INTERNATIONAL HELLENIC UNIVERSITY
in collaboration with
"VASILE ALECSANDRI" UNIVERSITY OF BACAU

MULTITRACES PROJECT

MODULE 3

SUSTAINABLE DEVELOPMENT OF THE RURAL AREA AND SMART VALORIZATION OF THE NATURAL RESOURCES

Trainers:
Prof. Vassiliki Kazana (IHU)
Prof. Antonios Papadopoulos (IHU)
Assist. Professor Dimitrios Raptis (IHU)
Assoc. Professor Roxana Grigore(UB)

Greece

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1. Introduction

Rural areas are important for economic development and support for the well-being of the people living either in rural or urban areas, because rural areas afford a high proportion of natural resources and agricultural land. In general, rural areas are territories with lower economic diversification, lower population and development density and lower employment, educational and income opportunities than most of the urban areas. In addition many rural areas are more vulnerable to environmental problems, such as soil loss, water, air and soil pollution, wildfires, floods and climate change.

The achievement of environmental and energy transition goals in rural areas is closely linked with their sustainability transition, as the latter contributes both to the improvement of the economic performance of these territories, as well as the improvement of air, water and soil quality, biodiversity and energy security. Adoption of circular economy as a development strategy in rural areas requires optimization of the natural resources use, minimization of environmental pressures, transformation of the supply chains and the consumption patterns and the redesign of the production systems (OECD 2019).

There many opportunities in rural areas towards achieving environmental, energy and sustainability transition goals. The main domains of action include development or renewable energy, sustainable agriculture and forestry and the circular economy and bio-economy. In all these domains important factors for the rural areas to successfully address the associated challenges are the active social participation, capacity building and increase of the rural community awareness about the transition issues.

Module 3 of the ERASMUS plus MULTITRACES project online course places particular emphasis on the issues related to identification of natural resources in rural areas and their associated risks, the ecosystem services of natural resources and methods of their valuation, as well as smart valorization opportunities and requirements of natural resources towards achieving environmental, energy and sustainability transition aims.

2. Sustainable development of rural areas, natural resources and circular economy

2.1 How do we define rural areas?

One issue of importance for the sustainable development of rural areas is the rural - urban typology or in other words how rural areas are distinguished from urban areas. It was back in the 1990's when the Organization for Economic Cooperation and Development (OECD) developed a three-way classification based on the population density of districts (Local Administrative Unit Level 2, which is usually the Municipality Level). At present OECD is applying this approach at the TL3 level which largely corresponds to NUTS 2. The term NUTS is an abbreviated term standing for the "Nomenclature of territorial units for statistics", which is used to divide the economic territory of the European Union (EU) into regions at three different levels (NUTS 1, 2 and 3 respectively), moving from larger to smaller territorial units. Above NUTS 1, there is the 'national' level of the Member States. The NUTS is based on Regulation (EC) No 1059/2003 of the European Parliament and of the Council of 26 May 2003 on the establishment of a common classification of territorial units for statistics (NUTS), which is regularly updated.

The population size constraints for NUTS 2016 regions are shown in the following table.

Table 1. Population size constraints for NUTS 2016 regions (number of inhabitants)

	Minimum population	Maximum population
NUTS level 1 regions	3 000 000	7 000 000
NUTS level 2 regions	800 000	3 000 000
NUTS level 3 regions	150 000	800 000

(Source: 2020 Regional Statistics Yearbook)

The OECD approach classifies an area as:

- Predominantly rural (rural), if more than 50% of its population lives in rural communities
- Predominantly urban (urban), if less than 15% of the population lives in rural communities
- Intermediate, if the share of population living in rural communities is between 15% and 50%

The OECD rural-urban classification approach has evolved by including other functional factors, which diversify rural areas depending on their access to a Functional Urban Area (FUA), for example how easy it is to drive to a city. This was done following the seminal work of Dijkstra and Poelman (2008), who basically claimed that an important distinction for rural areas should be the level of access to city services. Rural areas in relation to FUAs can be any of the following types:

1. Rural areas within a FUA: This typology the FUA consists of an urban center surrounded by a commuting zone. The rural areas form an integral part of the FUA and their development is therefore part of the FUA development.

2. Rural areas with access to a FUA: – This typology includes the rural areas that are strongly linked to a nearby FUA through the flow of goods, ecosystem services and economic transactions without however being part of its labour market. Despite the economies of the rural and the FUAs are not integrated, the development of these rural areas is heavily dependent to the FUA. Almost 80% of the rural population in the OECD countries lives in this type of rural areas.

3. Remote rural areas: These areas are located far from a FUA. Links to the FUAs are largely due to the market exchange of goods and services. Personal interactions outside the rural area are limited and infrequent, but connections within the rural region are good. The local economy of these rural areas depends to a great extent on the exports of primary production outputs. Growth of these rural areas can be attempted through improving connectivity to export markets, matching skills to areas of comparative advantage and improving the provision of essential services.

In Europe the city-access issue was introduced in Eurostat's 2010 regional typology yearbook, where the OECD concept was applied at NUTS 3 regions. Currently, the main classification described in detail in the working paper of Dijkstra and Poelman (2014) is based on data for 1 km² population grid cells obtained from the decennial population census. Each 1 km² cell is described as belonging to one of three categories:

- rural grid cells: all grid cells outside of urban clusters/centers;
- urban clusters (or moderate-density clusters): a cluster of contiguous grid cells of 1 km² (in other words, grid cells that share a common border including grid cells that only touch diagonally at corners) with a population density of at least 300 inhabitants per km² and a minimum population of at least 5 000 inhabitants;

- urban centers (or high-density clusters): a cluster of non-diagonal contiguous grid cells (in other words, excluding those cells with only touching corners) with a population density of at least 1500 inhabitants per km^2 and collectively at least 50000 inhabitants after gap-filling.

The spatial concepts which were used to describe the degree of urbanization are shown in the following Table.

Table 2. Spatial concepts used in the degree of urbanization

Grid cell concept	Criteria
High density clusters (urban centres)	Population≥50000inhabitants and contiguous grid cells of $1km^2$ with ≥1500 inhabitants per km^2
Urban clusters	Population ≥5000 inhabitants and contiguous grid cells of $1km^2$ with ≥ 300 inhabitants per km^2
Rural grid cells	Grid cells outside urban clusters and urban centres

Degree of urbanization concept	Alternative terminology	UN classification	Criteria
Cities	Densely populated areas	Large urban areas	≥50% of the population lives in high density clusters
Towns and suburbs	Intermediate urbanized areas	Small urban areas	<50% of the population lives in rural grid cells and <50% of the population lives in high-density clusters
Rural areas	Thinly populated areas	Rural areas	>50% of the population lives in rural grid cells

Note: the sum/average for cities may be combined with towns and suburbs and are then referred to as urban areas (in contrast to rural areas).
Source: Eurostat, the European Commission Directorate-General for Regional Policy, OECD

On the basis of these spatial criteria, the regions at any administrative level are classified based on whether their population falls mostly in rural cells or not. A map of LAU units (which correspond to municipalities) based on the 2011 census follows below and it pretty much validates the fact that most of Europe is rural! What is currently used can be found in the 2020 regional statistics yearbook.

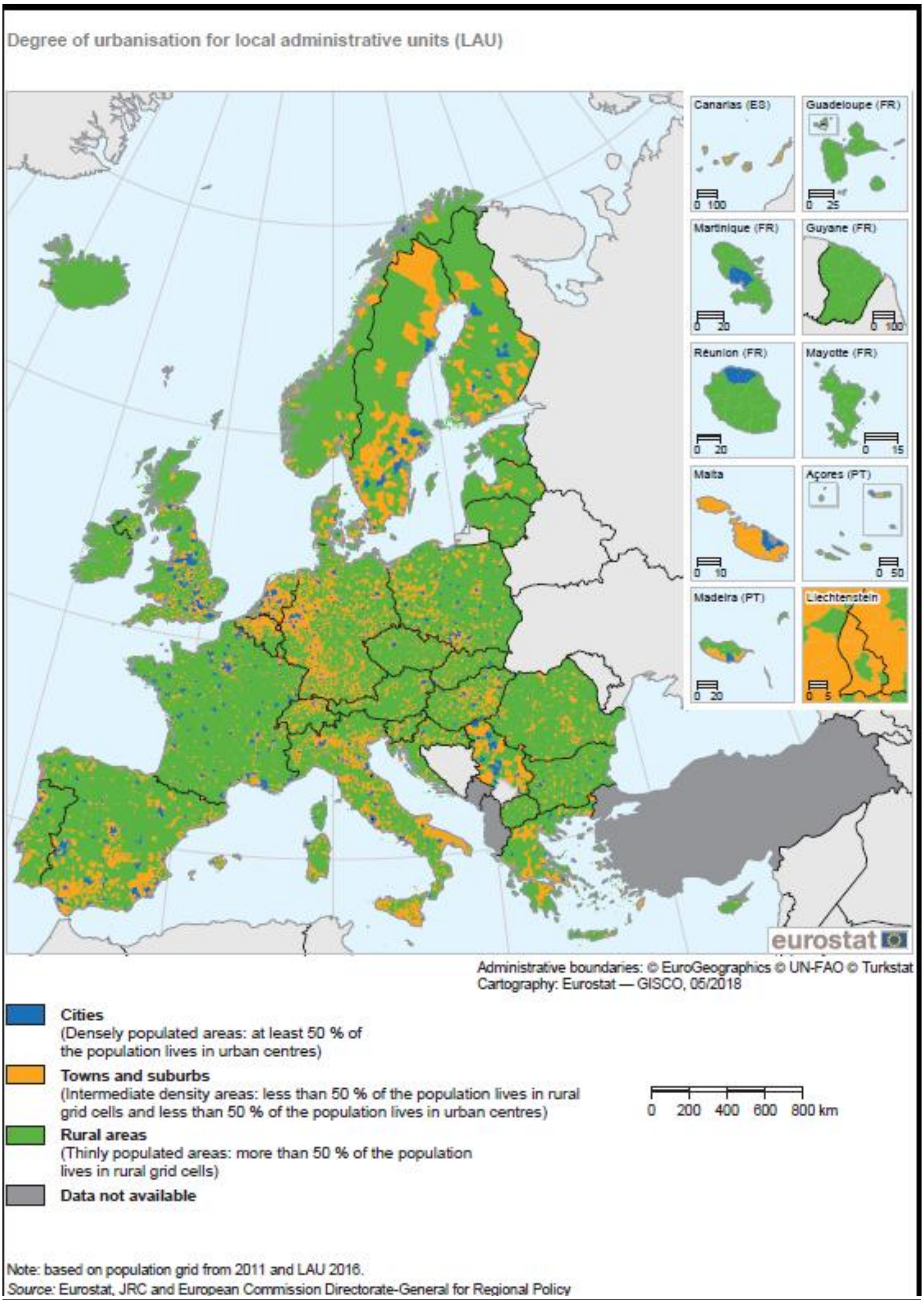


Figure 1. Degree of urbanization for local administrative units in Europe (Eurostat, 2018)

2.2 Concept of sustainability-Sustainable Development Goals

Sustainable development according to the most accepted definition, which appeared in the Brundtland Report (1987), is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs". Sustainable development is based on three pillars in terms of pursued goals, economic, sociocultural and environmental. When it comes to the rural areas sustainable development strives to balance economic, socio-cultural, political and environmental goals for the continuous improvement of the rural communities' well-being in the long run. The main differences between "rural sustainability" and "urban sustainability" lie with the challenges and solutions that need to be constructed for the rural areas because of the differences in the types of natural resources present, population densities and activities taking place in the rural areas (Bryant and Granjon 2009).

In 2015 the United Nations in order to promote sustainable development adopted the 2030 Agenda, an international agreement with 17 Sustainable Development Goals, shown in the figure below to be pursued at global level. Each goal has been linked with specific targets to be achieved over the next 15 years (https://www.un.org/sustainabledevelopment/sustainable-development-goals/).

Figure 2. The UN Sustainable Development Goals, Agenda 2030

Goal 1 aims to end poverty everywhere. To this end economic growth should be inclusive to provide sustainable jobs and promote equality. According to the UNU World Institute for Development Economics Research about 10% of the world population corresponding to 700 million people currently live in extreme poverty with the rural areas suffering three times more than the urban areas with poverty rate of 17.2% worldwide. The COVID-19 pandemic is estimated to increase global poverty even further by as much as 8% of the total population.

Goal 2 aims to achieve zero hunger by 2030. Today about 9% of the total population or 690 million people suffer from hunger, of which 135 million from acute hunger due to man-made conflicts, climate change and economic turndowns. The future outlook is not optimistic, as more than 2 billion people are expected to suffer from hunger by 2050.The need for drastic changes of the food and agricultural system to become sustainable is very important to help alleviate hunger.

Goal 3 aims to ensure health and the well-being for all at all ages. This goal is even more of critical importance currently because of the COVID-19 pandemic, which has generated a global health crisis and a subsequent economic turndown. Before the pandemic most of the efforts related to this goal were directed to the improvement of peoples' health by reducing the child and maternal mortality. It is now more than apparent that to achieve this goal more funding is required for the health systems, while improving sanitation and hygiene, as well as access to physicians.

Goal 4 is targeted to strive for quality education for all and particularly for girls. Access to education is vital for nearly one fifth of the global children population who are out of school. The COVID-19 pandemic jeopardized greatly this goal as due to the temporary closure of schools in most of the countries about 1.6 billion children and youth were out of school and 369 million children who relied on school meals lost their source of daily nutrition.

Goal 5 strives for gender equality and empowering of all women and girls. Actions to achieve this goal focus on increasing the access of girls to school, reducing the number of girls that are forced to early marriages, encouraging women to take positions of leadership and promoting laws that advance gender equality.

Goal 6 aims to ensure access to water and sanitation for all. In particular, under this goal increasing access to clean drinking water and sanitation as billions of people worldwide mainly in rural areas lack such basic services.

Goal 7 is related with access provision to affordable, sustainable and clean energy. Access to electricity for all, improvement of energy efficiency and expansion of use of renewable energy are pursued under this goal.

Goal 8 concerns the promotion of sustainable and inclusive economic growth, as well as employment and decent work for all. Sustainable economic growth can drive progress and improve the living standards. However, even before the outbreak of the COVID-19 pandemic it was expected that one in five countries worldwide would see in 2020 the per capita income fall. The situation has become worse with the pandemic as according to the ILO estimates almost half of the global workforce is at risk at losing their livelihoods. It is important therefore the countries to develop and implement socio-economic response frameworks in order to face the imposed economic recession that endangers the global economy.

Goal 9 aims to promote innovation, sustainable industrialization and build resilient infrastructure. Investing in research and development and communications infrastructure and making infrastructure resilient to disasters and climate change are among the actions to be pursued towards achievement of this goal, as these can unleash competitive economic forces that will generate employment and income.

Goal 10 targets to reduce inequality within and among countries. Inequalities are hitting the hardest the poorest and most vulnerable communities and may include economic, social and political dimensions. Gender equality and women's rights are also important related to this goal issues.

Goal 11 strives to achieve sustainable cities and communities. This is a very important goal, since almost one billion people worldwide live in slums and overcrowding settlements with inadequate or non-existing infrastructure and services, such as waste collection and water and sanitation systems and in most cases with limited access to food. Moreover, cities where more than half of the world population lives account for 70% of global carbon emissions and over 60% of resource use.

Goal 12 concerns achievement of responsible consumption and production. Decoupling economic growth from environmental degradation, increasing resource efficiency and promoting sustainable lifestyles should be pursued to achieve this goal. Achieving this goal can lead to poverty alleviation and promote the transition towards the low carbon and green economy.

Goal 13 is related to the global aim of combating climate change and its impacts. Climate change is one of the biggest global environmental problems connected to changes in weather patterns, extreme weather events and the rising of the sea levels. At the political level, the Paris Agreement adopted in 2015 was the global response towards limiting the global warming to 1.5^0 C and reducing the greenhouse gas emissions by 7.6% every year starting from 2020. Climate change has very disruptive effects to national economies and peoples' lives and this is why most countries are seeking to adopt appropriate financial tools, new technology and appropriate capacity building to combat climate change.

Goal 14 refers to the need to conserve and use in sustainable ways the marine resources, the oceans and the seas. Reduction of overfishing, marine pollution and ocean acidification constitute the specific aims to pursue with respect to Goal 14.

Goal 15 aims to the sustainable management of forests and combating of desertification, land degradation and biodiversity loss. Moreover, the sustainable management of forests is vital in the fight against climate change, while land restoration can improve livelihoods and reduce risks for the economy.

Goal 16 concerns the respect of human rights and promotion of just, peaceful and inclusive societies. Access to justice, strengthening of institutions and minimization of conflict and insecurity are vital to achieve this goal.

Finally, ***Goal 17*** calls for partnerships at all levels, local, regional, national and global to achieve sustainable development.

Although the Agenda 2030, that is the above described 17 sustainable development goals have been adopted by the UN General Assembly, that is by its 193 member countries, it serves more as a compass for the governments, which are called to develop their own plans and determine how these goals will be implemented. In the frame of sustainable rural development such plans should take into account the state and valorization of natural resources, as well as the active engagement of the rural communities and businesses operating in the rural space. Moreover, close links need to be established between rural sustainability and circular economy.

2.3 Natural resources of the rural areas

Natural resources are the environmental constituents that occur naturally on earth and they are valuable for human life, such as for example the forests, the water, the soil, the sun, the wind, the coal and the oil. Natural resources are essential for the development and growth of human societies, particularly in rural areas. Various types of criteria have been used to classify the natural resources. These involve the source of origin, the state of development and use, the availability (stock), and the distribution of resources.

In terms of the state of development and use, natural resources are distinguished in two groups:

1. Actual resources: These are the resources with known amount of reserves that are currently being used, for example coal deposits, iron ores and oil.
2. Potential resources: The resources with unknown amount of reserves which have not been utilized up to their optimum levels mainly due to lack of appropriate technology. A windmill for example is a potential natural resource in this type of classification.

According to the source of origin natural resources are classified also in two groups:

1. Abiotic resources, which include the non-living resources, for example soil, minerals and rocks.
2. Biotic resources, which include the living resources, used mainly to satisfy the human needs, for example plants and animals.

Among the most widely used classifications is that based on the stock or availability of the resource. The main categories in this scheme include:

1. Renewable resources that can be regenerated or recycled naturally. Some of these resources do not deplete with their use, for example solar energy or geothermal energy or wind power. Other natural renewable resources, like forests and water or soil do not have unlimited stocks and therefore their use should be subject in sustainable ways. These resources are called alternatively sustainable natural resources.
2. Non-renewable resources, which cannot be recovered. They are finite or exhaustible, that is non-sustainable and their use eventually leads to exhaustion, such as the fossil fuels and the minerals which take millions of years to form.

Finally, according to resource distribution, natural resources are classified as:

1. Ubiquitous resources, which can be found anywhere on earth, such as for example the air around us or the sunlight and
2. Localized resources, which occur only on certain areas, such as for example the minerals.

In this module the focus will be on the renewable sustainable natural resources.

2.4 Link between sustainability/natural resources and circular economy in the rural areas

The link between sustainable management of natural resources in the rural areas has long been established particularly as regards the harvesting of yields, which should not exceed the growth rate of the natural resource stocks on annual or periodic basis. A basic question however arises when it comes to circular economy. Is circular economy different from sustainable development? Circular economy as a concept and practice has been developed to promote sustainable development by substituting the linear economy model, which involves in a linear way the processes of extracting, producing, consuming and throwing away by the circular model, which instead of throwing away is reusing and recycling before starting extraction process again. The following two figures depict the different approaches of linear and circular economic development.

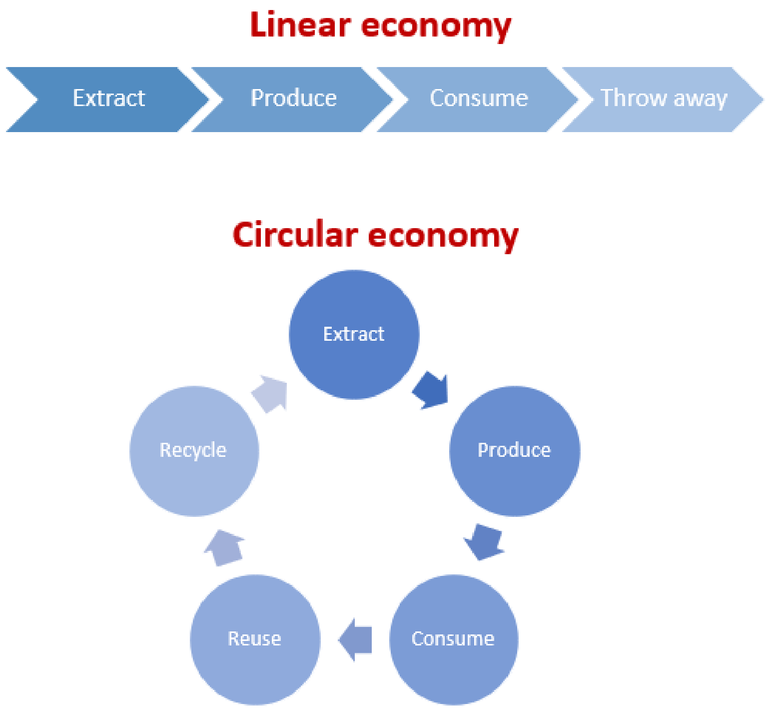


Figure 3. Processes of linear and circular economy

Overall, circular economy does not necessarily imply sustainability, despite if applied it can promote goals of sustainable development. In particular,
Circular economy,

- assumes that the current and future demographics make the actual consumption levels unsustainable
- refers mainly to production (economic dimension) and how this is carried out (environmental effects)
- refers to a system able to regenerate by itself by reducing the use of resources and energy, wastes and emission. In this respect, the economic system will become more sustainable in terms of production.

Sustainability

- It involves more than economic growth, that is, it includes also environmental and social dimensions. Therefore, for an economic system to become sustainable, social, human and environmental dimensions, such as those described through the sustainable development goals above need to be added, for example poverty, famine, health, education, gender equality, peace and justice, as well as protection of forest, water and energy resources and conservation of biodiversity.

3. Identification of natural resources in the rural areas

Any natural material in raw form that humans may use to support life and meet their needs can be considered a different type of natural resource. In a wider framework, natural resources in rural areas include the sun energy, the atmosphere, the woodlands, the water, and land (including all minerals) along with all vegetation, and the biodiversity. Our analysis on the natural resources of rural areas will focus on their four main types: biological resources, mineral and energy resources, soil resources and water resources.

The demand for natural resources continues to increase following population growth and social development. The circular economy has been proposed as an alternative solution to minimize raw material input and waste generation (Velenturf *et al.* 2019). In March 2020 a new action plan focusing on circular economy has been adopted by the European Commission, with the current status of circular economy to be shown in the following butterfly - shaped diagram (Figure 4).

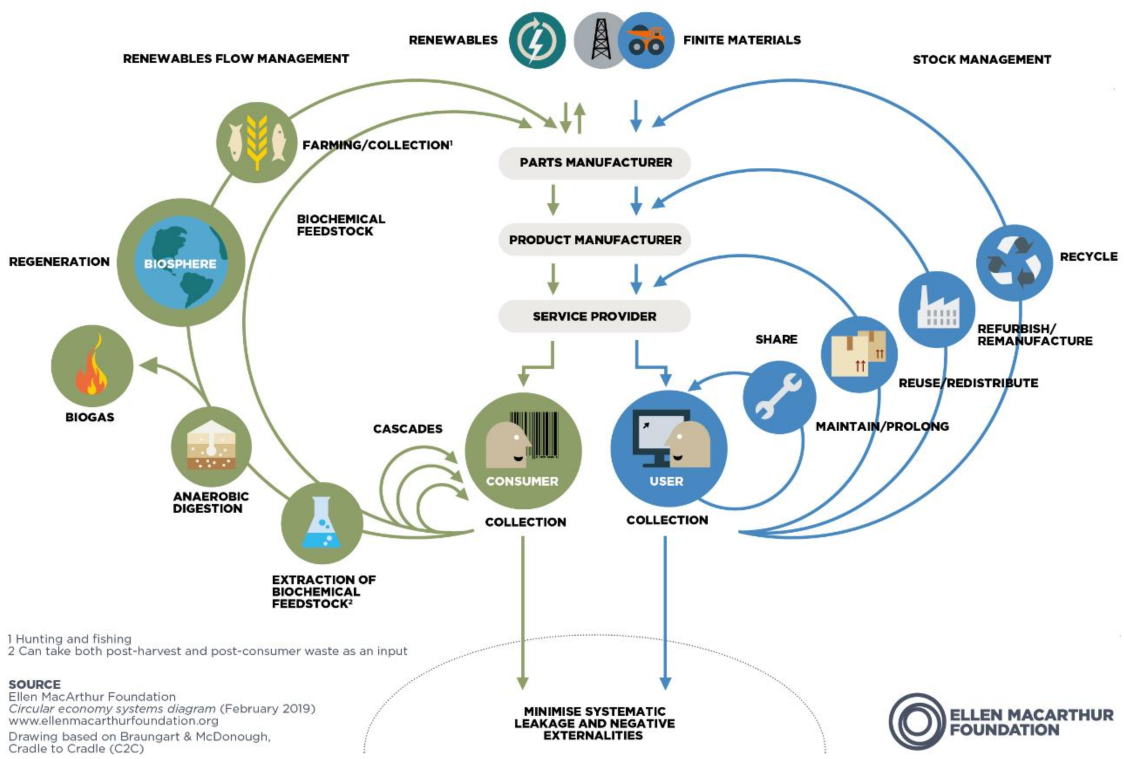


Figure 4. The Current views on circular economy

The utilization, allocation and temporal dynamics of natural resources in conjunction with human activities are critical information needed for sustainable land management. Spatial distribution of land-cover is essential to support and promote this ecological-based approach. In this sense, the extent of some significant types of natural resources is closely related with their land-cover percentage at European level.

According to Eurostat, the total area of the 28 EU Member States was estimated to 4.3 million square kilometers (km^2) in 2015. Woodland covered by far the largest proportion, and was close to 37.8 % of the total area (Figure 5). About one fifth (22.2 %) of the EU-28's total area was occupied by cropland, while approximately one fifth (20.7 %) was covered by grassland. The other land-use types covered low shares: the shrubland covered 7.1 % portion of the total, followed by artificial areas (4.2 %) and bareland (3.3 %), while the least common forms of cover were water areas (3.0 %) and wetland (1.7 %).

At European level, the percentages deviate significantly between countries. Finland appeared to be covered by woodland at 72.3% whereas the corresponding percentage for the Netherlands was just 15% and for Malta 19.1% (Table 3).

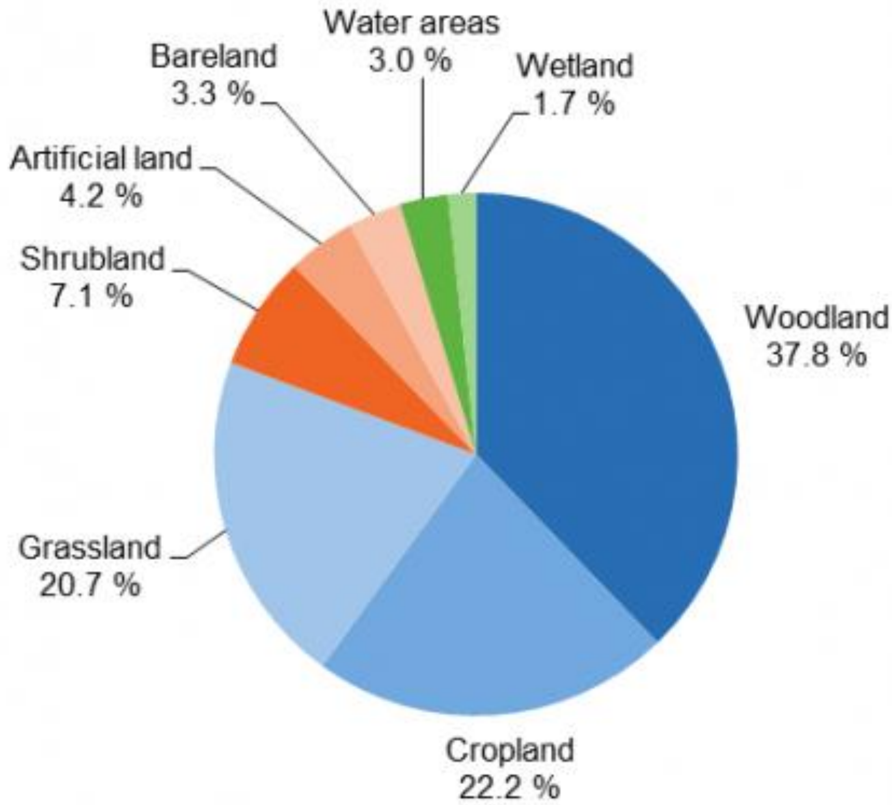


Figure 5. Land-use percentage at European Level (from: Eurostat – (lan_lcv_ovw))

Table 3. Land cover percentages across the EU Member States in 2015.

	Total area (km²)	Share of total area by type and land cover (%) Woodland and shrubland	Cropland	Grassland	Water areas and wetland; bareland	Artificial
EU-28	4 369 364	44.8	22.2	20.7	8.0	4.2
Belgium	30 668	26.3	28.5	31.0	2.8	11.4
Bulgaria	110 995	46.6	29.2	18.8	3.5	1.8
Czech Republic	78 874	38.5	32.0	22.3	2.6	4.6
Denmark	43 162	20.4	50.6	17.5	4.7	6.9
Germany	358 327	34.9	32.3	21.9	3.6	7.4
Estonia	45 347	58.6	13.5	15.9	10.1	2.0
Ireland	70 601	25.3	5.8	56.3	8.8	3.8
Greece	131 912	56.7	15.3	19.4	5.1	3.4
Spain	498 504	45.7	21.3	19.0	10.6	3.4
France	549 060	33.8	28.9	26.7	5.2	5.4
Croatia	56 539	58.0	16.7	19.1	2.6	3.7
Italy	301 291	39.5	25.1	21.7	6.8	6.9
Cyprus	9 249	45.3	19.4	13.2	16.8	5.4
Latvia	65 519	55.8	14.3	22.5	5.8	1.6
Lithuania	65 412	38.7	29.4	24.9	4.2	2.8
Luxembourg	2 595	37.2	23.3	28.9	0.7	9.8
Hungary	93 013	26.0	43.7	19.9	6.4	4.1
Malta	315	19.1	26.3	23.4	7.6	23.7
Netherlands	37 824	15.0	24.2	36.3	12.4	12.1
Austria	83 944	48.3	15.3	24.7	7.4	4.3
Poland	313 851	36.7	33.2	22.6	4.1	3.5
Portugal	88 847	52.8	11.7	23.6	6.6	5.3
Romania	239 068	34.7	32.2	27.1	3.9	2.2
Slovenia	20 277	63.7	9.5	21.7	1.9	3.3
Slovakia	49 026	48.9	26.6	19.5	2.1	3.0
Finland	337 547	72.3	5.9	4.4	15.9	1.6
Sweden	449 896	69.8	4.2	5.4	19.0	1.6
United Kingdom	247 763	30.9	19.7	36.2	6.4	6.5

Source: Eurostat (online data code: lan_lcv_ovw)

3.1 Soil-agricultural land

The total cropland at EU level in 2015 occupied an area of about 1.63 million square kilometers (km²), as shown in Figure 5. This land cover type includes land under flowering shrubs, fruit trees, nut trees, and vines (European Environmental Agency). In addition to the land cover percentage which refers to the biophysical coverage of land, the land-use term is closely connected to the socioeconomic use of land and in this context it is presented in Figure 6.

The total land percentage for agricultural use includes several land cover types, such as arable land, permanent crops, grassland, artificial land and water. From Figure 7 it can be seen that in 11 out of the 28 EU Member States, in 2015, slightly more than half of the total area was used for agricultural purposes. The highest portion of land under primary agricultural use can be observed in Denmark (about 63%). In Ireland, Romania and Hungary the reported agricultural land shares were quite similar and close to three fifths. The lowest share of agricultural land use was reported in Sweden and Finland accounting for less than 10 % of the total land area and Estonia with the next lowest share, close to one fourth of its total area.

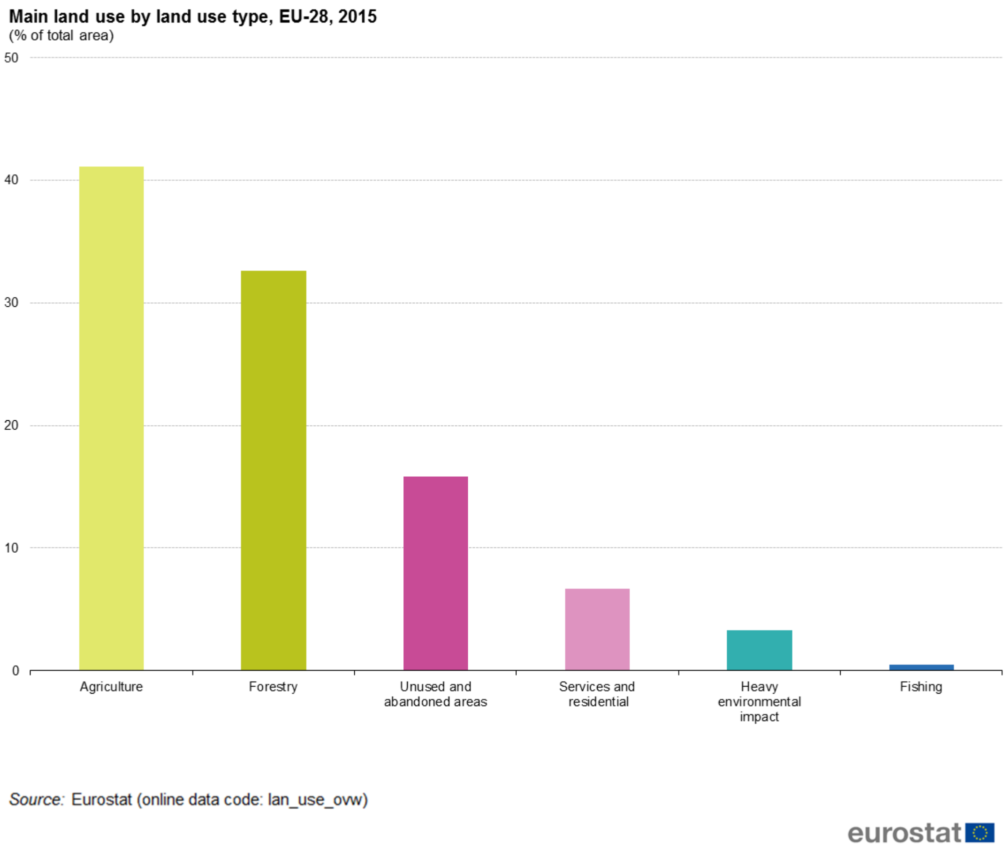


Figure 6. Main land use types in the 28 EU Member States, 2015

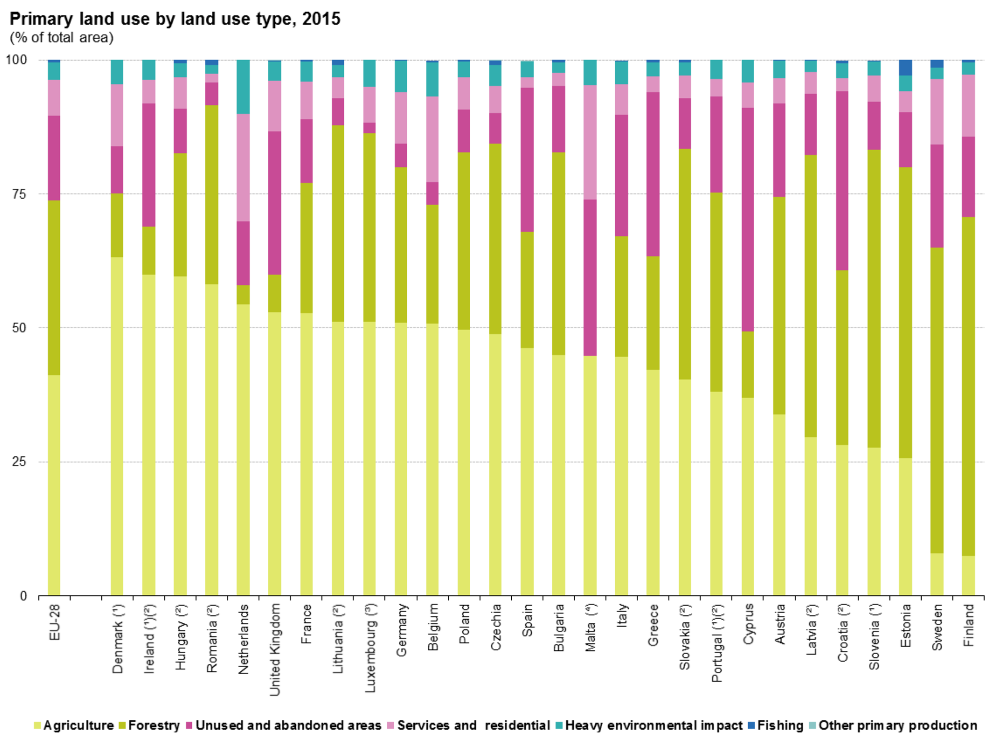
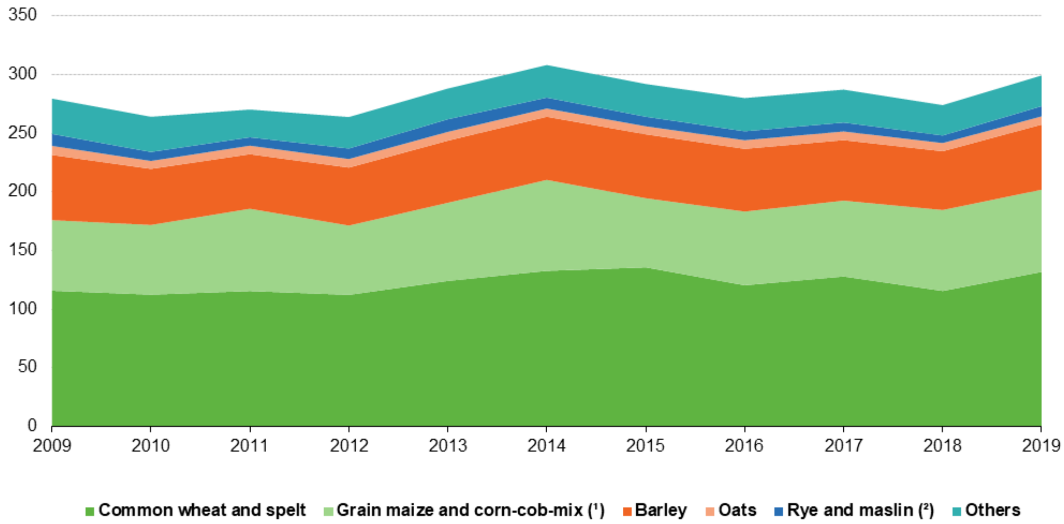


Figure 7. Primary land use types by EU country (2015)

Agricultural crops can be distinguished into two categories, the annual and the perennial crops. By definition, the annual crops are those that last approximately one growing season, but not more than two. The perennial, which are also termed permanent crops, last longer than two growing seasons and either die back after each season or they grow continuously. Specifically, crop production includes cereals, potatoes and sugar beets, oilseeds, fruits, vegetables, grapes and olives, as shown in the following Figure 8.

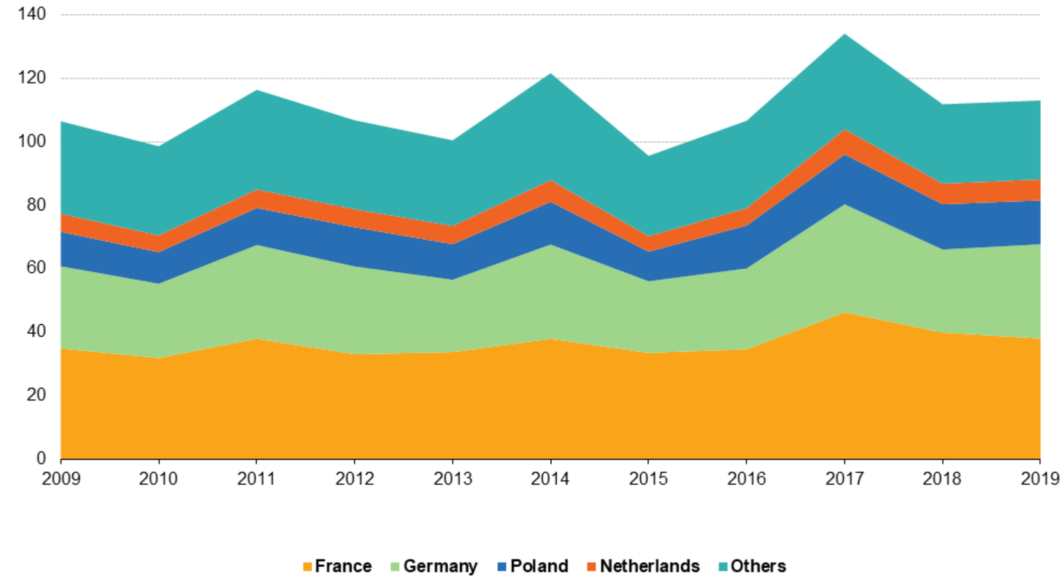
Production of main cereals, EU-27, 2009-2019
(million tonnes)



Note: 'Rye and maslin' includes mixture of rye with other winter sown cereals. 'Others' includes rice, triticale and sorghum.
(¹) Includes estimate for Denmark, 2009.
(²) Includes estimate for Italy, 2013.
Source: Eurostat (online data code: apro_cpnh1)

eurostat

Production of sugar beet by main producing EU Member States, 2009-2019
(million tonnes)



Source: Eurostat (online data code: apro_cpnh1)

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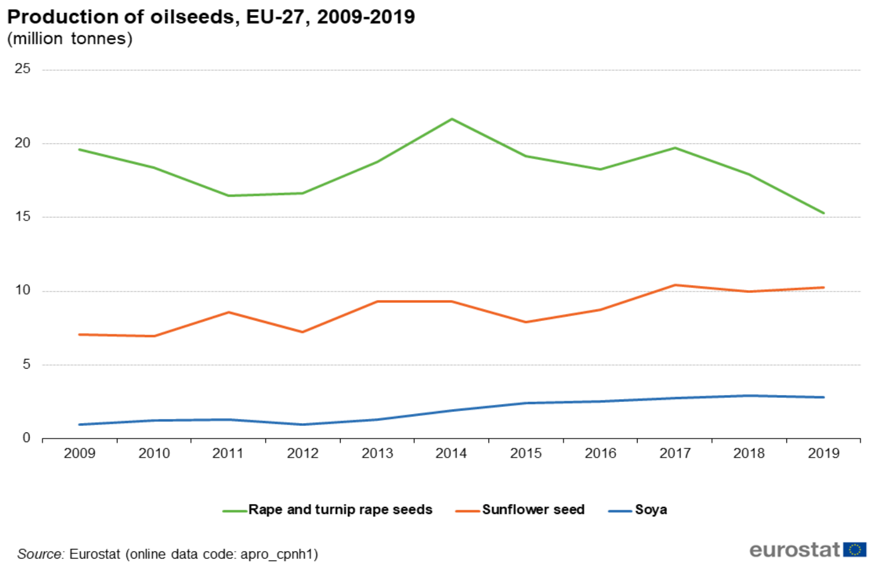


Figure 8. Production of cereals, sugar beets and oilseeds in the EU-27 during 2009-2019

The EU produces a wide range of fruits, berries and nuts. In 2019, the EU-27 produced 34.1 million tons of fruits (Figure 9), about 0.6 million tons of berries and approximately 1.1 million tons of nuts.

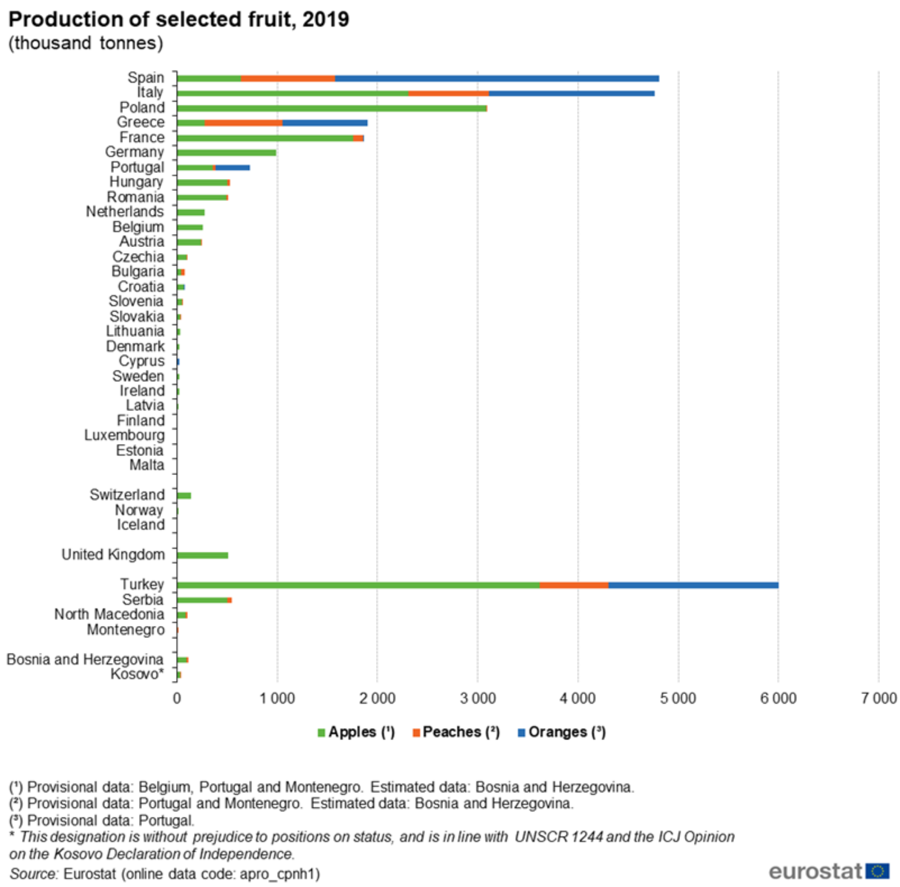


Figure 9. Production of selected fruits per EU country in 2019

The EU production of vegetables was close to 60.9 million tons in 2019. Compared to the 2018 production, a notable increase of 1.1 million tons of vegetables was observed.

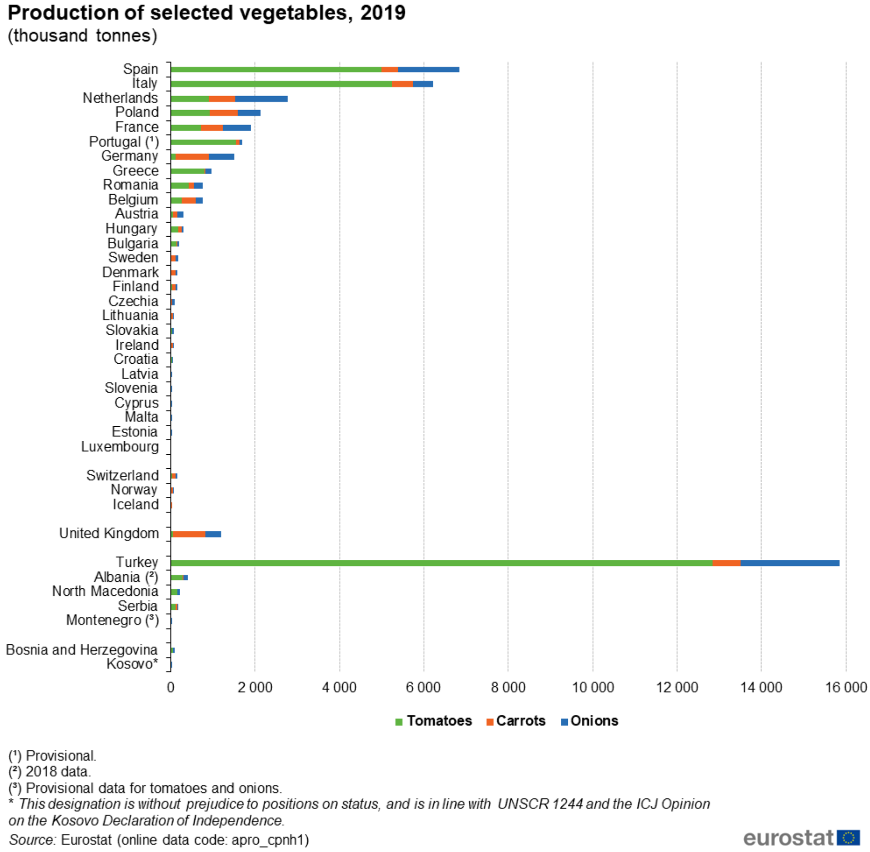


Figure 10. Production of selected vegetables per EU country in 2019

The total production of harvested grapes in the EU in 2019 was about 22.3 million tons, reduced by 3.3 million tons in comparison to 2018 (Figure 11).

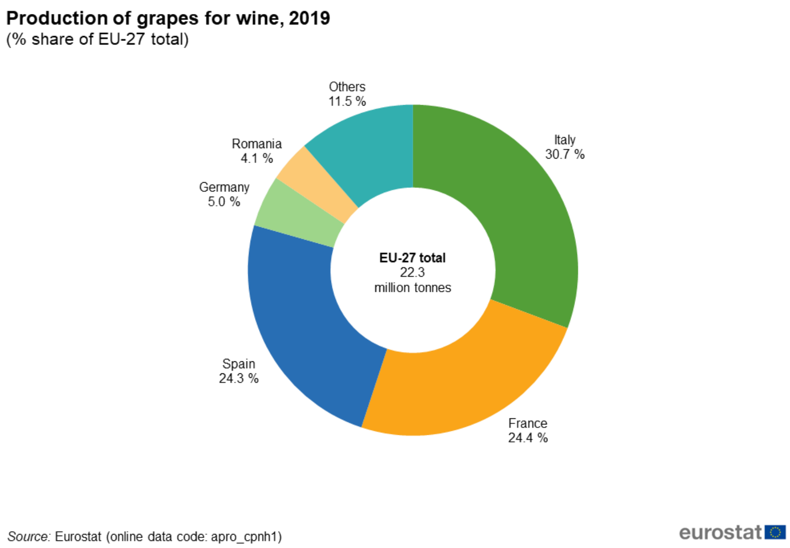


Figure 11. Production of grapes per EU country in 2019

The total production of harvested olives in the EU was approximately 9.8 million tons in 2019, less by 3.1 million tons compared to the production level of 2018.

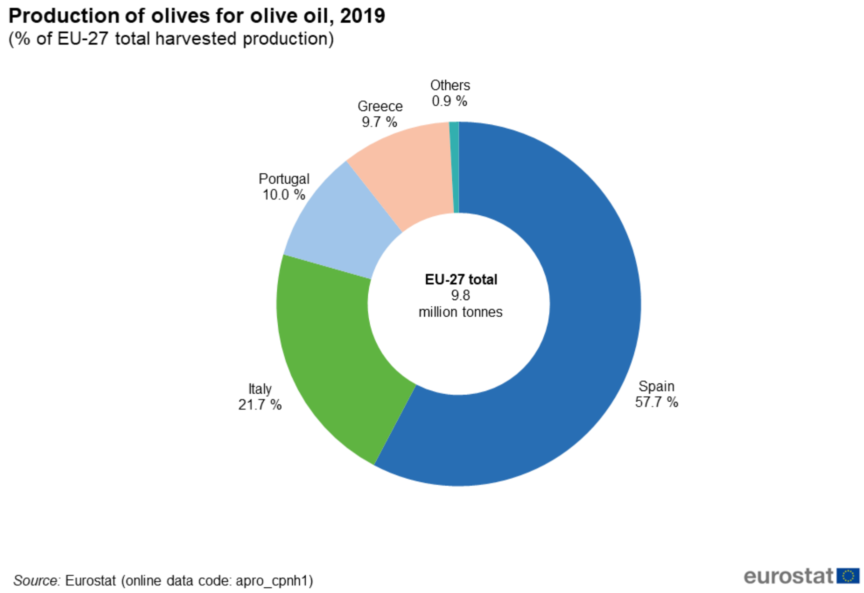


Figure 12. Production of olives per EU country in 2019

The concept of circularity in food systems was introduced in the field of industrial ecology (Jurgilevich et al. 2016). The basic aim of circularity was to reduce resource consumption and emissions by closing the loop of materials and substances (Boer and Ittersum 2018). Under this concept, losses of natural materials and substances should be mitigated, endorsing reuse and recycling.

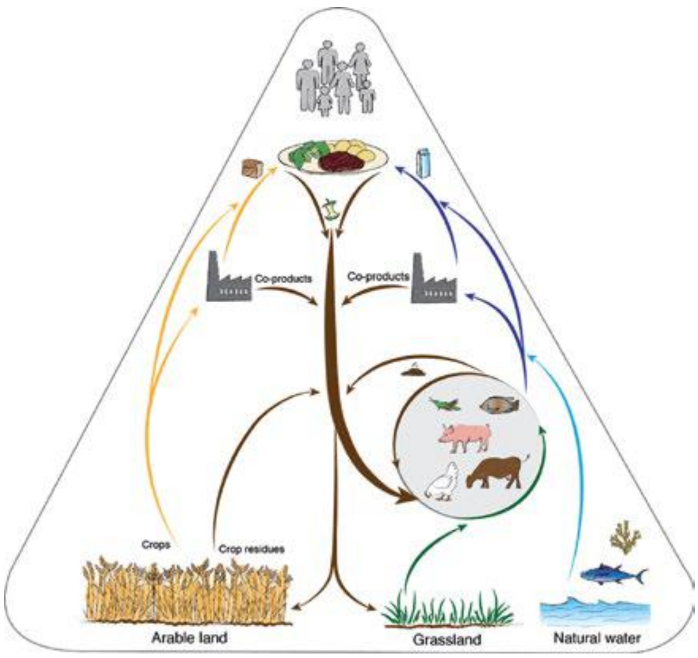


Figure 13. Circularity in food systems (from: Van Zanten et al. 2019)

Circular agriculture is based on the principle of optimizing the utilization of all biomass. Within the framework of circularity, arable land should be used primarily for the production of plant biomass for further human consumption, preventing edible by-products losses and food waste. However, the basic aim in recycling by-products should be to secure the soil quality, as it constitutes the basis of agriculture. The latest development in circular agriculture is precision agriculture, which applies digital technologies on soil conditions. These technologies include satellite positioning systems and remote sensing and spatial data collection, in order to minimize the use of inputs, such as fertilizers, pesticides and water, while increasing food production at the same time.

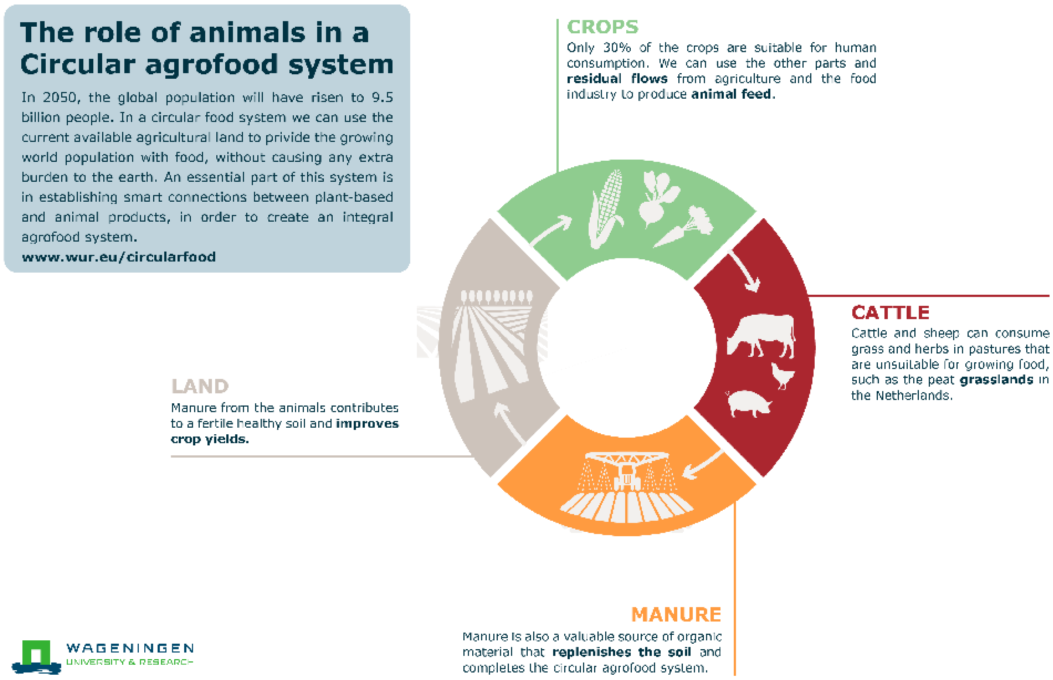


Figure 14. The animal role in a circular food chain

The waste streams of a supply chain may constitute the input raw materials for the next chain, and within this concept, the animals are possible to be fed from food waste.

3.2 Forests

In 2020, it was estimated that the EU-27 area was covered by 159 million hectares of forests (excluding other wooded land). In general, the forest area in all EU-27 countries has seen an increase by almost 10% from 1990 to 2020, except Portugal, where a notable decrease by 3% was reported, and Sweden, where forest area has been decreased by almost 0.5 % over the same period. The largest increases were reported in Ireland (69 %), Spain (34 %) and Malta (31%).

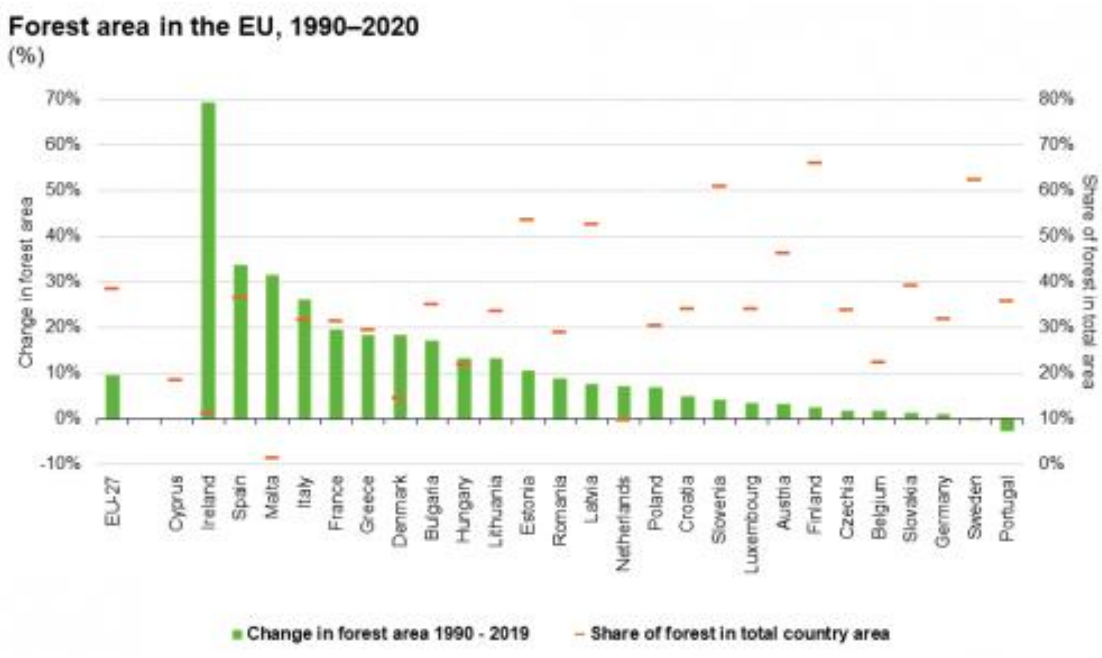


Figure 15. Forest area and forest area change in the EU-27, per country during 1990-2020

From the total forest area about 75% is available for wood supply. In addition, 46% of European forests are predominantly coniferous, 37% are broadleaved, and the remaining percentage corresponds to mixed-types (Forest Europe 2020). The distribution of coniferous and broadleaved forest area in Europe are depicted in the following Figures 16 and 17.

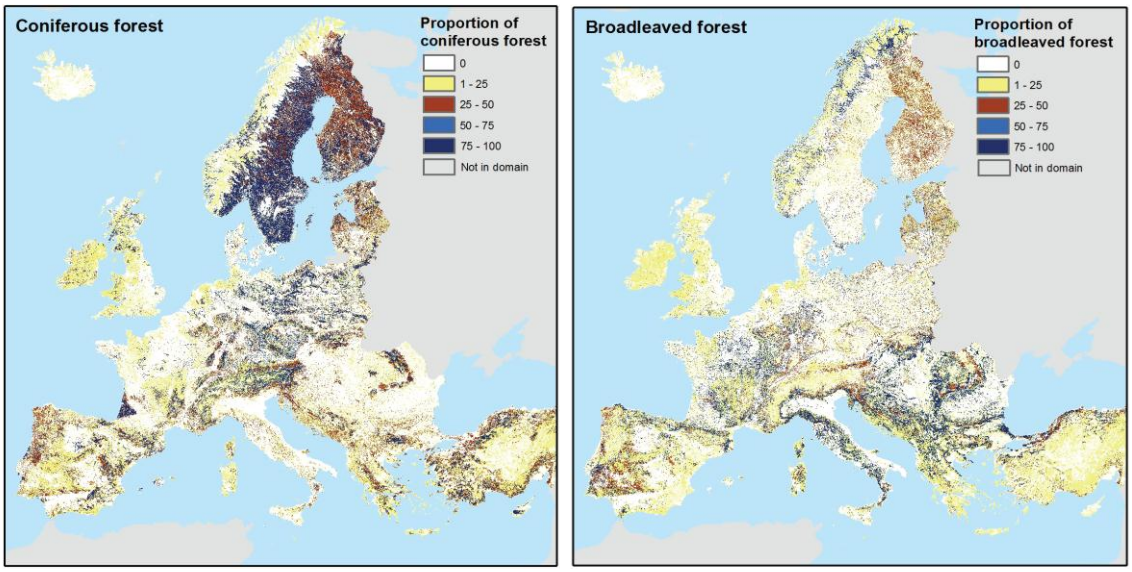


Figure 16. Coniferous (left) and Broadleaved (right) forest map of Europe with data from CORINE land cover at 1 km grid size (from: Barredo *et al.* 2012).

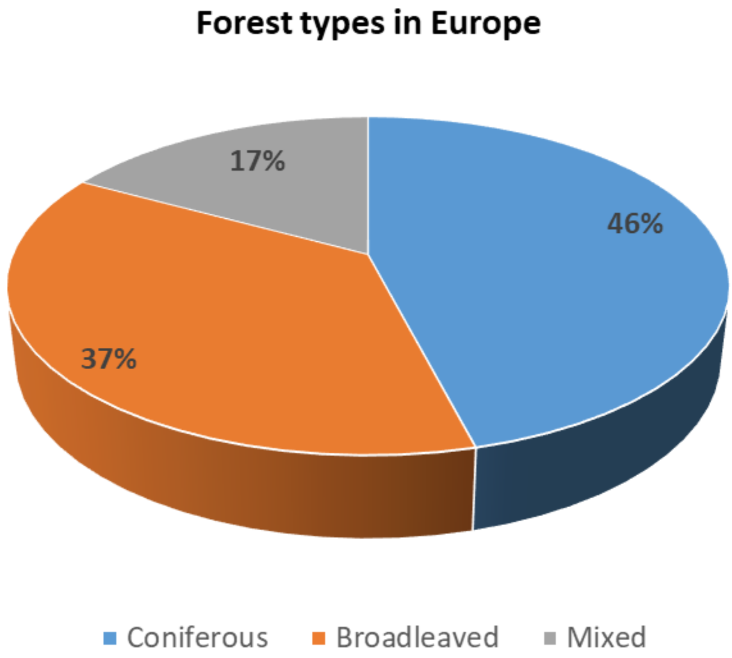


Figure 17. Main forest types in Europe

Circular bio-economy in the forest sector is twofold; the first level is referred to various processes and wood products of the traditional industries in the forest sector, such as timber, pulp and paper, resin, cork. The second level is focused on the valuable ecosystem services that provide social benefits and are necessary for the well-functioning of the ecosystem processes. A complete bio-economy framework provides natural resources such as carbon, water, solar energy and soils to sustain biodiversity and enhance ecosystem functioning, which in turns provides goods and services for nature and society in a continuously changing but resilient balance. If equilibrium succeeds and the system continues to develop, the circular bio-economy can help reconcile economic development with environmental protection (de Arrano et al. 2018).

3.3 Water

Water is one of the most important types of renewable natural resources. The continuous supply of high quality water is essential for people, ecosystem and economic activities. Large quantities of water are necessary for energy production, food growing and manufacturing of goods.

Table 4. Renewable freshwater resources – long term annual average in million m^3 (source: Eurostat 2020)

	A. Precipitation	B. Evapotranspiration	C. Internal Flow C=A-B	D. External Inflow	E. Renewable freshwater resources - total E=C+D	F. Renewable freshwater resources per 1000 inhabitants
Belgium	28 039	15 757	12 282	11 565	24 032	2.1
Bulgaria	73 310	57 252	16 058	83 731	99 789	14.2
Czechia	54 104	38 410	15 694	575	16 260	1.5
Denmark	38 485	22 145	16 340	0(e)	16 340	2.8
Germany	278 000	161 000	117 000	71 000	188 000	2.3
Estonia	29 018	:	12 347	:	12 347	9.4
Ireland	87 632	38 308	49 324	3 469	52 793	10.9
Greece	115 000	55 000	60 000	12 000	72 000	6.7
Spain	333 657	226 453	107 204	0	107 204	2.3
France	512 563	317 327	195 236	11 000	206 236	3.1
Croatia	66 625(e)	42 095(e)	24 529(e)	93 782(e)	118 312(e)	28.8(e)
Italy	281 752	147 283	134 469	:	:	:
Cyprus	3 030	2 709	321	0	321	0.4
Latvia	43 220	23 573	19 647	16 992	36 639	18.9
Lithuania	44 886	31 584	13 854	8 413	22 267	7.9
Luxembourg	2 030	1 125	905	739	1 644	2.7
Hungary	55 707	48 174	7 533	108 897	116 430	11.9
Malta	177	93	85	0	85	0.2
Netherlands	31 618	21 293	10 325	81 500	91 825	5.3
Austria	99 800	43 100	56 700	29 300	86 000	9.7
Poland	195 656	142 772	52 884	7 669	60 553	1.6
Portugal	82 164	43 571	38 593	35 000	73 593	7.2
Romania	154 630	115 432	39 198	366	39 564	2.0
Slovenia	31 746	13 150	18 596	13 496	32 092	15.5
Slovakia	37 352	24 278	13 074	67 252	80 326	14.8
Finland	222 000	115 000	107 000	3 200	110 000	20.0
Sweden	344 572	164 623	180 474	14 859	195 333	19.3
Norway	374 833	141 052	233 781	12 325	246 106	46.5
Switzerland	61 207	21 382	39 825	12 560	52 385	6.2
United Kingdom	287 607	127 290	161 369	6 454	172 861	2.6
Serbia	57 029	43 714	13 315	158 330	171 644	24.5
Turkey	503 100	275 700	227 400	6 900	234 300	2.9
Bosnia and Herzegovina	55 863(e)	25 940(e)	29 922(e)	2 000(e)	:	:
Kosovo *	763	478	285	11	296	0.2

Furthermore, protecting waterways to maintain their naturalness is essential in order to ensure water diversity and habitat restoration. The efficient management and protection of water resources is a priority target for the European Union through the Water Framework Directive (WFD) (2000/60/EC) for water policy. Water resources currently refer to the total freshwater available for use within an area including surface waters (rivers, streams, lakes) and groundwater (Table 4).

Water follows a cycle as it circulates continuously between sea, air and land, through rivers, lakes and the ground and back to the sea according to Figure 18.

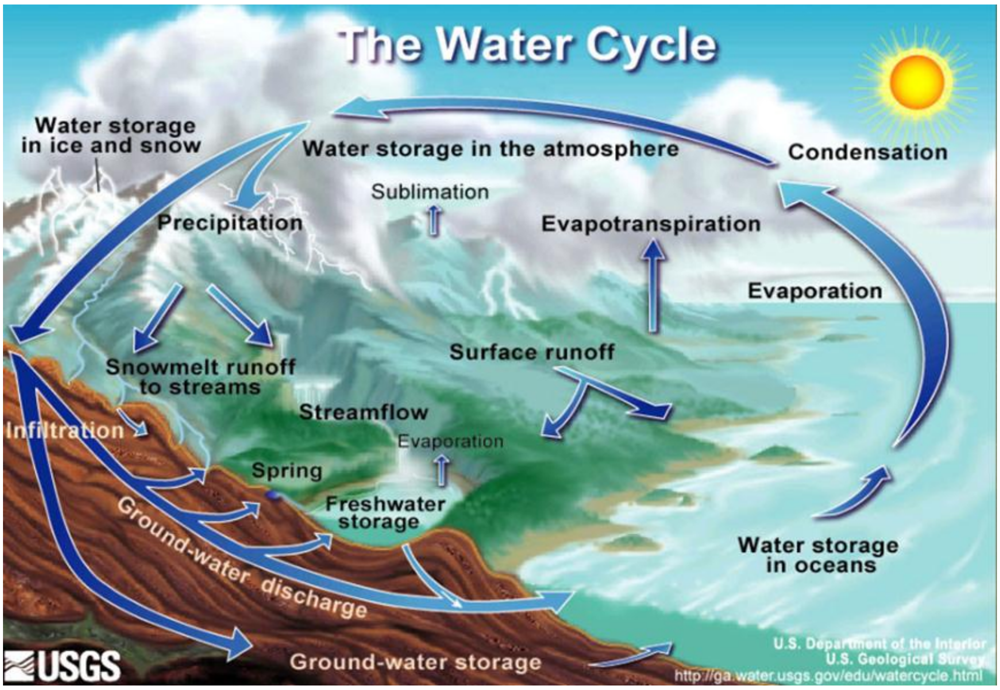


Figure 18. The water cycle

The water cycle is a process where water moves with solar energy through the three forms (as gas, liquid or solid) over the four spheres (atmosphere, lithosphere, hydrosphere and biosphere) and fulfill a complete cycle. The water cycle is a closed cycle, as there are no new inputs of water from external sources (Australian Water Association 2002).

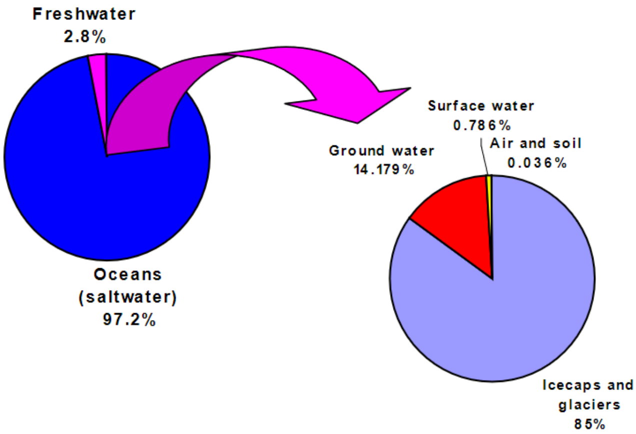


Figure 19. Distribution of fresh water sources (from: Bellette et al. 2003)

About 97% of the total water is saltwater in Oceans and it is not suitable for human consumption. Only 3% is freshwater, but its largest share is not available since it forms ice glaciers and icebergs (Figure 19). The accessible freshwater is located in streams, rivers, lakes and underground sources (Segar 1998), representing less than 1% of the Earth's total water amounts. The main pressures affecting the aquatic ecosystems are related to alterations of water quantity and quality, and changes in the physical habitat and the biological components (Grizzetti et al. 2016).

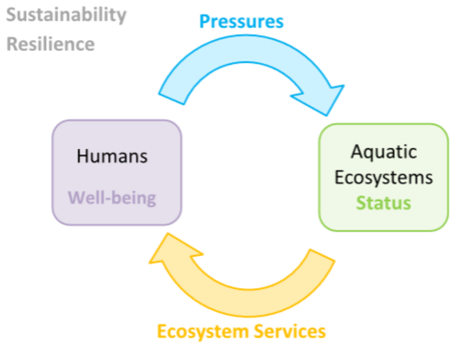


Figure 20. Humans and aquatic ecosystems (from: Grizzetti et al. 2016)

Pressures affect the biodiversity and the status of the aquatic ecosystem, which can result in a change in the ecosystem services and their economic value. For this reason, it is important to consider the resilience of the system and to introduce the notion of sustainability when assessing the delivery of ecosystem services (Grizzetti et al. 2016).

Water management can provide significant assets to the circular economy by closing water loops and recovering resources or energy from water. Beyond this water is used and increases value in a number of different ways. These alternatives of water use can be distinguished into the tree main concepts of Service, Energy and Carrier. Water provides significant services, such as sanitation in infrastructures, cooling and heating systems, and contribution as part of production in industrial processes. As a liquid natural resource, water is a commonly available and universal carrier in the natural and built environment. In both contexts water is acting as a carrier of chemicals, particles and droplets which represent potential resources or pollutants. Removal of these chemical and nutrients improves the quality of outflows to increase opportunity for water reuse, reduces environmental impacts and affords the opportunity of their use as fertilizers (Tahir et al. 2018).

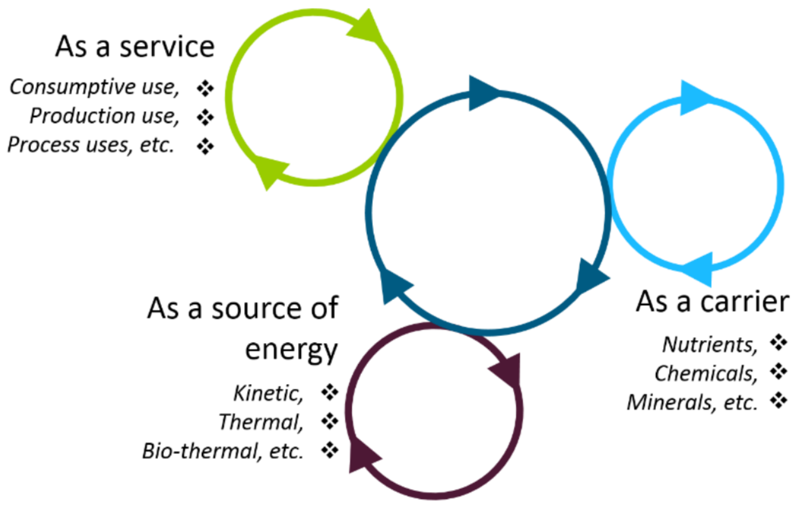


Figure 21. Potential dimensions of water use in circular economy (from: Tahir et al. 2018)

Water, through its physical properties can act as a source of hydro-electric energy, as thermal energy absorption and provide bio-thermal energy such as anaerobic digestion from municipal sewage (Tahir et al. 2018).

3.4 Biodiversity

Biodiversity entails the total number, the variety and the variability of plants, animals and other living organisms. Specifically, biodiversity (or biological diversity) is 'the variety of life', and refers collectively to variation at all levels of biological organization (Gaston and Spicer 2004).

Although the relationship between circular economy and biodiversity is not quite clear due to less attention given, some research efforts are undergoing towards this direction (Figure 22).

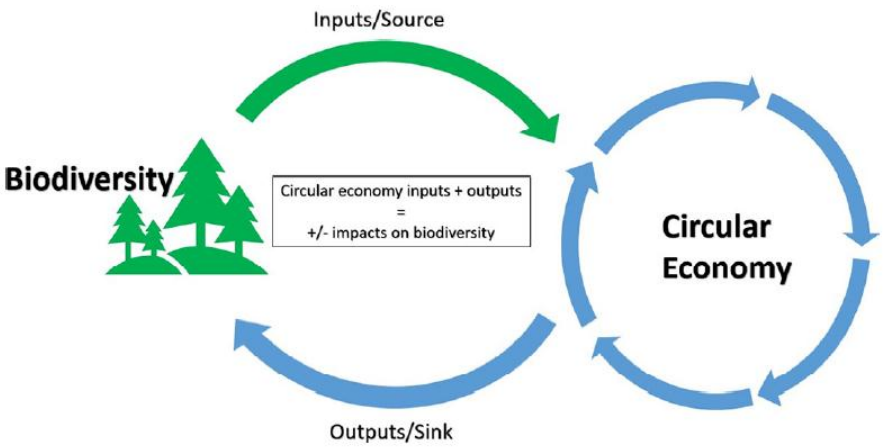


Figure 22. Potential link between biodiversity and circular economy (from: Buchmann - Duck and Beazley 2020)

Buchmann - Duck and Beazley (2020) proposed that as a true circular economy does not yet exist globally or nationally, limited conclusions on how a circular economy would impact biodiversity at a holistic scale could be achieved. Hence, as no relevant peer-reviewed articles exist in the world literature, further investigation is needed to assess their linkage.

4. Ecosystem services of natural resources-Risks

4.1 Classification of ecosystem services

The ecosystems according to the definition adopted by the Convention on Biological Diversity (CBD, United Nations 1992) form functional units consisting of dynamic, complex interactions among plants, animals and microorganisms and their nonliving environment. Humans form also an integral part of ecosystems. The ecosystem concept although very crucial for understanding how life is sustained on earth is a relatively new research and management approach described first as a concept in the seminal textbook of Eugene Odum in 1953. In order to assess ecosystems it is important to understand the notion of ecosystem boundaries. According to the Millennium Ecosystem Assessment (MEA) framework the spatial delimitation of an ecosystem is the place, where relative discontinuities, such as the distribution of organisms, the biophysical environment particularly soil types, drainage basins and depth of water bodies, as well as spatial interactions involving home ranges, migration patterns and fluxes of matter coincide. At large scales, regional or even global the evaluation of ecosystems can be based on the commonalities of basic structural units. Such a framework was applied by MEA to assess the ecosystem properties and changes. MEA in particular for the global assessment has used 10 categories: marine, coastal, inland water, forest, dryland, island, mountain, polar, cultivated and urban. Each of these categories does not constitute ecosystems themselves, but contains a number of ecosystems with boundaries, which can and do overlap. Ecosystems in each category share a specific pattern of biological, climatic and social factors, different across categories. These factors in particular refer to i) climatic conditions, ii) geophysical conditions, iii) dominant use by humans, iv) surface cover (vegetation), v) species composition and vi) resource management systems and institutions. For example, grasslands occur in places where potential evaporation exceeds precipitation. However, such areas are used either as grazelands or agricultural purposes. If they are used as grazelands they may have a pastoral or nomadic resource management system. Therefore, these factors involving the high potential evaporation relative to precipitation, the grassland cover, the use for livestock and pastoral or nomadic management system constitute a commonality, typical of the dryland system category mentioned above.

Ecosystem Services (ES) are the "multiple benefits provided by ecosystems to humans (MEA 2005) and the "direct and indirect contributions of ecosystems to human well-being" (TEEB 2010). Ecosystems produce goods and services, which people value for their well-being. In this sense, ESs include both the "final" ESs, for example agricultural crops, as well as the "intermediate" ESs, for example pollination, which support the "final" ESs (Haines-Young and Potschin, 2011). Research on ESs started relatively recently in the late 90's, while ESs entered the global policy agenda with the publication of the Millennium Ecosystem Assessment (MEA) initiative in 2005. Later initiatives related to ESs include TEEB (The Economics of Ecosystems and Biodiversity) in 2007, the Wealth Accounting and the Valuation of Ecosystem Services Partnerships of the World Bank in 2010 and the CICES (Common International Classification of Ecosystem Services) in 2009 promoted by the European Environment Agency (EEA).

Classification of ESs has been a cross-cutting basic issue in terms of their study. Different schemes have been proposed since early 2000 (De Groot et al. 2002, MEA 2005, Wallace 2007, Constanza 2008) with the most globally recognized and adopted in several studies to be that of MEA 2005 (Figure 23). MEA defined the following four ES categories:

Provisioning services: These are the products obtained from ecosystems, such as food and fiber, fuel, genetic resources, biochemical, natural medicines and pharmaceuticals, ornamental resources and fresh water.

Regulating services: These are the benefits obtained from the regulation of ecosystem processes, such as air quality maintenance, climate regulation, water regulation, erosion control, water purification and waste treatment, regulation of human diseases, biological control, pollination and storm protection.

Cultural services: These concern the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences. Cultural services include cultural diversity, spiritual and religious values and traditional and formal knowledge systems, educational values, inspiration, aesthetic values, social relations, sense of place, cultural heritage values, recreation and ecotourism.

Supporting services: These are necessary of all other ecosystem services. Their main difference from the other ES categories is that their impact on people is indirect or long-term, while changes in the other ES categories have direct or short-term impacts on people. Supporting services may include the primary production, soil formation and retention, nutrient cycling, water cycling and habitat provisioning.

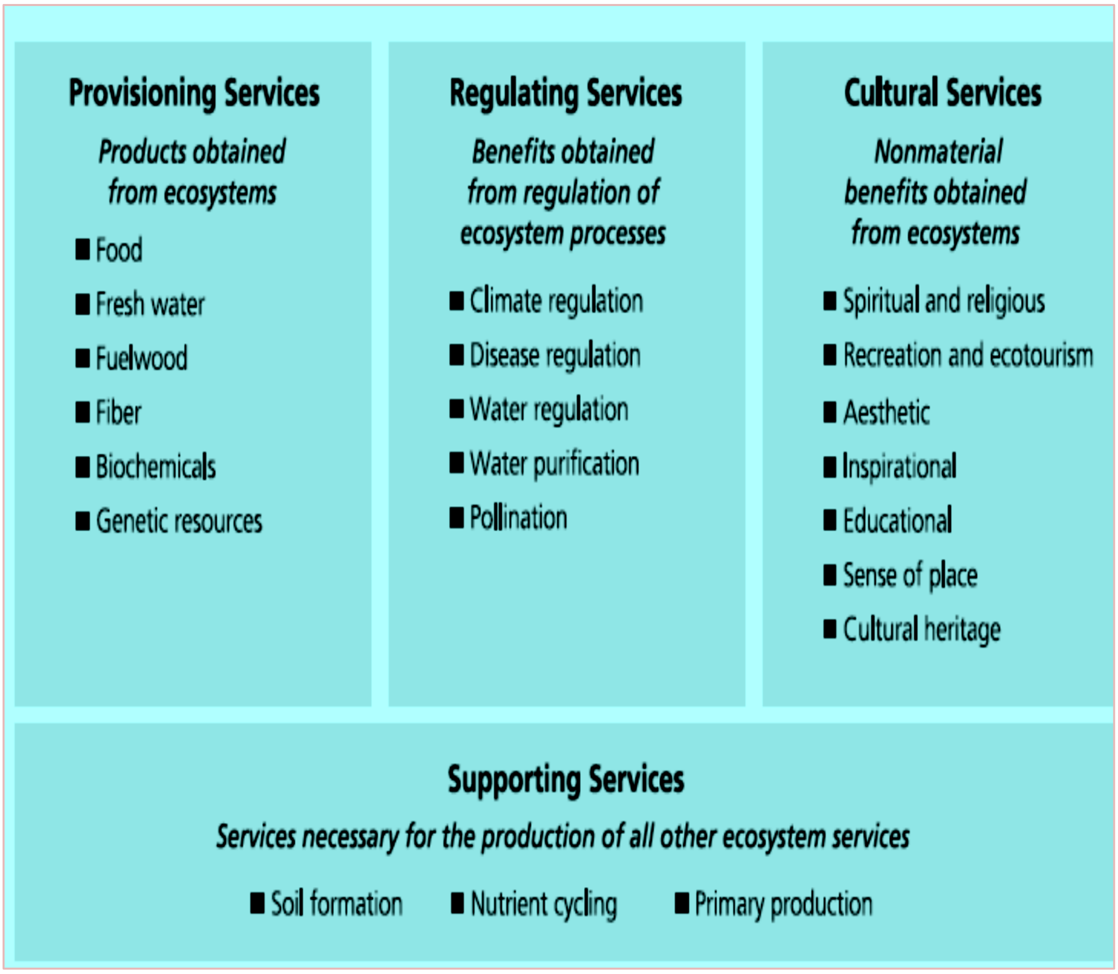


Figure 23. Ecosystem services (MEA 2005)

Any specific location on earth produces a bundle of services, which influence human well-being. On the other hand, it receives energy flows, water, carbon, pollutants and other materials from adjacent areas, while letting similar materials into these areas. An ecosystem consists of different types of areas, such as forest, agriculture, residential areas, each producing a different set of services. Therefore, any ecosystem assessment process should take into account both the production of services from each type of area and the flows of materials between the areas (Figure 24)

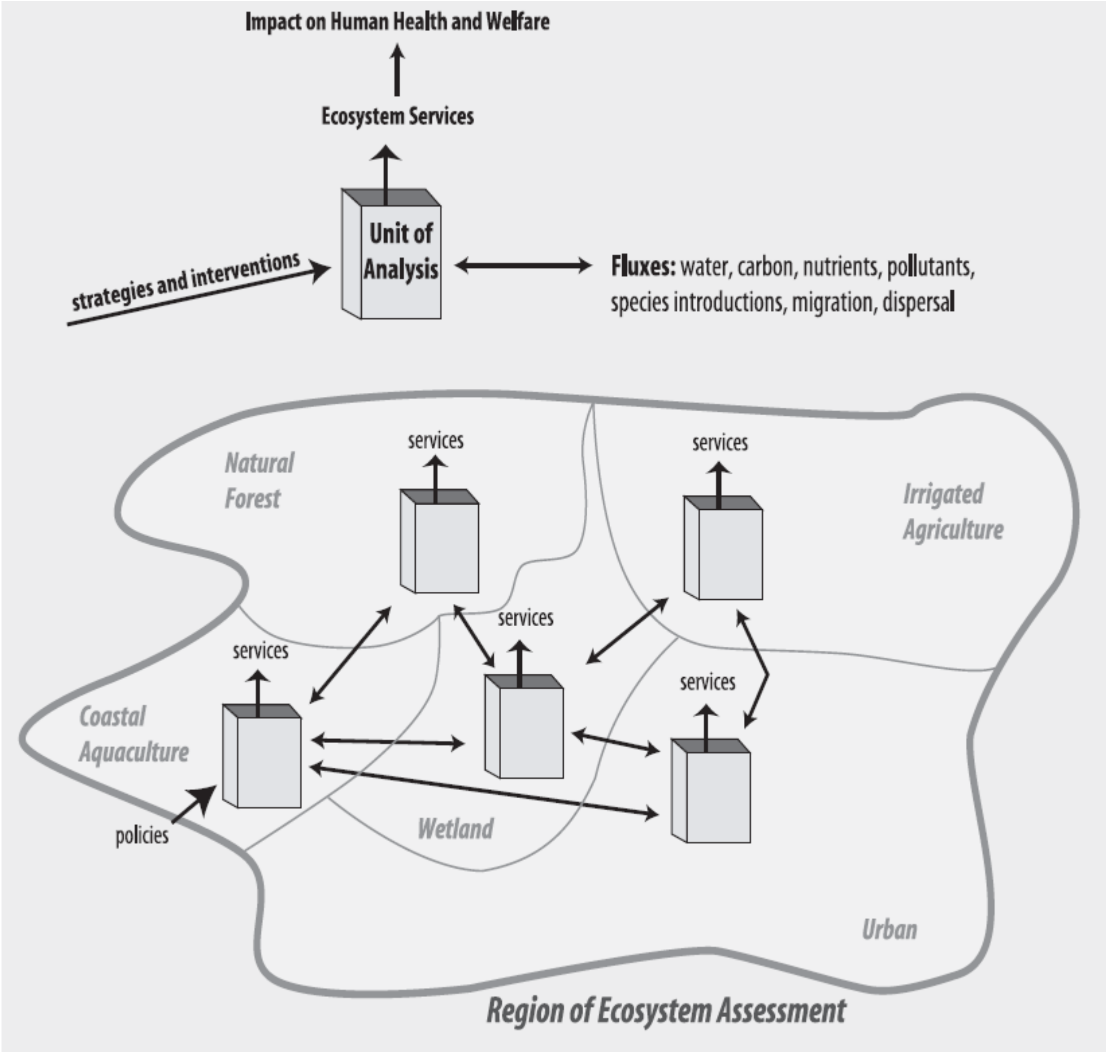


Figure 24. Analysis of ecosystem services (Source: World Resources Institute/MEA 2003)

The ES categories as shown in the following Figure 25 are interactively linked with human well-being. The main constituents of well-being involve i) security, which includes access to natural and other type of resources, personal safety and security from natural and man-made disasters, ii) basic material for a good life, which includes adequate and secure access to sufficient food, shelter and clothing, iii) health, which includes a healthy environment with access to clean air and water and feeling well, iv) good social relations, which refer to social cohesion, mutual respect and the ability to help children and others and finally v) freedom of choice and action, which concerns the opportunity for the individuals to achieve what they value doing and being. Freedom of choice and action is influenced by other constituents of well-being, while it is also a precondition for achieving other constituents of well-being.

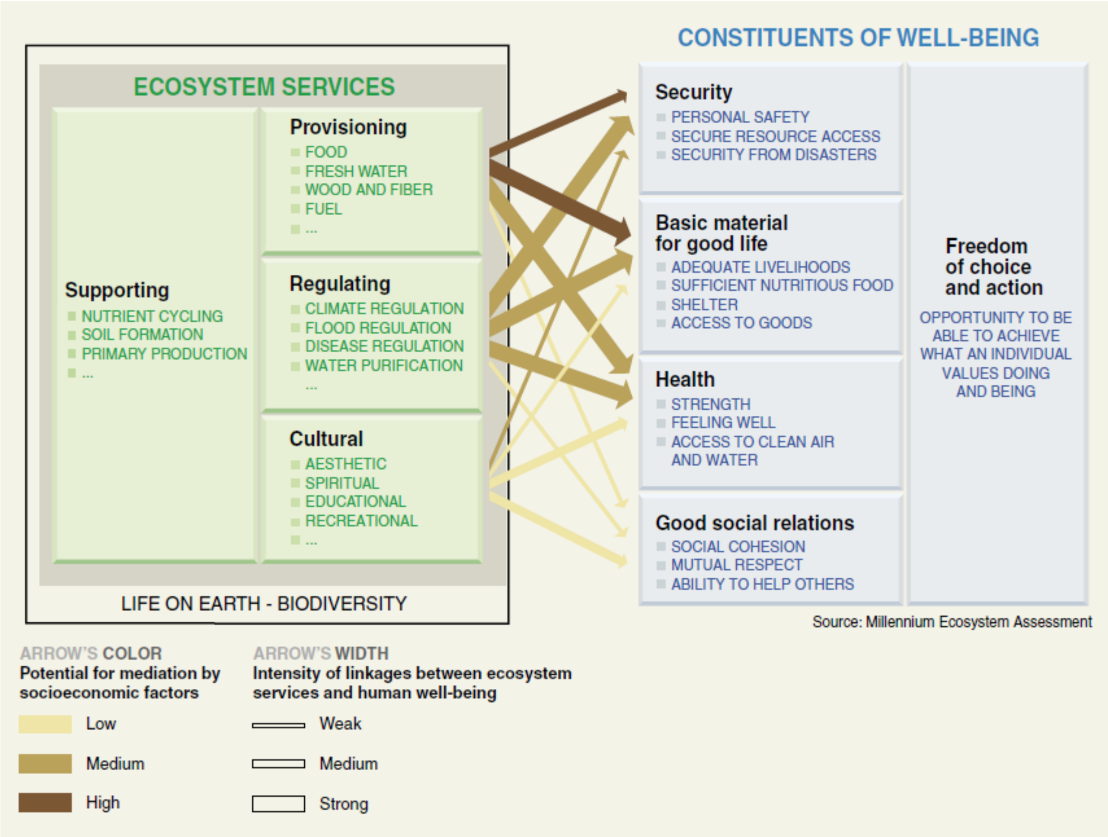


Figure 25. Linkages between ecosystem services and human well-being (MEA 2005)

Interactions between ES, human well-being and specific changes in drivers occur at multiple spatial and temporal scales and across scales. A conceptual framework depicting these interactions was developed by MEA in 2005 and it is shown in Figure 26. Driver changes affecting biodiversity indirectly, such as for example technology or lifestyle may lead to changes in drivers affecting biodiversity directly, such as the application of fertilizers. These may cause changes in the ecosystems and the services they provide, thus affecting finally human well-being. Similarly, a global change for timber demand may cause a forest cover loss at a regional level and this in turn may increase the flood risk along a local stretch of a river. Human well-being can be enhanced and ecosystems can be conserved by applying different interventions at different points in this framework.

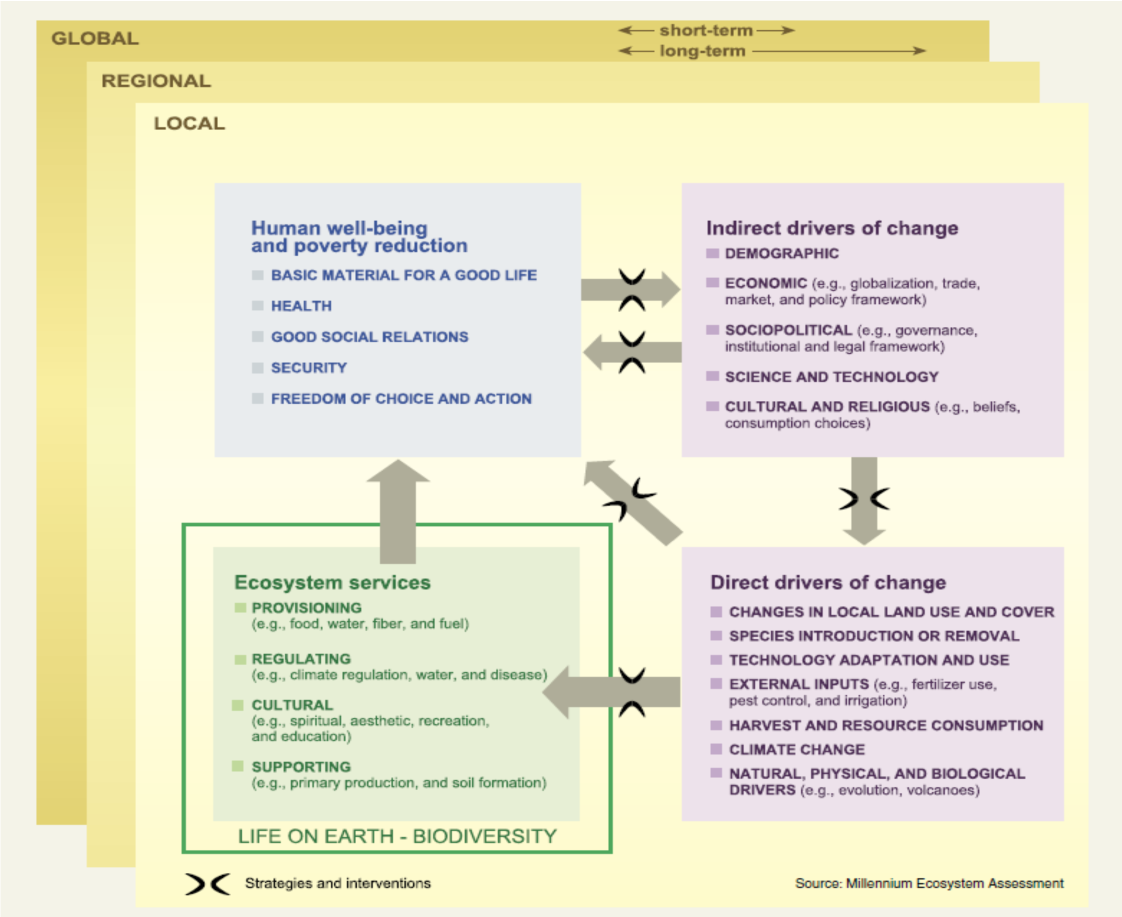


Figure 26. MEA conceptual framework of interactions between biodiversity, ecosystem services, human well-being and drivers of change (MEA 2005)

The four categories used in the MEA classification have formed the basis for adjusted ES classification efforts by other initiatives. TEEB for example, adopted one more category "the habitat services". Another initiative CICES (Common International Classification of Ecosystem Services), which was launched in 2009 and adopted also by EEA, excluded the "supporting services" category of the MEA classification scheme and introduced a hierarchical system. CICES uses "Sections", for example provisioning, regulating and cultural) and within each section classifications range from very general "Division" to very detailed "class" and "class type". Figure 27 provides an example of the CICES classification scheme.

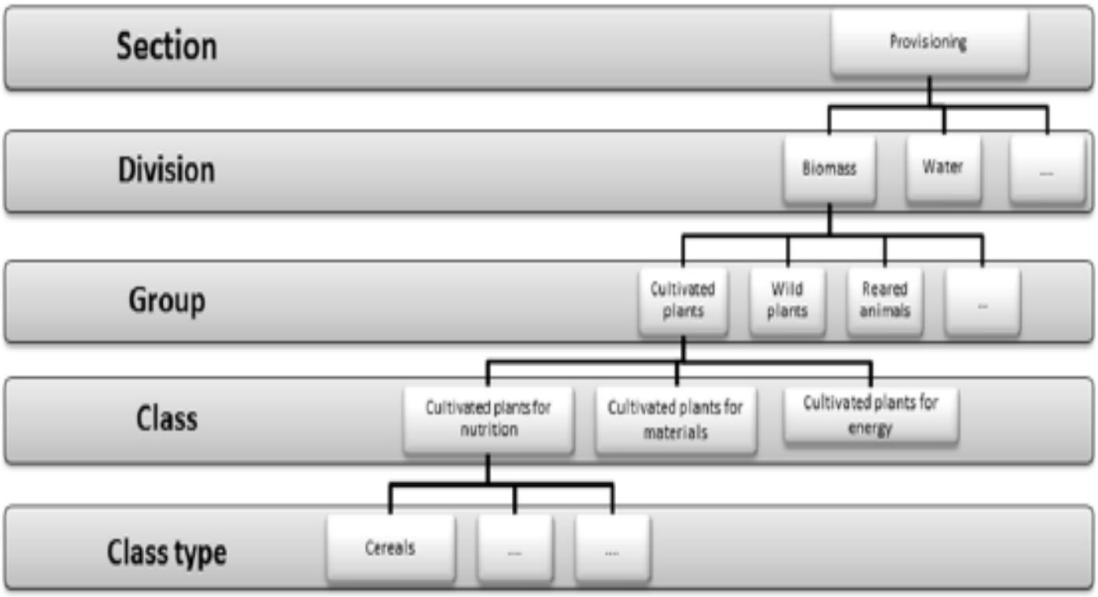


Figure 27. CISES (Common International Classification of Ecosystem Services)[Source: Haines-Young and Potschin, 2017)

CISES is considered to be better dealing with the environmental accounts adopted by the European Commission and the United Nations Statistical Service and it has been continuously updated since its launch in 2009. The latest revision was published in 2017.

4.2 Risks

Risks in general are considered as the negative impacts of natural or man-made caused events. In the framework of ecosystem services, as risk can be defined as the interaction of a hazard potentially causing harm to the state and condition of an ecosystem and the vulnerability of an ecosystem (Schröter et al. 2019). These hazards include the soil loss, wildfires, climate change and its implications, illegal activities in forested ecosystems, water quality and quantity degradation and biodiversity loss. At European level, these hazards seriously affect the country members, with the countries located in the Southern part to facing more adverse impacts. Thus, serious measures have to be taken by all countries in order to deal with the mitigation of the environmental risk levels.

4.2.1 Soil loss, excessive nitrogen deposition, nitrogen losses

One of the biggest environmental problems at European level is the soil loss and its related soil degradation. According to Panagos and Borelli (2017) the mean rates of soil loss in the European Union rural lands, including agricultural, forests and semi-natural areas, was estimated to about 2.46 tons per hectare per year, resulting in a total soil loss of 970 Mega tons per year.

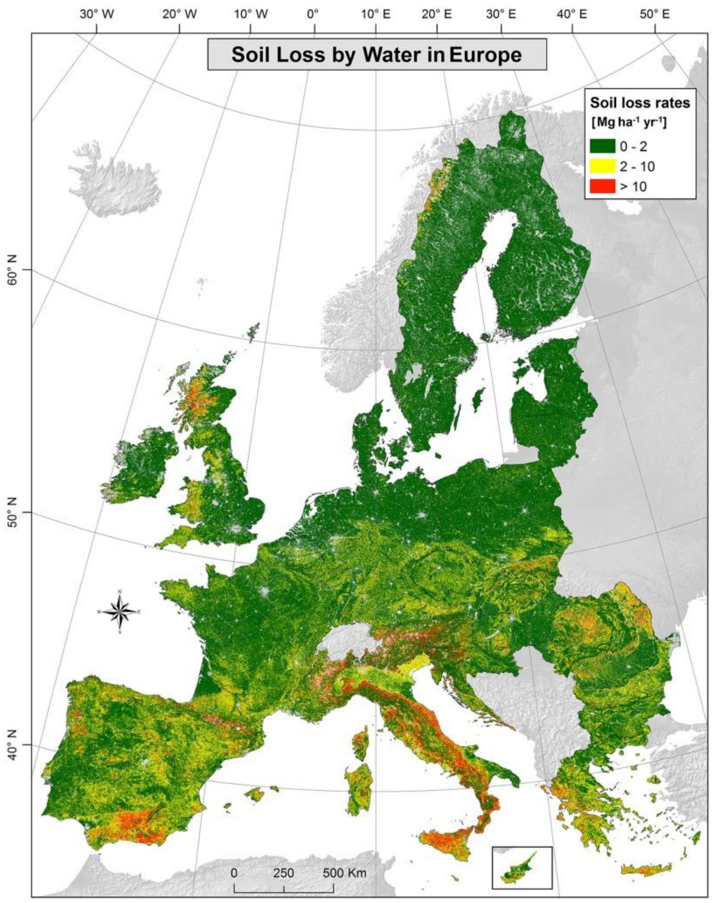


Figure 28. Soil erosion rate in Europe (from: Panagos et al. 2015)

The most important soil loss problems were observed in the Southern Europe and more specifically in Italy, Spain and Greece. According to the same authors, Slovenia and Austria are facing serious erosion problems, with the soil loss to be estimated to 7.43 t/ha/year and 7.19t/ha/year respectively (Table 5).

Table 5. Soil loss rate per country in the European Union based on Rusle outputs (from: Panagos et al. 2015)

Country		Overall Mean	Mean in arable lands	Mean in arable lands without GAEC	GAEC effect	% of the total soil loss in EU
		E (t ha^{-1} yr^{-1}) (%)				
AT	Austria	7.19	3.97	5.23	31.8	5.65%
BE	Belgium	1.22	2.06	2.71	31.8	0.30%
BG	Bulgaria	2.05	2.47	3.77	52.5	2.21%
CY	Cyprus	2.89	1.85	2.82	52.6	0.25%
CZ	Czech Republic	1.65	2.52	3.30	31.0	1.24%
DE	Germany	1.25	1.75	2.51	43.5	4.15%
DK	Denmark	0.50	0.61	0.68	11.4	0.20%
EE	Estonia	0.21	0.70	0.88	25.3	0.09%
ES	Spain	3.94	4.27	5.56	30.3	19.61%
FI	Finland	0.06	0.46	0.64	37.9	0.18%
FR	France	2.25	1.99	2.78	39.5	11.85%
GR	Greece	4.13	2.77	3.63	31.1	5.31%
HR	Croatia	3.16	1.67	1.80	7.5	1.74%
HU	Hungary	1.62	2.10	2.35	12.0	1.42%
IE	Ireland	0.96	1.32	1.52	15.7	0.55%
IT	Italy	8.46	8.38	9.80	16.9	24.13%
LT	Lithuania	0.52	0.95	1.02	7.5	0.32%
LU	Luxembourg	2.07	4.54	6.19	36.3	0.05%
LV	Latvia	0.32	1.01	1.11	10.1	0.20%
MT	Malta	6.02	15.93	18.72	17.5	0.01%
NL	Netherlands	0.27	0.54	0.68	24.7	0.08%
PL	Poland	0.96	1.61	1.79	11.2	2.92%
PT	Portugal	2.31	2.94	3.55	20.6	2.01%
RO	Romania	2.84	3.39	3.88	14.3	6.31%
SE	Sweden	0.41	1.12	1.31	16.6	1.57%
SI	Slovenia	7.43	4.63	5.33	15.0	1.49%
SK	Slovakia	2.18	3.54	4.09	15.6	1.03%
UK	United Kingdom	2.38	1.04	1.49	43.2	5.14%

Soil loss has serious impacts on soil productivity. It directly affects the ecosystem services, forest production and stored carbon, crop production and the quality of water. It has been connected with the climatic changes, the wildfire occurrences, the land-use changes and the loss of biodiversity. Soil loss rates are affected by the topography, climate (precipitation), soil properties, land use and human activity. The Universal Soil Loss Equation (USLE), as well as the Revised version (RUSLE) are the tools that are globally used to simulate soil loss rates at different scales.

Excessive nitrogen deposition

The total amount of Nitrogen (N) through deposition is one serious environmental problem with various adverse effects (Figure 29). The fertilizer production and the fixation of nitrogen during the combustion processes are the main sources of the nitrogen problem. Nitrogen compounds (NOx and NH3) may cause eutrophication and acid deposition, thus resulting to changes in soil and water quality. In addition, nitrogen compounds contribute to the formation of aerosols while, in particular, NOx plays a key role in the formation of the tropospheric ozone. The latest compounds consist of serious air pollutants with particularly adverse impacts on human health and life quality (Erisman et al. 2015).

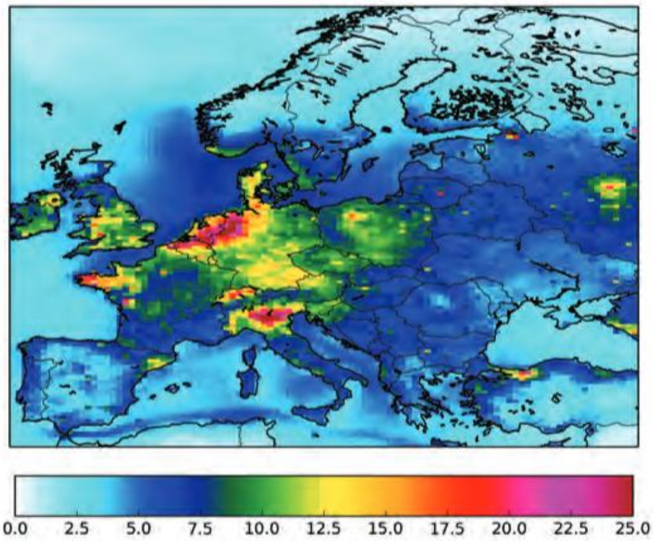


Figure 29. The total amount of N-deposition (kg(N)/Ha^{-1})

(source: Erisman et al. 2015)

Nitrogen losses

Nitrogen is a basic chemical element for agricultural use. However, the largest part of the total Nitrogen input is not currently utilized, with the remained amounts to be dissipated into the wider environment, causing a wide range of ecological and human health problems (figure 30).

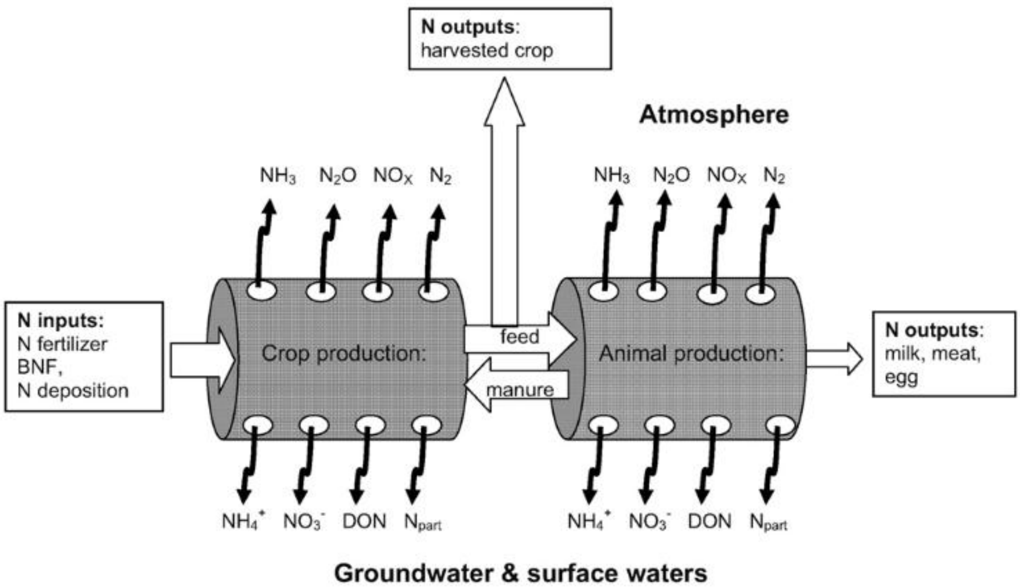


Figure 30. Nitrogen inputs, outputs in various products and Nitrogen emissions to air and water environments in crop production and animal productions (from: Oenema et al. 2009).

However, the European Union (EU) Nitrates Directive tries to achieve a further reduction and prevention of water pollution from nitrates losses from agriculture, by improving alternative farming practices.

4.2.2 Wildfires

Wildfires constitute a natural phenomenon that threatens the existence of a large number of natural resources. Each year in Southern Europe large areas of forests and forested lands are facing the devastating effects of uncontrolled high – intensity wildfires. Despite the decreasing trend of the burned area that has been observed over the past 40 years (figure 31), several factors seem to have contributed to the increase of the severity and the destructive effect of the wildfires. These factors include the increase of the accumulated forest biomass, the climatic changes, the land-use changes and the human invention to rural areas.

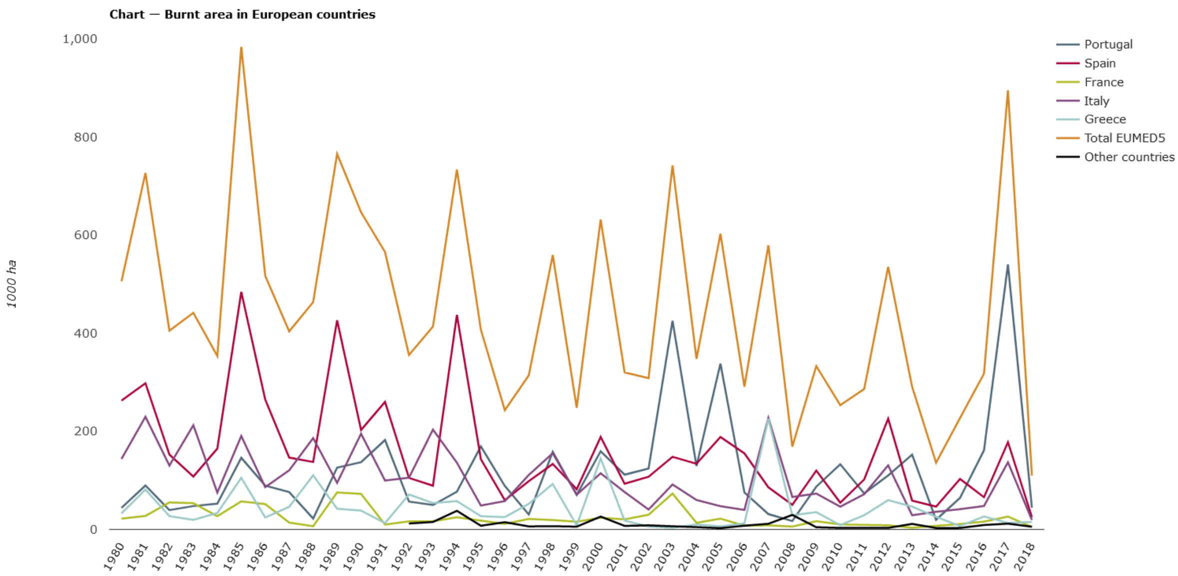
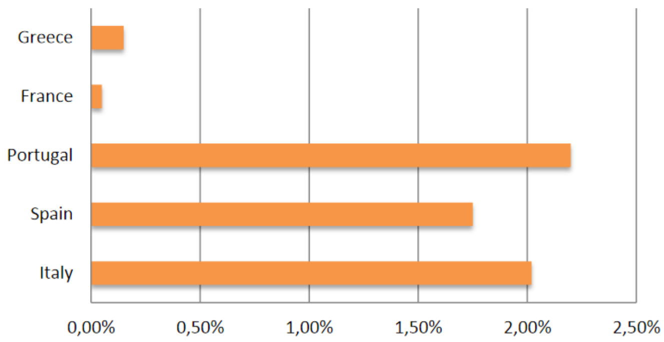


Figure 31. Burnt area in European countries (from: European Environmental Agency)

The total burned area during 2017 was the largest on record second only to 1985, due in particular large forest fires in Portugal, whereas the burnt area in 2018 was the lowest on record. On average each year about 500 000 hectares in Europe are destroyed by wildfires.



	Italy	Spain	Portugal	France	Greece
Burnt Area/Total Surface	2,02%	1,75%	2,20%	0,05%	0,15%

Figure 32. Environmental impact by country total surface (from: Di Fonzo et al. 2015)

In this framework, each year large amounts of woody vegetation is destroyed, triggering soil loss and soil degradation processes, causing water contamination and water cycle disturbance, disrupting basic ecosystem functions and releasing large amounts of carbon back to the atmosphere. From that perspective, wildfires consist a serious threat to natural resources and they directly impact benefits and resources that people receive from the environment, interrupting the circularity of use. The total damage cost is closely related to fire severity and it can be divided in three basic scenarios according to the following figure (33).

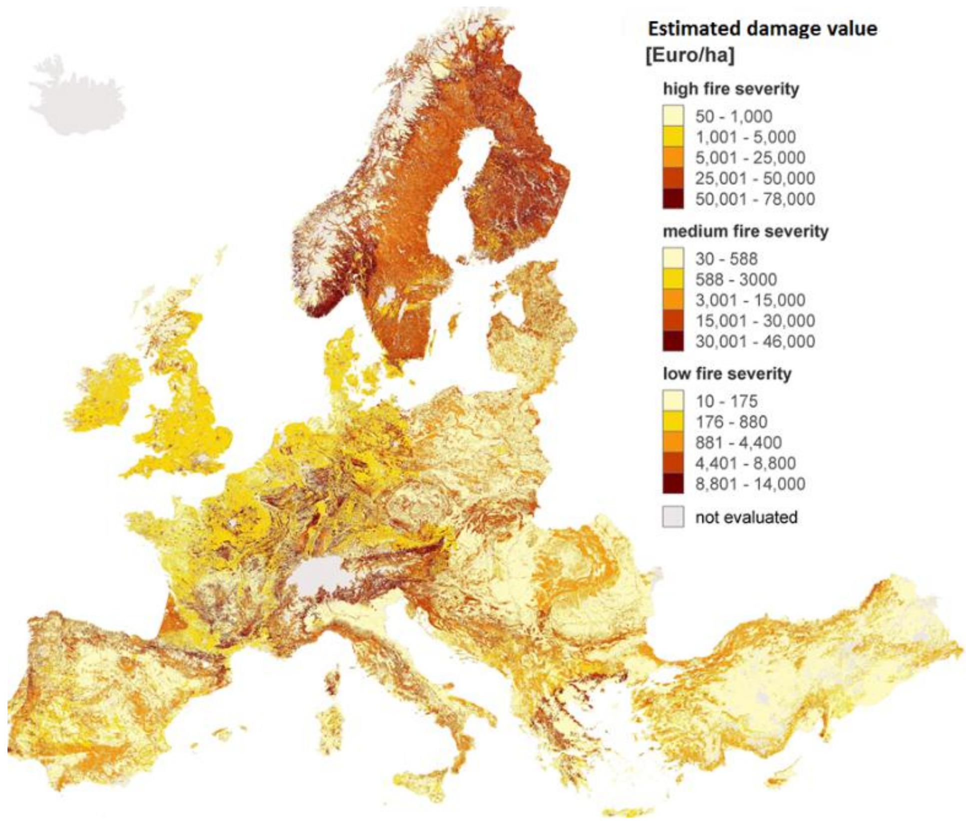


Figure 33. Estimated damage level from wilfire occurrence in Europe (from: Camia et al. 2017, after Oehler at al. 2012)

4.2.3 Climate change

Climatic research has supported that there are strong evidences that the climate has changed through the last centuries with severe impacts to natural resources and people's heath due to intense heat-waves, severe fires and floods, and increased prevalence of food- water- and vector-borne diseases. The climate change has already affected environmental and health determinants, such as food safety, air pollution and water quantity and quality (World health organization 2017). For the European Union and based on a number of reporting stations, the decadal average temperature over land area for 2002–2011 is 1.3°± 0.11°C above the 1850–1899 average (Kovats et al. 2014).

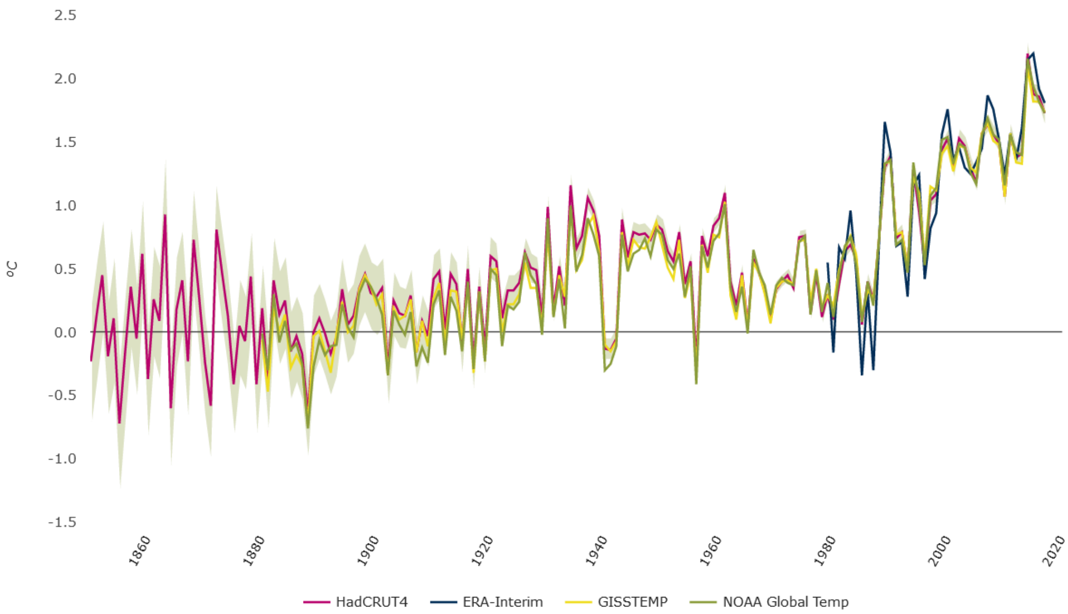


Figure 34. European average temperatures over land areas relative to the pre-industrial period (from: European Environmental Agency)

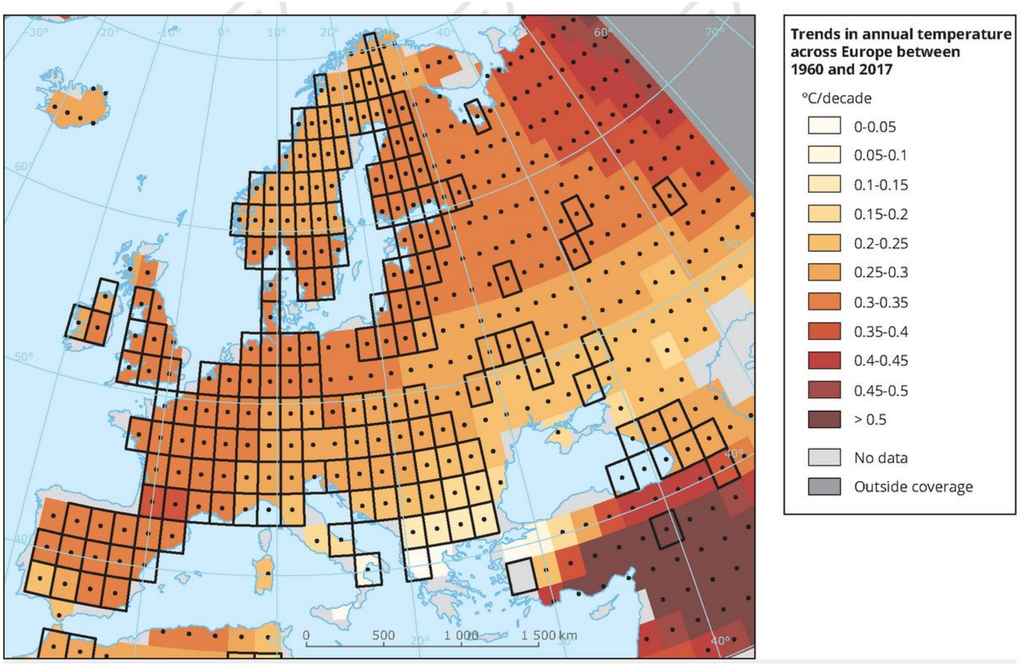


Figure 35. Trends in annual temperature across Europe between 1960 and 2017. Boxes outlined in solid black contain at least three stations and so are likely to be more representative of the grid (from: European Environmental Agency)

The responses of forests to climate change include changes in growth rates, phenology, composition of animal and plant communities, fire and storm damage, and insect and pathogen outbreaks. Deforestation is currently termed as the destruction of forests and woodlands and the permanent alteration to non-forest uses (European Commission). Deforestation is mainly observed in tropical ecosystems and it cause climatic disruption since it is closely linked to increasing CO_2 emissions. According to (Van der Werf et al. 2009) after fossil fuel combustion, deforestation is the largest anthropogenic source of CO_2 to the atmosphere. However, deforestation in Europe has showed decreasing trends in the last decades.

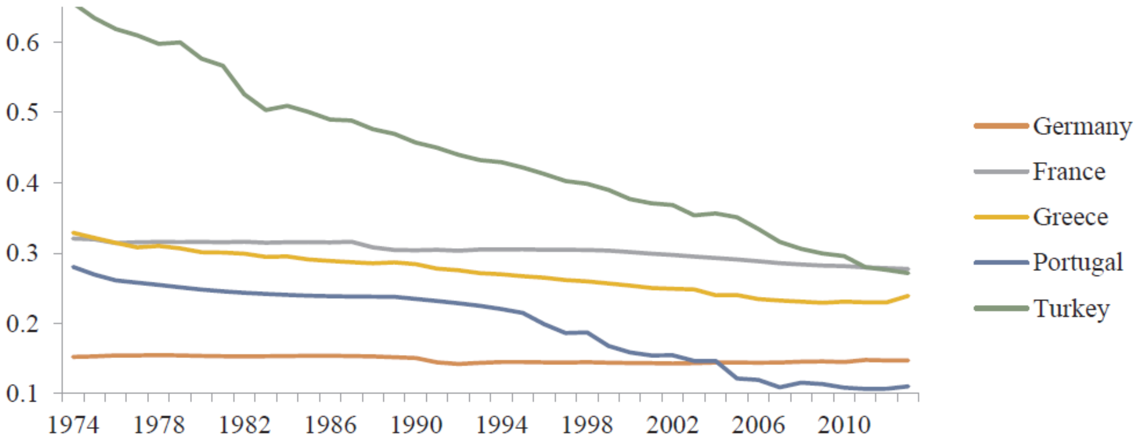


Figure 36. Arable land per capita (from: Zambrano-Monserrate et al. 2018)

As it is clearly shown in section 3.2, the forest area has increased by almost 10 % within the last 30 years (since 1990), which leads to the conclusion that the policies followed in the EU had a great impact on the protection and maintenance of forested ecosystems showing no deforestation trends.

Carbon sequestration

It has been long been recognized that forests contribute significantly to global carbon cycle forming an efficient and persistent carbon sink. The amount of CO2 sequenced by photosynthesis is one of the basic phases of the carbon cycle, and forests contribution is fundamental in this complex process. It has estimated that between 2010 and 2020, the average annual sequestration of carbon in forest biomass (including the trunk, branches, twigs, foliage and roots), was about 155 million tons in the European region (Forest Europe 2020). The total amount of carbon stock in these countries that are stored in forest biomass has estimated to about 9900 million tons (MCPFE, 2011). In the EU-28, forest carbon sequestration equivalents to about 10% of gross greenhouse gas emissions (Forest Europe 2020).

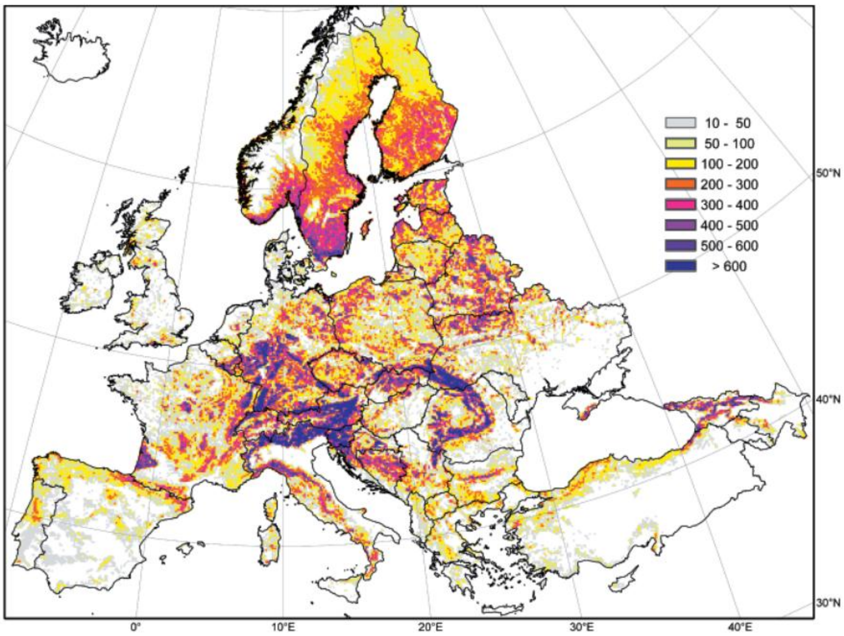


Figure 37. Carbon stock in aboveground forest biomass (from: European Forest Institute)

Forest degradation

Forest degradation involves a change process that negatively affects the characteristics of a forest such that the value and production of its goods and services decline (FAO 2011). It is mainly referred to low forest production rate compared to the station potentiality. It is mainly attributed to soil degradation following a number of significant disturbances in forest lands, such as forest fires, deforestation, forest management practices, over-exploitation, illegal logging, overgrazing, invasion of alien species and forest cover disturbance. It is one of the most important threats for the forested ecosystems across Europe.

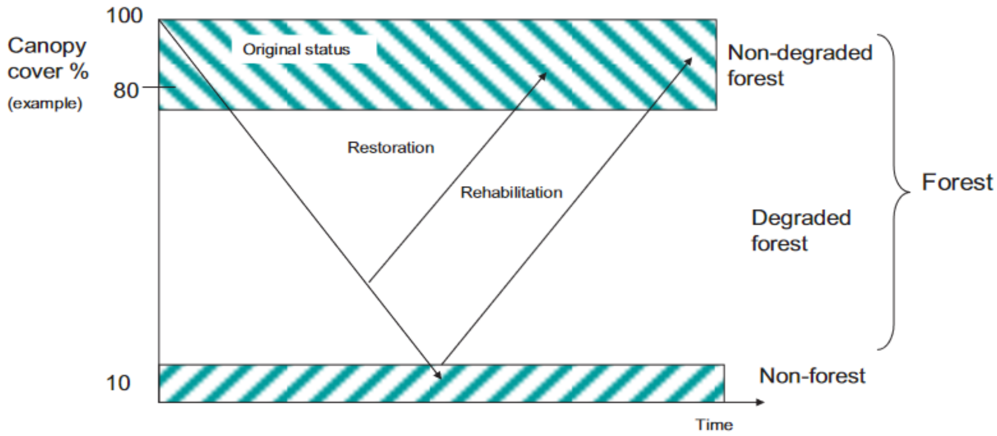


Figure 38. Degradation thresholds (from: FAO 2011)

Forest degradation causes a series of adverse impacts to growing stock, biodiversity and to the production of forest goods. The forest soil loss potentiality for the European forested land is presented in figure 39.

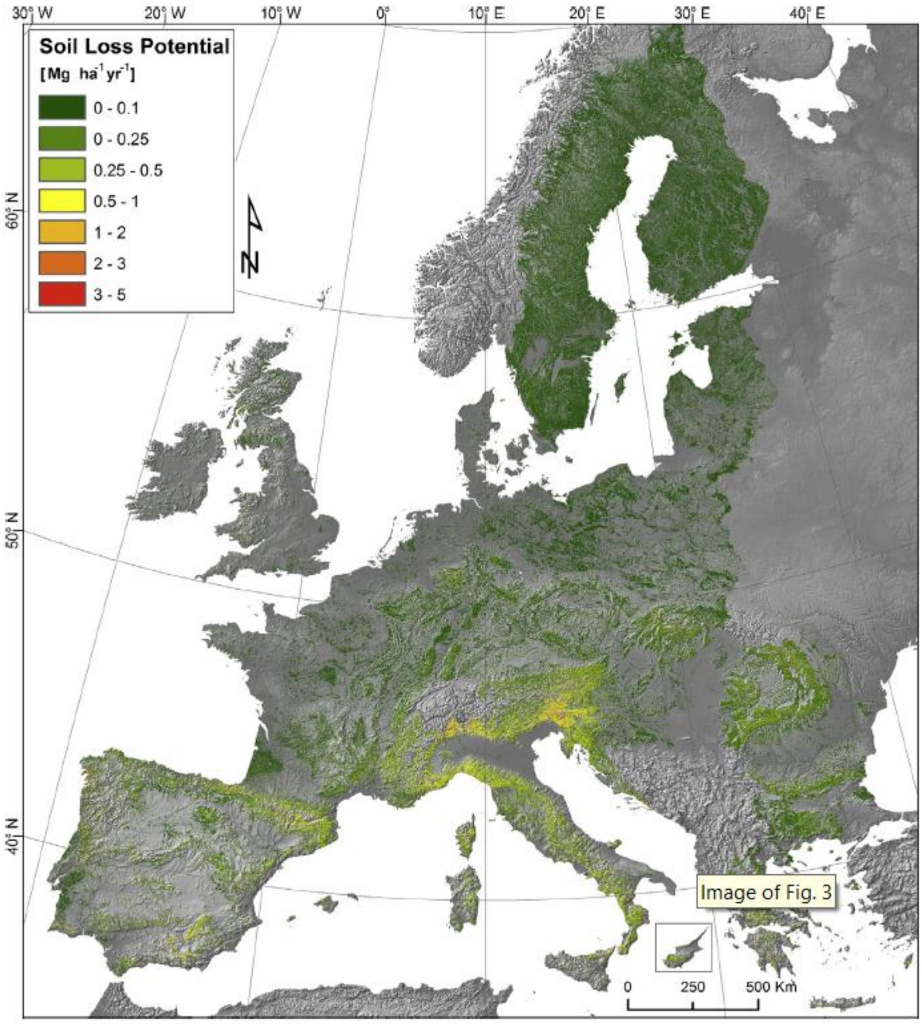


Figure 39. Estimated (modelled) soil loss in forests (from: Borelli et al. 2016)

Forests are closely linked with a number of significant ecosystem services. In this sense, a potential degradation process is expected to adversely impact people who depend on forest products and services at a local, regional or global scale (FAO 2011).

4.2.4 Illegal hunting

Illegal hunting include a variety of hunting practices such as shooting protected species, use of illegal trapping devices, shooting out of season or in prohibited areas, illegal use of poisons, that pose under threat the fauna and the biodiversity posing additional pressure to natural ecosystems.

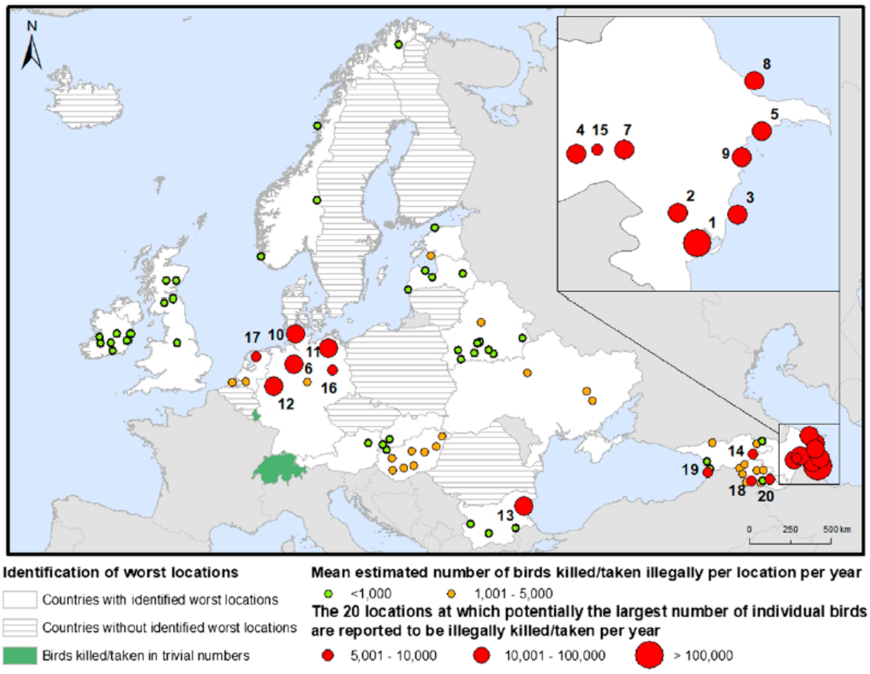


Figure 40. The potential worst locations where large number of individual birds are reported to be illegally killed/taken per year in Northern and Central Europe and Caucasus (from: Brochet et al. 2019)

In general terms, the illegal use of natural resources is a major threat to biodiversity at local and regional scale, with adverse implications to ecosystem stability and resilience. At European level, there is no systematic record of illegal hunting activity.

4.2.5 Degradation of water quantity and quality

European Union’s water policy is to ensure that a sufficient quantity of quality water is available to satisfy people's needs (European Environment Agency 2018). For surface waters, a secure chemical status is defined by limits on the concentration of certain pollutants found across the EU, known as priority substances. In general terms, more than 50% of the water bodies (both rivers and lakes) in Europe are reported to hold less than good ecological status or potential, according to figure 41 (European Environment Agency). The agriculture pollution has been reported to affect most the surface water bodies by causing nutrient enrichment. In north-western as well as in central Europe, where intensive agricultural practices and high population density are present, a large proportion of water bodies are characterized by poor ecological status, affected by pollution sources. It is estimated that about 1/4 of groundwater across Europe is classified of low chemical status, due to nitrate concentrations. However, EU water policy has contributed to improve water quality and today the water quality is significantly cleaner compared to 25 years before. For the period between 1992 and 2012, the nitrate concentration in European rivers declined by 20% on average (figure 42).

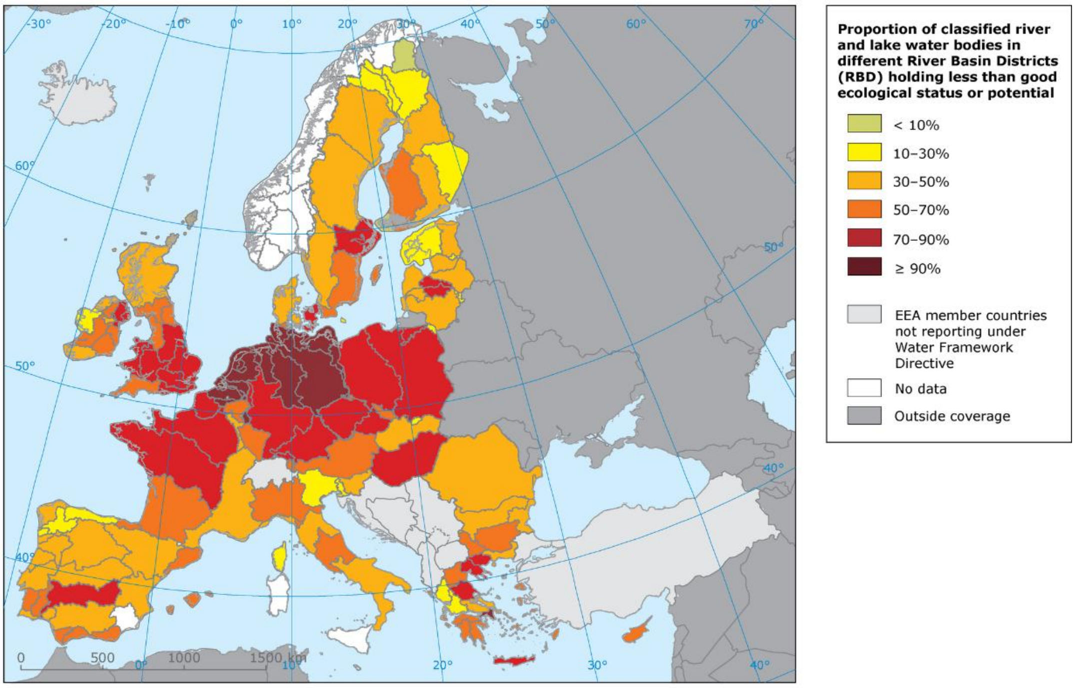


Figure 41. Potential ecological status of water bodies across Europe (from: European Environment Agency).

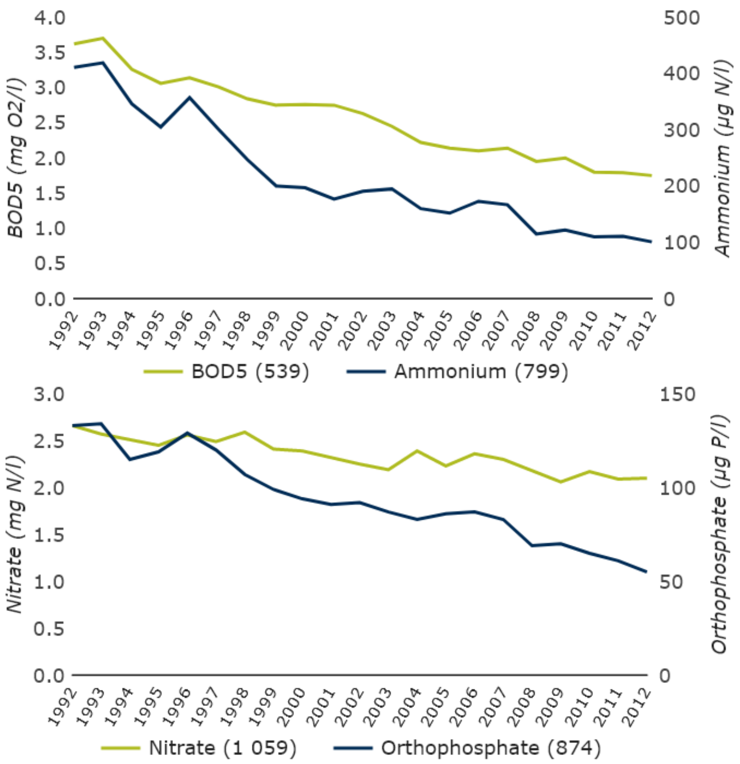


Figure 42. Changes in water quality from 1992 to 2012 (from: European Environment Agency).

When the need for water exceeds the amount available, then water availability problems start to emerge. Low rainfall in high density areas and high demand of water in agricultural lands are the main variables responsible for water scarcity. Water resources are unevenly distributed, with annual average run-off ranging from more than 3 000 mm in western Norway to 100-400 mm over much of central Europe and less than 25 mm in central and southern Spain (European Environment Agency). Freshwater abstraction by public water supply ranged across the EU in 2018 from a high of 157 m³ of water per inhabitant in Greece down to a low of 30 m³ per inhabitant in Malta (Figure 43).

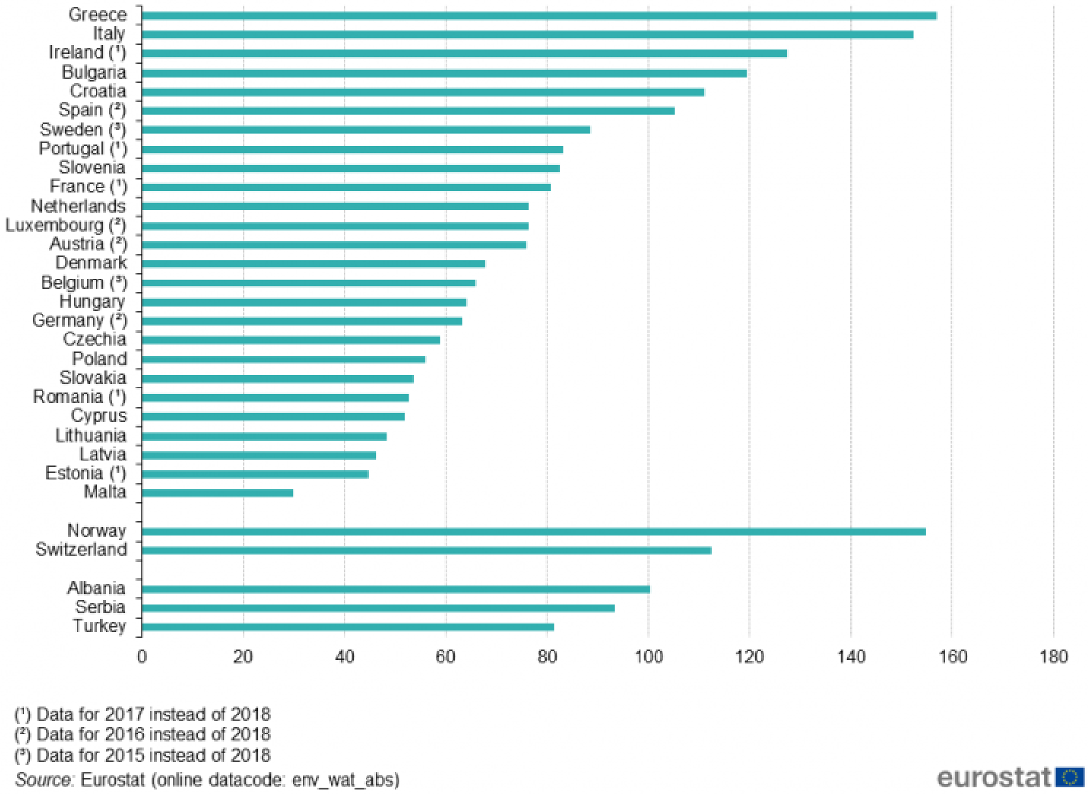


Figure 43. Total freshwater abstraction for public water supply (from: Eurostat)

4.2.6 Biodiversity loss

In European Union, a significant number of species is under continuous extinction risk, which has been assessed through the IUCN Red List Criteria as it is illustrated below (Figure 44).

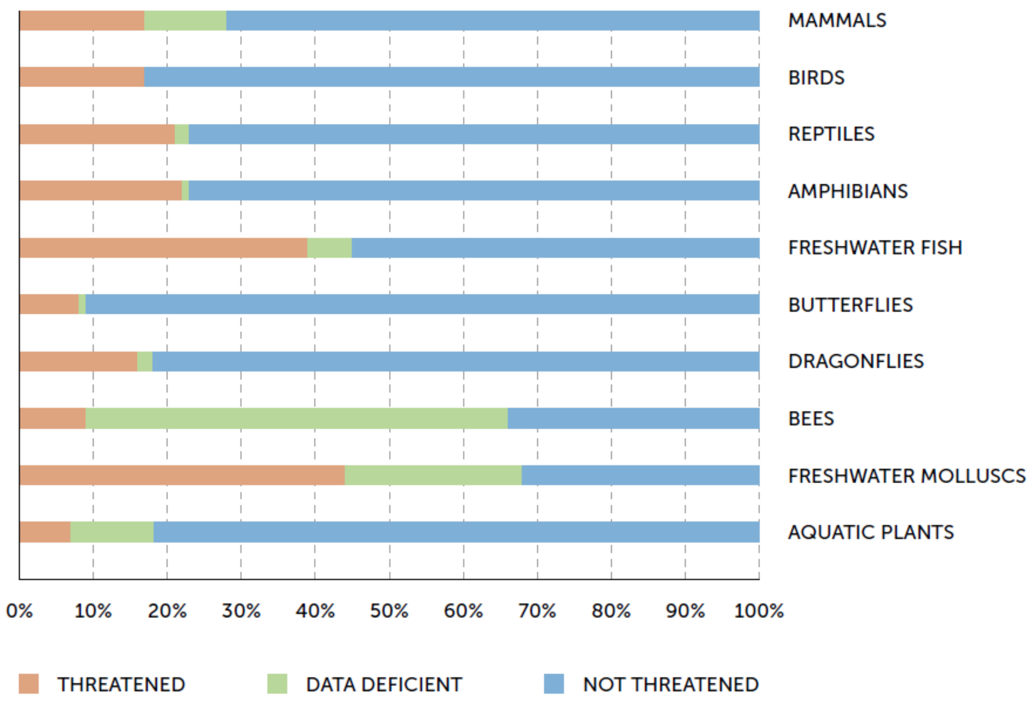


Figure 44. Extinction risk of several taxonomic groups in the European Union (from: Bird life international 2020).

However, from the analysis of 161 long-term biological time series (15–91 years) across Europe, significant increasing trends were reported in taxonomic richness, diversity and also in turnover, while no significant trend in abundance was observed as shown in figure 45 (Pilotto et al. 2020). This significant finding was reported by other studies also for the European Union. During the last 50 years, a number of species have returned to European Union Member States, sometimes after a long time of absence, and the populations of other species have recovered significantly. Since the 1950s, a notable increase of 30% in mammal's distribution was observed, while the distribution of the majority birds has increased by 14%, since the 1980s (Wildlife Comeback in Europe 2013). The largest increase of the mammal's populations was reported in Southern and Western Europe. It is worth noting that many species still occupy only a fraction of their historical range and some are still at risk of extinction.

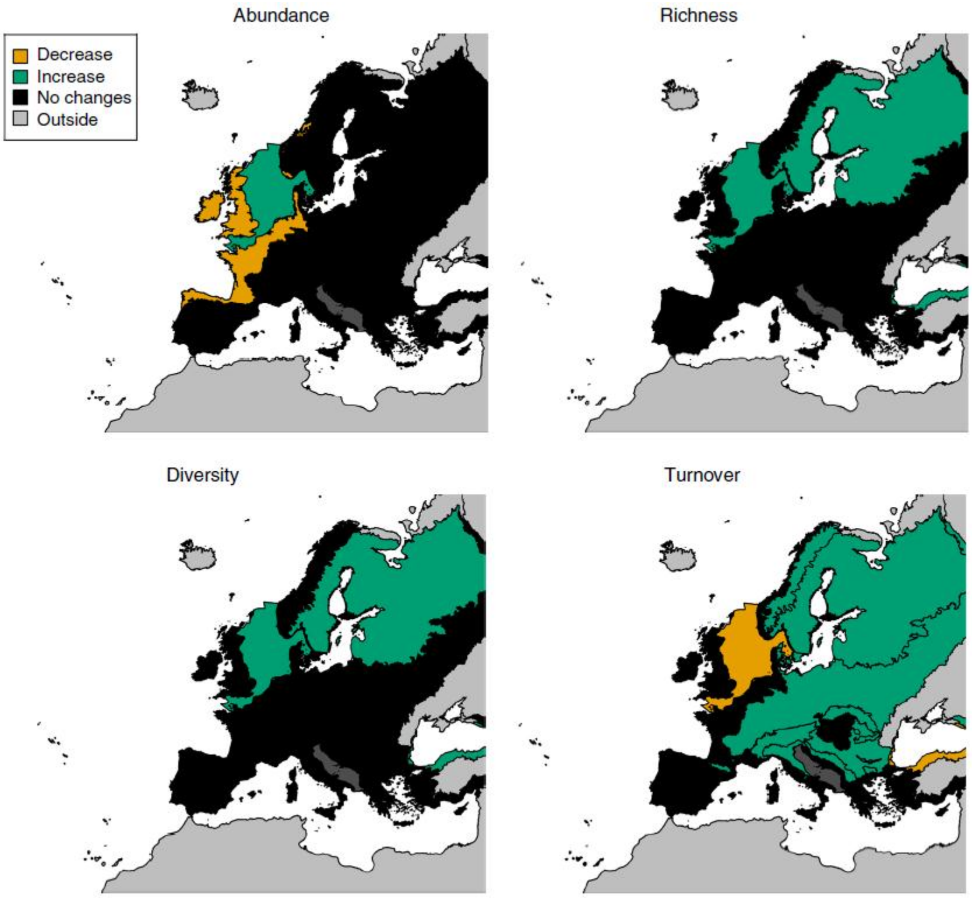


Figure 45. Biodiversity trends in the different bio-ecoregions (Source: Pilotto et al. 2020)

5. Natural resource regeneration-sustainable management of natural resources

The ability of natural resources to deliver multiple services can be assessed with various methods and measures. In order to determine the condition of the ecosystems, the provision of services and their effect on human well- being should be assessed and this requires an integrated approach. Based on such an assessment, a decision-making process can determine which bundle of services is most valued to manage the system sustainably.

In a strict sense, the sustainable management of a natural resource for the production of an ecosystem service refers to how the biological potential of the particular ecosystem to sustain the yield of that service, for example food production or wood production is being maintained. Thus, wood production is sustainable if the surplus (growth) of the forest but not the resource base (growing stock) is harvested and if the forest is not degraded by human activities. The same may hold true for a fish provision service or other services. In general, by the term "sustained yield management" we refer to the management and yield of an individual resource or ecosystem service.

Sustainability most often is used in the context of sustainable development which implies a pattern of development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (Bruntland Report 1987). Both sustainability and sustainable management of natural resources refer to the goal of ensuring that multiple services from a particular ecosystem are sustained. Although the condition and sustainability of each ecosystem service derived from natural resources are evaluated in different ways, in general a full assessment requires consideration of stocks, flows and resilience.

5.1 Stocks and flows

With regard to provisioning ES their condition is not accurately reflected by their flows, because any given flow is not necessarily sustainable in the long run. The flow is measured with reference to biophysical production, for example as m^3 of round wood per hectare or tons of potatoes per ha or tons of tuna landings. There is an analogy to the provisioning of ecological goods, fuelwood or food or fiber with the provisioning of manufactured goods, that is, the process depends on the flow and the stock of the good. The flow, which corresponds to the quantity of goods sold by a manufacturer, may come from the production of new goods or the depletion of built-up stocks. In this respect, the flow is an incomplete measure of the factory's productivity. In terms of the natural resources production may be maintained in the short term even if the resource is overharvested. However, the production of overharvested resources will be reduced in the long term. A typical pattern of rapid production followed by a collapse has been observed for example due to overharvesting in many overharvested fisheries around the world, which eventually collapsed. This pattern is typical also for all other provisioning services. Another example concerns agricultural production, which could be maintained through fertilizers or new crop varieties despite potential degradation of the ecosystem's productive capability as a result of soil erosion, or compaction or salinization or nutrient depletion or pollution. If manufactured capital can compensate for losses of the ecosystem's natural capital, the agricultural production will be maintained. However, manufactured and natural capital are not perfectly substitutable and therefore when a critical level of soil degradation will be reached, the agricultural production will fall.

This pattern became evident hundreds of years ago for wood production particularly in Europe, when first the practice of sustainable forest management was created and applied. According to FAO, the forest growing stock is the volume of all living trees, excluding smaller branches, twigs, foliage and roots.

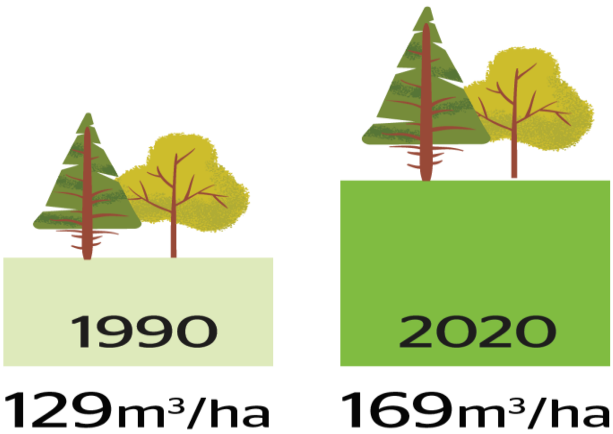


Figure 46. The Growing stock per hectare in European forests (from: Forest Europe 2020)

It is measured in solid cubic meters (m^3) over bark and includes trees of more than a given size of diameter at breast height (Eurostat 2011). It is a basic indicator to estimate and monitoring the sustainability of a forest sector and it is closely connected with biodiversity. According to Forest Europe (2020), the total Growing Stock of European forests is estimated to 34 900 million m^3, about 84% of which is available for wood supply. The average Growing Stock rate is 169 m^3 per ha and it has notably increased during the last 30 years to about 40 m^3 per ha (Figure 46). However, this trend is currently slowing down.

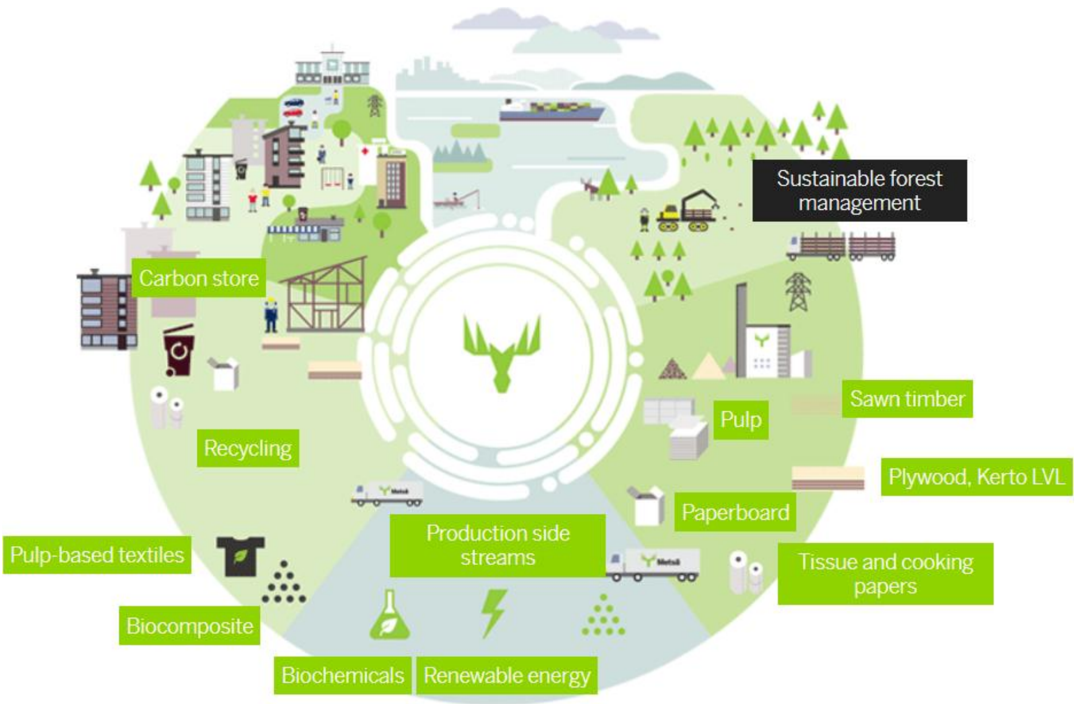


Figure 47. Graphical representation of circular bio-economy in forest sector (From: Metsä Group)

As shown in figure 47, the Sustainable Forest Management (SFM) is a critical link in the circular bio-economy chain. The management of forests "closer to nature" promote the basic idea to reach a better balance between productive, protective and social functions. Although there is no widely accepted definition for the SFM, it can reflects the "*process of managing permanent forest land to achieve one or more clearly specified objectives of management with regard to the production of a continuous flow of desired forest products and services without undue reduction of its inherent values and future productivity and without undue undesirable effects on the physical and social environment*" (International Tropical Timber Organization 1992). Within this concept, the continuous flow is currently ensured through circular regenerations of the forest natural resources at all phases of the production process. In this framework, timber harvesting via silvicultural interventions is applied sequentially at the different development stages of the forest, accelerating the natural cycle (figure 48) by extracting less woody volume than the total increment (harvest intensity) at annual basis (figure 49).

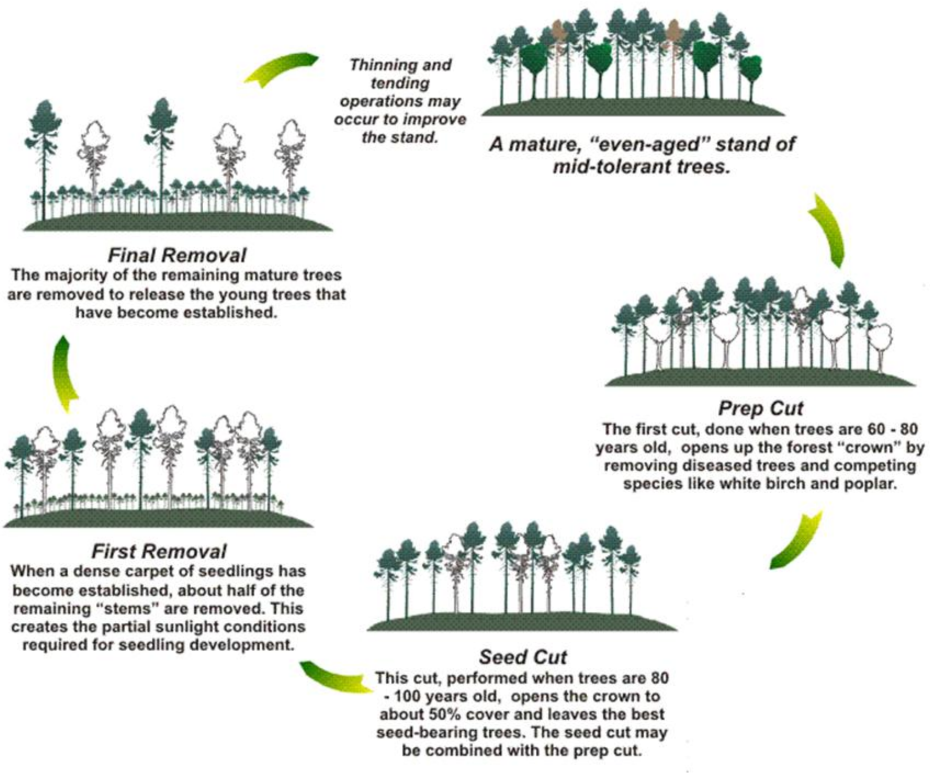


Figure 48. A forest life cycle for some shade tolerant species within the concept of SFM

It is worth mentioning that during logging activities, the largest part of the harvested trees (bark, leaves, thin and medium – size branches) currently remains in the forest to ensure soil productivity for the next cutting cycle.

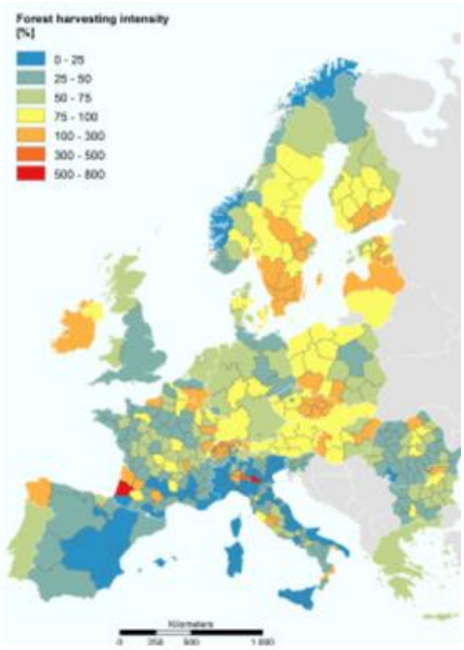


Figure 49. Harvest intensity in EU (from: de Arrano et al. 2018)

Regarding the regulating services the "production" process is not relevant. The condition of the service is assessed in terms of whether the ecosystem's capability to regulate a service has been improved or deteriorated. For example if deforestation of an area has caused decreased precipitation and negative effects on people, the condition of this regulatory service is considered to be degraded.

The condition of cultural services is even more difficult to assess. In some cases proxy measures through linked provisioning services, such as specific recreation activities can be used. In other cases, information on specific cultural, spiritual or aesthetic features of the ecosystem should be identified and their trend to be examined.

5.2 Variability, Resilience and thresholds

Sustainability of natural resources not only requires assessment of the mean levels of stocks and flows of ecosystem services but it also requires assessment of their dynamics and particularly their variability and stability. MEA has focused on three main characteristics of ES to assess their dynamics: variability, resilience and thresholds.

Variability in ES concerns the changes in stocks or flows over time due to stochastic, intrinsic and extrinsic factors. Stochastic variability is related to random or uncontrolled factors. Intrinsic variability refers to structural properties of an ecosystem, while extrinsic variability is due to forces outside the system.

Resilience is a measure of the ability of a system to return to its original state after a perturbation over a decade or more, such as for example a large scale fire. The shorter the duration of the recovery phase of a system, the more resilient the system.

Thresholds in ecosystems represent dramatic and sudden deviations from average system behavior. Such deviations are caused by steady changes in internal or external conditions which trigger the system's susceptibility to enter an alternative state. Sustainable management of natural resources in addition to stocks and flows aims also to reduce the system's variability through different interventions. Irrigating crops during droughts or maintaining forests to prevent soil erosion are examples of such interventions.

Figure 50 illustrates a hypothetical situation of provisioning of an ecosystem service, which has suffered two perturbations. The service exhibits stochastic and intrinsic variability. The system recovers after the first perturbation, but the second perturbation causes the service to cross the second threshold, which leads to a catastrophic change or an alternative stable state.

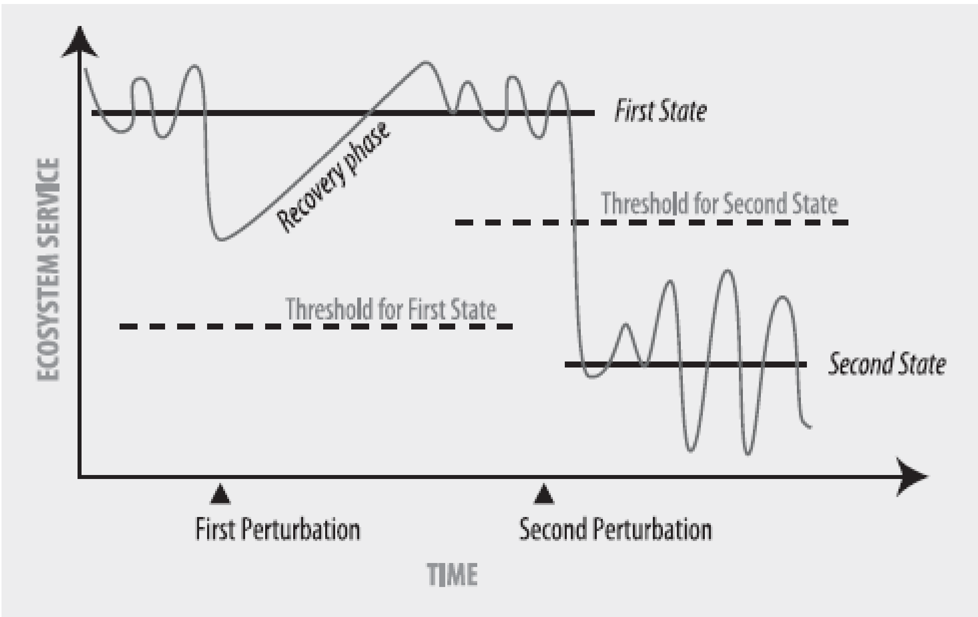


Figure 50. Dynamics and stability in Ecosystem Services

5.3 Valuation of ecosystem services

Valuation of ESs is required to ensure human well-being (Daily et al. 2009). Specifically, the reasons for valuing ESs include the following (Masiero et al. 2019):

- Identification of missing markets
- Internalization of externalities in planning and project formulation
- The correction of market failures
- The assessment of synergies and trade-offs among different land-uses

- The setting of market-based instruments for ES and development of market opportunities
- The management of uncertain future supply-and –demand scenarios for natural resources
- The design of ecosystem conservation initiatives and programmes by both private and public actors
- Natural resource accounting

The concept of "value", that is, what it is and how to measure it has been long debated by economists. It is now accepted that the ecosystems are valuable and their value should be taken into account in decision making processes both by individuals and governments. The term "value" in this respect implies the measurement of the extent to which people want or like a good or service. Three types of values for ES have been identified in the relevant literature (Oelschlaeger 1997, Callicott 2004, Masiero et al. 2019):

- Instrumental and intrinsic values
- Anthropocentric and biocentric (or ecocentric) values and
- Utilitarian and deontological values

The **instrumental value** of an ES refers to the value derived from the usefulness of the ES towards achieving a certain goal. **Intrinsic** is considered the value that exists regardless its usefulness and reflects the value of something for its own sake.

The anthropocentric value is based on the idea that only people can assign values. The **biocentric value** assumes that certain goods and services have values even if no people think so. **The utilitarian value** is derived from the ability of the good to provide welfare. **The deontological value** refers to a set of rights that includes a right to existence.

Valuation of ESs is the process of assigning an economic or non-economic value to them. The economic valuation assigns a monetary value to the peoples' preferences for the benefits they receive from a specific ecosystem service. Non-economic valuation focuses on how the peoples' preferences are formed on non-monetary terms. There are many methods and different metrics to assess ESs; qualitative, quantitative or monetary (Figure 51). Qualitative analysis includes non-numerical information; quantitative involves numerical data and monetary analysis converts quantitative data into money values (TEEB 2009). The choice of metric to measure a specific ES depends on the benefit being measured, the time and resources available, as wells the importance of the decisions to be made. As shown in Figure 51 it is not easy to measure all ESs in monetary terms. Only a small subset of the ecosystem services can be priced (Pascual and Muradian 2010). When only a few

ESs are defined in money value, natural resource management decisions based on costs and benefits may be biased.

Valuation methods may be preference - based or biophysical (Figure 52, TEEB 2010). ***The preference-based methods*** use human behavior models with values based on individual, subjective, context based and state dependent preferences (Nunes and van den Bergh 2001). ***The biophysical methods*** use values obtained from the measurement of the physical costs need for the production of a certain good or service and refers mostly to ecosystem resilience. There are many challenges to be addressed when valuing ecosystem resilience and this is why most of the valuation efforts adopt preference based models, which are based on the concept of Total Economic Value (TEV) (Figure 53).

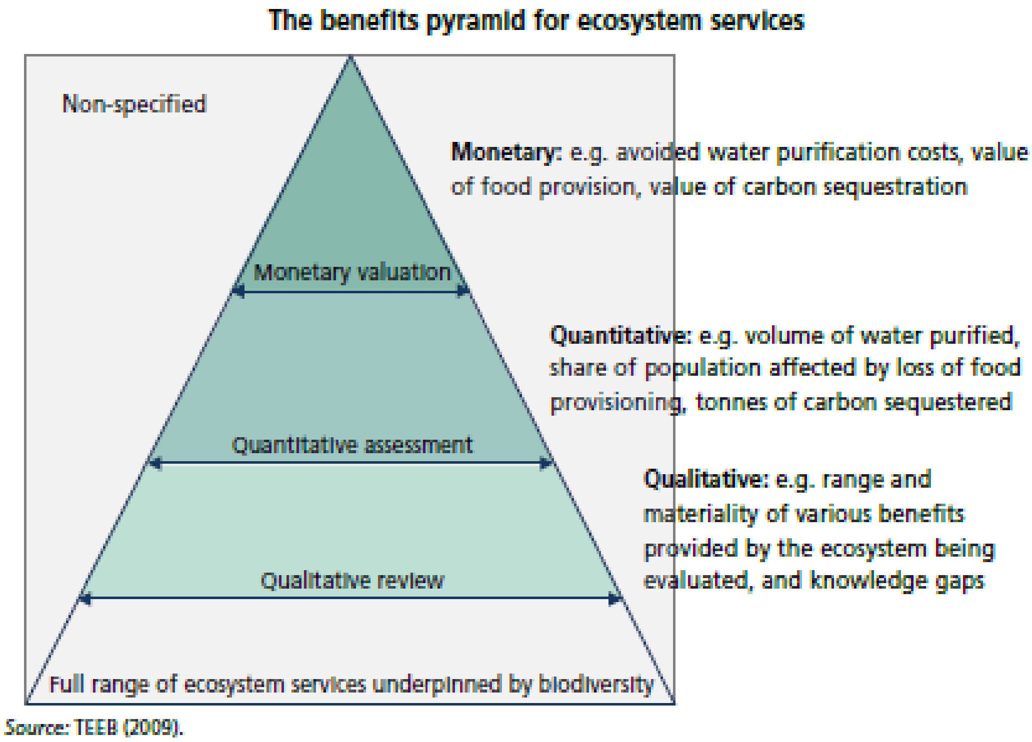


Figure 51. The benefits pyramid for ecosystem services (Source: TEEB 2009)

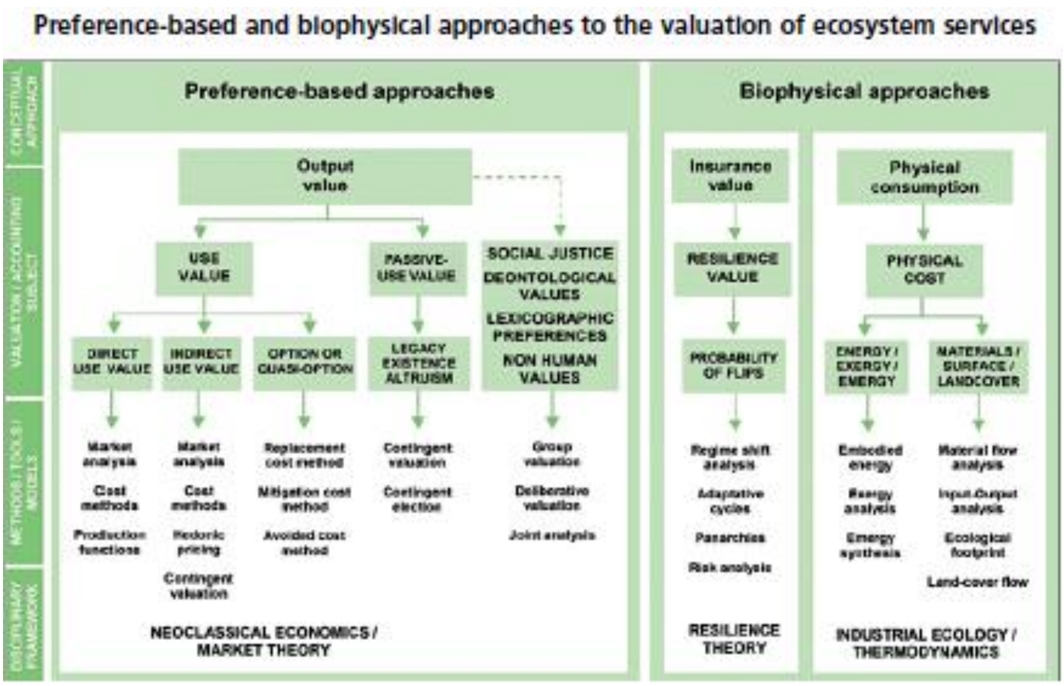


Figure 52. Approaches to the valuation of ecosystem services (Source: Based on TEEB 2010 in Mosiero et al. 2019)

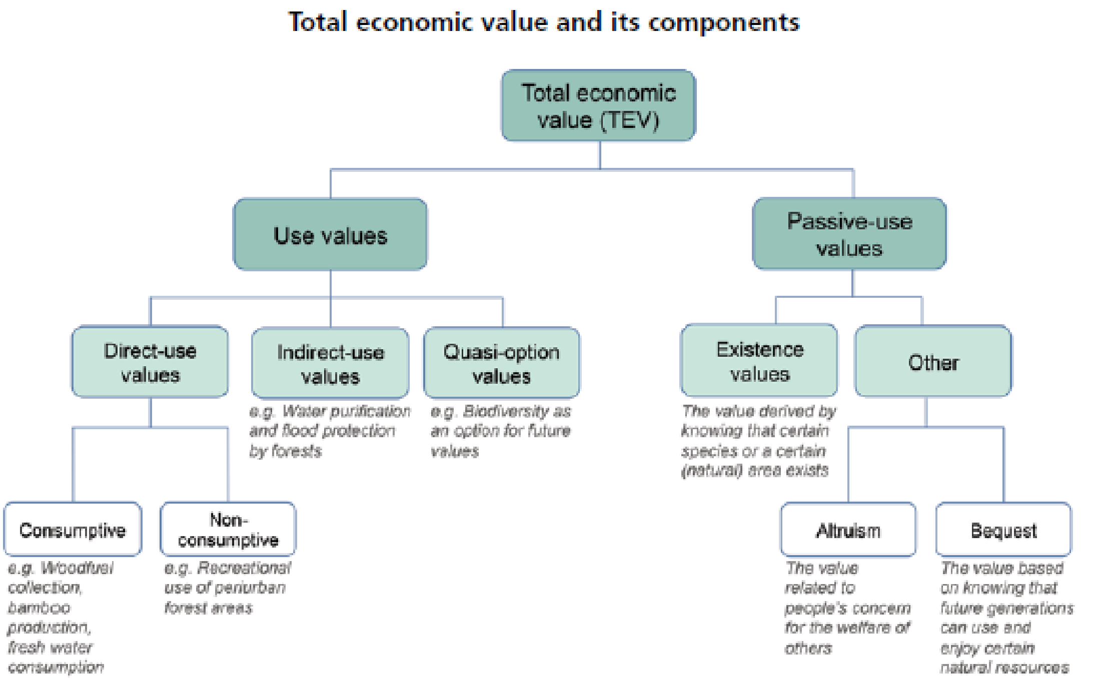


Figure 53. Total economic value and its components (Source: Based on Mavsar and Varela 2014 and cited in Mosiero et al. 2019)

According to Figure 53, the Total Economic Value consists of use and passive-use values. The use values can be direct or indirect.

As **direct-use values** are considered the benefits which are derived from the actual, direct use of an ecosystem (e.g. forest) and are distinguished in **consumptive** (or extractive, implying the consumption or the extraction of resources e.g. the extraction of timber, woodfuel or non-wood products (mushrooms, aromatic and medicinal herbs, ornamental plants, resin etc) or **non-consumptive** (or non-extractive, e.g. recreation activities, enjoying the beauty of a landscape etc.).

The **indirect-use values** refer to benefits derived from an ecosystem's functions without direct interaction with it, e.g. watershed protection, carbon sequestration, protection against natural hazards or pollination.

The **quasi-option values** concern the benefits derived from the option of directly or indirectly using natural resources in the future, for example to consider a certain ecosystem as a potential source of future recreation opportunities.

The **passive-use or non-use values** are the values which are not connected to the actual use. A type of passive-use value is the **existence value,** which concerns the benefits derived from knowledge of the existence of a particular environmental asset, such as biodiversity. For example, some people value the Amazon forest just because it exists, even though they will never make direct use of this resource. Other types of passive- use values are the **altruism value** and the bequest **value**, because of the benefits derived from placing a value on the conservation of a certain environmental asset for other people (altruism) and future generations (bequest).

The main methods for valuing ESs are distinguished into two categories:

- Market value methods
- Demand curve methods

An overview of the methods that can be used to valuate ESs is shown in Figure 54.

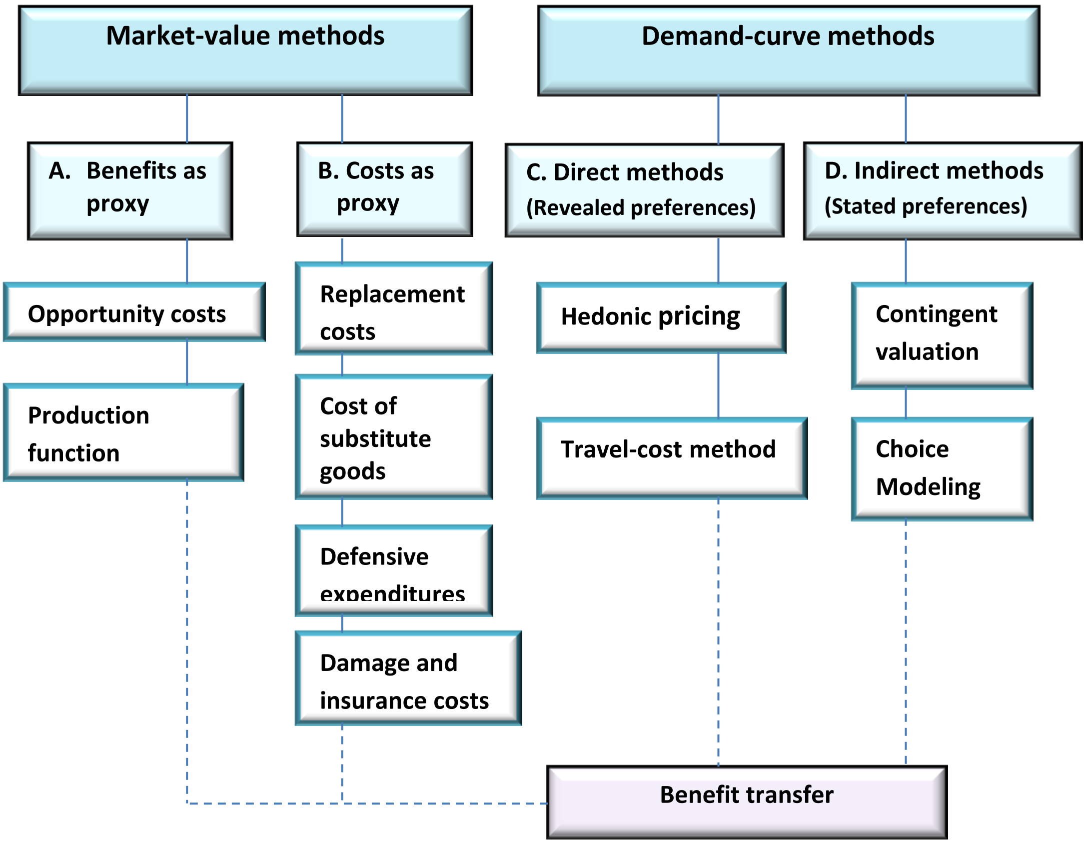


Figure 54. Methods for valuing ecosystem services (Source: Masiero et al. 2019)

The market-value methods are based on market values that can be estimated for the ESs directly or indirectly from data derived from actual markets. Therefore, these methods are easy to understand, while they make it possible to reflect the actual preferences of costs to individuals. For ES that are traded, such as wood and non-wood forest products, direct estimates of their value can be made on the basis of their market prices, although adjustments need to be made in order to take into consideration potential distortions, such as subsidies or other factors. The increasing interest in valorization and conservation of ES has promoted the marketing of ESs and led to the development of new market-based instruments and a larger number of values (www.ecosystemmarketplace.com).The market-value approaches for valuing ES use benefits or costs as proxies.

The market-value methods which use benefits as proxies estimate the value of an ES based on the economic benefits they generate. Two basic methods fall into this category: i) the opportunity cost and ii) the production function method.

Opportunity cost is the value of the benefit foregone, because another course of action has been decided to be followed. For example, the value a farmer would have received from agricultural production of a certain area of land, which is given up in order to maintain tree cover on this land. In other words, the foregone revenue of the agricultural production on the land covered by trees is the opportunity cost of maintaining trees on the farmer's land.

The Production function method expresses the relationship between a certain ES and the production of a market good. ESs can be the inputs to the production process and therefore their value can be derived by estimating the changes in the production of market goods as a result of an environmental change. For example, forests provide water infiltration services and increase water availability for irrigation, thus causing an increase in the production of agricultural crops (Masiero et al. 2019).

<u>The market-value methods which use cost as proxies</u> estimate the value of an ES based on different types of economic costs that may be associated with it, such as the costs needed to produce or reproduce a certain ES or the costs of providing substitute services. Four basic methods fall into this category: i) replacement cost, ii) substitute cost, iii) defensive expenditures and iv) damage and insurance costs.

The replacement cost estimates the ES value using as a measure of benefit the cost of replacing or restoring a damaged environmental asset to its original state. For example the value of a forest destroyed by fire or storm can be estimated by the cost of restoring it to its original state or the cost or cost of replacing the soil or nutrients lost due to deforestation. In some cases, the replacement cost can be considered as production cost, namely the cost of producing a certain asset regardless the damage that may have been caused. For example, the value of a new afforestation can be estimated on the basis of its cost.

The substitute cost estimates the ES value on the basis of the value of a substitute or surrogate good with similar function of the ES under consideration, for example, the value of the ESs of forests that maintain water quality for downstream users against the cost of constructing and maintaining water-treatment plants. Identification of adequate substitutes is a typical difficulty related to this method, mainly due to the fact that human-built alternative substitutes cannot ensure the same range of ESs as the natural infrastructure. Therefore, this method should be used with caution, particularly in cases with high degree of uncertainty (Barbier 2016, Masiero et al. 2019).

Defensive expenditures involve the costs of avoiding or reducing or compensating for damages incurred by negative externalities, for example the value of the protective service of a coastal forest can be estimated on the basis of the cost spent by coastal communities to upgrade their houses against the severity and frequency of storms. Such data information is easy to collect and use, although this type of cost is often made for multiple reasons, that is, multiple negative externalities. The defensive expenditures reflect the minimum willingness to pay of the people to prevent or avoid environmental degradation or damage (Abelson 1996).

Damage and insurance costs are the costs that would be or have been paid if damage occurs, mainly due to natural disasters, such as flooding, landslides, fires, storms or adverse weather conditions. This valuation approach is mostly relevant for valuation of regulating ESs, as the basic assumption of this method is that the regulating ESs usually reduce damages due to natural disasters and therefore reduce the costs associated with them.

Overall, the market-value methods, which use costs as proxies of ES benefits provide rough estimates of the economic value of ESs, while they do not include social preferences for ESs. These approaches are based on the assumption that the benefits are at least as great as the costs of replacing or restoring a certain ES, which is not always true. If an ecosystem is destroyed or degraded and the associated ESs are reduced does not necessarily imply that people will be willing to pay for alternatives (Anon 2017). Therefore, these methods should better be used when are alternative methods are not possible to use and time and budget limitations exist.

The demand-curve methods are used for ES valuation in cases market values are not available (Masiero et al. 2019). They are based on the demand curve of a certain ES referring to an existing or a simulated market related to the ES. There are two basic categories of demand-curve methods, the direct and indirect methods.

<u>**The direct methods**</u>, alternatively known as "revealed preferences" derive ES values by using data on the observed preferences of people and their actual behavior. The two main approaches in this category are hedonic pricing and travel cost.

The hedonic pricing method (www.ecosystemvaluation.org) estimates the value of ESs based on the use of residential housing prices to estimate the value of environmental amenities. The rationale of the method is that people value the characteristics of a good, rather than the good itself. Therefore, prices will reflect the value of a set of environmental characteristics, which people think important when purchasing the good. The method is used to estimate economic benefits or costs related to environmental quality, such as air pollution, water pollution, or noise and environmental amenities, such as aesthetic views or proximity to recreational sites. When applying the method, the price of a house is related to the characteristics of the house and property itself, the characteristics of the neighborhood and community, and environmental characteristics. Thus, by controlling the non-environmental factors the remaining differences in price are attributed to differences in environmental quality. For example, if all characteristics of houses and neighborhoods throughout an area were the same, except for the level of air pollution, then houses with better air quality would cost more. This higher price reflects the value of cleaner air to people who purchase houses in the area. Statistical analyses, mainly regression analysis are applied on large quantities of cross-section or time-series data on property values and area characteristics to identify and quantify factors influencing house prices. However, the ESs that can be valued using a hedonic approach are confined to those people take into consideration when purchasing a house. If people are not aware of the potential effect an ES may have on their quality of life, it will not be reflected in house prices.

The travel cost method is used to estimate the economic use values of ecosystems or sites that are used for tourism and recreation. The method is mainly used to estimate the economic benefits or costs related to changes in access costs for a recreational site, or elimination of an existing recreational site, or addition of a new recreational site, or changes in environmental quality at a recreational site.

The basic assumption of the travel cost method is that the time and travel cost expenses that people afford to visit a site represent the "price" of access to the site. Therefore, peoples' Willingness To Pay (WTP) to visit the site can be estimated based on the number of trips they make at different travel costs. This is similar to estimating peoples' willingness to pay for a marketed good based on the quantity demanded at different prices. Three different approaches can be used to estimate values using travel costs, the individual travel-cost method, the zonal travel-cost method and the random utility travel-cost method.

The individual travel-cost method refers to single visitors and determines the number of trips as a function of the travel costs and socioeconomic characteristics associated with each visitor: $t_i = f(K_i, X_i)$, where t_i = number of trips for visitor i, K_i=travel costs for visitor i and X_i= socioeconomic characteristics of visitor i.

The zonal travel-cost method defines the travel costs for different zones, usually an array of concentric circles indicating the distance from a study area. The visit rate of each zone is estimated using data on zone population sizes (number of trips per 1000 inhabitants): $t_j/P_j = f(K_j, X_j)$, where t_j = number of trips for visitor coming from zone j, P_j = the population living within zone j, K_j = travel costs from zone j, X_j = socioeconomic characteristics of visitors coming from zone j. Regression analysis is used then to identify the equation, which related visits per capita to travel costs and other important variables. This is accomplished by estimating variations to different hypothetical entrance fees.

The random utility method estimates the probability of choosing a specific site over all other available sites by taking into account the characteristics of all sites and the travel costs involved. This method uses complex econometric models.

The indirect methods, alternatively known as "stated preferences" are based on eliciting information about individual valuations/preferences through surveys in which people are asked hypothetical questions about their Willingness To Pay (WTP) for specific ESs. The best known indirect methods for ES valuation are contingent valuation and choice modeling.

Contingent valuation measures the respondents' WTP for increasing a certain ES, or their Willingness To Accept (WTA) losses or degradation. The method can be used to estimate all Total Economic Value components. It is implemented though surveys using any of the following elicitation methods:

- Open-ended (for example, "how much would you be willing to pay to restore forest X?"
- Single bound dichotomous choices (for example, "Would you be willing to pay an additional Euro 5 in income tax to restore forest X?")
- Double bound dichotomous choices (for example, "Would you be willing to pay Euro 10 to restore forest X? If YES, would you pay Euro 15? If NO, would you be willing to pay Euro 5?")
- Payment card (respondents pick a value from an array of values given on a card).

Choice modeling determines the economic value of ESs through surveys where respondents are asked to choose among alternatives associated with different ESs. Choice modeling is based on the premise that policy options and the benefits and costs associated with them imply positive or negative changes in ESs and therefore valuation should quantify the value of those changes.

The choice modeling method asks people to state a preference between one group of environmental services or characteristics, at a given price or cost to the individual, and another group of environmental characteristics at a different price or cost. The method focuses on tradeoffs among scenarios with different characteristics and therefore, it is especially suited to policy decisions where a set of possible actions might result in different impacts on natural resources or environmental services. For example, improved water quality in a lake will improve the quality of several services provided by the lake, such as drinking water supply, fishing, swimming, and biodiversity. Moreover, while choice modeling can be used to estimate monetary values, the results may also be used to simply rank alternatives, without focusing on monetary values. The data collected through choice-modeling surveys are analyzed with econometric tools to calculate the marginal value of each attribute, as well as the aggregated attribute value of each scenario. Choice modeling is a powerful tool for ES valuation, but it requires specific skills and expertise and it is usually time- and resource- consuming.

Benefit transfer includes methods which take results from one situation and extrapolate them to other similar situations. These methods are mainly used when there are resource constraints that prevent the collection of primary data and involve the following approaches (Bartczak et al. 2008):

- Unit value transfer, a single-point benefit-transfer approach, either simple or adjusted
- Function transfer, which transfers entire functions, that is values estimated at a single study site to the policy site (benefit function transfer) or values estimated at multiple study sites to the policy site (meta-analytic benefit transfer).

6. Valorisation of natural resources in the rural areas

6.1 Resource use, opportunities, innovation, entrepreneurship

6.1.1 Food production

According to OECD circular economy allows economic development by optimizing the use of natural resources, minimizing environmental pressures, transforming supply chains and consumption patterns and redesigning production systems (OECD 2019).

Several measures can be used along the whole value chain to achieve circularity. Such measures according to Ellen MacArthur Foundation may involve:

- Designing out waste. Digital technology and policy measures can be used to redistribute the surplus edible food for human consumption (Ellen MacArthur Foundation 2019)
- Keep material in use. Any surplus organic material, such as agricultural by-products, food preparation leftovers and municipal sewage flows can become feedstock for other parts of the economy. Waste material can be used to produce value products, such as fabrics for clothes, materials for packaging and furniture or innovative new food products. Compost can be used in food growing as it contains nutrients that can strengthen soils, while reducing chemical fertilizers and irrigation needs.
- Regeneration of natural systems. Adoption of ways in growing food that improve soil and water resources and biodiversity and carbon sequestration (OECD 2019).
- Promote the bioeconomy. This leads to produce materials, chemicals and energy from renewable biological resources (Birner 2017). A bioeconomy involves all sectors of primary production, such as agriculture, forestry, fisheries and acquaculture, as well as all industrial sectors based on biological resources (European Commission 2018).

Forests and agroforestry systems also play a vital role as far as the food and nutritional security is concerned. Trees provide directly several types of food including fruits, leafy vegetables, nuts, seeds and edible oils and plants, fungi, bushmeat, fish and insects. Indirectly, forests and agroforestry systems support the income of rural communities to purchase foods and they also provide ecosystem services to further support crop production (Jamnadass et al. 2015).

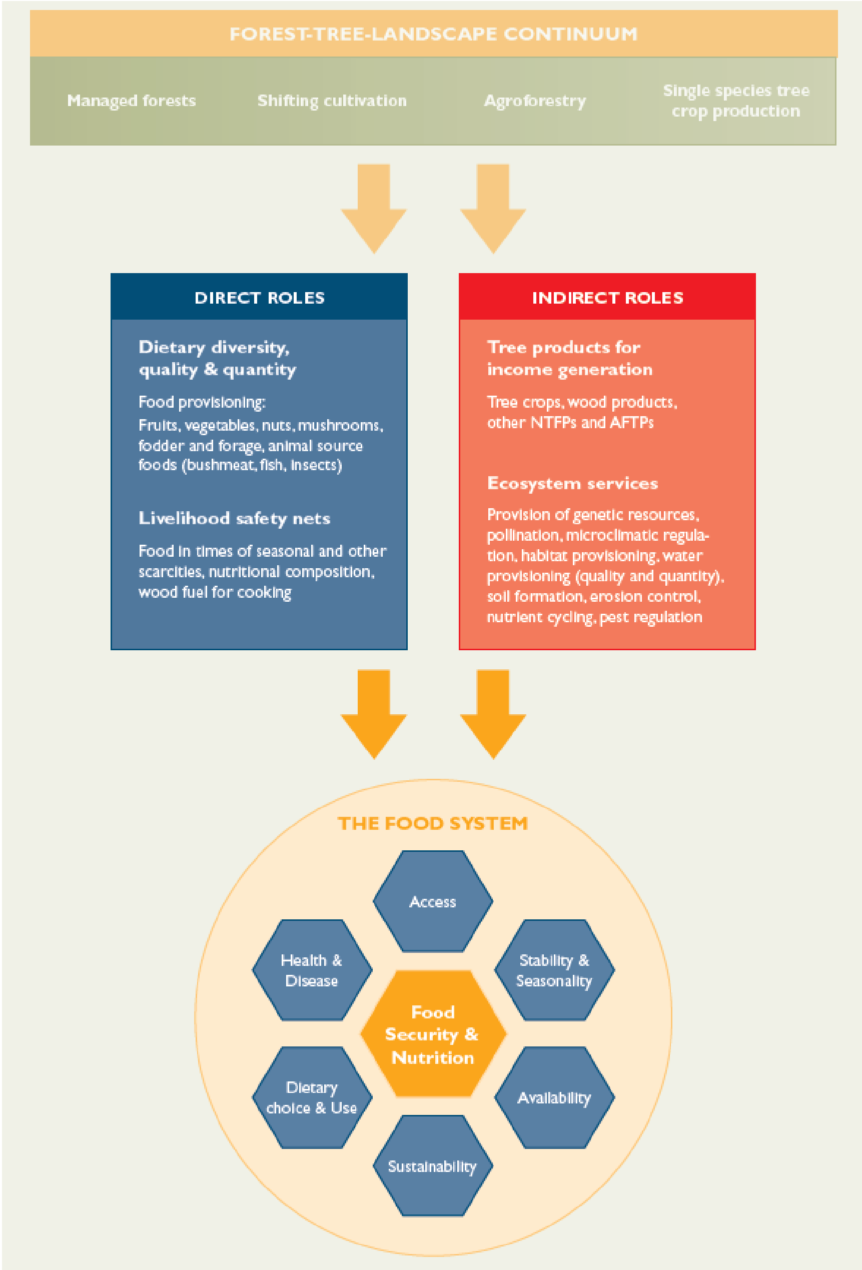


Figure 55. The direct and indirect roles of forests and other agroforestry systems in food provision (from: Jamnadass et al. 2015).

Figure 55 depicts the role of forests as far as the food provision is concerned. Access to forests as well as to other agroforestry systems has been mainly linked with fruit and vegetable consumption and secondly with dietary diversity.

6.1.2 Timber, fuelwood and pulpwood production

The roundwood production in the EU presents an increased rate (Figure 56). According to Eurostat, in 2019, it was estimated to 500 million m^3. It is also worth noting that in four Member States the roundwood production was decreased or remained stable, while no data were available for three Member States. All other EU countries recorded an increase in roundwood production in the period of 2000–2019. The largest relative increase in the amount of harvested wood was observed in the Netherlands (170 %) and Czech Republic (126 %). In 2019, Germany was the largest producer of roundwood in EU-27 (76 million m^3), followed by Sweden, Finland and France (each producing between about 50 and 75 million m^3) (Figure 56).

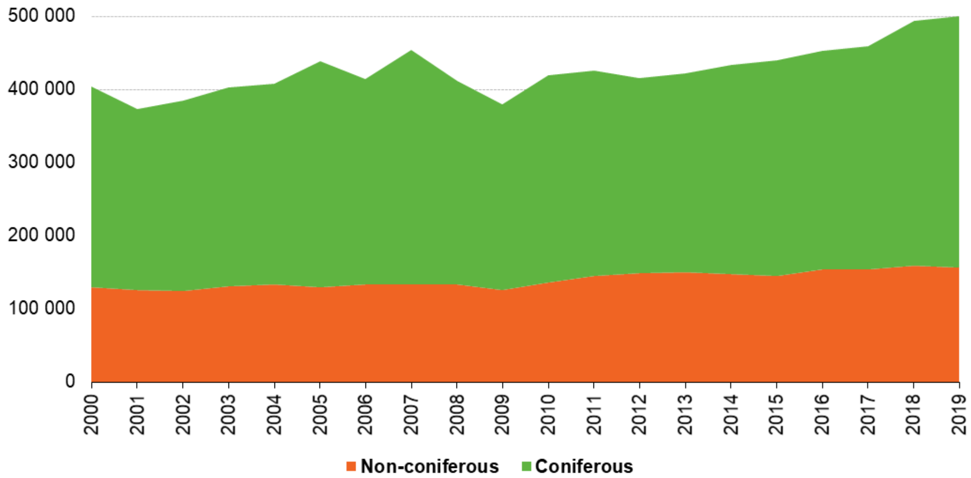
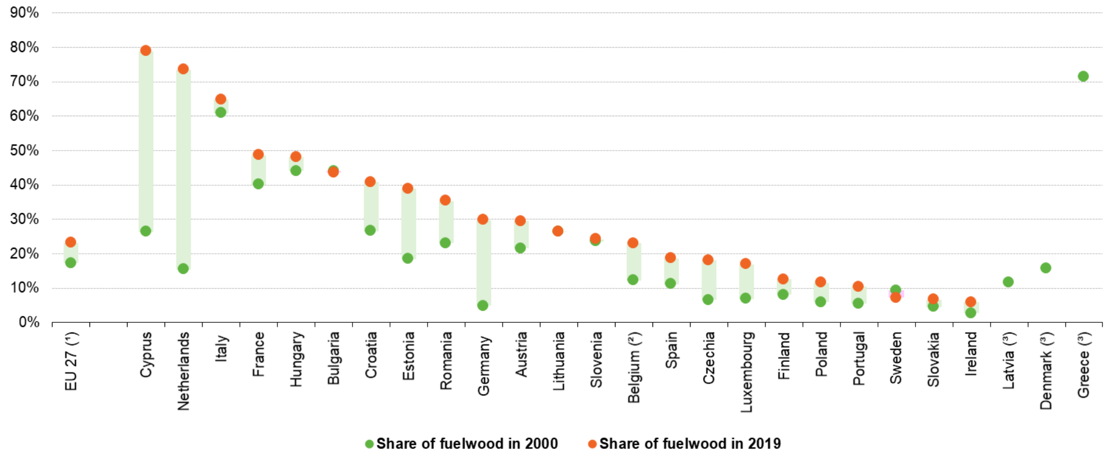


Figure 56. The total annual production of roundwood in EU countries (1000 m^3) during 2000 – 2019 (from: Eurostat)

Table 6. Roundwood production in 2019

	Roundwood production		
	Total	Fuelwood	Industrial roundwood
	(1 000 m^3 under bark)		
EU-27 (¹)	500 227	116 087	384 084
Belgium	:	:	:
Bulgaria (²)	6 529	2 849	3 680
Czechia	32 586	5 922	26 664
Denmark	:	:	:
Germany	76 167	22 742	53 425
Estonia (²)	12 034	4 681	7 353
Ireland (²)	3 541	211	3 330
Greece	:	:	:
Spain	18 961	3 538	15 422
France	49 686	24 186	25 445
Croatia	5 400	2 205	3 195
Italy	11 449	3 921	7 528
Cyprus	9	7	2
Latvia	:	:	:
Lithuania	6 688	1 771	4 917
Luxembourg	385	65	320
Hungary	5 575	2 684	2 892
Malta	0	0	0
Netherlands	2 805	2 063	742
Austria	18 904	5 579	13 325
Poland	43 521	5 069	38 452
Portugal	14 141	1 467	12 674
Romania	15 922	5 626	10 296
Slovenia	4 618	1 117	3 501
Slovakia	8 957	600	8 357
Finland	63 964	8 013	55 951
Sweden	75 472	5 460	70 012
United Kingdom	10 786	2 478	8 308
Liechtenstein	8	4	5
Norway	12 568	1 530	11 039
Switzerland	4 397	1 744	2 654

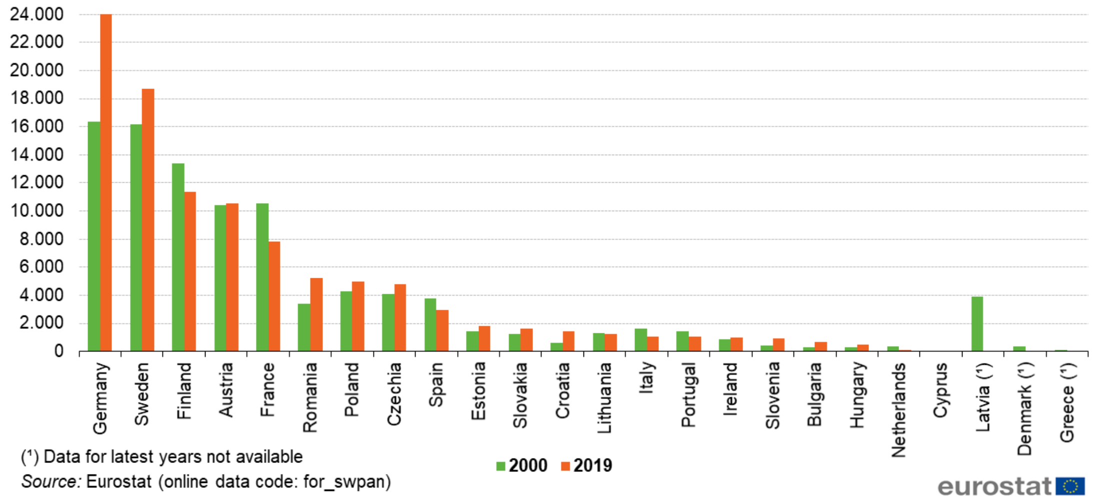
The wood as natural resource it is a source of renewable energy. It was estimated that 23 % of the total EU roundwood production in 2019 was used as fuelwood, while about 77% was industrial roundwood used for sawnwood and veneers, or for pulp and paper production, corresponding to a total increase of 6 % compared to 2000 (Table 6). However large differences were detected between EU countries, such as in Cyprus, the Netherlands and Italy, where the fuelwood represented more than 60 % of the roundwood in 2019 and the Ireland, Slovakia and Sweden where about 90 % of their total roundwood production was industrial roundwood (Figures 57 and 58). However, most country members reported increases since 2000, with the largest increase to be recorded for the Netherlands (58 %) and Cyprus (52 %) as shown in Figure 57.



(¹) Belgium, Bulgaria, Denmark, Estonia, Greece, Ireland and Latvia for the EU aggregate for 2019 were estimated
(²) Shows comparison for 2000 - 2017; data for 2019 and 2018 not available
(³) Data for the latest years not available
Source: Eurostat (online data code: for_remov)

eurostat

Figure 57. Change in the share of fuelwood in total roundwood production in the EU, 2000–2019 (%)



(¹) Data for latest years not available
Source: Eurostat (online data code: for_swpan)

eurostat

Figure 58. Sawnwood production, 2000 and 2019

6.1.3 Game and fish production

Hunters from European Union (EU) member states shoot over 6 million large game mammals, 12 million rabbits and hares and over 80 million birds annually, supporting an international game meat market estimated over 1.1 thousand million Euros (Thomas et al. 2020). In 2011, a total number of 15 countries from the European region provided accurate data on quantity and value of game meat production as it presented in the following Table 7.

Table 7. Game meat production in EU (from: FOREST EUROPE, UNECE and FAO 2015)

Region	Game meat		Living animals		Pelts, hides skins and trophies		Wild honey and bee-wax		Rawmaterial for medicines, colorants		Other animal products
	Quantity tonnes	Value 1,000 €	Quantity pieces	Value 1,000 €	Quantity pieces	Value 1,000 €	Quantity Tonnes	Value 1,000 €	Quantity Tonnes	Value 1,000€	Value 1,000€
North Europe	3,117	7,147	-	-	59	529	141	780	20	147	-
Central-West Europe	9,227	217,113	-	-	287	6,738	15,750	111,861	-	-	1,340
Central-East Europe	10,084	17,959	7	528	10	4,445	-	-	-	-	-
South-West Europe	-	73,228	-	-	-	-	36,199	124,690	-	-	-
South-East Europe	700	5,565	-	-	4	6,537	554	39,623	-	-	-
EU-28	23,080	317,013	7	528	351	3.312	52,090	237,330	20	147	1,340
Europe	23,127	321,012	7	528	361	18,249	52,644	276,953	20	147	1,340

On the other hand, fish is also a renewable type of natural resource under continuous movement. In a wider sense, fish natural stocks continue to be regarded as a common resource under management regimes that has led to several policies that regulate not only the amount of fishing but also the types of fishing techniques and consequently gear that can be used in fish capture within the EU (Eurostat).

The 2018 EU total production of fishery products was estimated to about 5.7 million tons of live weight. This was equivalent to about 3 % of the total world production of fishery products during the 2018 (Figure 59).

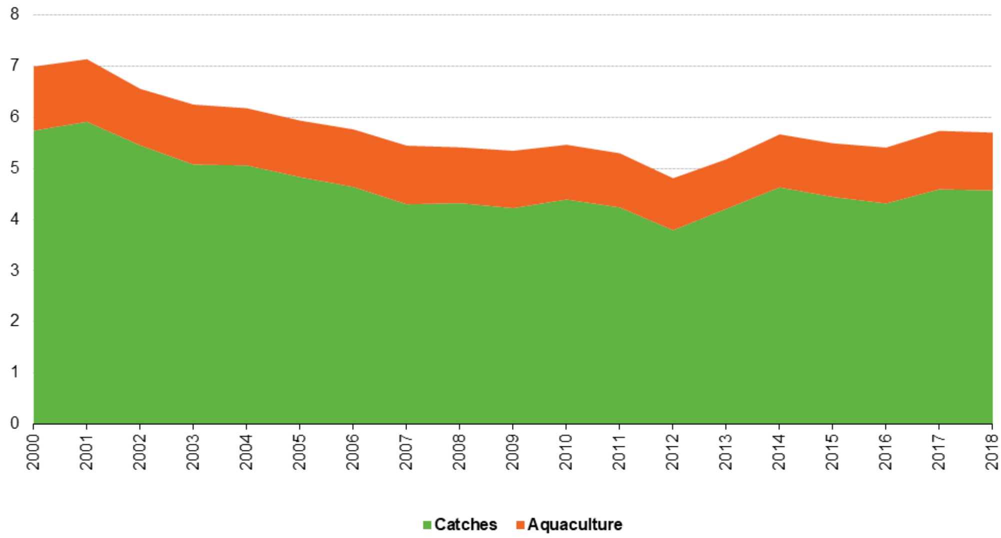


Figure 59. The total production of fishery products in the EU from 2000 to 2018 in thousand tons of live weight (from: Eurostat)

In addition, the EU fish catches in 2019 an estimated at 4.1 million tons of live weight according to the following Figure 60.

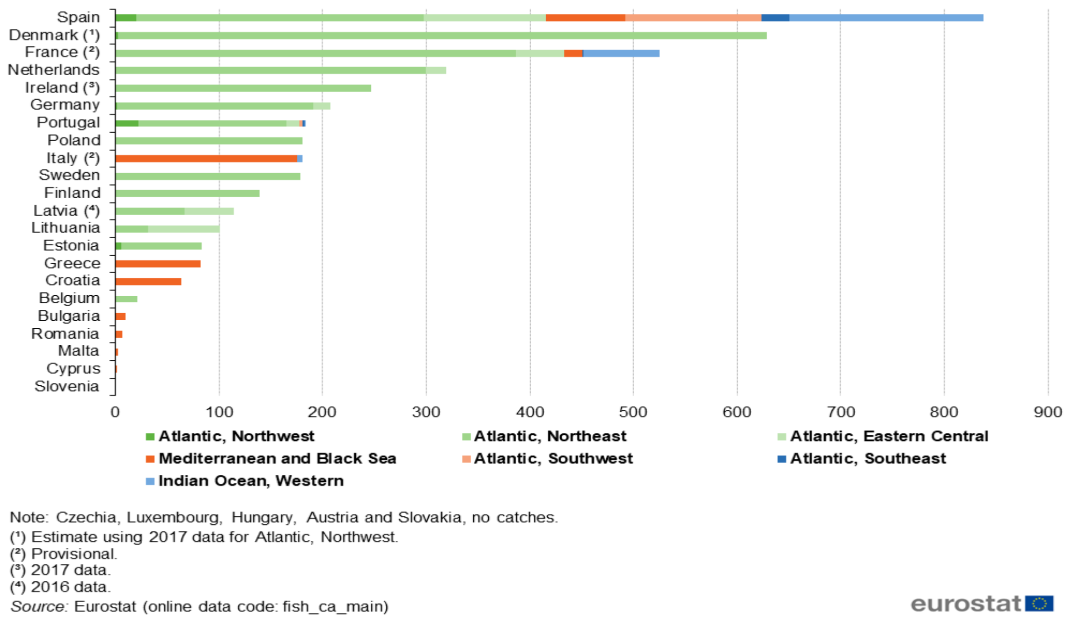


Figure 60. Catches by marine area in 2019 (thousand tons of live weight)

6.1.4 Non-wood forest products (honey, mushrooms, forest fruits, fodder, ornamental plants, etc)

Non-wood forest products can be termed as *"wild and semi-wild non-wood forest species and products thereof, as well as products in early stages of domestication, e.g. fruit trees, bushes, orchards, and with reference to specific services related to non-wood forest products such as well - being and tourism"* (Wolfslehner et al. 2019). According to Lovrić et al. (2020) non-wood forest products (NWFPs) include goods such as berries, mushrooms, aromatic, medicinal and decorative plant material, nuts, saps and resins.

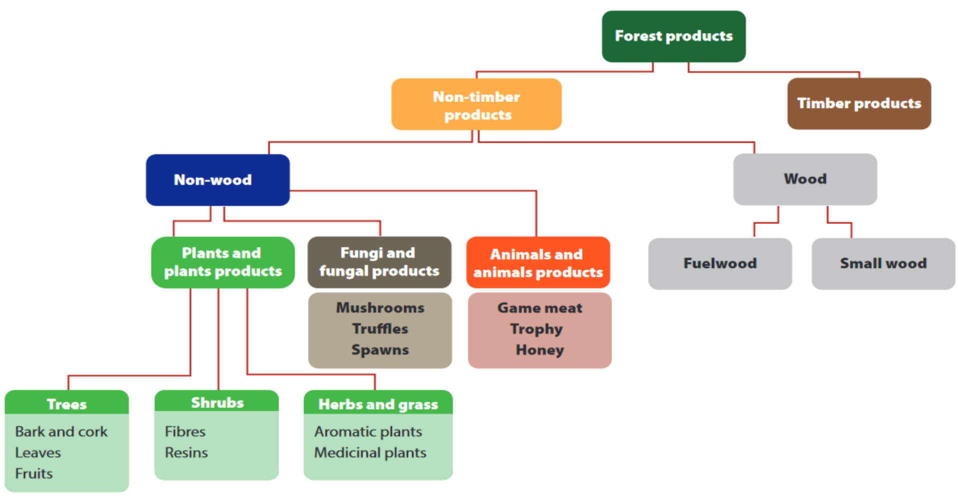


Figure 61. Non-wood forest products, categorized within the wider realm of forest products (from: FAO 2017)

Table 8. Non-wood products in some EU Member States (from: EUROSTAT 2011)

	Value of non-wood products / industrial roundwood	Plant products		Animal products		
		Food	Orna-mental plants	Hides, skins and trophies	Wild honey and beeswax	Bush meat
	(ratio)	(tonnes)		(units)	(tonnes)	
Bulgaria	0.03	:	:	:	:	:
Czech Republic	0.19	40 960	:	216 570	0	9 578
Denmark	:	:	71 000	:	:	:
Germany	0.22	:	:	:	:	34 000
Estonia	:	:	2 000	37 500	:	913
Spain	0.56	12 018	:	3 040	39 114	21 723
France	:	:	:	:	6 300	:
Italy	1.57	79 155	:	:	:	:
Cyprus	:	:	:	:	811	:
Latvia	:	:	:	37 800	:	1 500
Lithuania	0.09	3 800	3 000	30 000	:	1 250
Netherlands	:	:	6 000	:	:	362
Austria	0.12	:	:	:	:	:
Poland	:	15 088	843	:	:	10 456
Portugal	1.10	:	:	:	:	:
Slovenia	0.11	550	1 200	20 000	2 300	1 000
Slovakia	0.04	1 155	255	22 470	:	1 688
Finland	0.05	47 000	309	355 000	:	9 279
Sweden	0.04	35 860	14	177 200	:	16 790
United Kingdom	0.30	162	162 545	:	183	3 500
Iceland	:	:	92	0	0	0
Norway	:	462	:	:	550	1 700
Switzerland	:	19 000	5 517	33 110	:	7 586
Croatia	0.01	400	:	:	:	:
Turkey	0.00	9 979	152	:	:	:

(1) No information available for those Member States that are not presented.

Source: FAO (Global FRA, 2005 and 2010)

Figure 62 illustrates the data provided by country respondents to the 2015 State of European Forests (SoEF) report.

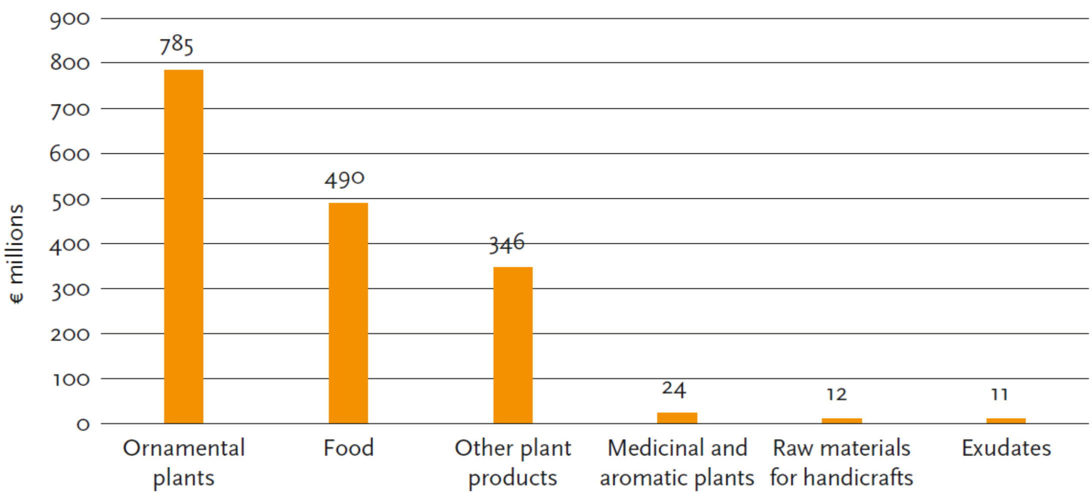


Figure 62. Value of marketed plant products/raw materials in 2010 (from: State of European Forest (FOREST EUROPE 2015) data for 28 countries).

6.1.5 Wastes and residues

The optimization of the efficiency of natural resources and the transition to circular economy has generated new actions to a more sustainable use of raw materials. Therefore, it is an imperative need the utilization and the concomitant conversion of waste materials into new high-value products. In particular, the use of wood residues, or recycled materials can be considered as eco-friendly, green potentials in order to face the challenge of an increasing demand for wood composites, worldwide (Anton et al. 2020, Anton et al. 2021). The definition of recycled wood, as stated in the Waste Framework Directive (2008/98/EC), includes a variety of residual and old wood, such as wastes from construction, furniture, etc and packaging (Deppe et al. 2000, EU Parliament 2008, Reh 2013). Both wood-based panel industries and pulp and paper facilities produce, annually, a substantial amount of by products, namely solid waste and non-hazardous sludge which require utilization as by-products or as waste materials (Eroglu and Saatci 1993, Ochoa 2008).

Wood waste generated at residential and commercial wood frame construction sites offers a greater potential for reuse because of the ease of separating the wood during various stages of construction (Figure 63 a-d). Cut-offs and scraps generated during framing and trimming constitute a relatively clean and homogeneous waste stream that can make an excellent feed-stock for engineered wood production. This type of wood waste represents a highly desirable form of recyclable material that processors are eager to obtain.

Markets for wood waste include feedstock for engineered woods, landscape mulch, soil conditioner, animal bedding, compost additive, sewage sludge bulking medium, and boiler fuel. All these end uses have similar processing requirements in that the wood waste has to be separated from other wastes, cleaned by removing contaminants and fasteners, and, in some cases, processed through grinding or chipping. The final use of the wood waste often determines how clean and consistent the feedstock must be:

- Lumber. A desirable option for wood waste management would be to reuse the structural or architectural elements, which include casings, banisters, and molding. Large timbers from older or unique structures can be salvaged and reused as structural elements in new buildings. If lumber is reused as a structural element, it must be re-certified by a lumber grading inspector.
- Engineered wood products. Another desirable option for wood waste is feedstock for engineered wood. Engineered wood is the term given to material derived from smaller pieces of wood that are bound together through a variety of glues, resins, and other chemicals to make a wood-like product. Examples of engineered wood include oriented strand-board,

particleboard, glued-laminated timber, laminated lumber, wood I-joists, and finger-jointed studs.

Source: http://www.waste2resource.co.uk/

Source: https://www.123rf.com

Source: https://geminor.no

Source: https://www.metroherald.com/

Figure 63. *Various types of wood waste*

- Mulch or compost feedstock. Chipped wood and bark are common mulches. Wood is an excellent bulking agent for composting, although a nitrogen source usually needs to be added.
- Biomass fuel.—Ovendry wood produces when burned, and it can be converted to liquid or gaseous fuel. In addition, different forms of solid fuel such as charcoal are possible. Industrial wood residues are commonly used for boiler fuel.
- Miscellaneous uses. Other uses for waste wood include alternative daily landfill cover, animal bedding, wood flour filler for plastic products, and a source of biofuels and chemicals.

At the moment, the main actions for the disposal of the sludge, involves burning for energy reasons or landfilling (Figure 64). In addition, during the primary mechanical wastewater treatment, the majority of the suspended solids are removed and the resulted liquid sludge incorporates great quantities of residual wood fibers (Bajpai 2015); this will be considered as an important feedstock for the manufacture of wood composites, although are significant different in composition (Scott and Smith 1995). Various methods have been developed worldwide for reconstituting the waste from wood based panels, such as particleboard and medium density fiberboard, in order to solve the problem of recycling the wood composites (Wan et al. 2014). These can be categorized as follows: chemically thermomechanical (Roffael et al. 2010), hydrothermal (Franke et al. 1998, Lykidis and grigoriou 2008), chemical (Michanickl 1997) or mechanical (Ye et al. 1998, Roffael 2002). However, these methods are considered to be quite difficult to be applied in practice, an exemption seems to be the mechanical processing when manufacturing particleboards (Hossain et al. 2018, Bowyer et al. 2001). A common problem is the hydrolytic way of obtaining wood particles from residual particleboards (Wan et al. 2014, Hossain et al. 2018).

Why Recycle Wood Waste?

There are a number of important reasons to recycle urban wood waste; the following discussion summarizes the primary reasons (Antov et al. 2020, Antov et al. 2021):

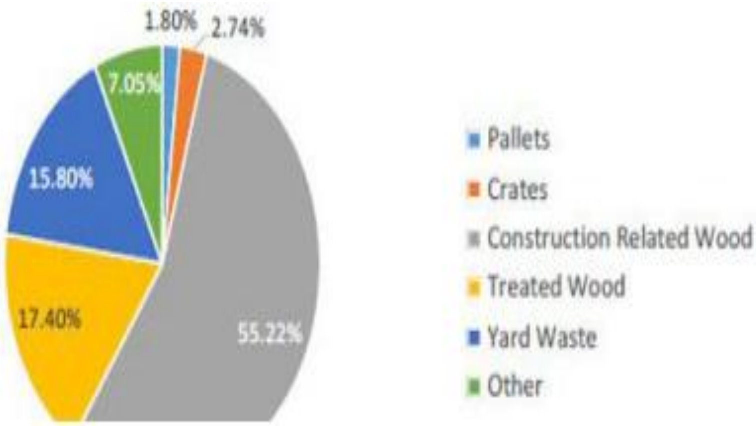


Figure 64. *Types of wood waste landfilled (https://palletenterprise.com/view_article/5086)*

(i) Landfill Cost and Space Savings. Landfill costs can be avoided by recycling wood wastes, generating savings that, along with revenue from the sale of recovered wood waste materials, can be credited toward the processing costs associated with recovery.

(ii) Environmental Benefits. The environmental benefits attributable to wood waste utilization depend on the method of recovery. The major direct environmental benefits appear to be most noteworthy and quantifiable when wood waste is used to displace coal for electricity or steam generation.

(iii) Natural Resource Benefits. Recovering and recycling wood from the waste stream result in the conservation of natural resources. By developing new markets for wood waste, forest owners have more opportunities to offset the costs of sustainable forest management and improve the overall health of the forests and can reduce carbon emission (Figure 65). It is interesting to notice the life-cycle from regeneration to disposal of wood materials, as this depicted in Figure 66.

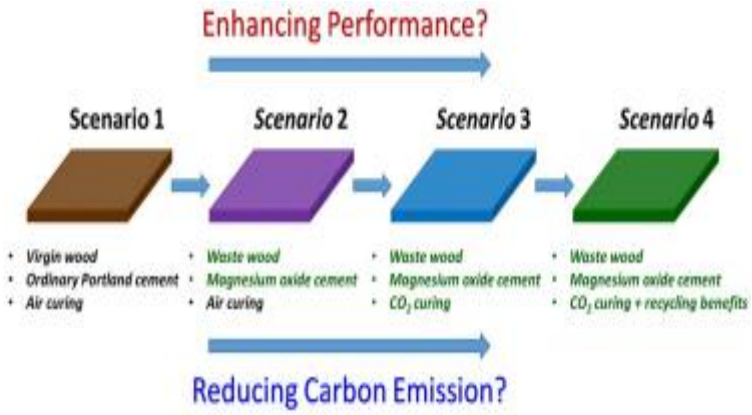


Figure 65. *Wood waste can be valorized into secondary wood products (Bawyer et al. 2001)*

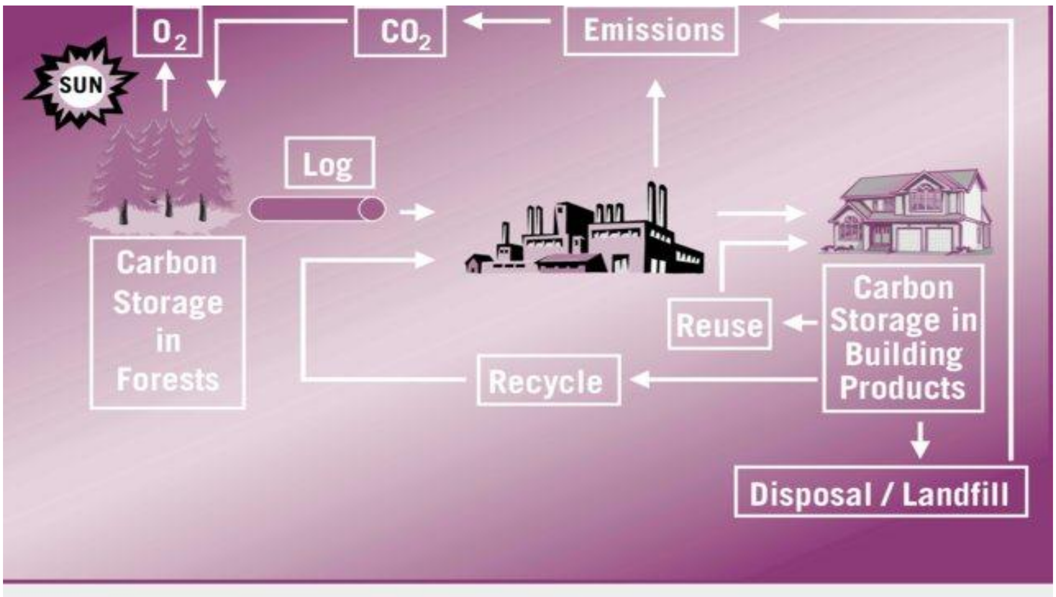


Figure 66. *Life-cycle from regeneration to disposal of wood materials (Bawyer et al. 2001)*

Can wood be recycled?

Most wood waste can be reused as a building material, recycled into mulch for landscaping or pulp for paper production, and used profitably as a fuel. Also, reusing and recycling wood reduces the need to cut down trees (Antov 2020).

Wood waste recycling is the process of turning waste wood into usable products. Products generated from scrap wood recycling are used in such sectors as paper production, panel board production, wood pellets, energy production, and more.The rising cost of waste material disposal and a growing consciousness for the environment also contribute to the increasing importance of waste wood recycling. A common belief is that by recycling wood waste, the demand for "green timber" will fall and this will benefit the environment.

Recycled wood grades:

The main recycled wood grades can be summarized as follows (Wan et al. 2014):

- **Grade A**: “Clean” recycled wood – material produced from pallets and secondary manufacture etc and suitable for producing animal bedding and mulches.
- **Grade B**: Industrial feedstock grade – including grade A material plus construction and demolition waste, this is suitable for making panelboard.
- **Grade C**: Fuel grade – this is made from all of the above material plus that from municipal collections and civic amenity sites and can be used for biomass fuel.
- **Grade D**: Hazardous waste – This includes all grades of wood including treated material such as fencing and trackwork and requires disposal at special facilities.

Risk assessment of wood material

Contamination of wood wastes with preservatives and other pollutants limits opportunities for their recycling in panelboard production. Knowledge on the kind and conditions of usage and the age of wooden products can only be a rough indication on what types of pollutants might be expected to reside in the material (Antov et al. 2020, Antov et al. 2021). For precise identification, techniques for reliable, quick, specific and sensitive assessment of potential pollutants within wood waste materials are required and in many instances yet to be established. Organic compounds might be detected by complex gas chromatography/mass-spectroscopy (GC/MS) and ion-mobility spectrometry.

Recycling of wood based panels

Various studies have been published concerning the effect of various types of recycled wood and other lignocellulosic wastes on the properties of wood composites. Hossain et al. (2018), manufactured three layered particleboards bonded with urea formaldehyde resin (UF) and they replaced, 10 to 60% in the core layer, conventional wood chips with chips obtained from particleboards made from formaldehyde resins, namely urea and phenol formaldehyde (PF). They found that bending properties were lightly declined when 10 to 50% particles obtained from recycled PBs bonded with UF resin were used whereas internal bond strength was significantly reduced when the portion of recycled particles in the PBs was only 10%. It was further stated that boards made from particles obtained from recycled PBs bonded with PF resin showed by far the worst properties. This was attributed to the negative interaction of the new UF resin used with the original PF. The properties of particleboards manufactured from plywood waste (bonded with UF or PF resin) were investigated by Laskowska and Maminski (Bowyer et al. 2001) They concluded that the substitution of 20–100% of virgin particles with the recovered material was possible without negatively affecting the performance of the produced particleboard. Particleboards were also manufactured using four different types of wood recyclates, originated from demolished buildings, namely plywood, timber, particleboards and medium density fiberboards (Azambuja et al. 2018). Particleboards made from recycled timber were shown the best performance, however the use of wood recyclated was recommended only for the core layer of the boards, since the bending properties were very low. Hameed et al. (2019), made three layer particleboards from two types of recycled raw material, untreated wood and wood treated with various coatings. They reported that the produced boards met the requirements of no load-bearing panel for interior use in dry conditions. Izdinsky et al. (2020), made three layer particleboard bonded with UF resin, from fresh spruce wood, recycled wood chips and recycled faulty UF bonded particleboards, at various proportions. They reported that both mechanical and physical properties were negatively affected by the incorporation of the recycled material, whereas the boards made from 100% recycled material showed the worst performance.

Conventional adhesive systems that are mainly used for the manufacture of wood composites, are primarily made from petroleum-derived components and based on formaldehyde (Kumar and Pizzi 2019, Pizzi et al. 2020, Pizzi 2017). It is estimated that, nowadays, approximately 95% of the total adhesives used in wood composites manufacture are formaldehyde-based resins (Kumar and Pizzi 2019), and in particular urea formaldehyde resin is by far the most predominant type (Wibowo et al. 2020). Formaldehyde based resins have many advantages, such as superior adhesion properties, low curing temperature, short press times and ease of handling

(Pizzi et al. 2020, Kumar and Pizzi 2019, Bekhta et al. 2016), however they also have a major drawback which correlates to the hazardous emission of formaldehyde and some other volatile organic compounds, all these are well connected with environmental problems (Tudor et al. 2020, Mirski et al. 2019). Since 2004, when formaldehyde was classified as known human carcinogen by the International Agency for Research on Cancer (IARC 2004), the wood based panels industry started to move from formaldehyde based adhesives to the development of alternative resins systems for the production of environmental friendly composites. The stricter legislative regulations on formaldehyde emission along with the increased consumer environmental awareness was the driving force for the development of eco-friendly, less toxic wood composites, where the traditional thermosetting resins have been completely or partly replaced by renewable, bio-based adhesives (Papadopoulou 2009, Hemmila et al. 2017, Hosseinpourpia et al. 2019, Antov et al. 2020, Sarika et al. 2020, Ghahri et al. 2021) or by adding to adhesives systems ,inorganic (Reh et al. 2019, Mirski et al. 2020, Reh et al. 2021) or organic compounds (Costa et al. 2013, Costa et al. 2012), as formaldehyde scavengers. A potential solution in order the negative effect of formaldehyde release to be addressed, is the use of isocyanates adhesives, where no formaldehyde is added (Frazier 2003), however their relatively high cost and the need for the adjustment of the glue line limited their wider application in the wood based panel industry (Hornus et al. 2020).

Lignin, the second most abundant polymer encountered in nature, is considered as a by-product from the chemical pulping process of wood, it is reported that approximately 2% is used for value-added applications, such as adhesives, polymer reinforcement materials, surfactants, while the rest is burnt for heat and energy (Bajwa et al. 2019, Klapiszewski et al. 2018). Lignosulfonates (R-SO3H), the salts of lignin sulfonic acid, are one of the main sources of technical lignins. The main drawback for their application in the composition of wood adhesives is their increased hydrophilicity of the finished products and the longer press times required (Antov et al. 2021, Chen et al. 2020), investigated the potential of producing environmental friendly composites from waste wood fibres, composed of two wood species and bonded with a lignin-based adhesive. They found that the composites exhibited satisfactory mechanical but showed deteriorated moisture properties. Eco-friendly fiberboard panels with acceptable mechanical and physical properties, made from residual wood fibers were manufactured and bonded with calcium lignosulfonate at various contents (Antov 2021). It was concluded that only boards made from 14% lignosulfonate exhibited bending properties values, and these were comparable with the standard requirements for medium-density fiberboards for use in dry conditions.

Polystyrene is a synthetic, aromatic, thermoplastic polymer made from the monomer styrene. Styrene was first introduced to the market on industrial scale in early thirties by the German company IG Farben industries and by the Dow Chemical Company in USA; these employed the catalytic dehydrogenation of athylbenzene, a process that is still used nowadays (Chaukura et al. 2016). Polystyrene is widely used for packaging applications and its Society for Plastic Industry code is 6, indicating the difficulty associated with its recycling. The common forms of polystyrene are general purpose polystyrene (GPPS), expanded polystyrene (EPS), high impact polystyrene (HIPS) and syndiotatic polystyrene (SPS). Waste polystyrene has very serious environmental risks, particularly in developing countries, where disposal facilities are in shortage and its proper management is a big problem because it is easy to recycle. It is known that despite the efforts being made by the industry to incorporate a small percentage in the manufacturing process, their management entails considerable costs of transportation, storage and disposal. Due to obvious lack of effective and appropriate strategies of its recycling, huge quantities of waste polystyrene are discarded in landfills, recycling plants or incinerated. Waste polystyrene are not decomposed in these facilities, getting dissolved by leaching of decomposition of another organic matter. Similarly, the gases resulting from the incineration of polystyrene are harmful (Merino et al. 2019).

Various researchers investigated the potential of using polystyrene as a binder in order to produce value-added wood composites. Masri et al. (2018) successfully manufactured particleboards from expanded polystyrene (EPS) wastes and date palm and reported that the bending strength and stress reached acceptable values coupled with good fibre-matrix interface adhesion. Akinyemi et al. (2019) made experimental particle boards from wastes of wood and expanded polystyrene foam. They concluded that wood and expanded polystyrene foam wastes can be considered as sustainable materials for producing panels that can be durable in moist environment. Hermawan et al. (2010) manufactured oriented strand board bonded with disposal expanded polystyrene as binder. The results revealed that the mechanical properties met the Japansese standards, however thickness swelling remained a problem. Chanhoun et al. (2018) examined the possibility of upgrading plastic waste, expanded polystyrene and wood, that pollute the environment of cities in Africa in general and those of Benin in particular. The study showed that, for the same polymer, the physicomechanical characteristics are different depending on the granular composition of the wood particles. It is further reported that the expanded polystyrene polymer provided high mechanical performance composites compared with those made with the plastic-based polymer. Polystyrene has been used for the manufacture of lightweight gypsum-based composites. Merino et al. (2019) reported on the physicomechanical properties of lightweight gypsum-based composites made from various mixtures of polystyrene wastes, both expanded (EPS) and extruded (XPS). It was concluded that these type of composites complied with the current standards and have lower density than currently used lightweight gypsums and mechanical strengths. Expanded polystyrene has also been used for the manufacture of light weight concrete sandwich wall panels (Fernando et al. 2017, Carvalho and Motta 2019).

The above survey clearly shows that the development of alternative wood composites based on the use of waste or recycled materials can be beneficial due to over exploitation of natural resources

6.1.6 Precision agriculture – Precision forestry

Precision agriculture involves the adoption of advanced technology to collect and analyze data of high spatial and temporal resolution required for decision making and operations in the management of crop production.

Precision agriculture improves crop management by:

- Providing farmers with tools to optimize and increase soil quality and productivity and select appropriate interventions
- Reduce consumption and waste
- Reduce the production costs
- Improve environmental conditions through the reduction in waste of fertilizers and herbicides, emissions and soil compaction

Example cases involve:

- Satellite crop monitoring of the health of the fields with multi-spectral imagery of high resolution satellite images
- Agricultural drones for land mapping
- Environmental sensors installed in the fields to record climatic data and information on soil water requirements
- Equipment capable of dosing fertilisers and plan protection products according to the requirements of the crops
- Precision steering and automated driving systems for tractors and agricultural machinery
- GPS to geolocalise agricultural machinery in the fields
- Robots for automated seeding and harvesting
- Grippers to handle fruits and vegetables without damaging them

Precision forestry involves the adoption of advanced technology to improve forest management by (Choudhry and O'Kelly 2018):

- Improving the data collection processes for tighter control of operations

- Increase selectivity of prescriptions to match site and needs, for example soil nutrients and the genetic material of seedlings planted
- Automate operations from nurseries to wood logistics
- Optimize decision making with advanced analytics

Example cases involve:

- Advanced genetic improvement: breed selection to match the plants' genetic profiles to the site and end use.
- Forest management prescriptions adapted to site needs based on data from soil sensors
- Digital monitoring of potential outbreaks with UAVs and coordinated responses to minimize damage to the forest
- Increased use of machinery to improve safety, labour productivity and forest silvicultural operations, for example weed control.
- Digital forest inventories by aerial remote sensing and in-forest devices
- Remote/automatic loading for wood delivery
- Forestry planning models (software) to support management decisions at different levels from strategic to tactical and operational
- Field support tools, such as mobile devices deployed in the forest to grant supervisors access to forest information systems and planning tools
- Fully automated nurseries
- Digital monitoring of fires with UAVs or satellite for early warnings or fire-fighting coordination
- Water management systems, such as flood gates with central control of water infrastructure, based on weather, soil moisture, canal water levels and analytics
- Fully mechanized forest harvesting systems (robots)
- Advanced software for wood logistics optimization
- E-dashboards to visualize performance data
- Advanced analytics to solve complex problems, such as to identify constraints on tree growth at micro level and determine effective interventions

7. Institutional framework for sustainable use of natural resources and circular economy in rural areas

7.1 Policies

About 29.1% of EU population lives in rural areas and 31.6% in towns and suburbs, which are mostly intermediate rural areas. The rural areas typically follow a different development path from the urban areas. The development of rural areas is dynamic and certainly not homogenous. Some rural areas, particularly those near urban centers are more prosperous, than the remote rural areas, which are sparsely populated with weak infrastructure and low economic and employment prospects. Most of the rural areas however are in an intermediate condition aiming through better coordination to a capacity balance between rural and urban components. In this frame the ultimate policy objective in the EU territory to move towards a low carbon economy targeting to carbon neutrality by 2050 presents several challenges for rural areas and requires specific policy tools to manage transition and in particular energy transition, sustainable management of natural resources and bioeconomy and circular economy.

Rural areas play an important role for the successful energy and environmental transition. Due to their richness in natural resources rural areas contribute to human well-being through the supply of ecosystem services and particularly through food and water supply, energy security, biodiversity and improved air and water quality. However, at the current state there are several limitations of rural areas that need to be considered in their energy and environmental transition, since rural transition so far has received much less attention than the urban transition. These limitations according to Phillips (2019) are the following:

- *Limited economic diversification of the rural areas*. Rural communities face difficulties in diversifying their economies due to the traditional agriculture, livestock and industry restructuring and the need for growth in non-farm rural activities.
- *Low educational and employment opportunities in rural areas*. The limited education and employment opportunities in rural areas lead to rural-urban migration particularly of young people and to the shift of political power from the rural communities to the urban centers. The latter results in reduced funding for infrastructure, public services and financial assistance from central government to the rural areas.
- *Vulnerability of rural areas to climate change and natural resource degradation and depletion*. Rural communities depend their living mainly on agriculture and natural resources, which due to greater pressure they become more vulnerable to climate change and extreme climate events.

- *Difficulty in valorization of ecosystem services*. Despite the progress that has been made in terms of methodological tools for assessing the economic value of ecosystem services, still application difficulties remain due to their complexity.
- *Capacity lack of rural areas for energy and environmental transition*. Lack of capacity refers to lack of financial, human and infrastructure resources in rural areas to address environmental and economic problems.

To successfully address these limitations the rural energy and environmental transition should be closely linked to rural development. There has been a clear change in rural policy over the last decade moving the focus from the centralized sector based approach to an integrated, diverse and multi-sectorial approach. These evolving changes in rural development policy making have been summarized by OECD in 2020 (Table 9) starting from the "old paradigm" of the sixties and seventies to the "new paradigm" around the millennium decades and to recent "rural policy 3.0" and "rural well-being: geography of opportunity". In the recent approach the objective of the rural development policy is along with economic and social aspects to achieve individual well-being through integrated investments which provide services adapted to the needs of rural communities. Such a framework should include governments, the private sector and the rural communities.

Table 9. Changes in rural development policy making

Changes in rural development policy making					
Rural Development Strategies	**Objectives**	**Key actors and stakeholders**	**Policy focus**	**Policy Approach**	**Rural Development Concepts**
Old rural paradigm	Equalisation and food supply	Agricultural organisations and national government	Primary sector focused	Uniformly applied top-down policy	Exogenous Rural Development
New rural paradigm	Competitiveness	All levels of government plus key stakeholders	Multiple sectors based on their competitiveness	Bottom-up policy, local strategies	Endogenous Rural Development
Rural policy 3.0 and Rural well-being: Geography of opportunity	Improvement in multiple dimensions of economic, social, environment	Multi-sectoral and multi-level	Low-density economies differentiated by type of rural area	Integrated approach with multiple policy dimensions	Neo-Endogenous Rural Development

	al well-being				

Source: Phillips (2019) "Challenges and policies to support rural environmental and energy transitions", Background Report for an OECD/EC Workshop Series on "Managing environmental and energy transitions for cities and regions", OECD, Paris, 5 September 2019; OECD (2020) *Rural Well-being: Geography of Opportunities*, OECD Rural Studies, OECD Publishing, Paris, https://doi.org/10.1787/d25cef80-en

At the local level rural development policy should strengthen synergies to integrate long-term transition actions in two key fields, the sustainable management of natural resources and renewable energy development towards a circular and bioeconomy.

Sustainable management of natural resources requires better alignment of food and water with climate change mitigation and adaptation policies. In this context, several challenges related to resource competition, such as land, energy, water and biodiversity, economic and social aspects, such as the rural community development, environmental concerns, such as ecosystem health and climate change, as well as human health need to be addressed. In addition, rural areas and rural communities towards energy and environmental transition may experience vulnerabilities with regard to certain economic impacts, such as for example the replacing of coal mining operations, or to reduced benefits from certain innovations or subsidies. It is therefore important attention to focus on the just transition of rural areas, that is, transition more fair and inclusive.

Based on the above, a crucial question arises: what policy tools should be applied to promote just transition of rural areas to climate-neutral and circular economy?

Several policy tools can support rural transition:

- *Policies focusing on food value chains*. These should aim at more sustainable land management systems, minimization of food loss, food waste and emissions and increase of food security. Land management practices should attempt to replace synthetic fertilizers by municipal waste or crop residues and/or use the wastes to produce energy. In cases food loss cannot be avoided, it can be re-introduced into natural nutrition cycles.

- *Policies promoting organic agriculture*. Organic farming is based on natural fertilizers and ecological pest controls. Moreover, organic farming can improve the provision of ecosystem services, particularly those related to soil, water and biodiversity, while creating business and job opportunities. However organic farming involves higher labour and equipment costs, certification and labelling processes and it should be supported through financial instruments and regulations. It is evident that not all agricultural farming can turn into organic; however there are still possibilities for increasing organic the farming activities. France for example has set an agricultural strategy which targets to turn into organic 15% of all agriculture by 2022 (Agreenium 2018).

- *Policies supporting digital technologies for the sustainable management of natural resources*. Precision agriculture and precision forestry are the main promising fields in rural areas where digital technologies can be used to collect data, measure factors of production and management interest with great accuracy and optimize their use as well as production yields. Agriculture and forestry can become more attractive for young people through new business opportunities and this may reverse the rural-urban migration. However, both precision agriculture and forestry require sufficient technical infrastructure, for example broadband connectivity to increase their expansion potential. Financial instruments therefore need to be established to support digitalization in rural areas.

- *Policies supporting sustainability of water resources*. Improved information systems on water resources are required at farm, community and national level to address quantity, quality and risk issues of water resources against weather and climate change events. A policy issue of concern with regard to water resources is that water charges should reflect the full water price, considering also the opportunity cost of water withdrawal and the compensation amount to poor farmers (Gruère and Le Boëdec 2019).

- *Policies supporting soil management practices*. Agroforestry is a land use system which integrates trees on farms with pastures and it can help restore degraded lands, while increasing production yields. Financial instruments should promote such land use systems.

-Policies protecting natural ecosystems. Such policies are required to secure provision of ecosystem services particularly those related to agriculture, forestry and biodiversity in order to overcome market failures. An instrument which has been used since the last decade mainly for biodiversity conservation aims are Payments for Ecosystem Services (PES). Through this instrument farmers or forest owners are paid to manage their resources while safeguarding watersheds or carbon sequestration or biodiversity conservation goals. Also, agricultural subsidies can be structured in ways that support environmental goals along with direct payments for production purposes (OECD 2019).

-Finally, *policies supporting the development of renewables*. Rural areas are endowed with renewable energy sources, such as biomass, wind, sun, hydropower or geothermal energy and therefore they present advantages regarding generation and use of electricity and heat from renewable energy sources. Certainly not all rural areas afford the same physical conditions for use of renewable energy sources and it is important to map first the potential of each area in terms of development of renewables. Moreover, it should also be taken into account that the development of renewables is not always an economic driver for rural areas and attention should be given on the distribution of social and economic benefits in rural areas. Clausen and Rudolph in 2020 pointed out that the supply chain and community benefits and community or shared ownership are the most important factors to be considered.

7.2 Governance

Energy and environmental transition of the rural areas and circular activities cannot be achieved without effective governance mechanisms. Such mechanisms should aim to enhance active participation of all the involved local stakeholders and in particular the local communities in decision making, build the required capacity and increase awareness about all issues related to rural transition and circular economy.

Active participation of the local communities can help assess the existing environmental and socio-economic conditions, land-use pressures and potential impacts in agriculture, forestry and food production, including environmental risks, such as land degradation, biodiversity decline, over-extraction of groundwater and soil loss. On the other hand, implementation difficulties arise because of the differences in capacity existing in the parties involved which support circular economy activities in the rural areas. Small businesses and municipalities in rural areas often lack the resources and expertise to pursue circular initiatives. Municipalities in particular due to limited capacity often fail to fulfill their role in fields, such as waste management, awareness raising or tendering procedures. National governments should carry out capacity and skill development activities both for the municipalities and small companies and farmers or forest owners to help close the gaps with the larger scale stakeholders.

Local communities also can participate in benefit-sharing schemes to generate better community projects with sustainable local impacts and positive perceptions and ensure distribution of monetary and non-monetary benefits. Non-monetary benefits in benefit sharing schemes applied to renewable energy projects in particular can include conservation, environmental education or sustainable tourism programs. Benefit-sharing schemes with regard to renewable development projects can be of different types:

- Financial benefits in the form of a "community fund" for the local population
- Direct or indirect "benefits in kind", for example new or improvement of existing infrastructure for the local population
- "Profit-sharing" benefits, for example local residents are granted a stake in the energy project and thus their benefits are connected to its performance.

In some cases, climate neutral and circular economy projects may create social resistance because of the decline of existing economic activities, such as for example the replacement of coal-mining operations. Public authorities in these cases can have an important role to mitigate the social turmoil. Listening to people’s worries, encouraging community participation in the early phases of policy design, offering compensation payments and providing training or other assistance to the groups most affected are governance actions that can help increase social acceptability of such projects.

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MULTITRACES

MULTIDISCIPLINARY TRAINING IN CIRCULAR ECONOMY AND SMART VALORISATION OF THE RURAL AREA FOR NEW BUSINESS MODELS

Co-funded by the Erasmus+ Programme of the European Union

10 May 2021

Renewable Energies in Rural Area

Open Education Resource: Multidisciplinary training in circular economy and smart valorisation of rural area for new business models

MODULE 3

SUSTAINABLE DEVELOPMENT OF THE RURAL AREA AND SMART VALORIZATION OF THE NATURAL RESOURCES

Trainer: Ass. Professor Roxana Grigore
„VASILE ALECSANDRI” UNIVERSITY OF BACAU

CONTENT

1.RENEWABLE ENERGY AND CIRCULAR ECONOMY

1.1.THE CONNECTION BETWEEN CIRCULAR ECONOMY, BIOECONOMY AND RENEWABLE RESOURCES OF ENERGY

The circular economy is an economic model which comes from the biosphere, where everything can become a resource for the next level of the trophic chain. This natural model can be industry adapted and it assumes that throughout the whole system of production and consumption the waste generated is as little as possible, thus protecting the biosphere.

According to [1], the basic principles of the circular economy are:

- The wastes are raw materials;
- Resilience through diversity;
- Energy from Renewables sources;
- Think from a systems perspective.

The connection between the transition from conventional fuels to the renewable energy sources and the circular economy is obvious. To protect the biosphere the following are required: to reduce of the greenhouse gases, to prevent the reduction of the ozone layer, to preserve the reproductive capacities of natural resources and to maintain water, air and soil quality within the limits imposed by standards.

In this context, it is clear that the use of renewables energy sources represents an important component of any country's energy strategy. All documents adopted at the EU level highlight the importance of using renewable energy sources both in terms of protecting the environment and increasing the safety in the supply of electricity and heat to consumers.

The European Commission defines the bioeconomy as *the production of renewable biological resources and the conversion of these resources and waste streams into value added products, such as food, feed, bio-based products and bioenergy*. Its sectors and industries have strong innovation potential due to their use of a wide range of sciences and, enabling and industrial technologies, along with local and tacit knowledge, [4]. The definition was established in The European Bioeconomy Strategy (2012) and points towards a real connection between bioeconomy and renewable resources.

The two concepts, the circular economy and the bioeconomy, are distinct from several points of view, but in principle have common goals. The circular economy is also based on the efficient use of non-renewable sources - a combination of reduction, reuse and recycling activities, while the bioeconomy is based on the use of renewable sources in an intelligent and efficient way. The circular economy focuses on the economic prosperity first, then on the environmental protection, while bioeconomy starts from the need to reduce the concentration of greenhouse gases (especially CO2) and thus the environmental footprint. The common goal of the two concepts is sustainability and the efficient use of resources, aimed at reducing the carbon footprint (reducing the amount of fossil carbon). The circular economy strengthens the processes eco-efficiency and the use of recycled carbon, and bioeconomy replaces fossil carbon with that from biomass from agriculture, forestry and aquaculture, [2]. Another objective resulting from the principles of the two models is development and support for rural areas by adding value to goods that are produced by the agricultural, forestry, fisheries or waste sectors. Bioenergy, produced as a result of existing biomass in rural areas, creates new jobs, replaces fossil fuels and contributes to energy security.

The special issue *Bridging the Circular Economy and Renewable Energy Dichotomy* of the Sustainability Journal, [5], highlights the need to integrate renewable energy into various production and consumption processes, ranging from manufacturing, use to reuse and recycling of materials, components and products. At the same time, it is suggested that the component elements of renewable energy systems (solar panels, wind turbines, batteries) should be made from materials manufactured by environmentally friendly technologies, taking into account the principles of a circular economy.

1.2. A BRIEF INTRODUCTION ABOUT ENERGY RESOURCES

The word ***energy*** comes from the Greek ενέργεια (energhia) and an ad literam translation would mean ***working***. In Latin there is also the term ***energia*** with the meaning of ***activity***. The history of the development of the energy concept is long and includes different approaches.

The concept of ***energy*** is fundamental due to the connection between matter and motion, but also due to the production and transformation of different forms of matter movement. These forms of movement can transform each other into strictly determined quantitative ratios, which allowed the introduction of the notion of energy as a common measure of them, [7].

Primary energy consists of all the energy that is in the original source. Primary energy is the energy that has not undergone any process of conversion or transformation. The following are considered primary energy resources:

- conventional, finite sources;
- renewable sources.

Conventional primary energy resources are considered to be limited in both time and space. They are able to cover the needs of human society only for a limited period of time. The size of this time period depends on the volume of primary energy reserves to which human society has access [8]. The most used fuels in this category today are crude oil, coal, natural gas and nuclear fuels.

Renewable primary energy sources refer to those categories of primary energy sources that are continuously generated by natural systems. The following main categories of renewable energy resources are distinguished: hydraulic, solar, wind, geothermal, tidal, wave, biomass. They are characterized by:

• Gross theoretical potential - represents the energy that would become available through the conversion into useful energy of all natural renewable flows, with an efficiency of 100%.

• Technical potential - represents the share of the gross theoretical potential that can be converted into useful energy, taking into account the level of technological development and the possibility of its use by human society (human geography).

• Economic potential: represents the share of the technical potential that can be converted into useful energy, taking into account economic profitability.

Fig. 1.1 presents the share from renewable sources, at the level of 2019 year, in % of energy consumption, in the countries of European Union.

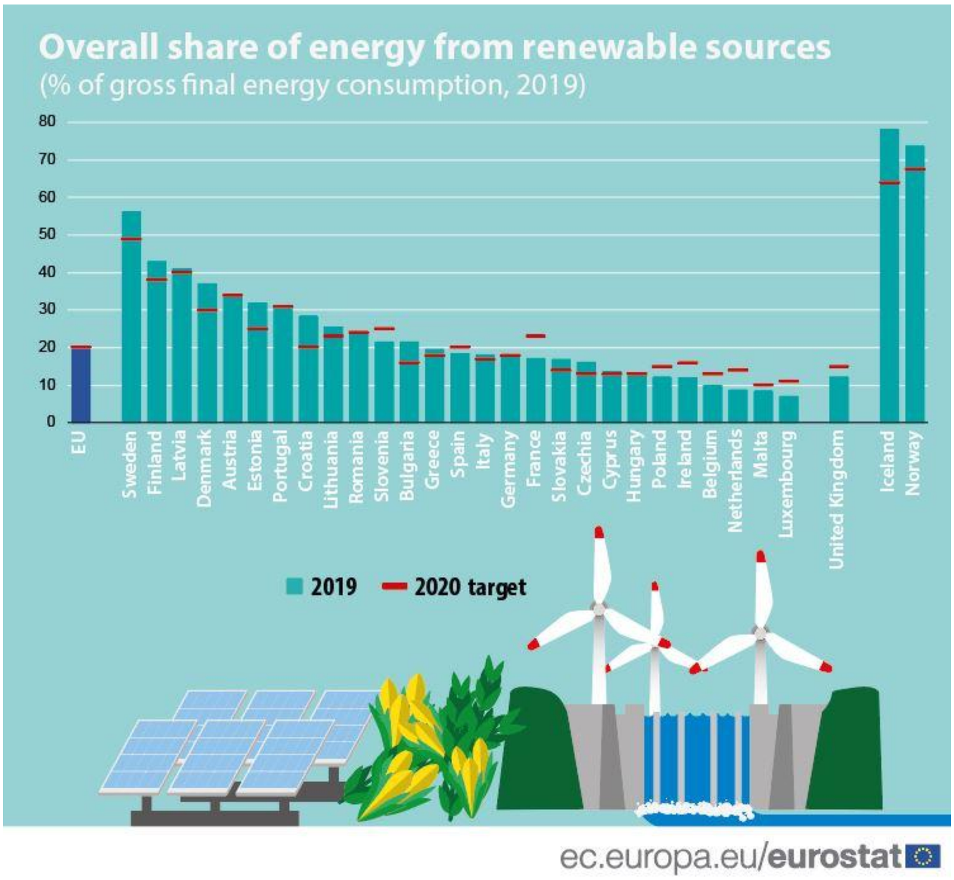


Fig. 1.1. Share of energy from renewable sources, 2019
(% of gross final energy consumption), [9]

According to [3], Table 1 presents values of percentages of energy from renewable sources in gross electricity consumption, 2010-2019 for Greece, Spain, Italy and Romania:

Table 1.1. Share of energy from renewable sources in gross final energy consumption, 2010-2019 for Greece, Spain, Italy and Romania, in %:

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Greece	10.1	11.2	13.7	15.3	15.7	15.7	15.4	17.3	18.1	19.7
Spain	13.8	13.2	14.3	15.3	16.2	16.3	17.4	17.6	17.5	18.4
Italy	13.0	12.9	15.4	16.7	17.1	17.5	17.4	18.3	17.8	18.2
Romania	22.8	21.2	22.8	23.9	24.8	24.8	25.0	24.5	23.9	24.3

In 2019, renewable energy represented 19.7 % of energy consumed in the European Union, only 0.3 % short of the 2020 target of 20 %.

The ambitious objective of the European Green Deal is that Europe will become the world's first climate-neutral continent by 2050.

2. SOLAR ENERGY

Motto: *Humanity is now the threshold of a new era that could be called the solar age*,

Werner von Braun, Paris, 1973

2.1. SOLAR RADIATION AND SOLAR CONSTANT

The sun is the most important source of energy on Earth, helping to maintain the planet's temperature well above the value of almost 0K, encountered in interplanetary space. In one second the Sun radiates more energy in space than mankind has consumed since its appearance on earth: 3.86×10^{26} J, [11].
For the study of solar radiation, it is important to define some important characteristics. The solar constant represents the total radiation energy received from the Sun per unit of time per unit of area, measured in the upper layers of the Earth's atmosphere, perpendicular to the direction of the sun's rays. The value accepted of the solar constant is approximately 1360 W/m^2, representing an average annual value, measured with the help of scientific research satellites. The Earth's atmosphere and Earth's surface interact with solar radiation, producing a series of transformations of solar radiation, as seen in figure 2.1.

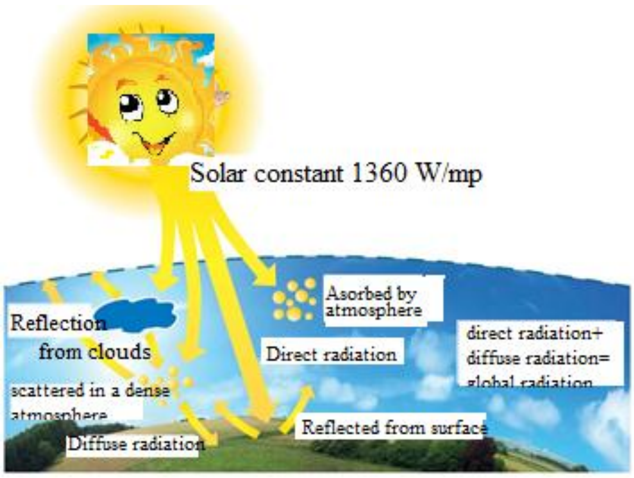


Fig.2.1 The interactions scheme between solar energy and the atmosphere, respectively the earth's surface

The mechanisms by which the intensity of solar radiation changes as it passes through the atmosphere, are absorption and diffusion. X radiation and part of the ultraviolet radiation are almost completely absorbed (retained, filtered) in the atmosphere. Water vapor, carbon dioxide and other gases in the atmosphere contribute to the absorption of solar radiation by the atmosphere. The absorbed radiation is generally transformed into heat, and the diffuse radiation thus obtained it is sent back in all directions into the atmosphere. Through these processes, the atmosphere heats up and produces in turn radiation with a length of big wave, called atmospheric radiation. In addition to the two mechanisms of changing the intensity of solar radiation, a part of solar radiation is reflected by the Earth 's atmosphere or some of its components (the air molecules and certain categories of clouds). By reflection, some of the solar radiation is dissipated, the mechanism of this process is called Rayleigh diffusion, and this phenomenon represents the radiation of the celestial vault.
Direct radiation is the component of atmosphere radiation that is neither reflected nor scattered, and which directly reaches the surface. This is the component that produces shadows.
Global radiation from the Sun, on a horizontal surface at ground level in one serene day, represents the sum of direct radiation, diffuse radiation and reflected radiation. Direct solar radiation depends on the orientation of the receiving surface. Diffuse solar radiation can be considered the same, regardless of surface orientation receivers, even if in reality there are small differences and reflected radiation has a very small value, [10].

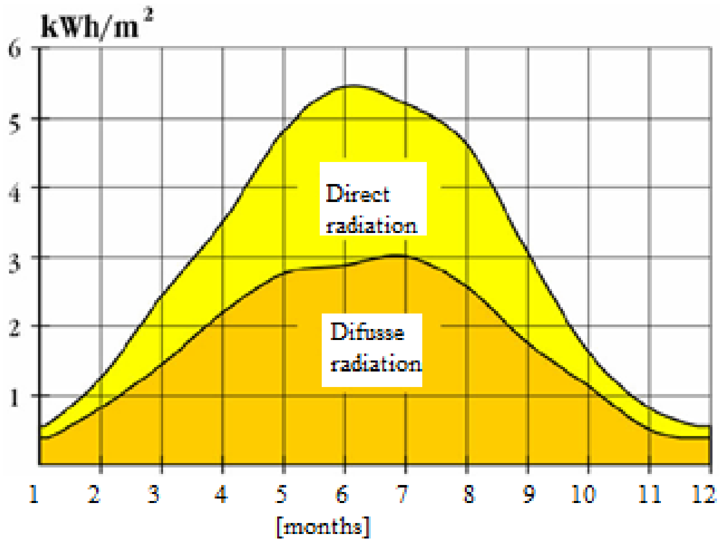


Fig.2.2. The ratio between diffuse and direct radiation,[10]

Depending on the amount and type of energy transmitted, the solar radiation that reaches the Earth consists of:
• Visible radiation from 0.38 to 0.78 microns,
• Ultraviolet (UV) radiation from 0.28 to 0.38 microns,
• Infrared (IR) radiation from 0.78 to 2.5 microns.

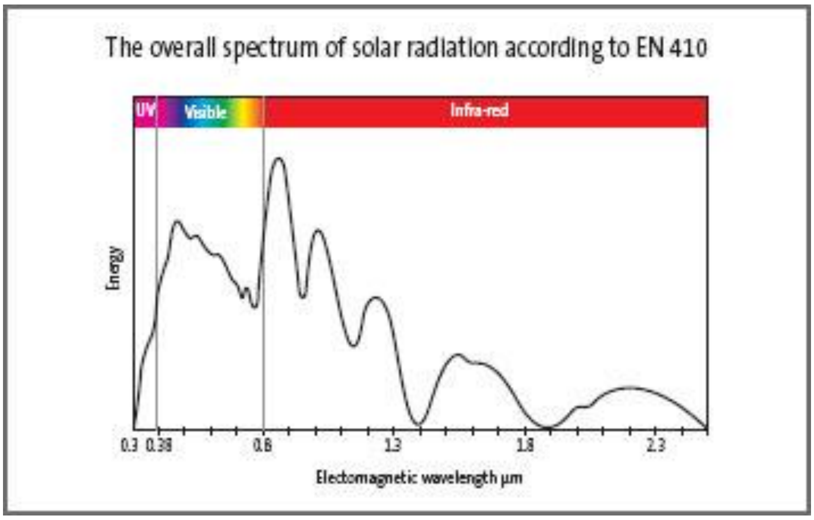


Fig. 2.3. The overall spectrum of solar radiation according to EN 410, [15]

Obs. 1 µm=1 micrometre=10^{-6}*m=1 micron*

According to the standards, the photovoltaic modules are evaluated for an air mass index (AM) of 1.5. It quantifies the reduction in the power of light as it passes through the atmosphere and is absorbed by air and dust.:

$$AM = \frac{1}{sin\gamma} = \frac{1}{\cos z} \qquad (2.1)$$

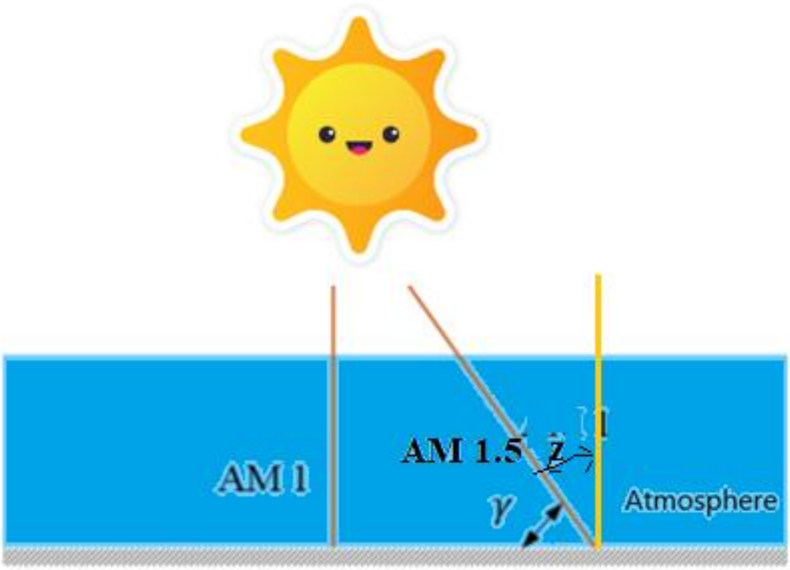


Fig.2.4. Air mass

Before entering the Earth's atmosphere, AM has the value 0, in which case the irradiance is the solar constant, respectively 1360 W / m². AM =1 corresponds to a trajectory perpendicular to the Earth's surface (the shortest path of radiation, through the atmosphere, to the Earth's surface), and AM =1.5 attests that the path of radiation through the Earth's atmosphere is 50% longer than for AM =1, which corresponds an angle γ = 41.8 °

Examples:

- AM=0: no atmosphere, great altitude, 1360 W/m²;
- AM=1: the sun at its zenith (z=90°);
- AM=1.5 the sun at z=48,2°,γ = 41.8 °, 833 W/m²;
- AM=2: the sunt at z=30^o.

The energetic distribution of the global solar radiation is made according to the wavelength whose value is between 0.3 and 2.5 μm in the case of a surface perpendicular to the respective radiation. It is observed that the largest amount of thermal energy is found in the field of infrared radiation and not in the field of visible radiation, which suggests the idea that this radiation can be captured efficiently even in conditions where the sky is not perfectly clear.
Several parameters influences the solar radiation:

- The angle formed by the direction of the sun's rays with the horizontal plane;
- The inclination angle of the Earth's axis;
- Changing the Earth-Sun distance;
- Geographical latitude.

The main advantages for the production of electricity and heat using solar energy are:
- Solar energy is practically inexhaustible;
- It is a form of non-polluting energy;
- It is available practically everywhere;
- As fuel, it is free;

Some main disadvantages are:
- The solar radiation incident on the Earth is variable, being a function of the day / night cycle, the season cycle and the local meteorological conditions;
- Solar energy at the Earth's surface is dispersed, reaching at noon in the best conditions about 1000 W / m^2.

These disadvantages are much smaller compared to what the sun offers as energy potential. Technology is constantly evolving, so things that seemed impossible yesterday, today become reality.

2.2. ASPECTS RELATED TO THE CONVERSION OF SOLAR ENERGY INTO OTHER FORMS OF ENERGY

According to Fig. 2.5, [11] the solar energy can be converted into other forms of energy in 4 ways:
1. Photomechanical energy conversion;
2. Photothermal conversion;
3. Photochemical conversion;
4. Photoelectric conversion.

1. Photomechanical energy conversion is applied in the field of space energy. The solar sail motor is a new application common to satellites [12], [13]. After the satellite or spacecraft reaches interstellar space, due to the interaction between photons and large reflecting surfaces, propulsion occurs through the impulse given by the photons to the interaction.

2. Photothermal conversion determines the climatic and meteorological conditions in various geographical areas, the formation and the preservation of the water cycle on the earth, an essential phenomenon for the existence of life on the planet. Photothermal conversion has many practical, industrial applications.

3. Photochemical conversion (along with photothermal conversion) is the basis of the life appearance on earth. Solar energy is used in two ways: either directly by light excitations of the molecules of a body, or indirectly through plants (photosynthesis) or the transformation of animal manure. Lately, the fuel cell sector has developed a lot as industrial applications.

4. Photoelectric conversion has multiple applications in both terrestrial and space energy. The direct conversion of solar energy into electricity is done by photovoltaic effect, with the help of photovoltaic cells.

Each area of Earth has a certain solar map. There are several variables depending on which such solar maps are made. To compare different climatic zones, global horizontal irradiance is used as reference radiation. Global solar irradiance is the sum of direct radiation and diffuse radiation received on a horizontal plane. Figures 2.6, 2.7, 2.8, 2.9, 2.10 show the solar maps of Europe, Romania, Spain, Greece and Italy, taken from the solargis.com website.

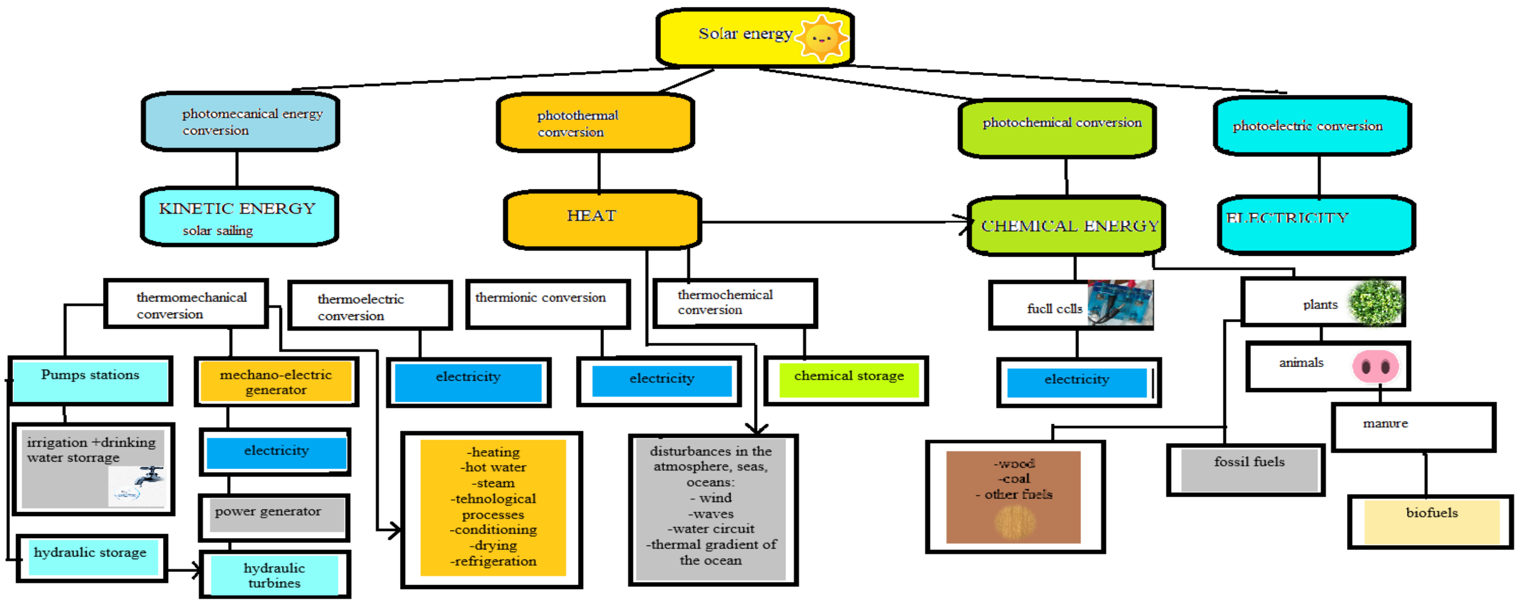


Fig.2.5. The conversion of solar energy in other forms of energy

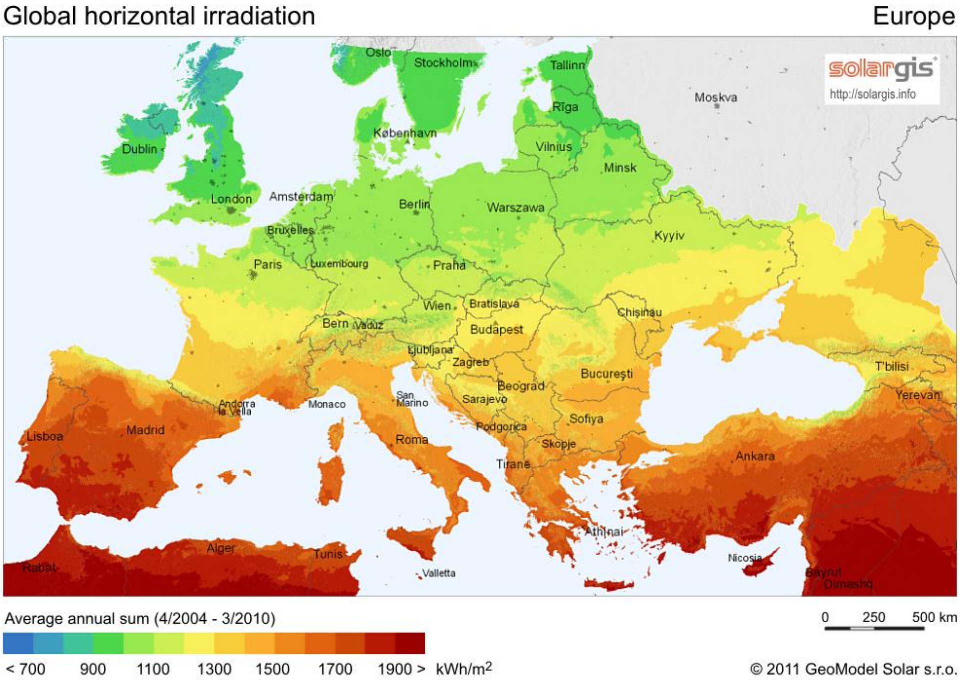


Figure 2.6. Solar map of Europe, [14]

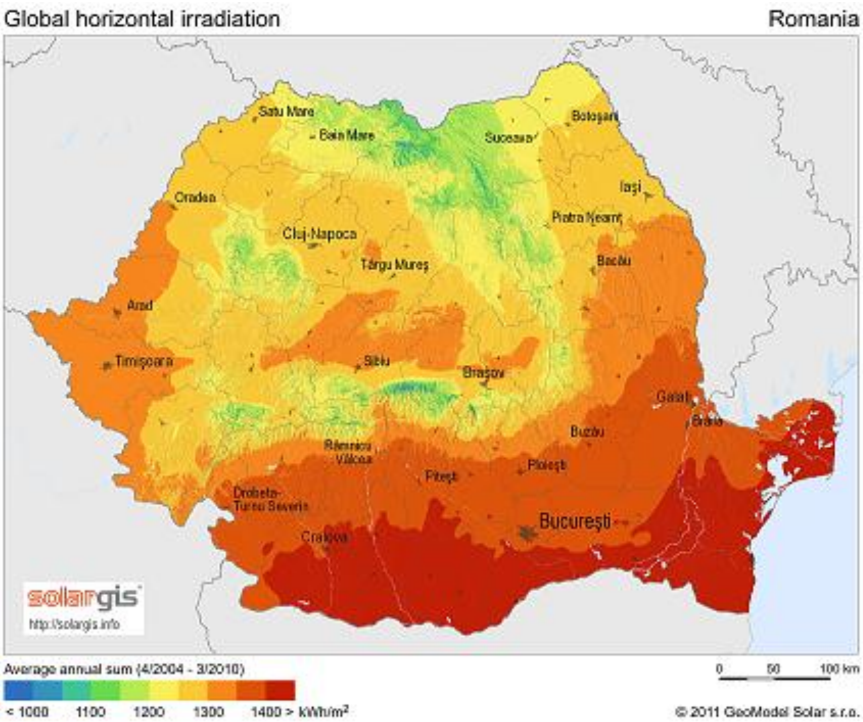


Fig.2.7. Solar map of Romania, [14]

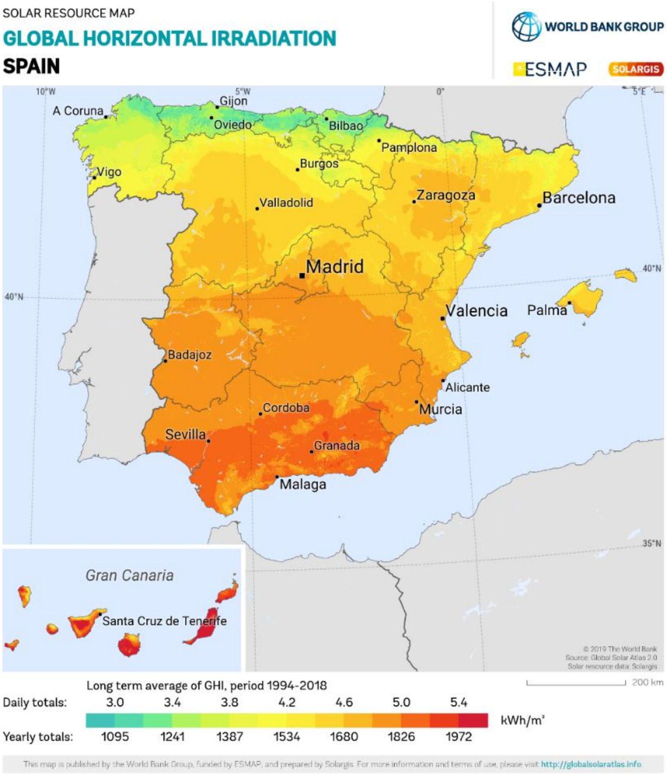


Fig.2.8. Solar map of Spain, [14]

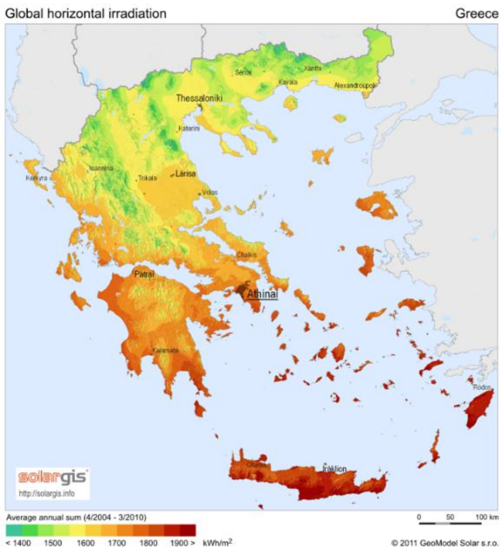


Fig.2.9. Solar map of Greece, [14]

Fig.2.10. Solar map of Italy, [14]

From a meteorological point of view, for the most efficient capture of solar energy, the following are important:

• The duration of the actual brightness of the Sun;
• Average number of sunny days;
• Distribution of daily irradiance in W/m^2, monthly irradiation in kWh/m^2 for various areas.

2.3. SOLAR THERMAL ENERGY

2.3.1 Capturing the sunlight for heat production

Regarding the solar-thermal conversion, there are two major categories, respectively:

- CSP - Concentrating Sun Power - solar energy is concentrated by using mirrors or lenses and used to increase the temperature of a thermal agent, subsequently used for electricity production, in an industrial scale system;

- low power collectors, generally intended for small - scale use, generally for obtaining hot water (low power domestic or industrial applications).

For the rural area of great importance are the various types of low power collectors.

In order for the conversion process to be carried out with the highest possible efficiency, the orientation of the collectors position towards the Sun must be as correct as possible, [16].

The position of the solar collectors is defined by two angles:

-the angle of inclination to the horizontal (tilt angle), *α*, shown in Fig. 2.11,

- the azimuth angle, γ, which represents the orientation towards the south direction, presented in fig. 2.12.

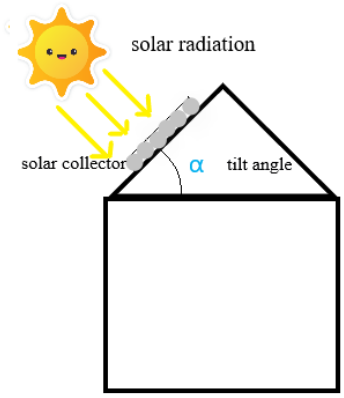


Fig. 2.11. The tilt angle α

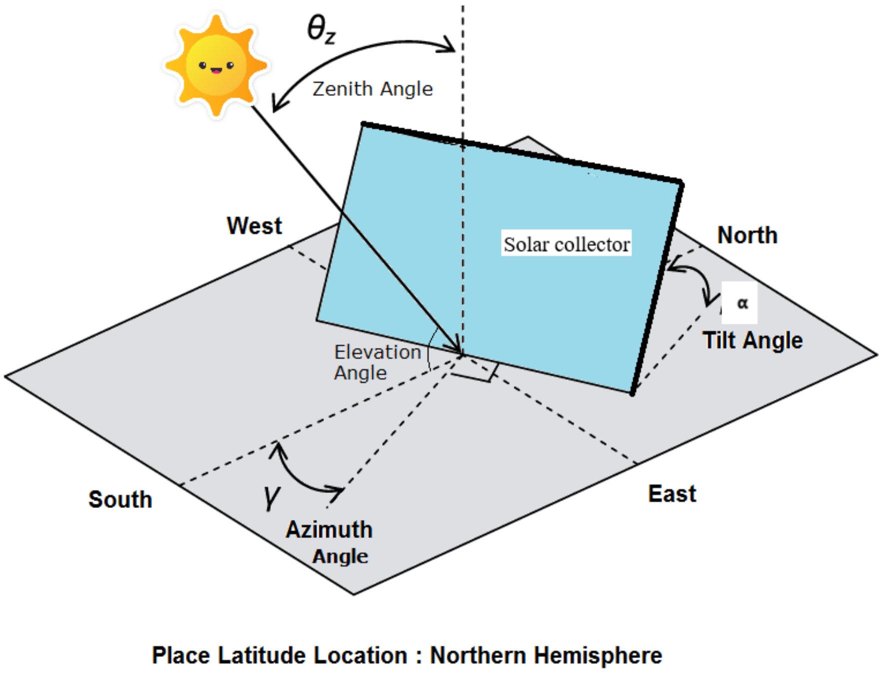


Fig. 2.12. The azimuth angle γ, the tilt angle α and the elevation angle, [17]

For residential applications, the most common solar collectors are:

- Flat solar collectors;
- Vacuum tubes solar collectors;
- Heat pipe solar collectors.

2.3.2. Flat solar collectors

Flat solar collectors are the simplest technical solution for solar collectors. The main components are shown in Fig. 2.13, [19]:

• Absorbent surface of solar radiation, flat, made of copper, stainless steel or aluminum, treated with a special black paint, provided with a system of copper or aluminum pipes through which the heat transfer fluid flows;

• A transparent surface for solar radiation, made of resistant, secure glass, with a low iron content, placed over the absorbent surface, with the role of reducing heat loss through convection and radiation to the environment;

• Thermal insulation of the absorbent surface, made of glass wool or rock (recommended), which reduces heat loss through conduction;

• Metallic container.

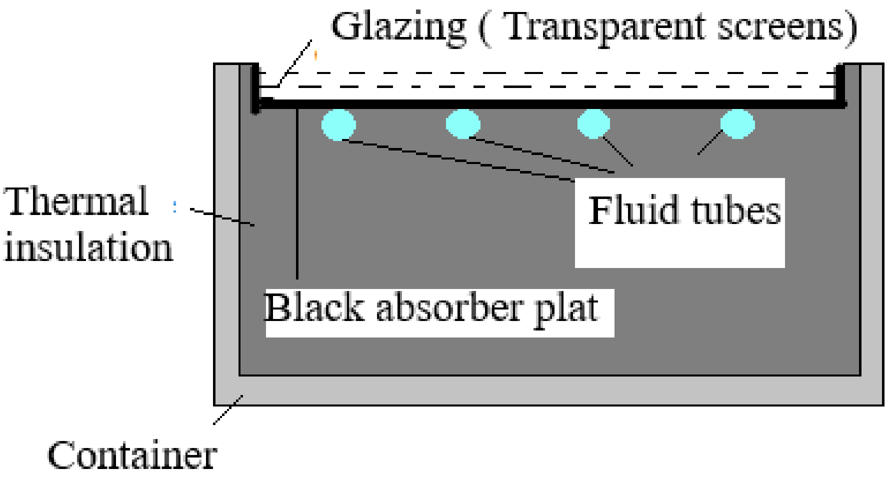


Fig.2.13. The main components of flat solar collector

The operating principle:

The absorbent surface heats up under the action of direct and diffuse solar radiation. The heat is transmitted to the fluid in thermal contact with the absorbent surface circulating in the pipes and then through the circulation of the fluid this heat is transmitted to the other elements of the installation which includes the solar panel. The heat can be transmitted directly to the consumer or stored in a storage tank.

The flat solar panels can be:

- with open circuit - the heat transfer fluid from the consumer's installation is the same as the one circulating through the panel pipes, the operating principle is that of the radiator;
- with closed circuit - the primary circuit (corresponding to the solar panel) is separated from the secondary circuit by the consumer through a building exchanger in which heat transfer takes place from the fluid in the primary circuit (glycol solution with water) to the water in the secondary circuit.

The main advantages of the flat solar collector are: the relatively low cost compared to other types of panels on the market and, at the times when direct radiation is strong, the thermal efficiency is high. The main disadvantage of this type of solar collector is the low efficiency during the cold season.

The solar radiation absorbed by a collector per unit of absorption surface is equal to the difference between the incident solar radiation and the optical losses. The heat losses of the collector in the environment by conduction, convection, and radiation are determined as the product of the heat transfer coefficient U_L and the difference between the average temperature of the absorbent plate *Tp* and the temperature of the environment *Ta*. At steady state the useful energy output of an surface collector *Ac* is given by the difference between the absorbed solar radiation and the heat loss, [18]:

$$Q_u = A_c \times \left[I - U_L \times (T_p - T_a)\right], [\mathrm{W}] \quad (2.2)$$

Where:

Qu - total heat flux in [W]; *Ac* - is the total heat exchange area in [m2]; *I* - density of heat flux received from the sun in [W / m2]; U_L - the global heat exchange coefficient in [W / m2 · K], *Tp, Ta* - the average temperature of the absorbent plate and of the environment, in [K].

The heat delivered to the collector can be written, [18]:

$$Q_c = D_{at} \times c_p \times (T_{out} - T_{in}), [W] \quad (2.3)$$

Where:

Dat - working fluid masic flow in kg/s; *cp*- capacity at constant pressure, in J/kg*K T_{out} and T_{in} - the outlet temperature and the inlet temperature of the working fluid in the heat collector, in K.

Flat solar collectors are mounted in a stationary position, on the roof for example, optimizing the orientation according to the time of year in which the solar device is intended to operate. The collectors usually have a fixed position and do not follow the position of the sun. The collector should face directly to the equator, facing south in the northern hemisphere and facing north in the southern hemisphere.

2.3.3. Evacuated tube solar collectors

The evacuated tube solar collectors are made of glass tubes, mounted in the battery. Unlike simple vacuum-tube collectors, heat-pipe collectors have a wing-shaped Cu pipe with an absorbent element inside, [18].

These types of collectors have been on the market for quite some time (over 25 years) and are of several types, respectively [1]:

- Depending on the absorption surface, fig. 2.14, [20]:
  - Tube-welded absorption surface,
  - Absorption surface not welded to the tube;

a. b.

Fig.2.14. a. Tube-welded absorption surface, b. Absorption surface not welded to the tube

- Depending on the type of heat pipe:
  - Collector with a completely vacuum tube,
  - Collector with a not completely vacuum tube;

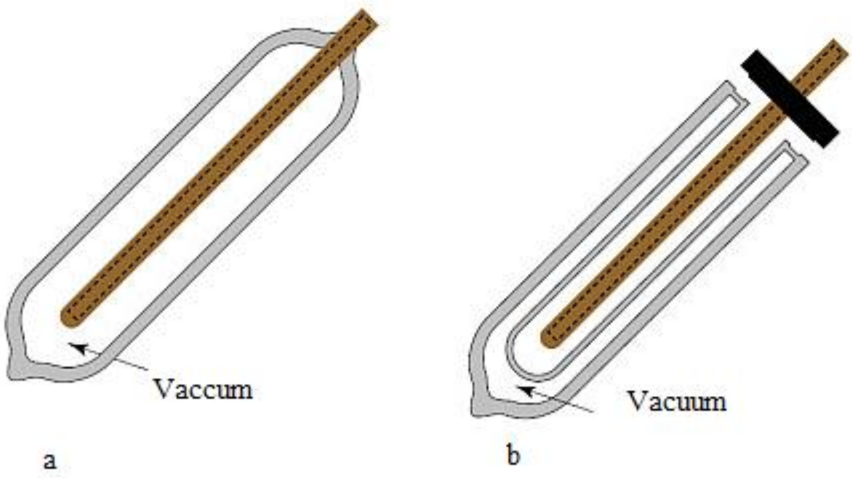


Fig.2.15 a. Collector with completely vacuum tube, b. Collector with a not completely vacuum tube, [20]

• Depending on how the heat exchange is performed, fig.2.15 [20]:
- Direct flow evacuated tube collector,
- Heat pipe evacuated tubes collectors:

The main components of heat pipe evacuated tubes collector are shown in fig. 2.16:

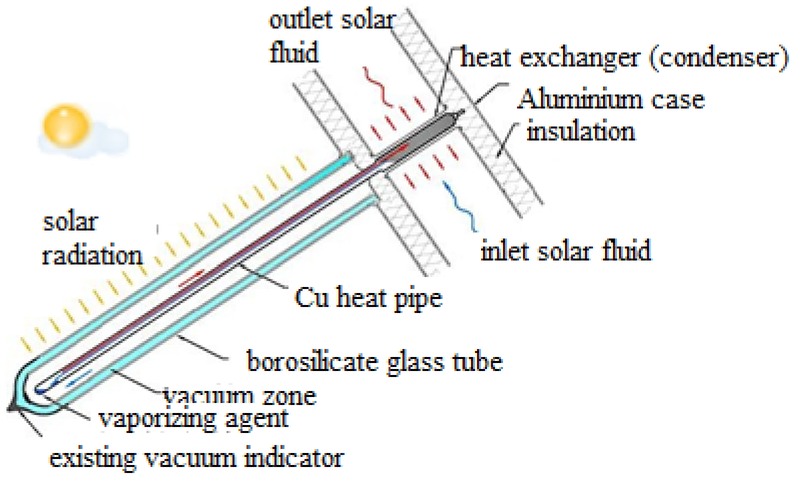


Fig.2.16. Components of heat pipe evacuated tubes collector

The operation principle

At the top of the panel is an insulated metal cylindrical tank, which holds the vacuum glass tubes. The tubes have double walls, between them being a vacuum. Due to the vacuum, the heat transfer to the environment is reduced. Inside the outer walls of the glass tubes is an absorbent material that increases the ability to capture solar radiation. In the cylindrical metal tank, the warmer water, with a lower density, will rise to the top, and the water with a lower temperature will remain at the bottom of the tank and will flow through the glass tubes, will receive heat from the Sun. It will heat up and becoming less dense it will climb into the tank at the top (the thermosyphon effect).

The advantage of direct flow evacuated tube collectors is the direct absorption of solar radiation without a heat exchanger.

The disadvantages of vacuum tube collectors are due to the fact that water circulates through glass tubes, which is a relatively fragile material, even if it is solar glass with good mechanical properties. Thus, the circulation of water cannot be achieved under pressure, due to the mechanical stresses to which the glass would be subjected. Another disadvantage is that the filling of the system with water must be done slowly and gradually, so as not to produce sudden thermal stresses in the tubes.

The disadvantage of heat pipe evacuated tubes collectors is represented by the high cost and the need to ensure a very good thermal contact between the condenser and the thermal agent in the collector pipe of the solar installation.

2.3.4. Examples of heat production systems using solar collectors for rural houses

The solar collectors can be mainly used for the production of domestic hot water, for heating, or a combined scheme may be used for heating and producing domestic hot water. These are the most common applications for houses in rural areas in particular. The solar collectors are also successfully used for heating swimming pools, for plant greenhouses, for the production of hot water for animal farms, for air conditioning, for drying installations, industrial ovens, etc ..

Solar domestic hot water systems

Figure 2.17 shows a simplified principle scheme, according to [21]. The scheme consists of three distinct zones: the first zone - the solar section ensures the preheating of the thermal agent in the consumer's installation, the second zone- the classic section allows to bring the temperature of the consumer's thermal agent to the value necessary for the delivery of domestic hot water delivery and, the third zone - the consumer section containing the thermal agent used in the consumer's installation..

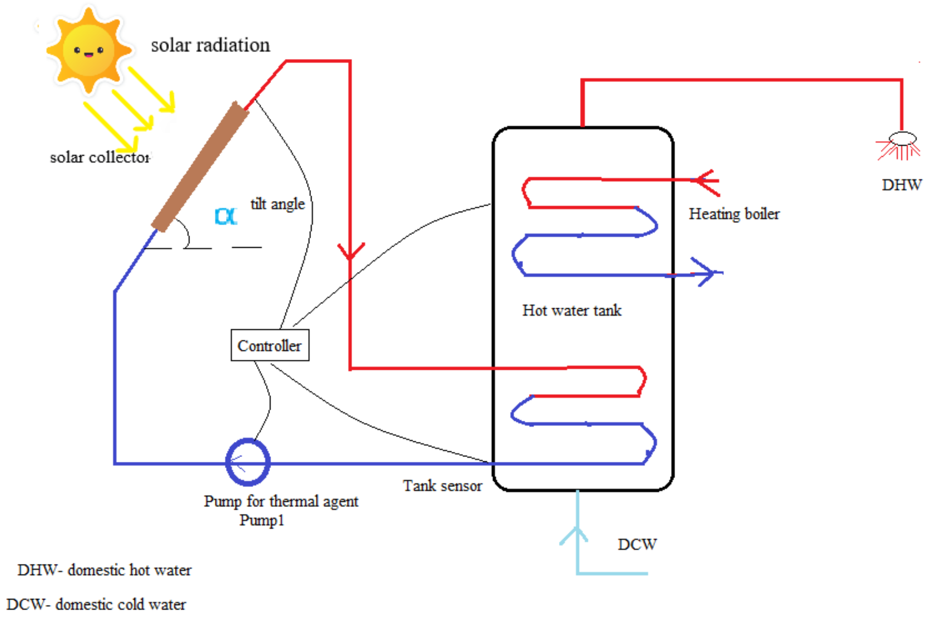


Fig. 2.17. Schematic diagram for solar domestic hot water system

The main components of the installation are:

Solar thermal collectors which capture and retain heat from the sun and use it to heat a thermal agent (water, solar glycol,etc). The solar collectors can be an integral part of the roof or building walls or can be separated from the building roof.

Pumps which force the water to circulate through the system.

Hot water tank which stores the hot water coming from the solar collectors; the tanks are equipped with insulation to reduce heat loss. It is recommended to have a storage capacity per unit of area of the collector surface of 200_{+} 300 kJ/m^{2}*^{o}C. This corresponds to a storage unit volume per collector unit area of 0.17_{+} 0.26 m^{3}/m^{2}.

Controller which can be used to control the solar panel pump and to control the safety valve or the recirculation pump in the house heating system. The solar panel pump will work on the principle of temperature difference. The controller starts the pump when ΔT between the water temperature in the solar panel and the temperature in the boiler is higher than H-10 degrees. The pump will run until the temperature detected in the solar panel is lower than in the boiler, set by hysteresis H. The stop of the pump is dependent on the set hysteresis. Starting hysteresis is the difference between the temperature at which the thermostat starts the pump and the temperature at which it stops. The thermostat has a fixed hysteresis. For example, if the set temperature is 50°C, the pump will start when the temperature detected by the sensor exceeds the set temperature, and will stop when the detected temperature drops below 48°C.

This ensures that stored water always gains heat when the pump operates and prevents the pump from excessive cycling on and off.

Solar collectors system for house heating

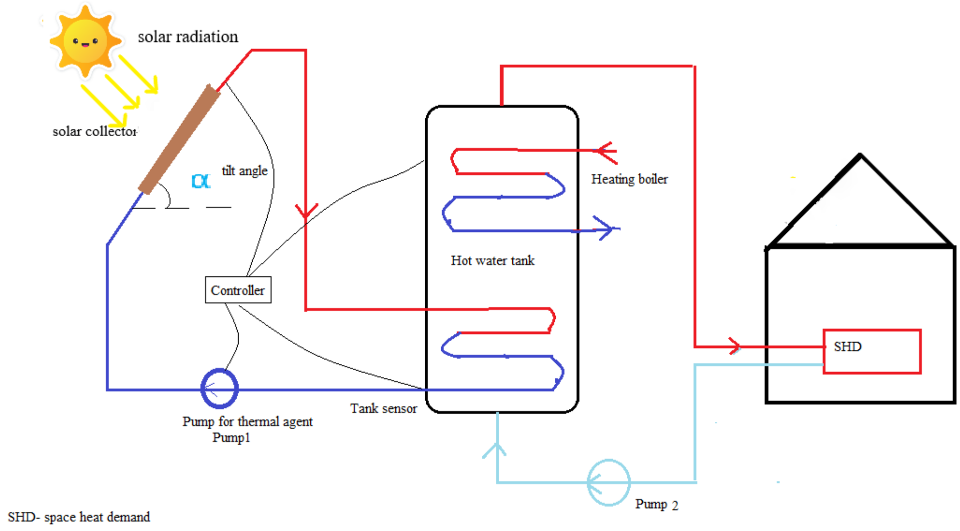


Fig.2.18. Schematic diagram scheme for solar heating system

The scheme consists of 3 distinct areas: the first area - the section for capturing solar energy and delivering thermal energy to the agent in the consumer's installation, the second area - the classic section for preparing the thermal agent and delivering thermal energy to the consumer's thermal agent and the third zone - the consumer section containing the thermal agent used in the consumer's installation.

System with solar collectors for heating and domestic hot water for a house

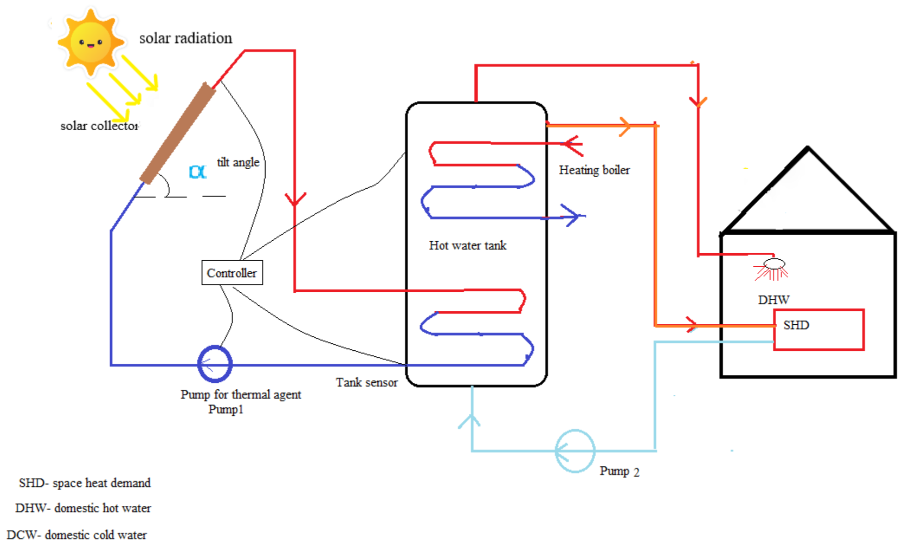


Fig. 2.19. Schematic diagram for heating and domestic hot water

The system is a combination of the 2 schemes presented above.

A very interesting system is the system that uses solar collectors to air condition homes. Air conditioning is required during the warm season to ensure indoor comfort. This is done with the help of absorption refrigeration machines in which water is prepared at low temperature (approximately 7 oC). The cold water is circulated in the fan coil units in the house. It is prepared in the evaporator of the refrigerated machine with absorption by using in the evaporator of the machine a thermal agent prepared by the solar installation in combination with a thermal power plant, [21].

2.4. SOLAR POWER

Solar power is the conversion of the sunlight into electricity (the photoelectric conversion). This conversion can take place indirectly using concentrated solar power, directly using photovoltaic panels or combination. Concentrated solar power systems use lenses or mirrors and solar tracking systems to focus a large area of sunlight into a small beam. Photovoltaic cells convert light into an electric current using the photovoltaic effect, [22].

Photovoltaic panels are widely used and can be used successfully in rural areas for the production of electricity for buildings or for various applications in agriculture and animal farms.

Obs. Agrivoltaic (agriculture – photovoltaic) is a new term, used for the first time by Adolf Goetzberger and Armin Zastrow in 1981 and established in vocabulary in 2011. This word means co-developing the same area of land for both photovoltaic power as well as for agriculture. This combination is made to maximize the land use. There are a lot of papers and studies that treat this topic and there are also areas in different parts of the world where agrivoltaic systems are made. Different crops and geographical areas should be explored to establish the agrivoltaic farming potential around the globe.

Fig.2.20. Agrivoltaic beekeeping project in Spain, [22] Image from Enel Green Power

The example is presented in [22] is an interesting pilot crop cultivation project between the solar panels in Los Naranjos and Las Corchas (two PV plants, 50 MW each) where it is expected that the crops will jump in productivity due to the bees.

2.4.1. Photovoltaic cell – operation principle

The word ***photovoltaic*** consists of the Greek word for light and the name of the physicist Allesandro Volta. This word refers to the direct transformation of sunlight into electricity through solar cells. Solar cells are the main components of a photovoltaic panel system.

The direct conversion of solar energy into electricity is achieved with the help of semiconductor materials, through the photovoltaic effect. This effect occurs in the photovoltaic cell, which is a device that has as its initial material for manufacture, usually crystalline or polycrystalline silicon. These semiconductor cells are sometimes called wafers.

The cell consists of two or more semiconductor layers between 0.001 and 0.2 mm thick, doped with certain chemical elements to form "p" and "n" junctions. Doping of a semiconductor material represents the introduction of excess loads into the structure of the material, in order to improve the conductivity of the material. In the pure state, called "intrinsic", silicon is not photoconductive, according to Fig. 2.21a. Being doped with phosphorus (5 electrons on the outer layer), an excess of negative charges will occur. The material will be a potential "donor" of electrons, available for electrical conduction. This type of material is "n" type silicon, according to Fig. 2.21b. Silicon can be doped with boron (3 electrons on the outer layer), causing a surplus of "gaps", respectively positive charges. The material will be a potential "acceptor" of electrons. This type of material is "p" type silicon, according to Fig. 2.21c..

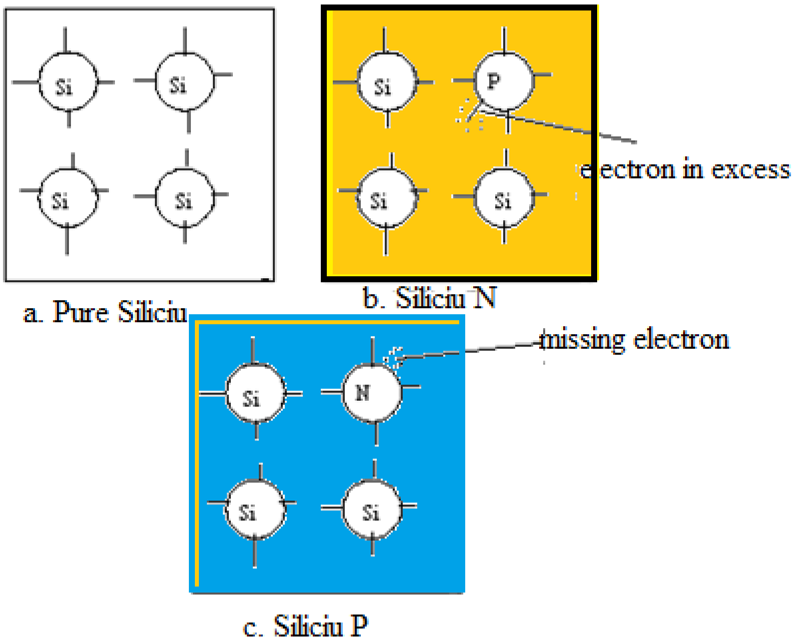


Fig.2.21. The schematic of Siliciu atom (4 electrons on the outer layer)

The structure of the PV cell is similar to that of a diode. When the silicon layer is exposed to light, an "agitation" of the electrons in the material will occur and an electric current will be generated. Fig. 2.22 shows a simplified diagram of a photovoltaic cell.

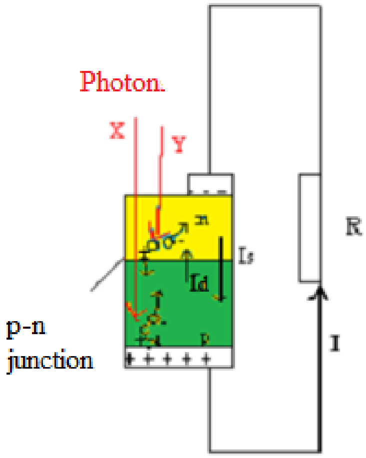


Fig. 2.22. Simplified diagram of a photovoltaic cell

This cell is based on a p-type semiconductor. The cell is exposed to incident radiation that can be approximated by a photon flux with the energy:

$$E_f = h \times \nu \, , \qquad (2.4)$$

Where:

h- Planck constant; h=6.62607015×10^{-34} J·s

v - photon's frequency.

As a result of the interaction of a photon with an atom, if the photon energy is greater than the energy of the forbidden semiconductor energy band, the electron in the valence band will move in the conduction band and become free. At the same time, a hole is generated in the valence band. So the action of photons leads to the generation of electron-hole pairs, producing the inner photovoltaic effect [1]. Fig 2.22 shows that the X photon which has a lower frequency, so a lower energy also, penetrates deeper into the material than the Y photon which has a higher frequency and energy. The free charge carriers are separated by the electric field of the p-n junction. The electrons are separated towards the n zone, and the holes towards the p zone. Thus, under the influence of light, the p zone charges positively and the n zone negatively, which leads to the appearance of an electric current through the external circuit, determined by the photovoltaic radiation conversion process of solar radiation. A voltage drop *V* appears on the resistor *R*, connected to the grid contact shown in fig. 2.22. The voltage drop *V*, in relation to the junction p-n, acts in direct direction and will determine by junction the current of the diode *Id* which has opposite direction to the current *Is*.

The current flowing the diode is determined by the relation:

$$I_d = I_O \times \left[exp\left(\frac{e \times V}{n \times k \times T}\right) - 1\right], \qquad (2.5)$$

Where:

I_o- reverse saturation current, in A

e- electron charge;

V- the voltage across the device, in V

k- Boltzmann's constant, $k=1{,}38\times10^{-23}$ J*K^{-1}

T- the absolute device temperature, in K

n –the the diode ideality factor; it reflects the deviation of a real diode from the ideal model and can take values between 1 and 2; 1 for an ideal diode, dimensionless.

The net flow of current is calculated with next relation:

$$I = I_s - I_d = I_s - I_O \times \left[exp\left(\frac{e\times V}{n\times k\times T}\right) - 1\right]. \quad (2.6)$$

Where: I_s – the short-circuit photocurrent, in A. I_s is proportional with the intensity of the incident illumination.

An ideal photovoltaic cell is electrically equivalent to a current source and a diode connected in parallel (fig.2.23a). In reality, the situation is like in fig.2.23b, with a shunt resistance Ri and a series component resistance Rs added to the model circuit. For the simplified calculation, the diagram 2.23 a can be used with enough accuracy.

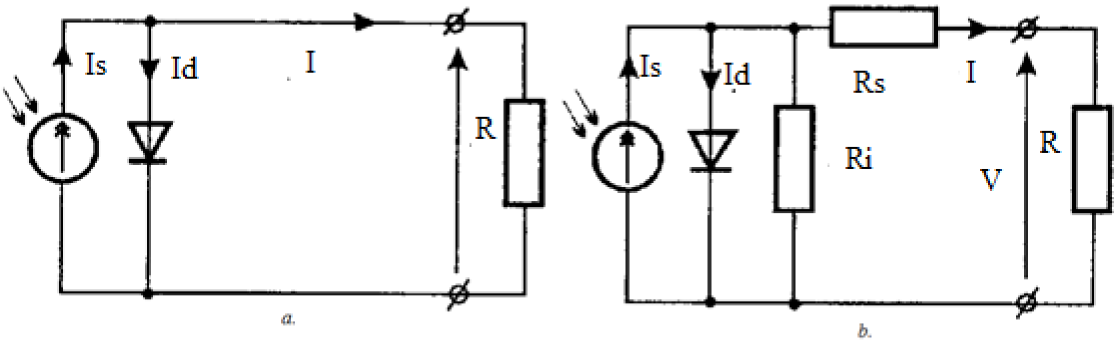


Fig.2.23. The electrically equivalent diagrams of the photovoltaic cell

a. simplified diagram, b, complete diagram [24].

The electrical power given to the load of the photovoltaic cell,,R is expresed in the next formula:

$$P = V \times I = V \times (I_s - I_O \times \left[exp\left(\frac{e\times V}{n\times k\times T}\right) - 1\right]) . \quad (2.7)$$

The maximum value of this power is obtained in a point M of the current-voltage characteristic, setting the condition *dP / dV = 0.* Point M is called Maximum Power Point (MPP).

The voltage at the maximum power point:

$$V_{MPP} = V_{oc} - V_T \ln\left(1 + \frac{V_{oc}}{V_T}\right), \text{[V]} \quad (2.8)$$

Where V_T=*nkT/e* – thermal voltage.

The current at the maximum power point:

$$I_{MPP} = I_s\left(1 + \frac{I_o}{I_s}\right)\frac{V_{MPP}}{V_{MPP}+V_T}, \text{[A]} \quad (2.9)$$

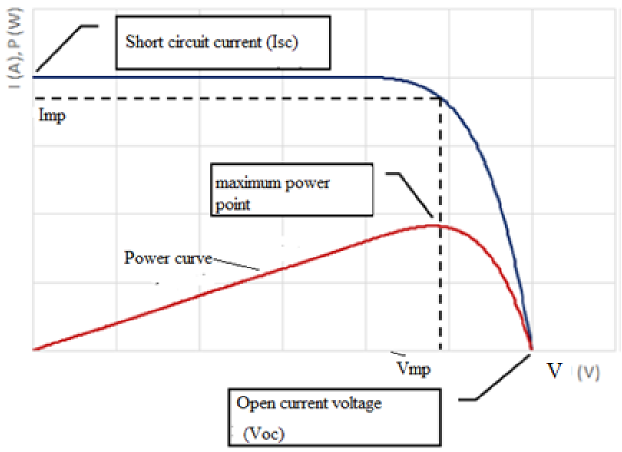


Fig. 2.24. The characteristics of the cell

2.4.2. Photovoltaic cell parameters

The short-circuit current of a cell is obtained by short-circuiting the load terminals R in figure 2.23. On the characteristic in fig. 2.23 a, this is the point for which *V = 0* and *I = Isc*. In this case, the power supplied is 0.

The open current voltage corresponds to the characteristic point V_o = *V* and *I = 0*. The open current voltage:

$$V_0 = \frac{n \times k \times T}{e} ln \frac{I_S + I_O}{I_O} \quad (2.10)$$

The peak power is the product between current and voltage at point M. For the standard test conditions (STC), the peak power is the maximum electrical power that it can generate. The cell generate peak power only few hours each year.

Obs. The standard test conditions are next :

- *Solar irradiance 1000 W/m^2:*
- *-airmass AM=1.5;*
- *Temperature of the cell 25^{0}C.*

These conditions aren't really conditions, because, for in real life the cell temperature is much higher than 25 ^{o}C.

The fill factor *FF* shows a measure of cell quality and shows how close the real characteristic is to the ideal one. The lower the internal resistance Rs, the higher the *FF*. The fill factor is calculated as a ratio between the maximum power of a photovoltaic cell to the product of V_{oc} and $I_{sc.}$

$$FF = \frac{V_{MPP} \times I_{MPP}}{V_0 \times I_{sc}} < 1 \qquad (2.11)$$

The efficiency of the cell η is determined as the ratio between the power generated by the cell at the optimum operating point M (maximum power) at a specified temperature and the solar radiation power.

$$\eta = \frac{P_{max}}{A \times G} = \frac{V_0 \times I_{sc} \times FF}{A \times G} \qquad (2.12)$$

Where: P_{max} , in W, is calculated for the standard test conditions (STC),

A, in m^2, is area of the solar cell,

G, in W/m^2, incident radiation flux.

The efficiency of a solar cell is generally quite low, of the order of 10-20%. Better efficiencies have been obtained with new materials (in the laboratory, AsGa gallium arsenide offers an efficiency higher than 25%), with experimental technologies (multilayer technology), often difficult and expensive to put into practice. Under these conditions, the most used photoelectric material is silicon, which represents an economical solution. For such cells, the energy efficiency does not exceed 15%.

Example: For standard test conditions, a cell with η=20% =0,2 and an area A=100 cm^2 =10^{-2} m^2 will be able to produce:

$$P_{max} = 1000 \times 10^{-2} \times 0.2 = 2\,W$$

Conversely, if this cell would operate in a zone with good climatic conditions, when the irradiance can exceed G=1400 W / m^2, the maximum product power calculated with the same ratios would be at least 2.8 W, so at least 40%.

Fig. 2.25 shows the efficiency of photovoltaic cells depending on the manufacturing technology.

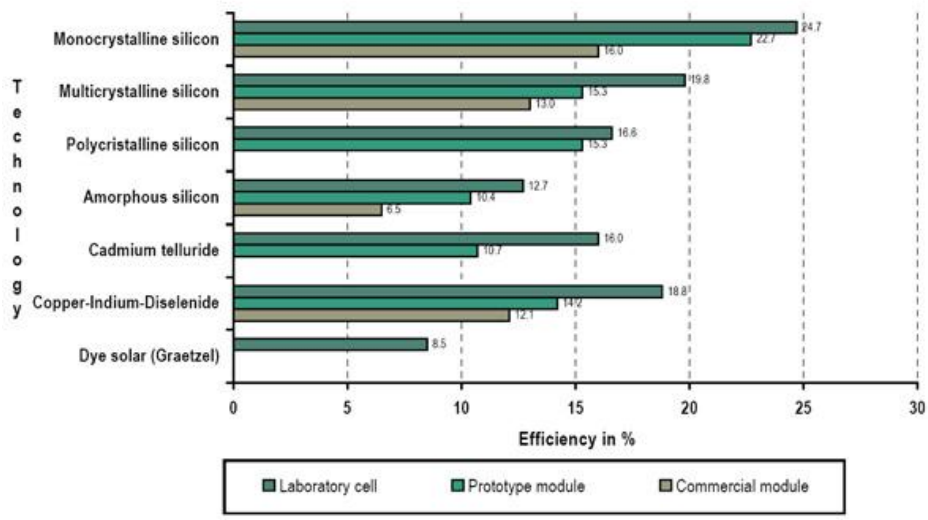


Fig.2.25. Efficiency of photovoltaic cells depending on the manufacturing technology.

2.4.3. The connecting of photovoltaic cells

These connections must be made in compliance with certain precise criteria, taking into account the imbalance that is created during operation in a photocells network. Practically, even if the numerous cells that form a generator are theoretically identical, due to the inevitable dispersions of manufacturing, they have different characteristics. In the same time, the illumination and temperature of the cells is not the same for all the cells in the network. For these reasons, measures must be taken to avoid cell damage (protection diodes).

The series connecting of the cells causes the voltage at the terminals of the assembly to be higher, the current being the same in all the cells.

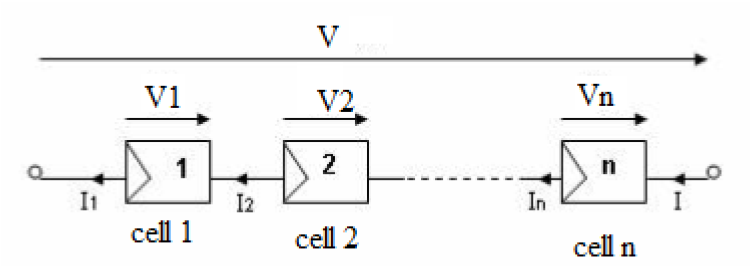


Fig.2.26. The series connected photovoltaic cells

$$V=V1+V2+....+Vn \text{ , [V]}$$

$$I=I1=I2=....=In \text{, [A]}$$

The main disadvantage of series connecting is: if one cell failed, all the cells which are in series with the damaged cell will not produce energy. To avoid electrical damage to the cells, so-called "bypass diodes" are connected in parallel with each PV cell, one bypass diode for each solar cell,[25].
The parallel connection increases the flow current, the voltage at the terminals of the assembly being the same.

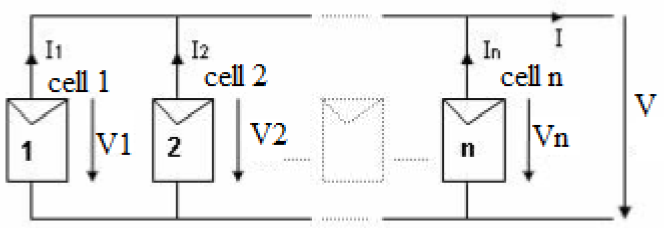


Fig. 2.27. The parallel connected photovoltaic cells

$$V=V1=V2=....=Vn \text{ , [V]}$$

$$I=I1+I2+....+In \text{, [A]}$$

According to [25], the preferred photovoltaic panel for most solar charging applications is a 36 cell module which delivers about 21V open circuit voltage assuming a peak cell voltage of 0.58 V reducing down to about 16.5 V under full load conditions.
.

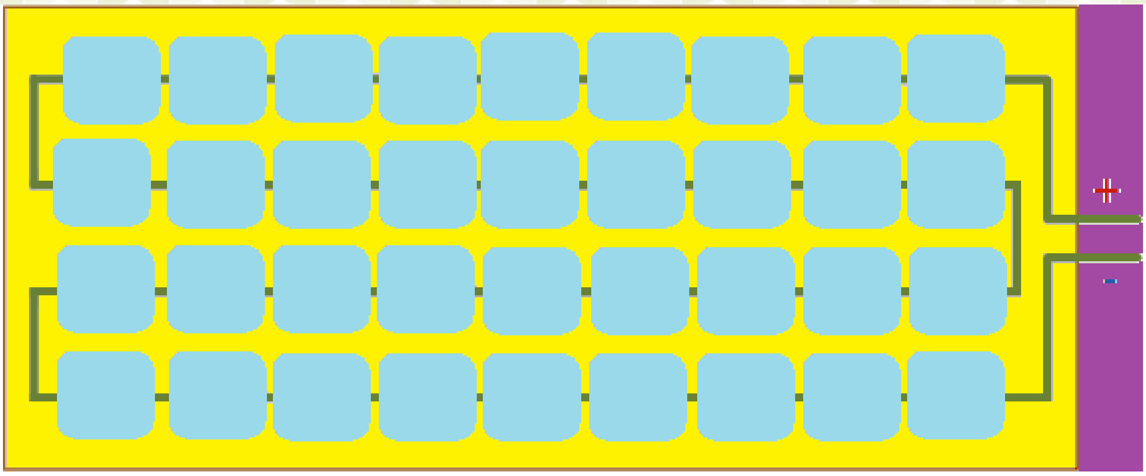


Fig.2.28. 36 Cells Photovoltaic Panel, [25]

Methods of installing photovoltaic panels

There are mainly two types of installation of photovoltaic panels:
-on a building, where the modules can be integrated replacing certain elements of the construction, or not integrated by overlapping them on the facade or roof.
- structured in solar plant consisting of the panels and a moving part mounted on a tracker for each panel. The tracker is a device that allows the orientation of the panels according to the direction of the sun's rays
Depending on the location of the solar panels we can highlight advantages and disadvantages for each situation.
The photovoltaic systems range from small systems, mounted on the roof or integrated in buildings, with capacities from a few to a few tens of kW, to large utility power plants of hundreds of MW.

2.4.4. Some examples of PV panels systems for rural area

The photovoltaic system is composed of the photovoltaic generator (photovoltaic panels) and of several other components that work together. In order to compensate the dependence of the electricity generation on the level of the solar radiation, in most cases a means of storing the electricity is required, respectively on a battery. Proper operation requires the existence of a load control block. Adapting the electrical and consumer parameters to those of the photovoltaic generator requires either a DC-DC converter, or a DC-AC inverter, or both. In some situation the photovoltaic generator is doubled by alternative resources. In this situations, the PV system is called hybrid PV system.

The photovoltaic systems are divided into two large groups:

- Off-grid PV systems or stand-alone PV systems;
- On-grid PV systems or grid-connected PV systems.

2.4.4.1. Off-grid PV systems

Off-grid PV systems are autonomous systems ("stand-alone"). These systems feed consumers which are not connected to the main electrical grid. These systems are used in areas without electricity (small rural areas) and can generate the power and run the appliances by themselves.

In principle, the energy produced by the PV panels is stored in the batteries, and from there it is provided with the help of an inverter DC-AC, to household users at 220 V. (Fig.2.29).

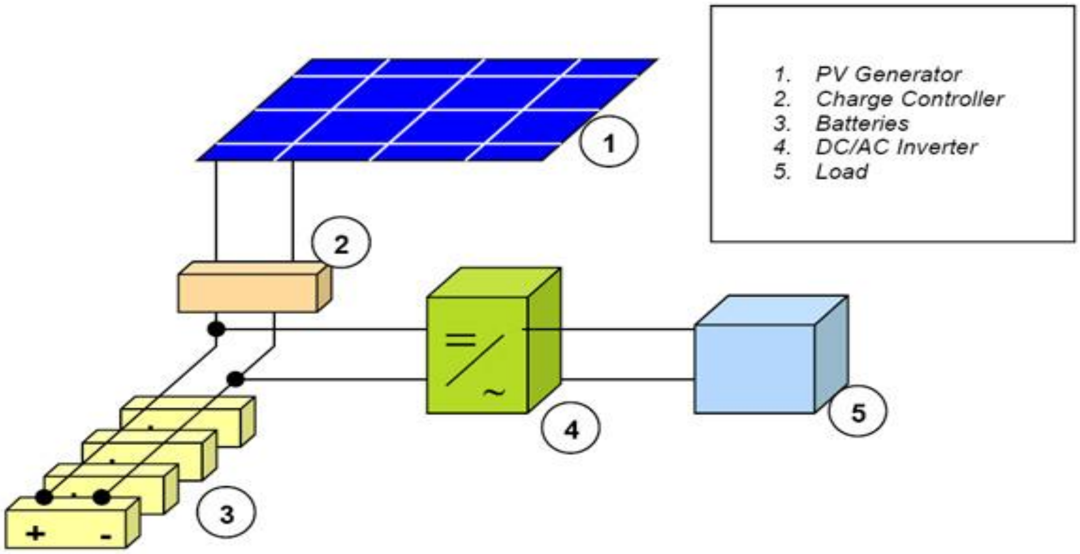


Fig.2.29. Off-grid PV system

A very simple type of this system is the PV water pumping system without batteries, [26]. The water tank serves as a battery and has no DC-AC converters.

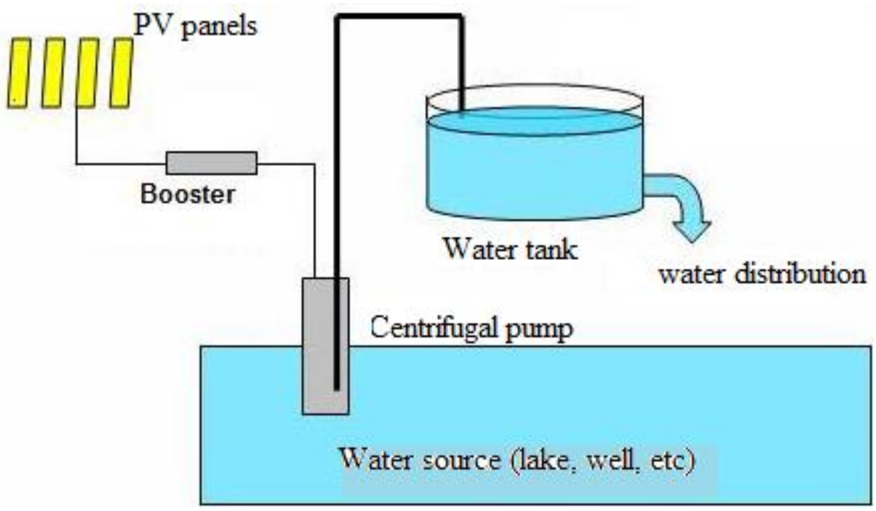


Fig.2.30. PV water pumping system without batteries

As a general rule, autonomous PV systems are installed where they represent the most economical source of electricity. You can always opt, for environmental reasons, or to ensure a more reliable system without network connection, for a hybrid system.

2.4.4.2. On-grid PV systems

The on-grid PV systems or grid-connected PV systems are used in areas with electricity. In principle, the energy produced by solar panels is delivered in the national grid and at the same time used for home applications.

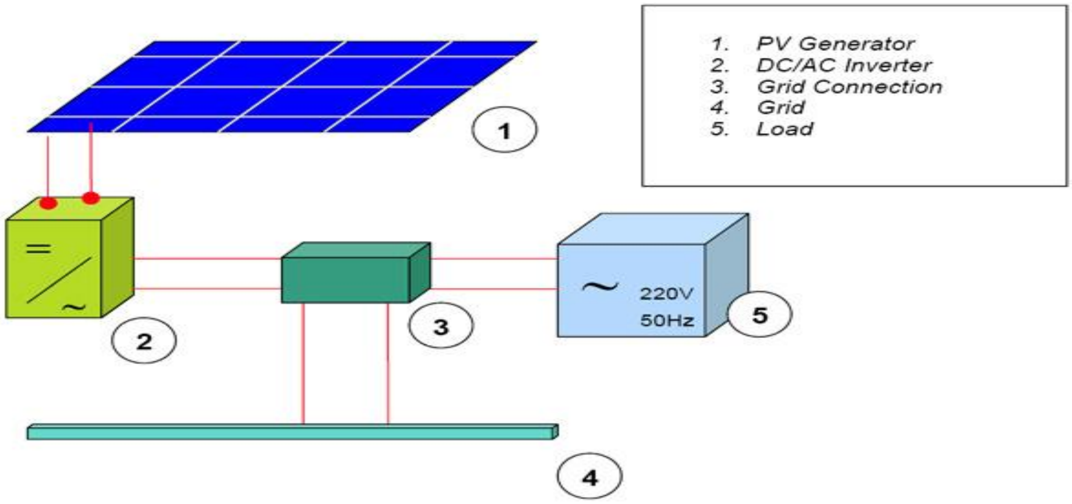


Fig.2.31. On-grid PV system

On-grid PV systems for residential applications (houses, buildings) do not require a batery system. The house or buiding can use the produced energy in such a system for their energy needs and if in the cloudy days or in night there is not enough solar energy, they can take energy from national grid.

On-grid PV systems are the result of the trend of decentralization of electricity networks. Energy is produced closer to where it is consumed and not only in large thermal power plants or hydropower plants. Over time, connected systems will reduce the need to increase the capacity of transmission and distribution lines. A system connected to the grid provides the local need for electricity, and the eventual surplus charges it in the grid.

In some urban regions with warm climates, the cost of kWh of electricity produced by grid-connected PV systems is comparable to that produced by other "classical" methods. In regions with low solar radiation, this type of system is less interesting. There is some potential in the market for grid-connected residential PV systems, but their price must continue to fall in order to become economically competitive with the "classic" distribution of energy, relatively cheap and available, [27].

2.4.4.3. Hybrid systems

Hybrid systems, which are independent of the electrical distribution network, consist of a photoelectric generator, associated with a wind turbine or generator set with an internal combustion engine, or both. Biogas is also used. Such a system is useful for applications that require continuous power supply with relatively high power, if there is not enough light during certain periods of the year or to reduce investment in photoelectric modules and batteries' accumulators. Hybrid systems are most common on islands. Pellworm Island in Germany and Kythnos Island in Greece are notable examples (both are combined with wind).

The PVT (hybrid PV / T) system, also known as photovoltaic solar thermal collectors, converts solar radiation into thermal and electrical energy. Such a system combines a solar module (PV) with a solar thermal collector in a complementary way.

Fig.2.32. shows the hybrid system from campus of Vasile Alecsandri University of Bacau, [27] .

Fig.2.32. Hybrid system from campus of Vasile Alecsandri University of Bacau

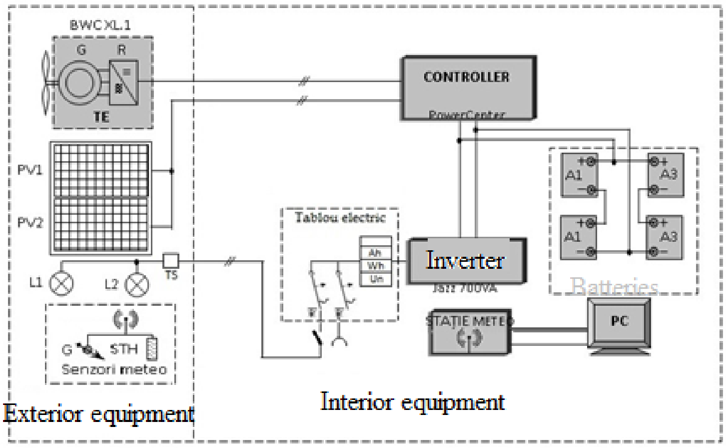


Fig.2.33. The diagram of the Vasile Alecsandri University of Bacau hybrid system , [27]

3.WIND ENERGY

3.1. Wind energy in rural area. Wind map

Wind can be defined as the movement of air masses from the Earth's atmosphere, generated by differences of pressure between two areas of the globe (baric gradient). These differences are determinated by the uneven heating due to solar radiation and to Earth's rotation. When the air is heated, the warmer air rises faster because a volume of hot air is lighter than an equal volume of cold air. Hot air particles have a higher pressure than colder particles, therefore, it takes fewer particles to maintain the same air pressure. When warm air rises, cold air flows into the spaces that hot air leaves behind it, and the air that rushes to fill the gap is called wind. The wind presses on any object that lies in its path, and in the process, energy transfers occur to the object which was in the path of wind. This is how wind turbines produce energy, [28].

Wind energy is the most rapidly expanding source of energy in the world today, [28]. The main advantages of wind power are:

- Lack of pollutant emissions and greenhouse gases,

- Does not require any combustion process to obtain this form of energy;

- Does not involve the generation of waste;

The cost per unit of energy (€/MWh) produced with this technology has declined substantially in recent years, making it competitive with traditional generators in most of the electricity markets worldwide.

The principal characteristic wind sizes are:

- the wind intensity and the wind speed variation in time;

- The variation in wind speed with altitude;

- the wind direction.

The wind intensity in meteorology is measured by a scale of speeds. The ranges are identify by the effects on the environment (smoke, leaves, etc.).

The variation in wind speed with altitude refers to the profile of the wind speed in the boundary layer land.

Terrestrial boundary layer is the layer of air that manifest the influence of the Earth surface on the wind speeds field. This influence is one of the friction, the layer of soil having zero velocity. The wind velocity profile in the boundary layer depends on the topography and roughness of the terrestrial land.

The wind direction is determined by the part of the horizon from which the wind blow, the obtained information indicating the repetition of the wind in a certain time (usually average meteorological year) after cardinal directions, plotted in the form of so-called wind rose, shown in fig. 3.1.

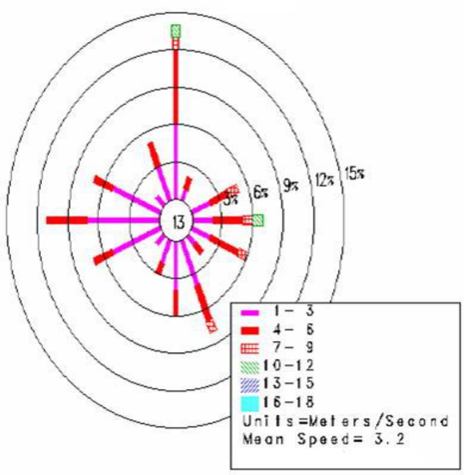
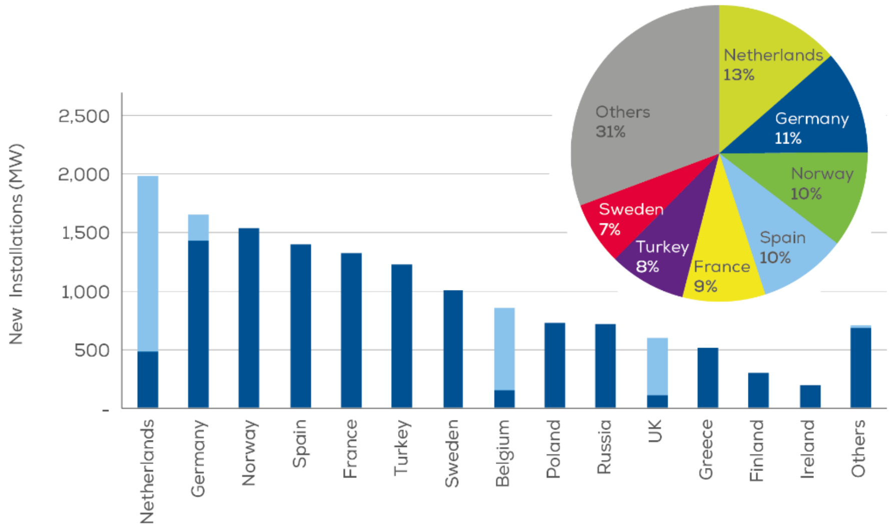


Fig. 3.1. Example of the wind rose diagram, [28]

In Europe was installed 14.7 GW of new wind capacity in 2020. This is 6% decrease compared with 2019, because of the pandemic situation. 10.5 GW of new installations were in the EU,

[29]. Wind farms on the continent (onshore farms) accounted for 80% of new installations with 11.8GW.



	Netherlands	Germany	Norway	Spain	France	Turkey	Sweden	Belgium	Poland	Russia	UK	Greece	Finland	Ireland	Others
Offshore	1,493	219	-	-	-	-	-	706	-	-	483	-	-	-	17
Onshore	486	1,431	1,532	1,400	1,318	1,224	1,007	152	731	713	115	517	302	196	688
Total	1,979	1,650	1,532	1,400	1,318	1,224	1,007	858	731	713	598	517	302	196	705

Fig.3.2. New wind installations in Europe in 2020, [29]

The wind map from Fig. 3.3 highlights the wind speed at a height of 50 m in Europe. It is observed that Spain, Italy and Greece have some areas with important wind potential.

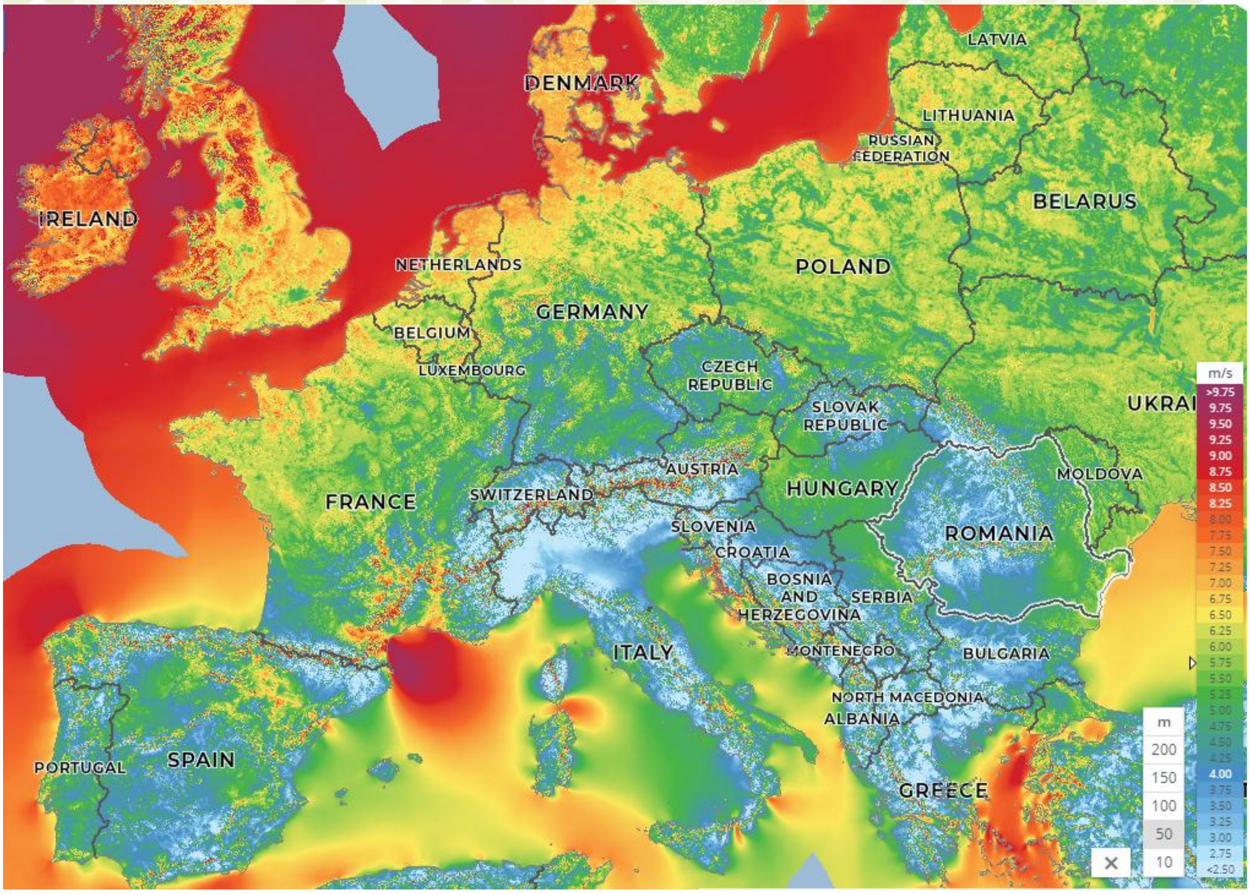


Fig.3.3. The wind map for Europe at a height of 50 m, [30]

This kind of map should be used for information, because every individual sites has a different wind potential and varies greatly from case to case occurring turbulence due to terrain, buildings, forests, vegetation around, even if they are in the distance.
In rural environment are two possible types of wind installations, mainly:

1. The development of wind farms, which can be connected to the network and which can provide electricity for a community made up of several families

2. A small wind turbine that would provide energy needs for a home. This can be combined with other energy producing systems.

In the first case, the investment is very high and difficult to support by rural community, even when using European funds. Policy to promote renewable energy sources varies from country to country, taking into consideration that there are different national action plans in the field of energy production from renewable sources. [28].

For rural area, very important are decentralized applications of wind energy conversion (each household should have its own turbine, possibly combined with solar and / or a biogas system).

3.2. Types of small wind turbines

A system with a small wind turbine can be used in a highly efficient mode in rural areas without electricity, or when electricity saving is desired.

Heating water is another application of small wind turbines. The most flexible electricity production is based on the use of heaters and temperature sensors (this kind of electricity production is independent of the relation between energy production and use, [28]).

The small wind turbines are constructed today in various embodiments. They can have a horizontal axis with the rotor upstream or downstream of the wind direction, with two, three or more blades, or they can have a vertical axis. These turbines can be with electronic or mechanical safety systems against over-wind.

In this subchapter there are going to be given examples of several types of small vertical axis turbines, putting afterwards emphasis on small horizontal axis turbines.

Small vertical axis turbines (VAWT – ”vertical-axis wind turbine”)

a. The Marilyn Wind Turbine presented in fig. 3.4 is a vertical axle, helix type, omnidirectional foil. The turbine from the picture has a nominal power of 1200 W, at a wind speed of 11m/s. The turbine's main rotor is a (2m diameter x 2m high) fiberglass construction which incorporates three helix mono-block surfaces, [32]. The rotor movement begins at a wind speed of approximately 1.4 m/s, and at high wind speeds of more than 20 m/s. Its geometrical construction provides a hydraulic self-braking mechanism.

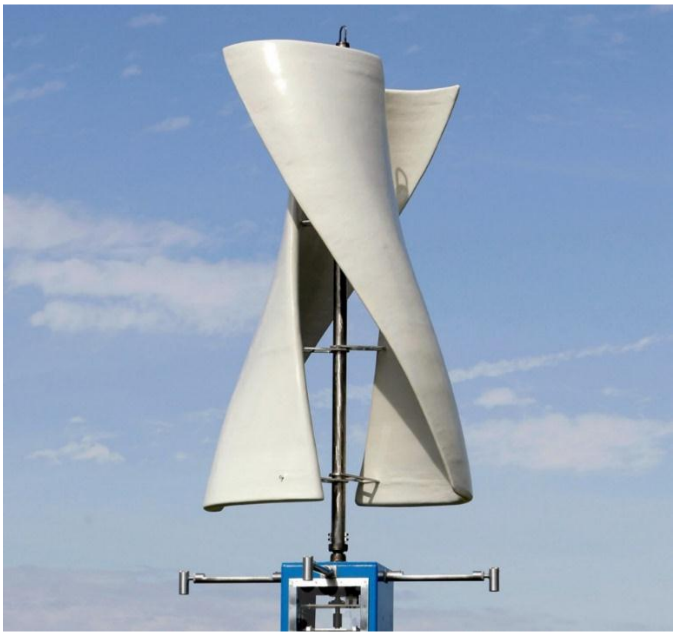


Fig. 3.4. Marylin model wind turbine

b. The Darrieus wind turbine uses lift forces generated by the wind hitting airfoils to create rotation. Its great disadvantage is that it is not self-starting. Therefore a small powered motor is required to start off the rotation, and then when it has enough speed, the wind passing across the airfoils starts to generate torque and the rotor is driven around by the wind.

c. The Lentz turbine. This turbine has blades type "cup", which ensures high efficiency at low wind speeds, reliability and low noise.

Fig. 3.4. Lenz model wind turbine.

Source: http://www.palebludot.com/2008/01/08/ed-lenzs-wind-turbine-powered-home/

d. Savonius wind turbine. The power from the Savonius turbine design is based on the difference in air pressure across the blades as one set of blades retreat from the wind and the other set of blades advance into the wind. This is in turn related to the difference in the drag coefficients associated with the convex side of the blade and the concave side of the blades. Generally, compared to other forms of wind turbine designs, the Savonius rotors has fairly low efficiencies, [5]. This type of turbine can be used to generate electricity in strong windy conditions and also for pumping water, and grinding grain for which are desired slow rotation and high torque.

Fig.3.5. Savonius wind turbine.

Source: http://www.reuk.co.uk/Savonius-Wind-Turbines.htm

There are combinations of these types of turbines. In fig. 3.6 is shown a Darrieus-Savonius turbine. This type of wind turbine combines two types of blades, the S-shaped Savonius and the curved Darrieus arerofoil. Whereas the Savonius-blades are drag-driven, the Darrieus-blades will experience a lifting force when the wind is blowing across the turbine. Since a pure

Darrieus Wind Turbine is (mostly) not able to start without an initial net rotational force, the Savonius-Vanes are added to make the turbine self-starting.

Fig. 3.6. Darrieus- Savonoius wind turbine. Source: http://www.alternative-energy-tutorials.com/energy-articles/vertical-axis-wind-turbine-design.html

Another interesting model is the combined wind turbine Darrieus-Maglev. This kind of turbine uses the advantages of Darrieus turbine with those of magnetic levitation turbine.

Small horizontal axis turbines (HAWT – ”horizontal-axis wind turbine”)

The majority of the marketed turbines are with horizontal axis. The rotation axis of the turbine coincides with the wind direction and is parallel to the soil surface. Based on the principle of the mills, rotor shaft is positioned horizontally. This type of turbine is currently the most widely used and available in several variants. Horizontal axis turbines in their aerodynamic efficiency is superior to the vertical axis and are less subject to mechanical stresses. Manufacturers of such equipment showing greater interest in this model because they have a lower cost. An important advantage of this type of turbine: it is characterized by a power coefficient Cp with values close to the limit of Betz, who according to his theory even for the most powerful turbine is maximum 0.593.

In the literature, **a classification of horizontal wind turbines** has been carried out on the basis of various criteria:

- Depending on the number of bladed, the horizontal axis generators can be grouped into two broad categories, namely:

- Quick turbines, which can have 1-3 blades;

- Slow turbines, which have multiple blades, their number can be from 3-18.

- after the placement of the blade:

a. placed blade against the wind - "upwind" (first encounters wind blades and nacelle then), Fig. 3.7 a; b. located downwind paddle - "downwind" (wind meets first nacelle and blades and then fig. 3.7.b;

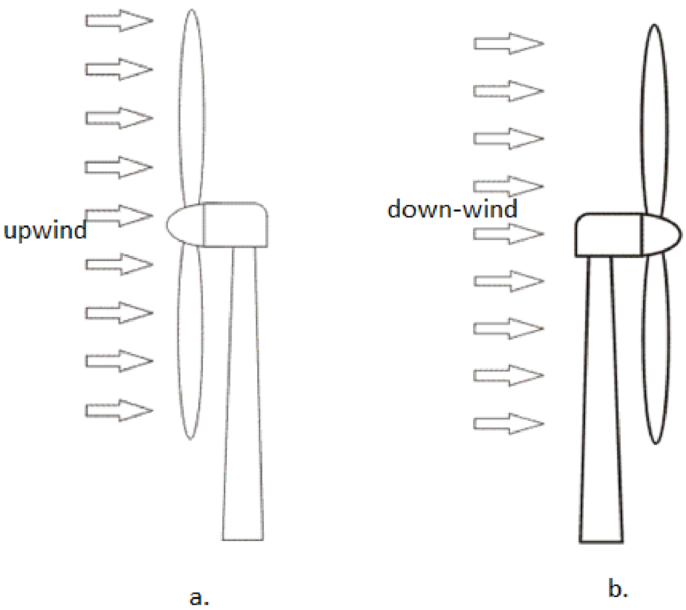


Fig.3.7. The location of the turbine blades relative to the direction of the wind:

a. upwind turbine, b. downwind turbine

- depending on the equipment used in the conversion process:

- with speed multiplier (gearbox), equipment that connects the hub of the wind turbine and electric generator;

- without speed multiplier, the hub of the turbine shaft is coupled directly to the generator

Fig. 3.8. Wind turbine with 2 blades.

Source: https://www.youtube.com/watch?v=5ttQQSH8jV4

In fig. 3.9 it is shown a popular wind turbine used for rural area, REDriven 3 kW, with three blades. The cut-in speed is 2 m/s and the cut-out speed is 18 m/s. The rated power output is 3 kW and it is realized at a rated wind speed of 10 m/s, [33].

Fig. 3.9. REDriven 3 KW wind turbine with three blades,

Source: http://www.roanokecountyva.gov/DocumentCenter/Home/View/2018

Fig. 3.10. Wind turbines with many blades (six and eleven blades)

As the turbine has more blades, the surface area which is swept by the rotor, increases. As a turbine has more blades, the turbine rotation speed is smaller and the developed torque will be higher and vice versa. Because of this, the turbines with fewer blades are used to generate electricity, while those with more blades are used for pumping water or for different equipment that require low speed rotation and high torque at startup, [34]. Nowadays, the most used wind turbines have three blades. This is due to the power coefficient. The power coefficient describes the efficiency of producing electricity from wind. This coefficient is not constant; it varies depending on the type of machine and the wind speed. Fig. 3.11. shows that the wind turbine with three blades has the highest power coefficient followed by the turbine with two blades,[28].

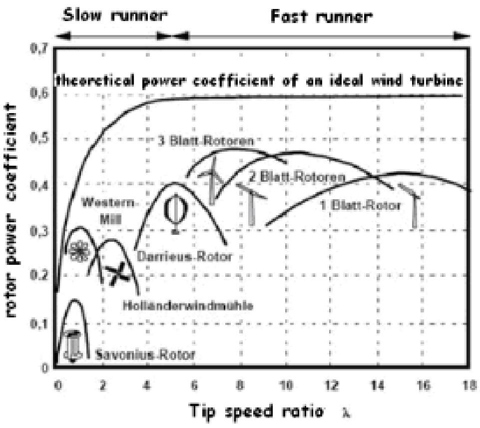


Fig. 3.11. The variation of power coefficient with tip speed ratio and wind turbine type.

Source: http://amet.ro/documents/Studiu_Energii_Regenerabile_Timis.pdf

Tip speed ratio, λ, is the ratio between the tangential speed of the tip of a blade, *U*, and the actual speed of the wind, *v:*

$$\lambda = \frac{U}{v} = \frac{\omega * R}{v} \quad (3.1)$$

Where *ω* is the rotor rotational speed in radians/second and *R* is the rotor radius in meters.

3.3. Wind energy conversion system with horizontal axis turbine

The construction of the small horizontal axis wind turbine is simpler, like it is shown in fig.3.12.

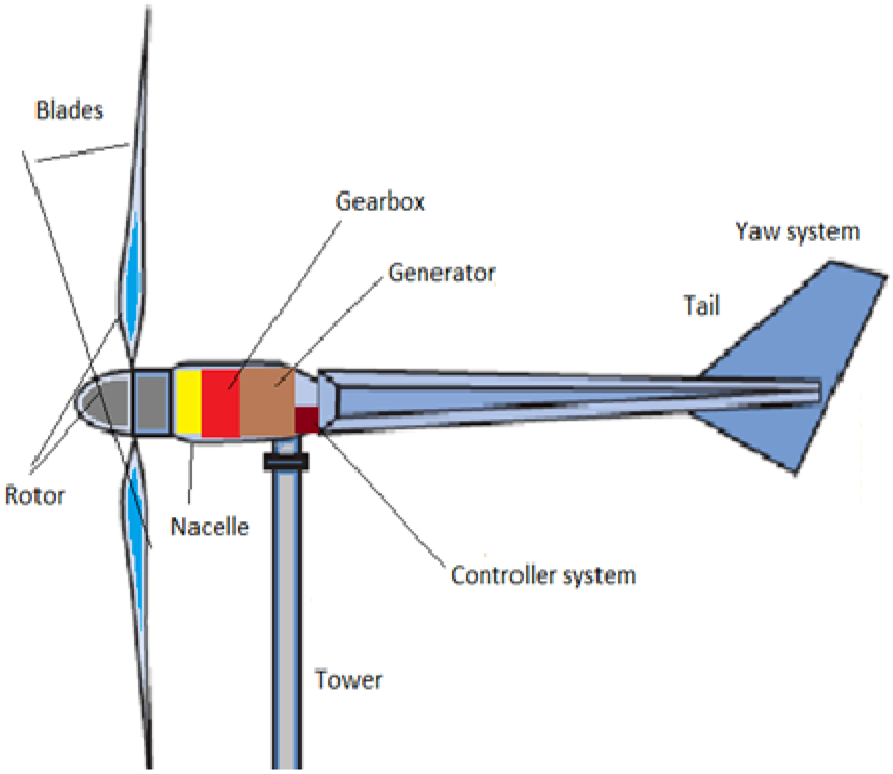


Fig. 3.12. Components of small horizontal axis wind turbine

Table 3..1.The description of components, [28]

No.	Component	Description
1	***Rotor***	The rotor is formed from the main-shaft and its blades. The blades have an aerodynamic shape and are made from composite materials mixed with fiberglass. In a complete rotation, the surface covered by blades determines the generated power. The main shaft is positioned horizontally.
2	***Generator***	The generator is the component which transforms mechanical energy of rotational movement of the propeller turbine into electricity.
3	***Gearbox***	The gearbox is used in small wind turbines with outputs greater than 10 kW. It serves in adjusting the rotation speed of the rotor.
4	***Nacelle***	The nacelle is the housing where are mounted the generator and the gearbox.
5	***Yaw system***	The yaw system assures the orientation of the nacelle to the wind direction. A lot of the small wind turbines have a simple system with tail.
6	***Controller system***	The controller or the electronic control system monitors the overall operation of the turbine. His complexity depends on the type and capacity of wind turbine.
7	***Tower***	The tower supports the guidance system, the nacelle and the rotor of the wind turbine. It is generally made from a metal and its purpose is to support the nacelle. There are two basic types of tower: free standing and guyed. The height of the tower is of a major importance because the higher it is, the greater the wind intensity becomes and so, the turbine will have a better efficiency. But, it has to be taken into account to reach a compromise between the cost of production and the exposure to wind. Generally, the tower height is smaller than the radius of propeller blades.

The design of the wind energy system for areas where it is possible that the national energy system has no coverage, highlights the need of ***storage batteries*** to sustain a minimum consumption for the periods in which the weather conditions are unfavorable for using the wind generator. They have the same role like in the case of use the solar power. So, the function of the batteries is to balance the outgoing electrical requirements with the incoming power supply. They offer a reliable source of electricity which can be used when wind power is not available. Batteries are able to provide short term power output many times higher than the charging source output.

Batteries for photovoltaic systems, wind hybrids are of a special construction regarding the free maintenance and the fact that it supports a large number of charge-discharge cycles.

The most common types of storage batteries in photovoltaic systems, wind systems and hybrid systems are lead-acid batteries. Recently, there have been developed ***Li-Ion*** batteries and nickel - cadmium (***Ni-Cd***) batteries for high capacity.

Lead-acid batteries continue to be the main option for energy storage, having the advantage of price and availability. Besides this, they can release a huge amount of energy in a very short span of time, being able to withstand very high currents. Lead-acid batteries used in photovoltaic systems, wind systems and hybrid systems are encapsulated and sealed. There are valve-regulated lead-acid batteries (***VRLA***).

Gel batteries use sulphuric acid that has been turned into a gel form. Sealed at the factory, they do not leak or spill, so they are easily transported and require no maintenance.

With ***AGM*** (Absorbed Glass Mat) lead-acid batteries, sulphuric liquid acid electrolyte is absorbed into mats fibers glass so they would not leak, even if cracked. Many AGM batteries are designed for stand-by ‘float’ applications, not for deep discharging.

Tubular plate batteries, also called ***OPzS*** (liquid electrolyte) or ***OPzV*** (gel) batteries, are made especially for off-grid applications and have excellent deep discharge characteristics. The positive plates in tubular cells are made of rods protected in a ‘tubular’ sleeve – not a flat plate – which gives them an exceptionally long life cycle.

The correct sizing capacity for a storage battery depends on the load rating chart and the consumer intervals. The lifespan of a pack of batteries is dependent on the depth of discharge and temperature. Depending on the capacity and the type of storage batteries, inverters are selected.

Power inverters transform stored energy from the batteries or from generated energy DC current from the wind turbine at 12, 24 or 48V into alternating current at the necessary voltage and frequency. There are two types of inverters: grid-tie inverters and stand-alone inverters.

In fig. 3.12 it is shown an example of an inverter used for power plants with renewable energy: PV systems, wind turbines and hydro power: Powador 2002-INT inverter 1600 W.

Fig. 3.12. Inverter 1600 W,

Source: http://elec.ro/136-powador-2002-int-invertor-kaco.html

3.4. Calculation elements for energy production by a wind turbine

The energy of a moving air stream to the linear velocity *v* (kinetic energy):

$E = m\frac{v^2}{2}$, [J] (3.2)

Where m – the moving air mass, in kg.

According to fig.3.13, the mass *m* is the product between density ρ and the volume *V* covered by the moving air flow at a distance *x*.

$m=\rho V$, [kg] (3.3)

The volume V is the product between surface *A* of the airflow and distance x.

$V=Ax$, [m^3] (3.4)

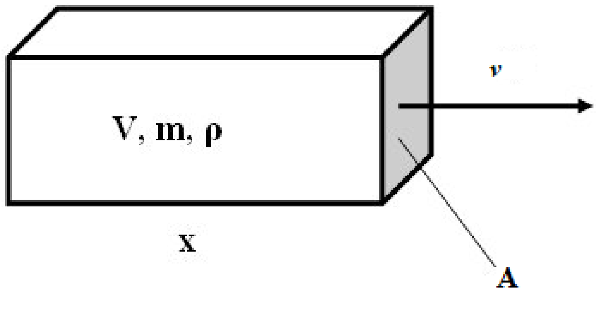


Fig.3.13. The calculation scheme for kinetic energy of wind

The formula (3.2) becomes:

$E = \rho A x \frac{v^2}{2}$, [J] (3.5)

The power that the wind can develop, due to its kinetic energy, in the time interval τ, is calculated with the relation:

$P = \frac{E}{\tau} = \rho A \frac{x}{\tau}\frac{v^2}{2} = \frac{1}{2}\rho A \frac{v^3}{2}$, [W] (3.6)

Ideal situations were considered, without losses and irreversibility, so that the calculated quantities represent the development potential of the mechanical work, the development potential of the kinetic energy, respectively the development potential of a power by the wind.

Ideal situations were considered, without losses and irreversibility, so that the calculated quantities represent the development potential of the mechanical work, the development potential of the kinetic energy, respectively the development potential of a power by the wind.

The German physicist Albert Betz, in 1919, established the law that answers the question: what part of the kinetic energy of an air flow can be transformed into mechanical energy? He set the value of the power coefficient (Betz limit) for which the power developed by the turbine will be maximum Cp=0,593.

The following conclusion can be drawn: the air flow will yield to an ideal turbine no more than 59.3% of its initial power P. In reality, the most efficient wind turbines do not reach this value of the power coefficient Cp=0,593.

The power generated by a wind turbine depends by the wind speed, according to next equation:

$P_t(W) = \frac{1}{2}\, C_p\, \rho\, A\, v^3$, [W] (3.7)

where C_p - the power coefficient,

ρ - the air density $(1{,}225\ \frac{Kg}{m^2})$ at a temperature of 15°C at the sea level and with an atmospheric pressure of 101 325 Pa,

A - the area swept by the rotor in squares meters, m^2

v - is the wind speed in m/s.

Fig. 3.14 shows a typical wind turbine power output (power curve). The wind speed is a decisive parameter that influences the choice of wind turbine, taking into account the influence of wind speed to turbine power curve (fig. 3.14). In choosing of the wind turbine must be taken into account the rated wind speed (12 m/s – figure 1) and by the cut wind speed (3 m/s – fig. 3.14).

Rated output power- this is the wind speed at which the turbine starts to generate the rated power

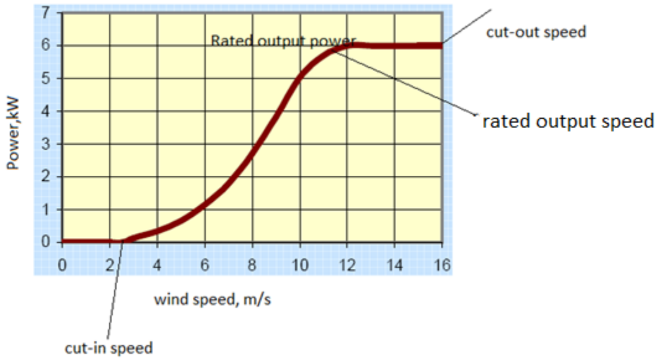


Fig. 3.14.Typical wind turbine power output

Cut-in wind speed - this is the minimum wind speed at which the turbine blades overcome friction and begin to rotate.

Cut-out speed - This is the speed at which the turbine blades are brought to rest to avoid damage from high winds. Not all turbines have a well-defined cut-out speed.

These important parameters are found in specialized data bases. For example, in Romania there is a data base available surcharge from National Meteorological Administration, site: http://www.meteoromania.ro/anm/?page_id=640.

3.5. Small wind electric systems used in rural areas

This section is devoted to introduce some of the applications derived from small wind power installations [28].

3.5.1. Household installations

Fig. 3.15 presents a domestic system of production and use of direct and alternating current using a small wind turbine.

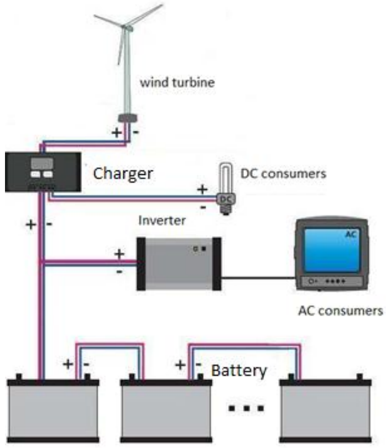


Fig. 3.15. Simple system of using wind energy for a residential house.

Source: www.lpelectric.ro

With this system it is possible to supply with energy both DC and AC loads.

3.5.2. Water-pumping installations

In areas where water is in limited quantities, but there is ground water in depth and wind blows regularly, a wind turbine can be successfully used to pump the water to the surface for further use of it.

The scheme of such a system is shown in Fig.3.16.

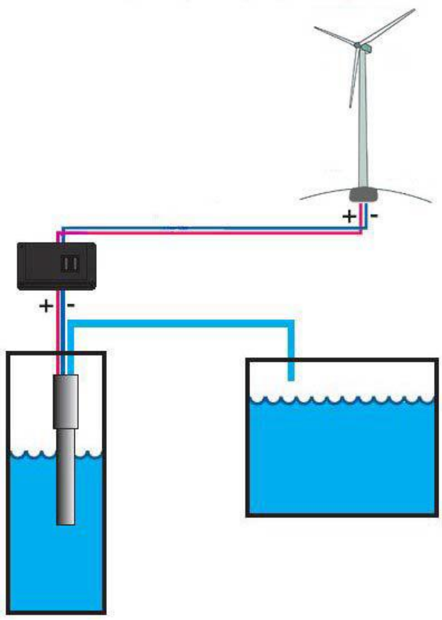


Fig.3.16 Water-pumping windmills.

Source: www.lpelectric.ro

This system is used in agriculture for irrigation in dry areas, pumping water from rivers, etc. Basically, the operation of such a system of water pumping windmill is almost free, except for eventual maintenance costs. The costs of the initial investment (which can solve a number of serious problems caused by water shortages in some regions) must be analyzed in the context of economic and social importance, [9].

4.BIOMASS

Biomass is the biodegradable part of products, waste and residues from agriculture, including plant and animal substances, forestry and related industries, as well as the biodegradable part of industrial and urban waste. From an energetic standpoint, biomass is the most abundant renewable resource on the planet. It includes absolutely all the organic matter produced by the metabolic processes of living organisms. Biomass is the first form of energy used by man, with the discovery of fire.

General data:

-Total mass (including humidity) - over 2,000 billion tons ;
-Total mass of terrestrial plants – 1,800 billion tons;
-Total mass of the forest – 1,600 billion tons;
-The amount of energy accumulated in the terrestrial biomass - 25,000 * 1018 J;
-Annual biomass increase - 400,000 million tons;
-Speed of energy accumulation by terrestrial biomass;3000 * 1018 J per year (95TWt);
- Total annual consumption of all types of energy - 400 * 1018 J per year (22TWt);
- Biomass energy use - 55 * 1018 J per year (1.7TWt).

Biomass burning has been practiced since ancient times, with people using wood as fuel. In terms of the carbon cycle, burning plants is environmentally friendly. Although by burning them, the carbon contained is released into the atmosphere in the form of CO_2, this carbon comes even from the CO_2 in the atmosphere, captured in the process of photosynthesis. So, burning plants is a process of recycling carbon, as opposed to burning fossil fuels, which introduces new amounts of CO_2 into the atmosphere. Biomass contributes 14% to global primary energy consumption, and for three-quarters of the world's population living in developing countries, it is the most important source of energy. Currently, in the EU, 4% of energy needs are provided by biomass. The International Energy Agency estimates that in Europe, oil resources will be depleted in 40 years, natural gas resources in 60 years, and coal resources in 200 years. This means that in about for 20 years, Europe will have to import 70 % of its energy needs. As a result, Union states are forced to make extensive use of renewable energy sources. Biomass is a diversity of elements of plant origin that surround us from nature or elements resulting from human activities, in order to optimize their use. We look at their diversity in nature and to the miraculous power of fast and permanent regeneration.

According to [37], there are five basic categories of material:

- Virgin wood, from forestry, arboricultural activities or from wood processing,
- Energy crops: high yield crops grown specifically for energy applications,
- Agricultural residues: residues from agriculture harvesting or processing,
- Food waste, from food and drink manufacture, preparation and processing, and post-consumer waste
- Industrial waste and co-products from manufacturing and industrial processes.

On the basis of the source of biomass, biomass can be classified into three categories:

1. Primary biomass: biomass produced by agriculture and forestry. It includes energy crops and agricultural crops such as short rotation trees, grasses and aquatic plants.
2. Secondary biomass: biomass such as straw, stover and crop residues that is

generated as a result of harvesting and processing of primary biomass such as lumber, pulpwood, and grains. It also includes processing residues and by-product streams from food, feed, fibre and materials production.

3. Tertiary biomass: post-consumer residue streams from urban activities such as fats, greases, oils, construction and demolition debris/wood, as well as animal manure and other by-products from concentrated animal feed operations.

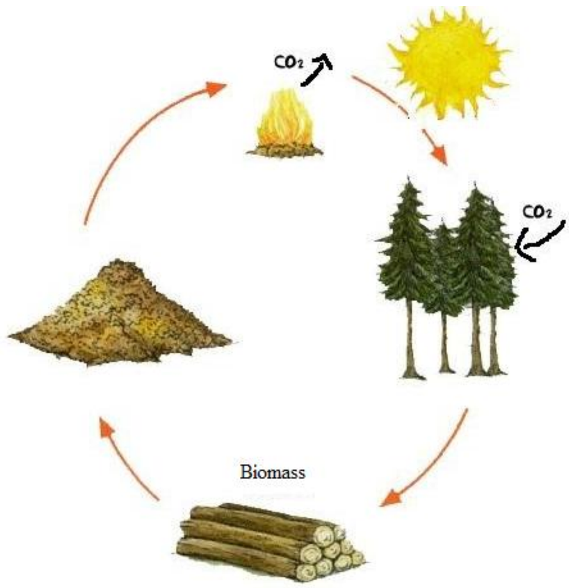


Fig.4.1. The biomass formation

The traditional use of biomass (usually wood burning) is favoring the growing deficit of wood. In the early 1980s, nearly 1.3 billion people were fuelled by declining forest reserves. There is enormous potential for biomass, which can be included in the circuit if the use of existing resources is improved and productivity is increased. Bioenergetics can be modernized thanks to modern technologies for transforming the initial biomass into modern and comfortable energy carriers.

The biomass production is both a renewable energy resource and a great opportunity for sustainable rural development. At the level of the European Union, it is expected to create over 300,000 new jobs in rural areas, precisely by exploiting biomass.

4.1. Forms of biomass energy recovery (biofuels)

Chemical composition of biomass

It can be differentiated into several types. Usually plants contain 25% lignin and 75% carbohydrates (cellulose and hemicellulose) or saccharides. The carbohydrate fraction is composed of a lot of saccharide molecules, joined together by long polymer chains. One of the most important carbohydrates is cellulose. The lignin component is composed of unsaccharized molecules. Nature uses long polymeric cellulose molecules to form tissues, which ensure the integrity of plants. Lignin occurs in plants as something like glue, which binds cellulosic molecules together. The energy embedded in biomass is released by various methods, which, however, ultimately represent the chemical process of combustion (chemical transformation in the presence of molecular oxygen, process by excellent exergonic).

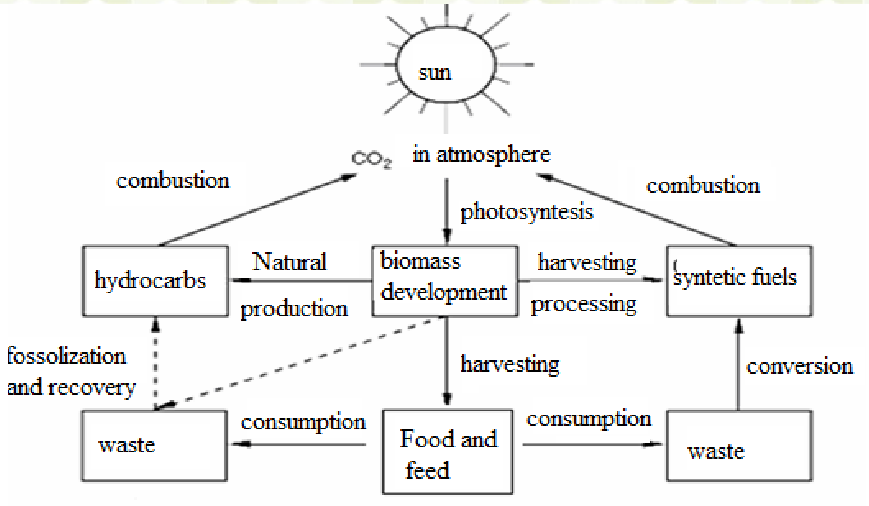


Fig. 4.2. Biomass transformation

Forms of biomass energy recovery :

- Direct combustion with thermal energy generation.
- Pyrolysis combustion, with singaz generation (CO + H2).
- Fermentation, with generation of biogas (CH4) or bioethanol (CH3-CH2-OH) - in case of fermentation of sugar products; biogas can be burned directly, and bioethanol, mixed with gasoline, can be used in internal combustion engines.
- Chemical transformation of vegetable oil biomass by treatment with an alcohol and generation of esters, for example methyl esters (biodiesel) and glycerol. In the next step, the purified biodiesel can burn in diesel engines.
- Enzymatic degradation of biomass with ethanol or biodiesel. Cellulose can be enzymatically degraded to its carbohydrate-derived monomers, which can then be fermented to ethanol.

Like the energy obtained from fossil fuels, the energy produced from biomass comes from solar energy stored in plants through the process of photosynthesis. The main difference between the two forms of energy is the following: fossil fuels can only be transformed into usable energy after thousands of years, while biomass energy is renewable and can be used year after year.

Fig.4.3. Biomass- examples

There are a wide variety of biomass sources, including high-growth trees (poplar, willow, eucalyptus), sugar cane, rapeseed, fast-growing herbaceous plants, and various residues such as wood from tree grooming and from construction, straw and cereal stalks, wood processing waste, paper waste and used vegetable oils. However, wood is the main biomass resource.

On the other hand, agricultural biomass (manure, cellulosic crop residues, fruit and vegetable residues and wastewater from the food industry) can produce ethanol or biogas. Unlike forest biomass, which is available year-round, agricultural biomass is usually only available once a year. Biogas from manure can heat homes; purified and compressed, it can feed agricultural machinery. The use of animal waste or the food industry can reduce pollution, minimizing the problems of garbage disposal and energy supply.

There are two major advantages of using biomass: reduced pollution (carbon footprint) and lower price than for other types of fossil fuels or renewable sources.

4.2.Wood waste - renewable energy source in rural area

All materials with a ligno-cellulosic structure (such as wood, straw, wood sawdust, paper, wood fibers) are important energy resources. Their main disadvantage is that they have a very low density, which leads to difficulties in the process of handling, transport, storage, leading to increased costs. In addition, large variations in material moisture can cause difficulties in the operation and regulation of processes in the power plants in which they are used. These shortcomings can be somewhat alleviated by drying and compressing the material (densification) at very high pressures, thus obtaining woody biofuels with a uniform structure, such as pellets and briquettes.

The main advantages of wood biomass densification are:

• increasing the density of the compressed material (from 80-150 kg/m^3 for straw or 200 kg/m^3 for wood sawdust up to 600-700 kg/m^3 for final products);

• higher calorific value and a homogeneous structure of compressed products;

• a low humidity content (less than 10%).

Table 4.1. Calorific values for wood waste

Combustible	Net calorific value GJ/tonă	Net calorific value kWh/kg	Density Kg/m^3	Energy/volum MJ/m^3	Energy/volum kWh/m^3
Wood sources (30% maximum umidity)	12.4	3.5	250	3100	870
Wood choping (20% maximum umidity)	14.7	4.1	350-500	5200-7400	1400-2000
wood (solid – very dry)	19	5.3	400-600	7600-11400	2100-3200

Wood pellets	17	4.8	650	11000	3100
Energy willow (25% maximum umidity)	13	3.6	140-180	1800-2300	500-650

Obs.

1 J = 1 Ws = 1/3600 Wh

• *1 Wh = 3600 Ws = 3600 J*

• *1 toe = 11630 kWh = 41,87 GJ*

• *1 BTU = 1055 J*

Pellets are solid, low-moisture fuels obtained from sawdust, wood chips, or even tree bark, wood dust from industrial wood processing plants, as well as from untapped trees from forestry operations. The resins and binders that naturally exist in sawdust have the role of keeping the pellets compact and therefore they do not contain additives. Wood pellets are ecological, economical and CO_2-neutral fuels, mostly produced from sawdust and wood scraps, compressed at high pressure without gluing additives. They are cylindrical in shape, usually measuring 6-10 mm in diameter and 10-30 mm long, with 18% maximum humidity. In order to reach these characteristics, the following processing is required: chopping, sorting, grinding, drying, conditioning and pelletizing, cooling, sieving, bagging. These processes are performed with specialized equipment for each processing in a fully automated technological flow, according to fig. 4.5.

Their energy density and fluidity make it a modern fuel that allows the automation of heating systems.

Fig.4.4. Pellets

Pellets are also a great way to use local resources and help preserve the environment and prevent climate change. The construction of sawdust pellets allows for the introduction of a new attitude towards environmental issues, as well as the creation of opportunities for the recovery and introduction of waste into the economic circuit that, if not treated properly, would cause massive environmental pollution, with major negative repercussions for long periods of time.

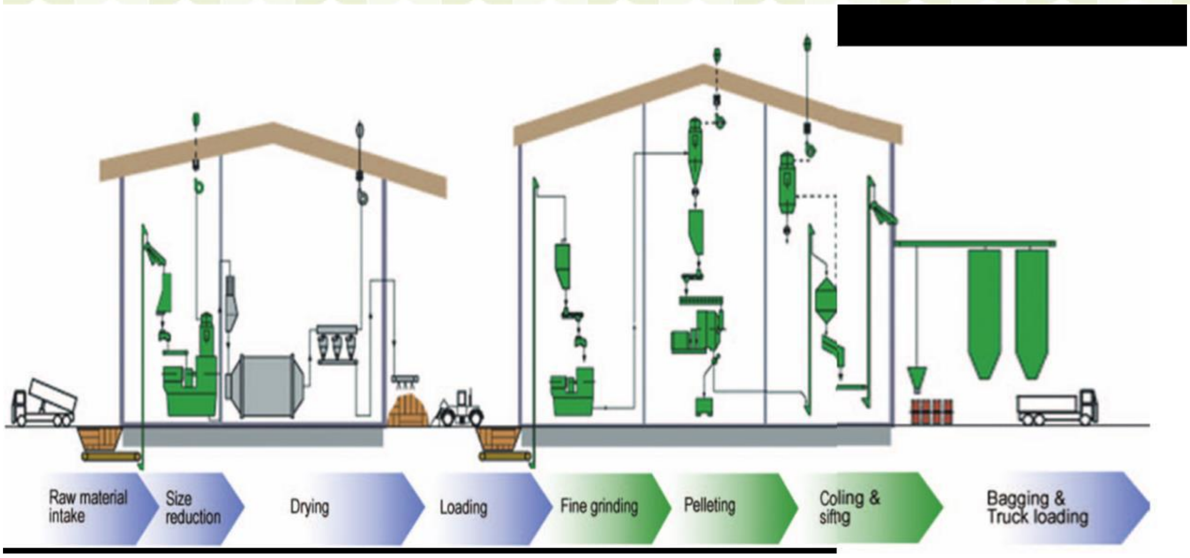


Fig.4.5. The pelletizing process, [35]

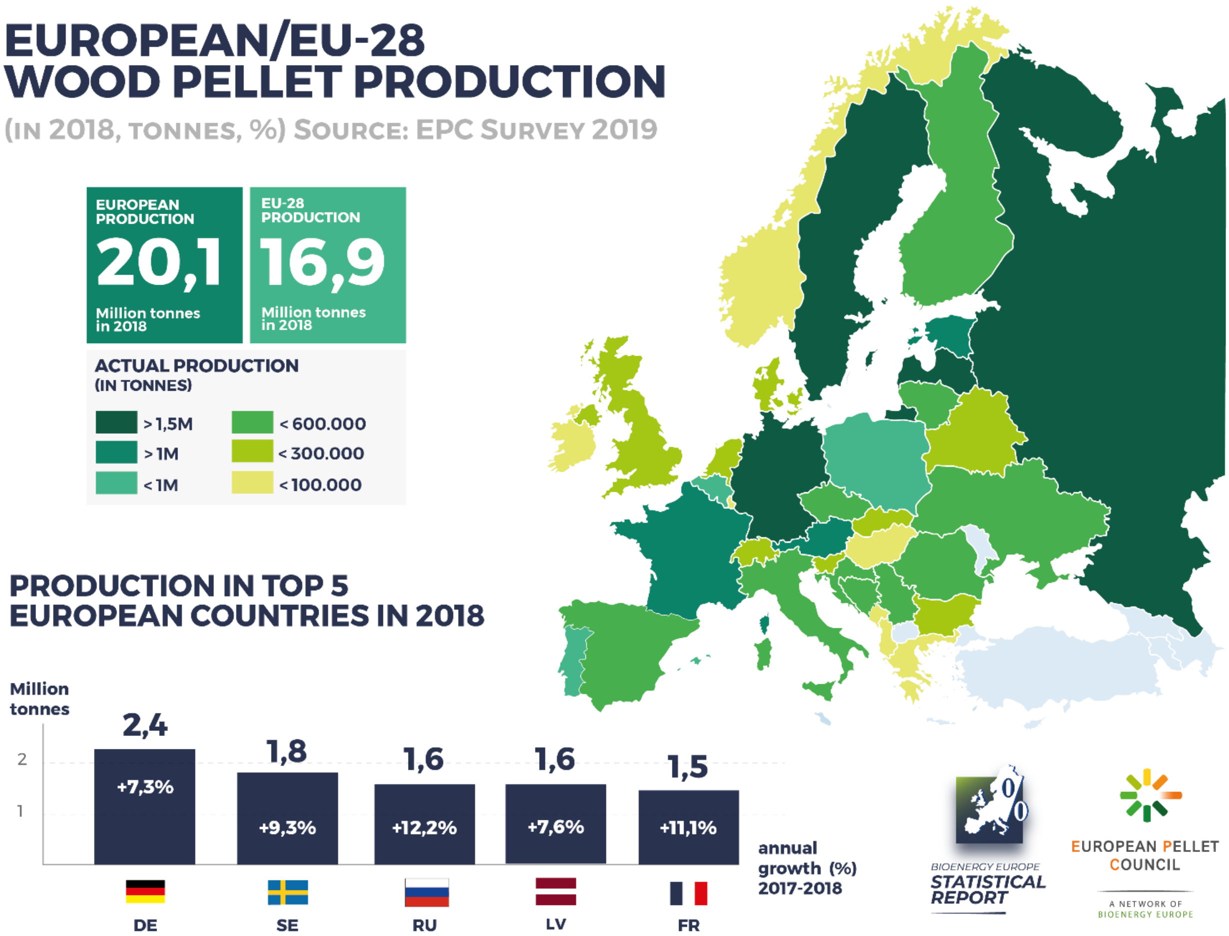


Fig.4.6. The wood pellet production in Europa/Eu-28 in 2018,

Source: https://epc.bioenergyeurope.org/about-pellets/pellets-statistics/european-production/

The term briquette comes from the French words briquette, which means blocks of flammable solid material (biofuel), used to initiate and maintain combustion. Lighters are classified into coal briquettes and biomass briquettes. Biomass briquettes have a density of approx.1100-1500 kg / m3 and a calorific value of 3500-4500 kcal / kg.

One of the most special and important qualities of briquettes from vegetable waste is the calorific value, which is higher than that of wood and brings a saving of 60% compared to gas heating and 40% compared to wood heating. In addition to this, the benefit of using briquettes comes from the production costs of briquettes made of straw or other vegetable waste which are very low.

The briquetting process consists in compaction by densification of biomass with approx. 80-90% in order to obtain parts with high density and homogeneous, regular shape, which can be used as fuel.

Fig. 4.7. Wood Briquettes

In rural areas, biomass for heating is traditionally used in stoves where wood logs or briquettes are burned to make heat at a decentralized level and with a low efficiency of up to 45%. In addition to stoves, small boilers can use similar types of fuel for small central heating units in the household. These systems can use small fuels, such as pellets or wood chips, which allow automatic feeding. In recent years, with the development of modern power plants using wood pellets, the efficiency of these systems has increased to almost 90%. Medium-sized central heating systems in small grids use fuels that allow automatic feeding, such as pellets or wood chips, and typically use hot water boilers to produce heat with up to 90% efficiency. Larger central heating systems and industrial plants powered by solid biomass typically use cogeneration technologies for heating, [35].

Biomass can be converted to biogas through a process called anaerobic digestion (AD). This is a staged biological process in which various types of microorganisms decompose digestible biomass in the absence of oxygen. Biomass is converted to biogas, which contains mainly methane (CH_4) and carbon dioxide (CO_2) and much smaller amounts of hydrogen (H_2) and hydrogen sulfide (H_2S). At the end of the process, the remaining digestate is often rich in nutrients such as ammonium and phosphate and can be used as fertilizer. Methane-producing microorganisms are found in various places in nature, such as the stomachs of ruminants (cattle). To initiate the process of anaerobic digestion in a biogas plant, an inoculum (cow dung) can be introduced into the raw material.

A wide variety of biomass resources can be used as raw material for anaerobic digestion, including agro-industrial waste, organic food waste, sludge from wastewater treatment plants, animal manure, agricultural residues and energy crops (e.g. corn, miscanthus, sorghum).

Fig. 4.8. illustrates a scheme of a biogas plant with an underground digester tank, a gas holder, mixing devices, and gas regulator valves.

Biogas is a valuable source of renewable energy and an important element of sustainable energy concepts for the future. The impact of biogas production on the circular economy is further enhanced by the organic nutrients recovered in the production process. Biogas is mainly used today directly in cogeneration plants (CHP) (combined electricity and heat) or in traditional gas appliances, such as gas ovens or gas dryers, [35].

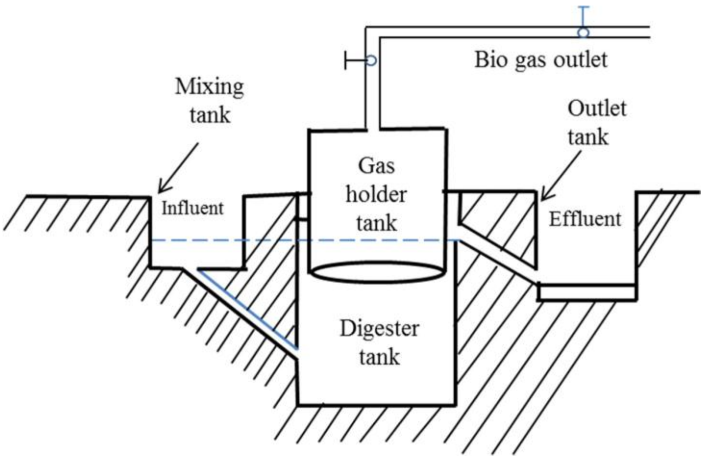


Fig.4.8. Scheme of a biogas plant, [36]

4.3. Biomass burning and energy production. Micro- cogeneration plant

CHP or cogeneration is a process of energy transformation in which useful electricity and heat are produced simultaneously, in a single process. Micro-cogeneration plant means a cogeneration plant with a maximum capacity 50 kWe, and the small cogeneration plant refers to a cogeneration plant with an maximum capacity 1 MWe.

The main argument in favor of cogeneration is the reduction of primary fuel consumption and, implicitly, of greenhouse gas emissions.

Cogeneration production has the following advantages:

- the possibility of obtaining energy efficiencies of over 80%;

- primary fuel economy compared to producing the same amounts of electricity and heat separately in conventional power and thermal power plants;

- less pollution and the possibility of control and reduction of pollutants including greenhouse gas emissions;

- low cost for energy produced in cogeneration plants.

Fig.4.8 shows the cogeneration plant. The principle of operation of the installation is the following: the fuel (sawdust, bark and chopped) is stored in a horizontal silo that is fed automatically from the exhaust system or manually with front loaders, after which it is transferred with a hydraulic system that also performs its dosing in a boiler with mobile grills. The combustion system with mobile grills allows the combustion of low-combustible and high-moisture waste. The hot gases in the boiler go through 3 thermal recuperators:

· 1 diathermic oil 315/255°C,

· 2 diathermic oil 255/155°C,

· 3 combustion air preheater.

The first two recuperators provide the thermal energy required for the ORC module and the third increases the combustion efficiency by preheating the combustion air. The ORC module is intended for the production of electricity, resulting in the secondary thermal energy circuit (hot water at 80/60°C).

In order to have an additional safety in operation, a cooler is mounted on the hot water circuit which is switched on automatically in the event of a decrease in thermal energy consumption in the secondary of the ORC module.

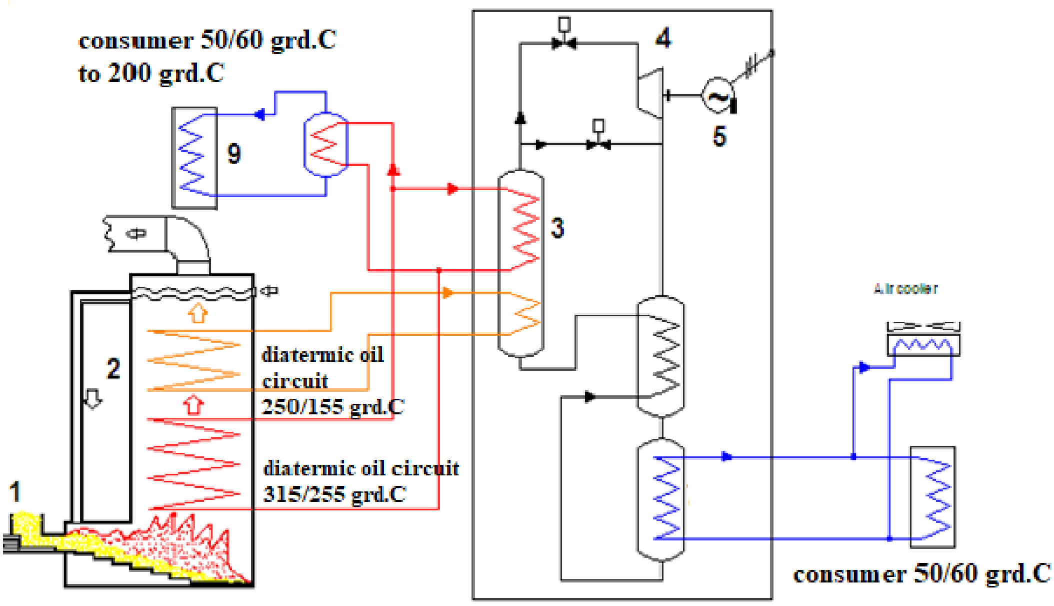


Fig.4.9. Thermal scheme for the cogeneration plant

Components parts:

1- Wet fuel silo
2- Pneumatic transport installation for boiler supply
3- Biomass boiler
4- ORC module
5- Electrical generator

The ORC module (Organic Ranking Circuit)

The diathermic oil in the installation heats an organic fluid in a vaporizer, this fluid drives a turbine, the turbine drives the current generator, the fluid in the secondary of the turbine passes through an economizer and reaches the condenser, where the excess heat (at a temperature of 90/70 ^oC) is taken over by a heat exchanger for hot water and then the organic fluid is pumped to resume the thermal circuit.

From the secondary circuit of the condenser heat exchanger results a surplus of thermal energy which is directly proportional to the power of the electricity generator.

Obs. Energy efficiency: Thermal power biomass 100% => Thermal power cogeneration 82% - Electricity 15% - Thermal and electrical losses 3%. Balance calculated for a biomass cogeneration plant (diathermic oil circuit temperature 300 - 250 ^oC, hot water temperature for cogeneration 60 – 90^oC).

5. GEOTHERMAL ENERGY

The Earth was formed about 4.6 billion years ago, undergoing several major geological and biological processes. It has a hot and liquid inner core consisting of molten sheath and a metallic core generating the magnetic field, as in Fig. 5.1. The temperature of the earth increases with depth, in the inner core reaching more than 4500oC [39]. But the core does not only generate the earth's magnetic field, it also generates heat, which can be used as a renewable energy source [40].

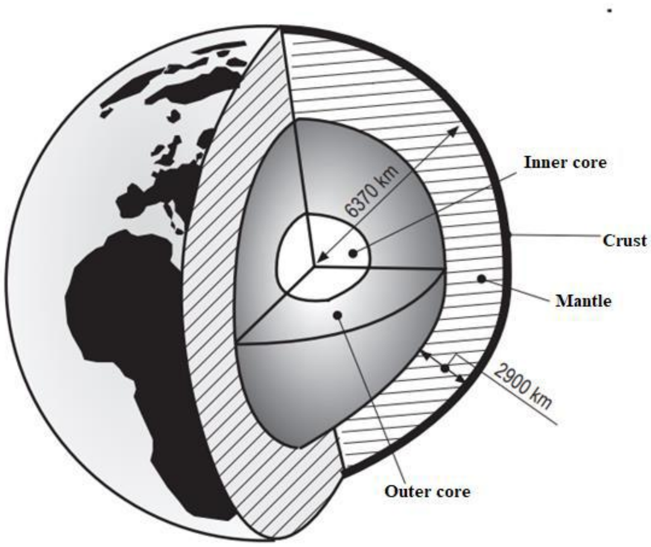


Fig. 5.1. The interior of the Earth, [39]

The high temperature at the boundary of the outer core (liquid), with the mantle, can reach over 4500 °C and due to the high pressure it causes the rocks to melt but also to heat them to the level of the earth's crust, where the water contained in it can reach temperatures higher than 350 °C. Consequently, it can be said that geothermal energy is the thermal energy generated and stored in the earth.

The term geothermal comes from a combination of words of Greek origin: GEO (earth) and THERMOS (warm). Geothermal energy contributes to reduced global warming effects and its deployment helps reduce a country's dependence on fossil fuels.

Used since the Paleolithic in the form of thermal springs for bathing, the most well-known use today is for the production of electricity and heat, industrial processes, water heating, in fish farming, desalination and agricultural applications (greenhouses, drying of plants, etc.), [43].

An important advantage of this kind of renewable energy is that it is not depending on weather conditions. A lot of countries such as Iceland, Kenya, New Zeeland, Philippines use geothermal energy for electricity production, with Iceland assuring more than 90% of heating demand with the energy of the Earth, [42].

Geothermal energy is considered to be cost-effective, reliable, sustainable and environmentally friendly, but limited in use only to the joint areas between tectonic plates. Technological advances in recent years have been able to expand the use of this resource to other functional areas, such as home heating, opening up new opportunities for wider exploitation.

The geothermal resources of the planet are theoretically more than sufficient to meet the energy needs of mankind, considering that the Earth's internal thermal energy reaches the surface, by conduction, at a rate of about 40 TW and is supplemented by the radioactive decomposition of minerals at a rate of 30 TW, more than double the needs of humanity. Unfortunately, only a very small part can be exploited profitably.

The geothermal resources are: low (temperature for enthalpy geothermal fluid under 90^{o}C) , intermediate (temperature for intermediate enthalpy geothermal fluid is (90 $_{+}$ 150) ^{o}C and high enthalpy resources (temperature for high enthalpy geothermal fluid is over 150^{o}C), [41].

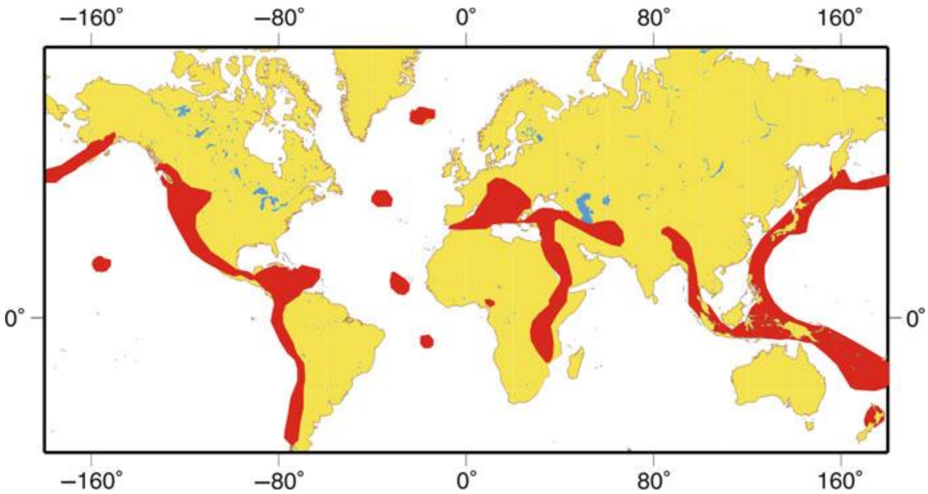


Fig.5.2. Geothermal regions (in red), [44]

The most important factors that characterize the ground from thermal point of view are thermal conductivity, density, specific heat, and moisture content. It is known that the evolution of ground temperature is practically constant at about 15 m depth and is equal to the average annual temperature of the exterior air. The temperature of the earth is bigger than the air temperature in winter and smaller than the air temperature in summer. It is also important to note that ground temperature does not depend on outside air temperature variation, [38].

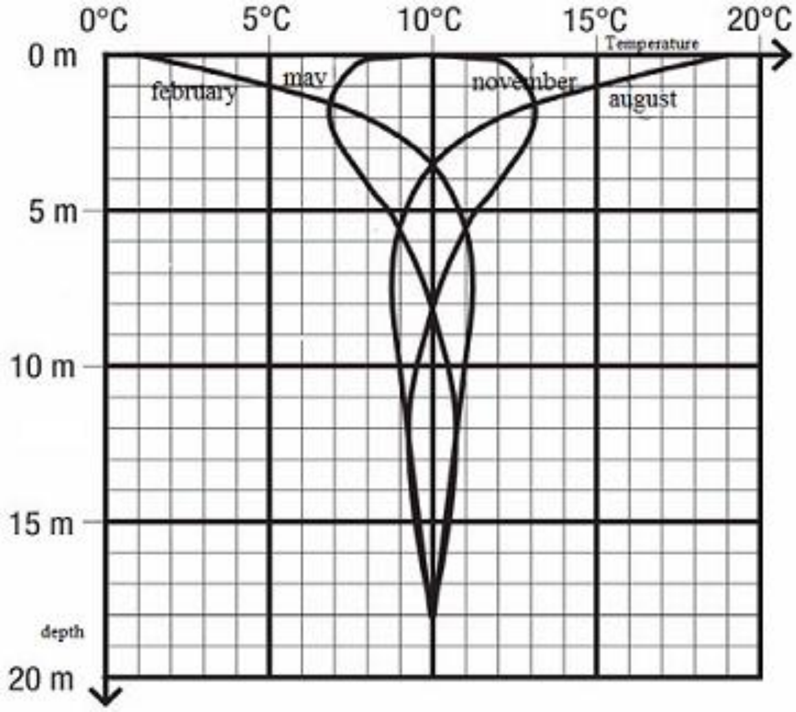


Fig.5.3. Variation of the temperature in the upper earth crust

5.1. Example of geothermal power plant

In present, there are three large types of geothermal power plants:

-dry steam power plants. These use the steam coming from underground wells to rotate the turbine, which activates a generator that produces electricity. There are underground steam resources such as Geysers.

-flash steam power plants. The hot water that flows through the wells to the ground, by lowering the pressure, turns some of the hot water into steam. The steam is then used to power a generator, and the rest of the water and condensed steam will be returned to the tank.

- binary cycle power plants. Binary cycle power plants differ from the first two, in that the water or steam from the geothermal spring does not come into contact with the turbine, respectively the electric generator. The water used reaches temperatures up to 200^{o}C.

For a country with reservoirs with lower temperatures, binary cycle power plant is the most suitable alternative. This plant uses two kinds of fluids: a geothermal fluid which evaporates at a low boiling point and a fluid which drives the turbine. The binary fluid is operated through a conventional Rankine cycle. This fluid can be an organic fluid such as Isopentane, Isobutane.

Fig. 5.4. shows the principal elements of this type of plant, [40].

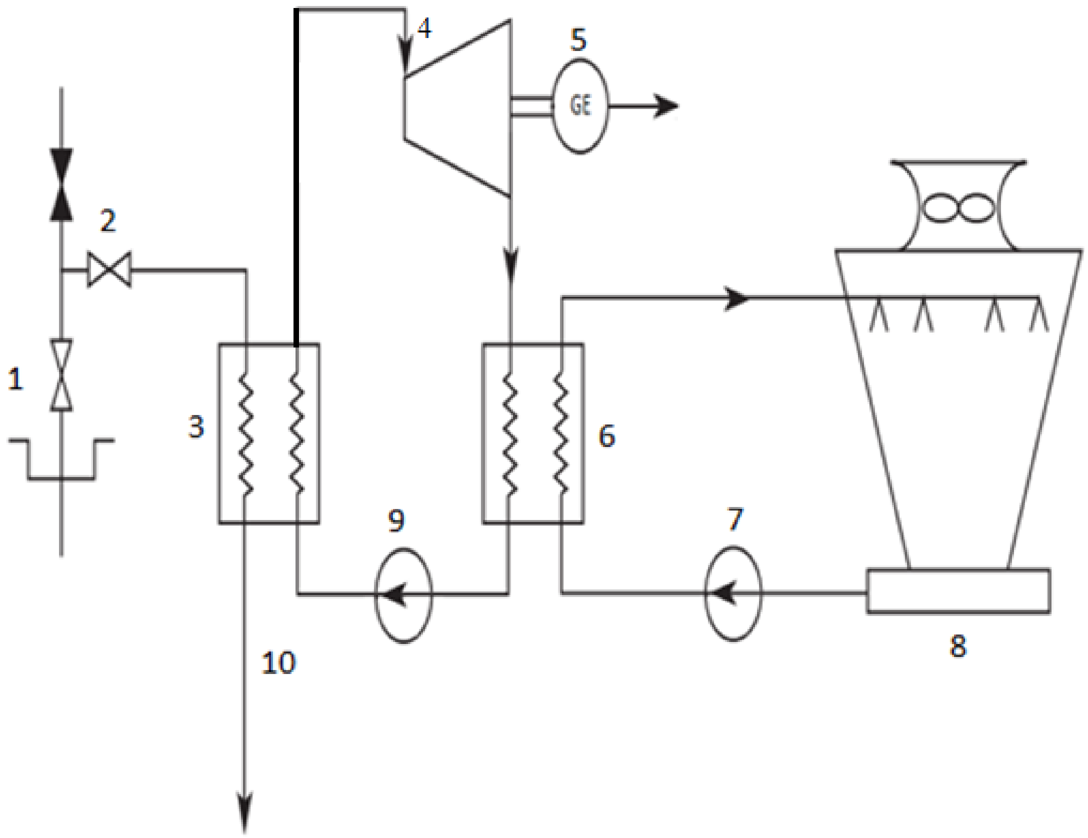


Fig. 5.4. Binary cycle power plant:1 –well production, 2 –pressure regulation valve, 3 –heat exchanger, 4 –turbine, 5 –electric generator,6 –condenser, 7 –cooling water pump, 8–cooling tower, 9 –condenser pump, 10 –Injection well.

The geothermal fluid (primary working fluid) is passed through at heat exchanger 3 to heat the organic fluid (secondary working fluid) that vaporizes at a lower temperature than water. This fluid is used to drive the turbine 4 and is then condensed in to the condenser 6. The fluid from the binary plant is recycled back to the heat exchanger and forms a closed loop [4]. The geothermal fluid is injected back to the reservoir. In this way, a relatively low geothermal thermal potential can be used.

Investment costs for a such a geothermal plant depend on the cost of geothermal drilling and the cost of the surface equipment. Higher uncertainties can be expected in respect to the drilling process and the number of geothermal wells required for the plant. The drilling cost of low temperature geothermal development is about 10%-20% of the total development cost.

5.2. Ground source heat pumps (GSHP)

Geothermal heat pumps transfer heat from the ground to the house in winter, and in summer the transfer takes place in reverse, from the house to the ground. Unlike a boiler, a heat pump transfers heat, does not produce it.

Ground source heat pumps (GHSP) are used for heating, domestic hot water or for cooling the air. These systems are more common than geothermal power plants, due to the fact that they do not require large funds for their building and installing. They also have a very low temperature geothermal source [40].

In fig. 5.4 the operation of the heat pump systems is illustrated. By denoting by L the energy consumed to achieve heat transfer from the lower temperature environment to the higher temperature environment, the energy balance of the installation can be expressed as follows::

$$|Q| = Qa + |Win|, \text{ [J]} \tag{5.1}$$

where: Q - heat energy given to the environment with higher temperature, in J;

Qa - heat energy taken from the environment with lower temperature, in J;

Win- energy consumed to achieve heat transfer, in J

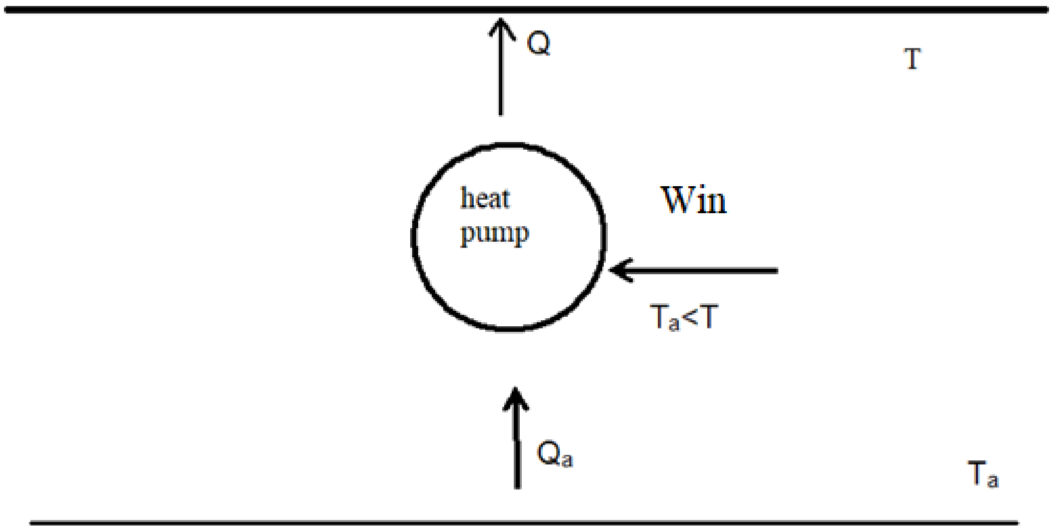


Fig. 5.4. Schematic of the operating principle of heat pumps.

The structure of a heat pump

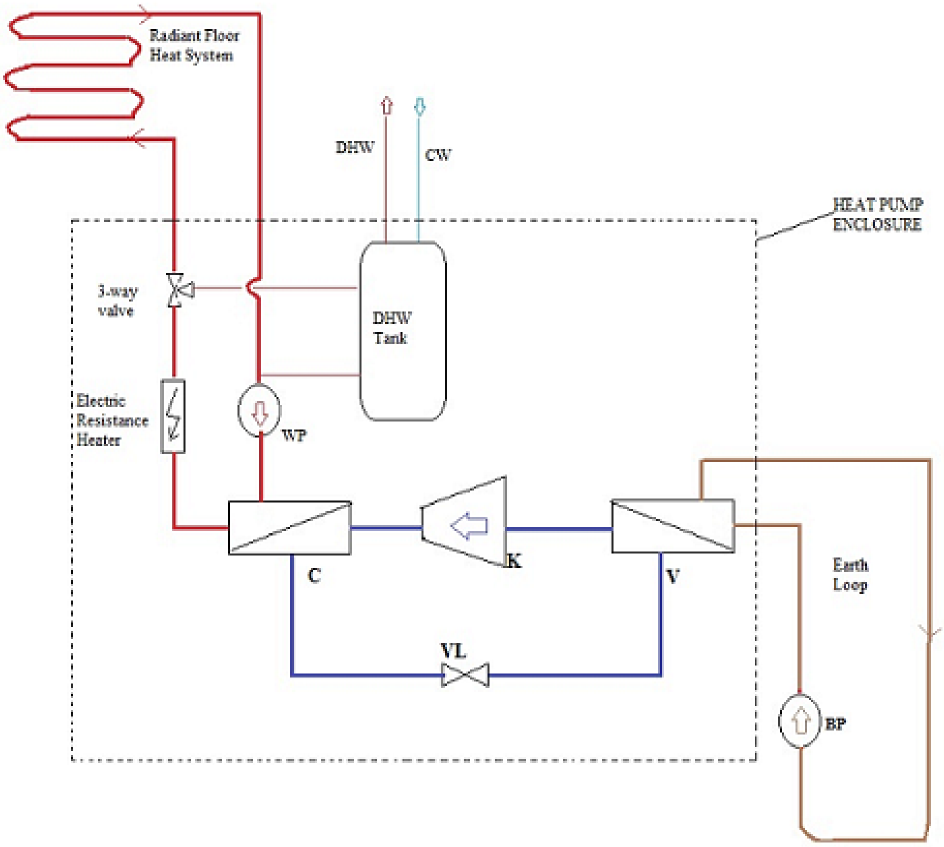


Fig.5.5. Ground source heat pump operating diagram. [45] Component parts: V- evaporator; K- compressor; C- condenser, VL- expansion valve; DHW Tank- boiler for domestic hot water, WP- water circulation pump; BP- brine circulation pump, [38].

1. Evaporator (vaporizer) V - the refrigerant fluid absorbs heat from brine from ground loop and evaporates. The evaporator is a heat exchanger.

2. Compressor K- it compresses refrigerant vapors and thus raises their temperature to high values.

3. In condenser C, compressed refrigerant gas is condensed to a liquid and the heat is absorbed by the circulating water in heating system. passes through it and turns into a liquid, which is then introduced into the heating system.

4.Depressurizer (expansion valve) - the above liquid passes through this system which greatly reduces its pressure and thus its temperature. The cycle starts again.

The ground source heat pumps GSHP system has three important components:

- ✓ a heat pump;
- ✓ a soil connection;
- ✓ heating distribution system.

The soil has the ability to store heat from the sun seasonally, which leads to a relatively constant temperature of this heat source and to achieve high seasonal coefficients of performance. The contribution of geothermal energy, that is, of that heat flow directed from the inside to the outside of the earth, is so small that it can be neglected. It follows that the energy extracted from the ground by this type of heat pump comes almost exclusively from the sun.

The heat taken from the source is transported by means of an antifreeze mixture, the freezing point being about -15 ° C. This ensures that the probe will not freeze during operation. The diagram of this circuit is shown in fig. 5.6.

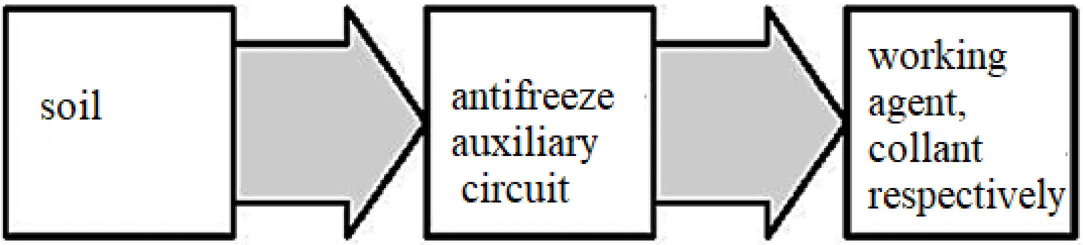


Fig. 5.6. Antifreeze circuit diagram

The category of ground-water or geothermal heat pumps can include all the variations of the existing heat pump that currently extract energy from the ground or groundwater. The unit that includes the condenser and compressor of the geothermal heat pump plus electronics is the same but the evaporator can be connected in different ways depending on the free source, from where it will take its name.

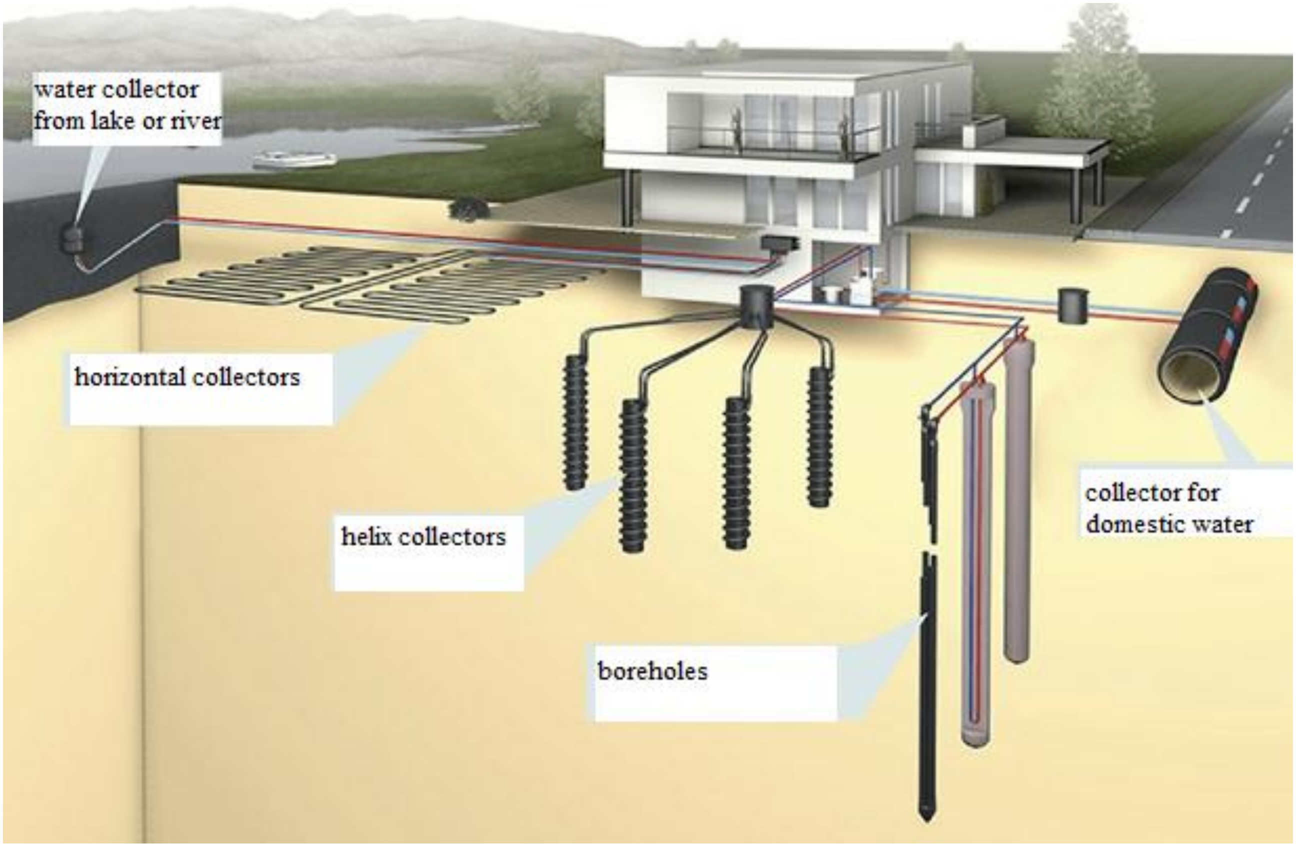


Fig.5.7. Types of geothermal heat pumps, [46]

The horizontal collectors are mounted at depths of approx. 1.2… 1.5 m, and the vertical collectors, also called boreholes, are mounted in holes drilled, at depths of up to approx. 100m, over these depths being difficult to obtain permits for drilling. Both horizontal and vertical collectors are made of polyethylene tubes, which ensure a very long service life, absolutely necessary for this equipment. The use of metal collectors in the soil, which would reduce the heat exchange surface, is not possible, due to the high corrosivity of the soil, which would destroy the collectors relatively quickly, and their replacement would be an extremely complex and expensive operation..

Both horizontal and vertical collectors are made of polyethylene tubes, which ensures a very long service life, absolutely necessary for this equipment. The use of metal collectors in the soil to reduce the heat exchange surface is not possible, due to the high corrosivity of the soil, which would destroy the collectors relatively quickly, and their replacement would be an extremely complex and expensive operation. Horizontal collectors have the advantage of relatively low costs of excavations required for location, especially in the case of new constructions, but have the disadvantage of necessity large collector storage areas, which reduces the possibility of using these types of collectors. Vertical collectors have the advantage of the need for small areas but have the disadvantage of high costs of drilling

The heat pump efficiency is measured by the coefficient of performance (COP):

$$COP = \frac{Q}{Win} \qquad (5.2)$$

COP is calculated for both heating and cooling can have instantaneous, seasonal or annual values.

6.HYDROPOWER

Water power is one of the most important sources of energy that does not involve carbon dioxide, sulfur dioxide, nitrous oxide or any other type of toxic emission and does not produce any solid or liquid residues.

The use of water for energy purposes has been known for thousands of years. Water has been used in many parts of the world for at least two thousand years and was originally used to grind grain. In the first decades of the industrial revolution, water mills were built in Europe and North America for a variety of purposes, from flax processing to spinning and weaving, to wood processing.

The hydroelectric plant uses a natural or artificial fall of a river and incorporates the main advantages compared to other energy sources, saving in terms of consumption of coal, fuel or firewood, being independent, without the need for other components. The conversion of hydraulic energy into electricity is not polluting, involves relatively low maintenance costs, represents a long-term solution and comes with no fuel problems.

Until the end of the 19th century, water energy was the main source of electricity, until coal, petroleum products, and later nuclear fuel, became more widely used. At the end of 2020, global renewable generation capacity amounted to 2 799 GW with hydropower -1 211 GW, 43,26%, [47].

Hydropower plants (CHE) have the lowest operating costs and the longest lifespan compared to other types of power plants. There is over a century of experience in the development and operation of CHE, which makes it possible for them to achieve very high levels of technical and economic performance. In the beginning, hydroelectric power plants were small facilities. However, the necessities industry and the needs of the population have led to the construction of larger dams and hydropower facilities.

6.1. Micro hydropower plants for the rural area

Solar energy evaporates seawater producing clouds. When the drops end up having a mass large enough, gravity pulls water back to the Earth's surface in the form of rain. If this rain falls on high ground and reaches the streams and rivers that flow rapidly there is the ability to extract some of their energy by arranging part of their course so that the water passes through a hydraulic turbine that drives an electric generator, using water to produce electricity.

Characteristics of micro hydropower plants:

• They are suitable for low power requirements, decentralized (light industry, private farms and enterprises, rural communities) and for operations outside the main network;

• Requires low voltage distribution networks and possibly sub-regional micro-networks;

• They can be used in private property, in co-ownership or common property, with a semi-skilled labor need and common administration;

• The short period of construction with local materials and the use of the skills of the population in the area, can have a significant impact on the quality of rural life;

• Their flexibility, in terms of adapting to variable loads depending on the tributary flow, makes them a privileged component in any integrated energy system;

• The plants have a very long period of use. Some are over 70 years old and still in working order. Plants ready to be put into operation recently can last even longer and can serve consumers for generations without polluting the atmosphere;

• Investments in micro hydropower plants have proven to be safe and profitable for several decades.

Table 6.1. Detailed classification of hydropower plants by size

Large hydropower plants	Over 100MW-usually power a larger network
Medium hydropower plants	15...100MW- usually supply a network
Small hydropower plants	1…10MW- usually supply a network
Mini hydropower plants	100kW…1 MW- can be self-contained, but generally power a grid
Micro hydropower plants	5…100kW- usually provide electricity for a small community or for industry in isolated areas of the network
Picohydro power plants	Several hundred W… .5kW

In hydroelectric schemes a separation (bifurcation) of a certain amount of water flow from the river is required using a water storage system 1. From the storage system, water flows through a channel called the "supply channel" 2. At the end of the adduction channel there is a stabilization tank, commonly called "bief" 3. The supply channel can be provided with overflow channels (4), so that the excess water flow is discharged back into the river. From the diversion the water enters a forced pipe 5, to begin the last stage of its journey which is the circulation through the hydro turbine. If a site has a difficult topography or if the environment requires it, the supply channel can be omitted and a longer forced conduit is made that transports water from the water storage system directly to the turbine. The hydraulic turbine and the electric generator are installed in the power plant 6. There may be arrangements in which a dam is built on the river, the turbine and the generator are arranged inside the actual dam in line with the river, and the supply channel and the forced pipeline are missing. After passing through the turbine, the water reaches the river or stream through a downstream channel 7, [48].

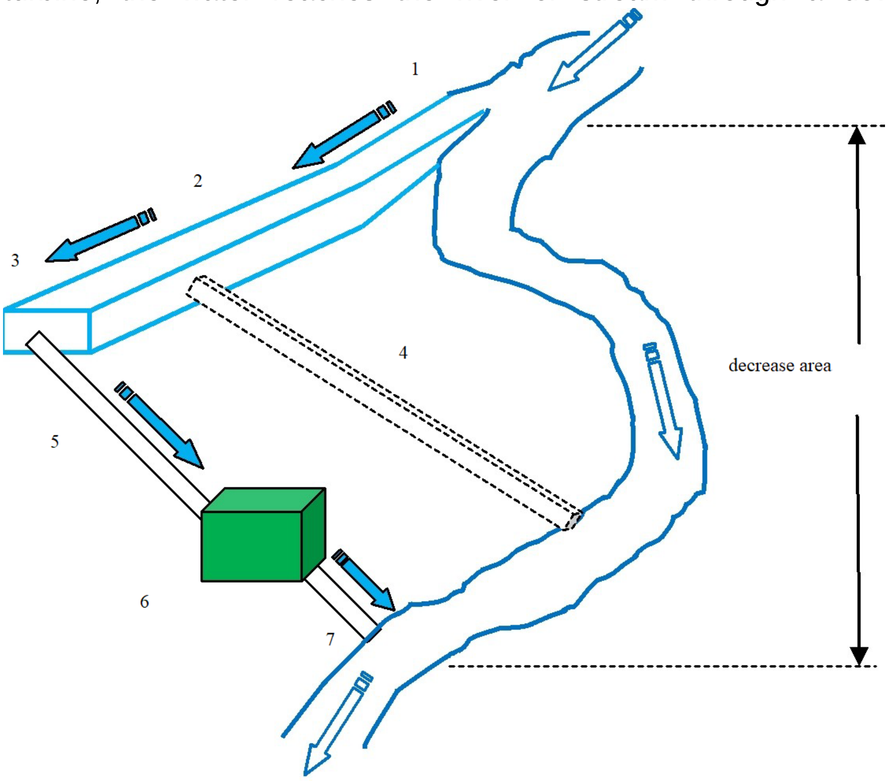


Fig.6.1. The components of the micro hydropower plant

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