MODULE 1

Renewable energy and local development

Open Educational Resources for online course of renewable energy for local development

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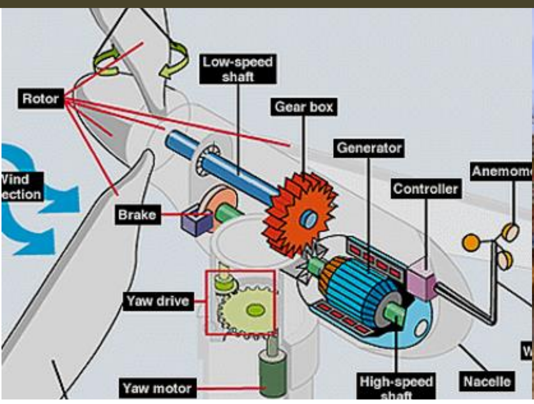

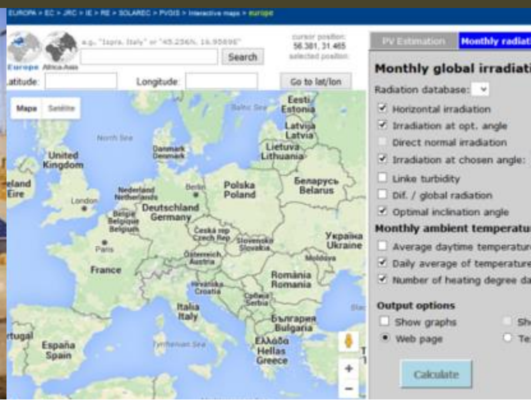

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MODULE 1: RENEWABLE ENERGY AND LOCAL DEVELOPMENT

CHAPTER 1. First steps into renewable energies

Subchapter 1.1 - The renewable resources: sun, wind, biomass

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Summary: To start the course, we will initially focus on the nature and characteristics of three natural and renewable resources: the sun, the wind, and the biomass. Although basically the three of them are obtained from the sun (solar rays themselves, movements of air caused by the heat of the sun, and energy to grow plants) their characteristics differ substantially from each other and this strongly defines the technology used to make them profitable.

Introduction

Renewable energy resources are defined as those materials, substances, or natural phenomena that are naturally replenished on a human timescale such as sunlight, wind, rain, tides, waves, rivers, woods, geothermal heat…. These resources are often used to provide energy in four important areas of our society: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energy services. Their biggest advantage with regard to conventional or traditional energy resources (oil, coal, natural gas) is that the latter present limited reserves that will be over in a given period of time while renewables are replenished periodically. To get an idea of the differences in the availability of resources humanity possesses nowadays, Figure 1 presents a comparison among the estimated conventional energy resource reserves versus the renewable energy resources annual potential.

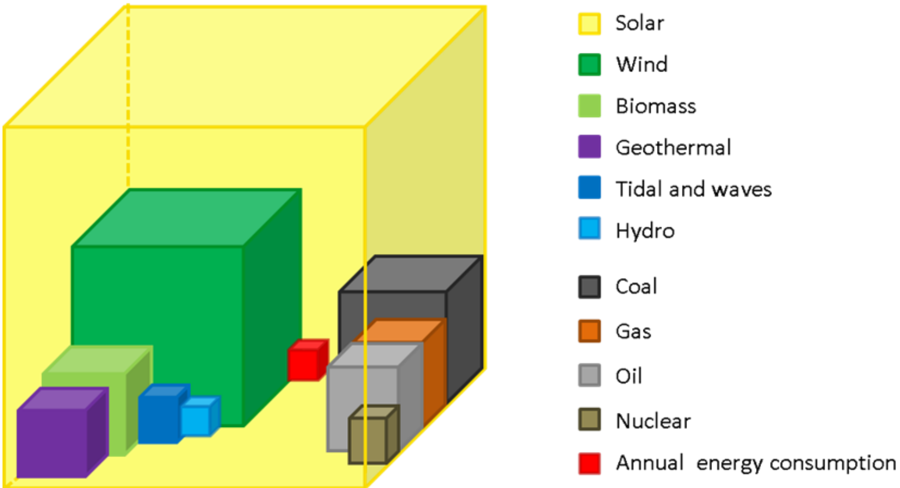

Figure 1. Estimated total reserves of conventional sources vs. the annual potential of renewable sources. Source: PVPS PhD Course by Remus Teodorescu at Aalborg University, Denmark.

Also in contrast with conventional resources, which are concentrated in a limited number of countries, renewable ones are present all around the world. The possibility to profit them in a commercial way opens the door to energetic independence or energy security for many countries, as well as cooperates with the climate change mitigation. So much that the international public opinion shows a strong support for promoting renewable projects and many countries already enjoy an important presence of these technologies in their energy mix. All in all, renewables already represented a 16,7% of the global energy consumption in 2010, Figure 2.

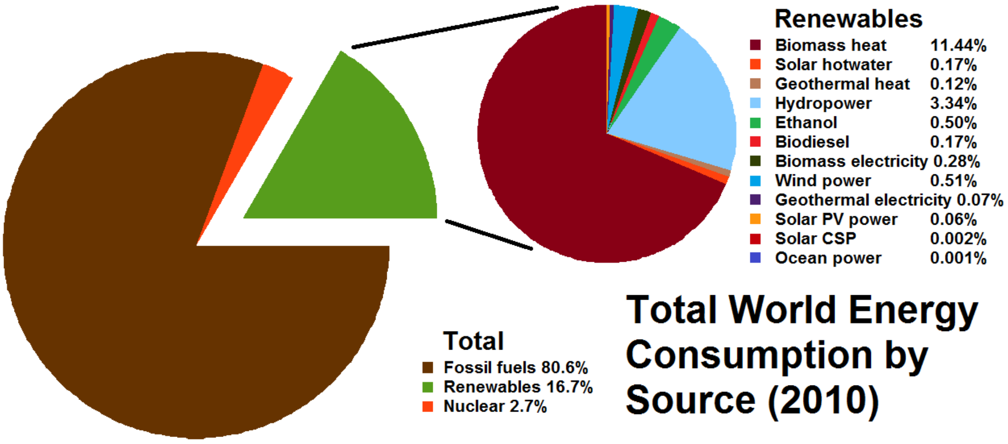

Figure 2. Total world energy consumption by source 2010, from REN21 Renewables 2012 Global Status Report.

At the national level, at least 30 nations around the world already have renewable energy contributing to more than 20 percent of their energy supply. National renewable energy markets are projected to continue to grow strongly in the coming decade and beyond. In fact, note how some regions (mainly islands) and at least two countries (Iceland and Norway) generate all their electricity using renewable energy already. Many other countries have set a goal to reach 100% renewable energy in the coming future. For example, the Danish government decided to switch the total energy supply (electricity, mobility and heating/cooling) to 100% renewable energy by 2050. Germany is also on the way. And, in general, all the countries in the European Union present this trend given that they have the overall goal of achieving the 20% target of renewables in 2020.

While many renewable energy projects are large-scale, renewable technologies are also suited to rural and remote areas and developing countries, where energy is often crucial in human development. United Nations' Secretary-General Ban Ki-moon has said that “renewable energy has the ability to lift the poorest nations to new levels of prosperity”. As most renewables provide electricity, renewable energy deployment is often applied in conjunction with further electrification, which has several benefits. For example, electricity can be converted into heat without losses and even reach higher temperatures than fossil fuels; can be converted into mechanical energy with high efficiency, and is clean at the point of consumption. In addition to that, electrification with renewable energy is much more efficient and therefore leads to a significant reduction in primary energy requirements, because most renewables don't have a steam cycle with high losses (fossil power plants usually have losses of 40 to 65%).

Among the natural resources that can be classified as renewable sources of energy, the following can be highlighted:

- Sunlight, which gives rise to technologies such as photovoltaic (PV) power, concentrating solar power (CSP), solar hotwater.
- Air movements around the planet, which give rise to winds that can be profited by technologies such as large and small wind turbines
- Water from rivers, which gives rise to technologies such as large hydropower and mini-hydraulic installations.
- Sea tides and waves, which give rise to technologies such as tidal and ocean power.
- Heat from the Earth, which gives rise to technologies such as geothermal energy.
- The growth of plants, which gives rise to technologies such as ethanol, biodiesel, and some types of biomass installations.
- And finally, although not so natural, one can classify part of the urban and industrial wastes, and some animal droppings, as renewable sources (produced periodically) adaptable to some type of biomass that gives rise to technologies such as biogas, or landfill gas.

During this course we will just focus on three of these resources: sun, wind, and biomass. This is because, with the exception of the mini-hydraulic installation, which is the one that could have also been included in the course, these are the resources with technologies properly developed to be adapted in rural environment. And this is the final framework of this course. Their nature, characteristics and availability are presented next.

Sun

Sunlight energy is directly provided by the Sun, located 150-million kilometres away from the Earth. It is important to highlight at this point to raise awareness around its unlimited potential that the Earth receives enough energy from the Sun in one minute to meet the needs of the whole planet for a year. Also, Figure 3 shows the area to cover on the Sahara Desert with PV panels in order to cope with the global and European electric consumptions, respectively.

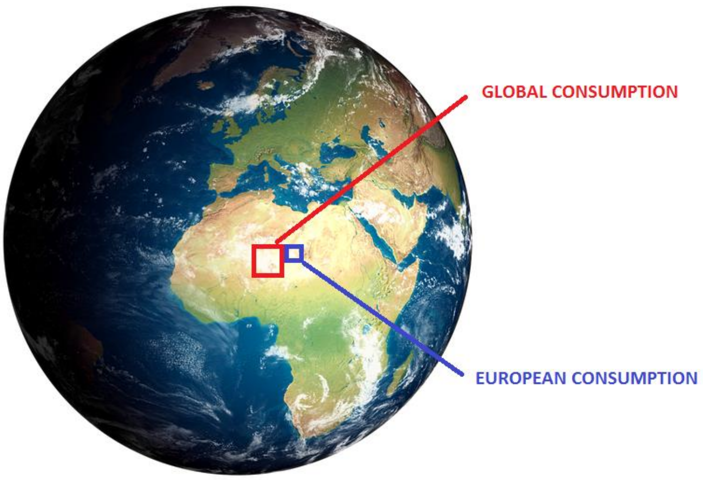

Figure 3. Surface of the Sahara Desert required to power the planet with PV technology. Source: DGS. Ludwig-Bolkow SystemTechnik.

We call solar radiation a set of radiations coming from the sun, of which only 70% enters the atmosphere (sunlight). The rest is reflected back into space. Regarding the sunlight, this is absorbed by clouds, oceans and land masses. This is the renewable energy that we can utilise converting it into something useful and controlled (electricity or heat). Most of the spectrum of sunlight that reaches the Earth's surface is radiation in the ranges of visible light and infrared, with only a small part in the ultraviolet. Solar technologies are progressively adapted to work optimally at these frequencies.

Around the planet, the solar resource is not constant but it is concentrated in the so-called "Sunbelt" (latitudes situated in between the tropics), Figure 4, which is where the solar rays reach more perpendicular to the surface throughout the year. In this sense, one can highlight areas such as California, Atacama, and North Africa.

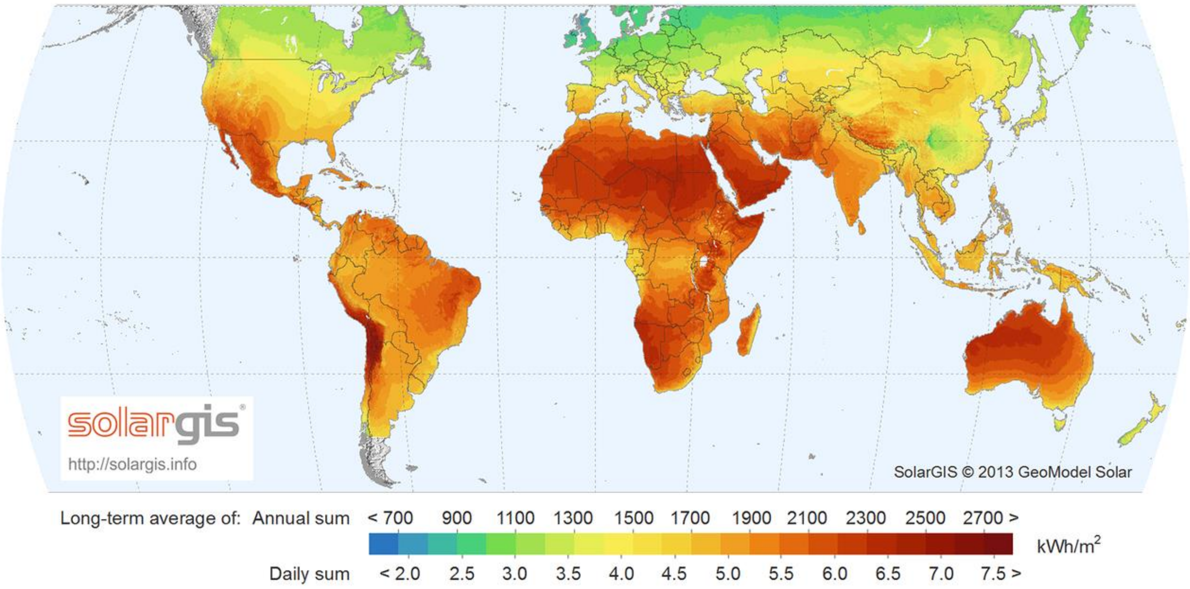

Figure 4. Irradiation World map by SolarGIS © 2013 GeoModel Solar. Licensed under CC BY-SA 3.0 via Commons - https://goo.gl/doa9jV

The global solar radiation incident on any type of inclination surface consists of three different components: direct, diffuse and reflected components (Figure 5). These can be described as:

- Direct: known as beam or direct normal irradiance, it is the solar radiation experienced at a given location on Earth by any surface perpendicular to the Sun's rays. It is equal to the Solar Constant (1366,1 W/m^2) minus the atmospheric losses due to absorption and scattering. These losses depend on the time of day (length of light's path through the atmosphere depending on the solar elevation angle), the cloud cover, the moisture content, and others such as aerosols, ozone, mixed gases…
- Diffuse: is the solar irradiance which is scattered or reflected by atmospheric components in the sky, reaching measurement surfaces with multiple angles.
- Reflected component: it is mainly exclusively considered for inclined surfaces since it is basically a ground reflected component, hence very influenced by the albedo parameter. Albedo is synonym for reflectance and denotes the reflection coefficient of the Earth surface in the visible range of the solar spectrum. Thus, this component may be quite important in northern European latitudes where Sun elevation is low for a

large part of the year, a phenomenon which is further increased by the permanent presence of a highly-reflecting snow cover, with an elevated albedo value.

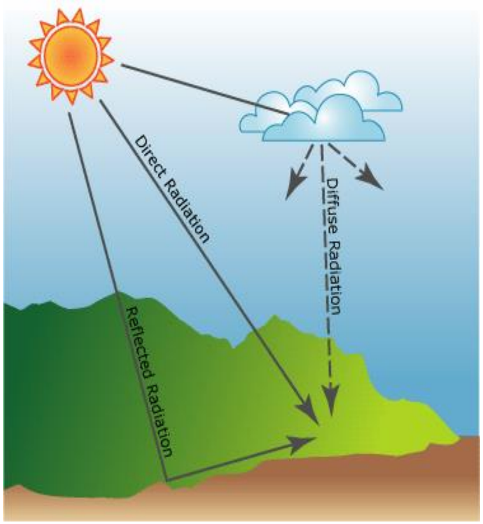

Figure 5. Components of solar radiation World map by SolarGIS Source: http://www.biofuturo.net/

Due to the cost and difficulty on measuring the different irradiance components, the three of them are not normally available. In fact, rarely any of them is available and the analysis of the solar radiation at a given location has been historically difficult or expensive to perform. Nowadays, there are different solar radiation databases (from public and private initiatives) that provide this information. These databases generate the statistically-expected radiation values for a place from a history of satellite images and meteorological data registered by stations relatively close to the place under study. Some examples are: Helioclim, Solar Energy Mining (SOLEMI), SATEL-LIGHT, European Solar Radiation Atlas (ESRA), Solar GIS, Meteonorm, and finally Photovoltaic Geographical Information System (PVGIS). The latter is a public free-access database fostered by the European Union, and it is the one proposed for consultancy in this course at the following link: http://re.jrc.ec.europa.eu/pvgis/

It stands out that PVGIS is a database which uses solar radiation ground measurements collected at 566 ground meteorological stations over the period the period 1981 to 1990 (although it is now being updated with satellite images, too).

Wind

Wind is generated by the uneven heating experienced by different parts of the Earth (Figure 6). One can understand that in our planet, the solar warming is the greatest at the Equator during the day, causing the air to rise. Once it cools, descends near the tropics. Above the tropics, the dominant trend is that of the western winds, which are due to the rotation of the earth.

At the large-scale, wind is a balance between the Coriolis force and the force of pressure and air-friction with the ground. A few thousand meters above the earth, the air-friction with the ground is not significant anymore. Therefore, Coriolis and pressure forces get equalized, making the wind trajectories that of the isobars (lines englobing regions subject to the same atmospheric pressure). These winds are called geostrophic wind and cause that an anticyclone (high atmospheric pressure region) turns clockwise in the northern hemisphere and it turns in the opposite direction in the southern hemisphere.

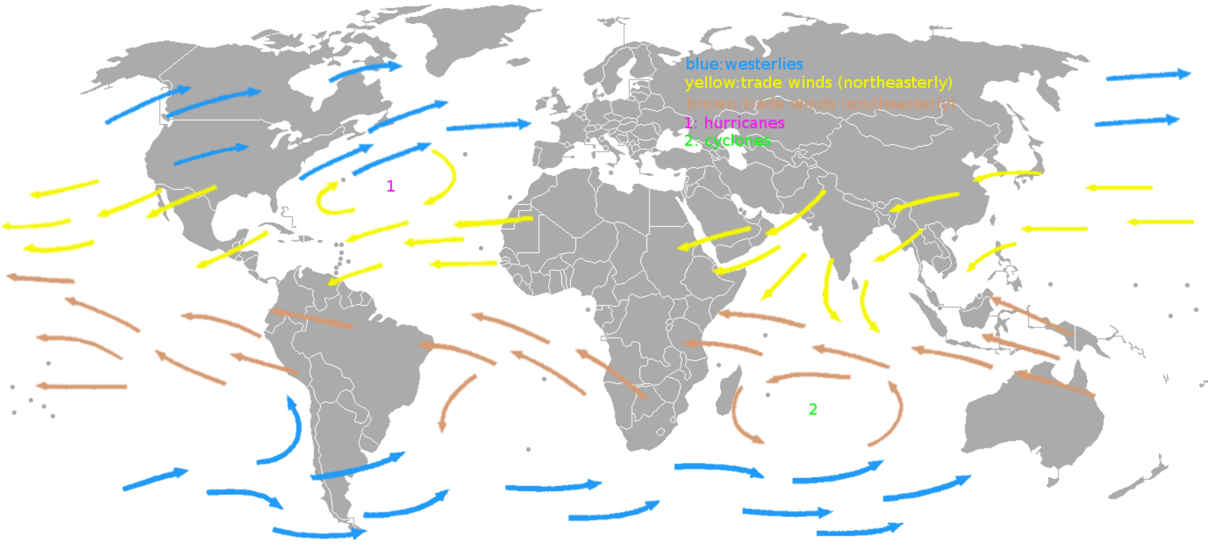

Figure 6. A map showing the prevailing winds on earth, by KVDP, via Wikimedia Commons.

At the medium scale, breezes in coasts, mountains or valleys, dominate the scene. These are due to the unequal warming of the sea and earth that generate air movements in one direction during the daytime and in the other direction during the night.

At the local level, there are countless factors influencing the wind such as obstacles or orography, which can cause accelerating effects as it is the case on the hills (optimal places to install wind turbines). Also height is an important factor as wind increases speed in a non-linear way (depending on the roughness and the obstacles of the location) as we get farther from the earth surface. Note that the roughness and obstacles are also guilty for the turbulence appearing in the wind gusts, and this is one of the main differences of the wind resources when analysed in the middle of the sea. In such a location, wind is laminar and more constant.

Therefore, the study of the prevailing winds and their availability at a given location is a must for the proper analysis of the economic viability of a wind power plant. Although the wind resource follows a Weibull distribution (statistical form of distributing the wind resource speed throughout a given period of time), it presents an inherent variability that implies the elaboration of the so-called “rose of the winds” at any location (Figure 7). This type of representation shows what the distribution (preferred directions), intensity (m/s^2) and frequency (percentage of time) of winds are at a given location along a whole year-time. Then, the distribution of the different wind turbines to be installed at the place can be decided accordingly. And also, an approximated estimation of the energy production can be performed.

As for the case of the irradiation, nowadays there are a number of databases where engineers and wind power promoters can consult wind resource data. The most noteworthy would the international atlas of developed by IRENA (available at: http://irena.masdar.ac.ae/)

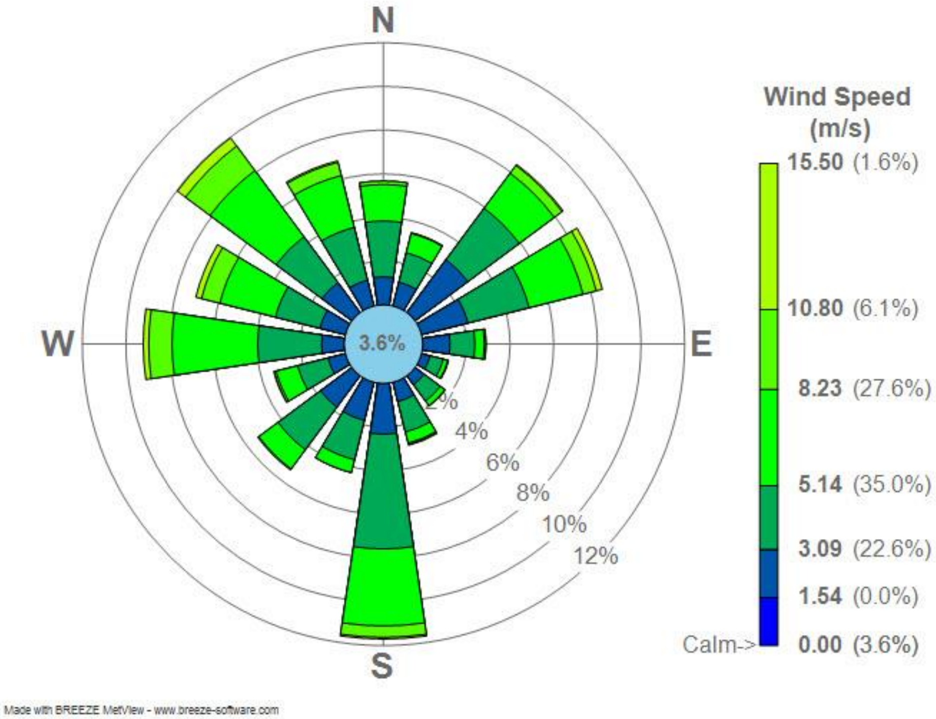

Figure 7. Wind rose plot at LaGuardia Airport, by BREEZE Software CC-BY-SA-3.0, via Wikimedia Commons.

Biomass

Finally referring to biomass, which is a very general term for encompassing quite a lot of different sources of energy and technologies, this can be more extensively defined as all those biological materials derived from living, or recently living organisms, which can be used for producing energy. In other words, biomass comprehends all biologically-produced matter based on carbon, hydrogen and oxygen, susceptible of use for energy production. That is why humans have historically harnessed biomass-derived energy since the time when people began burning wood to make fire. Even today, biomass is the only source of fuel for domestic use in many developing countries.

As an energy source, biomass can either be used directly via combustion to produce heat, or indirectly after converting it to various forms of biofuel.

In the first sense, biomass can often refer to plants or plant-derived materials which are specifically called lignocellulosic biomass. In this group, wood remains the largest biomass energy source today. Examples include: forest residues (such as dead trees, branches and tree stumps), yard clippings, wood chips (Figure 8). However, even municipal solid waste would be in this group, since they can be burned by pyrolysis in an incinerator plant.

Figure 8. Different types of biomass, by MarcusKauffman CC-BY-SA-3.0, via Flicker.

In the second sense, biomass also means plants or animal matter that can be converted into biofuels (ethanol, biodiesel, and biogas). Numerous types of plants can be grown for industrial biomass production including: switchgrass, hemp, corn, poplar, willow, sorghum, sugarcane, bamboo, and a variety of tree species, ranging from eucalyptus to oil palm. There are also crops that are specifically grown for use as fuel that offer high biomass output per hectare with low input energy. Some examples of these plants are: wheat, which typically yield 7.5–8 tonnes of grain per hectare, and straw, which typically yield 3.5–5 tonnes per hectare in the UK. The grain can be used for liquid transportation fuels while the straw can be burned to produce heat or electricity. Other crops such as corn and sugarcane can be fermented to produce the transportation fuel, ethanol. On the contrary, biodiesel, another transportation fuel, can be produced from left-over food products like vegetable oils and animal fats. Still in this second group, one can highlight rotting garbage, and agricultural and human waste. All of these release methane gas (also called landfill gas or biogas) by fermentation. Finally, it is to note that there is a great deal of research involving algal fuel or algae-derived biomass due to the fact that it's a non-food resource (one of the main handicaps of the use of crops as biomass instead of nourishment for humans and animals) and can be produced at rates 5 to 10 times those of other types of land-based agriculture, such as corn.

The biomass used for electricity and heat generation varies by region as a function of the potential availability of a given type of resource. To give some examples, forest by-products such as wood residues are common in the USA. Agricultural waste is common in Mauritius (sugarcane residue) and Southeast Asia (rice husks). Bioethanol is very common in Brazil (sugarcane production). And animal husbandry residues, such as poultry litter, are common in the United Kingdom and The Netherlands.

For any specific project to be developed in a rural European environment, promoters and engineers will have to analyse the biomass supply possibilities available in the region.

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MODULE 1: RENEWABLE ENERGY AND LOCAL DEVELOPMENT

CHAPTER 1. First steps into renewable energies

Subchapter 1.2 - Renewable energies along the history

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Summary: From the dawn of time, renewable resources have been used by mankind as sources of energy. However, these were partially forgotten in the first and second worlds from the industrial revolution onwards, mainly due to the massive and consecutive use of carbon and oil. Thanks to different factors that deserve some analysis, renewables are back as they always were, at least in the not so-developed countries.

Introduction

Renewables have represented the most important source of energy used by humans during history in all its forms and applications, (Figure 1). In fact, mechanical energy provided by animals or human beings have been used for construction (pyramids, Roman roads, Chinese wall…), for navigation (row galleys), for agriculture (animal traction), for transport of people and freight, etc… Other forms or renewable energy such as wind energy has also been historically used in windmills and navigation (7000 years ago in the Nile). Equally, hydraulic energy has been profited in mills. And even solar power has been traditionally used for cooking, drying things and industrial applications such as salt production.

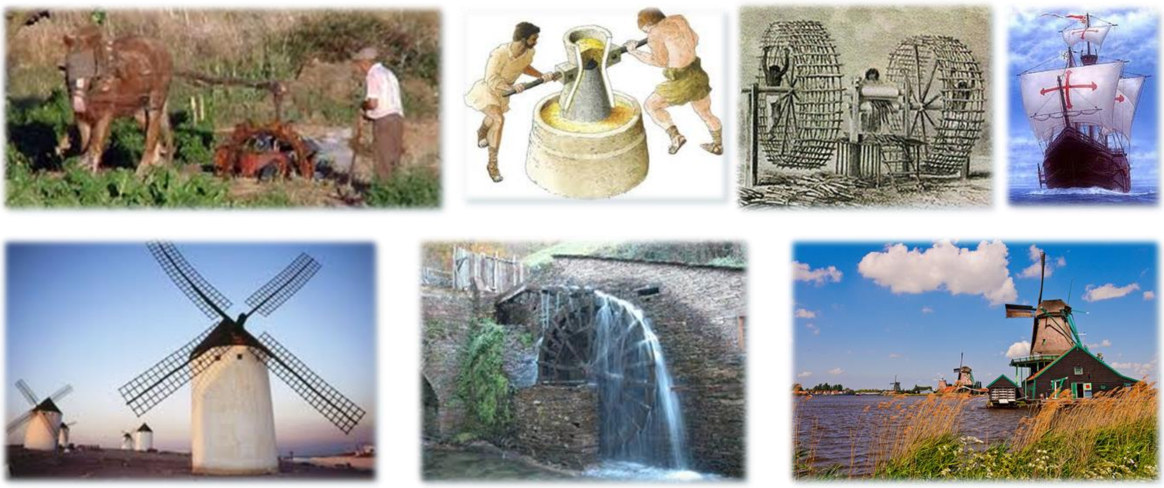

Figure 1. Ways of using renewable energy during centuries in the history of the mankind.

Finally, we should not forget the biomass, which is supposed to be the first source of energy used by the human being. It started to be used so as soon as 790,000 years ago to fuel fires. However, note that the use of biomass as fuel did not become commonplace until many hundreds of thousands of years later, sometime between 200,000 and 400,000 years ago.

Contemporary Era

The situation just described, with nearly all energy produced from renewable sources, was sustained till the development of coal in the mid-19th century. Although by 1873, some temporary concerns of running out of coal prompted experiments with using solar energy, the truth is that from the Industrial Revolution onwards, the industrial application of, first, the steam engine and, later, the more advanced combustion engines used for transportation of people and goods motivated the progressive abandon of the renewable forms of energy production. The drop that broke the camels' back was the appearance of oil and all its industry at the beginning of the 20th century. The widespread use of electricity from mid-20th century in the developed countries, obtained mainly from burning fossil fuel, contributed to minimize the share of renewables in the total energy consumption, which, in turn, increased rapidly year after year.

Thus, although a parallel development of solar engines continued until the outbreak of World War I, and the future potential of solar energy was recognized in a 1911 scientific article published in the USA and entitled: "In the far distant future, natural fuels having been exhausted [solar power] will remain as the only means of existence of the human race", the way was blocked for renewables from the 1920's onwards.

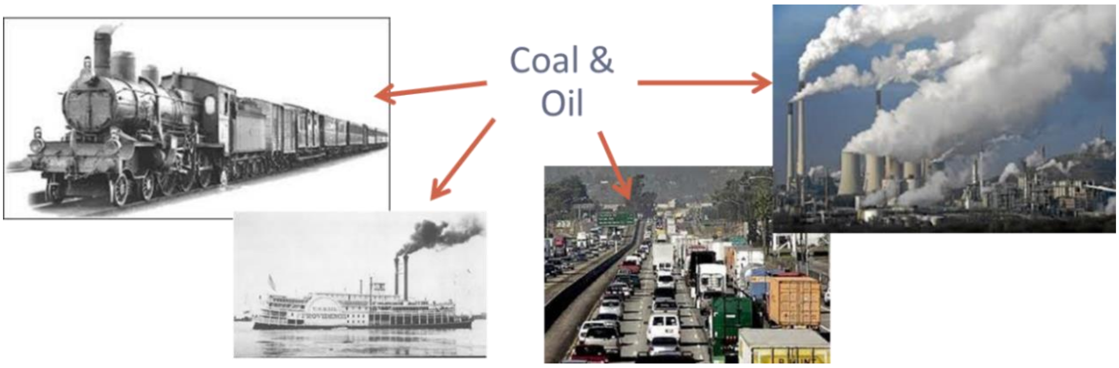

Figure 2. The 19th and the 20th centuries. Contemporary era or the era of carbon and coal?

Nowadays

It was the publication of the peak Oil theory in 1956 (announcing for the first time the limitation of the global oil resources and forecasting a future increment of the oil prices due to its scarcity) together with some environmental movements in the 1970s, what promoted a certain renaissance of the renewables. It was intended both as a replacement for the eventual depletion of oil, as well as an escape from the big dependence on oil in the OECD (Organization for Economic Cooperation and Development) countries. In fact, this procedure that mainly took place in the USA (Figure 3) was principally due to the two oil crises experienced during that decade.

Figure 3. President Carter inspecting a solar water heating panel installed on the roof of the White House, above the oval office, by the White House Staff Photographer (WHSP).

Although environmentalist movements claim their merit, only the exacerbated prices of petrol and gas that Europeans and Americans had to suffer from for more than 10 years (1973-1983, Figure 4) activated the search for alternatives (around 1975). Politicians in the first and second world realized they could not endlessly trust on cheap oil supplies provided by the Organization of the Petroleum Exporting Countries (OPEC). Due to political tension in the Middle-East between Israel and the neighbouring Arab countries, OPEC members decided twice to raise prices brutally within the same decade and occidental economies got strangled. Something had to be done to avoid such dependency on oil. That is why we can find pictures in the newspaper archives as that in Figure 3, in which President Carter is inaugurating a new solar installation installed on the roof of the White House in 1979. The ideology of certain politicians was clear at that moment: unconditional support to renewables.

The first commercial wind turbine installations appeared in these years (1980s). Solar energy, on the other hand, had long been used for heating and cooling, but solar panels were too costly to build until 1980. However, some concentrating solar projects were developed in the desert of Mohave (California, USA), totalling more than 200 MW of installed capacity.

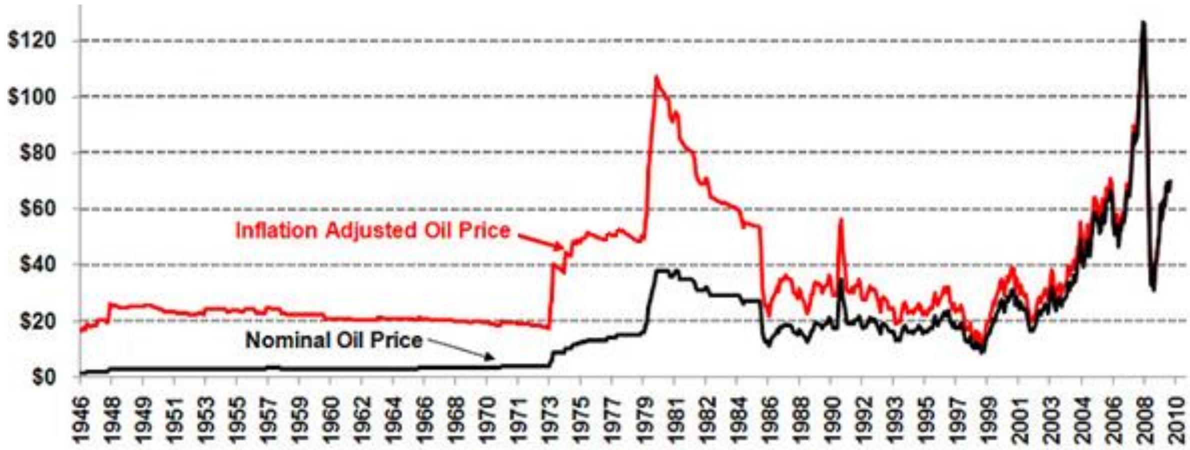

Figure 4. Oil price evolution during the past 70 years.

However, something changed with the arrival of the 80's. The Middle-East region got stabilized. Oil prices started to fall down and recovered very low prices from 1985 onwards. With the exception of the months around the first Gulf War (1991), when international markets were altered by tensions in Kuwait, the oil price was low and stable since then and for around 20 years (till 2004). With such prospects, renewable energies missed any option to compete either in price or in maturity with conventional technologies and the very well-developed oil industry. Most of the projects and research lines initiated in the previous decade (the 70's) were forgotten and kept in the box.

But history is cyclic, and the Middle-East is not the most stable region of the planet. In the last 15 years, new political tensions have been arising all around the region (remember the Al-Aqsa Intifada, which broke out in 2000, the Arab spring, the second Gulf War after the 11-S in NYC, the reappearance of the cold war with Iran, and so on...). This situation has inevitably involved a new increase of the oil prices and OECD countries' economies have suffered again.

The combination of these politico-economic constraints with a currently reinforced environmental movement that found a cornerstone in the progressive approval of the Kyoto protocol (elaborated in 1997) boosted again the research and development of new technologically-updated renewable projects in the first decade of this century. Many countries started introducing favourable policies and regulations for the installations of renewables, with different types of incentives that we will discuss further in the coming chapters of this course. These favourable policies and the progressive maturity of the technology that, thanks to an intensive research and development effort, has quickly attained very competitive prices, allowed an important deployment of renewables that can be appreciated nowadays in our surroundings. Even the USA and China (countries not very concerned with the global warming in the beginning) have finally got on board the moving train. Note Figure 5 where we can appreciate another president of the USA, Barack Obama in this case, inaugurating another solar installation some 40 years later than his colleague Democrat Jimmy Carter has done.

Figure 5. President Obama inaugurating a new PV solar plant. "Solar-crop" by White House Photographer Jesse Lee https://commons.wikimedia.org/wiki/File%3ASolar-crop.jpg

The question that arises now is: are renewables here again as a transient solution to the politico-economic situation or they are here to stay? The response is clear and it is certainly positive. This can be deduced from the analysis of the business dimension already generated by this sector, which has consolidated the renewable technologies as a mature industry, and the trending evolution that some renewables such as wind and solar PV are following and are expected to follow (Figure 6 and Figure 7). Note that the International Energy Agency (IEA) on its 2014 World Energy Outlook projects a growth of renewable energy supply from 1,700 gigawatts in 2014 to 4,550 gigawatts in 2040. And note finally that this can be done without great subsidies, which is demonstrated by the fact the fossil fuels received about $550 billion in subsidies in 2013, compared to $120 billion for all renewable energies.

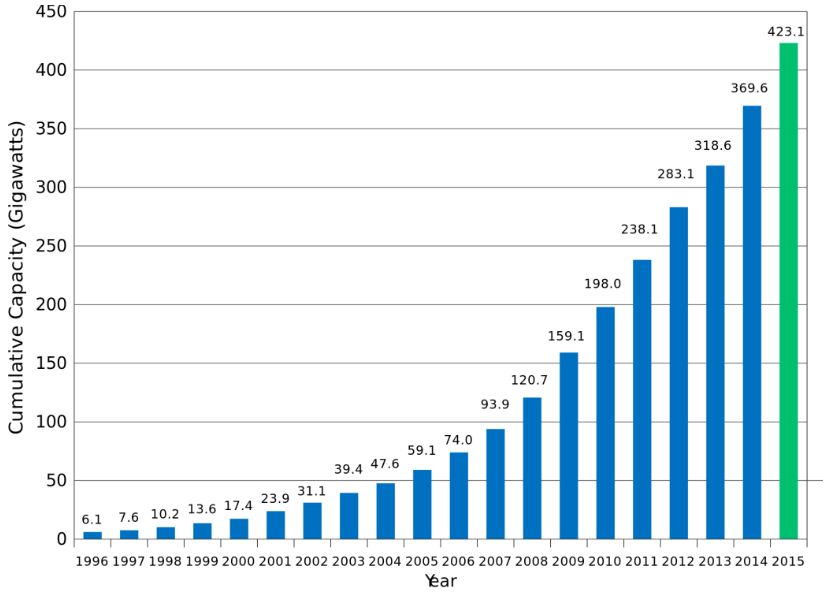

Figure 6. Global wind power cumulative installed capacity at the end of 2015, in gigawatts. Source: GWEC, by Delphi234 [CC0], via Wikimedia Commons

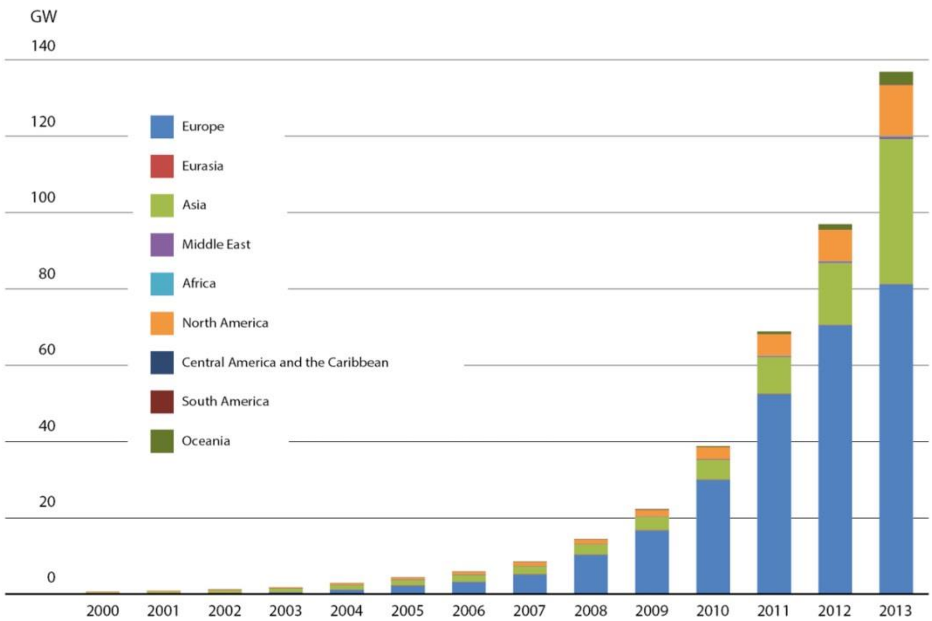

Figure 7. Global solar PV cumulative installed capacity, in gigawatts. Source: IRENA.

Finally, to close this subchapter and introducing a link with the coming one, one can summarize the main advantages and disadvantages of the renewable technologies, which are:

Advantages of renewables:

- They are more environmentally friendly. Do not pollute during operation and represent the cleanest energy alternative invented so far.
- It makes the country or region becoming more autonomous and independent in energy terms from third countries that are not always reliable or stable.

- Generates many jobs, which are expected to increase even more in a few years given the demand and implementation.

Disadvantages of renewables:

- The need for an important initial investment often hinders their profitability with the current prices of electricity.
- The stochasticity of some of the technologies (solar and wind) does not make them always available (need for greater storage). This is closely related to the fact that they are beginning to be increasingly popular.
- Their difficult integration into the landscape and the consequences that their introduction involves for the fauna.
- In some cases, they have negative impact on other industries (food shortage).

Evaluating their pros-cons, it seems clear the balance is positive. That is the reason why we can affirm renewables are here to stay and that their reappearance is modifying not only the conception of the society over the control and use of the energy, but the structure (physical and economical) of the energetic, mainly electric markets and infrastructures.

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MODULE 1: RENEWABLE ENERGY AND LOCAL DEVELOPMENT

CHAPTER 1. First steps into renewable energies

Subchapter 1.3 - The distributed generation, a new electric power system paradigm

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Summary: The consolidation of various renewable energy technologies to compete with conventional ones is transforming the electric power system paradigm, as we know it. All the experts recognize that the massive penetration of small generators all around the power system structure with multiple owners is converting the network in something more "democratic". Thanks to renewables, self-supply and local sustainability are closer and closer.

Introduction

In order to complete this introductory chapter while connecting with the advantages and disadvantages introduced by the renewable energies presented in the previous subchapter, it is important to highlight at this point that the large penetration of renewable energies experienced in some countries in the last decade is jeopardising the traditional model or structure of electric power system. In this sense, one can certainly affirm that nowadays there are many countries whose electric power system has already evolved from the traditional centralized structure paradigm into a more decentralized paradigm, also known as distributed paradigm. Hence, this subchapter introduces both schemes and compares their pros-cons.

Centralized generation paradigm

This is the traditional electric power system structure that has been implemented worldwide from the first electrifications built by Edison (first central power plant in Pearl Street Station in Manhattan, 1882) and his contemporary fellows. It was a coal-fired facility that produced electricity, which was then distributed to about 85 customers to light their businesses and homes. The system proved to work quite well and turned popular, promoting one idea: electricity was generated at a plant and brought to residents via a little wire that seemed to magically bring electricity right to their buildings or homes. It was so logic and popular that it was extrapolated all around and the interconnection of those initial systems settled the current electric power system that we have today. In fact, the classic electric system that we inherited in the 20th century still works basically the same way the Edison's system did 134 years ago, only on a much larger scale.

When you turn on the light in your kitchen, the power comes into your home via a small residential distribution line, which is attached to a larger utility-scale transmission line which might run hundreds of kilometres to a large, centralized power plant that is churning out energy. And this is not by chance, Edison's central generation and distribution model makes sense on a larger scale because of the way electricity was made at the time (by burning coal). Imagine if his idea would have been to install a tiny coal-fired power plant in each home that wanted electricity. Each family would have to get the coal, burn it to heat water, turn the turbine with the steam the burning coal makes, and have the machine to convert the steam's energy in to electricity, and then light their light bulb. It doesn't sound very convenient, cheap, or clean.

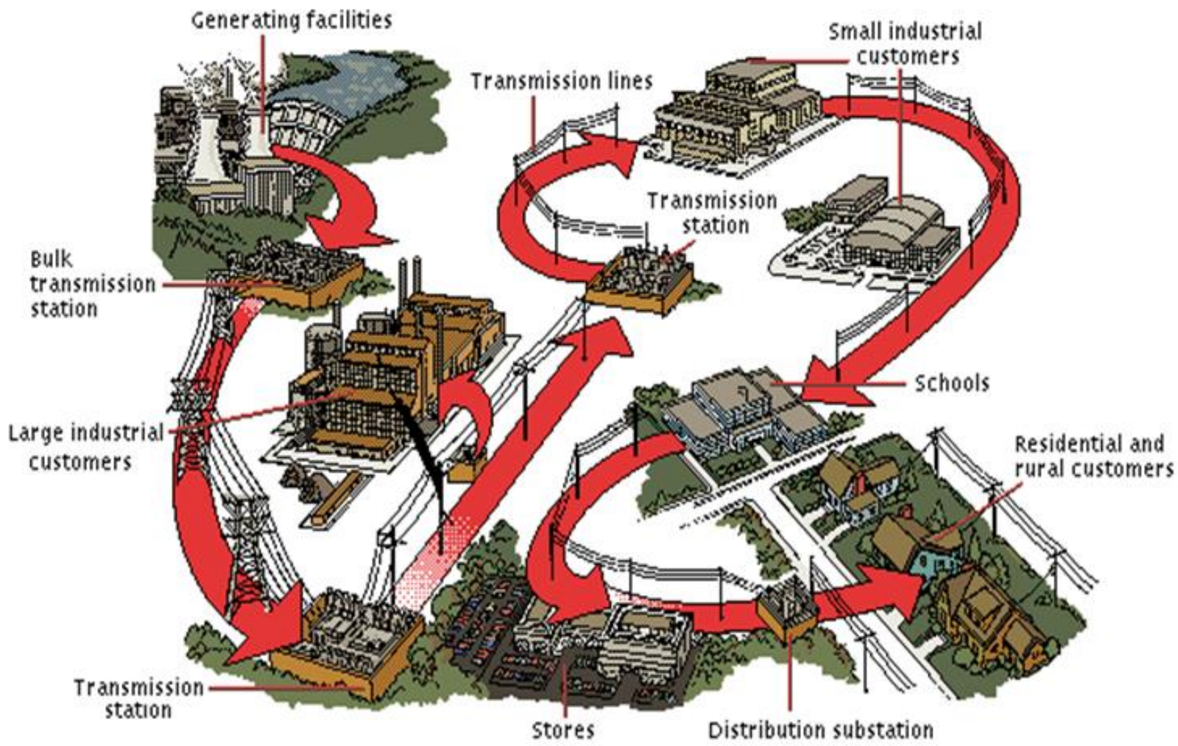

Figure 1. Schematic representation of a classic centralized electric power system.

The type of structure defined with this philosophy (**¡Error! No se encuentra el origen de la referencia.**), is characterized by the following key points:

- The majority of the demand, if not all, is covered or supplied by a few very large power plants.
- The generating power plants use traditional technologies exploiting conventional energy resources.
- The generating power plants are far away from the huge consumption cores.
- The power flow is unidirectional (from producers to consumers) and, therefore, the system is relatively easy to control.

This configuration implies a main drawback related to the level of losses experienced by the system due to the large amount of power transmitted among very distant nodes. These are estimated to be around 15-20% of the production in the first-world countries, and even larger in the rest of the world.

However, this is probably not the pure situation anymore in most of the systems, at least in a strict way, for the reasons explained at the beginning of this subchapter. Hence, there is a more or less accentuated transition towards a more decentralized distributed generation paradigm.

Distributed generation

This new paradigm implies the existence of many and many different small, and not so small, generators in countless locations around the globe. These generators formed by a variety of technologies, mainly renewables, can be connected to the network at different voltage levels (depending on their rated power capacity). For example, while large wind farms with power capacities above 50 MW will have to be connected to lines voltage levels above 50 kV (nominally, 63 kV, 132 kV and 220 kV), small PV or biomass installations rated below 2 MW can be connected to medium voltage levels (in the range 6,9 kV to 20 kV) or even at low voltage levels (below 1 kV) for the case of very small installations (with less than 50 kW).

This novel configuration is now possible because reality has evolved. Today, we do have energy sources that make good sense to have on a small local scale. Solar, geothermal, biomass, and small wind are all sources of energy that work really well at a local level, providing electricity and heat directly to a home, business, or group of connected buildings. The cited characteristics (geographic dispersion and diversity of technologies and rated powers) are the main descriptors to assign the name of distributed generation paradigm to this new reality of the forthcoming electric power systems.

But not only the generation mix is modified in this new paradigm; also other decentralized technologies such as storage or new protection and control methodologies are being introduced. And even on the consumption side, new demand side management strategies and control methodologies are stimulated within the distributed generation paradigm. Altogether, the distributed generation philosophy is the first step towards the “smart grid” philosophy, a term so much in vogue in international electric conferences and journals nowadays.

Note that this new paradigm does not necessarily mean the installation is going “off the grid”. That’s a possibility but, in the majority of the cases, the rest of the electrical grid will be still there. So if you need more energy than you can produce, you can buy more that was made somewhere else. And if you make more energy than you can use onsite, you can sell it back and put it on the grid for someone else to use.

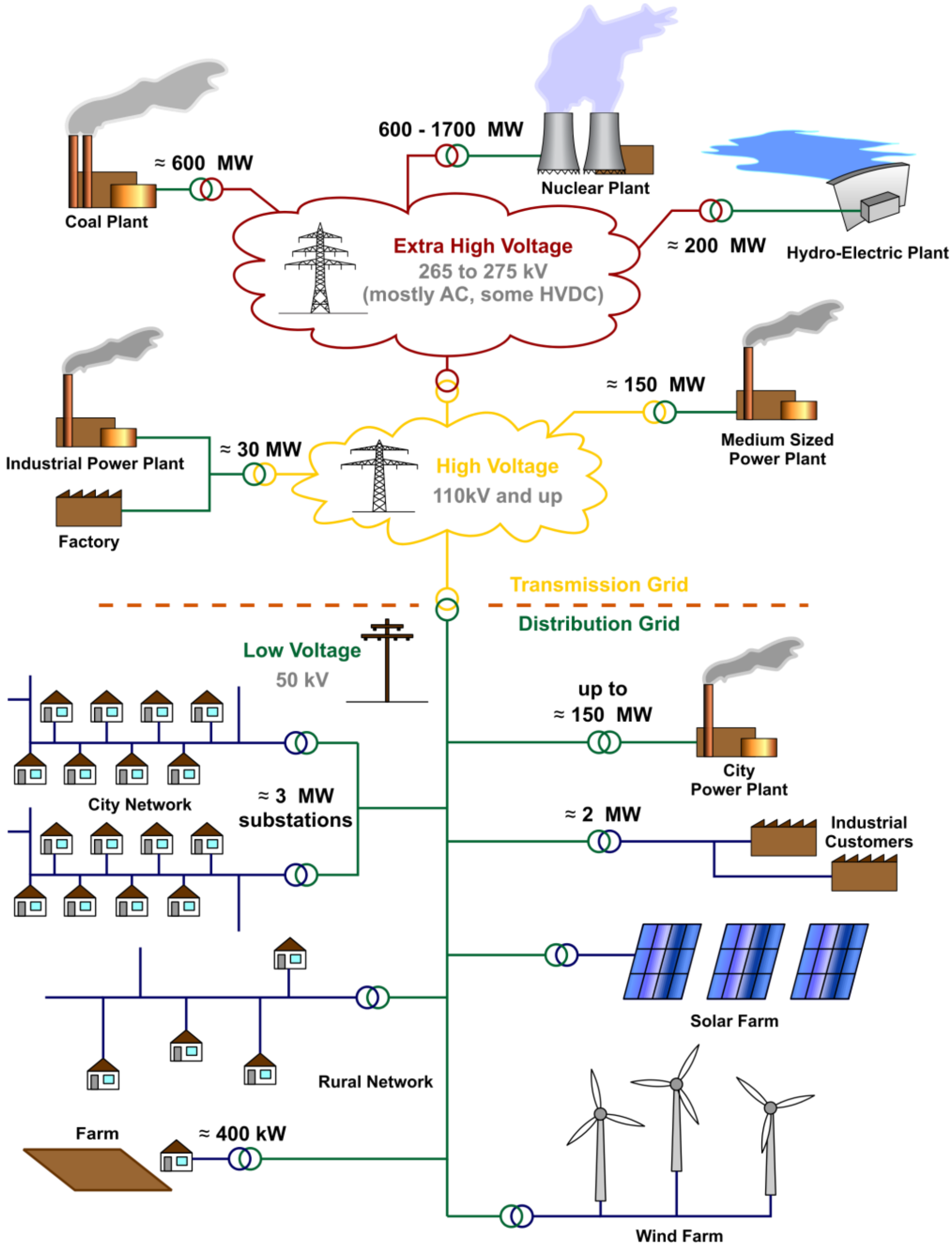

Figure 2. General layout of electricity networks (typical), by MBizon under CC BY 3.0, via Wikimedia Commons.

The ultimate goal of this evolution is to change the structure of the electrical system to improve its performance, reduce that 15-20% in transport and distribution losses, and promote free and real competition, which should reduce exploitation and final costs of the whole system. Moreover, it is a way to open the door to many small investors interested in the energy market that had no opportunity to enter the sector due to the high capital costs of all the elements in the system till now. In the coming format of the electric power system, one could say that anybody can produce and sell energy. Therefore, it is an evolution towards a more democratic system. Ideally, energy will not be only controlled by very rich big energy companies in the future.

So, what are the pros-cons of such a system compared to the centralized paradigm? These can be derived from the main characteristics or key points that can be observed in Figure 2, and have been already more or less introduced. These are:

- The presence of distributed generators at many different points of the network produces the appearance of bidirectional energy flows, contrary to the previous situation where energy was circulated from central generators to consumption zones.
- This same presence of distributed generators all around drastically decreases the mean distance that the energy has to travel to be consumed. Hence, transport and distribution losses are largely reduced.
- This configuration provides energetic independence for the consumers because energy is produced closer to the place of consumption. And certain parts of the grid could decide to work temporarily isolated from the rest, forming the so-called “microgrids”.
- Independence is also gained at a local or national level in the sense that it brings on the renewable energy expansion and the use of local resources.
- It increases supply security. This is because there are now much more providers of energy and when a given power plant goes down for any reason or a transport line between zones is overloaded, supply can be still obtained from other sources (probably closer) through other lines.

To mention an example of network evolution, we can shortly analyse the case of the Spanish Electric System. Around 20 years ago, there were no more than 900 energy production power plants that maintained the system in Spain. These involved technologies such as nuclear (8 power plants), thermal (65 power plants including those fed with coal, gas and fuel), hydroelectric (large and small), and Combined Heat and Power (CHP) installations.

After the huge penetration of renewables experienced in Spain from 2004 onwards, we can count nowadays around 68000 points of electric generation and injection of energy into the electric power system. These include those plants existing 20 years ago, except one nuclear and the three fuel-thermal plants already shut down, and around 66750 renewable energy distributed installations. Therefore, it is clear that most of the increment in the number of generators is due to the new solar PV, wind, and CSP installations developed in the last 10 years. In fact, there are so many that these cannot be clearly represented on a map and they are normally represented as an aggregated number by autonomous regions. For a further understanding, consult the map of Spanish power plants provided by Red Eléctrica de España (REE, the Spanish Transmission System Operator (TSO)) that is referred to in the bibliography below.

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MODULE 1: RENEWABLE ENERGY AND LOCAL DEVELOPMENT

CHAPTER 2. The renewable energies panorama

Subchapter 2.1 - Economic situation of energy and electricity around Europe

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Summary: Europe is not a great primary energy producer although it is one of the biggest energy consumers worldwide. Such casuistry has historically implied continued political and military tensions both within the continent and towards third countries. Nowadays, the assurance of the energy supply is still one of the most important topics of debate in Brussels. That is why electric and gas interconnections are a priority investment at the European level right now.

Introduction

Although being very diverse because it includes highly different countries with their corresponding local casuistries, the European energy sector is characterized as a whole by a series of predominant traits. However, in order to analyse them, firstly, it is important to define a series of concepts that has to be clearly differentiated:

- Primary energy: it is the energy found in nature that has not been subjected to any conversion or transformation process. It is energy contained in raw fuels, and other forms of energy received as input to a system. This energy is normally split into their sources such as gas, coal, nuclear, oil, renewables, etc.
- Final energy: it refers to the fraction of the primary energy that is used in its final form by humanity (electricity, heat…). This energy is normally split into the sectors that consume it such as industry, transport, agriculture, etc.
- Gross energy produced: is the total generation of electricity produced by the mix of electric power plants in a country. It is measured at the plant terminals right before the power leaves their stations and it is usually measured in megawatt-hours (MWh).
- Net energy produced: is the total generation of electricity in an electric power plant minus that used within the plant. It is also usually measured in megawatt-hours (MWh).

According to relevant sources of reference such as the European Environmental Agency (EEA), some of the cited characteristic or predominant traits can be explained (upon data from 2013) by means of Figure 1 and Figure 2. The first of them represents the overall primary energy consumption in both the 28 European countries (EU28) and the European non-EU countries, respectively. Nonetheless, the latter is a Sankey diagram (see references for further information) that shows the composition of the primary energy entering the energy system of the EU28 in 2013, and where this primary energy was used, either as losses or as consumption by specific sectors of the economy. The units are million tonnes of oil equivalent (Mtoe). Some points that can be derived from these graphics are:

- Primary energy consumption in the EU28 countries in 2013 (Figure 1 a), was almost the same as in 1990 and amounted to 1567 million tonnes of oil equivalent (Mtoe). Between 2005 and 2013, primary energy consumption in the EU28 countries decreased by 8,3 % due, in particular, to the economic recession, climatic conditions and energy efficiency improvements. Based on EEA preliminary estimates, in 2014 EU28 primary energy consumption continued to decrease by 3,3 % compared to 2013.
- Primary energy consumption in the non-EU European countries, (Figure 1 b), doubled from 69 Mtoe in 1990 to 143 Mtoe in 2013. The main reason for the difference in the trend for these countries compared to the EU28 was the large increase in primary energy consumption in Turkey and, to a lesser extent, in Norway.
- Fossil fuels (including non-renewable waste) continued to dominate primary energy consumption in the EU28, but their share declined from 82,1 % in 1990 to 72,9 % in 2013. The share of renewable energy sources more than doubled over the same period, from 4,5 % in 1990 to 12,6 % in 2013, increasing at an average annual rate of 4,5 % per year. The share of nuclear energy in gross inland energy consumption increased slightly from 13,1 % in 1990 to 14,4 % in 2013.
- A high proportion of the fossil fuels used in the EU28 in 2013 were imported from outside the EU, mainly Russia. Net import accounted for 87,4 %, 65,3 % and 44,2 % of the gross inland consumption of oil, gas and solid fuels, respectively.
- Only 72,3 % of the total gross inland energy consumption in the EU28 reached end users. Distribution, the energy sector’s own consumption of energy and other conversion losses represented 27,7 % of the total gross inland energy consumption in the EU28, of which 4,8 % resulted from energy consumption by the energy sector.
- The average energy efficiency of electricity and heat production from conventional thermal power stations and district heating plants in the EU28 reached 50,5 % in 2013.
- During the transformation of energy carriers into electricity in power stations, 55,6 % of the fuel input is lost as conversion losses. These losses are declining in the EU28 as power station efficiencies and electricity generation from renewables and Combined Heat and Power (CHP) increase. About 25 % of electricity was generated from CHP.
- Nuclear heat accounts for 45,5 % of the input into power stations (excluding CHP and district heating), followed by solid fuels (29 %), renewables (16,4 %) and gas (9 %).
- Industries consumed the highest amount of electricity, followed by the domestic sector and other final consumers (including the services sector). The largest consumer of natural gas in 2013 was the domestic sector (110,5 Mtoe), followed by industries (83,2 Mtoe) whereas for coal, the largest consumers were electricity generation plants (power stations and CHPs). Coal and gas are also input fuels for other transformation plants which produce manufactured fuels.

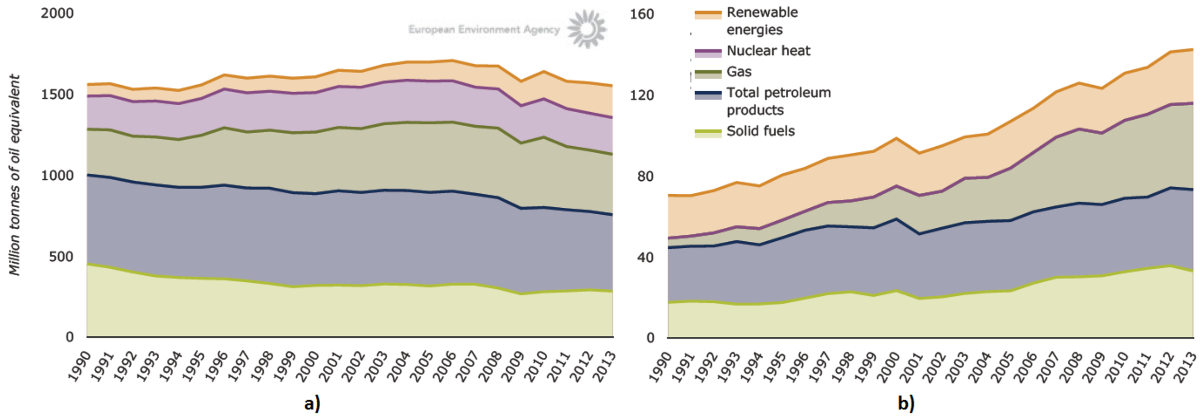

Figure 1~~.~~ Primary energy consumption by fuel at a) EU countries, and b) non-EU countries, by European Environmental Agency (EEA) [CC BY 2.5], via permalink: 43bec319178c4131b19da7defed56003

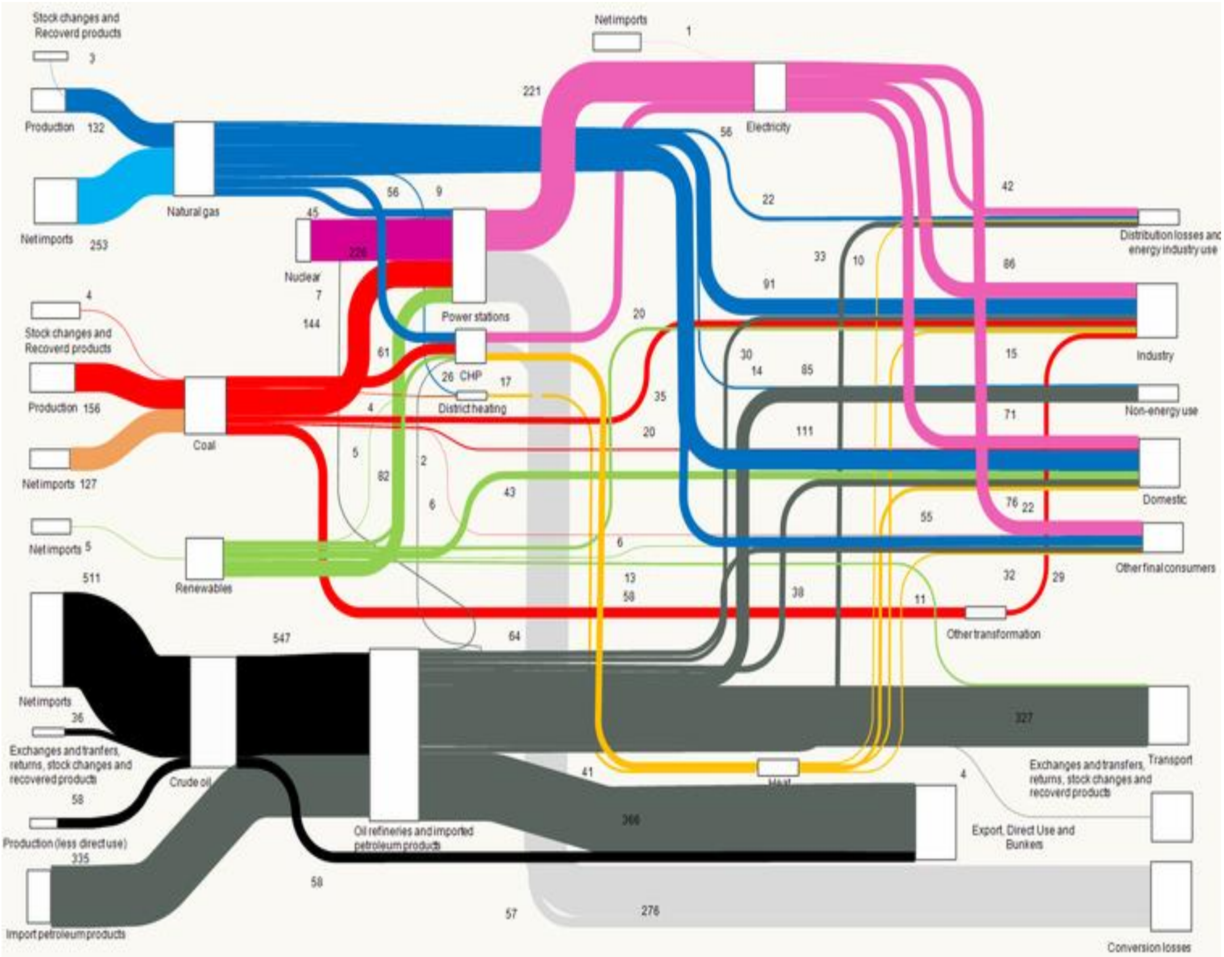

Figure 2. Overview of the EU28 energy system in Mtoe. Copyright holder: European Environment Agency (EEA). Permalink: N7P8HO3YZR

Finally, to close this introductory chapter, it is important to observe Figure 3 where the total gross energy production is represented (in the energy unit TeraWatts-Hour (TWh)). Note that it is classified by fuels used to produce it. It includes electricity production from both public plants and auto-producers. Renewables include electricity produced from hydro (excluding pumping), biomass, municipal waste, geothermal, wind and solar photovoltaics. The share of renewables presented in the chart is for production and hence it differs from the share of renewables in consumption 'Other fuels' include electricity produced from power plants not accounted for elsewhere, such as those fuelled by certain types of industrial wastes. It also includes the electricity generated as a result of pumping in hydro-power stations.

It is derived from the data depicted by the EEA in Figure 3 that the total net electricity generation in the EU28 was 3,10 million gigawatt hours (GWh) in 2013 which was slightly less (-0.9 %) than the year before. This was the third consecutive fall in output, following on from a 0,1 % fall in 2012 and a reduction of 2,2 % in 2011. As such, the level of net electricity generation in 2013 remained 3,6 % below its peak level of 2008 (3,22 million GWh). This pattern observed for the EU28 of falling electricity generation in 2011, 2012 and 2013 was reproduced in only four of the EU Member States, namely Cyprus, Hungary, the Netherlands and the United Kingdom. By contrast, Slovakia was the only Member State to report growth in all three these years. Regarding only 2013, the largest increase in electricity generation was recorded for Croatia, with growth of 27,9 %. Denmark, Estonia and Portugal also recorded double-digit growth, while none of the other Member States reported growth of more than 4,0 %. By contrast, 15 Member States reported a fall in electricity generation, with the largest reductions in Hungary (-13,3 %) and Luxembourg (-24,4 %).
Individually, in a static picture, Germany had the highest level of net electricity generation in 2013 among the EU Member States, accounting for 19,2 % of the EU28 total, just ahead of France (17,7 %); the United Kingdom was the only other Member State with a double-digit share (11,0 %).

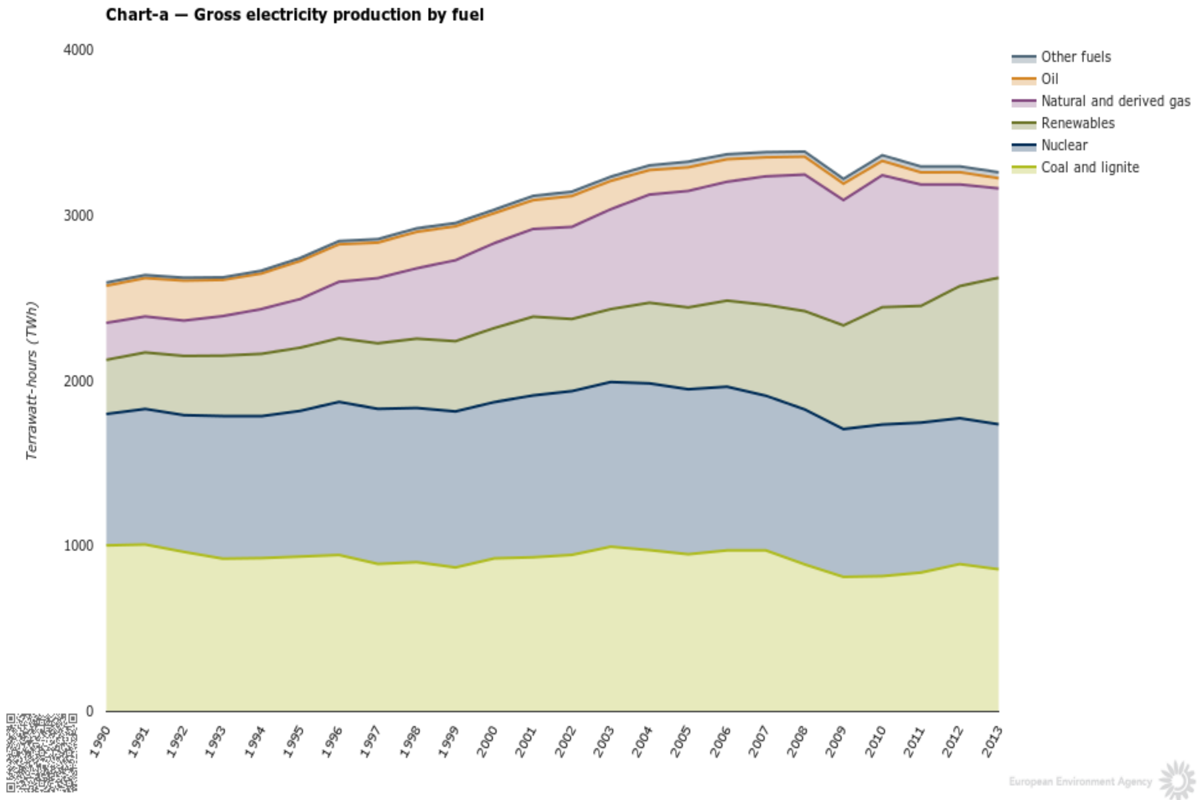

Figure 3. Gross electricity production by fuel, EU28. Copyright holder: European Environment Agency (EEA), from http://goo.gl/OBiv7n.

Regarding technologies, more than one quarter of the net electricity generated in the EU28 in 2013 came from nuclear power plants (26,8 %), while almost double this share (49,8 %) came from power stations using combustible fuels (such as natural gas, coal and oil). Among the renewable energy sources, the highest share of net electricity generation in 2013 was from hydropower plants (12,8 %), followed by wind turbines (7,5 %) and solar power (2,7 %).

However, note how the relative importance of renewable energy sources grew between 2003 and 2013 from 12,6 % to 23,2 %, while there was a relatively small decrease in the relative importance of combustible fuels from 56,4 % to 49,8 % and a larger reduction in the amount of electricity generated from nuclear power plants from 30,9 % to 26,8 %. Among the renewable energy sources, the proportion of net electricity generated from solar and wind increased greatly: from 0,01 % in 2003 to 2,7 % in 2013 for solar power and from 1.4 % in 2003 to 7,5 % in 2013 for wind turbines. Most of this increase can be attributed to Germany, Sweden, France, Spain and Italy with a respective share of 17,7%, 13,3%, 13,1%, 11,1% and 10,7% in the EU28 electricity production from renewable sources.

Finally, it is to highlight that still with these figures, an even greater effort and a more substantial growth will be required to meet the indicative EU28 targets for 2020. These, which are derived of the Directive 2001/77/EC will demand a 20 % share of renewable in final energy consumption by 2020.

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MODULE 1: RENEWABLE ENERGY AND LOCAL DEVELOPMENT

CHAPTER 2. The renewable energies panorama

Subchapter 2.2 - Renewable energy situation around Europe

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Summary: The bloom of new renewable technologies offered Europeans the opportunity to start the path towards a green and autonomous energy economy about fifteen years ago. Not all the countries answered in the same way and, although renewables are a reality with an important share in all their energy production mixes nowadays, every country presents a different degree of penetration. Also, important differences are identified among renewables.

Situation of the renewables around Europe

As it was introduced in the previous subchapter 2.1, the production from renewable energies around Europe keeps increasing year after year, (**¡Error! No se encuentra el origen de la referencia.**). This is stated in all the reports performed by official and international agencies such as the European Environmental Agency (EEA) or the Renewable Energy policy Network for the 21st Century (REN21). The trend is such that the share of renewable energy in the gross final energy consumption in the EU28 countries reached 15 % in 2013, representing 75 % of the EU's renewable energy target for 2020. These targets are settled in the Directive 2009/28/EC, of the European Parliament and of the Council, dated 23 April 2009. This European Renewable Energy Directive (RED) sets a binding global target of 20% final energy consumption from renewable sources, savings of 20% by improving energy efficiency, and an impact of RES in gross final energy consumption which reaches 20% by 2020 in the European Union. In addition, it sets the objective that renewable energy sources account for, at least, the 10% of the gross final consumption in the transport sector by 2020 in all the Member States.

To achieve these goals, each European country had to define a National Renewable Energy Action Plan (NREAP), which established their national renewable targets and defined the actions the country should take to meet the targets in 2020.

In the medium term, the target for the whole EU is an overall RES share in the final energy consumption of, at least, 27% for 2030. The agreement of the European Council [EUCO 169/14] provides that Member States may set more ambitious national targets, but always in accordance with the existing guidelines on state aids. After all, the Energy Roadmap 2050 defined by the European Commission in 2012 aims to increase between 55% and 75% the proportion of RES in gross final consumption of energy, and that one, along with energy efficiency, are considered critical in any model that could be adopted.

Therefore, according to these European strategies and upon data of Eurostat, renewable energy sources already contributed with the 17,7 % of gross final energy consumption for heating and cooling in 2014 (compared to 10,3 % in 2005 and 14,1 % in 2010), the 27,5 % of final electricity consumption (compared to 14,8 % in 2005 and 19,7 % in 2010), and the 6 % of transport fuels consumption.

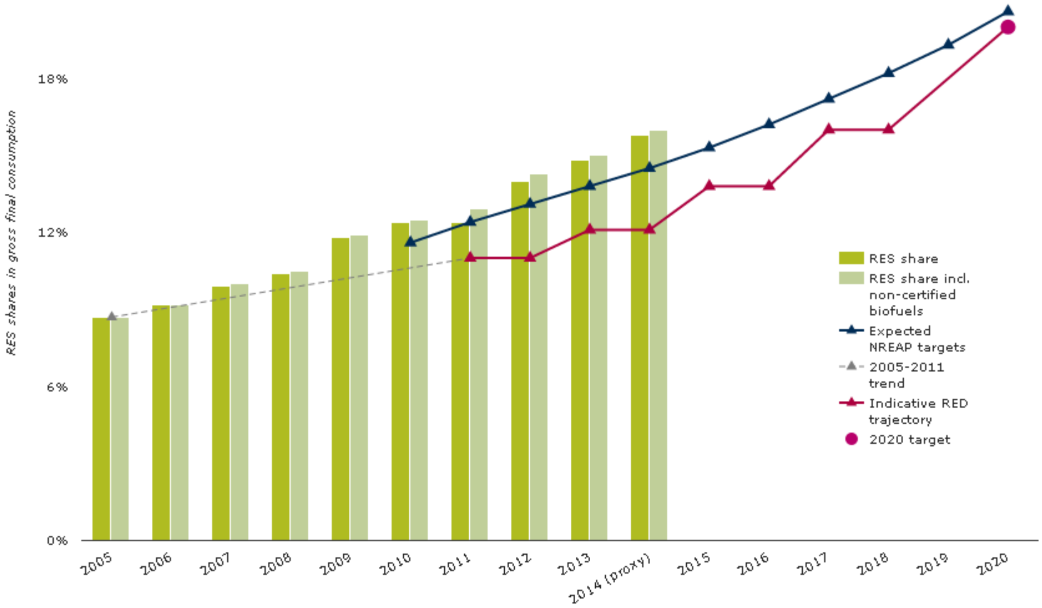

Figure 1. Progress of renewable energy sources in EU28, by European Environmental Agency (EEA) [CC BY 2.5], via permalink: f71323a27c864a9eb7019a8b067ceddb

¡Error! No se encuentra el origen de la referencia. shows EU-wide shares of renewable energy sources (RES) until 2013 (including options for all biofuels and only biofuels complying with the RED sustainability criteria) and two trajectories in the run-up to 2020: the indicative RED trajectory and the expected trajectory attending to the current NREAP being in force.

Therefore, it can be observed how the consumption of renewable energy has increased annually between 2005 and 2013 (with an average of 6,1 %). It is also worth noting that gross final energy consumption decreased, on average, by 0,9 % per year between 2005 and 2013, (including by 1,6 % per year from 2010 to 2013). This decrement is due to both the economic crisis and the reduction of industrial activity, but also to the energy efficiency initiatives taken in the last years around the continent.

When analysing the different countries (Figure 2), 25 Member States (i.e. all except Luxembourg, the Netherlands and the United Kingdom) already met or exceeded their indicative targets set under the RED, while 21 Member States (i.e. all except Denmark, France, Ireland, Luxembourg, the Netherlands, Portugal and Spain) exceeded the indicative trajectories set in their NREAPs. Also in 2013, Bulgaria, Estonia and Sweden managed to reach their binding renewable energy share targets for 2020 set under the RED. Then, there is a large variation in renewable electricity production among the Member States: from less than 6 % in Luxembourg and Malta, to 68,1 % and 61,8% in Austria and Sweden, respectively. This reflects, among other things, different starting points in the deployment of renewables in each country, differences in the physical capacity to produce renewable energy and, to a lesser extent, differences in policies to stimulate renewables.

At this point, it is important to highlight, for the interest it has within the scope of this course, the situation of Spain. Although figures are not bad for this country in Figure 2, the present situation has paralyzed the renewables sector since 2012 due to the legislative intervention of the last government, which is putting its NREAP's objectives at risk. In fact, the EU has already alerted Spanish authorities about the non-compliance implications and penalties.

On a separate issue, out of that 15 % penetration achieved on average around the EU28 in 2013, the weight of renewables in the three main EU28 energy consumption sectors was quite diverse (Figure 3). In summary, renewable electricity accounted for 41 % of the gross final renewable energy consumption in the EU28 (which represented 25,4 % in 2013 and around 27,7% in 2014 of the total electricity generation). Renewable energy for heating and cooling accounted for 52 % of gross final renewable energy use (which represents the 16,5 % in 2013 and the 17,7% in 2014 of the gross final energy consumption in this sector). Finally, renewable energy in transport accounted for 9 % of the gross final renewable energy consumption (which represents the cited 5,4% of the transport fuels consumption sector in 2013 and already 6% in 2014).

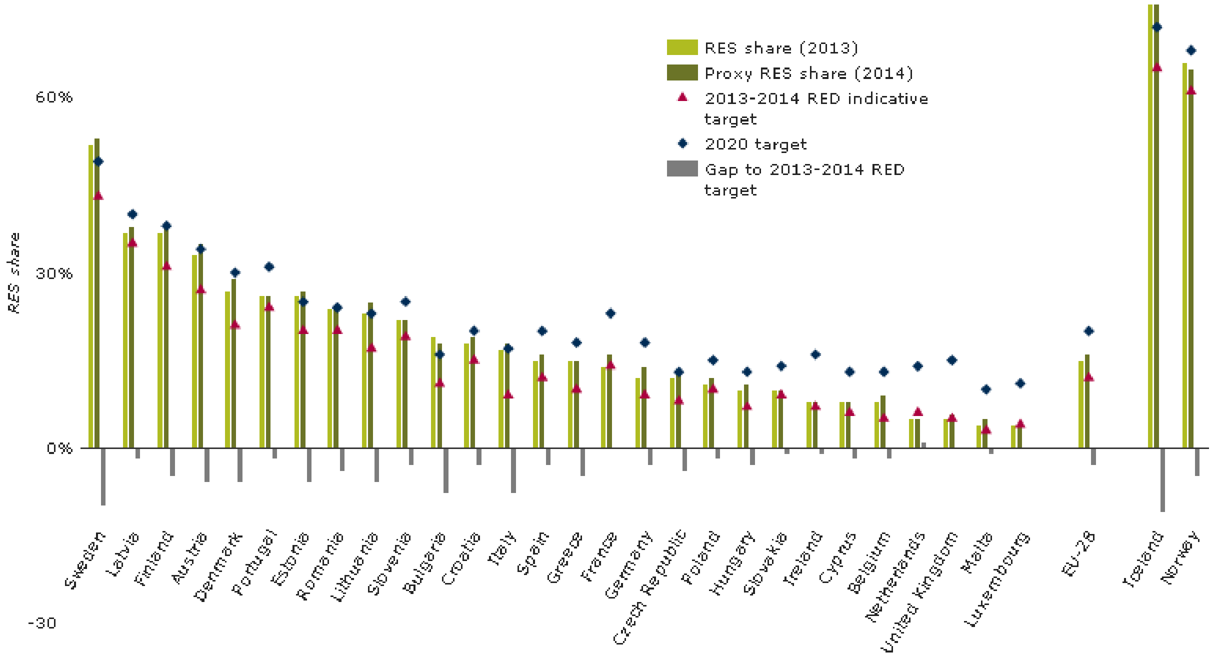

Figure 2. Progress in renewable energy sources by country, by EEA [CC BY 2.5], via permalink: f71323a27c864a9eb7019a8b067ceddb

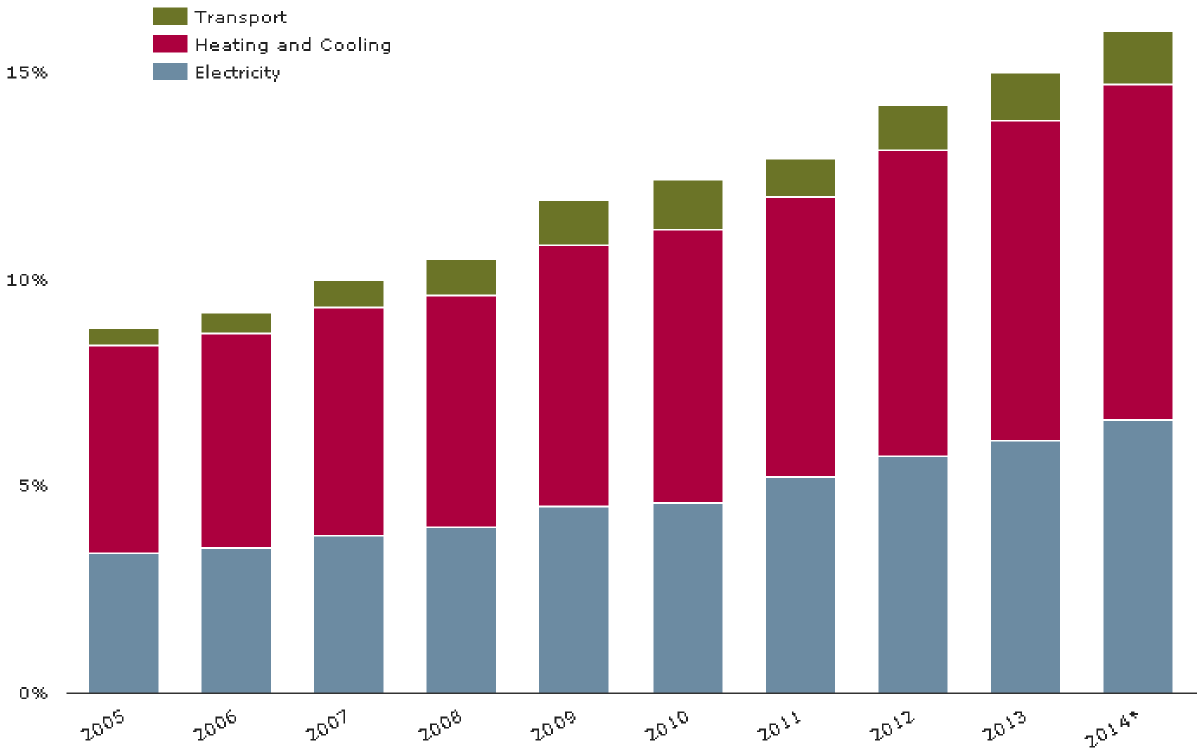

Figure 3. Share of renewable energy in gross final energy consumption in EU28, by EEA [CC BY 2.5], via permalink: f71323a27c864a9eb7019a8b067ceddb

And regarding the renewables 25,4 % participation in the cited gross electricity consumption in 2013, the share of the different technologies was patently uneven (**¡Error! No se encuentra el origen de la referencia.**). This can be detailed as follows:

- Hydropower accounted for the largest share of renewable electricity in EU28, representing 42 % of total renewable electricity production. The relative importance of hydropower has been decreasing substantially since 2005, however, when it still generated 70 % of renewable electricity, due to the fact that wind and solar energy have been rapidly developing over this period.
- Wind already accounted for 27 % of renewable electricity in 2013, compared to 14 % in 2005.
- Solar energy accounted for 10 % of it in 2013, compared to 0,3 % in 2005.
- Solid biofuels also accounted for 10 % of it in 2013, compared to 9 % in 2005.
- All other renewables accounted for 10 % of it in 2013, compared to 7 % in 2005.

Conversely, what forms the 16,5 % of the total final energy consumption for heating and cooling in the EU28 in 2013 coming from renewables? This percentage is clearly disaggregated in the “Energy from renewable sources” report from Eurostat, and it can be mainly broken into the following points:

- Renewable heat production from large biomass combined heat and power (CHP), and heat plants connected to heat-distribution networks accounted for 13,5 %.
- Renewable heating and cooling from heat pumps represented 8 % of total renewable energy for heating and cooling.

- The main producers of biomass-derived heat through CHP and heat plants are Sweden (24 %), Finland (15 %), Denmark (12 %), Germany (12 %) and Austria (8 %), which together accounted for 70 % of the total biomass use for heat production in CHP and heat plants within the EU28 in 2013.

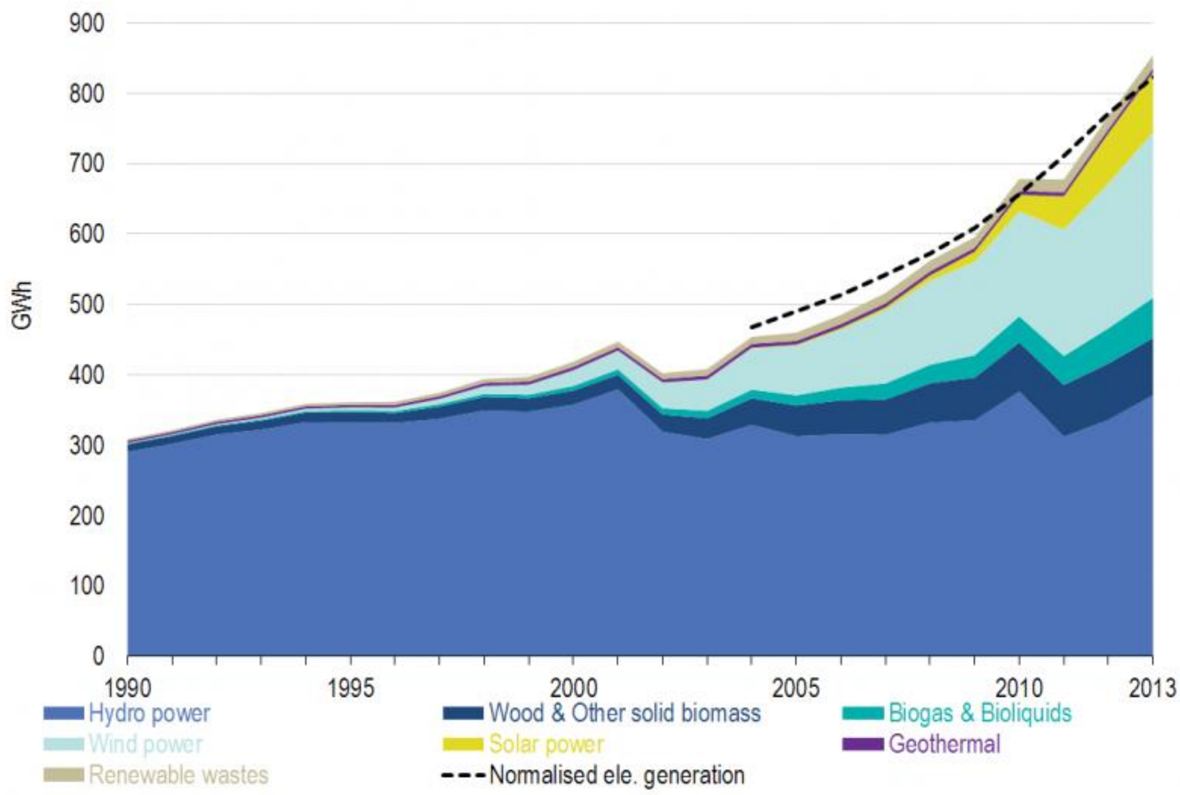

Figure 4. Gross electricity generation from renewable sources, EU28, 1990-2013, by Eurostats, via http://goo.gl/5VFyIi

In conclusion, it can be withdrawn from the figures enumerated in this subchapter that although the degree of penetration of renewables in the different EU28 State Members is not homogeneous, and neither is the type of renewables implemented on each of them, the panorama has changed and renewables are a reality in Europe nowadays. This situation, together with the widespread environmental consciousness of the European citizens and politics will favour a further development of renewables. This scenario poses renewable energies in a good position to experience a significant development around Europe in the coming years and even decades. There is no doubt that European Directives and Global Environment Forums are on this way. The future must be green or will not be.

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MODULE 1: RENEWABLE ENERGY AND LOCAL DEVELOPMENT

CHAPTER 2. The renewable energies panorama

Subchapter 2.3 - Influence of the regulatory framework on the current panorama

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Summary: As described in the previous subchapter, the evolution of the renewable energies' penetration across the length and breadth of Europe is very diverse. It goes without saying that the current panorama is a direct consequence of the regulatory framework that the different countries experienced towards renewables during the last fifteen years. Also in this sense, clear differences can be encountered among large and small installations.

Introduction

Policy measures to support renewables have had a demonstrated impact on its development in different jurisdictions around the world. A wide range of policy mechanisms to support renewable energies, have been used by different jurisdictions over the recent decades. Among them, four general energy support policy mechanisms have dominated the main international markets. These are:

- Tender Schemes: its theoretical basis is highly promising. Governments can set a target of installed capacity or total public expenditure, and invite prospective project developers to submit project tenders that specify the government support (capital $ or $/MWh) required to proceed. Governments can then choose the lowest cost project providers.
- Feed-in Tariffs: these schemes adopted by Denmark, Germany, and Spain have without doubt been the primary drivers of their significant renewable energy deployment over the last two decades. Initial policy settings in these three countries, announced in the 1990s, were similar and relatively simple schemes with a single tariff for all renewable producers. These feed-in tariffs (FIT) schemes provided an electricity consumer funded fixed price for each MWh of generation over a given time period. Any project meeting the scheme requirements was eligible for this payment. As renewable penetration started to rise, however, these policies have been significantly amended. Each country has followed different strategies.
- Quota System/Tradable Certificates: as quota system, this is usually related with tradable renewable energy certificates (or credits) and has different names depending on the country. In the UK, for example, the scheme that came into force in 2002 is known as Renewables Obligation (RO). Renewable generators received a Renewable Obligation Certificate (ROC) for each MWh of electricity generated. The ROCs are sold to electricity suppliers in order to fulfil a mandated obligation placed upon them

by the government according to its national renewable energy quota or target. Suppliers can either present enough ROCs to cover their obligations or they can pay for any shortfall into a buyout fund.

- Tax Credits: it is the system applied in the USA. There, a Federal production tax credit (PTC) system for renewables was launched several years ago. Taxpayers eligible for the PTC are allowed to take a business energy investment tax credit (ITC) equal to 30% of the construction costs for the installation or to receive a cash grant of equivalent value if the construction began by the end of 2011. That is a reduction in their taxes for investments in renewables.

Experience to date suggests that FIT policies have been the most successful approach in rapidly expanding renewable generation capacity, as demonstrated in countries such as the cited Denmark, Germany and Spain. This approach, however, may cause increasing integration challenges for the electricity industry as renewable penetrations continue to rise.

This is because the value of electricity within a power system varies over time by location, and it is subject to uncertainties reflecting, in aggregate, the changing costs and benefits of all generations and end-users. It is important to note at this point that there have been worldwide movements over the last two decades to restructure electricity industries so that generators and end-users see price signals that more appropriately reflect these underlying industry economics. In their simplest form, FIT schemes can effectively shield renewable project developers from such energy market signals through a fixed payment for each MWh of renewable generation independent of the value it actually provides for the industry at that time and location within the network. Note also that simplified tendering processes awarded to projects on the basis of lowest required government payments per MWh of renewable generation, which were adopted in countries such as Ireland and China, can have similar impacts. Other policy approaches such as renewable electricity production tax credits, as seen in the USA, and tradable green certificates as seen in a number of European countries and Australia, provide another approach for supporting renewables. By comparison, these can ensure that renewable installation developers and operators are still incentivized by electricity market "signals" to maximize overall industry value.

During the last few years there have been important developments in a number of countries that can help us better understand these issues. For example, Denmark and Spain have moved from a conventional FIT to a tariff premium above the electricity market price, the latter with additional arrangements that cap potential incomes to renewable producers. The UK RO scheme now appears to be driving greater industry development, especially in offshore wind projects. The USA Federal production tax credits and state-based renewable portfolio standards have also driven very significant, although sometimes boom–bust renewable uptake, particularly in Texas with a quarter of the USA's wind power installed capacity.

Therefore, although the influence over the development of renewables of the legislated policies regarding them is not under discussion, it is still not clear what the best policy is. In fact, it could be concluded from the discussion just introduced that there is not an optimal regulatory framework and that the best alternative will always depend on different factors such as the state-of-the-art of the technology, the countries' market configuration, and the degree of penetration of the renewables already achieved.

Regulatory influence on the current panorama – case of Spain

As already described, Spain has traditionally worked with a feed-in tariff structure and it is a paradigmatic case when analysing the effect of the regulatory framework on the ease of development for a sector such as the renewable sources industry. This influence is even more significant with regard to the evolution of the photovoltaic sector in this country.
The Spanish legislation on renewable energy has changed several times over the last 20 years and this has clearly modelled the development of the market. Taking the example of photovoltaics, this sector has been subjected to numerous legislative changes. Among them, one can highlight the following:

- Law 54/1997 which liberates the electricity sector from the previous public monopole situation.
- Royal Decree 436/2004 (dated 12 March 2004) that regulated renewables incentives for the first time.
- Royal Decree 661/2007 (dated 25 May 2007) that modified renewables incentives for the first time, announcing a reduction in September.
- Royal Decree 1578/2008 (dated 26 September 2008) that reduced feed-in tariffs for renewables to a more adjusted or reasonable level (according to the state-of-the-art of the PV technology).
- Royal Decree 1565/2010, (November) that limits the feed-in remunerated years to 25.
- Royal Decree Law 14/2010 (December) that limited the annual operating hours for all photovoltaic facilities, making it impossible to sell electric power to the electric power system when this limit was exceeded.
- Law 2/2011 (dated March 4, 2011) that introduced new taxes on all the electricity producers, including renewable generators.
- Royal Decree-Law 1/2012 (dated 27 January 2012) that cancelled all the feed-in tariffs for any newly installed renewable project.
- Royal Decree 900/2015 (dated 9 October, 2015) by which the government regulated the administrative and technical conditions, as well as the financial modalities of power supply with self-consumption and self-production with self-consumption. According to GreenTechMedia, Energy Storage Reports, and other international analysts on energy topics, this law has been classified as one of the strictest laws regarding self-consumption worldwide. Therefore, it is considered a law that regulates the industry but it does not boost it at all, quite the contrary.

As it can be observed in Figure 1, these laws favoured the big evolution of the sector in Spain in the beginning while providing a proper financial frame, but the changes and the continuous support cuts succeeded in freezing the sector, which is nowadays far away from the goals settled in the National Renewable Energy Action Plan (NREAP) for 2011-2020. This aims to reach 7250 MW of PV installed capacity by 2020.

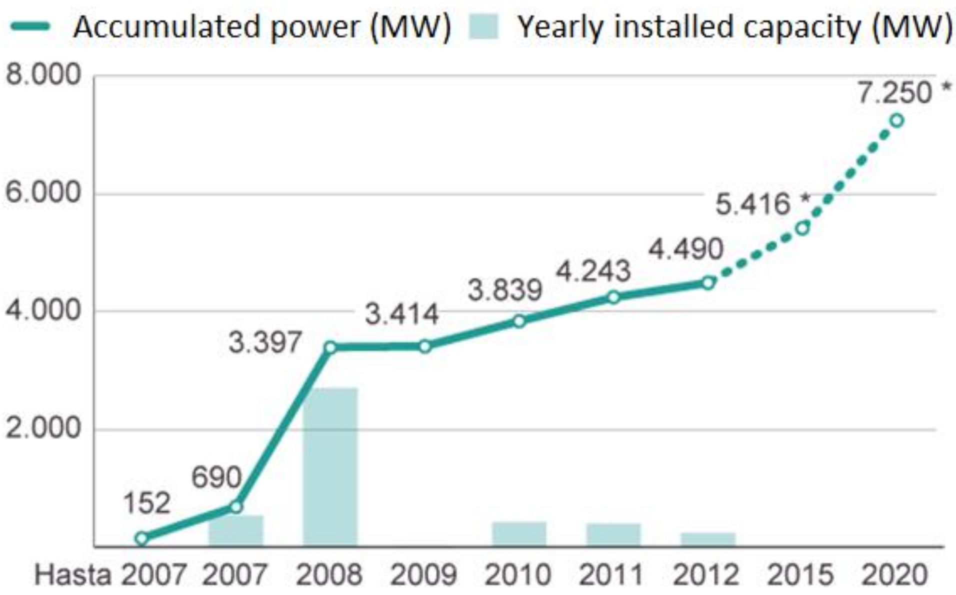

Figure 1. PV goals defined at the National Renewable Energy Action Plan (NREAP). Source: Spanish Ministry of Industry.

Reality is that, due to the current regulatory framework, only 22 MW of photovoltaic capacity were added in 2014, and around 45 MW are estimated for 2015 (balance to be performed). Therefore, far away from the planned 5416 MW in January 2016, Spain counts with scarcely 4700 MW at this moment (Figure 2). Moreover, current perspectives do not stimulate new investments and NREAP seem further and further as time goes by.

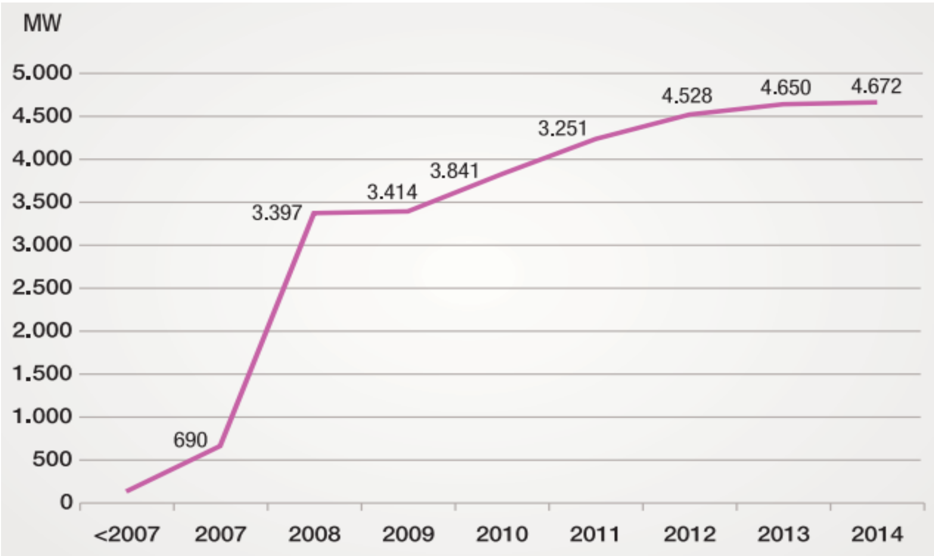

Figure 2. Current registered Spanish PV capacity evolution. Sources: UNEF and CNMC.

And a similar regulatory situation, to that of the PV technology, is being more or less experienced by other renewable technologies in Spain. Note the evolution of wind power in Figure 3. This was hardly frozen from 2011 to 2013 and keeps being so. Indeed, recent publications have confirmed that 2015 was the first in the last 15 years in which no megawatts of wind power capacity were added to the system.

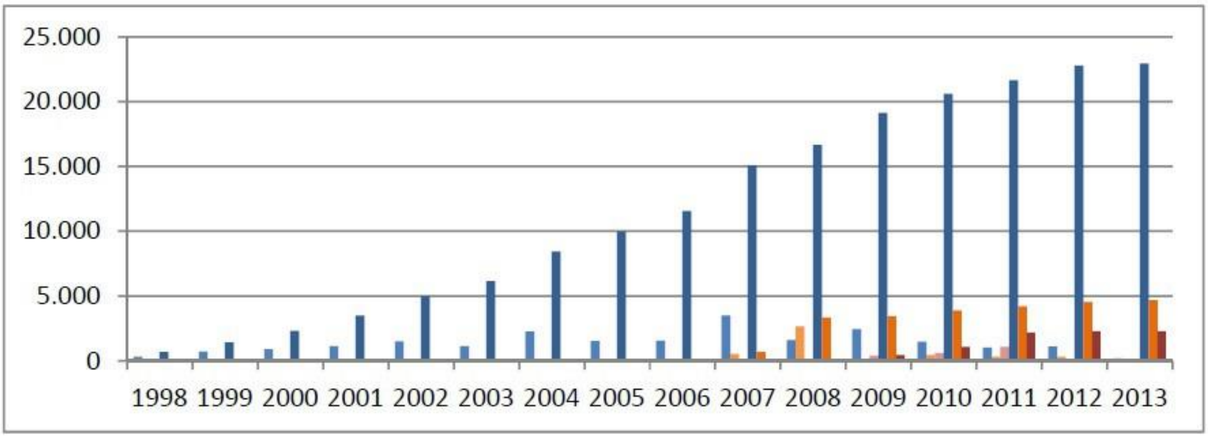

Figure 3. Renewable power installed in Spain (in MWs). Wind (blue bars), solar PV (orange bars), solar thermal (bars burgundy); yearly installed power (light colored bars) and cumulative capacity (bars on dark colors), by Frans Bakker at http://goo.gl/OZ6P0u

These have been difficult times for large power renewables in Spain. Only a new change in the regulatory framework or an unexpected boom of small self-consumption installations could modify these trends. And we say unexpected due to the already cited Royal Decree 900/2015. Maybe the development of isolated installations using PV, small wind turbines, or/and biomass generation, working as microgrids, and their future interconnection, is the way for the coming future in countries such as Spain.

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MODULE 1: RENEWABLE ENERGY AND LOCAL DEVELOPMENT

CHAPTER 3. The renewable energies technology

Subchapter 3.1 - Basic technological introduction to the renewable systems

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Summary: The previously described different renewable sources require the corresponding differentiated technologies in order to adapt and transform the primary energy into electricity or heat. These technologies vary largely not only with the source of energy to be profited but also with the size or energetic requirements of the installation. An overview of technologies seems compulsory before addressing the design of installations to be done in the coming modules of the course.

Introduction

Among the different renewable energy resources profitable nowadays, the present course only focuses on three of them: sun, wind, and biomass. The present subchapter summarizes the different technologies that can be found in a commercial state of development to transform these primary energy resources into some type of useful energy as heat or electricity.

Solar Technology

It has already been discussed in previous subchapters that the industry of the solar power is mature and very well developed. In fact, it already represents an important portion of the energy production mix in different countries around the world. But, when we talk about solar power, it is not only about one single technology but about a group of them. And they differ quite a lot from each other.

The first big division can be done among technologies devoted to heat up water and those devoted to generate electricity.

Within the first group, the technology that can be highlighted is the Solar water heating (SWH) that uses solar thermal collector to convert the sunlight into an increment of temperature of the circulating water. Solar thermal installations fall into two groups: passive (sometimes called "compact") and active (sometimes called "pumped") systems. The main difference among them is that, in a compact SWH systems, the storage water tank is horizontally mounted immediately above the solar collectors (Figure 1, right). In this way, no pumping is required as the hot water naturally rises into the tank through thermosiphon flow. Conversely, in a "pumped or pumped-circulated" system, the storage tank is located on the ground or floor-mounted and is below the level of the collectors (Figure 1, left). In these installations, it is an electric pump that moves the water or heat transfer fluid between the tank and the collectors. While perhaps these are quite well known in a residential setting to provide domestic hot water, solar hot water also has industrial applications. And this is a very promising and, we could affirm, certainly consolidated technology in the rural environment with a great potential to be deployed in the coming years all around.

Figure 1. Solar water heating installations, by Alanmak~commonswiki, licensed under CC-BY-SA-3.0, and by KVDP [Public domain], respectively, via Wikimedia Commons,

Among the latter technologies, those designed to generate electricity, there are also different technologies that can be, in turn, split into those based on concentrating the sunlight and those that do not concentrate it. These characteristics and differences are described in the followings.

Concentrated solar power

This technology (also called concentrating solar power, concentrated solar thermal, or CSP) generates solar power by using mirrors or lenses to concentrate a large area of sunlight, or solar thermal energy, onto a small area. Electricity is generated when the concentrated light is converted to heat, which drives a heat engine (usually a steam turbine) connected to an electrical power generator or powers a thermochemical reaction.
Concentrating technologies mainly exist in four common forms: solar power tower (Figure 2), parabolic troughs (Figure 3), dish Stirlings (Figure 4), and concentrating linear Fresnel reflectors. It can be observed in the pictures that although all of them perform some kind of sunlight concentration, their operation modes are completely different.

Figure 2. "Ivanpah Solar Power Facility from the air 2014" by Craig Butz. Licensed under CC BY-SA 4.0 via Commons - https://goo.gl/fB7hky

Figure 3. Part of the 354 MW SEGS solar complex in northern San Bernardino County (California), via Wikimedia Commons.

A solar power tower consists of an array of dual-axis tracking reflectors (heliostats) that concentrate sunlight on a central receiver atop a tower; the receiver contains a fluid deposit, normally water or molten salts. The working fluid in the receiver is heated to 500–1000 °C and then used as a heat source for a power generation or energy storage system. An advantage of the solar tower is the reflectors can be adjusted instead of the whole tower. On the contrary, a parabolic trough consists of a linear parabolic reflector working as a sun receiver that concentrates light onto a receiver positioned along the reflector's focal line. The receiver is a tube positioned directly above the middle of the parabolic mirror and filled with a working fluid (industrial oil or molten salts). The reflector follows the sun during the daylight hours by tracking along a single axis (north-south). The working fluid is heated to 150–350 °C as it flows through the receiver and is then used as a heat source for a power generation system. Trough systems are the most developed CSP technology. By comparison, power-tower development is less advanced than trough systems, but they offer higher efficiency and better energy storage capability.

Figure 4. A dish Stirling, via Wikimedia Commons.

A dish Stirling or dish engine system consists of a stand-alone parabolic reflector that concentrates light onto a receiver positioned at the reflector's focal point. The reflector tracks the Sun along two axes. The working fluid in the receiver is heated to 250–700 °C and then used by a Stirling engine to generate power. Parabolic-dish systems provide high solar-to-electric efficiency (between 31% and 32%), and their modular nature provides scalability.

Finally, Fresnel reflectors still englobe different technological proposes whose description falls beyond the scope of this course because most of the proposals are still in a research state with only a few prototypes worldwide. These include technologies from concentrating sunlight onto tubes through which working fluid is pumped, to concentrating sunlight 300 or 500 times onto silicon based cells (concentrating solar photovoltaics, CPV). The latter is a promising technology due to the cost reduction experienced thanks to the minimum crystalline silicon they require, substituting it by very cheap concentrating mirrors. Moreover, the silicon dice is forced to operate at extreme insolation conditions, where silicon presents very good efficiencies.

CSP technology is being widely commercialized and the CSP market evolved in about 740 megawatt (MW) of generating capacity added between 2007 and the end of 2010, according to Wikipedia. More than half of this (about 478 MW) was installed in 2010 itself, bringing the global total that year to 1095 MW. Spain added 400 MW in 2010, taking the global lead with a total of 632 MW at that moment, while the US ended the year with 509 MW after adding 78 MW, including two fossil–CSP hybrid plants. The Middle East has been also ramping up their plans to install CSP based projects and, as a part of their global Energy Plan, they developed the Shams-I power plant which was the largest CSP Project in the world in Abu Dhabi in 2013 (by Masdar). But the CSP growth continues at a fast pace. As of January 2014, Spain

had a total capacity of 2,300 MW consolidating this country as the world leader in CSP. Interest is also notable in North Africa and the Middle East, as well as India and China.
However, the largest CSP project in the world until January 2016 is Noor in Morocco. This plant could be considered as the first stone for the ambitious and interesting Desertec Project that is being boosted by the Sahel and the north-African countries.
Finally, note that the global market has been dominated by parabolic-trough plants, which account for 90% of CSP plants. The second technology is solar power tower which also accounts for a significant number of installations, although these present lower power capacity ratings. Installations with Dish Stirling or Fresnel Lenses can still be considered residual nowadays.

Photovoltaic technologies

The photovoltaic technology can be considered as the milestone of the solar industry. It was the first technology that made economically possible to take profit of the sunlight in a commercial way. It is well proven nowadays, as photovoltaic systems have now been used for fifty years in specialized applications, and grid-connected PV systems have been in use for over twenty years.

Basically, photovoltaic system employs solar panels composed of a number of solar cells of different semiconductor materials that exhibit the photovoltaic effect and, therefore, transform sunlight into direct current electricity. This transformation process is both physical and chemical, as in a first step it involves the photoelectric effect from which a second electrochemical process takes place involving crystallized atoms being ionized in a series, generating an electric current.

Within the photovoltaic industry, there are various technologies which are principally defined by the type of semiconductor material used in the solar panels. The options include nowadays: monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium gallium selenide/sulphide. The different materials produce the corresponding differences in efficiency among solar panels. The records in solar cell efficiency are annually published by the National Renewable Energy Lab (Boulder, Colorado, USA) (Figure 5).

It can be observed how efficiencies diverge among technologies. But note that the represented values are only lab demonstration while the commercial efficiencies are well below this. A more significant comparison of commercial efficiencies is summarized in Figure 6.

However, Figure 5 is also useful to introduce the different PV technologies that are being developed and, more or less, commercialized. These are: the excellent but expensive multi-junction cells (used in satellites), the also good and expensive Single-Junction GaAs cells, the commercially well-known Crystalline Silicon Cells (for solar PV grid connected and isolated applications), The Thin-Film technologies (for the same applications), and some emerging technologies being very well developed lately. The physical and electric differences among the different panels of these technologies are beyond the scope of this chapter.

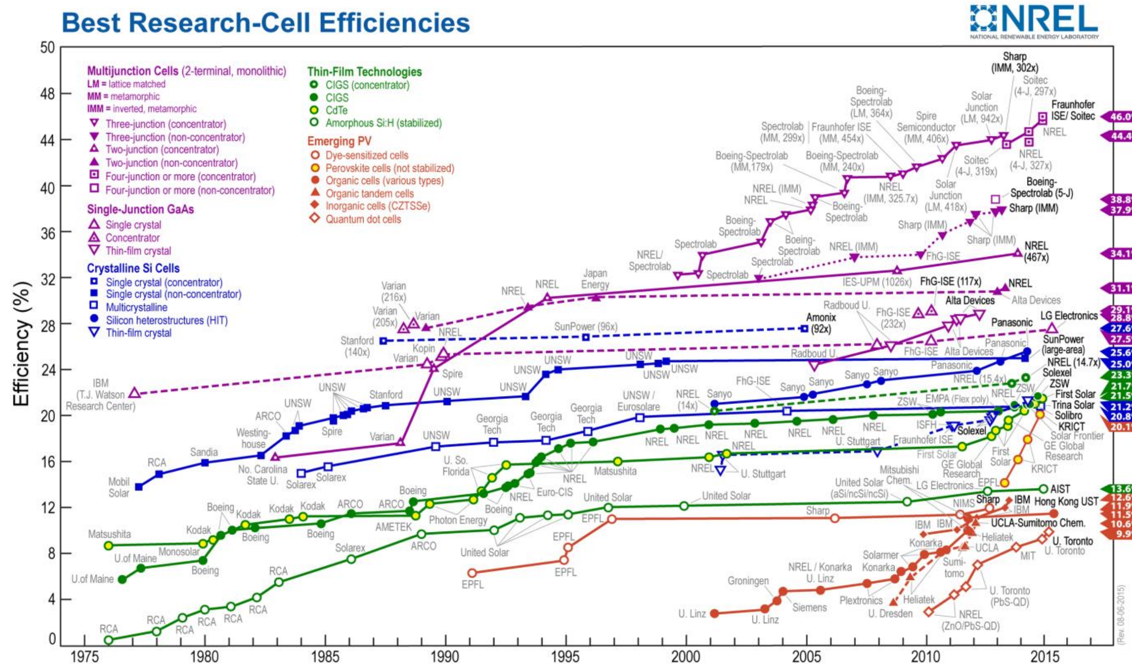

Figure 5. Reported records of solar cell efficiency since 1975. Source: National Renewable Energy Laboratory (NREL).

CELL MATERIAL	MODULE EFFICIENCY	SURFACE AREA NEED FOR 1 KWP
Monocrystalline silicon	13–19%	5–8 m²
Polycrystalline silicon	11–15%	7–9 m²
Micromorphous tandem cell (a-Si/μc-Si)	8–10%	10–12 m²
Thin-film copper-indium-diselenide (CIS)	10–12%	8–10 m²
Thin-film cadmium telluride (CdTe)	9–11%	9–11 m²
Amorphous silicon (a-Si)	5–8%	13–20 m²

Figure 6. Efficiency comparison for the different Silicon-based technologies. Source: Institute of Energy Technology (IET) of the Aalborg University (AaU), Denmark.

Coming back to Figure 6, this also provides an idea on the amount of surface will be required to generate a 1 kW of power. This value is directly related to the efficiency of the panels and is very used for initial estimations of the power that can be extracted at a given location.

Although solar PV installations are typically recognized by the outlook of the PV solar panels (Figure 7), these are much more than this. Apart from the connection wiring and the protections, if panels are the “heart” of these installations, the “brain” would be the inverters. These power converters are those elements in charge of converting the direct current generated by the panels into alternating current that, under certain quality conditions, can be injected into the electric power system, or consumed by local loads (which do not normally

operate with dc and also require the conversion). As it will be described in future chapters, there are different types of inverters depending on their required functionalities and power ratings. They will normally operate to inject as much active power as possible into the network but, under certain circumstances, there are inverters that could even isolate the solar PV plant together with some local loads from the network generating a so-called microgrid.
Finally, note that for isolated installations, other elements such as batteries and charge regulators (which control the batteries state and the flows of energy) will be required.

Figure 7. Nellis Solar Power Plant, by U.S. Air Force photo/Airman 1st Class Nadine Y. Barclay, via Wikimedia Commons

Wind Technology

According to the “Joint Research Center” Wind Status Report for 2014, the type of wind turbine mainly used nowadays comes from the 1980s when the Danish three-bladed, single fixed speed, stall-regulated turbine became the dominant model in the market at rated power levels of less than 200 kW. Since then, turbine dimensions, both in terms of generator capacity and of rotor diameter, have grown steadily. Currently 2–3 MW / 97–117 m rotor diameter wind turbines are commonly installed in onshore projects and 3–8 MW / 112–164 m rotor diameter in offshore wind farms (Figure 8).

Figure 8. Offshore wind farm, using 5 MW turbines, at Thornton Bank. © Hans Hillewaert, via Wikimedia Commons.

As it can be observed in Figure 9, the main components included in the nacelle and the technological characteristics of a typical wind turbine are:

- A steel, concrete or hybrid tower, reaching up to 150 m in height.
- An upwind rotor with three blades, active yaw system, preserving alignment with the wind direction. The rotor efficiency, its acoustic noise, its costs and the visual impact are the most important design factors being updated and improved in this part of the turbine year after year.
- High-wind-speed control. The pitch regulation system, an active control where the blades are pitched along their axis (flapwise) to regulate the extracted power and reduce loads.
- A variable rotor speed. This was introduced to allow the rotor and wind speed to be matched more efficiently in particular at lower wind speeds, to reduce mechanical loads and to facilitate an output more in agreement with the needs of the electricity grid at which the wind turbine gets connected.
- A drive train system. It is the group of elements that can be observed in the figure (gearbox + generator) that are in charge of the transformation of mechanical energy into electricity.

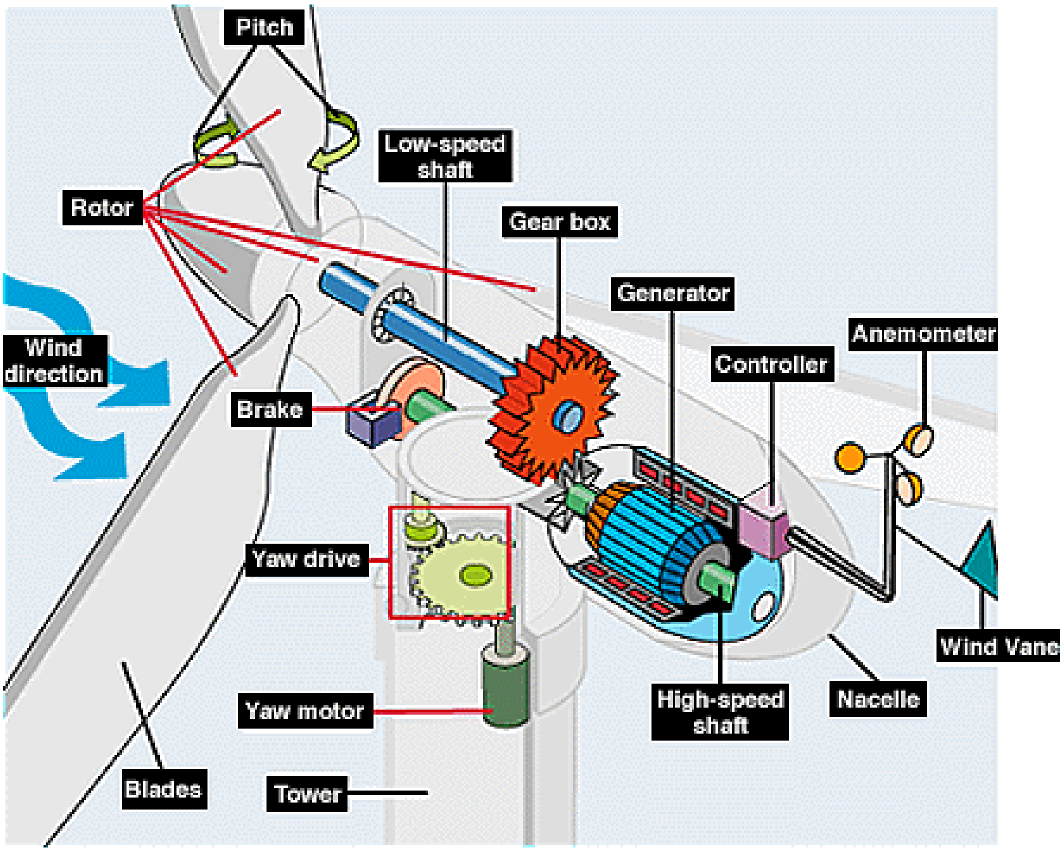

Figure 9. Components of a horizontal-axis wind turbine, by Office of Energy Efficiency and Renewable Energy, via Wikimedia Commons.

Most of the commercial models provided by the different manufacturers present all the cited elements. And the main difference among the various wind turbine proposals lies in the type of drive train configuration they present. Three main configurations are currently adopted:

- A fast-rotating electric generator (normally a doubly-fed asynchronous generator) with a gearbox to adapt the slow-rotating rotor to the higher rotational speed of the electric generator. Manufacturers such as VESTAS, GE Wind or GAMESA use this configuration.
- A low-speed generator directly coupled to the turbine rotor (i.e. without a gearbox). Manufacturers such as ENERCON, GoldWin, or Liberty use this configuration
- A medium-speed generator with a gearbox using a Wound-Rotor Induction Generator. Manufacturers such as SUZLON or Siemens use this configuration.

The main wind turbine design driving goal is nowadays to reduce the “levelized costs of the energy” (LCOE) through lower capital and operating costs, increased reliability and higher energy production, which translate into: specific designs for low and high wind sites, grid compatibility; low noise, good aerodynamic performance and redundancy of systems in offshore machines.

In opposition to these large commercial wind turbines, small wind turbines are used for microgeneration for local applications with not very large power requirements. These turbines may be as small as a fifty-Watt generator for very small applications (boats, caravans…) or can present up till 10 kW, or even more. In fact, IEC 61400-2 standard establishes as small

wind turbines all those sweeping an area smaller than 200 m^2. This corresponds to equipment with a diameter of 16 m and a potential capacity of around 50 kW.
The structure of these small wind turbines is much simpler than that of their larger brothers. These basically present:

- A rotor: consisting of different blades (from 2 to up to 10, although normally 3), and this also presents a wind energy capture system which can be passive (the wind itself with its force defines the position of the rotor) or active (electronically controlled).
- A tail: in charge of guiding the small wind turbine according to the wind direction at all times.
- A generator: usually implementing a permanent magnet synchronous machine or even a dc generator. It converts the mechanical energy into electricity.
- The tower: normally using some type of tubular steel bar.


Figure 10. Small wind turbines, by Anders Sandberg from Oxford, UK (Vertical axis wind turbine) [CC BY 2.0], and by Nenad Kajić / Veneko.hr [CC BY-SA 4.0], respectively, via Wikimedia Commons.

Commercial models of this technology for domestic installations, informatics & telecommunication installations, industrial plants, or commercial environments, as well as for grid connection are being more and more developed. One can find models with vertical and horizontal axis (Figure 10). However, although vertical axis models may seem more futuristic and modern (for building integration), the horizontal axis ones are leading the market to their clearly higher efficiency and lower price (for any practical integration where outlook is not so important as economic viability and energy efficiency).

Note some models such as EcoBlade, from Schneider Electric, which consists of blades the size of a 30-inch flat screen, weighing less than 25 kg, and contains a smart connected battery module ready to be used in standalone applications. Different models for various power ratings can be found on the catalogues from manufacturers such as: Zytech Group (http://www.zytechgroup.com/), Bornay (www.bornay.com), Enair (http://www.enair.es)…
As for the case of the small PV installations design for off-grid installations or for small grid-connected applications, small wind turbine installations will usually include some kind of

energy storage. Moreover, these installations will also count with a battery charger regulator, potentially a power inverter and, from time to time depending on the requirements, with an auxiliary diesel generator.

It seems clear that, for the scope of the present course, small wind turbines will offer much more opportunities than big commercial wind generators. This is due to the power ratings each technology offers, being the big wind turbines industry focused on the large production directly connected to the high voltage transport grid. Thus, it would not be common to design a large 5 MW generator to power a local application in stand-alone mode. Although the distributed generation paradigm should lead us in this direction, this level of power is still to be connected at the grid all the time.

Biomass Technology

Finally, the third technology to be briefly analysed in this subchapter is that used for producing energy from biomass. As it can be derived from the significant variety or sources of energy classified as biomass, introduced in the previous chapters (mainly biomass to be used directly via combustion to produce heat; or indirectly to produce heat or electricity after converting it to different forms of biofuel or biogas), there are many different ways and technologies for using biomass to produce energy. The form and properties of the biomass, together with the needs of the user, will determine which are the most appropriate
Thereby, the biomass conversion process to useful energy can be performed in four different ways that are:

- Thermal conversion processes. These use heat as the dominant mechanism to convert biomass into another chemical form. The basic alternatives of combustion (torrefaction, pyrolysis, and gasification) are separated principally by the extent to which the chemical reactions involved are allowed to proceed (mainly controlled by the availability of oxygen and conversion temperature). Some of the applications of thermal conversion are “combined heat and power” (CHP) and co-firing. In a typical dedicated biomass power plant, efficiencies range from 20–27%. Biomass co-firing with coal, by contrast, typically occurs at efficiencies near those of coal combustion (30–40%)
- Chemical conversion processes. These may be used to convert biomass into other products such as a fuel that is more conveniently used, transported or stored, or to exploit some property of the process itself. Many of these processes are similar to coal-based processes, such as Fischer-Tropsch synthesis, methanol production, olefins (ethylene and propylene), and most of the times imply an initial gasification. Others such as transesterification facilitate the production of biodiesel.
- Biochemical conversion processes. These are based on the use of certain enzymes of bacteria and other microorganisms to break down biomass. Typical processes in this sense are anaerobic digestion, fermentation, and composting. Biogas, landfill gas and compost are produced with them, respectively.
- Electrochemical conversion processes. In addition to combustion, biomass or biofuels can be directly converted into electrical energy via electrochemical oxidation of the material in a fuel cell. This is not a very typical process nowadays but it is being researched and presents positive expectations.

According to these transformation processes, biomass technologies can be classified into two main groups. These are:

- Anaerobic digesters: when the type of biomass to be used presents high moisture content, it is not very well suited for combustion, but may be appropriate for anaerobic digestion (Figure 11). This biological process produces: a solid residue (fibre or digestate) that is similar, but not identical, to compost, some liquid liquor that can be used as a fertilizer, and some biogas with predominance of methane (CH_4) and CO_2. The latter can be burned for heat, used to power an internal combustion engine for combined heat and power (CHP), producing electricity, or purified (upgraded) compressed and used for conventional natural gas applications including transport.

Figure 11. Farm-based maize silage digester located near Neumünster in Germany, by Vortexrealm at English Wikipedia [CC BY-SA 2.5], via Wikimedia Commons.

- Stoves and boilers: both types of machines use solid biomass from different origins. These produce the combustion of the biomass to directly provide heat to the room in which they stand (stoves) or into water (boilers). These systems can be anything from very simple box stoves of a few kW output, to highly sophisticated boilers capable of heating an entire housing development via a district heating scheme, and with an output of perhaps a MW or more (Figure 12).

Figure 12. Biomass Gasification Power Plant - Sustainable Way.

It is worth highlighting one specific technology associated to the biomass energy resource that is getting popular in the last years, mainly in rural areas where gas installations are not granted, is that of the pellets's stoves, Figure 13. A pellet stove is a stove that burns compressed wood or biomass pellets to create a source of heat for residential and sometimes industrial spaces. By steadily feeding fuel from a storage container (hopper) into a burn pot area, they create a constant flame that requires little to no physical adjustments. Today's central heating systems operated with wood pellets as a renewable energy source can reach an efficiency factor of more than 90%.

Figure 13. Modern pellet stove, by Jeanhup (Own work) and, by GUNTAMATIC Heiztechnik GmbH, respectively, [CC BY-SA 3.0], via Wikimedia Commons.

Therefore, depending on the type of biomass available in a region, one type or other technology should and could be implemented. As it can be observed in Figure 11 and Figure 12, biomass power plants can be large and many times, for the economic viability of the project, have to be so. This can be a handicap for its development in rural areas where sometimes there are certain limitations in both financial support capacity and biomass available resource.

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MODULE 1: RENEWABLE ENERGY AND LOCAL DEVELOPMENT

CHAPTER 3. The renewable energies technology

Subchapter 3.2 - Energy storage systems as a key factor for renewable energies

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Summary: The intermittent and stochastic production obtained from some of the renewable energy sources poses technical and economic challenges when integrated on a large scale due to the introduction of significant uncertainties into the operation and planning of the power systems. This is especially important for wind or photovoltaic power technologies. Energy storage (ES) technologies are identified as the main potential solution to deal with this issue.

Introduction

Energy Storage (ES) is the capability of storing energy for a period of time releasing it to be used at any moment when its usefulness or cost is more beneficial. When released, the energy can either be delivered in large amounts for commodity use, or in a controlled manner to optimize operation and enhance the reliability of the Electrical Power System (EPS). ES systems (ESS) have already been used for more than one century in our society, notably in the electric domain, and over that time a big variety of technologies has been developed. In fact, ES already became a dominant factor in the economic and industrial development with the widespread introduction of refined chemical fuels, such as gasoline, kerosene and natural gas in the late 1800s. Unlike other common ES systems used earlier, such as wood or coal, electricity is transmitted in a closed circuit and, for essentially any practical purpose, could not be stored as electrical energy. Actually, electricity has always been used when generated. This means that changes in demand could not be accommodated without either cutting supplies (as by brownouts or blackouts) or by storing the electric energy in another medium [1, 2].

As already introduced, many Renewable Energy Sources (RES) present intermittent and stochastic power generation patterns due to their weather dependency (e.g. wind blows intermittently or solar energy depends clearly on clouds evolution). Hence, a further RES integration into the EPS requires storage in order to make this kind of power sources reliable and sustainable [3-8]. For the case of PV power, as for the wind power, it is clear nowadays that a more controllable and non-fluctuating production should be assured to increase its sharing in the power generation mix, offering ancillary services such as frequency and voltage control, power oscillations damping (POD), etc. This fact paves the way to implement hybrid generation technologies and integrate ES systems into PV and wind power plants [4, 5, 9-12].

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The first steps on ES integration into PV power plants were done some 20 years ago [13]. However, the youth of the ES technologies and the small size of the PV power plants at that time made this solution impractical. Subsequently, in the early 2000s, when the renewable experience aroused, this topic pushed hard again. As an example, note the creation of a European Network for research on storage technologies for intermittent renewable energies (INVESTIRE) [14], established between 2001 and 2003 under the 5th EU Framework Program, and which made a thorough study on the contribution of ES systems (ESS) to the integration of renewable generators. However, the main objective in that case was the evaluation of storage technologies maturity and the recommendation of R&D strategies to improve their use with renewables. Thereby, it is not till recent years that a significant development on ES technologies has been carried out, partially due to the increasing demands regarding renewable generation systems (for large installations but also for small and isolated installations) and partially due to different parallel industries such as the electric vehicle (EV) or the portable electronic ones. This new scenario makes the installation of ESS an increasingly interesting solution to be combined with renewables. As a result, the possibility of implementing ESS in the evolving photovoltaic and wind power sectors is of particular relevance nowadays [16-21]. The cited research was further complemented by demonstration projects, like the one started in 2010 as part of the Eurogia+ cluster [22], in which a demonstration PV power plant with 1.1MW of Lithium-Ion batteries was developed with the overall objective of reducing the cost of energy, provide ancillary services, improve network stability and offer back-up functions.

From there on, ES technologies sector has experienced a boom. It is nowadays confirmed as one of the most dynamic sectors in the electric industry

ES technologies classification.

Different ESS classifications can be established nowadays [24-31]. Most of them usually divide ES technologies in two main groups: those storing energy in an electromagnetic way (direct storage), and those storing energy in a mechanical, thermal, chemical or electrochemical way (indirect storage).

As it can be appreciated in Figure 1, the direct storage group or electromagnetic storage includes two technologies such as ultracapacitors (UC) and the superconducting magnetic energy storage (SMES). In parallel, the other group includes technologies such as:

- pumped hydro (PHES), compressed air (CAES), or flywheels as mechanical systems.
- hydrogen technology including fuel cells (FC), batteries (BESS) and flow batteries as electrochemical systems.
- thermoelectric energy storage (TEES) is the main technology in the thermal group nowadays. It can use industrial oils or salts, or even sand, as a medium to store the heat.

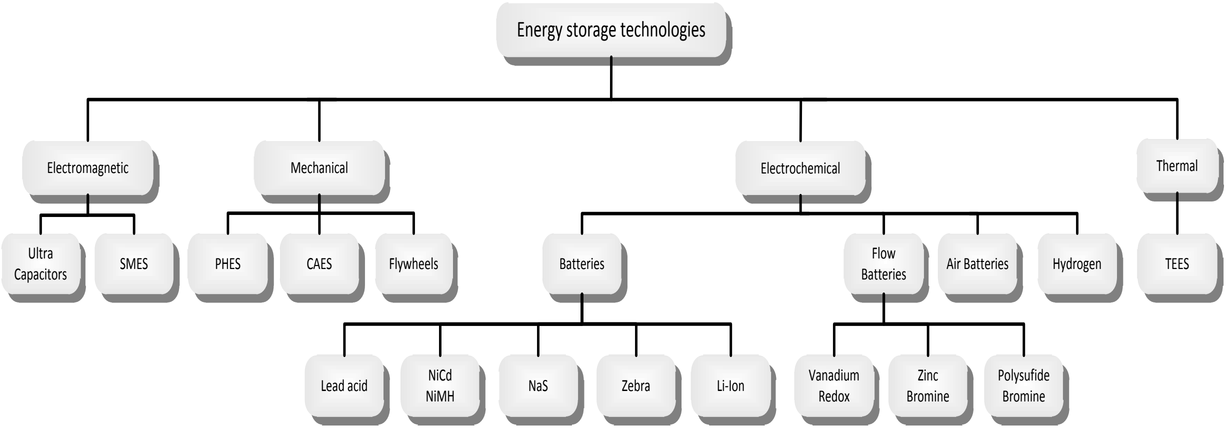

Figure 1. Classification of ES technologies. Source: [32].

These different technologies with their characteristics are reviewed in the following

ES technologies description

In order to get a general idea on the functioning and the technical characteristics of the different ES technologies, a brief description is now introduced for each of them:

UltraCapacitors (UC)

This ES technology (also known as supercapacitor (SC), and formerly electric double-layer capacitor (EDLC)) is composed by high-capacity electrochemical capacitors with capacitance values much higher than other regular electronic capacitors (but lower voltage limits) that bridge the gap between electrolytic capacitors and rechargeable batteries. They typically store 10 to 100 times more energy per unit volume or mass than electrolytic capacitors. They can also accept and deliver charge much faster than batteries, and they tolerate many more charge and discharge cycles than rechargeable batteries, which makes them very suitable for high-cycling operations (regenerative braking (KERS)). However, they are 10 times larger than conventional batteries for a given charge, which limits their use in high energy demanding applications such as energy back-up (Figure 2).

Figure 2. Ultracapacitors by Maxwell Technologies, Inc. - www.maxwell.com. Licensed under CC BY-SA 3.0 via Commons - https://goo.gl/ZLzw3b

Superconducting Magnetic Energy Storage (SMES)

The SMES technology started its development with the appearance of the high-power magnets at the beginning of the 60s, with a first serious proposal for SMES facility arising in 1969. From then on, several research projects have been established around the world but difficulties deriving from the complexity of the system have stopped a rapid evolution of this technology. So much so that it keeps being a lab technology with just a bunch of demonstration prototypes operating around the world. Its functioning principle is that of storing energy in the form of a very intense magnetic field created when a constant current flows along the coil of cryogenically cooled superconducting material, usually made of Niobium-Titanium (NbTi) filaments that operate at very low temperature (around 4K). Normally, SMES systems consists of five parts (Figure 3), which are: the superconducting coil with the magnet (SCM), the power conditioning system (PCS), the cryogenic system for refrigeration (CS), the cryostat/vacuum vessel (VV) and the control unit (CU).

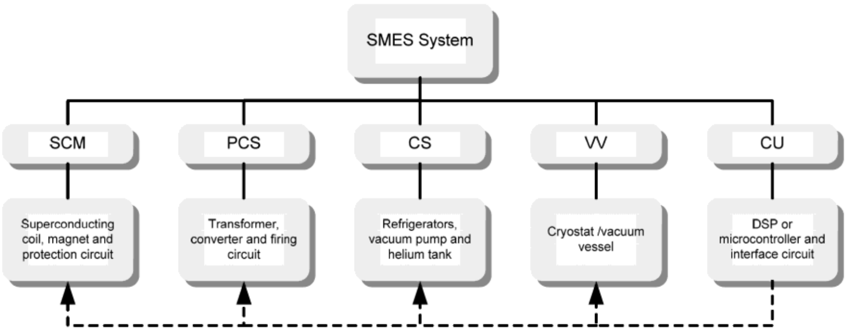

Figure 3. SMES classification of components. Source: [33].

Pumped-Hydro Energy Storage (PHES)

This kind of ES technology can be firmly underlined nowadays as the most mature and the largest one with regards to energy capacity availability. Not for nothing, pumped-hydro is the oldest kind of large-scale ES technology since it was used from the beginning of the twentieth century being the sole commercially available solution for large-scale ES until 1970. Nowadays, there are currently over 90 GW installed around the world comprehending more than 240 PHES installations, which represents roughly 3% of the global electric generating capacity. The main idea of the PHES technology is to take profit of some specific regional geographic features, places where two water reservoirs with different heights can be established, to even out the daily generating load. This is managed by, on the one hand, pumping water to the upper storage reservoir during off-peak hours and weekends using the excess base-load capacity in the EPS from coal, thermal or nuclear power plants. On the other hand, the water stored in this upper reservoir can be used during peak hours for hydroelectric generation, dropping it to the lower one. A small-scale variant of this technology could be used as ES solution to complement a small PV or hybrid PV+wind plant devoted to power an irrigation system isolated from the EPS.

Figure 4. The Seneca Pumped Storage Generating Station reservoir. Source: Wikipedia.

Compressed Air Energy Storage (CAES)

CAES is also a mature storage technology for high-power long term load-levelling and demand side management applications. This technology can trace its roots already in the early 60s experiencing a great development along the 70s. As a result of this evolution a first installation was culminated in Germany in 1978. From then on, although all the technology needed in CAES installations has been continuously evolving and gas turbines are much more efficient nowadays, for different reasons only one of the subsequent projects, in Alabama (USA) in 1991, came to fruition. The functioning principle of this technology is that of storing low cost off-peak energy, in the form of compressed air in an underground reservoir, releasing the stored air during peak load hours, mixed with a fuel and used to power combustion turbines that produce environmentally friendly, dispatchable, and economical electricity. The underground reservoirs used in CAES facilities can be of different nature accounting from human-made rock to natural salt caverns, or even porous rocks created by water bearing aquifers or as a result of oil and gas extraction. As for the case of the PHES, a small-scale variant of this technology that uses high-pressure vessels could be used as ES solution to complement a small PV or hybrid PV+wind plants in the coming future. However, this technology is not mature enough to be applied commercially.

Flywheel Energy Storage Systems (FESS)

Adding inertia to a motor or generator was the first method ever used in the electric domain in order to store energy and smooth out their variable speed operation, reducing or limiting in this way the power interruptions to critical loads. So, flywheels were already in use prior to the development of the present cost-effective power-conversion electronics which have widened their applications horizon. Nowadays, these are devices that permit ES in the form of a rotating wheel which can be accelerated to a very high speed (>100000 rpm), converting electrical energy into kinetic energy in a low-friction flywheel. This energy stored in the rotating flywheel can be subsequently released or recovered as electrical energy via a generator or power converter to provide energy when required, usually peak demand periods.

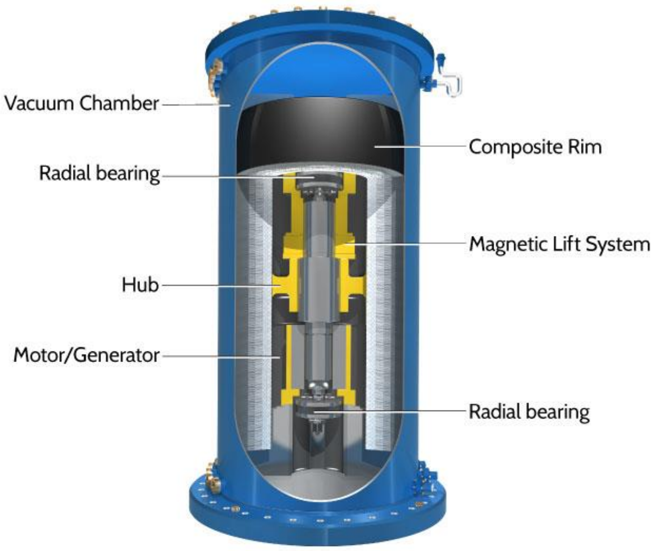

Figure 5. Commercial flywheel model by Beacon Power Corporation. Source: http://beaconpower.com/carbon-fiber-flywheels/

Fuel cells (FC)

Hydrogen is lately being considered as an ES medium, although it differs from the conventional idea of ES technologies because it uses different processes for hydrogen production, storage, and use. Therefore, the hydrogen technologies present 3 branches to enable the hydrogen as an EES. In this sense, hydrogen is not a primary energy source, but an energy carrier, because it must first be manufactured by other energy sources in order to be used. Within the hydrogen technology, one must highlight fuel cells.

There are many different FC technologies with their corresponding specific characteristics (varying in the operation temperature, the type of fuel and catalyst used …); however, they all work in the same general manner. They are made up of three segments (two electrodes: anode and cathode, and the electrolyte) which are sandwiched together (with similar structure to flow batteries).Two chemical reactions occur at the interfaces of the three different segments. The net result of the two reactions is that fuel (H_2) is consumed, water or carbon dioxide is created, and an electric current is generated.

Among the different FC technologies which have been proposed, there are five major types that have been developed to varying degrees which can be highlighted. They are differentiated and named according to the electrolyte used in the cells: polymer-electrolyte membrane or proton exchange membrane fuel cells (PEMFC), alkaline fuel cells (AFC), phosphoric-acid fuel cells (PAFC), molten-carbonate fuel cells (MCFC), and solid-oxide fuel cells (SOFC). The electrolyte also determines the operating temperatures of the cells, as shown in Table I.

Table I. Main characteristics for the different FC technologies.

Fuel cell	Electrolyte	Catalyst	Fuel	Efficiency	Operat. T (°C)	P output (kW)
PEMFC	Solid organic polymer	Platinum	H_2	45 **(%)**	60 to 100	50-250
AFC	Potassium Hydroxide	Platinum/Palladium Platinum/Gold	H_2	70 **(%)**	80 to 100	0.3-12
PAFC	Phosphoric Acid	Platinum	H_2	40 **(%)**	150-200	200

MCFC	Potassium, Sodium or Lithium Carbonate	Mostly Nickel	H_2/CO_2	60 **(%)**	600-1000	10-2000
SOFC	Solid Zirconium Oxide	Variety of nonprecious metals	H_2	60 **(%)**	600-1000	1000

Batteries (BESS)

Batteries have been used for long (remember Alessandro Volta in 1800 a.c.) and many different technologies have been developed. The differences among them lie in the various chemicals and electrode materials that researchers have employed along the history to make them work. The main families, industrially developed and finally commercialized for some kind of ES application, are:

- Lead Acid Batteries.
- Nickel Cadmium and Nickel Metal Hydride Batteries
- Sodium Sulphur and Zebra Batteries
- Lithium Ion Batteries.
- Air Batteries.
-

Their different properties and characteristics can be analysed in the following table:

Table II. Comparison of properties among different battery technologies.

	Lead-acid	**NiCd**	**NiMH**	**NaS**	**Zebra**	**Li-ion**	**Zinc air**
Specific Energy (Wh/kg)	30-40	45-80	60-120	150	100-190	110-250	470
Energy density (Wh/liter)	60-75	80	150	50-200	150	250-620	1300
Specific Power (W/kg)	180-250	150	200	150-240	150	250-340	105
Nom. Cell voltage (V)	2.105	1.2	1.2	2	HV (stack)	3.6	1.65
Life cycles	500-1000	2500	600	2500	500-3000	500-2000	500-2000
Fast charge time (h)	8-16	1	2-4	2-4	2-4	2-4	2-4
Monthly E discharge (%)	3-20	20	30	5	10	10	10

Flow Batteries

Flow batteries are a promising technology that stores and releases energy through a reversible electrochemical reaction produced between two electrolytes, which are stored in different tanks (avoiding the characteristic self-discharge so typical in traditional structure batteries), and through a microporous membrane that separates both of them but allows selected ions to cross through, creating the electrical current flow. In this sense, they are somehow a special type of batteries difficult to compare with the rest of conventional battery technologies. In fact, they are considered half way between them and the just explained hydrogen fuel cells.

They present also different families due to the various potential electrochemical reactions, usually called reduction-oxidation or REDOX reactions. However, only a few of them are useful in practice. In this sense, the main four groups of flow batteries which are being commercially developed are: vanadium redox flow batteries (VR), zinc bromine flow batteries (ZnBr), polysulfide bromide (PSB) flow batteries, and cerium zinc (CeZn) flow batteries Figure 6.

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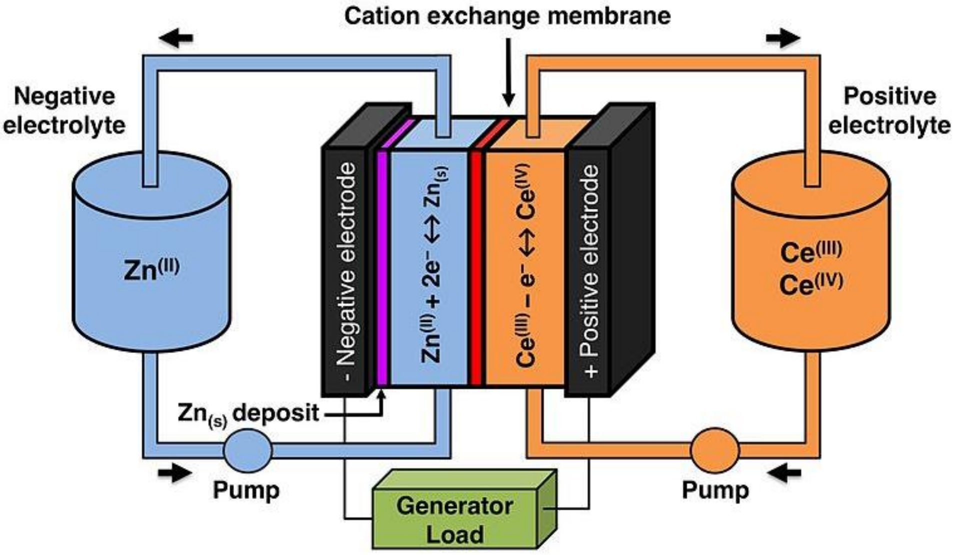

Figure 6. Diagram of the divided zinc–cerium redox flow battery, By Earth-Rare (Own work) [CC BY-SA 3.0].

Thermoelectric energy storage (TEES)
TEES technology is based on storing energy in the form of heat in a thermal reservoir so that it can be recovered later converting it back into electric power. Since it is not considered an option nowadays to be used in combination with small renewable plants, this technology falls beyond the scope of this course and is therefore not described in more detail.

ESS comparison

Once the different ES technologies have been classified and described, one can compare them paying attention to certain characteristic parameters defined for clarity such as:

- Power Capacity: is the maximum instantaneous output that an ES device can provide, usually measured in kilowatts (kW) or megawatts (MW).
- Energy Capacity: is the amount of electrical energy the device can store usually measured in kilowatt-hours (kWh) or megawatt-hours (MWh).
- Response Time: is the length of time it takes the storage device to start releasing power from the moment it is activated.
- Round-Trip Efficiency: indicates the quantity of electricity which can be recovered as a percentage of the electricity used to charge and discharge the device.
- Specific energy and specific power: these parameters correspond to the amount of energy and power that an ESS can store or generate for every unit of weight of the system.

By using these characteristic parameters, different comparisons among technologies can be represented. For example, a graphical representation as that in Figure 7, which depicts the specific energy versus the specific power of the different technologies (mainly batteries) can provide a clear picture of their energetic characteristics. This representation helps identifying potential applications for each of the technologies registered.

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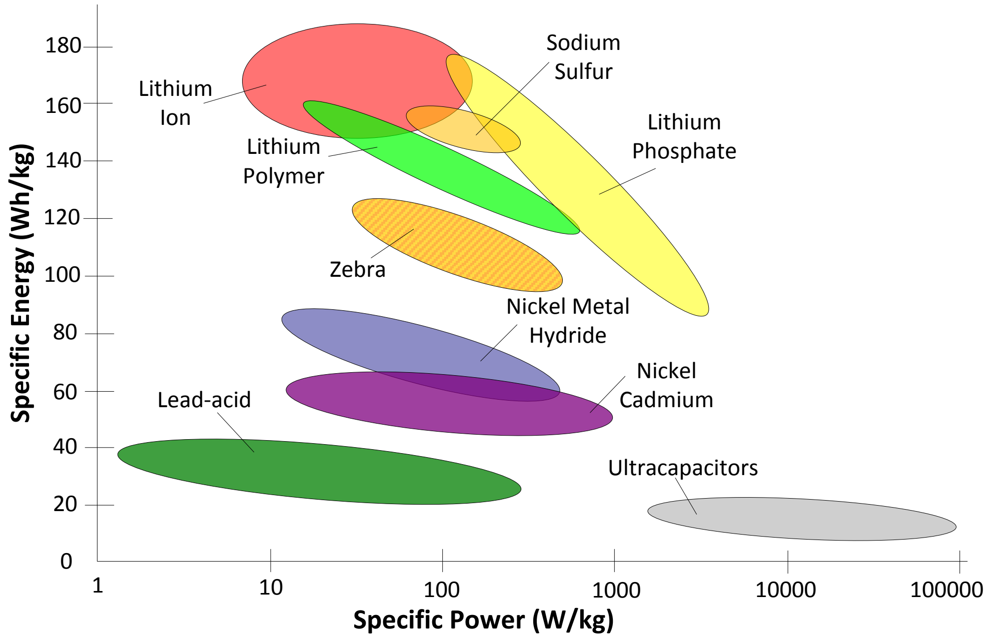

Figure 7. Specific energy vs. power for the different battery technologies. Source: [34]

Another interesting comparison which can be represented is the state of development for each of the technologies represented versus their various power ratings, Figure 8. This figure also provides an idea about the technologies that are commercially available nowadays for different levels of power capacity. This information equally helps deciding what ES technology options can be used right now for a determined application.

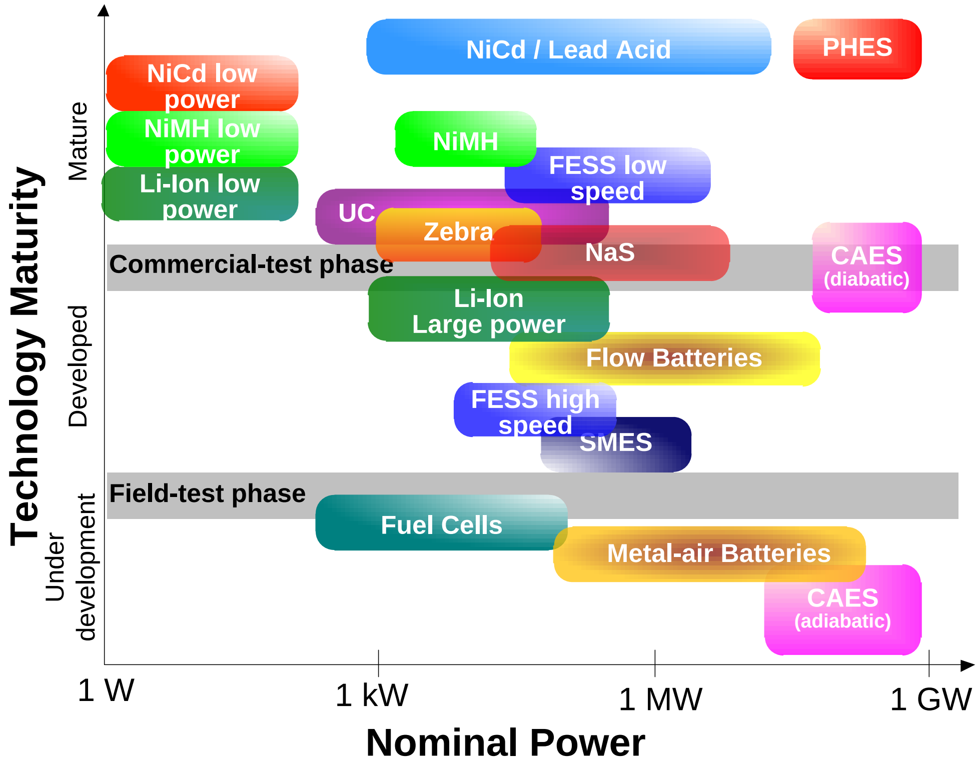

Figure 8. State of development vs. nominal power. Source: [35].

And many other comparisons can be made with all the information that is provided, in summary, in the following table:

Table III. General comparison of the different ES technologies.

ES technology	Power capacity	Energy capacity	Response time	Efficiency (%)	Lifetime	State of development
Pumped Hydro	30MW – 4000MW	500 – 8000MWh	Sec. to min.	70 – 85	Even 50 years	Commercial
Compressed Air	50MW – 300MW	500 – 2600MWh	Sec. to min.	64 – 75	Even 40 years	Commercial/prototypes for vessels
Flywheel	Up to 2MW	Up to 15 min	Milliseconds	90	20 years	Commercial / prototypes Depends on spin speed
Superconducting Magnetic	0.01 – 10MW	Up to 30 min	Immediately	95	30 years	Prototypes in test / Research
Ultracapacitor	Up to 1MW	Up to 1 min	Immediately	85 – 98	10 years	Commercial
Lead Acid Battery	0.001 – 40MW	Up to 40MWh	Milliseconds	75 – 85	1000 cycles	Commercial
Nickel Cadmium Battery	0.001 – 40MW	Up to 10MWh	Milliseconds	60 – 70	1000 – 3500 cycles	Commercial
Sodium Sulfur Battery	0.05 – 50MW	Several 100MWh	Few seconds	75 – 89	2500 cycles	Commercial
Lithium Ion Battery	0.001 – 0.5MW	Several MWh	Milliseconds	90 – 95	Up to 20000 cycles	Commercial
VanadiumRedox Flow Battery	0.05 – 3MWs	Several MWh	Milliseconds	70 – 85	10000 cycles, 7 – 10 years	Improved prototypes in test / Commercial
ZnBr Flow Battery	Up to 1MW	Less than 4h	Milliseconds	75	2000 cycles	Improved prototypes in test / Commercial
PSB Flow Battery	Up to 15MW	Less than 20h	Milliseconds	60 – 75	2000 cycles	Improved prototypes in test / Commercial
Air-metal Batteries	Still limited	Limited only by anode's life	Milliseconds	60-70	50 cycles	Under primary research
Fuel Cells	Up to 250kW	Rechargeable with H_2	Milliseconds	35 – 45	10 to 20 years	Improved prototypes in test / Commercial
Thermoelectric systems	1MW – 100MW	2 – 800MWh	Sec. to min.	30-70	20 years	Commercial

ESS applications

ESSs are recognized as a potential source of businesses on many different sectors concerning the electric grid. A large number of applications have been defined in the last years regarding consumers (demand side management and energy arbitrage), electric transmission and distribution systems (facilitating operation, deferring new investments), and mainly renewable energy generators (providing liability and smoothing production for grid connected installations, or back up power in isolated ones).

For the grid connected situation, it is clearly stated nowadays that intermittent renewables, mainly solar and wind, will need to be supported with other conventional utility power plants and ESS for a further penetration. This is because when high integration degrees are achieved, the system operation will become more complex and will require additional balancing power. Hence, the introduction of ESSs will allow a higher percentage of wind, photovoltaic, and other RES in the electrical mix contributing to fulfil the objectives for a more sustainable distributed structure for the electric power system. Thus, in order to integrate renewables, it is necessary to analyse what ESS can offer the energy capacities and what power levels are required by these generators.

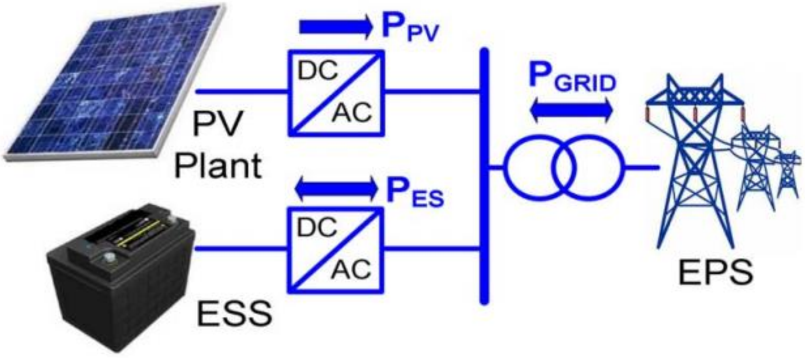

Figure 9. PV installation combined with an ESS and connected to the EPS.

Similarly, for grid isolated installations, the introduction of some kind of energy storage systems is a must nowadays. Nobody can assume an isolated installation which does not present an energy buffer that allows unlinking local energy production and consumption. Moreover, the recent evolution of the different energy technologies with the price reduction these are experiencing is one of the vectors pushing isolated installations towards a flourishing moment.

Amongst those ES technologies summarized in Table III, not all of them are able to meet the requirements of PV and wind power plant applications. These requirements that are common for isolated or grid-connected installations, include: fast reaction time, high efficiency, physical size and availability to be placed on the location, easiness of maintenance, long life cycle and, preferably, possibility to independently sizing storage power and capacity and maturity of the technology.

According to them, each of the ES technologies fits better or worse. Some of the technologies can be disregarded because they are still under development in a non-commercial stage (SMES, air-batteries). Others present limitations of use due to their geographic dependence (PHES, CAES). And others could still be expensive for energy intensive applications (ultracapacitors, flywheels). In this manner, batteries are referred to as the key technology to operate integrated with renewables. On the one hand, among the different battery technologies, lead-acid battery systems were mostly used in past applications, mainly due to their maturity and low cost but, performance limitations, short life cycles, and high maintenance demands are limiting their adoption in new PV and wind applications. On the other hand, breakthroughs in a new generation of Lithium-Ion based batteries are entering the market meeting most of the renewable requirements. Furthermore, their dynamical properties seem to fit perfectly for solar or wind variations. Finally, a further significant improvement in Lithium based battery performances is expected in the near future due to the great research effort that is being made to develop them, especially focused on its potential application to electric vehicles and home storage (combined or not with PV production). The selection of other types of batteries (chemistries) in a mature state of development such as NaS or flow batteries is still an option. These present both exhibition and already commercial projects and are also available for consideration under certain requirements concerning power and energy for the combined plant. However, market trends point to the Li-ion technology thanks in part to the quick evolution it is experiencing (note the Tesla Motors Company announcements on the sector and their Li-ion megafactory development plans in Nevada).

Therefore, Li-ion technology and also Lead-acid are the two main options of storage being combined nowadays with renewables, the former being more related to grid-connected installations and the latter still more present in the isolated installations sectors (because of their still lower price).

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MODULE 1: RENEWABLE ENERGY AND LOCAL DEVELOPMENT

CHAPTER 4. Development in rural areas

Subchapter 4.1 – Introduction to the rural development

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Summary: This section describes some characteristics of the rural areas, and selects those considered keys to understand the dynamics in rural areas nowadays.

As we advance through this subchapter, we will make an approximation to rural realities. In addition, we will observe historic transformation and significant data on Gross Value Added (GVA) shares. But there are ideological barriers we still have about rurality and the way we represent it.

This subchapter will show the weight of rural population in the three countries (Hungary, Romania and Spain), right beforehand we describe an attempt for a definition on *rural and urban areas* as used in the European Union since 2010. After that, some characteristics of rural dynamics and trends will be highlighted in order to offer an overview about it. This subchapter will conclude an interesting and useful theoretical approach to rural spaces and its dynamics.

Introduction

In our everyday practices - as in our mind - , *rural* is a concept that any of us can describe with multiple adjectives. We usually think in spaces not really crowded where nature and agriculture have a great predominance. In this sense, representations of rural areas move from «the idyllic to the oppressive» [Cloke, 2006]. But defining rurality nowadays became a hard issue for social scientists. Among others, geographers, economists or sociologists are looking at what that area is, how those in rural areas produce or how they live in those areas. So, despite we have clear images in our mind, in our memory and experiences, scientists do not agree on a simple definition about *rural*[1]. As a negative in a photography, rural is everything other than urban. Let's notice here that some relevant percentages of European people live in rural areas. Following World Bank data, Figure 1 shows how there are some differences between our three countries.

[1] Sometimes we will refer *rural* to name a concept that includes space, production, rural dwellers or the set of dynamic there occur.

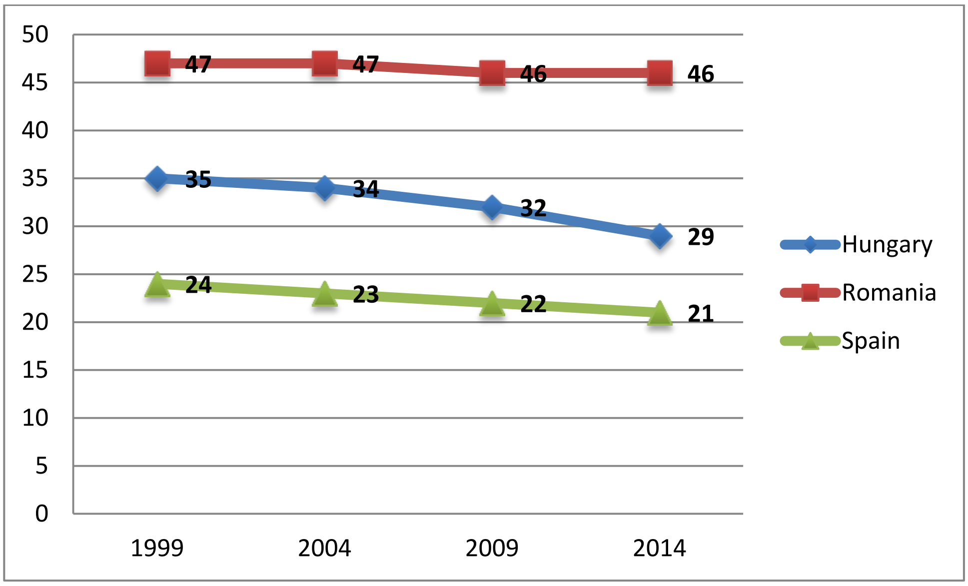

Figure 1. Percentage of rural population for each country. Source: Author, based on information from The World Bank

Here we observe the same trend for the last 15 years. Although the three countries have different starting points, there is a continuous drop in their percentages of rural population. Europe shares a global mainstream, so the percentage of people living in cities exceeded 50% in 2008 [UNFPA, 2008]. But, still, we can observe the importance of the rural population in Europe. Indeed, values between one-fifth (Spain) to nearly half (Romania) of total population of those countries live in rural areas.

Pointing to our European areas, how do we determine a region to be rural? Can agricultural places close to cities be named as *rural areas*? Even though agricultural land use could be an argument, criteria for EU administration apply demographic data. Indeed, some attempts from the European administration have provided quantitative measures in order to execute policies. In 2010, there was an agreement by DG for Regional Policy, DG for Agriculture and Rural Development and Eurostat to use a new methodology to classify urban and rural areas.

As there is a great variety of nomenclature for municipalities among the European countries, the correspondent phrases for Local Administrative Units at lower level (LAU2) for these countries are:

- Hungary: *Települések*
- Romania: *Communes + Municipiu + Orajse*
- Spain: *Municipios*

Eurostat takes these units to build up a definition about rural based on density and size of the population. As follows in Box 1, this objective definition helps administration in Europe to apply policies. It modified previous definitions about what rural spaces are, so rural spaces are being constructed from the outside, too. Administrations still have to make some decisions on what *is rural* and what *is not rural*. Therefore, policy makers draw borders and decide what is rural or urban. These decisions, in the end, will affect people living in those particular places.

The new typology builds on a simple two-step approach to identify population in urban areas:

1. a population density threshold (300 inhabitants per km²) applied to grid cells of 1 km²;
2. a minimum size threshold (5000 inhabitants) applied to grouped grid cells above the density threshold.

The **population living in rural areas is the population living outside the urban areas identified through the method described above**.
To determine the population size, the grid cells are grouped based on contiguity (including the diagonals); see *Grid Cells Figure* If the central square in Figure 2 is above the density threshold, it will be grouped with each of the other surrounding eight cells that exceed the density threshold.

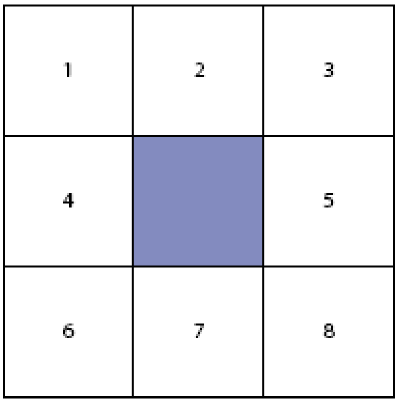

Figure 2. Grid Cells Figure

The 1 km² grid is already available for Denmark, Sweden, Finland, Austria and the Netherlands (see [EFGS, 2016]) and the new typology is based on the real 1 km^2 grid in these Member States.
For regional level, it will be defined as "**predominantly rural (PR)**, if the share of population living in rural LAU2 is higher than 50 %".

Box 1. Defining rural by population numbers. Source: Author, based on *Eurostat Urban-rural typology*

This methodology to define rural spaces as defined in Box 1 is intended to be used for all EU, even though definitions for rural have been following different parameters. Spain defined it by total number of inhabitants, Hungary bases its definition on population density and Romania by a set of conditions. As coming statistics will try to match Eurostat criteria, we recommend their approaches to this methodology. Since we just explained here, the 'predominantly rural' definition relates to regional level, therefore, Eurostat[2] to be consulted in order to understand some other complexities for space classification.

Features for a better understanding of rural areas

Beyond population density, there are some fundamental issues to understand how rural areas develop in their everyday lives. This section will focus on four features to spotlight what rural is in Europe nowadays. In the meantime, these descriptions should help to avoid some of the dragged stereotypes constructed around the rural areas.

Heterogenous

One of the first ideological barriers to avoid is the representation of rural life and, above all, of today's rurality as a poorly endowed space, simple, exclusively agricultural,..., etc. Rural areas, far from simple sets of relationships, represent complex communities. If you want to begin a development project, there is a complexity to grasp before starting, together with its inhabitants, a process of change in their lives, work or their social interactions.

Any approach to European rurality seeking to move away from topics or prejudices must, among other things, make some principal breaks. As Camarero et al proposed [Camarero, 2009] to understand and act with greater guarantee on rural areas it requires thinking in those who live in rural areas as people who are already taking part in the informational, global, postmodern society. We can rather find an "enormous plasticity in the territorial, economic and social levels" in the rural areas [Camarero, 2009]. This fact has as a consequence that it is a heterogeneous reality, hardly isolated from the global society. Local and global levels are combined, fed or reflected so that they build a dynamic space where rural inhabitants live as a growing diversity. When thinking of rural areas, anyone can believe that people live a simple life linked to nature and agriculture. As we try to emphasize, there is a high diversity of lifestyles shared at the same rural spaces. And, in fact, one of the factors related to this multiple lifestyles is mobility, a factor that helps to achieve a greater heterogeneity in any place.

Mobility

Following this, we often imagine rural areas as isolated people in remote villages. However, when observing the dynamics, we see "an intensification and diversification of circulation between rural and urban areas, but also between distinct rural spaces situated in different regional, national or international geographies" [Hedberg, 2012]. We find a scattered occupation of the space and an intense circulation of people, but also of information and materials. Some have called that a "nomadic sedentary" [Bericat, 1994] lifestyle. So inhabitants in cities and villages have fixed places to sleep and fixed places to work, and those differ in space. That dynamism generates people movements in the space, with diverse frequencies: daily, weekly… and, as a consequence, news visions of those who transited territories who, in the meantime, set up new forms of identity.

[2] Eurostat *Urban-rural typology. Statistics explained.* http://ec.europa.eu/eurostat/statistics-explained/index.php/Urban-rural_typology#Definition_at_the_regional_level

People move across territory in various ways. Although these movements are caused by leisure or shopping motivations too, we highlight commuting to work as an important phenomenon that takes also place in rural spaces. We are used to perceiving movement from suburban areas to the city, but the concept of *commuting* enlarges this dynamism also to rural places. Therefore, rural dwellers live in the rural areas and work in some other places. So, when travelling for working or study purposes in a periodical frequency; boundaries to places exceed the residential spot. Thereby, in the case of rural areas case, we can distinguish two cases:

- **Commuting** from one's rural residential municipality to other municipalities, either rural or urban, where one completes his/her job or studies.
- **Reverse commuting** from one's urban residential municipality to rural areas where one completes his/her job or studies.

When talking about mobility, means of transport are also a key factor. It happens very often that there is no alternative to commute other than owning a car. Car becomes the main way to move in these spaces and its use is highly determined by fuel prices. So availability of transport and mobility has to do, mostly, with access to automobile and access to fuel. Besides economic capacity to acquire a car or fuel, gender and age are other factors to take into account. In this sense, old people who do not drive or women who do not access to a driving license are two main groups to pay attention to. Both cases illustrates (im)mobility dynamics in rural areas. In Spain, for instance, 51,5% of 65 and older people do not have a vehicle in rural areas, and one out of five unemployed is in the same situation. On the other hand, the majority of 'support generation' (30-49 years old) and young (<35) rural residents work outside their municipality [Camarero, 2009]. So mobility is a trend assumed for *active* people who live in rural areas. However, we cannot lose sight of the *immobile* groups, since over-aging is another definitive trend for rural areas.

Over-aging

Even though there is an intense mobility in rural population, aging and over-aging phenomenon is an extended key factor for rural areas. Walking on the same mainstream, *population decline* became a big issue in Europe in the last decades. However, it happens to be more dramatic for rural spaces. Some trends and numbers can offer an overview for the three countries involved in this study.

When taking a look at Hungary, Romania and Spain, we share a similar demographic progression. But some differences should be appointed, too. In the case of Hungary "population decline is an important feature for all areas of Hungary and predominantly rural areas indicate an unfavorable age structure, decrease of economically active persons and an imbalanced gender structure" [Wiesinger, 2008].

Nowadays, rural Romania has 15,6% of its population over 65 years old [Ignat, 2014]. By 2030, one fifth of Romanian people are expected to be 65 or more.

The same aging tendency can be observed all over Central and Eastern Europe countries, becoming even sharper in rural areas, as "a generally higher share of older people in rural areas whereas the metropolitan cities provide growing attractiveness for the younger generations” [Hoff, 2015].

And for the Spanish case, 19% of rural populations are 70 years old and over. Of course, these rates of older people are accompanied by higher rates of dependency affecting families and caring services provided by public administrations.

This common population structure trend for the three countries means an imbalanced population pyramid to be modified when thinking about social sustainability. Demographic reproduction in rural areas has an urgent need of young people to develop life projects in best social conditions. In an era of low birth rates and low death rates for European countries, rural areas display the most severe numbers to maintain population for next decades. Figure 3 illustrates the transition from expanding to contracting population stage. In European rural areas, though, the base (young generations) for *stage 4* is extremely shrunken. Furthermore, we stress the masculinization process (rural areas have more men than women in middle age stages) as one of main difficulties to balance a population pyramid.

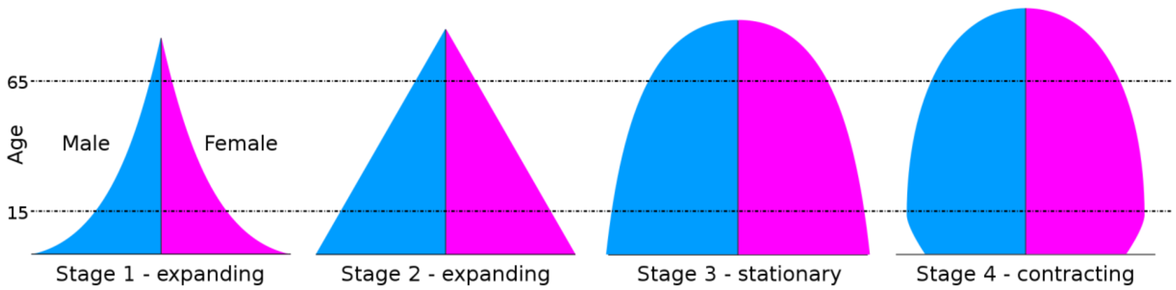

Figure 3. Population pyramid typology. Source: Population pyramid. Wikipedia

About men and women

Together with the above mentioned requirement about trying to balance population pyramids on rural areas, gender arise as a fundamental question to foster social sustainability.

For the case of (Western) Germany, Hungary, Poland as Slovenia, Wiest [Wiest, 2014] argues that “[m]ale-oriented and/or tight labour market limit the occupational and career opportunities of women irrespective of the degree of cultural acceptability of female labour force participation rate in the regions” in a population pyramid where men are more numerous in ages below 40 years [Wiesinger, 2008].

In Spain, for municipalities under 5000 inhabitants, there are 110,5 men for every 100 women [Camarero, 2008].

Same trend occurs in Romania, with a different demographic pattern. In this case, there is an increase of the number of rural women since 1990, from 45.6% to 50% in 2013. Although, that phenomenon responds to a feminization of old age, while “the share of young women population (0-19 years) in total rural women population decreased from 15,8% (1990) to

10,8% (2013)" [Florian, 2014]. We can say that future for rural space shares the same trend in the 3 countries.

This means, among other factors, that rural areas do not meet women desires for a life project. Female labour opportunities can pull new family settlements. Nonetheless, together with job opportunities for women, requirements related to life quality appear. Former experiences just fixed on male and female opportunities not taking into account quality life issues, have great difficulties to fix the population. What makes a place attractive for a life project? Maybe some social life, a great quality for education, a quick access to medical services, a cultural refreshing agenda...

One useful idea when trying to understand the possibilities of rural development is to "think about a couple who could have an attractive life project, with quality educational and social services accompanied by worthy and dignified jobs" [Aparici, 2015].

A theoretic proposal to approach to the rural

Then, it is clear when it comes to understanding how to develop a renewable energy project in a living space, considerations beyond counting people or looking at population density of the area should be kept in mind.

To integrate this vision of the rural space, with all richness of data, we find the Halfacree's three-fold model approach really useful [Halfacree, 2006]. This scheme has the virtue to include and relate different factors: the **space** we try to understand, the **opinions** in the minds of those who act in that space and, finally, the **individual and collective ways of life** happening there. This model gathers the above mentioned elements together with any others able to explain and properly identify the idiosyncrasy of a specific territory.

Then, dynamics on any rural space may have similarities with others, but its singular elements and relations with other rural contiguous spaces, in the regional level or in some international people or material flux, will define each rural area and its features.
For Halfacree's model, *practices* mean what different actors, agents or administrations do in rural spaces. And those practices occur in spaces recognized, by urban or rural actors, as a **rural locality**.

In the second place, **representations** of the rural areas are socially constructed. For this model, a **representation** is a set of values, opinions, ideas, metaphors, beliefs, and practices that are shared among the members of groups and communities" (Social Representation, 2014) and it can change through history for a particular place. Nowadays, these images of the rural space are built in a system shaped by market, one or several administration levels or politicians, too. And rural elements (from landscape to folklore) can be converted to products (commodities) to be exchanged in the market, which represent, more or less, that rurality.

Finally, beneath place and representations, **everyday life** occurs. Rural dwellers behave in a diversity of manners, in a constant negotiation with what is expected from them (representations).

These three dimensions gather up the totality of rural space. Any of the elements interact with the others to produce information about rural spaces. And "tensions exist between the forces of permanence and flow, as well as between the autonomous logics of the three facets" [Woods, 2011].

In Halfacree's own words, the elements of the three-fold model [Halfacree, 2006] are the following:

- *"Rural localities* inscribed through relatively distinctive spatial practices. These practices may be linked to either production or consumption activities.
- *Formal representations of the rural* such as those expressed by capitalist interests, bureaucrats or politicians. Crucially, these representations refer to the way the rural is framed within the (capitalist) production process; specifically, how the rural is commodified in exchange value terms. Procedures of signification and legitimation are vital here.
- *Everyday lives of the rural*, which are inevitably incoherent and fractured. These incorporate individual and social elements ('culture') in their cognitive interpretation and negotiation. Formal representations of the rural strive to dominate these experiences, as they will rural localities"

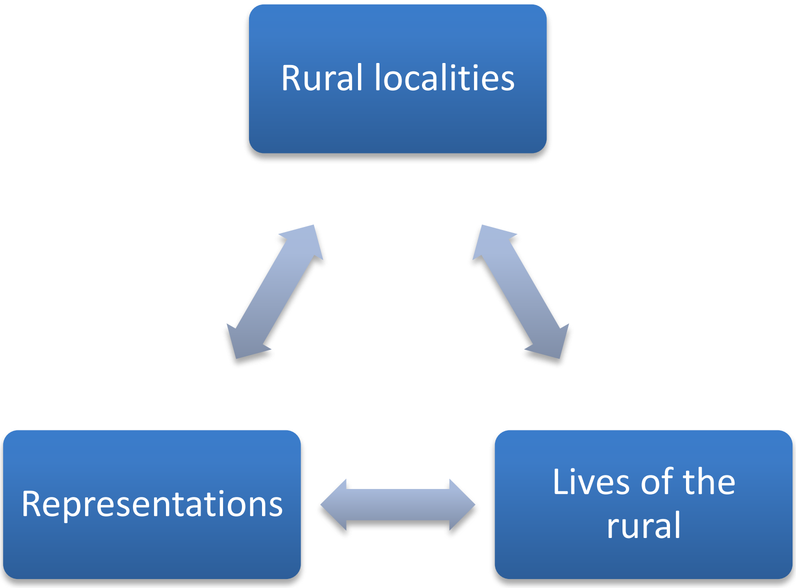

Figure 4. Halfacree three-fold model (2006)

Rural spaces make sense as being constructed "by living, acting and working" [Smith, 1984] [Halfacree, 2006]. Any space, mostly when being humanized, is not a "a practico-inert container of action' but 'a socially produced set of manifolds" [Crang,, 2000] [Halfacree, 2006].

Maybe some questions about renewable energies can be introduced to this model in order to understand rural spaces. How do we represent rural spaces as a place to install renewables? How do people who live there represent it? If we capture rural inhabitants representations about their work, life... as well as we have an exogenous representation for the rural, maybe we will achieve a better understanding of rural complexity. Then, as a practical exercise, add population density or over-aging structures to a picture of your preconceived ideas. Try to fit that in a municipality, think about needs for rural development, how their dynamics already work , finally, what would be the impact on the life of the people living there.

Conclusions

Our aim in this subchapter was to introduce some topics on rural spaces. As we described, heterogeneity and mobility of the rural areas go against some topic representations of that space. On the other hand, demographic trends are sharper (over-aging) than the general trend for European societies. Finally, we highlight the more or less imbalanced gender population pyramids and also the difficulty to maintain a sustainable rural population in some territories.
Throughout this subchapter, we tried to approach a better understanding of rural dynamics nowadays. Nonetheless, the ways to interact with rural community, actors, agents, landscapes... make another issue about sustainable development. It will be shown how sustainability can be implemented in rural areas in next subchapters. So, understanding is a first step but we still need strategies to engage people (rural and urban) to foster sustainable development. Subchapter 4.2 will focus on what development is and what the different ways have been to implement it.

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MODULE 1: RENEWABLE ENERGY AND LOCAL DEVELOPMENT

CHAPTER 4. Development in rural areas

Subchapter 4.2. Differencial aspects of development in rural areas

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Summary: Development has been used through decades as a mechanism that was assumed to improve life in societies. However, the concept changed over time and it is now adapted to new challenges. We selected three development theories: modernization and freedom-centred theory will be described as well as in the end, as a third and much more important approach: the sustainable development theory. Together with that, we make an approach on development closer to territorial level and rural spaces. We live in unbalanced territories where development tools can work to reverse it. Renewable energies can be a powerful tool to try to reverse it in collaboration with those who live in rural areas.

Introduction

Development is a concept used extensively and in which different areas coexist: economics, sociology, ecology, political science, psychology, engineering and other areas of knowledge. Regardless of the back and forward economic expansive periods, as we have seen over the last century, there is a powerful idea about a sustained improvement on our lives over time. Furthermore, we would also like to point out an extended idea in the so called Western countries over the past 60 years by which societies seem to be in a continuous development process and their living conditions keep improving *ad infinitum*. It seems clear that there is an expansive stage in the OECD countries called *The Glorious Thirty* (years) running since the end of World War II (1945) until the oil crisis (1972). That improvement in life conditions actually happened, and a set of data on infrastructures, economics, education, health, etc. pointed in that direction. So there were widespread improvements in population. Nonetheless, there were always coverage limitations for all social classes. Indeed, that was a society were 2 out of 3 people could enjoy middle class consumptions and lifestyle. This period has caused the image of a continuous evolution and development which improved our lives constantly.

However, with the 80s, economic policies changed in Europe, and the data pointed to the reversal of that trend: cuts in welfare state societies with clear reductions on the protection of workers and education and health public services, among others. Thus, the concept of development focused a lot on those areas tagged as underdeveloped. Some interventions had to be done to enhance living standards, so to approximate them to those more developed countries or cities.

Without forgetting that, in any case, “the ideas on development are inevitably molded, and therefore, limited by time and place where they develop” [Paynes, 2011]. Welfare states built during those *Glorious Thirty* concentrated mainly in Northern and West-Central Europe at that moment. In this sense, development of Welfare States in Europe has been unequal. When focusing on territorial and rural scope levels, development policies vary in history. Nonetheless, at least for the last 20 years EU made an effort to foster development on rural areas by common criteria.

What ideas lay at the basis of development? Any human change process responds to a conception for society and how its structure is going to be. So, what kind of society structures do we promote? In this sense, development can take multiple directions. A development project could reinforce previous inequalities or, in an opposite direction, could work for a more equal community. In our case, development of energy supplies is crucial for life quality standards, even for life minimum standards. In the meantime, there are several ways to implement those energies. Let's begin with two ways of development managed in last the decades. First of all, we will describe the idea of development close to modernizing a society. Secondly, we will focus on the impact on people involved and their agency, participation, decision-making and freedom in that process.

Development has been seen as a modernizing process boosted on some countries or areas. It tried to guide those spaces in the path of others considered already developed. Attempts to route *underdeveloped* areas to developed structures and dynamics often fell in continuous interventions from outside. For this, the so-called *modernization theories* reached a theoretical dilemma which required considerable changes induced from outside when theory advocated a change from the endogenous factors [Payne, 2011]. In an international scale, since the 80s, many of these development dynamics have been aligned with the structural adjustments advocated from the IFI (International Financing Institutions), mostly by those who provided the funding.

Besides *modernization theories*, some other points of view were built on development matters. The *freedom-centred development* approach incorporates, mainly, the agency and participation of the individuals involved and affected by the forms of development. There is a switch in the scope, so to focus on human conditions, and how development can work up for a more autonomous and endogenous control of that development. However, it was attacked by regarding it as an extension of neoliberal mainstream, without questioning the idea of the need to grow (especially in economics) as a requirement for development [Payne, 2011]. Thus, economic growth could have dangerous consequences on the social and environmental parts of a territory.

Sustainable development

What impacts does development have on nature? Can we grow indefinitely? Social scientists and ecology researchers, among others, began to raise these questions. Some of them informed about the relation between economic growth and its ability to devour resources, and they stressed the unsustainability of this form of development. Although Polanyi [Polanyi, 1944] early pointed out capitalism as a destroyer of nature, this idea was rigorously ratified by Georgescu-Roegen (1971) and put on the media agenda by the Club of Rome report *The Limits to Growth* [Meadows, 1972]. It was in the Bruntland report *Our common future* [Bruntland, 1987] when a form that should develop and respect the environment was coined.

After that, the concept of "sustainable development" has spread many areas of our lives. We use it for shopping, as sustainable consumption; when travelling, as sustainable tourism; when building a house, as sustainable architecture... We practice sustainability for singular aspects in our lives (recycled paper, efficient houses...). Nonetheless, those partial practices need to be articulated to a global system, since sustainability means that the “prevailing growth model is unsustainable for the planet and threatens the availability by future generations of certain non-renewable resources which at present are consumed without limitation” [Aparici, 2006]. This kind of development implies a cross-involvement of factors and actors enrolled in development. Besides, it “is expected from scientific disciplines that after their complicity or involvement with the model that has led to this situation, they would redirect the situation with globally corrective actions“ [Aparici, 2006]. Since energy runs this globally interconnected world and its intense mobility, renewable energies strongly determine the fate of sustainability.

More than forty years after scientists told us which are the unsustainable ways for our planet, we keep on using non-renewable resources. So far, conferences on climate change have been expected to arrange a possible agreement for a sustainable system during last decades. But taking into account the last one, the Paris COP21 (Sustainable Innovation Forum), the agreement, which was just reached in December 2015, is still a non-binding commitment, and to be performed with a lack of enforcement mechanisms.

In fact, this agreement comes to endorse the criticism that the concept of sustainable development has received. It would not be but a “vague concept that allowed accommodating and reaffirm the value of integrating environmental concerns into the development agenda“ [Payne, 2011]. Thus we see how the concept of development adapts to the prevailing public opinion in changing stages. However, one cannot forget the fact that these changes were able to put some concerns about the ways of growth or development of the system on the agenda. In the last three decades, we read about a concept called *sustainability* in newspapers, listened to and watched news about it on the radios and TV.

Following the last critiques to sustainable development, some reviews clarified the impossibility of extending worldwide the levels of welfare and consumption of the middle class to the most advanced societies. Then, development acts as a religion that does not address the serious inequalities generated by growth, with an experiment that seriously failed in the last three decades [Payne, 2011]. Given this evidence, inequality becomes one of the key focuses of the current situation, therefore development processes should create mechanisms for a more balanced situation between population groups. That means to cut the accelerated trend that, since the financial crisis, dramatically separates upper and lower classes by incomes, to a degree with no precedents in history. As *Oxfam 2014-2015 Annual Report* points out, only 62 people own as much wealth as the poorest half of the world’s population [Oxfam, 2015].

Sustainability for unbalanced territories

Inequality is a controversial and rich concept and the phenomenon registers structural differences between countries, on races, on gender, but also in spaces within the same countries or between rural and urban areas.

If we take a look at demography in our reference areas, we can observe great unbalanced occupation of territory. As we saw it in Subchapter 4.1, there is a common pattern of population decline in the Heves, Băcau and Castellón rural areas. Table 1 shows different unbalanced numbers between main cities and villages. Although indicators are different, they show a predominant rural territory with three reference cities (Eger, Băcau and Castellón) with less than 200.000 inhabitants.

Table 1. Some demography numbers Source: Author, based on information from IN2RURAL and [Querol, 2012]

	County population	**Main city population**	**Unbalanced approach**
Hungary	Heves county 309.351	Eger 54.609	most villages in northern area <1.000 inhabitants
Romania	Băcau county 616.000	Băcau 144.000	56,6% are rural population
Spain	Castellón province 587.508	Castellón 173.841	82% of villages <3.000 inhabitants

Main cities concentrate high percentages of population in a relatively small territory. The more balanced is a territory, in terms of sustainability, the more rational their fluxes could be. Territory plans should promote life quality in any point of the county or province. Since demographic trends in really small villages may have irreversible demographic points, there is a danger for these rural areas to get uninhabited. The first step to manage a territory, to preserve it, regarding its natural and cultural heritage is to maintain a place for living and working.

In this approach, at any territorial levels, attempts for development occur in different places and societies. Regardless of urban or rural areas, northern or southern countries, new development policies consider *territory* as a main focus. Besides, local development in rural areas should not reduce its focus on isolated local development for each municipality. Villages need to make common strategies in territory since they share the same economy, employment or demographic problems [GATER, 2015]. Some authors go further and regard territory as an *agent* [Albuquerque, 2015] that features action and structural relations in the space.
In the same trend, renewable energies as a technology to foster rural development is shifting the focus from centralized positions to those closer to territories.

So,

> "The need for a territorial approach to promote renewable energies was already underlined by Serafidis et al. (1999), who showed that promotion of renewable energies is a necessary element to change from a centralized approach for the energy sector (which characterizes conventional energy) to a territorial perspective" [Burguillo,2008]

When trying to develop a territory, we sometimes make the mistake of thinking how to help those who live in small villages, in remote places. The territory we live in is a common space where we all live: the ones in the cities and also those ones in the villages. Actions on any point of those spaces have an impact to other spaces kilometres away. And that happens both ways, on actions that concentrate activities in the city and, vice versa, on actions that promote activities in the rural areas [Aparici, 2015].

Conclusions

At the end of this subchapter, let's try to put together some of the ideas described above. Development concepts and their ways of implementation have been diverse. All over these years, learning about the different development approaches can help us to choose among them. Let's put clear that development is not a neutral, well tested evidence. Thus, "rural development is always a political process" [Woods, 2011] where experts have a role. So development or partial approaches to development, as renewable energies themselves, are not capable to guarantee better lives in the rural areas. But still, any action can point in a direction or another. Besides, the process of implementation (more or less participatory with local actors) will point to a particular governance form.

When the *oil civilization* seems to show some ends [García, 2015] for its future, new energies are coming to ensure our comfortable life needs. The construction of the future, partially, has to do with access to the energy from these renewable energies for citizens in a secure way. Is this going to foster more equal societies? How is the access to energy going to spread the territory? The access to energies, the cultural and legal ways to own it, the forms of distribution… mould, too, the structure of a society and a civilization [Mumford, 1945].

As we have seen on development concepts above, transformations of rural spaces could come from outside, in a *modernization ideology* way. But there are some other ways, closer to sustainable development, as those practiced by LEADER initiatives boosted by European Union. So it is possible to take into account people and their territory specificities, to make them participate for a more democratic development. Therefore, beyond economic development, one of the most accurate attempts to **improve lives in the rural areas, and make sustainable their spaces, culture and nature,** is the idea of **social sustainability** [Camarero, 2009] where renewable energies have a highlighted role to play.

In the next subchapter we will describe and develop this rich concept in rural sociology. Further on this module, in chapter 5, LEADER initiatives will also be shown and explained.

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MODULE 1: RENEWABLE ENERGY AND LOCAL DEVELOPMENT

CHAPTER 4. Development in rural areas

Subchapter 4.3. Social sustainability and development. Living and working in rural areas

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Summary: We will conceptualize *social sustainability* as an idea that puts the quality of life in rural areas right in the centre of development. We will describe the *new rural development paradigm* and how it fits into social sustainability. Then, we will focus on labour and the limits of jobs for development, as well as job conditions that lead to sustainable development in the long term. In the last part of this subchapter, we will show a brief panorama about living and working nowadays in rural spaces, just to end up with an experience that gathers the new rural development paradigm.

Social sustainability

The last subchapter covered the concept of development. As we saw, economic and environmental dimensions have been central, mostly related to chances for a sustainable economic growth. Economic development and preservation of natural resources are not enough to preserve the future generations' reproduction, therefore rural spaces have no guarantees to be a living space. Indeed, we understand rural areas as a place for living; with social, economic and a possible closer relation with nature, altogether to develop a project quality life. "Sustainable development is only possible if we understand territories as scenarios for life" [Camarero, 2009]. As it is shown in Table 1, changes occurred on how development initiatives interact with rural spaces and their dynamics.

Table 1. Features of the modernization paradigm and the new rural development paradigm [Woods, 2011]

Modernization paradigm	**New rural development paradigm**
Inward investment	Endogenous development
Top-down planning	Bottom-up innovation
Sectoral modernization	Territorially based integrated development
Financial capital	Social capital
Exploitation and control of nature	Sustainable development
Transport infraestructure	Information infraestructure
Production	Consumption
Industrialization	Small-scale niche industries
Social modernization	Valorization of tradition
Convergence	Local embeddedness

In the new rural development paradigm, we find a proximity to the space and to the actors who live in the rural surroundings. Since one of the risks in some rural areas is the possibility of disappearance in 20 years' time, towns and villages are to be kept alive. That idea of survival does not mean poor conditions; therefore the quality of life of those living there, must follow European society's development parameters [Camarero, 2009]. In our case, are renewable energies a source to improve life in the rural spaces? We can rapidly think about some of their benefits. Some would focus on providing energy supplies to remote spots to make life viable there. But some others would focus on boosting entrepreneur ideas based on sustainable energy. Anyway, each project should have *social sustainability* in mind.

When trying to shape *social sustainability*, Camarero (2009) appeals to Guattari (1996) and his *3 ecologies*. And that means three dimensions: environmental, social relations and human subjectivity. This unaccomplished desire, understood as an earth scale revolution, will always determine the chances for sustainability, at global and social levels in rural spaces.
For [Alario, 2006] cited in [Camarero, 2009] there is:

> "a sustainability basically social and it has a main aim: to fix population in spaces determined by emptiness and demographic atony, progressive aging and, for many towns, there is no guarantee for survival beyond one or two decades, if today's demographic dynamics keeps on"

As we said in previous sections, the rural area is a heterogeneous space in Europe. Hungary, Romania and Spain have differences, and there is also great diversity within each country. However, population draining is shared, in general, in the case of these rural areas. In some cases, warnings for a future of *ghost towns* are not far away considering rural statistics and tendencies.

European efforts on rural development could be felt in all the EU regions during last decades. The previous experiences observed in the EU offer an outlook on rural development. In the first place, employment does not seem to be enough to activate social dynamics in rural spaces. Neither it seems to be attractive enough to engage new settlers or keep new generations in place. We often have the idea to fix population in a place where they produce (job) and reproduce (family, friends...) their lives in a fixed place. And that would be a goal to reverse demographic trends. However, people in rural spaces increasingly have a commuting job. Dynamics in rural areas mean intense mobility, which is another reachable goal to intensify people's flow in rural territories. A high frequency flow of people in rural areas focuses on:

- working in quality jobs,
- living a quality life or
- having high quality experiences through tourism

Labour, as an important part of our lives, is always accompanied by social and leisure factors. Furthermore, a long-term perspective for labour dynamics in rural areas depends on non-speculative investments. Indeed, speculative investments which try to make quick benefit are neither compatible nor coherent with sustainability. Again, renewable energies due to their nature are one of the main tools to make sustainable rural spaces, so to make sustainable territories including cities.

Projects for a social sustainability based on renewables can increase employment opportunities in rural areas. If we try to ensure success in the long-term, jobs should be addressed to women, since this is a key factor to enhance social sustainability. For a demographic reproduction in rural areas, gender equality is to be fostered. Women will choose those spaces that enable a personal development, training and education, participation in the labour market… [Sampedro, 2008]. Therefore, work-life balanced jobs are needed and, somehow, rural spaces can provide some life cadency to benefit from that balance.

Entrepreneurial initiatives and individual ventures fill newspapers, radio and TV news. Every now and then, this news build a representation of the rural space as a place for opportunities. However, regarding rural conditions, any collective joint-venture fosters social sustainability better.

In this sense, and summarizing, the dynamics and processes in rural areas that we should identify and influence, are described as follows [Camarero, 2009]:

- "attraction and establishment of population in dispersed rural areas
- strengthening family and non-family social support networks
- implementation of gender policies and rural development projects
- creating and maintaining quality services
- improving accessibility to actual resources and services for dependent population and for caregivers
- articulation of the economic and social systems of production, distribution and local and regional marketing
- organization of strong social networks, consortiums, projects and collective initiatives"

Life and work in rural areas

Life in rural spaces in Europe shows multiple forms that co-exist and overlap even across the same rural territory. Rural communities are also evolving in a global context of social and economic change and structures. In this context of mobility, rural communities have been challenged in two opposite directions: *out-migration* and *counter-urbanization*. Thus, the access to mobility meant an out-migration to the city or some other countries in some spaces. But it also meant a migration in the opposite direction from the cities, which is a counter-urbanization process, which generally occurs in parts of OECD countries.

Besides the above mentioned mobility phenomena, there is also a third one described as *commuting*, motivated by work, shopping or leisure purposes in a short time scale. When moving larger distance or longer time, it generates part-time residents in the rural spaces [Woods, 2011] [Oliva, 2010]. Commuting is not a migration, but a pendularity movement. Summarizing, as we just described, a flow of people, commodities and information cross rural areas every day.

Mobility, when focusing on migration, is a dynamism all over Europe, and it affects rural areas, too. When observing data, we need to deal with mobility concerning retired people. In central and northern Europe, we can find clear patterns of settling down in some other areas for retirement. This reflects a trend, so we notice rural spaces converted as fully or partly retirement places. So, either in their own countries or the Southern ones, some authors stress the importance of the increasing number of retired people from other countries settling down in rural spaces in the near future:

> "mobilities can also be expected to become increasingly important in rural areas. Many of the migratory movements that reach such areas are relatively recent but will undoubtedly play a decisive role in the future because of their impact on the local demographics and economy. For example, over the next few years the first baby-boomer cohorts of central and northern Europe will start to retire" [Oliva, 2010]

Rural areas are spaces of fluxes and transit rather than a static community. In those territories, people from different background, expectations and interests meet. To live in rural areas rather means to interact and share spaces with groups of diverse origin.

So, what does it mean to live in a rural space? There is, as we highlighted in previous subchapters, a great diversity. In consequence, let's rather talk about *ruralities*. Life in each spot means a social constructed identity. And nowadays identities can be related to a village or shared between several places, since mobility, commuting or migration are one of the rural features. In fact, representations as *belonging to a village, town or territory* are acquiring new meanings. Identity with a place owned by those living there for generations is now a matter of negotiation: a negotiation, which is more or less explicit, and charged with conflict and created interests.

Belongings rooted to the space have multiple meanings. Some relate to cultural aspects or natural heritage. In this sense, there are some identities with deep emotional links to landscapes which new projects may impact. So, conflicts on identity linked to physical space, to beloved landscapes may arise. Again, participatory processes can make the difference for a success project. In the new rural development paradigm (see Tables 1 and 2), working through bottom-up innovation in a transparent, engaging process can move human resources. Some success projects engage inhabitants of a common tradition with the utilization of old knowledge. We present you here a project run by 6 women (Box 1) where innovation comes from tradition, where collaboration is needed and where identities are re-constructed, in a sustainable way.

Sustainability

Xisqueta is the brand supporting a project of local dynamism that we carry out in the Catalan Pyrenees.

The objective is to get the shepherd job back through the promotion of the Xisqueta and Merino breed wool.

Therefore, we help shepherds who protect this breed and we have created a wool craftsmen collective. Our mission focuses on maintaining living ancestral knowledge and to adapt to our contemporary society, under the direction of the designer Marine Mercieux. Design freshens up handcraft techniques and explores the wool potential.

Wool

A local resource

Each Xisqueta item and product are connected by a unique job, an extremely beautiful land, a material protected from oblivion and a talented local craftsmen network willing to work with material coming from their land. In the end, it is just a common sense: What could be better than making the most of the resources, to transform them locally and to commercialize them? Xisqueta loops the loop in this way.

Shepherds

An alive profession

Each year we buy the wool from the Assua Valley shepherds at a fair price. From the beginning we have bought more than 60 tons of wool from 25 flocks with which we realize various transformation and commercialization processes: textile, interior design, raw material for shepherds and building insulation.

Craftsmen

A territory production

We have created a craftsmen network with various people from the area. They form the production team of the project and make the main part of the products of each collection by creating unique masterpieces. They work with different techniques: felt, weaving loom, knitting and crochet needles. Numerous items are dyedwith natural colourants from plants and insects.

Box 1. The Xisqueta Project. Source: http://www.xisqueta.cat/en/sostenibilitat/

Xisqueta project means **endogenous development**: shepherds, wool in the valorization of their culture and traditional ways of life. Their project is totally **embedded in territory**, and making networks beyond villages, on a greater scale to ensure dynamics for success. A chain value process is added when, again, Xisqueta project is using endogenous craftsmen knowledge in an innovative manner. So, different professions come together in a **territorially based integrated development.**

Some invisible nets put a crucial weight on development projects. Actors and agents who develop projects have a baggage and a **social capital** that can make a difference. In this case, 6 women with a multidisciplinary and transversal background (www.montanyanes.net), plenty of energy and a clear confidence in rural chances keep enlarging a challenging project. Altogether, Xisqueta project boosted a new relation of shepherds and craftsmen with global commerce. So, an **information infrastructure** becomes an unavoidable tool to success in an informational society. E-commerce can fix some chain values in the territory and makes a basis for sustainable **consumption**.

Finally, this success made a call for companies to use their knowledge and high quality products in a standard commercial system. Nonetheless, Xisqueta project decided to stay embedded in the territory in a **small-scale niche production.**

We brought this experience, since Xisqueta project enhances a sustainable life and work in remote mountain areas in the Pyrenees. As you can see, among other merits, it accomplishes all features in the *new rural development paradigm.*

Table 2. New rural development paradigm. Source: [Woods, 2011]

New rural development paradigm
Endogenous development
Bottom-up innovation
Territorially based integrated development
Social capital
Sustainable development
Information infrastructure
Consumption
Small-scale niche industries
Valorization of tradition
Local embeddedness

Before we finish this subchapter, we invite you to take a trip on Xisqueta web page (http://www.xisqueta.cat/en/) and think about their chances to enhance their project with renewables and maintain all the sustainable features we have just described.

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MODULE 1: RENEWABLE ENERGY AND LOCAL DEVELOPMENT

CHAPTER 5. How initiatives can promote social sustainability for rural areas

Subchapter 5.1 – Considering actors, factors and agents

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Summary: This document offers an overview of how development interacts with territory, people and images. Images and representations about renewable energies or rural development are complex. Attempts to reduce this diversity are dangerous for project success strategies. We will show some ways of implementing initiatives in rural spaces and how to take the involved actors, factors and agents into account. Renewable energies will also be stressed as a changing factor that affects our lives. This subchapter will identify some of the best ways to collect social data and to capture potential initiatives through participatory processes.

Renewables images and representations

The course developed here focuses on renewable energies. However, the implementation and development of these energies do not occur in a space where relationships and interests are void. It is important to get a closer focus on the inhabitants of different territories in which renewable energies are used, as these technological changes will have an impact on their lives.

Rural areas, where there are no simple sets of relationships by far, represent places endowed with complexity, which is important to grasp before starting with a process of changing the inhabitants’ lives, work and social interactions . Clearly, when it comes to understanding how a renewable energy project will behave in a living space, considerations to be kept in mind must go beyond numbers. So, even though we understand the demographical picture, just counting people is not enough. Thus, it is essential to have a weighted evaluation of the relationship between the various actors, the territory they occupy and their representations about it in the process of implementation and development of renewable energy projects. Besides, it is important to evaluate which groups are going to have profits / losses in this process, how different interest groups interact, etc. when thinking about an improvement and a social sustainability project. Furthermore, any professional project needs an evaluation that monitors the process, namely: the preliminary studies, the project in progress, and follow-up assessment [Aparici, 2006].

Now, we investigate the social field, which is “complex, diverse, changeable, subjective and objective at a time and also thoughtful and deliberate” [González Fernández, 2006]. Rural development projects have an impact on rural lives, since we are on a social field, impacts can change through the project implementation. In addition, each "stage" has its own dynamics, and it affects different groups with different social actors, competing interests or groups. For our case, how important can a renewable energy project be in a rural community? The size of the community is a key factor together with the subjectivities about the project, about their lives in the present and their lives projected to future scenarios with renewable energy.

In these scenarios, shared visions of reality coexist, collide or complement each other. Those visions respond in diverse manners, too, for example, how the ideal ways of using resources, fuel or energy are defined. Sociology conceives the idea of visions as 'social representations' and it assumes forms of practical thinking that enable “communication, understanding and mastery of the social environment” [González Fernández, 2006].

Aiming to reproduce a set of values, attitudes or representations, individuals come to be socialized and they internalized a set of rules that guide their behaviors. This makes predictable patterns of behavior in everyday scenarios. However, social change or short-lived phenomena take part in the social processes as well as transforming the involved agents and scenarios. It is understood that great analysts of the history, such as the engineer Lewis Mumford (1945), described the energy shifts associated with changes in civilization. Consequently, the capacity of energy for sustainable development and for the transformation of the social frameworks contains changes in power relations. Indeed, new forms of energy production or distribution may provoke variations among agents’ roles in a social space. Before the arrival of elements that can change, to a greater or lesser extent, rural communities, residents are lined with a variety of opinions, representations or speeches. “The assignment of individuals, businesses or organizations to one of these existing speeches [representations] will be socially mediated, among others, through their geographical location and the impact of interests” [Aparici, 2006] individually or collectively to a change that may benefit or affect your role and position in this scenario.

Following [Mormont,1987] and substituting the concept of 'natural park' with that of 'energy', we paraphrased a vision of the process of implementing renewable energy projects right here:

> “So the representations of the 'renewable energy' [...] not only justify its implementation and management as a legitimate instrument of development, also legitimized a kind of social organization (and economy) that assign a role and status of those proposed application.”

Again, policies on rural spaces are not neutral and the reactions of the inhabitants will depend, among other factors and as literature tells us, on a more or less democratic process to be opened and dialogued with them.

Representations are not ‘for’ or ‘against’

Manuel González Fernández raises the 'deconstruction' of rural development essential, and usually, linked to economic, political and administrative developments; the author proposes, instead, a model of transversal understanding, including the "demographic, economic, cultural, political and social" dimensions. To make that possible, he highlights “[r]ecommendations to incorporate the positions of the agents (to study) and environmental management” [González Fernández, 2006].

It is essential to identify the "agents embedded in complex scenarios" for understanding this complexity and social plurality better. So far, the description of rural areas as diverse development scenarios for renewable energy has always been conceived far from any simplistic view. We, therefore, emphasize the dangers of any simplification of the rural areas and their development through renewable energies. A typical mistake relates to the reduction to opposing positions: there / here or residents / outsiders ... this reduction carries an “illusion of transparency” [Bourdieu, 2008]. But, these schemes are to be broken and to move towards more reflective visions.

Regardless of the diversity of interests in the rural areas, there are some beliefs in the reviewed literature on the benefits for rural areas of the implementation of Renewable Energy Sources (RES), which opens a real chance for development.

> “RES can make a decisive contribution to regional sustainable development in depressed rural areas. The renewable energy projects can promote sustainable rural development through the introduction of an alternative or complementary ways to traditional farming activity. This contribution to the overall sustainability takes place in three dimensions (economic, ecological and social)” [Burguillo, 2008].

However, the ecological factors and inputs that Georgescu Roegen (Subchapter 4.2) requested for environmental sustainability are not covered by these lines of development. Thus, we are approaching here, to some extent, a lighter or more relaxed version of environmental sustainability. In this sense, it is hard to conceive any project not linked, at any point, to non-renewable resources. Globalization and intense mobility of people, products and information make almost impossible to develop a sustainable system in present times. That means, as we open the scope to a global scale, an integral agreement gains necessity about a dramatic cut on the consumption of fossil resources.

Factors involved: (1) population, lives and work.

In this section some factors will be highlighted in order to identify some of the key elements involved in rural space dynamics. We will pay attention to the population, lives and work. Although these three social factors do not exclude any other identification, we focus on them in order to engage them to the energy factor. The importance of any factor depends on the territory and its social, economic and environmental features.

Population or demographic impacts (connected also with **labour** and **life**) are one of our first objective views of a social territory. As we act in smaller villages, impacts tend to be much more important. In this case, we think, of areas or municipalities suffering from a critical level of depopulation. Creating jobs and fixing people in the territory[1] is seen as one of the most defining rural development objectives. These two are being used as the basic need to keep rural areas alive. We see, however, that the difficulty lies, among others, in the ability to generate jobs well linked to a chosen lifestyle. And this is where the issue becomes really complicated. Life projects can be individual, but, as usual, they are accompanied by others. More closely, we talk about families: couples, couples with children. But family units are related to their families in a broader sense. And on the other hand, we perceive ourselves and

[1] Previous subchapter explained how the population flow, understood as living some days in the rural, working some days in the rural or consuming the rural (tourism) is also a goal to enhance rural dynamism.

our friends, coworkers, or other relationships connected with leisure activities, etc.

In demographic structures, it would be useful to look at the generations. First of all, we have to observe the different weights of different generations involved in that rural area. When doing that, we must be aware that many active people are not registered in demographic statistics. Again, mobilities make the panorama richer and more complex.

An accurate picture of the generations shows us potentials for development. Along with this, the age of people who join rural areas is another factor that, in the case of very unbalanced population pyramids, can redirect to the demographic viability of the environment to some degree. How many youngsters there are, and furthermore, how gender structure and trends behave, are crucial for social sustainability. And in many rural areas of southern Europe, as we just highlighted, the gender issue becomes the key factor to influence the renewal of these pyramids. A territory and its initiatives, with a capacity to generate qualified female employment, attractive working conditions and a work/life balance will be able to ensure demographic sustainability to a greater extent at the same time.

To begin with, let’s consider a previous approach. In this sense, we encourage you to make a diagnosis of qualification levels, to search potentials for initiatives or detect any training needs. Those are, roughly, some demographic clues when approaching to rural areas. And it could be useful when trying to fix people already living there. In some cases, we are interested in pulling people from other places to live in the rural areas. So, a question arises: what kind of people are going to be incorporated to live and work, or to work and partly live in rural areas? The vital project, as noted in subchapter 4.3 should enhance the arrival of couples with children that result in -that desired status for some rural areas- social sustainability.

Qualification of jobs, job quality thereof, will define the profiles of the people who live or transit through the rural areas driven, among others, by the opened renewable opportunities.
Another concern, given the exodus that has occurred in many rural areas, is the identification of profiles of workers who may have former identity links with a certain area. The representations of life in rural areas are sometimes reproductions of a *rural idyll*: ideal and homogeneous and harmonic life close to the nature, which can appeal to some city dwellers, “[f]requently inspired by perceptions of the 'good life' in to more remote countryside” [Short, 2006]. People who left their rural village as children or youngsters may know better what life can be in the rural areas. However, the forms of representation of the territory of those with previous identity links also contain various representations which sometimes become idealized, too. In this sense, nostalgia child experiences, “especially when they come largely from childhood, can be heavily nostalgic and idealised and may prove to be a very poor basis for present-day living” [Halfacree, 2012]. Let’s not forget that, commonly, motivation for living in a place is not the same as a child and as an adult.

There is not, in any case, a matter to ask for certificates of rural pedigree, since it is more attractive to vital projects that can take root in that space, creating places rich to develop life, work, cultural affinities, social relations, environmental richness, and quality family conditions ...

Thus we see the demographics of rural areas being difficult and complex: it is not only because of the need to reverse trends in many cases, but also the richness of conditions that surrounds it. As you read, we presented population trends together with representations, desires, opportunities, future or past projections that can be useful to understand rural areas, but also to make successful strategies for renewable energy projects.

Factors involved: (2) energy

If our main objectives are related to **energy**, briefly let’s think it overhow this factor correlates with those people involved in rural areas. Access to energy, obvious to say, is a vital element for our daily work. Overall, in Europe, energy poverty may affect nearly 11% of the EU population, “it is particularly prevalent in Central Eastern and Southern Europe” [Pye, 2015].

When observing the different EU Member States, we find that the three members evolved in this Erasmus+ course stress their situation in energy poverty. In some practical thoughts derived from this course, the next question rapidly arises: how renewables have the potential to mitigate this *poverty risk* for Hungarian, Romanian and Spanish citizens living in rural areas? Energy access for citizens has become a big issue in previous times, especially since finance and economic crises began in 2007. In the last years, we saw TV news, newspapers and listened to about energy conditions and serious problems to heat homes on the radio. Following the research study *Energy poverty and vulnerable consumers in the energy sector across the EU: analysis of policies and measures* [Pye, 2015], funded by the EU, we observe the next figure with average percentages of people with arrears on energy supply bills. Figure 1 shows a range of risks for European citizens on a basic supply as energy at home.

AROPE & arrears on bills (EU-SILC)

Figure 1 Energy poverty. Source: [Pye, 2015]

We can notice in Figure 1 that risks of poverty are real and they allow us to stress the idea of renewable energies as an opportunity to, at least, reduce this risk. The liberalization of the energy and power companies and the liberalization of self-production and consumption have been differently addressed by EU Member States. Thus, the possible answers to the above question are conditioned by the energy regulatory frameworks in each of the three countries involved here.

The degrees of support for renewable energies are different in each country, although the percentage for 2020 to move from 9,8% renewable to 20% is an objective for the entire EU. The possibilities of generating a more or less centralized, a more or less autonomous production, will have effects on more or less equal distribution of the income. Again, we may be observing a change in energy sources that might affect to power relations in multiple levels.

Another aspect to consider is the security of energy supply and if a source close to the production site thereof may represent greater security for inhabitants in rural areas (and urban areas too). Of course, this issue happens to be more important in a geostratetic scope.

As sociology often reminds us, things could be in a different manner [Marqués, 1980] that we are used to seeing it. Generally, changes in rural life provoked by renewables will be also proportional to renewable size projects. We have considered actors and agents as people involved in rural spaces together with territorial factors. In our case, energy arises as a factor when there are previous energy sources in rural areas and we can project changes through renewables.

Some methodology of working in/with the rural areas

Lives and jobs in the rural areas can be improved by a renewable energy project involved. Those who live in rural areas have a voice to be listened. So, as we presented it before, there is a diversity of interests or representations on what renewables mean or how *my* village can be improved. Previously to making decisions that will affect inhabitants, social debates are highly recommended. The participatory processes are themselves a tool to identify needs and better options for boosting some or other project contents. Of course, there is always a consensus to be achieved through negotiation on projects that look after inhabitants needs and rural spaces social sustainability. How to start that process is probably a question you are asking yourselves at this moment. As we have stressed before in this module, there is an accumulated experience on rural development. One way of practicing this participatory, bottom-up development is the European Union's adopted model on rural development. It began after the 1996 European Conferences of Rural Development in Cork (Ireland). Two decades later, Europe is a tested field where the so-called LEADER programme or Community-Led Local Development (CLLD), operated in a diversity of examples all over Europe.

The spread of LEADER programme in European Union and other *endogenous rural development* forms have produced uneven results. Endogenous development [Woods, 2011], has to be considered when talking about development in rural areas. Nonetheless, evaluations of LEADER initiatives agree that social networks have been reinforced as more democratic during the processes. LEADER projects act in rural spaces through Local Action Groups

(LAGs). These groups are called to provide specific projects to enhance social sustainability in rural areas. They are called to work in a participatory manner to reinforce governance in rural spaces. We understand governance here as a process to engage citizens on their own institutions (local, regional…) in order to enhance the quality of democracy and deep in a more participatory process for decision-making that affect their lives.

LEADER is the biggest display on rural development we have in Europe. However, other administration levels are staffed with really interesting agents. In this sense, Rural Development Agencies are diverse institutions all over Europe. Some are linked very close to agriculture, and some others act in a variety of sectors of the rural areas. Professionals who develop these jobs are either related to local institutions or some other regional levels. Our experience shows us that contact to rural reality of these workers is a key information source about the territory. Furthermore, they develop functions in the rural beyond de bureaucracy and administration daily routines.

> “The local development agent, logically, has the task of demonstrating latencies on his/her territory of action. Development latencies, we would say, to develop the local. The mission leads immediately to deal with the sense of development: what is development, which is developed and, above all, what develops.” [Ginés, 2008]

So there are, in various institutional settings, Territorial Development Agencies, Local Rural, Local Development Agency or attached at various levels of the administration and a body of professionals who work there. Some of these agents lead or may lead local / rural development in the territory. They lead it combining knowledge of the territory on which they work and, on the other hand, technical knowledge with a professional and complex vision of their environment. In many cases, more or less experience in this type of job position could be a point to underpin development. But, in any case, their function in the rural space will provide first-hand information about the complexity they work on.

Unfortunately, this Rural Agency jobs are not spread to each municipality. Either through them or by ourselves, when detecting latencies, there are often key figures in many municipalities of rural areas of which role can liaise with the community. Regardless of one or another source, we stress the quality of information here, so we can make an initial diagnosis of local reality. There are several types of diagnoses: some more participatory and others closer to an observation and less consensual information with stakeholders. Some of these methodologies would be Participatory Rural Appraisal (PRA), maps for relationships or sociograms or, other better known, as the SWOTs (strengths, weaknesses, opportunities, and threats) analysis. In a more or less systematic way, this information allows us to get closer to the territory to which the initiative will develop staffing renewable energy. The identification of needs and development potential for the institutions, housing, the economy or services of particular rural areas is a task that, in general, can come clearly provided by these agencies and development agents.

Those who live in rural areas-in the diverse ways we described in subchapter 4.1- can be informed of the initiatives and these can be discussed by democratic and participatory processes. In fact, the idea of effect and impact on rural areas entails a vision of the initiatives as an element of development to assess usually in a subsequent stage. Consequently, community participation is reduced to the consequences of the implementation and development. However, the most democratic and informed participation, as enacted from Rural Development initiatives of the EU and local community-driven development "(DLCC) represents a shift towards a horizon of development more democratic and participatory and rural areas 2014-2020 DLCC (LEADER) [which] continue to be a compulsory part of rural development programs financed by the European Agricultural Fund for Rural Development EAFRD" (ENRD, 2014).

Figure 2 gathers some key agents in rural areas, it also adds a method to analyze the information collected. Furthermore, what we also try to emphasize here is how participatory styles, democratic modes following LEADER perceptions make the process a tool to foster the quality of life. So living in rural areas would mean to participate in public decisions in community life and taking part in public policies. Then, living in rural areas would become a more democratic way of life.

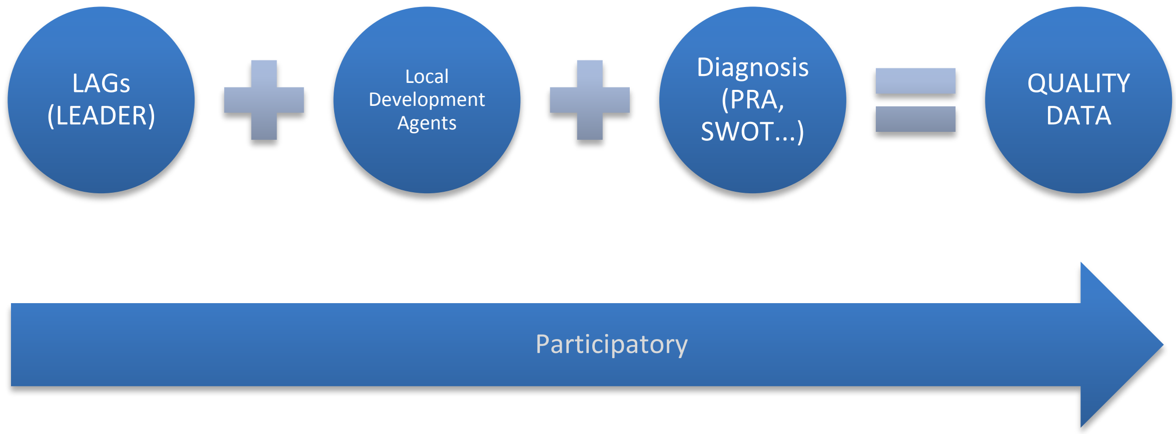

Figure 2 Making diagnosis. Source: Author

With all this, a first step towards a positive reception of renewable energy projects can be achieved. Indeed, you can go through the identification of the most pressing needs or those that can generate greater synergies and dynamic economies with the aim of improving welfare on a territory. Besides, to identify a development project that benefits rural community to be supported by renewables can be one of the images to guide your implementation ideas.

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MODULE 1: RENEWABLE ENERGY AND LOCAL DEVELOPMENT

CHAPTER 5. How initiatives can promote social sustainability for rural areas

Subchapter 5.2. Renewables as an opportunity for social sustainability and development in rural areas

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Summary: There is an urgent demand on changing from fossil fuel to renewable energies (RE). Climate change and the objectives marked by EU are a fair wind to promote renewables as an impetus to enhance life in rural space. Former experiences show us successful ways to implement renewable energies in rural areas. Nonetheless, RE by themselves do not ensure success for social and rural sustainability. Any of our actions in rural spaces should be registered by evaluation methods, since that provides a feed-back to improve projects in the meantime we share our experience for future initiatives.

Renewables as an *attitude*

Climate change is a topic that is already affecting our economy, our way of producing food, or will influence migratory movements in the present and future. Some consequences of the *oil civilization* foster multiple drafts for an irreversible stage where renewables are called to play a key role for energy supply.

Rural spaces have a chance to enter these new stages as far as it could also be a great benefit for its social sustainability. Thus, beyond a laboratory for a new era, rural areas demand guarantees to keep evolving their ways of life. And, as we saw in previous subchapters, that does not mean to preserve a static social structure. It rather means a development from an already diverse and heterogeneous society, where gender equality is required and the quality of life points to enhance social services, to improve environment and to enrich dynamics on culture, leisure or consumption.

Rural spaces have low density population, and that means an opportunity since "installations have to be located where renewable sources of energy are available and possibly abundant, and also where there is space to host them. For all these reasons, low density areas – i.e. rural regions – are more likely to have these characteristics" [OECD, 2012].

It is worth pointing out, in this regard, that initiatives should go along with the necessary coherence. For a sustainable development process, they "should incorporate the choices [...] criteria of environmental sustainability, which is a commitment to the future generations by lasting business and territorial competitiveness and its dynamism" [Albuquerque, 2015]. So, if it is to incorporate business dynamics, long-term energy, let's say renewables can be a good choice. Speculative and extractive energy options foster some kind of development, an alternative not without controversy and related risks even though they can create, at least, some jobs for a limited time in the area. But speculative investments should keep out of the development processes we describe here. It is understood, again, that sustainable development is built from below, together with the actors and agents in the territory. The decision to include renewable energies in their ways of life, at work and in the energy supply to their homes and businesses ... can be a set of, more or less, beneficial actions for social sustainable development in that territory. A first step, reduced to the scope of implementation of the energy facility, involves the incardination of this initiative to the territory, its landscape, its people, its institutions, etc.

But, just as discussed in subchapter 4.1, rural societies are complex and require a challenging relationship, negotiation and consensus as long as we think about sustainable development. The initiatives, then, need to keep up with those challenges. Along with the introduction of renewable energies in a particular territory, it requires a

> "recovery of the local natural and cultural heritage as an important asset of territorial development, the promotion of renewable energies, efficient use of natural resources, including the use of water and materials, promotion of organic production and eco-efficiency of production (industrial ecology, cleaner production, etc.), as well as promoting proximity between production and local consumption […] different forms of sustainable consumption, the efficient management of urban and rural waste and promoting education about sustainability among citizens, businesses and households in the territory". [Albuquerque, 2015]

The importance of creating opportunities in rural spaces has been stressed several times in chapters 4 and 5Since current dynamics concentrate opportunities in the cities, large areas in the same territory are maintained, most times, in the worst part of job creation. Following OECD (2012) report, some specific factors to bear in mind are really coherent with those described for social sustainability in rural spaces. Let's highlight some of them [OECD, 2012]:

- Embed energy strategies in the local economic development strategy so that they reflect local potentials and needs. […]
- Integrate RE within larger supply chains in rural economies, such as agriculture, forestry, traditional manufacturing and green tourism.
- Avoid imposing types of RE on areas that are not suited to them […]
- Focus on relatively mature technologies such as heat from biomass, small scale hydro and wind […]
- Create an integrated energy system based on small grids able to support manufacturing activities.
- Recognise that RE competes with other sectors, particularly for land. Poor siting can adversely affect local residents and disrupt tourism, which is typically a much larger source of income and employment.
- Assess potential projects using investment criteria, and not on the basis of short-term subsidy levels.

- Ensure local public acceptance by ensuring clear benefits to local communities and engaging them in the process: this is crucial as local opposition can slow construction and may make introducing future RE projects even more difficult.

The last factor should guide a participatory process, avoiding up-down policies. This process would guarantee inhabitants acceptance by engaging them to the project. It can also help to identify potential ideas and projects to enhance social sustainability in those places.

Clearly, any rural community should be able to decide on its own ways of development and those most sustainable in the long term. In this sense, isolated initiatives are not capable of bringing the necessary synergies to multiply in the territorial framework. An appropriate developing consensus can multiply sustainable initiatives (commerce, tourism, living and working …). So, territorial projects that mobilize for social sustainability: involving human resources, education, with new approaches to a better quality of life preserving nature… have more chances to engage actors rather than isolated business initiatives. Being part of a project means a set of attachments to take into account. Renewable energies usually come together with some ecological consciousness. This attitude towards nature, climate change, renewables or recycling, among other elements, can stimulate projects involving renewables. On the other hand, negative attitudes could hinder the progress or even impede it. So, changing representations about renewables may be a strategy to ensure success, too.

Projects including renewables have some exemplary favorites when EU institutions keep financing the energetic change. In this sense, renewables foster productive diversification, enhancing competition and reducing income polarization.

In a different way, enhancing commercial dynamism, some authors research about impact on consumption in rural places. As Burguillo and del Río show [Burguillo, 2008], an interesting research provides data about impacts of different renewable energies on local spending. Results tell that “multipliers coefficients are low for wind (1,00 to 1,09), higher for small hydro (1,13 to 1,25) and substantial for biomass (1,16 to 1,61)”. However, some authors are cautious about generalizing these results.

Challenges to improve social sustainability and a more preserved nature on rural and, of course, in urban areas is a nice objective for those involved in this course.

Case studies

If you take a look at literature on renewable energy and development, many small initiatives around the world have been reported and well-documented. Some of them have a common public investment policy. Therefore, conditions for a long-term, participatory and social sustainable development should not usually attract, so far, speculative and large-scale private finance investments. Changing from *oil civilization* to a sustainable one means an enormous policy effort. As we know, the future of our lives in this planet depend on that. And big energy companies do not seem to move in this direction. The next subchapter will show you some funding lines on rural development and renewables.

At this point, we will illustrate you with some experiences suitable for rural development. We have just selected the specific initiative for each case. For further reading, you can visit this document [OECD, 2012] to extend all factors involved in case studies.

Many rural communities are themselves producing RE and taking advantage of available subsidies. For instance, in Abruzzo (Italy) a small mountain municipality of less than 1.000 inhabitants has installed PV panels on the top of the roof of the old school. The installation allowed the municipality to profit from Italy's very generous 2009/2010 FITs (Terzo Conto Energia) for PV electricity. Using these subsidies, the local government refurbished the school building and improved the school's overall quality and safety, also protecting it from closure. There are also examples of rural communities implementing large-scale RE deployment to generate a very large income. The Shetland Islands in the UK largely depend on the royalties paid by the oil companies that extract petroleum and natural gas from the North Sea. The royalties are used to produce key public services to ensure the sustainability of this remote community. However, realizing that the oil and gas reserves will not last forever, the Shetland community has decided to invest in wind energy through a charitable trust. The Shetlands will host a large wind farm (around 120 turbines) that will generate a constant flow of electricity. By tapping into the UK's green certificates, the income should buffer the expected decline of the royalties paid by the oil industry.

Box 1 Local communities taking the initiative. Source: [OCDE, 2012]

Box 1 tells us a set of experiences about how remote areas can benefit from producing renewable energy. Thus, following some of the cases exposed, OCDE report (2012) highlights community empowerment through renewable energies as shown in Box 2.

RE policy can build capacity in rural communities. In several case studies, RE policy has invested in capacity building at the local level to help rural communities deploying sustainable energy according to their needs and potentials. For instance, in Abruzzo and in the island of Lolland (Region Zealand, Denmark), municipalities are involved in the European network known as the "Covenant of Mayors" (see case study assessing Abruzzo). This network is funded by the European Commission's Directorate-General for Energy to capitalize on local governments' ability to involve citizens and affecting citizens' behaviour. Municipalities participating in this network agree to set very ambitious targets for RE in their territory. They are expected to prepare an assessment of their energy needs and present an action plan in which RE gradually replaces conventional energy sources. In the case of Abruzzo, the regional and provincial governments provide rural municipalities with assistance, expertise (energy agents), and capacity building actions. In the same vein the Scottish government supports rural communities engaging in RE deployment through the Community and Renewable Energy Scheme (CARES). The aim of this programme is to promote local ownership of RE projects. It employs local project officers around Scotland to help rural dwellers with the process of applying for funds and developing installations that fit their needs [...]

RE policy has stimulated citizen engagement in several regional case studies. Several rural regions have developed specific institutions, organisms and authorities to deal with RE deployment as a reaction to large investment and national policies. This dynamism has been observed both in regions where local communities fully support RE deployment and in regions where populations oppose to specific developments that are perceived as a threat to their well-being or key assets. In general, our field research reveals a new governance model in which citizens (individuals or small groups) are highly vocal and visible (through the Internet, for instance) and do not accept to devolve their decision-making power to the traditional institutions, including local governments.

Box 2. Community empowerment. Source: [OCDE, 2012]

Even though this report exceeds European Union experiences, our selection goes through European cases. The above examples show successful projects inside the EU, but difficulties to enhance rural development are present in any case. Approaches to rural development through RE must be accurately tailored to place and community. Since we are learning from former experiences displayed in this course, our future experiences can help others. In this sense, any social and technological project is a process to learn from. Scientific community, due to its nature, learns better by registering processes. Diverse methodologies have been employed in social sciences to follow –in some rigor degree- how a rural development process occurs.

Evaluation - Registering the process

Methods to register or evaluate a process are multiple and all of them try to obtain useful feed-back from a diversity of audiences. In-depth explanations for each method exceed the objectives of this course. Nonetheless, students should be aware that they can contribute to improve rural development in the future by doing so. Besides, to follow an evaluation programme urges us, among others...

a) To register factors that help us in following phases of the same project.
b) To manage same difficulties and how they were solved in previous projects
c) To be aware of how objectives are achieved
d) To capture actor and agent representations and how they change
e) To register benefits or unfit impacts on rural community
f) ...

Evaluation processes may focus on client, public, project coverage, outcomes or the planned objectives. In rural development, monitoring processes which register data from the very beginning are highly recommended.

A basic distinction can subdivide evaluation between **formative** and **summative**. Formative evaluations reinforce or enhance the project being evaluated and summative evaluations, on the other hand, observe and register the effects or outcomes of some object. Box 3 illustrates a set of evaluation types.

Formative evaluation includes several evaluation types:

- **needs assessment** determines who needs the program, how great the need is, and what might work to meet the need
- **evaluability assessment** determines whether an evaluation is feasible and how stakeholders can help shape its usefulness
- **structured conceptualization** helps stakeholders define the program or technology, the target population, and the possible outcomes
- **implementation evaluation** monitors the fidelity of the program or technology delivery
- **process evaluation** investigates the process of delivering the program or technology, including alternative delivery procedures

Summative evaluation can also be subdivided:

- **outcome evaluations** investigate whether the program or technology caused demonstrable effects on specifically defined target outcomes
- **impact evaluation** is broader and assesses the overall or net effects -- intended or unintended -- of the program or technology as a whole
- **cost-effectiveness and cost-benefit analysis** address questions of efficiency by standardizing outcomes in terms of their dollar costs and values
- **secondary analysis** reexamines existing data to address new questions or use methods not previously employed
- **meta-analysis** integrates the outcome estimates from multiple studies to arrive at an overall or summary judgment on an evaluation question

Box 3. Evaluation: formative and summative types. Source: [Social Research Methods, 2015]

Evaluation methods can help to improve the project itself. Therefore, LEADER experiences (see Subchapter 4.3) require an evaluation of the process to deliver to the EU institutions. Participatory degree has been one of the transversal indicators for LEADER rural development processes. Following Box 3, a variety of types can be used to collect data. Therefore, beneath that ***process evaluation, needs*** appear to identify (training needs, e.g.), ***impacts*** on the community or demonstrable target ***outcomes*** achieved when RE will be working. Each project is a diverse reality to approach, so you can use in various ways and different types in order to enhance a project or observing the effects and impacts on rural spaces and communities.

We can collect data on any of these types by observing and registering phenomena. **Techniques** register diversity in a diverse manner. We can use **quantitative** or **qualitative** techniques. In the first case, we can apply surveys in order to quantify and standardize an experience, fact... When using qualitative techniques, we try to understand representations or to explore discourses around a problem, process... through focus groups or in-depth interviews[1].

In some initiatives as LEADER, evaluation is a requirement. We encourage evaluating any of our actions in rural spaces choosing a proper method, since that provides a feedback to improve projects on the mean while we can share our experience with future initiatives.

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MODULE 1: RENEWABLE ENERGY AND LOCAL DEVELOPMENT

CHAPTER 5. How initiatives can promote social sustainability of rural areas

Subchapter 5.3. European financing for Renewable Energy and Rural Development

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Summary: To finish the chapter, we will finally focus on the different regulatory frameworks that can be found in the European panorama regarding both renewable energies and rural development. Public investment is really needed in sustainable rural development and RE display into those territories. We present some funding lines and links to visit in order to find best funding mechanisms for your projects. It will be easy to check the big diversity of regulations that have been passed in the different State Members during the last years, making it clear that there are still sectors in which the European authorities do not have much to say against local politicians.

Financing for Renewable Energy

The different financing and support mechanisms deployed for renewables around the world were already introduced and also described in subchapter 2.3. The cited different support policies have been mainly applied to big renewable energy plants envisaged to maximize investments. However, at this point, it has been considered interesting to highlight, the specific regulations that have been progressively implemented not for large but for small renewable energy installations in connection with the overall goal of this course and the framework it embraces. This type of installations, promoted by small investors instead of big corporations or capitals most of the times, are also much related to the actual distributed paradigm philosophy and to renewable installations in rural areas. Likewise, most of these installations are being developed nowadays to be used for energy self-production and self-consumption.

In fact, it seems clear that with the current evolution of the system, as grids and markets become smarter around Europe, this emerging model of self-consumption is set to play a growing role in reducing consumers' energy bills, particularly of commercial consumers, and promoting market integration of variable renewable electricity. Member States are more or less proactively trying to anticipate and accommodate the emergence of this self-consumption model, while promoting energy security, efficiency and decarbonisation.

In this sense, the European Commission has already published some reports; as the one referenced “Best practices on Renewable Energy Self-consumption”, that approximately summarize the current state of the regulations in this sector around Europe. In the same sense, in this subchapter, we introduce a comparison table (Table 1) that collects some of the main points regarding self-consumption regulations in some of the main Member States, or at least, those that have legislated and present a significant degree of activity in the sector. For the sake of making a comparison with a place that could be considered a reference supporting renewables, the characteristics of the policy support to self-consumption in California (USA) has been also introduced in Table 1. Note at this point that California is the best market for self-consumption out of the 43 north-American states that have already regulated their own self-consumption Net Metering framework.

But, what is Net metering? According to Wikipedia, Net energy metering is a service to an electric consumer under which the electric energy generated by that consumer from an eligible on-site generating facility and delivered to the local distribution facility may be used to offset electric energy provided by the electric utility to the electric consumer during the applicable billing period (Figure 1).

Net metering policies can vary significantly by countries: if net metering is available, if and how long you can keep your banked credits, and how much the credit is worth (retail/wholesale). Most net metering laws involve monthly roll over of kWh credits, a small monthly connection fee, require monthly payment of deficits (i.e. normal electric bill), and annual settlement of any residual credit. Unlike a feed-in tariff (FIT), which requires two meters, net metering uses a single, bi-directional meter and can measure current flowing in two directions. Net metering can be implemented solely as an accounting procedure, and requires no special metering, or even any prior arrangement or notification.

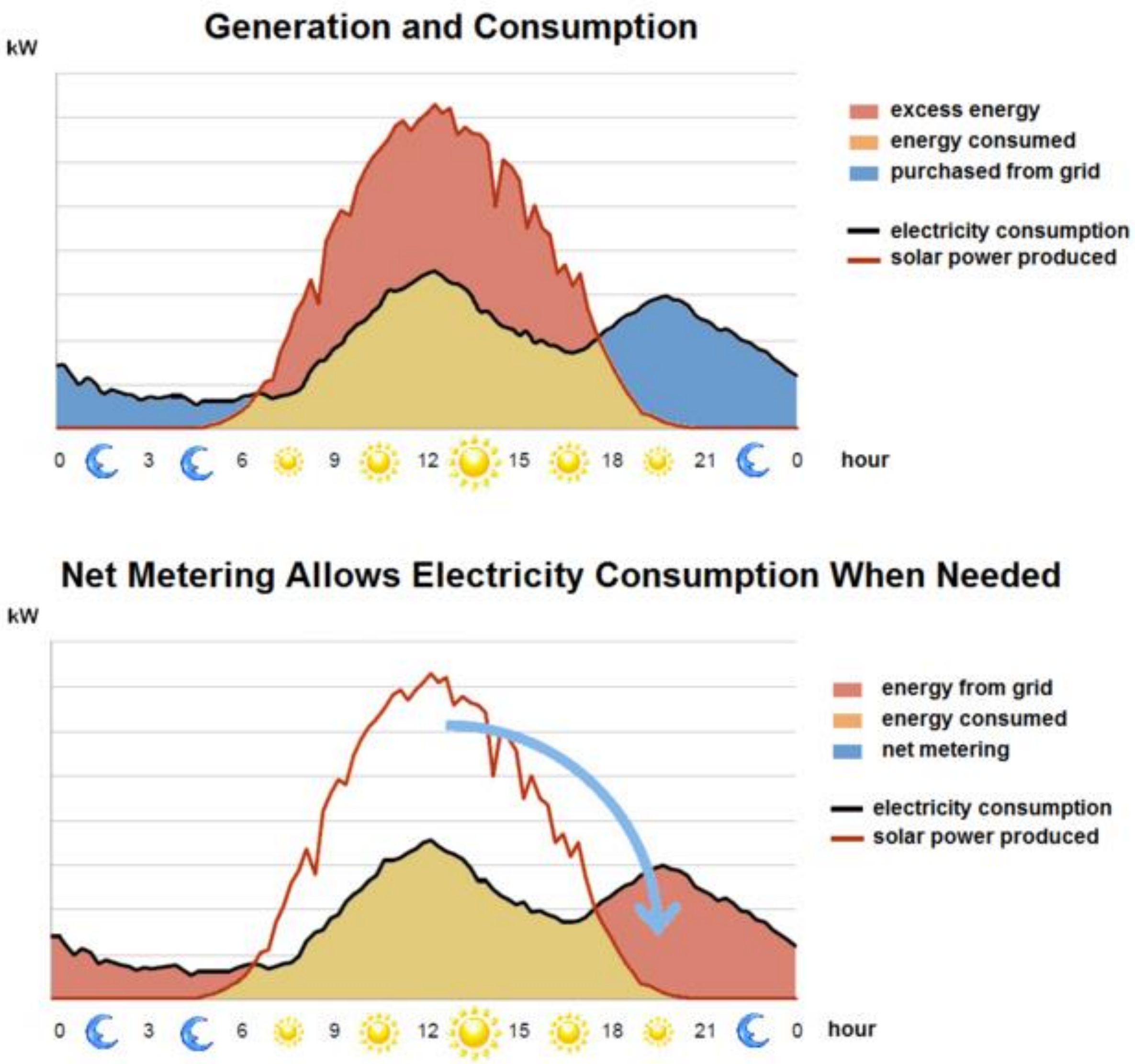

Figure 1. Daily net metering, by Delphi234 [CC BY-SA 3.0], via Wikimedia Commons.

Then, coming back to Table 1, note how the different Member States have introduced more or less favourable legislations towards self-consumption. This can be observed along the various characteristics collected in the table: there is or is not a right to self-consume in the country, if there are or are not revenues for the self-produced and self-consumed energy, if there are charges associated to the financing of the T&D costs, if there are revenues for electricity injected into the grid, the maximum timeframe allowed for credit compensation, if owners can compensate geographically with different installations, if a third party ownership is allowed or not, if there are grid operation codes limiting self-consumption installations connection and additional taxes; other enablers of self-consumption; and what is the maximum rated (nameplate) power of the installation allowed for inscription as self-production plant. From all this information, it follows that the Spanish policy framework (just passed in October 2015) is, by far, the strictest among them.

Although it is not included in the table, in this sense, one can consider interesting information regarding another European country which presents a regulatory framework on self-consumption, Portugal. The main characteristics are, in this case

- Net metering is allowed and the surplus production is paid up to 90% of the market price.
- It allows the development of consumption of up to 1MW without any toll.
- It favours self-consumption installations associated to electric vehicles or the installation of solar thermal energy.
- No restrictions to the introduction of storage systems.

Therefore, although the European Commission looks sympathetically towards self-consumption installations and promotes their deployment, there are important variations in the local legislations. What seems clear and must be determined once again prior to close this module is that with renewable technologies being competitive for residential and commercial applications in most European countries nowadays, investors need a secure political framework for generation, self-consumption and storage of renewable energy.

Table 1. Self-consumption/self-production regulatory framework around the world. Source: ECLAREON/CREARA

	Belgium	Den-mark	France	Ger-many	Italy	Spain	Switzer-land	Nether-lands	UK	Californ ia
Right to self-consume	Yes	Yes	Yes (but no specific law)	Yes (real time)	Yes	Yes	Yes	Yes	Yes	Yes
Revenues from self-consumption	Avoided cost	Avoided cost	Avoided cost	Avoided cost	Avoided cost	Avoided cost	Avoided cost	Avoided cost	Avoided cost + generation tariff	Avoided cost
Charges to finance T&D costs	None	None	None	None	None	A fee per consumed kWh	None	None	None	None
Revenues from excess electricity	Net metering	Payment (lower than cost of retail electricity)	FIT (above cost of retail electricity)	FIT (lower than cost of retail electricity)	Net billing: energy quota + service quota	None	Payments	Net metering (for up to 5MWh/year)	Generation tariff + export tariff	Net metering
Maximum timeframe for credit compensation	1 year	1 hour	Real time	Not applicable	Quarterly yearly balance	1 year	Not applicable	1 year	Not applicable	1 year
Geographical compensation	On site only	On site only	On site only	On site only	On site only	On site only	Virtual net metering	-	-	Virtual net metering
Third party ownership	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes
Grid codes and additional taxes	Standards and grid codes requirements	Grid code requirements	Grid code requirements	Grid code requirements	Not applicable	Grid codes and taxes on generation	Grid code requirements	Not applicable	Not applicable	Not applicable
Other enablers of self-consumption	TOU tariffs	TOU rates	TOU rates	Storage incentives	Not applicable	TOU rates	Demand side management incentives	Not applicable	Not applicable	Not applicable
System capacity limit	10 kW (5 in Brussels)	None	Not applicable	None	200 kW	100 kW	None	15 kW	30 kW	1 MW

Financing Rural Development

Rural development is the “second pillar” of Common Agricultural Policy (CAP) in the European Union. Current period started in 2014 and will last until 2020. Three long-term strategic objectives have been stressed for this period:

- fostering the competitiveness of agriculture;
- ensuring the sustainable management of natural resources, and climate action; and
- achieving a balanced territorial development of rural economies and communities including the creation and maintenance of employment.

For any of those, renewable energies can suit as a more sustainable supply.

What kind of measures can be supported? European Commission web page helps us to conceive future supported projects.

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Investments in Physical Assets and Farm and Business Development

Investments in Physical Assets can be supported in order to improve the economic and environmental performance of the agricultural holding and rural enterprise. Farm and Business Development is a business start-up measure for non-agricultural activities essential for the development and the competitiveness in rural areas. Both measures can offer support possibilities for renewable energy production in a complementary way.

Some examples of types of operations that may be supported:

- Processing of agricultural biomass for renewable energy by actors other than agricultural holdings.
- Energy supply, e.g. installations or energy infrastructure for distribution of renewable energy (to and from the holding) using biomass and other renewable energy sources (solar and wind power, geothermal energy).
- Investments in the access to forest roads or wood storing places.
- Starting new non-agricultural activities linked to renewable energy production.
- Investments in the production of other types of renewable energy besides biomass, i.e. wind, solar, hydraulic, geothermal etc.

Basic services and village renewal in rural areas

Basic services and village renewal in rural areas stimulates growth and promotes environmental and socio-economic sustainability of rural areas.

Some examples of types of operations that may be supported:

- Support to renewable energy infrastructure projects without any size limitation.
- Setting up of distribution networks for heat and/or electric power or gas from biomass or other renewable sources.
- Construction of additional facilities to produce and use renewable energy in rural municipalities such as district heating networks to use the process heat as a by-product of bioenergy plants.

The setting up of producer groups and co-operation

These measures help actors in the agriculture and forestry sectors to work together, such as farmers, forest owners and business organisations.

Examples of a type of operation that may be supported:

- Implementation of business plans that contribute to the efficient functioning of the supply chain for non-food purposes, e.g. the setting up of adequate organisation structures for biomass delivery (such as the utilisation of agricultural wastes and residues for renewable energy production or for bio-based products).

Forestry related measures

Some examples of types of operations that may be supported:

- The use of residues from harvesting and maintenance for energy purposes.
- The provision of biomass used for energy purposes by harvesting the wood before replanting the trees or from the collection of residues from thinnings or prunings.
- Investments in order to mobilize wood including the production of biomass for energy generation, for example investments into new harvesting machinery for the collection of residues from thinnings or prunings.

Box 1. Supporting measures for renewable energy. Source: [EC, 2015]

You can find a digital useful tool in Future for Rural Energy in Europe (FREE) http://www.rural-energy.eu/funding. This webpage hosts a powerful searcher, which collects data from Renewable Energy Funding Calls for the financing period 2014-2020. These are public European programmes. We made a selection of those close to local and rural development, or nature preservation. We encourage you to visit the webpage FREE http://www.rural-energy.eu and look for those funding mechanisms that fit best your RE project.

European Local Energy Assistance (ELENA). ELENA is a European technical assistance facility providing grants to regions and local authorities in order to accelerate their investment programmes in the fields of energy and climate change

EUROPEAN AGRICULTURAL FUND FOR RURAL DEVELOPMENT (EAFRD). The European Agricultural Fund for Rural Development (EAFRD) is a funding mechanism under the Common Agricultural Policy (CAP). The rural development regulation aims to set clearly defined common priorities for rural development at the EU level.

SUSTAINABLE ENERGY FINANCING FACILITIES (SEFF). Special credit facility supporting smaller companies to realise their investment efforts in sustainable energy **European Regional Development Fund (ERDF).** The ERDF aims to strengthen economic and social cohesion in the European Union by correcting imbalances between its regions.

EUROPEAN ENERGY EFFICIENCY FUND (EEEF). The European Energy Efficiency Fund (EEEF) is a public-private partnership dedicated to mitigating climate change through energy efficiency measures and the use of renewable energy in the Member States of the European Union. To reach its final beneficiaries, EEEF can pursue two types of investments; direct investments and investments into financial institutions.

HORIZON 2020. Horizon 2020 is the financial instrument implementing the Innovation Union, a Europe 2020 flagship initiative aimed at securing Europe's global competitiveness. One of the challenges which Horizon 2020 will address is secure, clean and efficient energy.

INTELLIGENT ENERGY EUROPE III. Intelligent Energy Europe III is a successor of Intelligent Energy Europe II, a programme aimed at helping organisations willing to improve energy sustainability. It supports energy efficiency and renewable energy policies with a view to reaching EU 2020 energy and climate targets.

INTERREG (2014 -2020). The INTERREG EUROPE Programme is an EU programme that helps regions across Europe to work together, sharing their knowledge and experience

LIFE+ Programme. A financing instrument from the European Union for environmental and nature conservation projects in the EU.

Box 2. Funding in EU Programs. Source: [FREE, 2016]

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