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The Potential for Renewable Energy in Satu Mare County

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About us

Vista Analyse is a social science consultancy with an emphasis on economic research, policy analysis and advice, and evaluations. We carry out projects to the highest professional standards, with independence and integrity. Our key thematic areas include climate change, energy, transport, urban planning and welfare issues.

Our employees have high academic credentials and broad experience within consulting. When needed we utilise an extensive network of companies and resource persons nationally and internationally. The company is fully employee-owned.

Preface

This report is a deliverable from the project RENEWSM, in which The Satu Mare Intercommunity Development Association and Vista Analyse collaborate to increase knowledge and raise awareness on renewable energy in Satu Mare, Romania. Specifically, the project aims to

- Increase knowledge about renewable energy, energy and energy efficiency for 50 representatives of regional/local public administration, NGOs, public institutions, universities;
- Raise awareness about renewable energy, energy and energy efficiency among 2 000inhabitants of Satu Mare: 1 000 pupils and 1 000 general public.

The RENEWSM project is running from March 2023 through February 2024. Project activities include a campaign directed at pupils and the general public, short-term training in Satu Mare, comprehensive training in Norway, and a report on the potential for renewable energy in Satu Mare (this report). The project RENEWSM is supported by a grant from Iceland, Liechtenstein and Norway through the EEA Grants 2014-2021, in the framework "Romanian Energy Program". The amount of the grant awarded is 138,000 Euros.

The EEA grants represent the contribution of the states of Iceland, Liechtenstein and Norway to a greener, more competitive and more inclusive Europe. There are two major objectives: reducing economic and social disparities in Europe and strengthening bilateral relations between donor states and the 15 EU states in Central and Eastern Europe and the Balkans. The 3 donor states cooperate closely with the EU within the framework of the Agreement on the European Economic Area. Donor states provided 3.3 billion Euros through grant schemes between 1994 and 2014. For the period 2014-2021, EEA Grants have a value of 1.55 billion Euros. More information on EEA Grants: www.eeagrants.ro.

This report was initiated by desk studies on the potential for renewable energy technologies in Satu Mare, including resource potential, policies and regulations, and financing options. A framework was developed for assessing renewable energy technologies. The framework is reproduced in chapter 2 below.

During the short-term training in Satu Mare (September 2023) and the comprehensive training in Norway (October 2023) hypotheses and ideas were discussed with Satu Mare stakeholders.

Nicoleta Lasan and Paul Dancu have been our main contact points in the development association, and we thank them for fruitful discussions as well as comments to an earlier draft, which have improved the content of the report.

January29th, 2024

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Glossary and abbreviations

Agri-PV	Agricultural photovoltaics which refers to the combination of agricultural production and solar PV production on the same land.
Biomass	Organic matter used as fuel.
CCGT	Combined cycle gas turbine.
CDD	Cooling degree days.
CSP	Concentrated solar power.
DNI	Direct normal irradiation.
EUR/MWh	Euros per megawatt-hour.
FLH	Full load hours: The number of hours a power plant is expected to operate within a year. For reference, one year has 8760 hours.
GHG	Greenhouse gases. Gases in the atmosphere that contribute to the greenhouse effect and warming of the planet. Important anthropogenic GHGs are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), in addition to sulfur hexafluoride (SF_6), hydrofluorcarbons (HFCs), and perfluorcarbons (PFCs).
HDD	Heating degree days.
Solar irradiation	The power from solar radiation per unit area.
kWh	Kilowatt-hour. 1 kWh is equal to 1 thousand Wh, i.e. the power consumption of one thousand watt for one hour.
kW_p	Short for kilowatt-peak. In terms of solar PV panels, it refers to the peak capacity of a panel, i.e. the panel's maximum capacity in an ideal setting. 1 kW_p means that a panel have a capacity to produce 1 kW of power under ideal conditions.
LCOE	Levelized cost of electricity. It is a measure of the average cost of producing electricity over the lifetime of a technology, considering investment, maintenance, and operating costs.
MWh	Megawatt-hour. 1 MWh is equal to 1 000 kWh, i.e. the power consumption of one thousand kilowatt for one hour.
NO_2	Nitrogen dioxide.
$PM_{2.5}$	Particulate matter smaller than 2.5 microns per cubic meter.
Prosumer	An individual that both produces and consumes.
PV	Photovoltaic.
RES	Renewable energy sources.

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Executive Summary

We survey the potential for renewable energy production and energy efficiency improvements in Satu Mare County, Romania. Solar PV and biogas are two promising technologies for renewable energy production. In addition, we believe there is potential for energy efficiency improvements.

Like the rest of Europe, Satu Mare is facing a green transition

Satu Mare is a county of 4,418 km^2in the north-western corner of Romania. It borders Hungary to the west and Ukraine to the north. The county has 330,000 inhabitants, of which 90,000 live in the county capital, Satu Mare.

Satu Mare county is preparing for a green transition as Europe strives to become net carbon neutral. Carbon neutrality requires new renewable energy sources incombination with improved energy efficiency. This report discusses the potential for renewable energy production in Satu Mare county.

Solar energy, biogas and energy efficiency seem the most promising solutions

Compared to the rest of Europe, Satu Mare has ample sunshine andsignificant biomass resources. By contrast, wind resources are lowand hydro resources are very low. The potential for energy efficiency improvements, particularly related to the building stock, may be substantial but should be investigated further.

Significant potential for solar energy

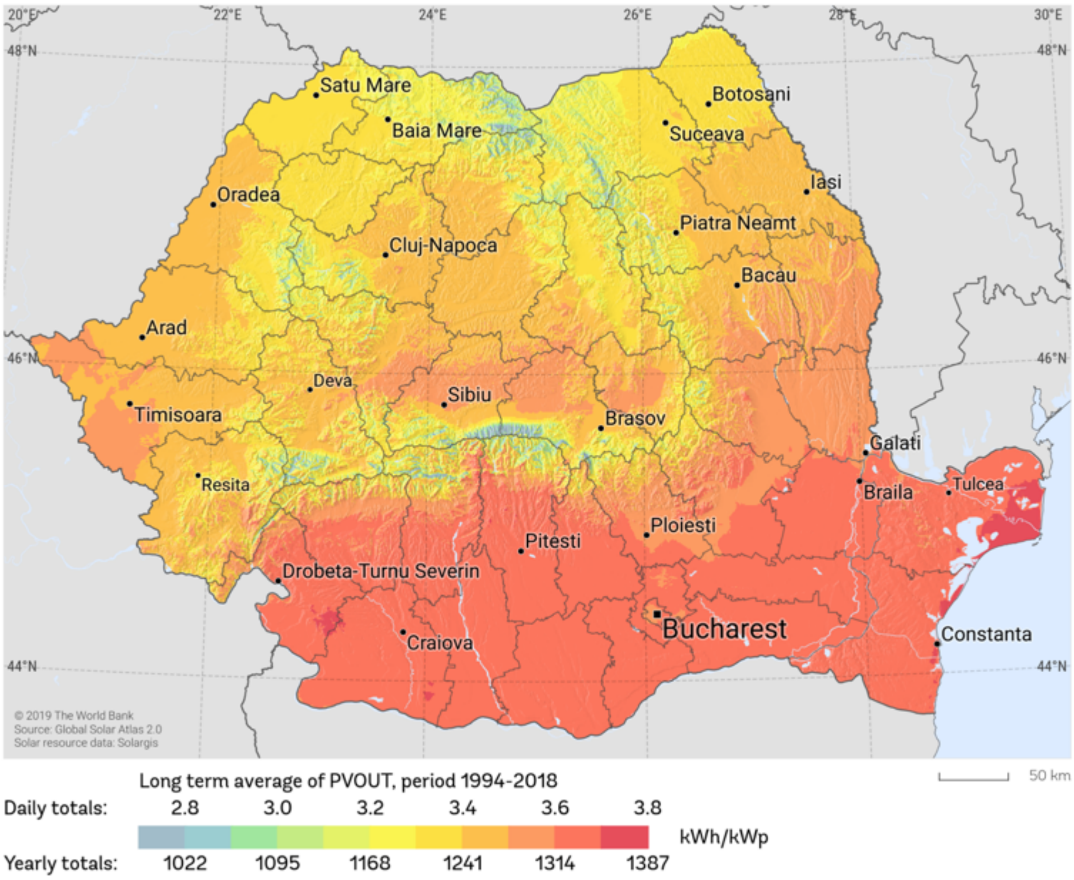
There are basically three technologies for exploiting energy from the sun:solar photovoltaics (PV), solar heating and concentrated solar power. Concentrated solar power requires fairly intense sunlight, more than 1900 kWh/m^2, while Satu Mare receives less than 1400 kWh/m^2. Hence, attention should be focused on the two other technologies.

Solar maps show that the potential for solar photovoltaics and solar heating is good in the whole of Romania. Figure S.1 shows the power potential per installed peak capacity of solar PV, where areas colored yellow and red indicate good potential.Conditions may be the best in southern parts of the country, but Satu Mare has better potential than, e.g., Germany. Solar PV supplies 10 percent of Germany's electricity, and we believe a similar result, or better, can be achieved in Satu Mare and Romania, where currently solar PV contributes only 3 percent of electricity production. Similarly, solar heating of water and air offers an attractive substitute to electricity used for heating in buildings. Solar heating is a simple, but reliable technology that can contribute to the overall objectives of increased renewable energy sources and energy security.

Solar energy has very few environmental issues – there is no pollution, no noise, no danger for birds. Solar heaters and panels can be put on rooftops with minimal disturbance. So-called agri-PV systems are situated above ground in agricultural fields, providing shade for plants. The economics depend on the amount of solar resources, but our calculations indicate a levelized cost of electricity (LCOE) at between 31.2 and 41.6 EUR/MWh, which is quite competitive. Adding a battery to a rooftop PV installation may increases the cost by up to 140 EUR/MWh,but gives benefits in the form of convenience.

A problem for large-scale solar energy in Satu Mare is the lack of electricity grid infrastructure. In a survey Solar Power Europe found that Romania received a low assessment along the dimensions of grid planning and grid connection(Solar Power Europe, 2022a).

Figure S.1 Photovoltaic power potential in Romania



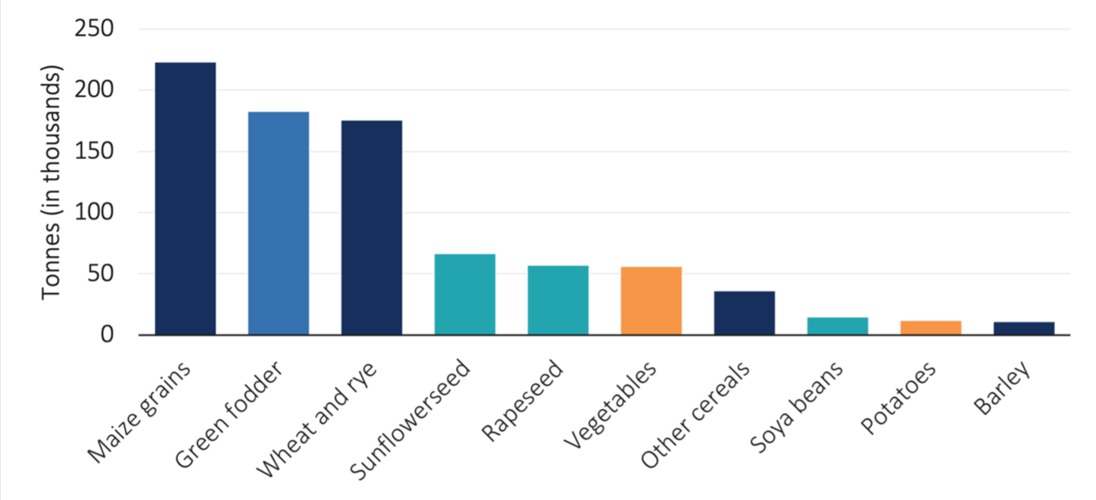
Source: The World Bank (2020).

Significant potential for bioenergy

Bioenergy refers to a family of technologies that use biomass to produce heat or electricity. For instance, biomass can beprocessed into e.g., pellets and used (burned) for heat and electricity, or converted to biogas. Biogas may be upgraded to biomethane. Biomass can also be converted to liquid form.

Biogas and biomethane are interesting possibilities for Satu Mare. Agricultural residues, animal manure, municipal solid waste and wastewater sludge are sources of biogas. Most of the land area in Satu Mare is used for agricultural purposes. Figure S.2 shows crop production in 2022. Cereals are coloured dark blue, green fodder is shown in blue, and oil crops are shown in light blue. Maize, wheat and rye are the most common cereals, while sunflower seeds, rapeseed and soya beans make up the oil crops. These crops are mainly grown for human consumption, but residues may be used for bioenergy.

Figure S.2 Crop production in Satu Mare in 2022



Source: INSSE.

Satu Mare has significant amounts of livestock as well. Total live weight of pigs for slaughter in 2022 amounted to 13 000 tons, and 12 000 tons of poultry (see chapter 4.2).

In terms of cost, international data indicate that biogas and biomethane electric plants have a cost comparable to combined cycle (natural) gas turbines (CCGT):80–350 EUR/MWh (see chapter 4.3). While these figures for resource potential and cost are suggestive, a more detailed resource and cost assessment should be made for Satu Mare.

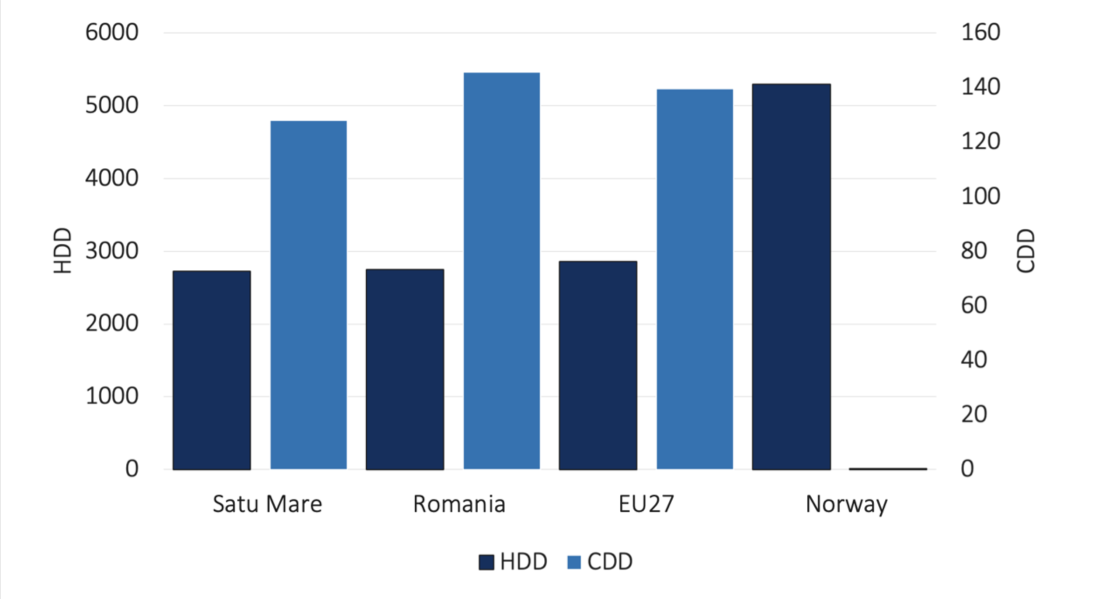
Energy efficiency will help the transition to renewables

While not a renewable energy source, energy efficiency improvements will help Romania and Satu Mare obtain goals for the share of renewable energy in the total mix. That is why the EU has established the *Energy Efficiency First principle* and set goals for energy efficiency improvements alongside goals for net carbon neutrality. The Casa Eficienta Energetic program in Romania supports the upgrading of energy efficiency by one energy class in single-family homes.

An important source of energy demand in buildings is heating and cooling. Figure S.3shows the need for heating and cooling in Satu Mare, Romania, the EU and Norway as measured by heating degree days (HDD) and cooling degree days (CDD).The HDD and CDD are weather-based indices that describe the need for heating and cooling ofbuildings, respectively. For instance, one day of 15 degrees below the base temperature gives a HDD of 15.

The figure shows that Satu Mare experience a HDD-value of close to 3 000 anda CDD-value of 140 per year. This fact requires buildings to be able to store heat when cold and remain cool when hot.

Figure S.3 Heatingdegreedays (HDD) and coolingdegreedays (CDD) in 2022



Source: Eurostat

Heat pumps, while common in parts of Satu Mare, come in different efficiencies, sizes and combinations of media (air, water, ground) for delivery and reception of heat. The expansion of heat pumps is an important energy efficiency measure in the REPowerEU plan. The technology is mature and could be implemented quickly. Support for heat pumps is included in the Casa Eficienta Energetic program. Good insulation is a second approach, e.g., targeting windows.Even though windows might make up only 5-10 percent of a building's outside surface, they can contribute about 40 percent of the building's heat loss in cold weather. Solar heating, exposing air or a fluid to the sun, is often mentioned in relation to energy efficiency since it reduces electricity and gas demand. The hot air or fluid can be used to heat the inside of a building directly or it can be connected to a heat exchanger and water tank for storage. Passive solarrefers to clever building design that exploits sunshine and natural warmth. Mindful planning is a key to passive solar, e.g., large windows facing south, but with an extended roof to provide shade during summer, and selecting building materials with high thermal mass. To aid energy efficiency it is useful to install monitoring and management systems, ranging from simple thermometers to thermal cameras and continuous monitoring through an app. In modern dwellings and commercial buildings, the system of ventilation is quite important as well.

The potential and applicability of these technologies in Satu Mare should be further investigated.

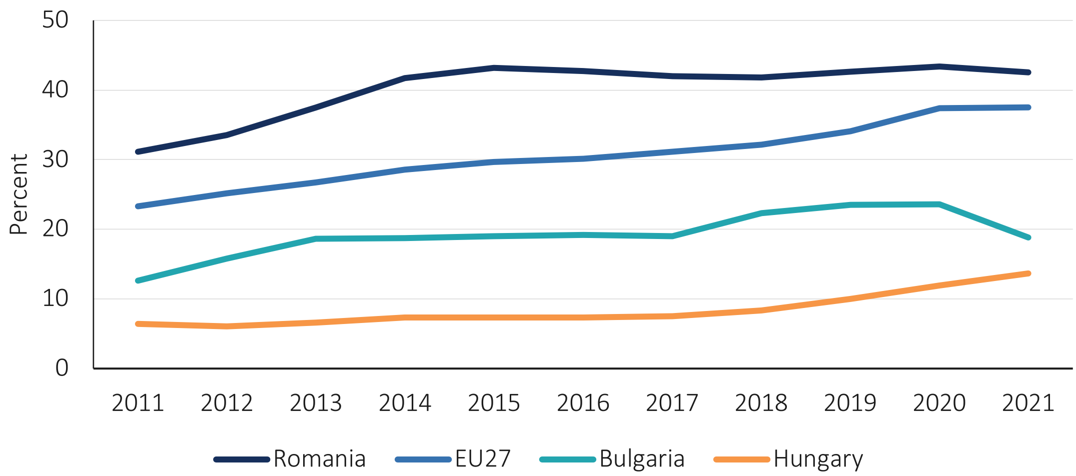
1 Useful backgroundinformation

This chapter provides useful background information for the chapters to come. We first take stock and briefly inform about renewable energy in Romania today, and the political goals and commitments to renewable energy in Romania and the EU. Then we discuss the motivation for the study. The motivation is the challenge facing Satu Mare, Romania, and the world in reducing global warming, reducing environmental impacts, and increasing energy security.Renewable energy sources may provide solutions to these challenges.

1.1 Energy production and consumption in Romania

Romania has a higher share of renewable energy sources in its *electricity* mix than its neighbouring countries, and higher than the EU-27 (Figure 1.1).The total renewable energy share in electricity production was 43 percent in 2021.

Figure 1.1 Share of renewable energy sources in electricity production



Source: Eurostat

Hydropower is by far the largest renewable energy source in Romania, making up 28 percent of all production in 2022, followed by wind at 12 percent (see chapter6). Solar PV is just 3 percent and bioenergy 1 percent. In chapter 3 and 4we argue that there is potential for additional solar- and bioenergy, respectively.

1.2 Where are we going?

1.2.1 The European Union

As a member of the EU, Romania is bound by EU’s goals and targets for GHG emission reduction, which implies more renewable energy.

The EU-wide goal is to cut GHG emissions by at least 55 percent by 2030 compared to 1990. There is also a separate goal for renewable energy: 42.5 percent of energy production should be renewable by 2030 (EU Directive 2023/2413). Note that the energy target refers to the share in *energy*, not electricity.

To support and supplement the GHG target, the EU directive on energy efficiency calls for a reduction of 11.7 percent in final energy consumption by 2030 compared to "business as usual" (EU Directive 2023/1791). In practice EU countries are required to achieve an average energy savings rate of about 1.5 percent annually between 2024 and 2030.

In the longer term, the EU goal is net climate neutrality by 2050. In effect this means that by 2050 all energy production should be renewable or using CCS.

1.2.2 Romania

Romania's National Energy Climate Plan (Ministry of Environment, Waters and Forests, 2021) has set a goal of 49 percent renewable energy in *electricity* production in 2030, in other words an increase of 6 percentage points compared to today. The goal for the share of renewable energy in *energy* production is 30.7 percent. This figure is pulled down by lower shares in transportation (14.2 percent renewables) and heating and cooling (33 percent).

To reach these goals, and as a part of the Romanian National Resiliency and Recovery Plan, coal and lignite will be phased out from electricity production by 2032. This entails replacing about 20 percent of total production and is a huge opportunity for renewable energy technologies. Factoring in some increase in total consumption, the goal is to develop 6.9 GW renewable energy by 2030, compared to 2015.

1.3 Why renewable energy in Satu Mare?

There are several reasons why renewable energy is important for Satu Mare. Four important reasons are:

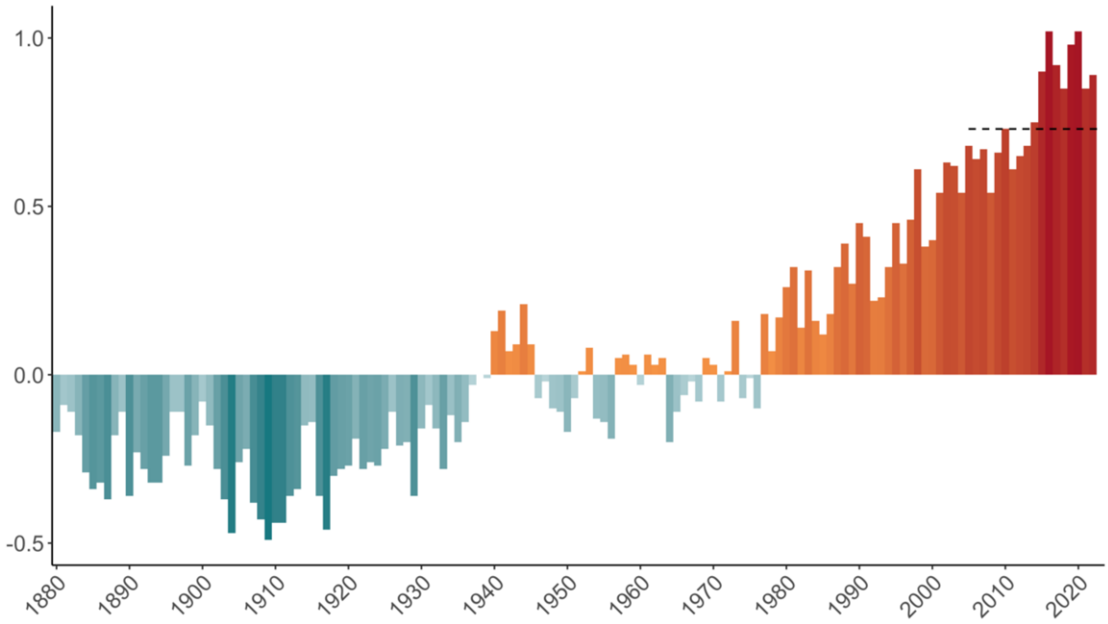
1. Global warming
2. Air pollution
3. Energy security
4. Economics

We will discuss these reasons in turn.

1.3.1 Global warming

The backdrop of almost all energy planning these days is climate change, and there is a global effort to minimize global warming. Figure 1.2shows global mean temperature relative to the average between 1951-1980.The dashed line shows the nine recent years: they have been the hottest on record. The world is getting warmer. The most recent IPCC report (IPCC, 2023) clearly shows that global warming has started – but also that it will accelerate in the decades to come. This strongly suggests that each and every community should consider new renewable energy for the future.

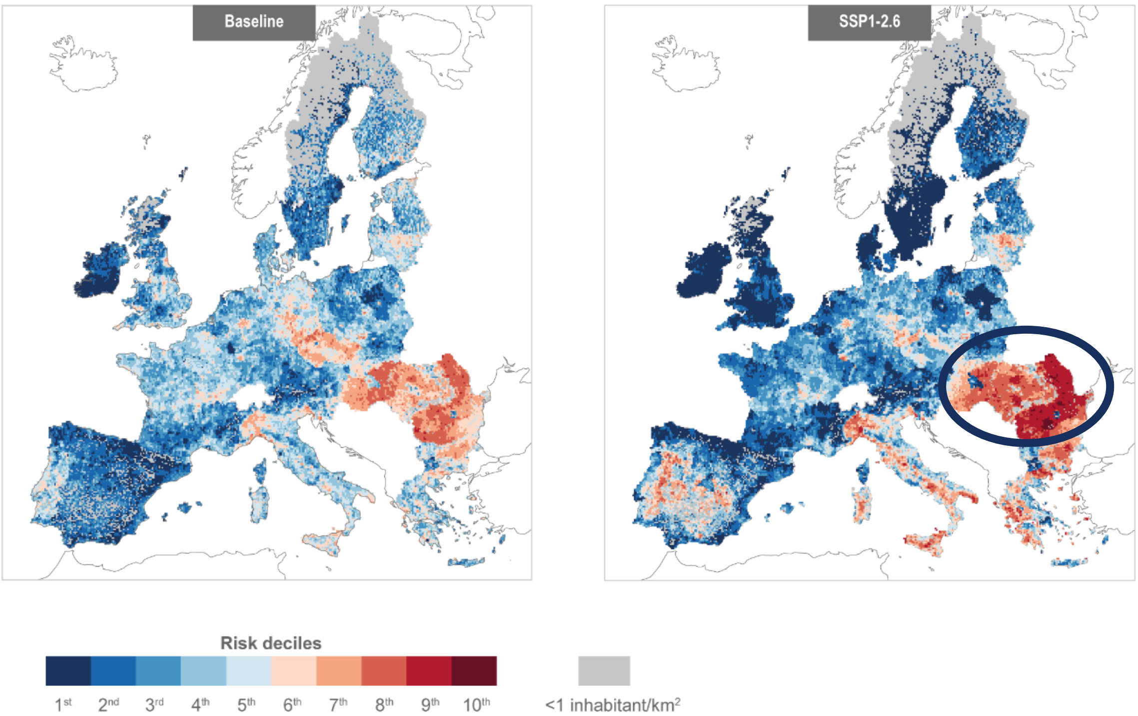
Figure 1.2 Global mean temperature is increasing



Source: GISTEMP – NASA Goddard Institute for Space Studies.

The map below (Figure 1.3) shows that Romania, Moldova and Bulgaria are particularly vulnerable to heat stress in the decades to come.The darker red colors in the map indicate regions that are likely to experience a higher number of heatwave daysand where the population is more vulnerable and exposed to this (IPCC, 2022). The panel on the right showsthe heat stress risk in the scenario where the world's CO_2 emissions are cut to net zero by 2075 (the IPCC's SSP1-2.6 scenario). The risk is even higher in the scenarios where we do not achieve this goal (IPCC, 2022).

Figure 1.3 Projected heat stress for people, 2040-2060



Source *IPCC (2022), Chapter 13..*

1.3.2 Air pollution

Thermal power is a source of air pollution while wind and solar are not. Air pollution caused by the "traditional pollutants" – particulate matter smaller than 2.5 microns per cubic meter ($PM_{2.5}$) along withnitrogen dioxide (NO_2) and ozone (O_3) – is still a serious problem in Europe. The European Environment Agency publishes estimates of annual premature deaths because of air pollution. The current estimate for Romania is about 25 500 premature deaths per year (Table1.1).

Table1.1 Premature deathsdue to air pollution ($PM_{2.5}$, NO_2, O_3) in Romania in 2021

$PM_{2.5}$	NO_2	O_3
19 600	4 900	1 000

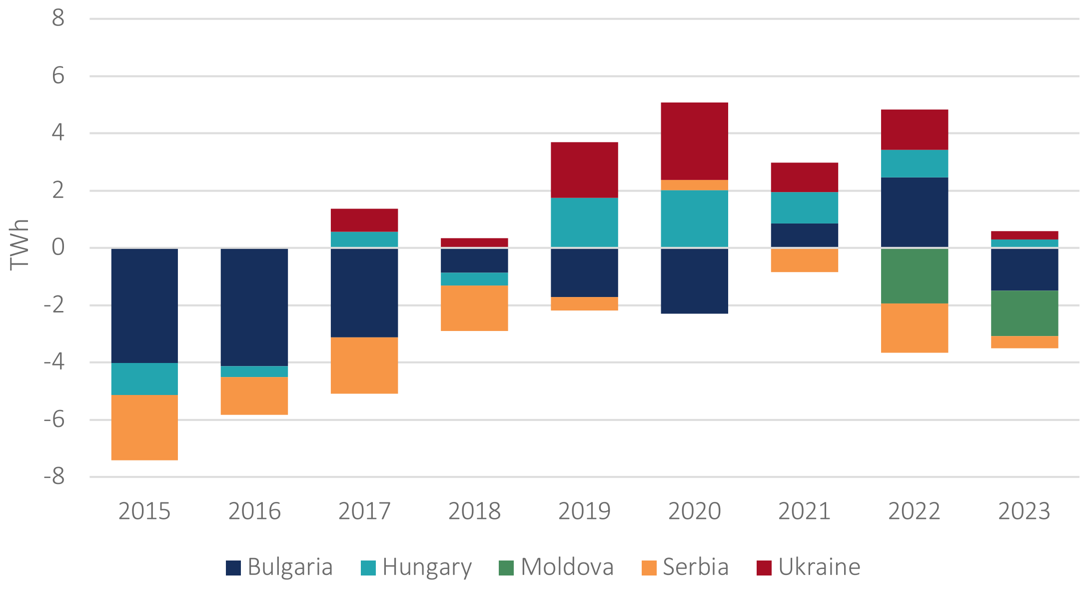
Source: European Environmental Agency (2023)

A premature death from air pollution does not mean that the death certificate says air pollution. People die of heart attack, lung cancer and similar. Premature deaths from air pollution means that there is a statistical association between these nominal causes of death and air pollution. According to the European Environmental Agency(2023), no other country has more premature deaths from air pollution than Romania.

1.3.3 Energy security

Following the strangling of natural gas supplies to Europe in 2022,energy security has climbed higher on the policy agenda. In recent years Romania has moved from a net exporterof electricity to a net importer. Figure 1.4 shows that in 2019-2022 imports from abroad were higher than exports. If this continues, Romania may be put in a vulnerable position with less energy security.

Figure 1.4 Cross-border physical electricity imports (positive) and exports (negative)

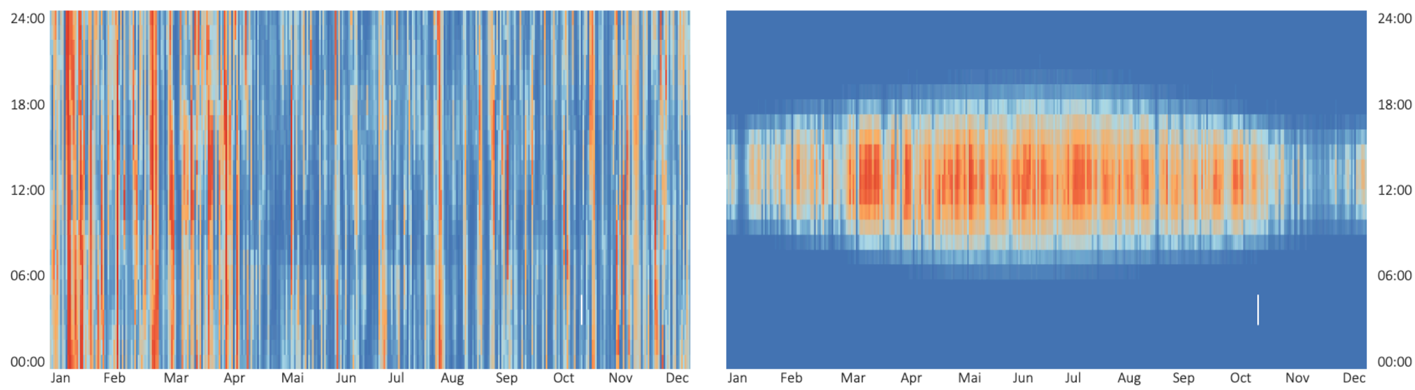


Source: Energy-charts.info (Entso-e). 2023 figures include data until August 23, 2023.

To be sure, renewable energy has some security-related problems of its own. A major problem is that renewable energy supply from wind and solar is volatile. Figure 1.5 showselectricity production in Romania from wind (left panel) and solar (right panel). The vertical axis shows the hours of the day, while the horizontal axis shows the days of the year. The colour red indicates days and hours where production is high, while dark blue indicatesno production.

The wind electricity production pattern in the left panel shows that windy days are followed by quiet days. But there is moreproduction (red) to the left, in winter, and morequiet (blue) in the middle, in summer. The solar electricity production pattern in the right panel shows production during the day (obviously), but less so in winter. Peak production is in summer.

Figure 1.5 Electricity production from wind (left panel) and solar (right panel) in Romania, 2022



Note: Red colour = high production. Blue colour = no or low production

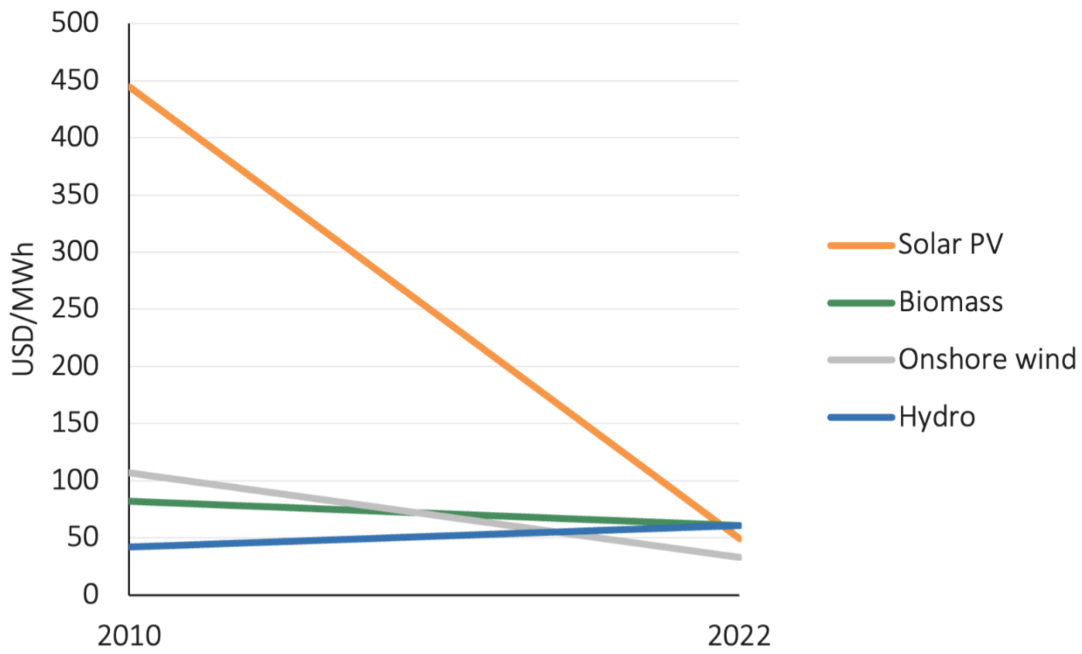
These patterns suggest two things. First, energy security is improved when wind and solar power are combined: the additional solar in summer and additional wind in winter complement each other. Second, volatility remains even when combining wind and solar. This means that for maximum energy security one should combine wind and solar with either back-up production, or transfer from other parts of the country, or transfer from other countries (imports). Back-up production could be bio-based or thermal. In the future, storage technologies (batteries, hydrogen storage etc.) will be developed, but large-scale storage is not commercial yet.

1.3.4 Costs are reduced

Cost is a traditional barrier to renewable energy. However, costs are being reduced. Globally, costs of solar photovoltaics (PV) and (onshore) wind are currently competitive with fossil fuels, following dramatic cost reductions, not least for solar, since 2010 (Figure 1.6).

Of course, for Satu Mare it is the local cost and price of electricity that matters. However, these global trends show that one should not plan for fossil fuels without seriously investigating the business case for renewable energy technologies.

Figure 1.6 Globalaverage levelized costs of selected renewable energy sources



Source: IRENA (2023).Note: Two data points: 2010 and 2022

2 What makes a good technology?

This chapter presents a framework of indicators for policy makers and stakeholders in Satu Mare as they develop ideas for investments in renewable energy. It may guide planning atSatu Mare county level, in individual cities and towns, and concrete investment projects and investments into ancillary services such as grid, resource logistics etc.

In short, the elements of the framework are:

1. The physical resource potential – a necessary starting point.
2. Land availability – for siting of plants, and for land-intensive physical resources.
3. Infrastructure and grid access – for moving resources in and electricity out.
4. Economics –to focus attention on low-cost alternatives.
5. Environmental and social impact – positive contribution is a gain to society.
6. Technical knowledge – successful implementation requires familiarity with the technology.
7. Policy and regulatory environment – price, support scheme etc. in the short and long run.
8. Impact on energy security – positive contribution isa gain to society.

2.1 The physical resource potential

Having the physical resources to produce energy is a necessary condition for any technology. Resources for renewable energy typically depend on weather patterns, such as wind, precipitation and solar radiation. Biological waste is another potential resource. Evaluating whetherthe physical resources are available and in which amount is a first step in assessing the potential of a technology.

2.2 Land availability

Land is a limited resource and land-use change is an important driver of global warming (IPCC, 2023). It also affects our environment and biodiversity. Some RES technologies, such as wind and solar power, are more land intensive than conventional energy sources (nuclear, natural gas, coal). In the context of Satu Mare, we focus on the land requirements such as the area needed for solar panels or wind turbines. This might include evaluating land ownership, zoning regulations, land-use restrictions, and negative spill-over effects and potential conflicts with existing land uses and near-by firms and households.

Having available land for the necessary infrastructure is a second aspect of "land availability". Here the difference between the RES and conventional energy technologies is less stark.

2.3 Infrastructure and grid access

Production and consumption of energy usually occur at different locations. Energy must be transported, and for large RES it is necessary to identify areas with sufficient transmission and distribution capacity. Grid infrastructure is often expensive, and a cost-efficient deployment of grid infrastructuremight require high-level planning, taking into consideration where consumption is established and where the best locations for production are. Distributed energy sources, such as small-scale solar panels, might also come with grid requirements, e.g.,in order to enable consumers to become prosumers and feed surplus power to the grid.

2.4 Economics

The potential for any RES will only be realised if a sound business case can be provided.Since prices are difficult to change,the question becomes what the costs of developing a RES project are. Although costs are falling for most RES technologies internationally,what matters for Satu Mare is the cost condition in Satu Mare, relative to prices and income.

From a societal perspective, it is total benefit to society, rather than total income over cost, that matters. A cost-benefit analysis is an analysis that starts from the business case and adds "income" if a project entails positive environmental and social impacts, or contributes to energy security, i.e., incorporates indicators below.

The potential of RES should only be realized if benefits exceed costs. With positive environmental and social impacts,benefits may exceed costs even if the business case is negative, i.e., the income is lower than the cost. In such cases it is important to strengthen the business case by means of public support. Most support instruments are found at the national or EU-level, but Satu Mare as a community may also consider support. The community may for instance provide land and certain infrastructure services, or help with financing (municipal bond, local bank).

2.5 Environmental and social impact

Different sources of energy consumption carry different types of impacts on its surroundings, both society and nature. For instance, fossil fuel technologies, such as coal-fired power plants, may have a severe impact on people's health due to polluting the air (see above). Wind turbines cause noise and disturb people living in their proximity; they may also have a negative effect on bird populations. Ignoring such impacts on the surroundings may lead to loss of public support and political backlash.The impact on greenhouse gas emissions, in particular, is important for decisions today and will probably become more important in the next few years.

2.6 Technical knowledge

Some technologies are more complex than others. The installation, operation and maintenance of energy systems may require skilled workerswhoare familiar with the technology. The practical potential for investing in and operating RES technologies may be severely limited if skilled workers of the right sort are not available.

2.7 Policy and regulatory environment

As indicated above, the political and regulatory environment may have significant effects on the costs and performance of the deployment of RES technologies. Regulation sets the rules of the game and can have severe impacts on the viability and profitability of projects. Permitting and licensing, grid access and interconnections, net metering, land-use regulations, market access and competition rules are some examples. In addition, political goals such as renewable energy targets and commitments set a direction and typically come with incentive programs.

It is important to note that regulation and policies often come with different welfare and distributional effects. For example, subsidies aimed at deployment of new energy technologies can be capital intensive which can lead to benefits being distributed to those that have the capacity to invest. Geographical distribution effects are another example, where areas that host new renewable energy infrastructure may attract economic activity at the expense of other areas, or conversely, the area can face environmental impacts such as land-use change.

2.8 Impact on energy security

Energy in general, and electricity in particular, is a necessary input for modern society. Energy security means always providing reliable production and transportation of energy to the end-users, at anaffordable price. Increasing energy security means reducing the risk of disruption or reducing the consequences of disruption (or both). Different technologies might have different effects on energy security.For instance,wind and solar power are intermittent.

2.9 Summary and guidance for the next chapters

It is beyond the scope of this report to delve deeply into all the indicators and all possible renewable energy technologies. In terms of technology, we will in the rest of the report focus mostlyonsolar and bioenergy and energy efficiency, which we will argue are the most promising technologies for Satu Mare. We will discuss these technologies in chapter3, 4and 7, respectively. Chapter 5 includes a brief discussion of other potential technologies.

In terms of indicators, we focus on the physical resource potential, land availability and costs. Some of the other indicators, like the availability of skilled workers or local infrastructure information, require intimate knowledge of the situation in Satu Mare. We leave it to our colleagues in Satu Mareto fill in on indicators where they have an advantage.

3 Solar energy has goodpotential in Satu Mare

In this chapter we assess the potential for solar energy in Satu Mare. Broadly speaking, technologies exploiting energy from the sun can be characterised as either passive or active solar energy. Passive solar energy technologies include smart building design and choice of materials that have good thermal mass or light-dispersing characteristics. These technologies are discussed further in chapter 7on energy efficiency.

Active solar technologies include concentrated solar power (CSP), photovoltaic (PV) cells, and various forms of solar heating systems. These technologies convert solar radiation to electricity or heat. It is the active solar energy that we focus on in this chapter.

3.1 Three important technologies for exploiting energy from the sun

We here highlight three important technologies that exploit energy from the sun: photovoltaic cells, concentrated solar power, and solar heating systems. These are mature technologies that are available in the market today.

3.1.1 Solar photovoltaics (PV)

Solar photovoltaic (PV) cells generate electricity directly from sunlight. A solar PV cell is made of a semiconductor material, i.e., a material that conducts electricity only when energy is provided. The most common semiconductor material used in PV cells today is silicon, employed in 95 percentof global PV production(IEA, 2022). The remaining 5 percentaremainly thin-film PV cells made from cadmium telluride, but this technology will not be discussed further in this report.

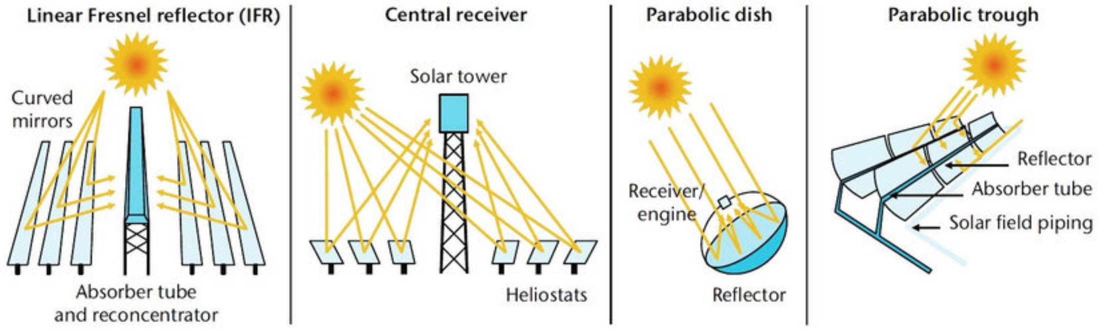
The semiconductor material is typically layered,where the layers have opposing charges to create the potential for an electric field. The layers are connected by anelectrode that creates a path for electrons to flow. When sunlight hits the PV cell, it absorbs the sunlight by transferring the energy to negatively charged electronsthat then flow through the electrode and produce direct current (DC) electricity. Many PV cells are connected to increase the voltage to usable levels. The DC electricity is then passed through an inverter to transform it to alternating current (AC) electricity that can be used in household appliances or fed into the grid.

Solar PV panels can be deployed at any scale. Hence, it is one of few technologies that offers a decentralized power production potential, where households, firms and farms can produce their own low-voltage electricity. Another major benefit is that it can be installed on any surface that receives sunlight. This includes surface areas that are already in use, such as buildings and other infrastructure. Thus, solar PV systems can be installed without the need to convert scarce land. Solar PV panels do not produce any emissions or noise during electricity production.

3.1.2 Concentrated solar power (CSP)

Concentrated solar power (CSP) technologies use mirrors to reflect and concentrate sunlight on a pipe or container with a fluid inside, e.g., synthetic oil or molten salt. The concentrated sunlight heats up the fluid before it is transported to a heat exchanger where it transfers heat to water or another fluid that can drive a steam turbine to generate electricity. Alternatively, the heat can be used directly in industrial processes or in district heating systems. Figure 3.1 illustratesfour different CSP technologies. One major benefit of CSP is that heat can be stored (by heating up adjacent reservoirs of fluids), thus a CSP plant that incorporates thermal energy storage can be a dispatchable form of renewable energy.

Figure 3.1 Illustration of common types of CSP technologies



Source: Enache et al. (2019)

CSP works best in regions with clear air that receive a lot of sunshine. In Europe, this is mostly in Spain, as indicated inFigure 3.2, where there is already 2310 MW of installed capacity of CSP in 2023, compared to only 22 MW in the rest of Europe.[1]

3.1.3 Solar heating

Solar energy can also be used to directly heat water and air in buildings. Although solar heating systems do not produce electricity, they offer an attractive substitute for electricity used for heating in buildings. A solar heating system is a simple, but reliable technology that can contribute to the overall objectives of increased renewable energy sources and energy security.

Solar heating can be used both for water and air heating. A solar water system typically consists of a collector and a storage tank. The collector area might consist of tubes containing some antifreeze liquid and a material or coating that absorbs heat from the sun. The liquid is passed through the tubes in the collector area where it heats up before being transported to a heat exchanger where the hot fluid transfers heat to water that can then be stored in a tank. A best-practice example on using solar heating is described in section7.4.

Similarly, air can be circulated through a collector area where sunlight heats the air before this hot air is circulated into a house for heating. A well-designed solar air heating system can provide air with temperatures well above normal indoor temperatures even in winter when outside temperature is below zero degrees Celsius.

[1] Installed capacity data are from SolarPACES – NREL database, which is found here: https://www.solarpaces.org/worldwide-csp/csp-projects-around-the-world/

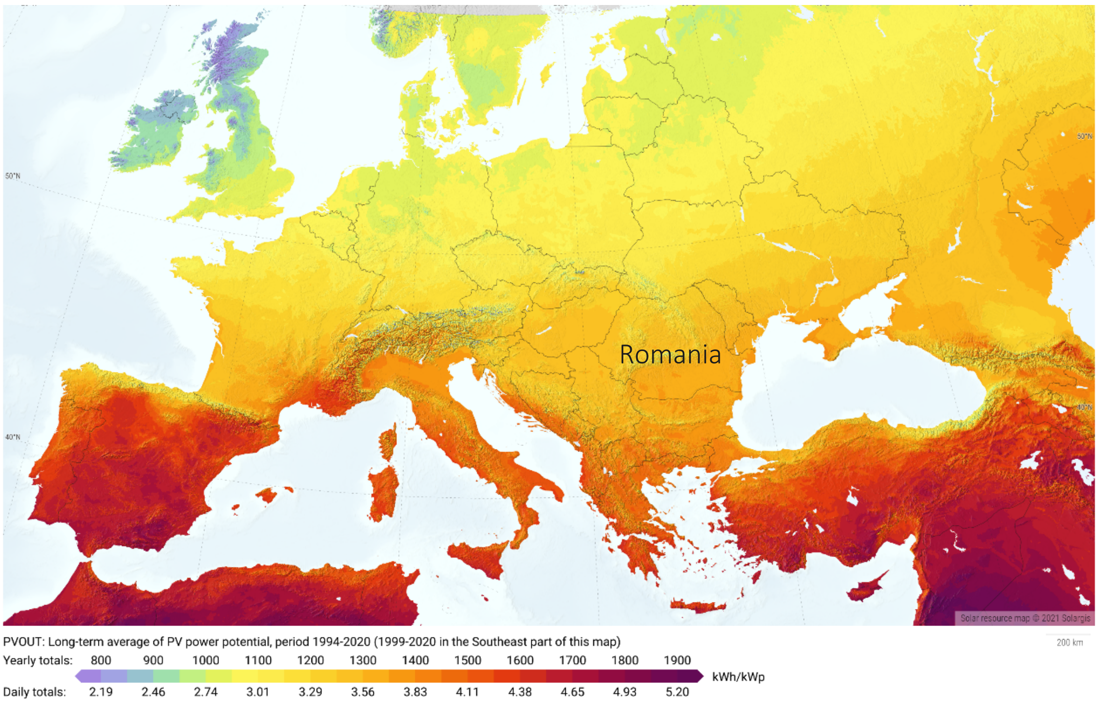
Solar air- or water heating is a mature and simple technology that has existed for decades and might be an attractive option as a renewable energy source for dwellings in Satu Mare.

3.2 Resource potential

There are several issues to consider when estimating the power potential of solar PV panels in a region. One of the most important and basic parameters for the resource potential and energy yield estimation is*solarirradiation*.Figure 3.3 shows estimated solar PV power production potential in Romania and Satu Mare, where red indicate the highest potential and blue indicate the lowest potential. For comparison,Figure 3.2 show the same for Europe. The estimation assumes a PV system configuration with ground-based crystalline-silicon PV modules installed in a fixed position with optimal tilt, and it considers solar radiation, air temperature, and terrain.[2]

Southern Romania has excellent potential for power production from solar PV. The potential in northern Romania and in Satu Mare is relatively smaller as indicated in Figure 3.3 and Figure 3.5. Nevertheless, Satu Mare is well suited for solar energy production compared to the rest of Europe (Figure 3.2).

Figure 3.2 Photovoltaic power potential in Europe

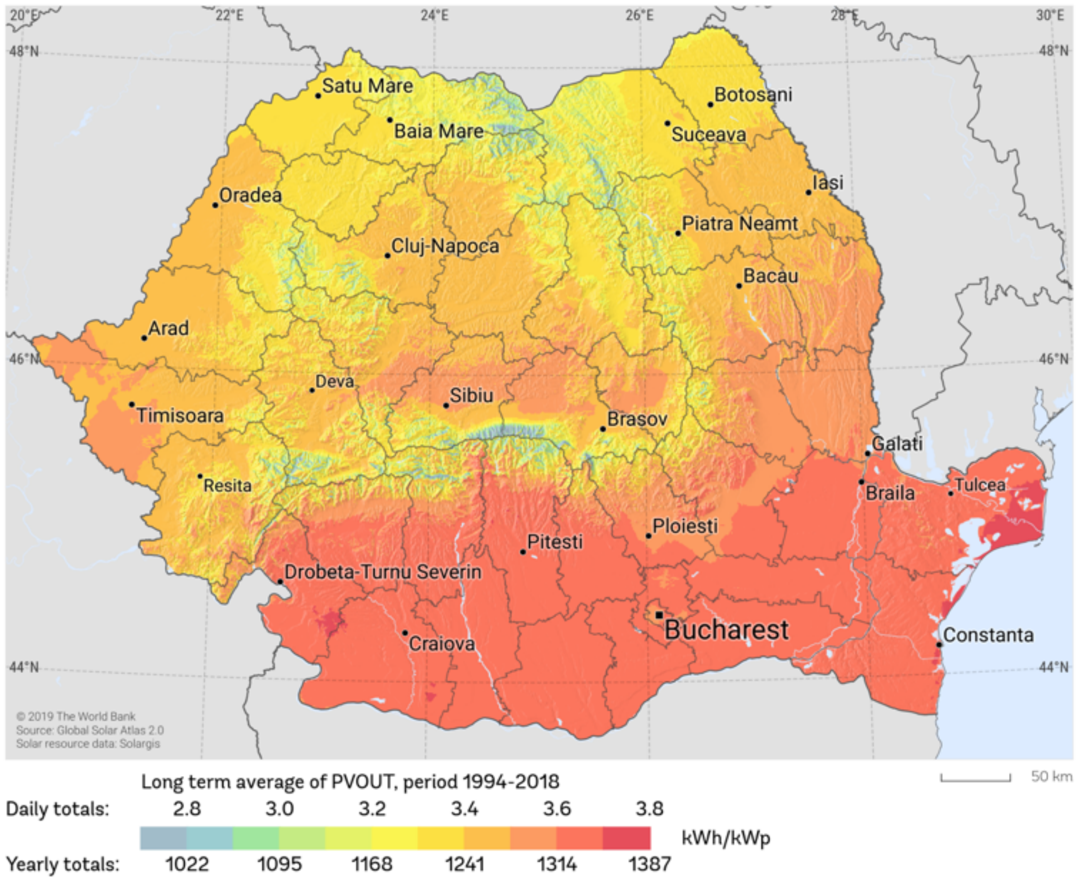


Source: The World Bank (2020).

Large solar PV farms should be coordinated on a higher level to ensure system efficiency. It might be more cost-effective to build large solar farms with higher output in the south and transmit power to the north, compared to building solar farms with lower output in the north, but it is beyond the scope of this report to investigate this trade off further.

[2] The calculation assumes 3.5 percent losses due to dirt and soiling and 7.5 percent of other conversion losses such as inter-row shading, inverters, cables and transformers.

Figure 3.3 Photovoltaic power potential in Romania.



Source: The World Bank (2020).

As indicated in Figure 3.3, the resource potential in Satu Mare is estimated to be higher than 1 200 kWh of yearly production per kW_p of installed capacity. This means that a solar PV panel that has a peak capacity of 1 kW, can be expected to produce 1 200 kWh in one year.[3] Depending on the efficiency of the PV panel, a $1kW_p$ panel might take up an area of 5-7 m^2.

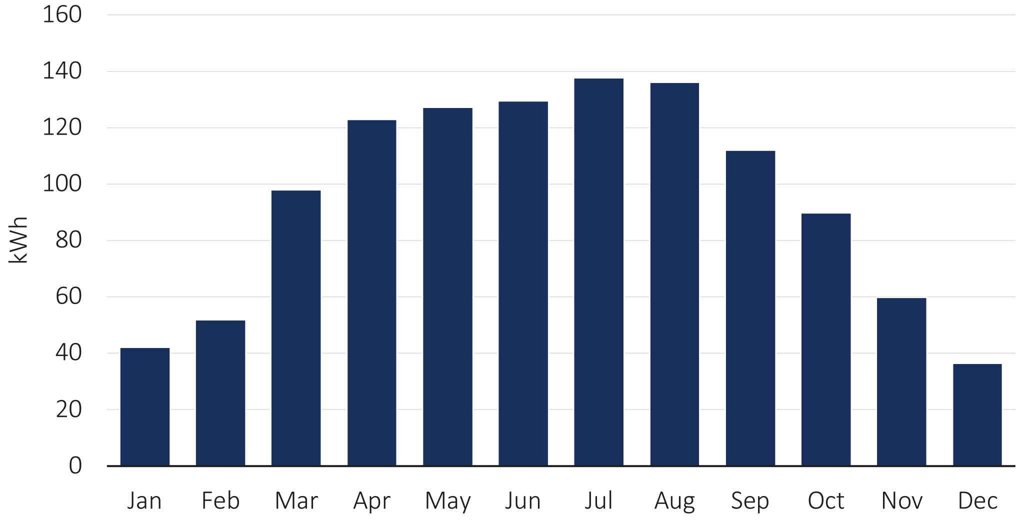
The average household consumption of electricity in Romania is around 2 600 kWh per year, meaning that even a small PV system that covers 5-7m^2 can provide about 40 percent of a household's electricity needs.[4]

It is important to note that production will not be evenly spread across the year, since irradiation is lower in winter months than in the summer months. Figure 3.4shows how the production is estimated to spread across the year, with more than three times as much being produced in July than in January. This variation across seasons and across the day will necessitate other energy sources or storage to balance demand.

[3] 1 kW for 1200 hours gives 1200 kWh. For comparison, there are 8760 hours in the year.

[4] The European Commission's Joint Research Centre has made available anestimation tool called PVGIS that can be used to simulate how much electricity can be generated from a solar PV panel of different technologies and system assumptions. The tool can be found on this website: https://re.jrc.ec.europa.eu

Figure 3.4 Estimated average monthly power production from a 1kW$_p$ panel in Satu Mare



Source: EU JRC (2022).

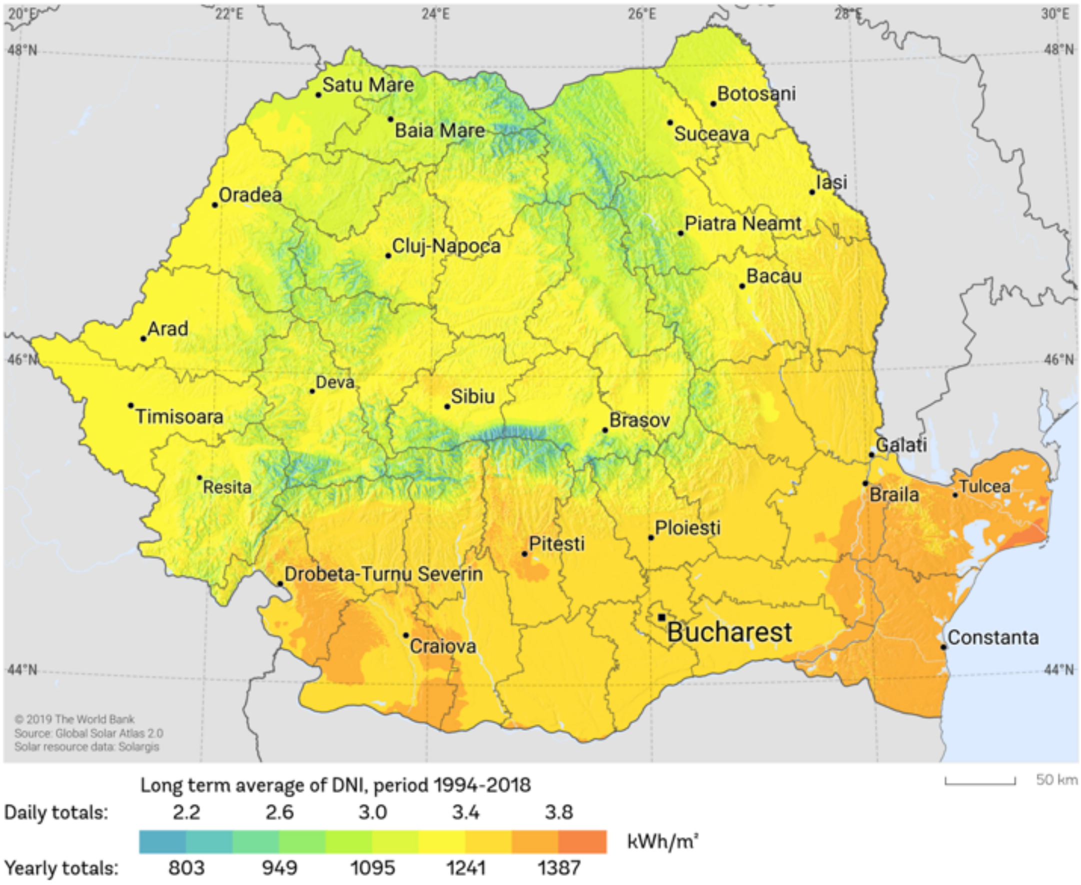
To putthe potential into perspective: power production from solar PVs contributed only 2.5 percent of net electricity production in Romania in 2022.Most of the production took place in the large solar farms in the south. In comparison, solar PV contributed to more than 10 percent of net electricity production in Germany in 2022.[5] This is despite Germany having a lower resource potential for solar energy than Romania, as shown inFigure 3.2. Other things equal, and given Romania's better resource potential, the share in Romania should be higher than Germany's 10 percent.

The physical resource potential for CSP seems limited in Satu Mare. The amount of direct normal irradiation (DNI) received is an important measure of the resource potential for CSP plants. CSP plants are in general suitable for regions with annual direct normal irradiation of more than 1900 kWh/m^2(Alami, et al., 2023). In regions that receive less DNI than this, PV cells might be better as they can better capture diffuse irradiances.

Figure 3.5 shows that Romania in general, and Satu Mare in particular, receive DNI well below 1400 kWh/m^2. Thus, based on this theoretical resource potential, CSP is probably not the renewable technology with the best potential in Satu Mare.

[5] The numbers are collected from energy-charts.info and based on data from ENTSO-E.

Figure 3.5 Direct normal irradiation in Romania



Source: The World Bank (2020).

3.3 Land availability

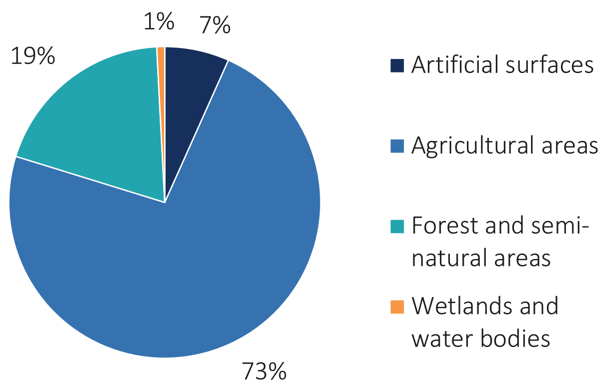
Producing electricity from solar irradiation requires large land areas where the solar panels have a direct view of the sky. Land-use change, typically in the form of deforestation or soil degradation, can lead to higher CO_2-emissions in addition to reduced biodiversity. It is therefore preferable to exploit land for PV that has already been converted to human use and infrastructure, rather than converting forests and natural areas.

Figure 3.6shows how land area in Satu Mare is distributed between artificial surfaces, agricultural areas, forests and semi-natural areas, and wetlands and water bodies. Forests and semi-natural areas make up 19 percent of the total land area. These areas also consist of several Natura 2000 sites, which are protected areas for animal species or habitat types listed in the EU's Habitats and Birds Directives. These areas are coloured green inFigure 3.7.

More than 70 percent of the land area in Satu Mare is agricultural land, consisting mainly of non-irrigated arable land (52 percent) and pastures (12 percent). In addition, there are artificial surfaces, which include buildings, roads, and other human infrastructure, that make up 7 percent of the total land area in Satu Mare.

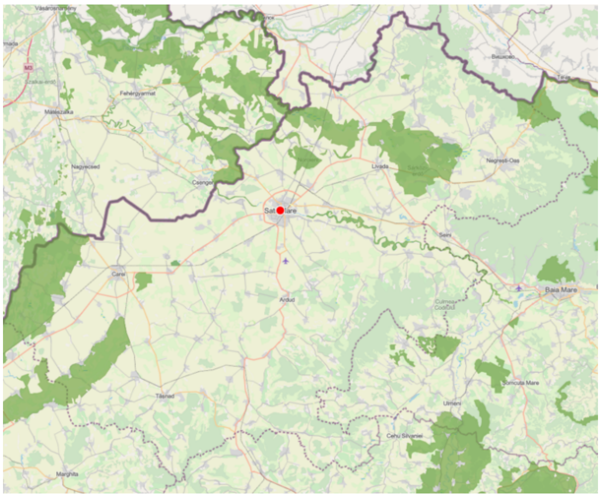
Solar PV panels can be deployed both on artificial surfaces, such as building rooftops, and on agricultural land, either by replacing agricultural production or by combining solar PV production and agricultural production, often called *Agrivoltaics* or *Agri-PV*.This option is further discussed in chapter 3.4.

Figure 3.6 Land cover classification in Satu Mare



Source: The European Environment Agency(2019).

Figure 3.7 Natura 2000 sites in Satu Mare



Source: The European Environmental Agency (2021))

3.4 Agri-PV

Agri-PV, or *agrivoltaics*, is the dual use of land with ground-mounted solar PV panels and agricultural production. Agri-PV offers the opportunity to use existing agricultural land for solar power production, while at the same time continuing with agricultural production. The technology has developed rapidly since the first agri-PV systems were installed in France and Italy in 2011. Global installed capacity in 2021 was 14 GW_p, an increase from 5 MW_p in 2012(Fraunhofer Institute for Solar Energy Systems, 2022).

Agri-PV technologies can be roughly separated into two categories: open systems and closed systems, where closed systems typically mean greenhouses with PV installations. Open systems include ground-level interspaced PV panels and overhead PV panels. Open systems might be more relevant for Satu Mare. Ground-level interspaced systems are generally cheaper, but only allow farming in between panels. Overhead systems are typically installed a few meters above ground, which allows the ground beneath to be used for farming. Hence, overhead systems use land more efficiently, as the PV panels do not displace as much farming land. However, overhead systems might reduce crop yield as the amount of sunlight reaching the ground is lower. This will depend on local conditions and the type of crop farmed. Many crops are shade tolerant, such as potatoes, tomatoes, peppers, lettuce, broccoli, and corn. In some cases, overhead agri-PV systems might even increase crop yieldas they can offer protection from hail, frost, drought and heat, which can offset the negative effect of reduced exposure to the sun(Fraunhofer Institute for Solar Energy Systems, 2022).

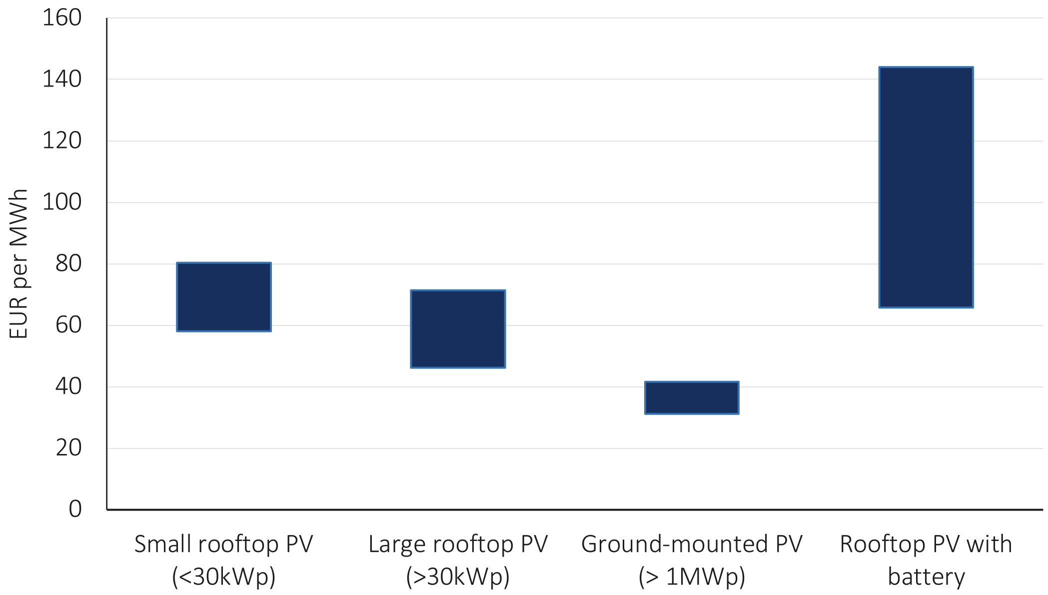
In addition to the benefit of more efficient land-use and potential to increase crop yield, especially in years with more extreme weather, agri-PV can also give farmers an additional source of income. Whether this income is enough to offset the investments in the infrastructure and PV modules needs to be assessedcase by case in Satu Mare.

In some specific cases, agri-PV can also help to improve bio-diversity by improving local flora and fauna, in particular in land with monoculture agricultural production (Solar Power Europe, 2022b).

3.5 The economics of solar PV

Figure 3.8 shows the levelized cost of electricity (LCOE) for solar PV panels. The calculation is based on observational data from Germany, but the level of global horizontal irradiation used in the calculations is 1300 kWh/m^2 per year (southern Germany) which is similar to the level in Satu Mare, making the calculations relatively comparable.

Figure 3.8 Levelized cost of electricity of solar PV



Source: Vista Analyse based on Fraunhofer Institute for Solar Energy Systems (2021)

The LCOE is an average cost measure taking into consideration the cost of construction and installation, financing costs, operating costs, and plant lifetime.

Large ground-mounted PV panels offer the lowest levelized cost of electricity (LCOE) at between 31.2 and 41.6 EUR/MWh (2021-€). Costs per unit of electricity is higher for smaller systems and for rooftop systems. Adding a battery will significantly increase costs. However, the LCOE does not consider the value of the electricity produced. A battery can store power and dispatch it when prices are high, which can contribute to the financial viability of battery systems not captured in the LCOE measure.

It is important to note that the LCOE is an average cost measure. It does not consider dynamic effects, such as when production is available and if the technology is dispatchable. Dispatchable technologies, like traditional gas-fired power plants, can turn on production when prices are high, while intermittent renewable technologies, like solar PV, only produce when the sun is shining, which is not necessarily when prices are high. Thus, the LCOE does not include the value of the produced electricity. Further, LCOE does not consider other advantages, such as ability to integrate energy storage, the number of full load hours and decentralized power production.

The costs of agri-PV systems vary greatly depending on aspects such as installed capacity, agricultural activity, position and necessary additional infrastructure, and the PV module technology. Compared to ground-mounted PV systems, agri-PV systems incur additional investment costs in the necessary substructure. This is in particular the case for agri-PV systems used in arable farming, where substructures might be more than 4 meters high(Fraunhofer Institute for Solar Energy Systems, 2022).

3.6 Other issues

In the following, we briefly discuss some of the issues mentioned in chapter2 that could influence the viability of solar energy in Satu Mare.

Although not investigated in detail in this report, participants at the seminar in Satu Marebelieved that **grid infrastructure**in the region could be a limiting factor for the expansion of solar energy. The lack of available grid capacity mayincrease costs and cause delays in the developmentof solar projects. In a survey circulated to national solar PV industry associations and in interviews with local industry representatives, Solar Power Europe found that Romaniareceiveda low assessment along the dimensions of grid planning and grid connection(Solar Power Europe, 2022a).

Some seminar participants voiced concernsabout the **environmental impact**of used solar PV panels.Solar PV panels can to a large extent be recycled.In silicon-based PV panels around 95 percent of the glass is recyclable and metal parts can be reused to form new frames for solar modules. In addition, 85 percent of the raw silicon material can be recovered (Ratner, et al., 2020). Whereas the share of end-of-life PV modules being recycled is less than 10 percent in the United States, it is almost 95 percent in the European Union (IEA, 2022).In addition, the lifetime of solar PV panels is long. Most solar panel manufacturers guarantee that the output will be at least 80 percent of the original power rating for 25 years and the average lifetime of a panel is 30 years (Faircloth, et al., 2019; IEA PVPS, 2018).

Solar PV panels can also be installed on existing infrastructure and artificial surfaces with little impact on nature and biodiversity. They may also be installed in combination with agriculture production, discussed in chapter 3.4. In some cases, solar PV panels installed on agricultural land can even help enhance biodiversity(Solar Power Europe, 2022b)

There are mainly two ways solar energy can impact **energy security**. Firstly, it can improve energy security as it brings productionclose to demand and under local jurisdiction/control. When distributed, solar power also has the benefit that it spreads production units across space and thus reduces the risk of disruption by reducing the concentration of production units.

A downside of solar energy with respect to energy security is the intermittency and dependence on the weather and seasons. Also, the panels themselves must most likely be imported from abroad. China currently dominates the solar PV supply chain, in particular in wafer production where it has above 97 percentof global manufacturing capacity, but efforts are being made in the European Union to strengthen the local PV supply chain. Norway is an important supplier of wafers in this respect. China is also well integrated into global markets and whether the high market share influences energy security is not clear.

Technical knowledgedoes not seem to be an issue. There are already several larger solar farms and many smaller ones in Satu Mare. Local seminar participants highlighted that there are several companies setting up small-scale units in the county.

4 Significant biomass resources in Satu Mare

Bioenergy refers to the energy contained in organic materials, also known as *biomass,* and the utilization of the energy. This includes biological materials that are directly or indirectly produced by photosynthesis. Through the photosynthesis, plants and plankton store energy, which can later be released either for the plant itself to grow, when eaten by an animal or human, when consumed by bacteria or when set on fire. In each of these cases energy is released.

Carbon is stored in the biomass. In a chemical reaction that releases the energy, the carbon will be released as well.[6]As long as the *consumption* of biomass is lower or equal to the *production* of the biomass, there will be a zero or negative addition of carbon to the atmosphere. Simply put, this means growing more trees than we burn. It is important to note that bioenergy is only *renewable* and *net zero* if this is the case. If combined with carbon capture and storage (CCS), bioenergy can also provide negative emissions.

There is a huge variety of biomasses. Some examples of biomass include wood, crops, algae, biodegradable garbage, and sewage. The energy contained in the biomass can be harnessed through different conversion processes to generate heat, electricity, or biofuels.

One way to categorise bioenergy sources is by types of technology, either as "traditional" or "modern" bioenergy. Traditional bioenergy refers to the direct combustion of biomass and is often associated with low energy efficiency and high negative impact on the environment through the release of pollutantsand carbon dioxide. Examples of traditional bioenergy are burning wood or animal waste for heat. Modern bioenergy includes advanced methods for burning biomass, indistrict heating units or heatandpower plants to produce heat and electricity; or converting biomass to syn-gas or bio-oil in a process of pyrolysis or gasification. A detailed discussion of these technologies is beyond the scope of this study.We focus here on a third technology, that is promising for Satu Mare:biogas. Biogas is produced through anaerobic digestion of residues or sewage waste, or wood-pellets heating systems.

4.1 Different ways of producing biogas from biomass

When we talk about *biogas* we typically mean a mixture of methane (CH_4), carbon dioxide (CO_2), and small quantities of other gases produced from organic matter. The exact content of a biogas sample will depend on the method used and on what type of feedstock is used in the production. There are three main technologies:

1. **Biodigestion**is a method where micro-organisms (bacteria) break down biomassin an environment without oxygen (referred to as an*anaerobic process*). This produces methane and digestate as a by-product depending on the feedstock.

[6]Fossil fuels are also a type of biomass. However, they are created in what is called *the slow carbon cycle*, which works over millions of years. Thus, the creation of fossil fuels will be lower than the consumption (burning) and add carbon to the atmosphere, essentially moving carbon from the slow carbon cycle to the fast carbon cycle.

2. Landfill gas-recovery systems capture methane gas that is produced by the decomposition of municipal solid waste under anaerobic conditions in landfills.
3. Wastewater treatment plantscan extract organic matter from sewage sludge anduse it to produce biogas in an anaerobic digester.Formally, it is an input or pre-stage to the technology biodigestion.

The methane content of the biogas produced (which is the part containing the most energy) depends on the method and feedstock used. As much as half of the biogas can be made up of CO_2,which is a stable gas that cannot be used for energy. Thus, the energy content of the biogas can vary greatly. Some consumptionpurposes, like transportation, require (almost) pure methane, which is called biomethaneif produced from biomass.

Biomethane can be produced by *upgrading* biogas, i.e., removing CO_2 and other gases so that only methane is left. Biomethane can also be produced from solid biomass through *thermal gasification,* but this is less common. Biomethane has identical chemical properties to methane (natural gas) and the same consumption purposes. Like natural gas, it will emit CO_2 when it is burned. The important difference is that biomethane is made from a renewable source, and as long as the biomass is sustainably sourced, emissions will be net zero.[7]Thus, biomethane can be used in gas-fired power plants, as fuel in buses and ships, or used for cooking and heating, with net zero emissions.

4.2 Biogas can be made from several types of feedstock

There are several feedstock options to produce biogas and biomethane with the methods discussed above. Energy crops are crops grown specifically for bioenergy purposes. These are typically low-cost and easy to grow, such as maize, sugar beet and millet. Energy crops are controversial for two reasons. Firstly, they require a largeland area and increased production may directly or indirectly lead to land-use change and deforestation. Second, they typically require fertilizers which, as of today, are mainly produced using fossilenergy sources, meaning net emissions can be high.

Due to the issues with energy crops, we instead focus on feedstock options that, in principle, do not require additional land or fertilizer use. From a circulareconomy perspective, it is better to look for biomass resources that are produced today, but underutilized. There are four main categories of biomass that can be used to produce biogas and biomethane: crop residues, animal manure, the organic content of municipal solid waste, and wastewater sludge. Using waste and residues as feedstock avoids the land-use issues and present a good circular-economy solution by utilizing existing resources better.

Agricultural production often leaves residuesthat can be used to make biogas. Examplesare residues from the harvest of wheat, maize, grains, sugar beet, and oilseeds like sunflowers. Sequential crops used in soil management, but not for food production, can also be used as these do not displace crop area for food production. Residues from forest management and wood processing can also be used to make biogas through thermal gasification.

[7]In fact, biomethane is sometimes referred to as *renewable natural gas*.

Animal manurecan be a good source of biomass. Livestock such as cattle, pigs, sheep and poultry produce manure over their lifecycle, which can be collected and used as input in anaerobic digesters to produce biogas. This is a common source of feedstock for biogas production in Europe today, and the most common feedstock used in China(IEA, 2020).

Municipal solid wasteis a more specific term for what is otherwise known as garbage or trash. Households and businesses produce waste in various forms that are typically collected by municipalities. Some of this waste is organic material that can be used for biogas production. Examples include food, leaves and grass, paper and cardboard that is otherwise not recycled. The organic content can be separated at the time of disposal, which for example is done in most of Norway (see chapter 4.5 below for a case example). It is also possible to extract biogas from landfills by using wells.

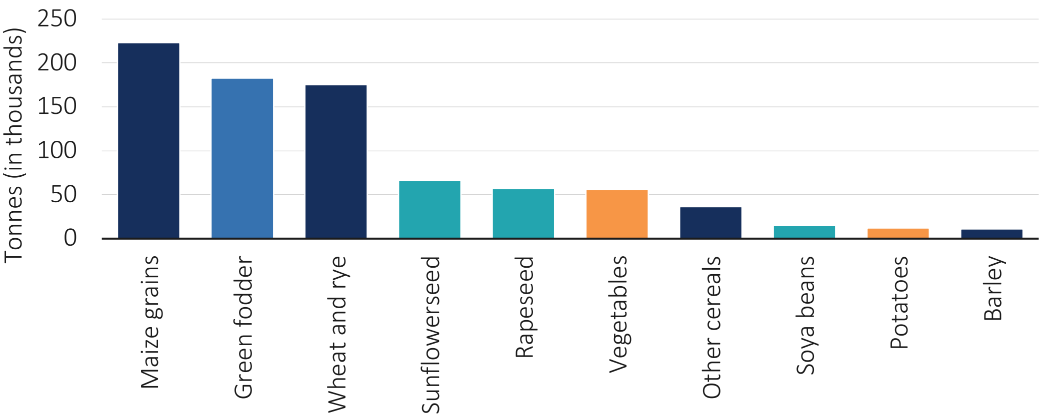
Wastewater sludgeis another feedstock that can be used to produce biogas. Sludge water contains semi-solid organic matter, which can be recovered as sewage gas in wastewater treatment plants. Chapter 4.5 shows a best-practice example from Norway of this method.

4.2.1 The agriculture sector in Satu Mare can provide feedstock for biogas production.

Most of the land area in Satu Mare is used for agricultural production(Figure 3.6). These agricultural areas mainly consist of non-irrigated land (72 percent) and pastures (17 percent). Cereals is the most common crop measured in tonnes, followed by green fodder, oil crops, and potatoes and other vegetables.

Figure 4.1 shows crop production in 2022. Cereals are coloured dark blue, green fodder is shown in blue, and oil crops are shown in light blue.Maize, wheat and rye are the most common cereals, while sunflowerseeds, rapeseed, and soya beans make up the oil crops. These crops are mainly grown for human consumption,but residues may be used for bioenergy. We do not have detailed data on the amount and quality of the residues to infer the potential for bioenergy production in Satu Mare.

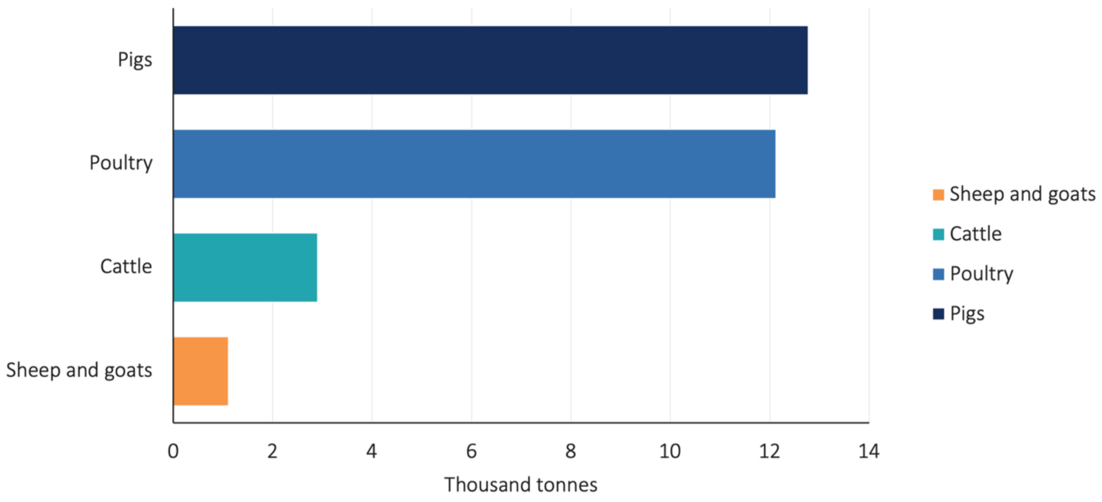
Figure 4.1 Crop production in Satu Mare in 2022



Source: INSSE.

In addition to crop production, there is also a lot of livestock in Satu Mare. Pigs and poultry dominate in terms of live weight, but there are also some cattle, sheep and goats. Livestock manure can be used to produce biogas, however, the energy content of manure is lower than in crop residues and municipal solid waste(IEA, 2020). Manure from pig and poultry contain more energy than manure from cattle, sheep and goats and thus provide higher biogas production yield.

Figure 4.2 Total live weight of livestock for slaughter in Satu Mare in 2022



Source: INSSE

4.2.2 Untapped potential in municipal waste collection

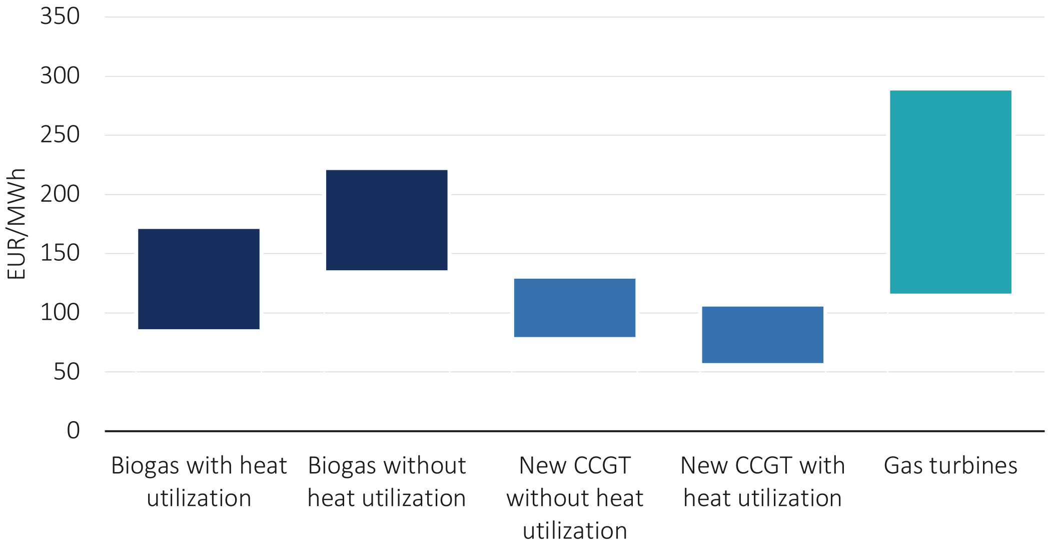
Household food waste is currently not separated and utilized in Satu Mare county. Waste is separated in glass, metal and plastic, but there is room for improvement in also separating food waste. Food waste, in addition to garden waste, has higher energy content than animal manure and about the same energy content as some energy crops like maize and oilseeds(IEA, 2020). In terms of resource utilization, this might provide an untapped potential for better utilization of biomass, e.g., to produce biogas. However,a more detailed resource assessment needs to be made to see if the resource potential is large enough to be financially viable.

4.3 Costs are competitive

The costs of biogas vary greatly depending on the technology, e.g., biodigester, wastewater digester, landfill gas recovery. Landfill gas recovery systems are typically the cheapest, followed by large biodigesters and wastewater digesters (IEA, 2020). Costs also depend on scale, with larger biodigesters typically having lower levelized cost of energy. Additional cost differentials also exist based on the feedstock used, e.g., animal manure has a lower energy content than energy crops, and on the costs and efforts required for collecting the feedstock. The business case for biomethane will also depend on the natural gas price, which can vary greatly.

We do not have data for electricity production from biogas plants in Satu Mare. However, we have data from Germany. Figure 4.3 show estimates for LCOE with a lower and upper limit for biogas plants, combined-cycle gas plants, and gas turbines, with and without heat utilization.

Figure 4.3 Levelized cost of electricity production from gas power plants.



Source: Vista Analyse based on Fraunhofer Institute for Solar Energy Systems (2021)

LCOE is an average measure that considers investment, financing, maintenance and operating costs over the lifetime of a plant. For a biogas plant with heat utilization (cogeneration) the LCOE will be lower than if the heat is not utilized.The estimated interval captures differences in investment costs and the amount of full load hours. The lower estimate show plants with high number of full load hours and a low investment cost. The upper estimate shows high investment cost and a low number of full load hours which contribute to a higher LCOE. Biogas with heat utilization is estimated to have a LCOE between 84.5 and 172.6 EUR/MWh of electricity generated. Without heat utilization, the costs arebetween 134.4 and 222.4 EUR/MWh. This is more expensive, but still competitive with a newly built CCGT gas plant, that has costs in the range of 55.9–107, and 77.9–130.6 EUR/MWh, with and without heat utilization respectively.

The LCOE estimates are sensitive to the substrate costs. The calculations assume a substrate cost of 38.4EUR/MWh.The LCOE can decrease with 9.0 EUR/MWhif substrate costs are reduced 20 percent. Thus, using predominantly manure and agricultural residues as substrate, which Satu Mare have good resources of, can reduce the LCOE-estimate of biogas plants that is shown here, making them even more competitive with CCGT plants.

4.4 Land availability and other factors

Land useof bioenergy depends on the feedstock used in production. Preferably, there should be no direct or indirect land-use change as a consequence of expanded bioenergy production. If energy crops are the main feedstock, this will add pressure to convert new land for crop cultivation, either by replacing crop production made for human consumption or by converting land areas such as forests. Using feedstock that is already produced but is underutilized may offer bioenergy resources without the negative effects of land-use change. Examples include waste water sludge, food waste, crop residues, and animal manure.

Biomethane can be animportant back-up capacity and increase energy security.Increased share of intermittent renewable energy sources, like wind and solar, will, in the absence of battery technologies, require adispatchable power source that can balance demand in time periods without wind and sun. Today that back-up capacity is often based on fossil fuel. Whereas fossil fuels do not get replenished in a relevant time scale, biomethane, sustainably sourced, offers a net zero backup-capacity technology. If it is also combined with carbon capture and storage (CSS), it can offer negative emissions.This is often referred to as BECCS (bioenergy with CCS). Having a stable and sustainable supply of biomethane can improve energy security by offering back-up capacity to balance demand without positive emissions of carbon in the atmosphere.

4.5 Best practice example of biogas in Norway

Below, we highlight two cases where surplus biomass has been utilized to produce biogas and biomethane. Biogas is made from organic matter from wastewater in Oslo's wastewater treatment plant *Veas*, and from food waste collected from residents in the city of Oslo and neighbouring municipalities in the *Romerike biogas plant*.

4.5.1 Veas Wastewater treatment plant outsideOslo

As part of the RENEWSM, a comprehensive workshopwas held for a delegation from Romania in Oslo in October 2023. The workshop included a visit to Veas' wastewater treatment plant outside of Oslo. This facility is Norway's largest wastewater treatment plant and collects wastewater from 800 000 individuals in Oslo and surrounding municipalities.It is a good example of how to extract additional value from already existing biomass.

Veas uses the organic contents of the wastewater to produce biogas, in addition to clean wastewater, liquid fertilizer, soil products, heat energy, and CO_2. In 2020, a new production facility for liquified biogas was commissioned. Wastewater sludge is separated and processed through anaerobic digestion. In the upgraded facility, the biogas is upgraded to biomethane (liquified). The plant produces and sells around 60 GWh of liquid biogas per year. One of its customers is the city of Bergen, which uses the biogas as fuel in public buses.

The plant also produces around 5 000 tonnes of liquid fertilizer (ammonium sulphate) per year and 40 000 tonnes per year of soil products based on sludgethat is sold to the agricultural sector.

Another subsidiary of the company, Hoop CO_2, was established in June 2023. CO_2 is a by-product of the biogas upgrading. Hoop CO_2 aims at collecting the $CO_2$and purifying it to food-grade quality. Thus, the CO_2 produced in the making of biomethane is collected, purified and can be resold to the food and beverage industry,which uses it for example for sodas and beverages. It offers a non-fossilsource of CO_2 for the food and beverage industry. Hoop CO_2 also plans to provide technical solutions for the extraction of CO_2 at other biogas facilities.

Figure 4.4 A can of beer produced using CO_2 collected at the wastewater treatment plant Veas

Photo: Vista Analyse

4.5.2 Romerike biogas plant – utilizing food waste

Food waste is separated from other types of waste in the city of Oslo and its surrounding municipalities. There are various ways this can be done. In Oslo, citizens sort their everyday garbage into three differently coloured bags:a green bag for food waste, a purple bag for plastics and an arbitrarily coloured bag for other trash. The coloured bags are available for free in local supermarkets.

The bags are disposed of in the same container outside the residences. The bags are sorted at the collection facility, which is made easier by the coloured bags. Plastic is recycled, while the food waste is sent to *Romerike biogas facility*. In addition to the household food waste, the facility accepts liquid food waste from industry and other businesses.

Figure 4.5 Household separate waste in three containers

Photo: Oslo kommune

Figure 4.6 Green bags for food waste

Photo: Oslo kommune

The food waste is processed and sterilized before it goes through anaerobic digestion that creates biogas and digestate. The digestate is made into bio-fertilizer. The biogas will contain about 60 percent methane and about 40 percent CO_2 (in addition to small quantities of some other gases). The biogas is upgraded in two steps.

First, it is purified through water scrubbing,resulting in a biogas with 97 to 99 percent methane that can be used as compressed biogas (CBG). In a second step, the biogas can be purified further to a methane content of 99.9 percent, which can be liquified. The liquified methane is only one sixth of the volume of compressed biogas, saving transport costs. The liquified biogas is used in public buses and in the garbage collection trucks. One green bag of food waste is enough to power a bus 250 meters.

These examplesmay act as an inspiration to stakeholders in Satu Mare.

5 Geothermal energy

Geothermal energy exploits heat generated within the Earth's crust and located underground or near the surface. The heat can be extracted and used directly for heating purposes, or the heat can be used in geothermal power plants to generate electricity. Geothermal energy is an attractive supplement in the energy supply mix. For all practical purposes, it is a renewable source of energy and is associated with very low greenhousegas emissions.

Geothermal energy is one of the few renewable energy sources that can provide base load generation. The heat is stably regenerated from within the earth and it is weather-independent which makes it an attractive supplement to other intermittent renewable sources such as wind and solar energy. Another benefit is that heat energy is easier to store in large quantities than electricity.

The total installed capacity of geothermal electricity production in the world was about 15 GW, and only 0.05 MW in Romania in 2022 (International Renewable Energy Agency, 2023). Geothermal energy contributes to a significant portion of power production in only a handful of countries worldwide, most notably in Iceland where it contributed 26 percent of power production capacity in 2020 (Orkustofnun, 2021). The production capacity in the EU is dominated by Italy (87 percent), Germany (5 percent), and Portugal (3 percent) (International Renewable Energy Agency, 2023). These numbers are complemented by some direct use of geothermal heat.

5.1 Different technologies at different temperatures

What technology is used to extract geothermal heat depends on local conditions such as depth and resource temperature. The heat utilization technologies can be separated into either electricityproduction or direct heat use. Electricity generation requiresresource temperatures of above 90 degrees Celsius(Nardini, 2022). At medium temperature levels (90-150 degree Celsius) binary cycle power plants can generate electricity.Various types of steam power plants can be used for electricity production at higher temperatures.

At lower temperatures, electricity generation is not feasible, but heat pumps and direct-use geothermal technologies can utilize the resource for heating or cooling in district heating systems or other industrial and commercial activities. Some commercial activities include greenhouses, snow melting, fish farming, resorts, and spas (Nardini, 2022).

It is also possible to exploit geothermal heat for individual houses or neighbourhoods. Underground temperatures are more stable than surface temperatures and offer good conditions for underground heat pumps. The stable underground temperatures are also good for storing heat, for example in combination with solar heaters as seen in the best-practice example in chapter 7.4.1.

5.2 Geothermal resource potential

In theory, there is some potential for geothermal energy at any location, as the ground temperature increases with depth (the temperature gradient in the earth's crust is around 25 degree Celsius per kilometre). However, the drilling costs mean it is not economically feasible to exploit resources at higher depths. The potential is greatest in locations where hot fluids rise through faults and fracturessuch that the resource is closer, or at, the surface.

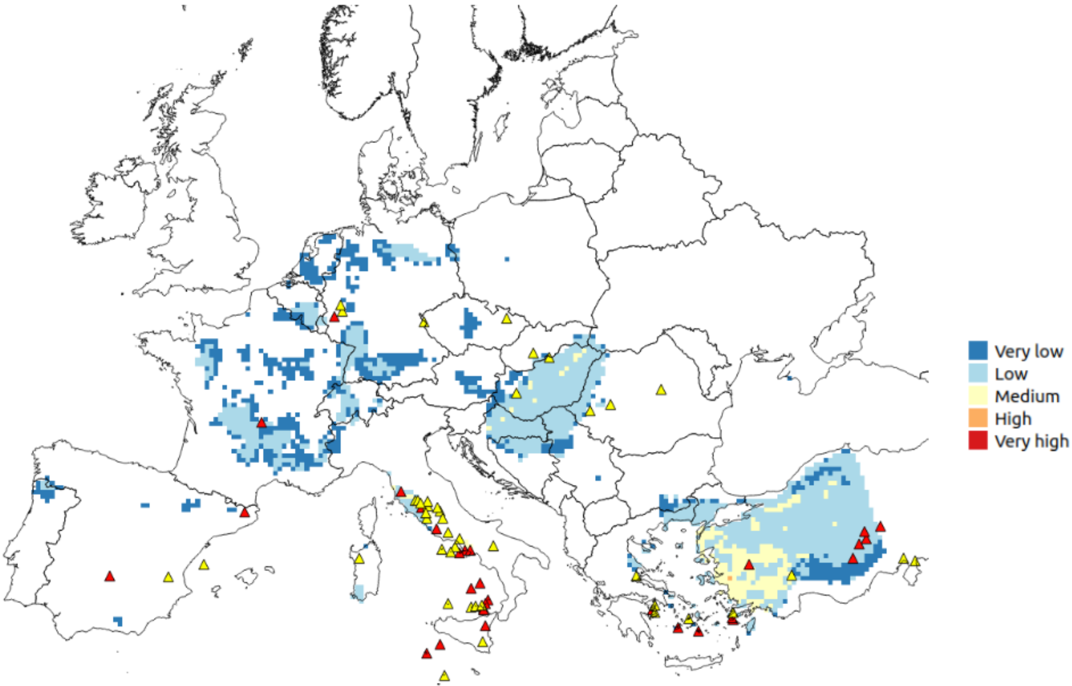
There are some studies that indicate a potential for geothermal energy in Satu Mare county.Satu Mare is located on geothermal aquifers that stretch along the border with Hungary (see Figure 5.1). The temperature of the resource fluids isaround 50-85 degree Celsiusat around 250-400 meters(Bran, 2016). As indicated above, these low temperatures do not lend themselves to electricity generation, but the resource can be utilized for direct heating purposes.

Figure 5.1 Geothermal reservoirs in Romania

Source: Antal & Rosca(2008)

Geological surveys and ultimately drilling is necessary for a detailed mapping of the resource potential for geothermal energy. This makes it more challenging to assess the potential as compared to other renewable sources such as wind and solar, where the resource is easier to observe. It is too early to conclude whether or not there are geothermal resources with high temperatures in Satu Mare. Manzella et al.(2019)find that the western parts of Satu Mare, along the border with Hungary, have some possibility to host high-temperature and high-pressure reservoirs that can be accessed by drilling as indicated in Figure 5.2.

Figure 5.2 Map of regions with potential to host high temperature and high-pressure geothermal reservoirs.



Source: Manzella et al. (2019).

5.3 Some obstacles for geothermal energy

The installation costs of geothermal energy technologies are typically highly site-dependent. Costs are heavily influenced by the quality of the reservoir, such as thermal properties, depth, extent, and fluids. Different types of reservoirs require different type of extraction technologies, plant infrastructure, and quantity and depth of wells.

In addition to traditional project development costs, it is also important to include costs of exploration and resource assessment, such as seismic surveys, test wells, and drilling, as these can be higher in geothermal projects compared to other renewable sources such as wind and solar where the physical resources are tangible.

The geothermal resources in Satu Mare seem to have low temperatures and direct heat utilization seems the most realistic application. Satu Mare does not have infrastructure for district heating. Thus, exploiting geothermal energy for direct heating in municipalities would require investment in a district heating system, which could add significant cost to pursuing this type of renewable energy. More single-source use seems realistic such as industrial use of geothermal heat.

There might also be some environmental costs depending on the technology used in extraction. For example, water- and land use, and impacts on human health through potential air emissions. Public acceptance can often be an issue, e.g., with concerns related to groundwater contamination(Taylor, et al., 2023). Workshop participants in Satu Mare expressed concernabout the effect of geothermal energy production on local water resources, and some of the geothermal resources are located in Natura 2000 protected areas.

6 Other potential renewable energy sources

As discussed in the preceding chapters, this report argues that solar energy and bioenergy seem to offer the best resource potential for renewable energy in Satu Mare county. However, we emphasise that this does not mean that other renewable energy sources should not be assessed or pursued. Given the intermittent characteristic of renewable energy,the future energy mix will and should be made up of several renewable energy sources. In the absence of large-scale storage technologies, several sources are needed to match production and load demand, as discussed in chapter 1.3.3.In addition, intermittency of renewables can be mitigated by spatial balancing through the grid network.

Below, we briefly discuss other renewable energy sources and present our arguments for why we believe these do not have the best potential in Satu Mare county. This should not be interpreted as a definitive conclusion on their potential, as they have not been researched in great detail along all the indicators in the framework described in chapter 2.

6.1 Wind

Wind is a renewable energy source that, like the sun, is found everywhere in the world, but with regional and local variation in intensity. Wind turbines harness energy from the wind by using mechanical power to spin a generator that creates electricity. A wind turbine is a relatively simple technology. Loosely speaking, it consists of rotor bladesthatare driven by the wind. The rotor-blades are connected to a gear box that increases the rotational speed to a level that is appropriate for the generator. The generator translates the rotational power to electricity, which is then transported to a transformer and into the grid.

Wind power can be divided into three categories: onshore, onshore distributed, and offshore wind power. Onshore windincludes ground-mounted turbines with above 100kW capacity, or *utility-scale*. Distributed wind power refers to ground-mounted turbines below 100kW capacity, typically used for residential, agricultural, and small commercial or industrial applications that are below utility-scale. Offshore wind refers to turbines installed at sea where winds tend to be stronger.

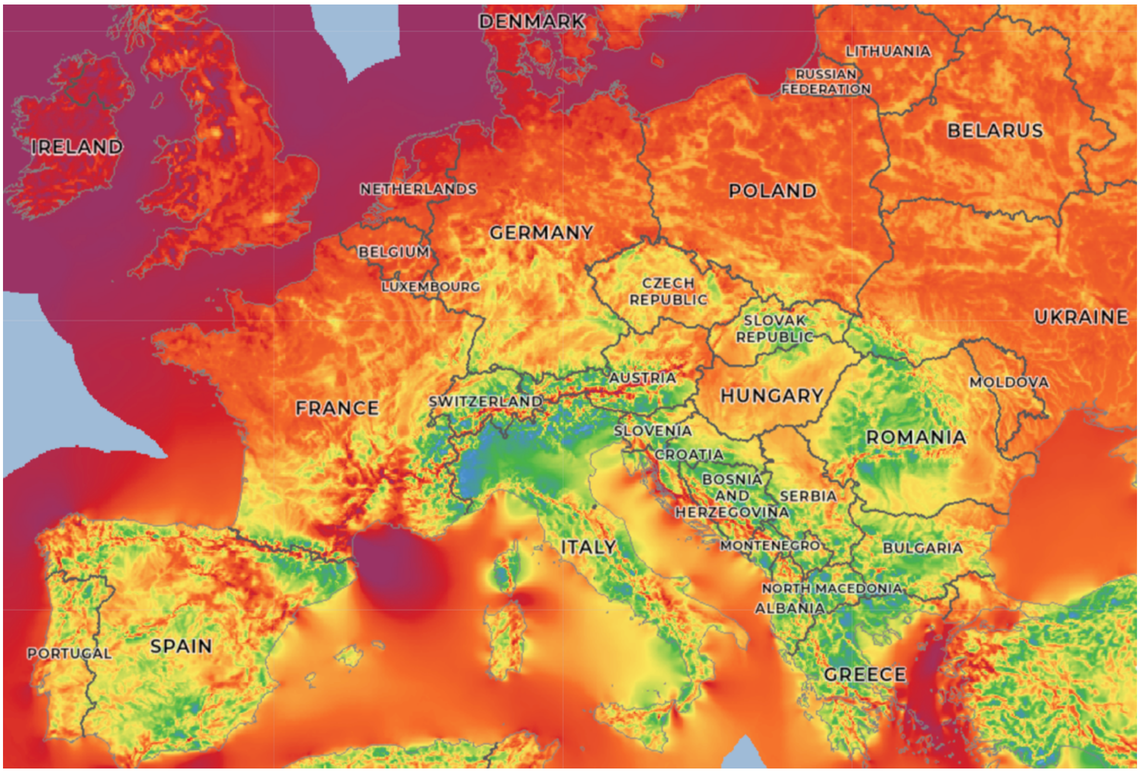
There are three main aspects that determine how much electricity a turbine can produce:

1. Wind speed. Wind at higher speed carries more energy to spin the rotor blades and can producemore electricity.
2. Air density. Denser air contains more mass and will exert more lift on the rotors, resulting in higher power production. In general, air density decreases with altitude.
3. Rotor blade radius. A larger radius, or *swept area*,means a larger area where more wind can pass. As a rule of thumb, doubling the radius can result in four times more power being generated.

Wind speed is typically higher the higher one reaches above ground, resulting in taller turbines being able to produce more energy. In addition, larger rotor blades result in disproportionately higher power output. In the case of wind turbines, economies of scale matter and bigger is better.

The resource potential for wind power in Satu Mare does not look particularly promising, relative to other parts of Romania and Europe. Figure 6.1shows an estimate of the mean windspeed in Europe. Areas coloured dark red indicate mean wind speed of above 10 m/s, which is a good resource potential.Yellow indicatesmean wind speed of around 5 m/s and blue/greenindicate very low mean wind speed.Based on this initial resource assessment, the lack of wind speedmakes wind power more expensive in Satu Mare than in several other regions in Europe.

Figure 6.1 Mean wind speed in Europe



Source: The Global Wind Atlas 3.0 (2023)

Wind turbines do not require large area in terms of square meters on the ground. This means that they can be combined with other land-use activities like agriculture and thus reduce the need to convert nature land. In terms of available land area, Satu Mare seem to have good potential for wind power. However, wind turbines are large and can be visually dominant. The visibility from public dwellings and viewpoints is a factor that should be considered. In addition, wind turbines make noise when in operation and can create a flickering shadow. This suggests that they should be located far from towns and dwellings.

A potential concern for wind power is its effect on the environment, in particular on bird life. Wind turbines can kill birds, who are not able to perceive the danger that the moving rotor blades pose. Further, wind turbines are more effective when spread across large areas, this can create large «belts» where birds find it hard to pass. Local stakeholders in Satu Mare indicated that the region is an important corridor for migrating birds, which could mean that this issue is of greater importance in Satu Mare than in other regions.

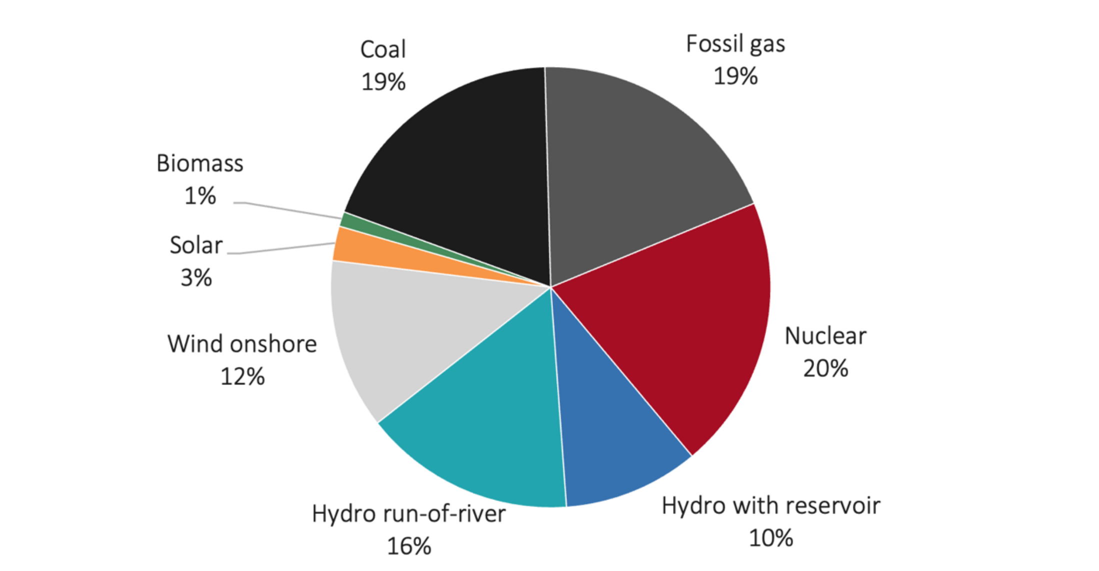
In terms of economic costs, generally speaking, wind power is one of the cheapest sources of power today. However, due to the meagre wind resources in Satu Mare, the cost per unit of energy produced will be higher here than in regions with better wind resources.

6.2 Hydropower

Hydropower can be divided into hydropower with reservoirs and run-of-river hydropower. These technologies use running or falling water to run a turbine that generates electricity. A hydropower plant with a reservoir uses a dam to collect water and control the flow of water. Falling water then runs a turbine that through a generator can generate electricity. The waterflow can be controlled and turned on and off, meaning reservoir hydro power is dispatchable form of renewable energy. Water is stored during periods of high precipitation and used to produce electricity in periods of high demand and/or low precipitation. A run-of-river hydropower plant is not dispatchable in the same way as there is no dam for storing water, but it uses the running water.

Hydropower is an important part of both Romania's and Norway's electricity mix. As shown in Figure 6.2, hydropower contributedto 26 percent of Romania's net electricity productionin 2022.In Norway, hydropower contributedto 89 percent of net electricity production in 2022.

Figure 6.2 Public net electricity production in Romania in 2022



Source: ENTSO-E

The resource potential of hydropower is determined by having access to rivers in the case of run-of-river hydropower or a lake or suitable location for the creation of a dam with a sufficient height differential. Satu Mare does not seem to have the conditions for a large expansion of hydro power. The region is relatively flat and only about 0.67percent of the land area is water bodies. Parts of the river Somes, that runs through the city of Satu Mare, is a Natura 2000 protected area.

7 Energy efficiency – helping the transition to renewables

7.1 What do we mean byenergy efficiency?

Energy efficiency essentially entails measures and actions that ends up using less energy to *solve the same task*. This is related to but is not equal to *energy saving*. When we talk about energy efficiency, we mean measures that savesenergy, but not at the expense of reducing the objective.

For example, we might have an objective to maintain room temperature at 21ºC. An energy efficiency measure could be to insulate the room better so that we would need less energy to heat (or cool) the room to maintain this temperature, i.e., using less energy to solve the same task.An energy saving measure could instead be to use less energy by reducing the room temperature to 20ºC, i.e., saving energy by *changing the task* or objective.Both are important and can complement each other to reach the overall goal of mitigating climate change and using our planets resources more efficiently.[8]

7.2 Energy Efficiency First

Energy efficiency has become a crucial part of the EUs energy targets and energy policy.This is made clear in the *Energy Efficiency First principle*,which acts as a guiding principle for EU energy policy and investment decisions(EU Directive 2023/1791). The principleaims to ensure that energy is managed in a cost-effective way and to reduce the demand for energy, which will help make the transition to renewables easier.

The principle is anchored in EU legislation through the directive on energy efficiency(EU Directive 2023/1791).[9]The directive was first adopted in 2012andrevised in September 2023,consideringthe climate policy target of 55percent reduction of GHG emissions in 2030 (compared to 1990-level). The directive entails an energyefficiency goal of reducing the EU's final energy consumption by 11.7percent by 2030 (compared to projections of expected energy use in 2030). In practice, EU countries are required to achieve an average energy savings rate of about 1.5percentannually between 2024 and 2030. Improving energy efficiency in buildings will be an important part of achieving this target.

Through the *Energy Efficient House programme* (*Casa Eficienta Energetic*), the Environmental Fund Administration (EFA) of Romania offers financial support for measures taken to increase the energy efficiency in single-family homes by one energy class. The programme offers to reimburse up to 60 percent of eligible investment expenses, up to 70 000 RON (approx. 14 000 EUR). Eligible

[8]There is a real risk that energy efficiency may lead users to change the task or objective away from energy saving, in order to increase their level of comfort. This is called the rebound effect. For instance,one may increase indoor temperature from 21 to 22 degrees after insulation, since the costs are reduced.

[9]The directive can be found here: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:JOL_2023_231_R_0001

expenses include insulation of roofs, windows and walls, solar heaters, ventilation systems, motion sensors, and some heat pumps.

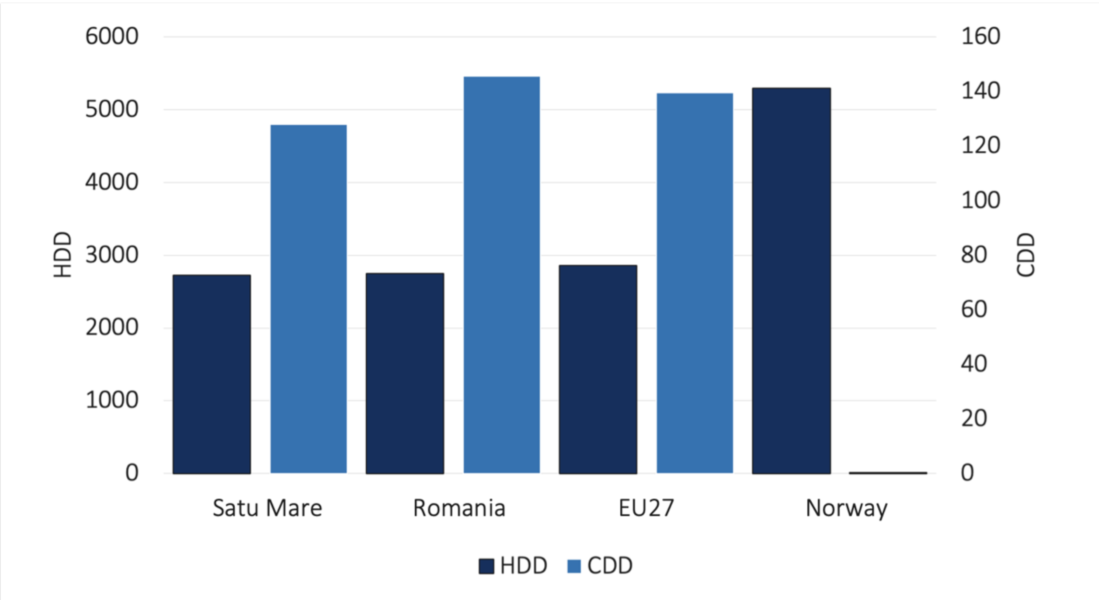
Energy efficiency measures can apply to anything that uses energy, but we restrict our analysis here to measures in dwellings, commercial and public buildings. The energy consumption in buildings typically come from firewood, gas, and/or electricity. Firewood is a renewable bioenergy resource, but it pollutes the local air. Heating based on natural gas produces CO_2 emissions.Thus, using these energy sources more efficiently may reduce local air pollution and CO_2 emissions. In addition, using less energy also means *spending* less money on energy.

We do not have data on the energy performance of dwellings and commercial- and public buildings in Satu Mare. However, an important source of energy demand in buildings is heating and cooling. Figure 7.1showsthe need for heating and cooling in Satu Mare, Norway and the EU. The measures are weather-based indices that infer the need for heating (HDD) and cooling (CDD) in buildings based on observed temperatures in the region.

Heating-degree-days (HDD) measure the severity of the cold in a specific period of time, considering the outdoor temperature and average room temperature. Lower temperaturesincrease the need for heating, and longer time periods of cold temperature increase the need for heating. Analogously, cooling-degree-days (CDD) measure the severity of the heat, considering the outdoor temperature and the average room temperature.

The indexes indicate that there is a significant need for both heating and cooling in Satu Mare, whereas there is only need for heating in Norway.Below we briefly discuss some technologies that can improve the energy efficiency in buildings. Some of these technologies are also showcased as examples for bestpractice in chapter7.4.

Figure 7.1 Heating-degree-days (HDD) and cooling-degree-days (CDD) in 2022



Source: Eurostat

7.3 Some technologies to improve energy-efficiency

Overall, there are three main ways to improve energy efficiency in buildings:

1. *Design and construction techniques*include design and techniques that reduce the need for heating, cooling, ventilation, lighting, and other activities that require energy. This can include the choice of construction materials and construction process.
2. *Upgrading existing buildings*can include refitting insulation, installing heat pumps, closing cold-bridges, replacing windows and other upgrades that do not require the building to be demolished.
3. *Managing energy use* include monitoring and optimising the building's energy use, for example through behavioural change or identifying and reducing the waste of energy.

Below we briefly discuss some common energy efficiency measures along these dimensions.

Heat pumpsis the heat source of the future

A common energy efficient technology isthe heat pump. Essentially, a heat pump uses electricity to transfer and amplify heat from a cool area to a warm area. For example, it can extract some heat from a coldermedium(either the air, water, or the ground)outside of a building and transfer and amplifythe heat to the inside of the building. The process can also be reversed to cool the inside environment when it is hotter outside (i.e. acts as an air-conditioner). Figure 7.1indicates that Satu Mare is a region where both heating and cooling is required.

Because the heat is mainly transferred, and not generated as in an electric heater, heat pumps are very energy efficient. A typical household air-to-air heat pump can produce 4 kWh of thermal energy per 1 kWh of electric energy applied.However, output will depend on the seasons.[10]Heat pumps using water or the ground as the heat source can have higher efficiency than air heat pumps because water sources and the ground are typically warmer in the winter and colder in the summer than the air. This means that the temperature difference between the heat source and indoors is lower and thusthe pump will use less electricity to move and amplify a certain amount of heat.

Heat pumps can contribute to energy security by reducing the reliance onimported fossil fuels used for heating, and, depending on the electricity mix, help reduce GHG-emissions. It should be noted that using heat pumps for heating will mean that heating is exposed to power outages, and heat pumps are thus not immune to energy security concerns.

The expansion of heat pumps is an important measure in the REPowerEU plan. The technology is mature and could be implemented quickly.

Although heat pumps might be a good financial investment over its life-cycle due to their low operating costs, the upfront installation and purchase cost can pose a barrier. Heat pumps are relatively costly to purchase and install, and the more efficient water and ground source heat pumps are more expensive than air heat pumps. Romania is one of many countries that offer public support to consumers to overcome these upfront costs.[11]

[10]A heat-pump's efficiency is typically measured by the *coefficient-of-performance (COP)*, which is the ratio of energy output to energy input. In the example, 1kWh of energy input that gives 4 kWh of energy output yields a COP of 4 ($COP = \frac{4\ kWh}{1\ kWh} = 4$).

[11]See https://www.afm.ro/casa_eficienta_energetic.phpfor more information on the program for energy efficiency improvements in housing in Romania.

Good insulation saves energy

Good insulation is crucial to reduce the need for heating and cooling in buildings. Improving a building's insulation can reduce heat loss and the energy needed to maintain a certain temperature, whether in winter or summer. Improving insulation can mean refilling existing wallsand roofs with superior insulation material or increase the thickness of the insulation, installing sealing strips in doors and windows, or installing new doors or windows with better insulative capacity. Even though windows might make up only 5-10percent of a building's outside surface, they can contribute about 40percent of the building's heat loss in cold weather.

Solar heating is a renewable source of heating

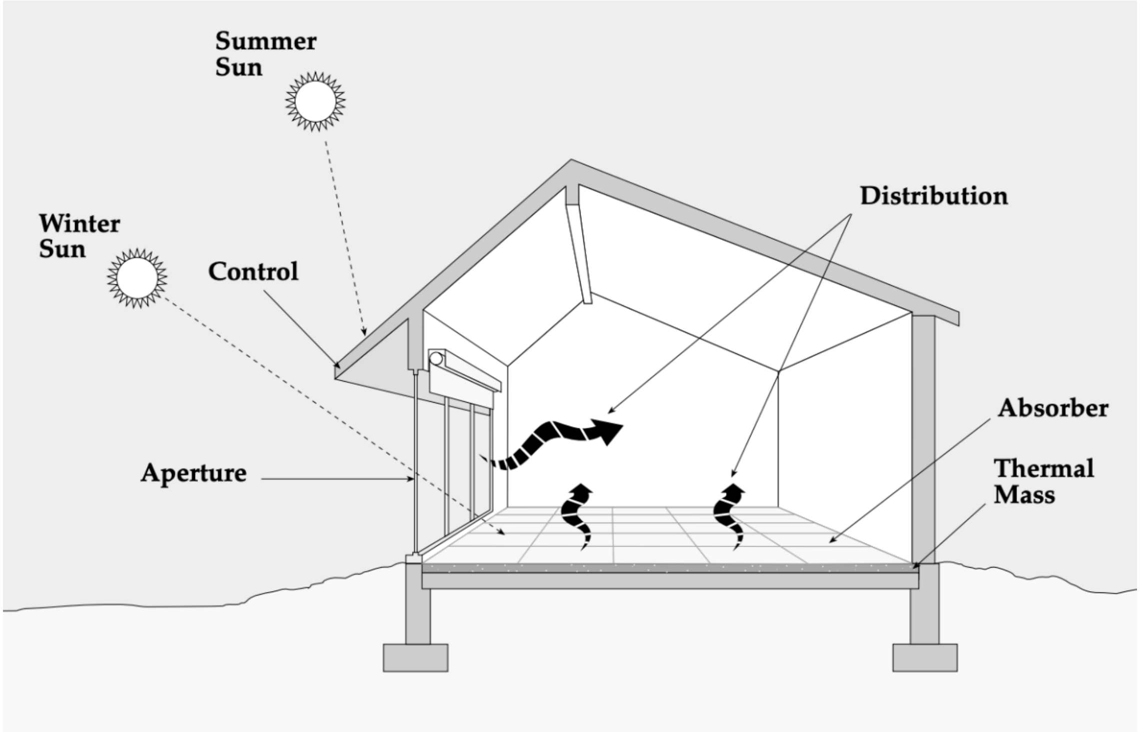
In addition to using solar energy to generate electricity (either through PV cells or CSP technologies), it can be used to create heat directly, as discussed in section 3.1. This involves exposing air or a fluid to the sun. The hot air or fluid can then be used to heat the inside of a building directly or it can be connected to a heat exchanger and water tank for storage.

Passive solar and using thermal mass

The sun provides energy to the surface of the earth every day. Clever building designs can exploit this energy. These techniques and technologies are typically referred to as *passive solar*. Many of these designs do not need complicated technologies to work, only mindful planning.

Figure 7.2illustrates several of these design elements. Large windows are facing south such that the sun is allowed to heat the room during winter and reducing the need for external heat sources. An extended roof provides shade from the same sun during summer (when the sun is higher in the sky) when the building needs to be kept cool, rather than hot. This can also be complemented with window blinds.

Figure 7.2 Illustrative example of passive solar design



Source: National Renewable Energy Laboratory(NREL, 2001)

Selecting objects and building materials with good thermal mass can help exploit the solar energy more efficiently. Materials with high thermal mass, like concrete, bricks and tile, have a high heat capacity and take a long time to heat (and cool). If used correctly, high thermal mass can even out temperature fluctuations between day and night by absorbing and storing heat from the sun during the day (reducing the need for cooling) and slowly releasing the heat during the night (reducing the need for heating).[12]

Both the bestpractice examples in chapter7.4, *the Bellona house* and *Deichman Bjørvika*, purposely considered passive solar in the design of the buildings.

Monitoring and management systems

A first prerequisite for an effective management of energy use in a building is the ability to measure energy use. Getting data on the energy use can identify the most important sources of consumption and energy loss in a building. Measurement equipment can include the simplest technologies, like a thermometer, to more advanced measurement devices, like a thermal camera that can measure and visualisethe thermal loss in walls and windows. A smart metering device can show electricity consumption in real time. For larger building complexes, a good management system can effectively redistribute surplus heat to parts of the building where it is needed. The Bellona house, described in section 7.4.1 below, is part of a larger building complex with an*energy central*and is a good example of this.

[12] If done incorrectly, the same characteristics can have the opposite unwanted effect.

7.4 Bestpractice examples

Below, we present two bestpractice examples from Norway, where energy efficiency played a key role in the design, construction, and management of the building in question. The comprehensive training session in Norway for the Romanian delegation included a visit to these two sites. First, we present *The Bellona house*which showcases a down-to-earth project employing well-known technologies.Second, we present the public library in Oslo, *Deichman Bjørvika*, which was a project requiring tailor-made solutions.

7.4.1 The Bellona house – Norway's first A-class office building

Bellona is a non-profit NGO focusing on environmental issues. When they needed a new office, they decided to put high demands for an energy efficient building, to set an example for others to follow. Together with the developer*Aspelin Ramm*, they created an office building that would satisfy the demands for energy class A in the Norwegian classification scheme.[13]At its completion in 2010, it was the first office building in Norway with energy class A. They achieved this using only technologies that were well known at the time.

Some energy efficient features of the building included:

- Solar water-heaters on the south façade.
- An energy centre to redistribute surplus heat to neighbouring buildings.
- Geothermal wells.
- Control system for ventilation, heating, cooling and light through motion and CO_2 sensors.
- A ventilation system that reuses heat.
- Thermal mass through exposed concrete.
- Few and well insulated windows.
- Heat pumps.

The south-facing façade has two main functions: to capture solar heat and to reduce direct sunlight in the office. The windows are equipped with automatic blindersand are tilted outward to reduce direct sunlight when the sun is at its highest and strongest, and thus reducing the need for cooling in the summer. There are 291m^2 of solar heaters mounted above the tilted windows, with 350 litres of circulating water. The water is heated by the sun and circulated in radiators that heat the office space. The surplus heat is transferred to the *energy centre* where it is distributed to other connected buildings.

The energy centresupplies the Bellona house and neighbouring buildings with heating and cooling. The centreis based on geothermal wells, solar heating, and district heating.There are 14 geothermal wells that are 300 meters deep. They are used for heating in the winter and cooling in the summer through heat pumps. The energy centre is connected to the district heating system in the city of Oslo, which supplies the building complex when the solar heating is insufficient.

[13]The classification scheme ranks a building on the need for energy per square meter based on normal use. The scale is from A to G, where A is the highest.

The solar heaters provide 79percent of energy need for hot water and 23percent of the energy need for heating. The heat pumps contribute 14 percent of the energy for hot water and 50percent of the energy for heating. The district heating contributes the remaining 27 percent for heating and 7 percent of hot water.

Lighting, heat, and ventilation are automatically controlled through sensors. Motion detectors control the lighting, while the ventilation is connected to CO_2-gauge that adjust the ventilation based on the current need. When many people gather in a room, the CO_2-concentration in the air rises and the ventilation is increased.The ventilation system also reuses heat by allowing the cold air entering from outside to be heated by the hot air going out. The efficiency rate of this process is reported to be 88 percent.

Around 50 percent of the concrete ceiling is left exposed to exploit the thermal mass in the concrete. Concrete is a material with high thermal mass, meaning it can help even out temperatures across the day.

The additional measures needed to increase the energy classification from C to A reportedly increased investment costs about 10 percent. According to the developer, a significant portion of this was due to the increased need for planning and project management. Bellona agreed to a slightly higher rent to mitigate the extra cost for the developer but reported that they recuperated the additional rent cost through lower utility bills.

Figure 7.3 Deichman Bjørvika Library

Photo: Vista Analyse

7.4.2 Deichmann Bjørvika Library

Deichman Bjørvika is a public library in the centre of Oslo that opened in 2020. The city of Oslo requiredhigh environmental performancewhen building the library. In contrast to the Bellona house, the architectural design of the building required customization in many aspects of the construction, meaning the costs are high and not directly comparable to other projects. But there are still important principles to learn from.

The building stretches across six levels with a glass façade and large open spaces inside. It is classified as energy class A in addition to being a *passive house*, which means the building must fulfil certain criteria on energy efficiency. Several measures were undertaken to achieve this.

The building makes use of the thermal mass of concrete. Ventilation is provided through hollow spaces in the concrete floors on the second to the fifth level. The hollow spaces cover the entire floor area. This means that the circulating air has a large contact surface with the concrete to exchange heat. This exploits the concrete in order to reduce temperature variations in the building and reduce the need for cooling. Concrete is also left exposed where possible.

Concrete does not have good acoustic properties. Good acoustics are very important in a library. To leave as much as possible of the concrete ceiling exposed, while maintaining good acoustics, the ceiling in the upper levels was partially covered with a sound-absorbing material shaped as a "bee-hive", as shown in Figure 7.4. This allows 64 percent of the concrete to remain exposed while still achieving good acoustics.

Figure 7.4 Bee-hive shaped ceiling in Deichmann Bjørvika

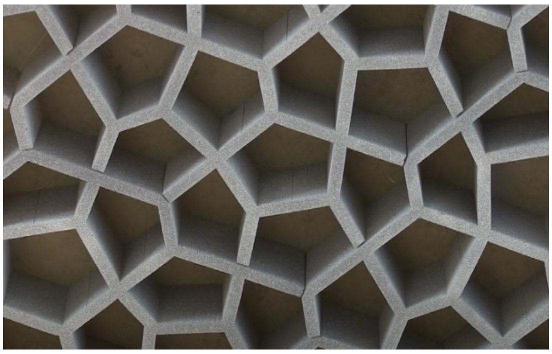


Photo: FutureBuilt

Figure 7.5 Ventilation channels inside the floors

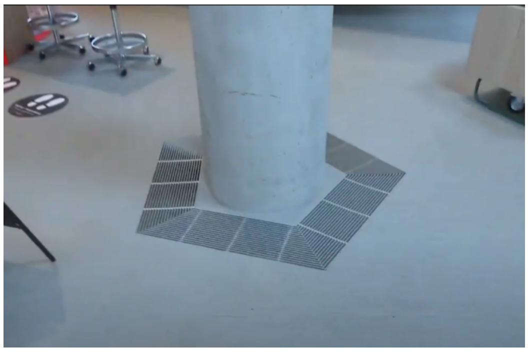


Photo: FutureBuilt

The building is heated and cooled through a *thermal active building system*, which is an air conditioning system with embedded heating and cooling pipes in the concrete in both the floor and ceiling.

The building's need for cooling during summer is reduced by having automatic external solar shading on the large glass façade. The glass façade is also made up of a three glass layers, one outside glass for better insulation, one 3-layered insulative glass in the middle, and a frosted glass layer on the inside to diffuse light. The load-bearing elements between the glass windows are made of composite fibre filled with mineral wool, which provides superior insulation compared to elements made from steel and aluminium. A water-to-water heat pump and connection to district heating provides the building with energy in addition to electricity.

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