by installing thermal solar panels connected to the water heating system, aiming the reduction of the thermal energy consumptions from fossil energy sources. From a technical perspective, it was decided to design the solar systems accounting 50 litres or water per person-day, value that was considered sufficient to satisfy at least 60% of the thermal energy needs. In addition, the installation of a thermal storage system was also considered to maximize the self-consumption of the generated solar energy.

In some cases, the old energy generation heating systems was to be replaced; in these building it was possible to evaluate the opportunity of RES integration for heating generation. The gas feed heat pump was designated as the thermal energy technology to be used which, apart from being cheaper than the electrical energy, it is considered a renewable energy source according to the European regulations. However, to make this technology feasible from the economic point of view, most of the buildings required to drastically reduce their energy needs and a low temperature emission system. For this reason, this technology is proposed for 3 of the selected buildings.

The figure below reports the thermal energy production - divided into renewable and non-renewable energy source - of the three heat pumps proposed. On average, the renewable energy production by the heat pump is equal to 25 % of the total thermal energy produced.

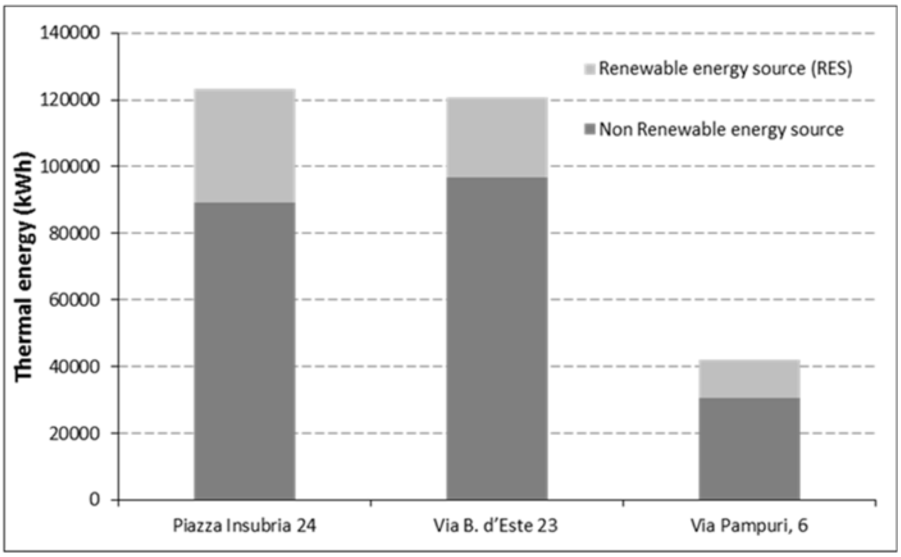

Figure 5 – Distribution of renewable and non-renewable energy sources on the thermal energy production of the 3 selected buildings

All these activities were conducted through a co-design process, involving those who live and use the buildings. This has led to more informed decisions on the use of the local energy production and increased citizens' awareness and attitude to energy retrofit, and therefore to energy saving.

In addition to the buildings, the Milan City will provide, though NHP, 10 Mobility Areas specifically dedicated to electric mobility. Each area will be equipped with 6 smart charging stations powered by 60 kW photovoltaic power plants. This is expected to provide fuel to electric vehicles for about 60,000 kms per year, guaranteeing pure and clean energy for more about 100 electric vehicles.

NHP's charging station infrastructure is based on ICT tools designed to be integrated in a smart grid environment. In short terms, NHP ICT platform could be able of managing the whole energy workflow of mobility areas integrating photovoltaic, charging station, storage and electric vehicles and powering with the excess energy Porta Romana buildings through the integration with the district's Sustainable Energy Management System.

LISBON

Lisbon's South-Western geographical location represents great opportunities but also challenges in terms of energy supply and demand, differing from other European regions. In the building sector, cooling requirements are significant, delivering a much more oriented role of natural gas for cooking and domestic hot water (DHW) purposes in comparison to heating. In the last decades, the building situation has been critical, due to the lack of energy ordinances until the late 1980's, and to the old and historical heritage, which represented much higher refurbishment costs, in comparison to new construction outside the city centre (the leitmotiv of the past decades). Currently, the refurbishment policy moved to the forefront of priorities and significant improvements are being made, with the Lisbon’s Sharing Cities demonstration area experiencing deep changes in this scope. A lot of financial and tax incentives are being launched by the City of Lisbon, to boost this activity.

From a strategic point of view, Lisbon vision and ambition on renewable energy were put into practice by the Lisbon-Europe 2020 Strategic Plan. This Plan focus on a big scale open-innovation ecosystem, in line with the Sustainable Energy Action Plan (SEAP), within the framework of the Covenant of Mayors. The 2012 Municipal Master Plan provides the SEAP operationalization, fostering the adoption of good practices to promote a more sustainable performance of city neighbourhoods, based on sustainable plans assessment, including: more energy efficiency in public infrastructures, street lighting and integration of renewable energy technologies. In addition to these, Lisbon's Strategy Chart 2010/2024, includes practical Action Plans for a refurbished and re-inhabited city, including:

i) Major awareness campaigns on energy efficiency;
ii) A specific technical support programme for small interventions in buildings (RE9);
iii) A set of local incentives for old private buildings (‘Re-Inhabit Lisbon’ and ‘Refurbish first and Pay after’);
iv) Funds programme for energy efficiency in condominiums to improve their energy efficiency; and
v) A financial programme for refurbishment to increase energy efficiency – the ‘Community Support Framework 2014-2020’.

Regarding the intervention in social housing districts (multicultural and vulnerable communities), the city is a good example of a truly Integrated Model for Sustainable Innovation. Several building refurbishments were performed in recent years, are made through the joined cooperation of various stakeholders, with the local housing and the local community associations, in order to effectively improve energy performance, active behaviour change and encourage energy efficiency.

Energy related targets were set by the Lisbon Municipality to fully deliver its climate and energy package by 2020, involving the establishment of agreements on the next steps of climate policy, by actively participating in the Covenant of Mayors, and implementing the SEAP. The use of renewables has been a long tradition in Lisbon’s strategy, namely the use of photovoltaic and solar thermal systems in social housing, schools, and swimming pools, private buildings and University Campus. With this in mind, and as a complementary action for the Municipality, Lisboa E-Nova has developed the solar potential chart in 2012. This innovative tool is available online, via a Google Maps application, and covers every building in Lisbon. It provides to users the identification of preferable areas for investing in solar technologies, and represents an efficiency awareness tool, both for local authorities, investors, business, and citizens.

Apart from these concrete measures, Lisbon Municipality has also approved the local Master Plan in 2012, which fosters good practices for promoting more sustainable performance for the city’s neighbourhoods, promoting the integration of renewable energy technologies, regulated by the RMUEL- Lisbon’s Municipal Urban Planning and Edification Regulation.

Within Sharing Cities an extensive set of activities are expected including the deep retrofit of 2 public social housing blocks (with 20,000 sqm), 3 private residential buildings (with 3,000 sqm) and 1 Municipal service building (with 5,000 m2). Within these activities, a significant amount of PV and solar thermal renewable sources are likely to be implemented aiming the total generation of more than 600 MWh per year. In addition, other energy efficiency measures are also being used a complement to reduce the energy demand of the buildings, including the application of innovative insulation materials based on cork composites.

All these activities are aligned and linked to the efforts being made regarding the electrification of city' mobility modes, e.g. EV charging.

REFERENCES

[1] Hammer, S. A., J. Keirstead, S. Dhakal, J. Mitchell, M. Colley, R. Connell, R. Gonzalez, M. Herve-Mignucci, L. Parshall, N. Schulz, M. Hyams, 2011: Climate change and urban energy systems. Climate Change and Cities: First Assessment Report of the Urban Climate Change Research Network, C. Rosenzweig, W. D. Solecki, S. A. Hammer, S. Mehrotra, Eds., Cambridge University Press, Cambridge, UK, 85–111.

[2] IEA (International Energy Agency), 2015: Energy and Climate Change, World Energy Outlook Special Report, OECD/IEA, Paris.

[3] EC (European Commission), 2010: Directive 2010/31/EU of the European Parliament and of the Council, of 19 May 2010, on the energy performance of buildings.

[4] EC (European Commission), 2010: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Energy 2020 – A strategy for competitive, sustainable and secure energy. COM(2010) 639, Brussels, 10.11.2010.

[5] EC (European Commission), 2009: Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009, on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

[6] EC (European Commission), 2017: Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources. COM(2016) 767, Brussels, 23.2.2017.

[7] EC (European Commission), 2017: Annexes to the Proposal for a Directive of the European Parliament and of the Council on the promotion of the use of energy from renewable sources. COM(2016) 767, Brussels, 23.2.2017

[8] EC (European Commission), 2009: Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009, on establishing a framework for the setting of ecodesign requirements for energy-related products.

[9] Wamukonya, N., 2005, Legislative and Policy Instruments for promotion of renewable energy in the power sector. Paper to be presented at the Parliamentarian Forum on Energy Legislation and Sustainable Development. Parliament of South Africa, Cape Town, 5-7 October 2005.

[10] Schellekens, G., Wongnapapisan, B.; et al., 2011, Scaling Up Renewables Developing Renewable Energy Capacity – Addressing Regulatory and Infrastructure Challenges in Emerging Markets April 2011, World Economic Forum, prepared in collaboration with PwC, Scaling Up Renewables Initiative, World Economic Forum, Geneva, 2011.

[11] Connolly D., et al., 2009, A review of computer tools for analysing the integration of renewable energy into various energy systems. Applied Energy (2009), doi:10.1016/j.apenergy.2009.09.026

[12] Rosen, J., 2007, The future role of renewable energy sources in European electricity supply. A model-based analysis for the EU-15. Karlsruhe University, Karlsruhe 2008.

[13] Ravn, H. Balmorel. Available at: http://www.balmorel.com/

[14] MacDonald, M., 2007, BCHP Screening Tool Users Manual, Version 2. Oak Ridge National Laboratory, US Department of Energy's Distributed Energy Program, November 2007.

[15] Aalborg University. EnergyInteractive.NET. Available at: http://energyinteractive.net/COMPOSE.ashx
[16] Argonne National Laboratory. Electricity Market Complex Adaptive System (EMCAS). Available at: http://ceeesa.es.anl.gov/projects/emcas.html
[17] Aalborg University. EnergyPLAN: advanced energy system analysis computer model. Available at: http://energy.plan.aau.dk/
[18] EMD International A/S, 2014, energyPRO User's Guide. Aalborg, Denmark. Available at: http://www.emd.dk/
[19] Argonne National Laboratory. Energy and Power Evaluation Program (ENPEP-BALANCE). Available at: http://ceeesa.es.anl.gov/projects/Enpepwin.html
[20] FROnT. Fair RHC Options and Trade. Available at: http://www.front-rhc.eu/
[21] Argonne National Laboratory. Generation and transmission maximization (GTMax) model. Available at: http://ceeesa.es.anl.gov/projects/Gtmax.html
[22] Instituto Superior Técnico, University of Zagreb. H2RES. Available at: http://h2res.fsb.hr/
[23] HOMER Energy LLC. HOMER. Available at: http://www.homerenergy.com/
[24] INFORSE-Europe. Vision 2050: visions for a renewable energy world. Available at: http://www.inforse.org/europe/Vision2050.htm
[25] Vienna University of Technology, Invert, Available at: http://www.invert.at/
[26] The International Renewable Energy Agency. IRENA Project Navigator. Available at: https://navigator.irena.org/index.html
[27] Stockholm Environment Institute. Community for energy, environment and development. Available at: http://www.energycommunity.org/
[28] International Institute for Applied Systems Analysis. Energy modelling framework: model for energy supply strategy alternatives and their general environmental impact (MESSAGE). Available at: http://www.iiasa.ac.at/Research/ENE/model/message.html
[29] National Technical University of Athens. Energy–economics–environment modelling laboratory research and policy analysis. Available at: http://www.e3mlab.ntua.gr/
[30] Renewable.Ninja. Available at: https://www.renewables.ninja/
[31] The World Bank. Renewable Energy Financial Instrument Tool (REFINE). Available at: http://www-esd.worldbank.org/refine/
[32] Energy Saving Trust. Renewable Selector. Available at: http://www.energysavingtrust.org.uk/
[33] National Resources Canada. RETScreen International. http://www.retscreen.net/
[34] Herbergs, S., Lehmann, H., Peter, S., 2012, The Computer-modelled Simulation of Renewable Electricity Networks. Sustainable Solutions and Innovations. Available at: http://isusi.de/downloads/simren.pdf
[35] Energinet.dk. SIVAEL. http://www.energinet.dk/en/menu/Planning/Analysis+models/Sivael/SIVAEL.htm
[36] National Renewable Energy Laboratory. System Advisor Model (SAM). Available at: https://sam.nrel.gov/
[37] University of Wisconsin-Madison College of Engineering's Solar Energy Lab. Transient System Simulation Program – TRNSYS. Available at: http://sel.me.wisc.edu/trnsys/
[38] IEA and IRENA, 2017: Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System, OECD/ IEA and IRENA, 2017.

[39] EC (European Commission), 2011: Commission Staff Working Document on Definition, Expected Services, Functionalities and Benefits of Smart Grids, accompanying the Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions on Smart Grids: from innovation to deployment. SEC(2011) 463 final, Brussels, 12.4.2011

[40] BIRD, L., MILLIGAN, M., LEW, D., 2013, Integrating Variable Renewable Energy: Challenges and Solutions. Prepared under Task No. WE11.0820. NREL/TP-6A20-60451. No. DE-AC36-08GO28308. National Renewable Energy Laboratory Denver, USA, September 2013.

[41] BEIS (Department for Business, Energy and Industrial Strategy), 2016: Digest of United Kingdom Energy Statistics (DUKES), July 2016.