OUTPUT 2.1

Studies of Potential Solar Projects

Document prepared by University of Portsmouth

Based on the WP2 deliverables and the contributions from consortium partners

Executive summary

This document summarises the results of the activities in Work Package 2 of the Interreg 2 Seas SOLARISE project and includes also information emerging from the interaction among consortium partners and with the target groups. This document is a guide package reporting on the diversity of solar energy applications cases, including historical buildings, public buildings, municipal housing, living labs, and solar farms. Since the applications of solar energy and associated technologies is in continuous change, this document may reflect just the current situation in a specific region, and it may not be up to date in just a few years.

The solar energy deployment in the 2 Seas countries involved in the SOLARISE project, which has partners in Belgium, France, Netherlands, and the UK, is carried out in unique ways in each country and involves different regulatory and legal environments. Despite the barriers and challenges due to the different national policies and local measures of each country, a common methodology for feasibility studies of each case of application has been developed in this project. The information related to the diversity of application cases for the successful deployment of solar energy harvesting is gathered in 6 factsheets that summarise the findings from deliverables D2.1.1, D2.2.1, D2.3.1, and D2.4.1. The first factsheet in this report starts by describing this common methodology that has been used to help to carry out feasibility studies of solar energy projects in a way that is applicable to different types of projects, which are described in the five subsequent factsheets.

The identification of best practices in solar energy projects is important, as this helps develop awareness on the processes, systems and technologies that are the keys for success in these endeavours. However, it is not straightforward to identify good practices in solar energy applications, since goodness depends on different subjective factors, and relative goodness between alternatives may change over time.

Within SOLARISE, a small database containing relevant and newer solar installations has been started with the contribution of the consortium partners. The collected information represents an extended set of best practices in solar energy harvesting in Belgium, France, the Netherlands, and the UK. A few best practices are presented in this report in a condensed form, together with a short explanation of the main evaluation criteria, including site analysis, selection of technologies, financial feasibility, legal & social aspects that are often considered for decision making in solar energy projects.

The uptake of solar energy as proposed and exemplified by the SOLARISE project may be a step forward in reaching the 2030 EU-targets.

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The solar energy deployment in the 2 Seas countries involved in the SOLARISE project, which has partners in Belgium, France, Netherlands, and the UK, is carried out in unique ways in each country and involves different regulatory and legal environments. Despite the barriers and challenges due to the different national policies and local measures of each country, a common methodology for feasibility studies of each case of application has been developed in this project. The information related to the diversity of application cases for the successful deployment of solar energy harvesting is gathered in 6 factsheets that summarise the findings of Work Package 2. These factsheets are presented in the next few sub-sections.

1.1. Factsheet: methodologies for solar feasibility studies

A feasibility study is an analysis that takes all relevant factors of a project into account to ascertain the viability of the project or the likelihood of completing the project successfully. Its objectives are then to:

1. Give focus to the project.
2. Provide valuable information for a “go” / “no go” decision in each case.
3. Narrow the alternatives.
4. Increase the probabilities of contributing to the success of the project by identifying weaknesses at an early stage.
5. Ensure compliance with the overarching objectives of the project.
6. Consider the life cycle and impact of each subproject beyond the end of the project.

In general terms, a feasibility study includes the definition of the functional requirement, development of alternative concepts, and a quantitative assessment of alternatives. However, several available methods can be used for the feasibility study of energy systems:

1. *Cost-benefit analysis*: more focused on the financial aspects.
2. *Environmental impact analysis:* focused on the consequences of the system on the environment, mostly during its functioning period.
3. *Life cycle assessment:* taking into consideration the impact of each stage of the project’s life on the environment (Design, Manufacture, Operation, Dismantling, Recycling).
4. *Multi-criteria decision analysis:* bringing together and comparing all assessment criteria of a project.

It is important to consider various aspects of the project instead of focusing only on one or two of the many criteria. Methods such as cost-benefit analysis and environmental impact analysis emphasise and analyse a single major aspect and are therefore only relevant to reach conclusions on that aspect. However, these methods do not to compare in a meaningful way the different aspects of a complex project that can be of relevance for the decision-maker. Therefore, it is challenging to choose a method that can be simple, robust, and effective in assisting the decision-making process.

During the SOLARISE project, a key difficulty with the feasibility studies was finding a method that is able to compare different kinds of solar project application cases (historical buildings, public buildings, municipal housing, solar farms, and living labs), through different countries (implying mainly different national policy and local measures), with common relevant criteria but with different objectives from each stakeholder. Thus, many project partners have considered multicriteria decision analysis as a suitable choice and have used it to perform their feasibility studies.

Multi-criteria decision analysis (MCDA) is a way of looking at complex problems that are characterised by any mixture of monetary and non-monetary objectives, of breaking the problem into more manageable pieces to allow data and judgments to be brought to bear on the pieces, and then of reassembling the pieces to present a coherent overall picture to decision-makers. The purpose is to serve as an aid to thinking and decision making, but not to take the decision. MCDA often involves experts assigning scores to compare key performance indicators/criteria of a system. The scores are collectively used to compute the weights for all the criteria.

We have found that most feasibility studies related to solar energy installations consider technical, financial, environmental, and social/legal aspects. We give more details of each of these aspects below:

- **Technical aspects**

Technical analysis of solar projects often involves estimating the energy yield, considering features of land/roof area, evaluating the ease of connection to the grid, considering the presence of objects causing shading, the efficiency of key equipment, life cycle of equipment, maintenance requirements, equipment warranties, etc.

- **Financial aspects**

Studying the financial feasibility of a project often involves estimating capital costs, operational and maintenance costs, revenues and electricity tariffs, debt servicing & capital repayment, taxes, and financial modeling. The financial model estimates the key parameters of the projects such as net present value, internal rate of return, payback period, cash flow available for debt service (CFADS), debt service coverage ratio, loan life coverage ratio, and levelised price of electricity.

- **Environmental aspects**

Analysing the environmental feasibility of a solar energy project often involves assessing the potential land use and habitat loss, water use, life cycle environmental impact, landscape and visual impacts, and reduction in carbon emissions.

- **Social and legal aspects**

Social and legal aspects that are often considered in the feasibility analysis of solar projects include the easiness of permit and license acquisition, public approval, impacts on cultural heritage, contribution to energy independence, and easiness of agreement between stakeholders.

Once all the different aspects of a project have been detailed, a general multi-criteria decision analysis framework consists of the following steps:

- Identifying the alternatives and defining the system goal
- Identify the key criteria and sub-criteria
- Assign performance scores for criteria
- Compute weights of the criteria/sub-criteria

In the context of the SOLARISE project, a simple weighted sum multi-criteria decision analysis methodology is used as a part of the feasibility study tool in work package 2. Each sub-criteria is assigned performance scores between 1-10. Some studies have considered risk as one of the criteria to conduct the feasibility analysis.

Feasibility studies should be made available at the project permit application stage. In practice, this means that the review of options must be included in the overall program for the new system. Feasibility studies of solar installations at historical buildings, public buildings and housing, solar farms, and living labs have been carried out to evaluate best practices that will help accelerate the adoption of solar energy. The following list includes various feasibility studies that have been performed during the SOLARISE project:

- Sustainable renovation of a historic public building in Zoersel (BE)
- Deployment of solar technologies at the heritage mill in Middelkerke (BE)
- Innovations for solar energy applications in historical and public buildings in Middelburg, with specific applications for three buildings (NL)
- Deployment of photovoltaic solar power generation systems at public buildings in Fourmies (FR).
- Deployment of solar technologies at social housing sites of Brighton & Hove City Council (UK)
- Solar Farm Feasibility Study by Brighton & Hove City Council (UK)
- Feasibility study emphasising the environmental impact of a solar farm by Enercoop
- Feasibility study for a solar farm by Heerhugowaard (NL)
- Feasibility study for a concentrating solar plant by Flux 50 (BE)
- Feasibility study of living labs at the University of Portsmouth (UK), University of Picardie Jules Verne (France), and KU Leuven (BE)

1.2. Factsheet: historical buildings

Historical buildings are usually low-performance buildings from an energy point of view and are protected by law from alteration, not only in relation to their visual appearance preservation, but also concerning materials and construction techniques to be integrated into the original architectures. The extent of the protected area is dynamic, and it entirely depends on the location of the monument. Some monument protection also includes associated buildings and landscapes. Specific challenges that are faced when integrating solar technologies into historical buildings include visual impact, potential damage to items of historical value, different airflow patterns to similar-sized modern buildings, difficulties with the approval of planning permissions, and sometimes difficulties in physically retrofitting some solar technologies. The integration of solar energy installation on historical buildings usually requires a careful feasibility study.

The feasibility study will normally analyze energy potential, risks, and investment requirements, legal and regulatory aspects, cost/benefit analysis, required work, equipment, and potential CO_2 reduction and further aid in the assessment of successful integration of solar technologies. An important aspect of solar photovoltaic panels for example, is that they come in different forms including modules, thin-film panels, roof tiles, and semitransparent panels, which allow for a wide range of integration possibilities to the building envelopes. In the case of solar thermal heating technologies, it is possible to increase the comfort of the people in addition to meeting the heating demands of the buildings. However, important challenges of the integration of solar technologies include coping with limited useful space and the requirement to protect the architecture of the building.

When addressing these challenges, the availability of photovoltaic technologies in different physical forms becomes a facilitating factor. For example, consider solar photovoltaic tiles, which are tailored modules that can match the visual appearance of the existing roof substrate. It is also sometimes possible to discretely locate PV modules on or the heritage site, such that they are not visible to the public.

In terms of technologies, traditional monocrystalline silicon or multi-crystalline silicon modules are the most efficient technologies available for deployment. However, due to specific constraints, building-integrated PV (BIPV) may be better suited for applications on historic buildings. These technologies can act as rooftop shingles, tiles, building facades, windows, or glazing for skylights. It is important to highlight that BIPV can add cost and complexity to a project and may not be universally available but may help enhance the acceptance of the deployment of technology on a visible surface. In addition to generating electricity, BIPV will also act as insulation or exterior weather barrier.

In general terms, the key criteria for a successful project are solar photovoltaic system design and historic preservation. The PV system performance and economics are predominant drivers for a project to achieve the demands of a building. Historic preservation is largely driven by the impacts of the deployment of solar technology on the historic character of the building. There is a necessity to balance these impacts with the economics, comfort, and resulting energy savings of a project.

The use of a checklist will generally identify several challenges specific to the project. This is part of the feasibility study and sometimes it is referred to as a pre-feasibility study. The objective of the checklist is to collect the data relevant to the project's main assessment criteria.

Within the SOLARISE project, several feasibility studies involving historical buildings have been performed. They are listed below:

- Sustainable renovation of a historic public building in Zoersel (BE).
- Deployment of solar technologies at the heritage mill in Middelkerke (BE).
- Innovations for solar energy applications in historical and public buildings in Middelburg (NL), with specific applications for three buildings.

As mentioned above, one of the first steps of a feasibility study is to consider various scenarios for the solar energy system. Below we list some of the options that have been considered by SOLARISE partners:

- Solar collectors combined with ice water buffer system
- Slate solar panels which are visually hidden
- Black solar panels on the roof of the building
- Flat roof and facade photovoltaic panels
- Photovoltaic tiles

To conclude, we provide below a list of key points of feasibility studies of historical buildings in the SOLARISE project.

- The shading factor is discussed as a part of the feasibility studies.
- Energy generation and meeting the total demand are vital for every project.
- Aesthetic application of solar panels on the existing roof is carefully considered
- Technical risks of aesthetic systems are considered as a part of the feasibility study.
- Payback time is another important factor for all the projects in the study.
- Including the consideration of batteries in the feasibility study for load shifting and for maximizing photovoltaic energy self-consumption.
- The installation of demonstration systems is a common practice to evaluate new technologies. In such cases, the analysis of feasibility shows that these studies can not only help in informing 'go'/'no-go' decisions, but also provide further directions in proceeding with the next stages of the implementation of a project.

1.3. Factsheet: public buildings

Public buildings may include government offices, educational institutions, hospitals, churches, etc. The installation of solar energy systems in public buildings not only helps reduce CO_2 emissions and energy bills, but also promotes the use of solar energy among the public. To ensure the best possible use of public funds, it is important conduct appropriate feasibility studies that consider key factors and allow to study alternatives and narrow down the options. Usually, a feasibility study analyses energy potential, risks, and investment requirements, legal and regulatory aspects, cost/benefit analysis, required work, equipment, and potential CO_2 reduction.

The public authorities have long time horizons and very low costs of capital. Moreover, the authorities are subject to more stringent energy performance standards than the private sector, which encourages the deployment of solar energy technology in public buildings. For example, hospitals have a high round-the-clock power consumption and may need an uninterruptible power supply, thus creating the need for backup supplies, which can be provided through smart battery units. An adequate amount of energy storage capacity paired with the solar installation contributes to making a photovoltaic system self-sustainable and resilient to time of use. Other public buildings, such as schools, are meant for predominantly daytime energy usage, and this encourages the self-consumption of solar energy during the daytime.

In terms of available technologies, traditional monocrystalline silicon or multi-crystalline silicon modules are currently the most efficient technologies available for photovoltaic deployment in public buildings. Additionally, solar thermal systems can be included during the construction of new buildings or when existing buildings undergo renovations.

An important criterion for a successful solar energy project in public buildings is the ability of the solar photovoltaic system to contribute as much as possible to the provision of electricity to cover the demand of the building. The geographical location, photovoltaic system performance, economics, and the available space for the installation of photovoltaic modules, are predominant factors that determine the percentage of the electricity demand that can be covered by the photovoltaic system. Some solar installations on public buildings can generate income for the public authority by selling excess solar electricity back to the grid or to other customers, depending on local regulations.

Given that public buildings without heritage or historical value have fewer planning restrictions, there is the opportunity to consider the deployment of advanced solar technologies, such as photovoltaic thermal (PVT), or other hybrid energy systems involving solar electricity and heat, during the construction or refurbishment phase. The resulting challenge for the study associated with the consideration of hybrid energy systems is the increase of complexity, which can then be viewed as a barrier depending on the context of the project.

1.4. Factsheet: municipal housing

The installation of solar energy systems in municipal housing buildings also contributes to promoting the use of solar energy among the public. These installations may also help providing energy for communal services, such as lighting. Moreover, they can bring some social benefits as discussed below. To ensure the best possible use of public funds, it is important conduct appropriate feasibility studies that consider key factors and allow to study alternatives and narrow down the options. Usually, a feasibility study analyses energy potential, risks, and investment requirements, legal and regulatory aspects, cost/benefit analysis, required work, equipment, and potential CO_2 reduction.

Municipal housing buildings also offer a great opportunity to install the modern solar energy systems to produce both electricity and heat. Key benefits include reducing energy costs for the tenants, tackling fuel poverty, and reducing CO_2 emissions. Different options have been considered by SOLARISE partners in feasibility studies relating to municipal housing, such as multi-array, photovoltaic-thermal, sub-metering, heating through air source heat pumps, or ground source heat pumps, as well as smart battery storage.

The main challenges of integrating solar technologies into municipal housing relate to site constraints. The suitability of the roof for the installation of solar modules needs to be analysed by means of appropriate engineering surveys. The age, complexity, and capacity of the existing electrical system are critical factors in determining where and how the photovoltaic system is integrated to the building electrical network. Consumer units in some buildings may not be suitable and may need to be replaced. Photovoltaic-thermal technology can only be fitted in buildings with extensive centralised heating systems. In the case of sub-metering, potential issues to consider are related to regulation, stakeholder perception, and the administration of the system.

In terms of available technologies, traditional monocrystalline silicon or multi-crystalline silicon modules are currently the most efficient technologies available for photovoltaic deployment in municipal housing buildings. Also, solar thermal systems can be included during the construction of new buildings or when existing buildings undergo major renovations. Photovoltaic modules or photovoltaic-thermal collectors are typically installed on the rooftop and the choice of technology is done to maximize energy yield and minimize the payback period.

The role of the tenant can be important and including the electricity sales in the financial criteria is crucial. The provision to include the tenant behavior through risk rating or by other means can be helpful to make the analysis more realistic. Appropriate consultations with the tenants at the feasibility stage are usually necessary.

1.5. Factsheet: living labs

Living labs are defined as user-centered, open innovation ecosystems based on a systematic user co-creation approach integrating research and innovation processes in real-life settings. The key stakeholders of a university-based living lab are academic staff, researchers, students, and external partners.

A living lab provides the opportunity for staff and students to build solutions that directly address immediate real-world problems and to analyse the behaviour of real systems as they operate. Moreover, university-based living labs provide access to live testbeds for innovative scientific research and training. They can serve as flexible tools that allow users to focus on issues and themes of importance at a real scale. External stakeholders benefit from living labs by gaining access to expertise and facilities that support them in addressing important issues that affect them.

In the SOLARISE project, the three solar living labs for which feasibility studies have been carried out are intended to display and demonstrate the latest solar panel technology, inverters, energy storage, smart metering and monitoring systems, among other applications. We have listed below the features for each of the SOLARISE living labs:

University of Picardie Jules Verne	**KU-Leuven**	**University of Portsmouth**
• Hybrid photovoltaic/thermal technology to produce electricity and heat • Electricity and heat storage • Air conditioning • Grid connection • Energy management	• Photovoltaic and hybrid photovoltaic/thermal technology to produce electricity and heat • Solar storage system • Small scale photovoltaic setup for demonstration	• Ground-mounted photovoltaic solar system • Smart battery energy storage system • Photovoltaic and battery monitoring system • Small scale photovoltaic setup for demonstration

The environmental impact of these living labs may be observed by the measurement of energy generation from solar technologies and associated carbon savings. Students, lecturers, and researchers will benefit from their involvement with and use of the living labs. The labs can be used as technology demonstrators for visitors and other stakeholders. Moreover, the number of research articles produced out of the living lab equipment can be considered to measure their academic impact.

The feasibility studies for the assessment of living labs in SOLARISE have considered technical, financial, environmental, social, and legal aspects. Specifically, the available budget, technical aspects of the equipment, planning permission requirements, visual impact, CO_2 emission reduction, and institutional approval, are all factors that had to be evaluated when analysing the feasibility of the different options. As these installations are intended for research, training, and demonstration purposes and not to generate an income, return of investment indicators, such as net present value or repayment period, were not deemed to be important.

1.6. Factsheet: solar farms

A solar farm is a large-scale photovoltaic or concentrating solar power installation used to generate electricity that is usually fed into the distribution or transmission grid, or occasionally is consumed locally by one or more nearby customers. Solar farms may be owned by utility companies, communities of investors, municipalities, etc. Most solar farms have a peak power capacity of over 1 megawatt (MW). About 96% of solar farms are photovoltaic installations. They often require a large area of land for their installation. It is estimated that 25,000 m^2 of land are required for every 1 MW of photovoltaic solar energy harvesting system. As an illustrative example, the largest photovoltaic solar farm in the world is in Karnataka, India, with a peak capacity of 2050 MW installed over an area of 5,260 hectares of land.

The purpose of a feasibility study for a solar farm is to confirm whether its construction is technically possible, financially viable, compliant with planning regulations, supported by the local community, and able to deliver social, environmental, and economic benefits to the region. Feasibility studies for solar farms usually analyse energy potential, risks, investment requirements, legal and regulatory aspects, cost/benefit analysis, required work, equipment, and potential CO_2 reduction, technology choices, and configuration options.

Solar farms constitute and excellent way of reducing carbon emissions by producing abundant clean energy. Besides, solar farms require minimum maintenance with occasional cleaning and monitoring of tracking systems. Required staffing levels are minimal compared with other ways of generating electricity.

Solar farms have similar characteristics to other photovoltaic systems and power output levels are affected by weather conditions, the day/night cycle, and seasonal variations in sun irradiance, resulting in an intermittent output. This intermittence can be compensated for by using energy storage, which may unfortunately increase costs.

The major milestones of solar farms are in order concept development and site identification, pre-feasibility study, feasibility study, permitting, financing and contracts, engineering, construction, and commissioning. Operation and maintenance are coming after commissioning and usually, the farm owner enters into a contract with one of the original EPC contractors.

Some of the environmental impacts of solar farms are discussed below.

- Components in solar farms with photovoltaic technology have no large moving parts, and the inverters and transformers produce little noise. However, concentrating solar technologies use prime movers and generators for steam expansion over the turbine blades to convert mechanical power into electrical power. These devices can produce noise and disrupt nearby communities.
- Solar panels[1] are designed and manufactured to absorb irradiation and do not reflect it. The chances of glint or glare are low. However, these are considered in the environmental

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[1] Utility Scale Solar Power Plants: A Guide for Developers and Investors. International Finance Corporation

assessment to understand the potential impacts on landscape, railways, vehicular traffic and aviation. Solar farms can influence cultural heritage if the designated site has a underground archaeological deposits, which can be disturbed during the construction phase. Regarding food production and agriculture, many solar farms are installed on brownfield sites or unused low-grade agricultural land with an option for vegetation co-location and hence do not pose any risk. Potential impacts on ecology can include habitat loss or displacement of vulnerable species. However, appropriate mitigation measures are deployed wherever necessary to offset the adverse influence on sensitive habitats.

- Photovoltaic solar farms do not require large amounts of water. However, concentrated solar systems may have higher water requirements, which can be a problem in areas with limited water resources.

Many solar farm feasibility studies focus on financial viability analysis with emphasis on evaluating the financial investment risk. Other criteria are embedded during the evaluation of key economic parameters such as the internal rate of return, net present value, and payback time. Social and legal aspects are usually analysed based on risk rating only. It is useful to consider all the criteria and compute a feasibility score to produce a consistent result that allows making comparisons between different options.

Within the SOLARISE project, a number of feasibility studies for solar farms have been performed. They are listed below:

- Feasibility study for the solar farm at the Middenweg in Heerhugowaard (NL).
- Solar farm feasibility study by Brighton & Hove City Council (UK).
- Concentrated solar power feasibility study in the Port of Antwerp by Flux 50 (BE)
- Environmental impact analysis of the installation of a photovoltaic power plant by Enercoop (FR).

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https://consultations.rochdale.gov.uk/research/solar-farm/supporting_documents/STA%20solar%20farm%20factsheet%20NEW.pdf

2. SOLARISE – Best practices in solar energy feasibility studies

During the SOLARISE project, several feasibility studies for different types of solar energy projects have been carried out. This presents an opportunity to identify best practices in solar energy feasibility studies. To best consider relevant best practices that can be of interest to the SOLARISE consortium and beyond, the project partners have decided to provide the identified best practices as they relate to different aspects of a solar feasibility study, including site analysis, selection of technologies, financial viability, legal aspects, social aspects, and decision making. Each of these aspects is elaborated below and accompanied by a few examples from the feasibility studies provided by the consortium partners.

2.1. Best practices: site analysis

Site selection is associated with several constraints that can impact the cost of electricity generation. Hence, it is a critical consideration in the feasibility study under the technical aspects section. Some of the key site analysis[2] indicators are:

1. Solar resource
2. Suitable land area
3. Local weather
4. Topography
5. Land use
6. Local regulations and land use policy
7. Environmental designations
8. Accessibility
9. Ease of grid connection
10. Module soiling
11. Water availability
12. Financial incentives

During the SOLARISE project, the following best practices for site analysis have been demonstrated as through various feasibility studies.

- Using a Geographical Information System (GIS) mapping tool to explore various constraints and identify a suitable land area for the solar project.
- Identify the owner and current use of land and seek advice from local regulatory authorities regarding potential restrictions.
- Estimate the solar resource, likely revenues, all capital and operational costs, taxes, interest, and consider any applicable financial incentives and their durability.
- Evaluate access routes, and the topographic characteristics of the terrain.
- Identify the local, national, and international environmental designations.

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[2] "Utility-Scale Solar Photovoltaic Power Plants: A Project Developer's Guide", International Finance Corporation, June 2015.

- Assess the grid connection capacity, stability, and availability.
- Asses soiling risks. One of the feasibility studies in Middelburg assumed the soiling losses to be 3%.

2.2. Best practices: selection of technologies

A feasibility study involves critically examining the merits and demerits of a potential solar project. The objective of a solar project will determine the choice of solar technology, and some projects can consider installing multiple solar technologies.

In the SOLARISE project, the following best practices for the selection of solar technology have been demonstrated as a part of various feasibility studies:

- Using 3D modeling to understand the suitable installation area and estimate energy yield by considering different losses.
- Being flexible to explore different solar technologies to meet site-specific conditions. One of the studies used slate solar panels as those are visually discrete. Another study at the Zeeuws archives had to install matt photovoltaic panels. The analysis at Stadsschouwburg theatre involved color-coding the panels and the study has calculated energy yield considering different scenarios naming them conservative, base case, and ambitious.
- The feasibility analysis at De Helm building considered rectangular solar thermal plates as a demonstration to build the same technology at a larger scale after assessing its potential.
- The living labs at University of Picardie Jules Verne and KU Leuven universities use a mix of solar technologies and the potential of hybrid energy technologies is evaluated.
- The Brighton and Hove City Council solar farm feasibility study consulted the engineering, procurement and construction contractors and asked questions about what technology they may recommend for the site given the topography and obstacles around the area. This is very good practice as it makes use of the prior experience of trusted partners.

2.3. Best practices: financial viability

Many solar projects are expected to generate revenues and a return of investment within a reasonable period and with acceptable risks. Even if a project is not aimed at generating revenues, as is the case for example with living labs, it is important to at least consider financial affordability when the feasibility study is carried out. Therefore, it is of paramount importance to analyse the relevant financial aspects when performing the feasibility study of a solar project.

In SOLARISE, the following best practices for financial viability analysis have been demonstrated:

- It is useful to consider different system configurations and solar energy technologies, along with the financial implications of these choices. For example, the Brighton and Hove City Council solar farm feasibility study considered two different installed photovoltaic capacities, along with three different options relating to battery storage: no battery store and two different storage capacities. The key financial indicators for each possible combination were considered.
- Where appropriate, and given the significant cost of battery storage, it is critical to carefully analyse the cost and benefits of integrating battery storage systems into the solar energy project. An important consideration in utility scale battery storage is the possibility of generating revenues by providing support services to the electricity network, including capacity market, frequency response and balancing mechanism, or by buying and storing energy at off-peak periods, and selling it at peak periods.
- When it is possible to sell electricity to one or more customers, it is essential to identify the potential customers, to understand their willingness to purchase energy and any legal/commercial barriers to do so, to be aware of their current and future electricity demand, to carefully analyse the possible export routes such that the generated electricity can be delivered to them, and the key terms of power purchase agreements (PPAs), including electricity prices. The Brighton and Hove City Council solar farm feasibility study considered four different potential customers along with various connection options that included private wire as well as sleeving through the distribution network. The study assumed that each customer would have a designated solar array with an appropriate capacity. The percentage of generated energy that is likely to be sold to external customers (as opposed to self-consumption or direct sales to the grid) was an important consideration. All these options were financially analysed based on capital cost, net present value, internal rate of return, and payback period.
- Scenario analysis allows organisations to evaluate the impact of unexpected changes in the business, political, social, and legal environments. It helps them test the robustness of future decisions, understand the potential impact of unexpected influences, and identify potential opportunities and threats. The use of scenario analysis increases the quality of the feasibility study and the robustness of decisions that are made by the organisation. The feasibility studies in Middelburg considered three different scenarios that they called conservative, base, and ambitious based on the extent of installed capacity and self-consumption. The Brighton and

Hove City Council solar farm feasibility study formed four main scenarios, some of which had different options, for a total of 9 variations. These variations were formed by considering two different total photovoltaic capacities, different for battery storage, and different combinations of potential customers.

- Sensitivity analysis determines the variations of the project's main financial indicators to changes on a given input variable. It then shows how sensitive the projections of the key financial indicators are to that variable. Sensitivity analysis differs from scenario analysis because sensitivity analysis only alters one input variable at a time, while scenario analysis can involve many input adjustments at the same time. The Brighton and Hove City Council solar farm feasibility study looked at the sensitivity of the key financial indicators with respect to increases in the distribution network operator (DNO) grid connection costs.

2.4. Best practices: legal aspects

Obtaining permits and licenses required for a solar energy project can be a lengthy process involving multiple agencies in the central and local governments. Depending on the characteristics of the project and the local or national legislation, at least some of the following may be needed: land lease agreement, site access permit, planning permission, environmental permit, grid connection agreement and operator/generation license. A good understanding of the applicable legal requirements is essential, as is consultation with the relevant authorities.

In the SOLARISE project, the following best practices for legal impact assessment have been demonstrated as a part of feasibility studies:

- The solar farm feasibility study by Brighton and Hove City Council explored the option of incorporating the photovoltaic development into a whole estate plan in collaboration with a neighbouring local authority. This may increase the probability of planning consent. Also, the report performed the risk assessment for various elements of local plan policies pertinent to the planning application.
- The solar farm feasibility study by Brighton and Hove City Council study also included previous planning applications involving nearby lands in their feasibility study, stressing the importance of the concept of learning from previous experiences. This is a good planning practice.
- The Flux 50 feasibility study has included the local authority's preference of dual use of land in their feasibility study. Accordingly, they shortlisted the potential installation sites.
- The feasibility study of the solar energy system at De Helm building in Middelburg, which is a historical monument, involved assessing the impact of the esthetical appearance of the installation, even though the installation is a demonstrator. The type of technology was chosen by considering previously approved permits for nearby sites.
- Depending on the applicable legislation, the location of battery storage determines the need to include battery storage as part of the planning application. In the UK, for example, if battery

storage is not located on the same site as the photovoltaic installation, it does not need a planning application, whereas if the battery storage is located on the same site as the photovoltaic installation, it has to be considered as part of the planning application. The solar farm feasibility study by Brighton and Hove City Council considered this when exploring potential locations for the battery storage.

2.5. Best practices: social aspects

Social impact assessment is often a part of environmental impact assessment, and this could lead to overlooking some key social indicators. A robust and separate social impact assessment is recommended as a part of the feasibility study to review the social impacts of a solar development project. The assessment may include different stakeholders. Information sharing and communication are considered vital for social impact assessment. In the SOLARISE project, the following best practices for social impact analysis have been demonstrated:

- The municipality of Heerhugowaard has incorporated a local energy strategy involving an integral people-planet-purpose framework into its feasibility study. This strategy aims at balancing ecology, socio-economic and stakeholder-societal factors. It considers energy generation and food production, housing, jobs creation and local and regional multi-stakeholder welfare
- The installation studies on the Zeeuws archives and Stadsschouwburg theatre in Middelburg have considered the esthetical boundary conditions for their photovoltaic system in the feasibility study, and the degree of energy independence of the site is demonstrated by the predictions of energy self-consumption.
- The photovoltaic project at the village hall in Zoersel recommended the use of slate solar panels, which will preserve the appearance of the vicarage and will have virtually no impact on its cultural heritage or aesthetics.
- The feasibility study for the installation of a photovoltaic system on social housing buildings by Brighton and Hove City Council indicates that the expected significant reduction in fuel bills in individual households will result in the virtually complete elimination of fuel poverty in those buildings.

2.6. Best practices: environmental aspects

The potential environmental impacts associated with solar power — land use and habitat loss, water use, the use of hazardous materials in manufacturing, landscape and visual impacts, and global warming emissions — can vary widely depending on the technology used, the location, the scale, and other aspects of the project.

When a habitat is destroyed, the organisms that occupied the habitat have a reduced carrying capacity so that populations decline, and extinction becomes more probable. A key threat to organisms and biodiversity is the process of habitat loss.

Depending on their location, larger utility-scale solar facilities can bring about worries about land degradation and habitat loss. Habitat loss impacts from utility-scale solar systems can be minimized by placing them at lower-quality locations, such as former landfills. Smaller scale solar PV arrays, which can be built on homes or commercial buildings, have minimal or no land use impact.

It is not desirable to displace potentially productive agricultural land as a result of a solar installation. Although in some countries the use of agricultural land is restricted by policy measures, an alternative to such restrictions is low-impact solar development and co-location of solar and agriculture. This approach, which is also known as ground concurrency, has the potential to alleviate agriculture displacement by allowing solar arrays, vegetation, and livestock to occupy the same land area.

Solar PV cells do not use water for generating electricity. However, some water is used to manufacture solar PV components. Concentrating solar thermal plants (CSP) use water for cooling. Water use depends on the plant design, plant location, and the type of cooling system.

There are many ways of measuring environmental impact, and each organisation may have their own preferences. Perhaps the simplest measure is to consider the global warming emissions associated to the solar installation. While there are no global warming emissions associated with generating electricity from solar energy, there are emissions associated with other stages of the solar life-cycle, including manufacturing, materials transportation, installation, maintenance, and decommissioning and dismantlement.

Landscape and visual impacts can include the visibility of the solar panels within the wider landscape and associated impacts on landscape designations, character types and surrounding communities. Common mitigation measures to reduce impacts can include consideration of layout, size and scale during the design process as well as landscaping and planting to screen the modules. Glint and glare should also be considered in the environmental assessment process.

The reduction in carbon emissions because of the substitution of fossil fuel generation that a solar installation enables has a positive impact in the environment. A simple initial calculation of carbon savings from solar panels involves the assumption that all solar electricity directly replaces electricity produced by large power stations. A common way of calculating this is by using the ‘average grid carbon intensity’, which is the average amount of CO_2 emitted for each kWh of electricity produced for the power grid. This figure varies over time and from country to country.

In the SOLARISE project, the following best practices for environmental impact analysis have been demonstrated:

- Due to the limited availability of land in some areas, the authorities have considered the future use of ground-mounted solar installation sites. For example, one idea is to temporarily install the solar panels on the ground and shift them onto built structures when required. Therefore, all the new installations must be adaptive to the strategies of the municipalities.
- Effective space utilisation and appropriate sizing of the system seem to be important criteria in all the locations. Local and self-consumption of produced energy were given priority instead of exporting to the grid. The municipalities are keen to meet the local climate targets and consider solar energy as a viable option.
- Significant importance is given to the environmental impact associated with the proposed utility-scale systems. The maintenance of biodiversity is one of the key goals, and appropriate risk mitigation measures were identified to minimise any damage.
- At Brighton and Hove City Council need solar energy projects need to ensure that they follow a local planning policy that mandates that all developments in the area need to be of an appropriate scale for the location in terms of environmental impact and meeting the energy needs of the user.

2.7. Best practices: decision making

Decision-making is the final step in a feasibility study which involves combining the analysis of the different criteria to compare between project options, rank the options, and when appropriate make ‘go’ or no-go’ recommendations. It is useful to consider both subjective and objective data as inputs to a objective method that can aid in decision-making.

Well known tools to support decision making in feasibility study of energy systems are multi-criteria decision analysis (MCDA), cost-benefit analysis, environmental impact analysis, and life cycle assessment. Among these, MCDA is a widely used method for energy system analysis as it allows to consider different performance criteria.

In the SOLARISE project, the following best practices for decision making have been demonstrated as a part of feasibility studies:

- The solar farm feasibility study by Brighton and Hove City Council performed risk assessment for all the project options by identifying the impact and likelihood of risks for the different criteria. Mitigation strategies are recommended for each risk. Decision-making to select the best options is performed by simultaneously considering the outcomes of financial analysis and risk assessment. Sensitivity analysis is performed to overcome the underestimation of returns due to the conservative price assumptions for power purchase agreements.
- The impact assessment study performed by Enercoop used an inventory tool controlled by the Ministry of Environment to aid in decision making in the areas of land use and planning.
- The solar farm feasibility study by the municipality of Heerhugowaard reported the use of a framework built on the grounds of sustainable development which includes socio-economic, legal, stakeholder involvement and risk elements.
- A comprehensive and flexible feasibility analysis tool for solar energy projects based on MCDA was developed as part of work package 2 of SOLARISE and is described in Deliverable 2.1.1. This

tool was used effectively in the feasibility studies of living labs, the new village hall in Zoersel, and for the selection of potential PV installation sites and technologies by Middelburg.