Deliverable D5.4

Public report on the results from the feasibility studies for the most promising joint energy projects in the Lighthouse Parks

Organization: Energieinstitut an der JKU Linz (EI-JKU)

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Envisioning and Testing New Models of Sustainable Energy Cooperation and Services in Industrial Parks

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DELIVERABLE 5.4 – VERSION 0.9

WORK PACKAGE N° 5

Nature of the deliverable		
R	Document, report (excluding the periodic and final reports)	X
DEM	Demonstrator, pilot, prototype, plan designs	
DEC	Websites, patents filing, press & media actions, videos, etc.	
OTHER	Software, technical diagram, etc.	

Dissemination Level		
PU	Public, fully open, e.g. web	X
CO	Confidential, restricted under conditions set out in Model Grant Agreement	
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

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More information on the project can be found at http://www.sparcs-h2020.eu/

Disclaimer

Executive summary

This report summarizes the key results of the feasibility studies of promising energy cooperation solutions for the S-PARCS Lighthouse Parks. Furthermore, it shows that the involved companies but also their closer environment can benefit from energy cooperation in multiple ways.

The individual feasibility studies take into account technical, economic, environmental and also social, legal and political aspects, i.e. the overall assessment was strongly oriented towards a classic PESTEL analysis. The focus was on technical and economic aspects as these are commonly very decisive for companies, nevertheless environmental aspects are highly valued and of increasing interest, which is why life cycle assessments were carried out. Additionally, S-PARCS' key performance indicators, which allow the comparison and measuring of different energy cooperation opportunities, were calculated.

The following table gives an overview of the most promising investigated energy cooperation opportunities for each of the S-PARCS Lighthouse Parks. Each feasibility study was carried out in close collaboration of the local scientific and consulting S-PARCS partners and the Lighthouse Park representatives. The life cycle assessments were conducted by Tecnalia on behalf of all other partners involved. Reporting was done by the partners involved, reviews and consolidation were monitored by RINA-C (D5.3) and EI-JKU (D5.4) respectively.

S-PARCS Lighthouse Park	Evaluated energy cooperation solution
Ponte a Egola, Italy	CHP network
Ennshafen, Austria	Jointly organized PV installations
	Joint e-charging stations
Chemiepark Linz, Austria	Cooperation with neighbourhood outside the park: High temperature waste heat feed in to DHN
Okamika-Gizaburuaga, Spain	Solar PV for shared self-consumption
	Small hydroelectric plant
Bildosola-Artea, Spain	Small hydroelectric plant

Ponte a Egola is part of one of the most important industrial clusters of the leather producing sector in Italy and internationally. In the feasibility study, the implementation of a combined heat and power (CHP) network based on three gas-based CHP plants was analysed. The concept would allow to supply the Ponte a Egola tanneries, Cuoiodepur as well as external partners with heat and electricity. Furthermore, in the future, locally produced biomethane based on tannery sludge could further increase the local economic and environmental benefits.

For **Ennshafen,** two feasibility studies are presented. As approx. 95 % of the employees in the park are car commuters, a future increase of e-vehicles is expected for which an attractive charging infrastructure at the workplace could be conducive. Therefore, the first feasibility study evaluated the benefit of shared e-charging stations compared to a scenario in which the companies installed their own e-charging stations. Economic benefits are expected as the utilization factor of the e-charging stations would be higher and potentially lower electricity prices could be obtained. The second feasibility study evaluated the jointly organized installation of solar-photovoltaic panels (PV) on company roofs. Hence, suitable roofs and power capacities were evaluated and business models were developed, e.g. financing the PVs via small local investors, in order to reduce financial barriers and generate additional benefits for the companies as well as other local stakeholders.

The **Chemiepark Linz** in Austria is special as it maintains a steam and cooling water network that is jointly used by several independent companies located in the park. Although the existing system is constantly optimized, further optimization opportunities exist – e.g. when heat sinks outside the park are considered. In this study, the waste heat utilization potential from Chemiepark Linz for a feed-in to the local district heating network (DHN) was analysed. The implementation could lead to economic as well as environmental benefits, furthermore it would benefit the local community.

For the two Spanish parks, **Okamika-Gizaburuaga** and **Bildosola-Artea,** in the Basque Country, the joint investment into micro hydropower plants was evaluated. Focus was laid on self-consumption of the produced electricity by the local companies, still, (surplus energy) grid feed-in would be possible. For both locations, environmental and social aspects are to be highlighted, economic feasibility is given when public subsidies are taken up.

For **Okamika-Gizaburuaga** the installation of joint PV was analysed, additionally to the micro hydropower plant. Different scenarios were investigated, leading to different PV capacities and hence varying self-consumption, feed-in quantities and consequently economic balances. It was shown that medium-sized PV installations designed for joint self-consumption of the companies generate the highest economic benefit. In case more companies with different load profiles join, the overall economic benefit but also the size of the PV system could be further increased.

In summary, in the course of the S-PARCS project the identification and analysis of several energy cooperation opportunities was achieved, proving that energy cooperation can be as manifold as described in theory in the previous deliverables. Most of the feasibility studies lead to the conclusion that it is worthwhile to either carry out an even deeper analysis (e.g. with more data), potentially expanding the scope of the project (e.g. looking for additional partners) in order to achieve optimal economic results or to look for potential investors and engineering companies in order to develop a detailed implementation plan.

Additionally, some of the cooperative projects owe their profitability mainly to their cooperative character, showing that energy cooperation can significantly expand the pool of sustainability, renewable energy and energy efficiency measures that are available to companies. This is the case for the CHP network investigated for Ponte a Egola, which can only be energetically and economically balanced via the inclusion of several suppliers and customers. Some energy cooperation opportunities such as joint PV installations or e-charging infrastructure could be implemented by individual companies as well, however economic feasibility and the overall impact of the project (e.g. in sense of the local community) tend to be lower. In other cases, limits of internal energy efficiency optimization are close to be reached (at least for some energy streams) – in such cases energy cooperation with third parties can open up new economic and technical possibilities as was shown for Chemiepark Linz. Lastly, some projects would not be feasible at all in case an individual company would try to implement them – such as the Spanish micro hydropower plants. Although subsidies still would be needed in order to achieve economic feasibility, the joint investment and operation of the plants increases the overall feasibility significantly, i.e. otherwise no implementation at all would be possible, as risks would not be shared and the economically beneficial self-consumption not be optimized.

Further details on the current or future activities of the Lighthouse Parks in relation to the implementation of the energy cooperation solutions described in this report (also beyond the S-PARCS project duration) are outlined in D5.5 “Energy cooperation plan per park”.

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Abbreviation	Meaning
CAPEX	Capital Expenditure
CHP	Combined Heat and Power Plant
CO_2	Carbon Dioxide
CO_2equ	Carbon Dioxide equivalents
CW	Cooling Water
DHN	District Heating Network
ESCO	Energy Service Company
EV	Electrical Vehicle
GHG	Greenhouse Gas (emissions)
IAT	Initial Assessment Tool
ICEVs	Internal Combustion Engine Vehicles
IRR	Internal Rate of Return
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
O&M	Operation & Maintenance
OPEX	Operational Expenditure
PBP	Pay-Back-Period
PV	Photovoltaics
WP	Work Package

1 Introduction

This report summarizes the work performed in Work Package 5 (WP5) of the S-PARCS project in the five S-PARCS Lighthouse Parks. Multiple feasibility studies were elaborated and the key results of the most promising ones are outlined below.

For all S-PARCS Lighthouse Parks, potential joint energy projects were identified. Within other work packages of the S-PARCS project, the different solutions were analysed in terms of their identification (Deliverable 1.1 - [1]), the barriers that might arise (Deliverable 1.2 - [2]) and possible instruments to address them (Deliverable 2.1 and 2.3 - [3, 4]), whilst in the present document the approach focuses on a number of tailored solutions, which have been studied in detail, applying the concepts developed in S-PARCS to the actual situation of the project-specific Lighthouse Parks. For chosen energy cooperation solutions, which were deemed promising in terms of interest from the companies and their respective technical feasibility, feasibility studies were conducted. These studies take into account technical, economic and also social, legal and political aspects of their implementation.

Each feasibility study has been developed by the scientific and consulting partners (EI-JKU, SSSA, RINA-C, Tecnalia) in close cooperation with the respective Lighthouse Park representatives (park operator - EHOO, Borealis, Cuoiodepur, BSI - as well as the involved companies). While a common template was provided, a precise choice has been to allow a wide flexibility due to the very diverse nature of the various analyses performed, which ranged from economic aspects to technical ones. The method applied is strongly oriented towards the PESTEL[1] [5–7] method that is a classic business environment respectively investment decision evaluation tool.

Figure 1-1: PESTEL analysis and its 6 factors. Source: EI-JKU

Focus of the analyses differed depending on the evaluated solution and connected barriers, however, the main focus was generally laid on technical and economic as well as environmental aspects. To assess the latter, life cycle assessments were carried out.

The software-based [8] life cycle assessments were conducted by Tecnalia including the product stage (Module A1-A3), the construction stage (Module A4-A5) and the use stage

[1] Also known as PESTLE or STEEPL analysis.

(Module B1-B7) according to EN 15804:2012 + A2 [9]. The ecoinvent 3.5 database [10] was selected as reference database to define basic materials and processes. Depending on the individual solutions analysed, case-specific data were added whenever needed.

Additionally, S-PARCS key performance indicators[2] (KPIs) that allow the comparison and measuring of different energy cooperation opportunities for economic, sociocultural, environmental, legal and organizational factors, were calculated in order to complement the overall feasibility study.

The subsequent sections summarize the key results of the following auspicious feasibility studies for each S-PARCS Lighthouse Park (see Table 1-1):

Table 1-1: Most promising energy cooperation opportunities of each Lighthouse park.

S-PARCS Lighthouse Park	Evaluated solution
Ponte a Egola, Italy	CHP network
Ennshafen, Austria	Jointly organized PV installations
	Joint e-charging stations
Chemiepark Linz, Austria	Cooperation with neighbourhood outside the park: High temperature waste heat feed in to DHN
Okamika-Gizaburuaga, Spain	Solar PV for shared self-consumption
	Small hydroelectric plant
Bildosola-Artea, Spain	Small hydroelectric plant

As this report summarizes the full feasibility studies and will contribute to the development plans of the Lighthouse parks, it closely relates to these two other deliverables:

- D5.3 “Feasibility studies for the most promising joint energy projects in the Lighthouse Parks”, which is the confidential version of the present document that contains all studies and is the basis of the present report. [13]
- D5.5 “Energy cooperation plan per park”, which is the natural prosecution of these feasibility studies and which will detail the strategy to achieve the most promising results.[3]

<u>Note:</u> As the full feasibility studies contain sensitive data and/or confidential information, the public summaries may differ in their level of detail to ensure protection of privacy and trade secrets. Additionally, the aim of this deliverable is to focus on key findings of the feasibility studies instead of reproducing D5.3, which is why detailed procedures of the feasibility studies were curtailed.

[2] Note: The following sections include radar charts showing KPIs that were calculated based on the methodology developed in D4.1 [11] and D4.2 [12] of the S-PARCS project. Reason for the KPIs are that performance evaluation is an inevitable step towards performance improvement. Additionally, the KPIs allow to easily compare solutions that are contrarious in their concepts in order to support investment decisions. Lastly, the performance of a solution after implementation can be monitored regularly. More information on the KPIs can be found in aforementioned public deliverables, also they are implemented in the Initial Assessment Tool (IAT) available at https://iat.sparcs-community.eu/.

[3] Under development.

2 Ponte a Egola, Italy

2.1 CHP Network

2.1.1. Description / Background

Ponte a Egola industrial park belongs to the Tuscan Leather industrial area, which extends in a territory of about 100 000 inhabitants across several municipalities between the provinces of Pisa and Florence. The Ponte a Egola industrial park is one of the leading industrial parks in the field of tanning at Italian and international level, with more than 100 companies involved. The companies are mainly small-medium family businesses, with an average number of 12 employees and a 2.5 million euros turnover respectively.

Ponte a Egola industrial park is a homogeneous industrial area since it includes tanneries or businesses related to the tannery industry. For such companies, energy costs are not particularly relevant as compared to their total costs, and the knowledge about energy management within companies is scarce. However, the tanneries are interested in fostering energy cooperation solutions.

2.1.2 Objectives

One of the most promising energy cooperation solutions regards the development of a **combined heat and power plant (CHP) network**. In the first step, the CHP network will be served with natural gas and in a second implementation (and second feasibility plan) an anaerobic digestor is planned that will utilize waste and produce biogas for the CHP.

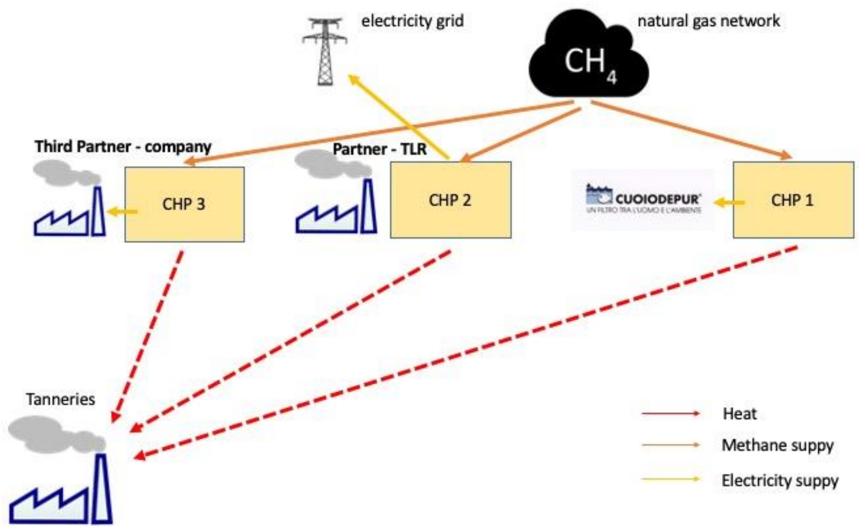

Figure 2-1: Initial configuration of the intended CHP network – utilization of natural gas. Later on, on-site biogas/biomethane production and utilization is planned. Source: Cuoiodepur

The idea is to use biogas (and further biomethane) yielded by the anaerobic digestion of sludge (from Company A - Cuoiodepur) and solid wastes (from tanneries) to produce heat and electricity for companies within the industrial park and for the wastewater treatment plant managed by Company A. The plant is contrived to be located in the area of Company A, which represents the partner with the highest consumption of energy. The transport of heat and electricity from Company A to the Ponte a Egola industrial area would result in minimum losses, since the linear distance is less than 1 km.

2.1.3 Technology description

Out of 28 tanneries considered to be connectable, with a declared need of 31 GWh/year, it was assumed that 80 % of them would be supplied with thermal energy, for a total of 24.7 GWh/year.

Three separate CHPs are foreseen after modelling of several constellations:

- CHP 1 in Company A (Cuoiodepur) will work for 8 000 h/year, Company A will consume all the electricity and the thermal energy will be sent to the grid (9.1 GWh_{th}/year).
- CHP 2 in Company B will work for 4 650 h/year and the thermal energy sent to the grid will be 2.6 GWh_{th}/year.
- CHP 3 (Partner TLR) will cover the remaining thermal needs and will sell the electricity to the national grid.

2.1.4 Economic key parameters

Total investment of the CHPs 1, 2 and 3 will rise around 10 million euros approximately.

Regarding functioning, it is expected that the CHPs installed will operate such as:

- Company A: it will be kept in operation for about 8 000 hours per year and that, in addition to supplying electrical and thermal energy to the treatment plant, it will transfer the excess thermal energy to the thermal grid (TLR) network (equal to approximately 9.1 GWh_{th}/year);
- Company B: it will be kept in operation for about 4 650 hours per year and that, in addition to supplying electrical and thermal energy (in the form of steam) to the site of Company B, it will transfer excess thermal energy to the TLR network (equal to about 2.6 GWh_{th} / year).
- The third CHP will cover the remaining thermal needs.

From the economic analysis it was conducted that the CHP network seems to be perfectly feasible. Revenues from saving of self-consumption of energy, plus heat to be sold to tanneries and energy to Company B, are going to cover the costs expected for the initial investment and the maintenance of the plant, such as operational expenditures.

2.1.5 Environmental impacts

The environmental performance of co-generation was carried out according to the *EN-15804:2012 + A2 - Sustainability of construction works – Environmental product declarations - Core rules for the product category of construction products*. In a first step, the natural gas supplied CHP network was modelled – in case locally produced biomethane is utilized even higher positive environmental impacts are expected. All the CHPs were included in the study.

During the LCA some assumptions had to be made where no specific data was available:

- "Ecoinvent v3.5" database was selected as reference database to define basic materials and processes;
- Flows related to human activities such as employee transport are excluded;

- The electricity generated will replace the electricity generation mix of the park as a whole. In case of heat generated, it will replace the heat generation from a natural gas fed conventional boiler;
- The allocation method in order to distribute the benefits gained from improved fuel utilization as well as the environmental impacts connected to combined heat and power generation are distributed between the two products, electricity and heat. The relationship of distribution is expressed as percentage of the fuel needed for each alternative process with respect to the total quantity needed. The distribution was taken as 60 % for electricity and 40 % for heat.
- During the reference study period (25 years) there are no replacements. The lifetime of the main components is considered to be longer than or equal to the study period.

LCA results show that environmental impacts are dominated by the operational stage, (i.e. use of fuel), which is the major contributor to the environmental impact throughout the life cycle. The good results are partly reached due to increased efficiency of the cogeneration process by reusing the waste heat from electricity generation.

The savings potential in the total environmental impact during the use phase for electricity generation is around 50 % reduction of CO_2 emissions (-8 221 tons/year) and the use of non-renewable primary energy (-30.9 GWh/year). For thermal energy generated, the CO_2 emissions will be reduced by 38 % (-2 558 tons/year) and the use of non-renewable primary energy by 98 % (-28.78 GWh/year).

2.1.7 KPI overview

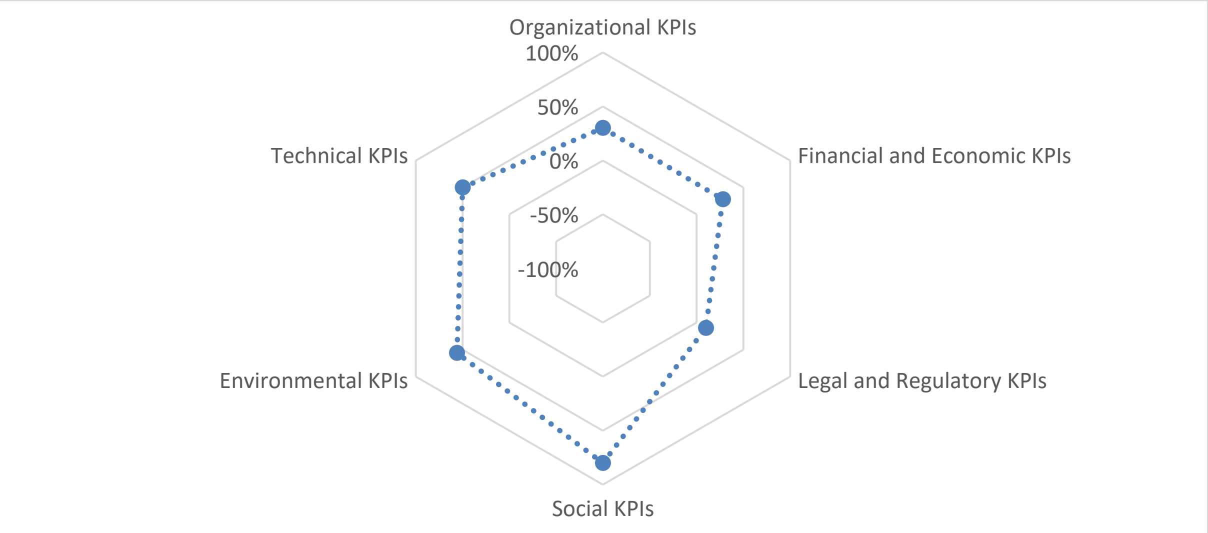

Figure 2-2: KPIs of the CHP network at Ponte a Egola. Source: SSSA

The KPIs have been calculated assuming the implementation of the proposed solution. The lowest results are related to the legal and regulatory KPIs and, partially, to the financial and economic KPIs. This is due to expected restrictions and obstacles that may arise during the stipulation and the contract period (between the companies and the park). Additionally, the investment is significant compared to other investments at the park already existing. With respect to the companies, high involvement of them is expected. This determines a medium result of the organizational KPIs. Finally, regarding the technical and environmental KPIs, excellent results are expected. In particularly for the latter, as high emission savings are expected. Also, significant beneficial social impacts can be assumed, such as an increasing employment rate in the park for operation and maintenance of the plants.

2.1.7 Conclusions and outlook

The economic analysis shows that the investment is feasible as the CAPEX and OPEX (maintenance costs) will be covered by cost savings achieved through the self-consumption of energy plus the revenues resulting from the heat sold to tanneries and power to Company B. LCA results show that environmental impacts are dominated by the operational stage, (i.e. use of fuel), which is the major contributor to the environmental impact throughout the life cycle, whereas the efficiency of the cogeneration process by reusing the waste heat from electricity generation yields environmental benefits. Cost estimation and timetable planning were also conducted, defining the next steps to be performed and related costs. In addition, meetings and engagement activities were carried out to involve relevant stakeholders – i.e. the owner of the heating infrastructures in the industrial area of Ponte a Egola and the technology providers. The next steps will consist in carrying on the engagement of all relevant stakeholders, particularly financing bodies for support in covering the investment costs.

3 Ennshafen, Austria

3.1 Joint e-charging stations

3.1.1 Description / Background

The global share of electric vehicles (EV) by the year 2040 is forecasted to equal up to 80 % [14–16]. Given the importance of alternative forms of mobility to reach the climate objectives stipulated by the Paris agreement, action plans and planned measures such as the EU's green deal or the Austrian National Energy and Climate Plan, emphasize the need to focus – among other measures – on electrifying passenger transport. In the light of an increasing share of electric vehicles, a roll-out of additional charging infrastructure (on company premises) is necessary.

3.1.2 Objectives

The objective of this report is to evaluate the costs and feasibility of installing electric charging points on company premises and compare the costs, expressed in a surcharge on top of the price of electricity, of individually installed charging points versus shared charging points in four suitable locations in the industrial park.

3.1.3 Technology description

11- and 22-kW-AC Type 2 charging points were taken into consideration as they represent a large share of the charging points currently installed in Austria.

3.1.4 Economic key parameters

The feasibility analysis of the potential locations for the installation of shared charging points show that they result in significant cumulative economic advantages compared to individual charging points which is primarily due to the increasing share of electric vehicles per charging point with growing numbers of electric vehicles. On individual company level economic advantages arise especially for small companies that can share charging points with companies that feature a larger electric vehicle fleet (and thus a larger number of electric charging points). Smaller companies (with lower consumptions of electricity) could also benefit from lower prices of electricity of larger companies, making it cheaper to load an EV at the shared charging point. Shared 22 kW (as opposed to 11 kW) charging points result in higher net present values. Surcharges of as low as 7 cents/$kWh_{charged}$ can lead to a positive net present value within the useful life of a charging point depending on the number of vehicles and the corresponding number of charging points.

3.1.5 Environmental impacts

The environmental impact of the production of charging stations is negligible compared to the impacts resulting from the production, use and waste processing of electric vehicles [17]. In some scopes literature suggests that electric vehicles in Europe may have a higher environmental damage than internal combustion engine vehicles (ICEVs). This is especially due to the production of the battery packs. Still, they generally cause less greenhouse gas emissions during their useful lifetime than comparable ICEVs, depending on the electricity mix used as fuel [18].

3.1.6 Social / Legal / political aspects

From a macro-economic perspective, the increasing market share of EVs (and thus the installation of additional charging infrastructure) will have both winners and losers as the replacement of ICEVs will cause job losses in some areas while creating jobs in others. From an Ennshafen perspective positive impact is expected as low operation costs for transport can lead to significant cost savings. Furthermore, the social interaction and possibly also long-term business relations of the Ennshafen companies are strengthened. [19]

3.1.7 KPI overview

The following Figure 3-1 shows the results of the KPI evaluation based on information derived from this report (assuming an EV share of 10 % for the local implementation and a surcharge of 0.10 €/kWh for all four analysed sites) as well information gathered during the confidential interviews, using a selection of KPIs as indicators for the respective sub-categories.

Given that all percentage values are above 0 (0 = neutral), the implementation of this energy cooperation solution (namely the installation of shared electric vehicle charging points) shows to be a promising one, whereas the least positive values can be found in environmental and organizational KPIs. The reason for these results is the negligible reduction of primary energy consumption and GHG emissions (compared to individual charging points per company) as well as little effects of the installation on local employment and stakeholder involvement respectively. Compared to conventional ICEVs these KPIs are expected to become significantly more positive.

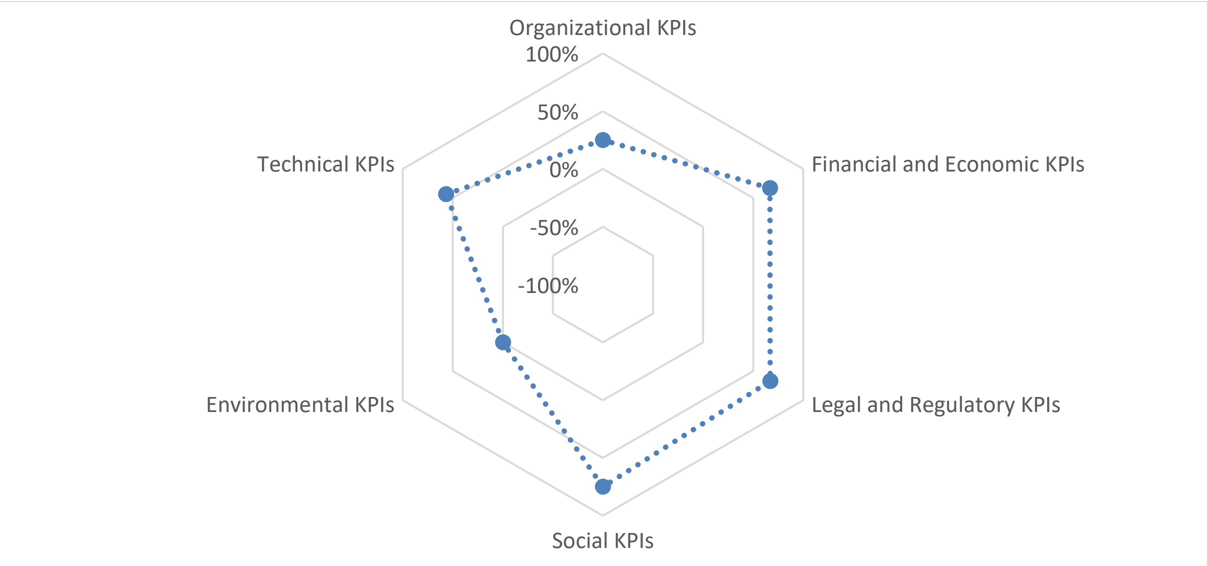

Figure 3-1: KPI evaluation electric charging points Ennshafen business park. Source: EI-JKU

3.1.8 Conclusions and outlook

The feasibility analysis of potential local installations of shared charging points show that shared charging points on company premises result in significant cumulative economic advantages over individual charging points and that they are competitive with charging rates offered by energy service companies or household electricity prices. Shared 22 kW (as opposed to 11 kW) charging points result in higher net present values.

As no literature exists that addresses the recommended / reasonable number of charging stations depending on the number of electric vehicles in a fleet in detail, assumptions with respect to charging stations per electric vehicle were based on expert interviews. Given the crucial effects of the share of electric vehicles per charging point on the feasibility, it is necessary to fortify the empirical basis for determining this share (of electric vehicles per charging point) in the future in order to be able to fully evaluate the feasibility of installing (shared) electric vehicle charging points as well as determining the recommended / necessary number of charging points per EV. For individual companies or groups of companies, it therefore seems recommendable to start with small numbers of charging stations while at the same time providing room for installing additional ones in order to avoid extensive financial burdens.

3.2 Jointly organized PV installations

3.2.1 Description / Background

The Ennshafen industrial port & business park offers a significant amount of rooftop area that provides an estimated net area of approximately 160 000 m² for the installation of rooftop PV power plants in addition to a significant amount of open areas that are likely to be suitable for the erection of ground-mounted systems. In the light of the Austrian government's ambitious objective to provide 100 % of the electricity demand in Austria from renewable sources until 2030 according to the national energy and climate strategy, a significant increase in the erection of PV power plants and attractive business models are necessary [20, p.12].

3.2.2 Objectives

The objective of the feasibility study is to evaluate the feasibility of the installation of joint PV power plants on five selected companies in the Ennshafen business and industrial park as well as outlining potential advantages, disadvantages and barriers of a joint installation. "Joint" in this case refers to several separate PV power plants on the roofs of a selection of (five) companies in the industrial park that are to be financed by small private investors such as employees of companies, residents of the local communities or other small private investors who in return receive interest rates above current interest rates in the EU.

3.2.3 Technology description

The PV power plants on the company roofs are assumed to be composed of poly-crystalline 300-Wp-PV panels with string converters and mounting systems suitable to the local conditions. The total PV power is expected to amount to 1 470 kWp for the five companies evaluated, generating close to 1 500 MWh of electricity per year of which close to 95 % will be self-consumed by the respective companies without feeding into the grid, thus having little effect on grid stability and creating no necessity for additional grid infrastructure or an upgrading of the latter.

3.2.4 Economic key parameters

The feasibility analysis shows the reaching of the break-even-point after 13 to 17 years depending on the specific investment costs payable. The main factors affecting the feasibility in the analysed case are the price of electricity, the rate of self-consumption as well as the specific investment costs. The non-financial benefits of e.g. an increased identification with the companies as well as the business park are assumed to be significant even though they cannot be quantified at this stage of the potential project.

3.2.5 Environmental impacts

The European Commission assumes the European PV-capacities need to increase 16-fold between 2018 and 2050 to meet set climate objectives [21]. Despite differences in the calculated energy return on investment depending on the source (ranging from 2 [22] to 10 [23] in Austria) there is broad agreement that PV panels are an essential part of a future climate friendly energy mix. With emission factors of 0.042 $kgCO_2$equ/kWh for PV-generated electricity versus 0.124 $kgCO_2$equ/kWh for the overall Austrian electricity mix the emissions reductions of the analysed joint PV power plant amount to 121.12 tCO_2equ/year. [10]

3.2.6 Social / Legal / political aspects

The physical installation of PV power plants is subject to a number of federal and state laws that differ to a certain extent within the Ennshafen area as it spreads over two Austrian federal states [24]. The most critical issue when implementing this kind of joint PV power plant project including interest payments to small investors is to establish a legally save company construct and funding scheme. Among those funding schemes available the sale-and-lease-back model has been found to be the most promising whereas the most suitable company construct depends on the partners and investors involved [25].

3.2.7 KPI overview

The following Figure 3-2 shows the results of the KPI evaluation based on information derived from this report as well information gathered during the confidential interviews using a selection of KPIs as indicators for the respective sub-categories.

Given that all percentage values are above 0, the implementation of this energy cooperation solution (namely the joint installation of PV power plants) shows to be a promising one, whereas the least positive values can be found in environmental and organizational KPIs. The reason for these results is the relatively small reduction of primary energy consumption and GHG emissions compared to the large amount of remaining (fossil fuel) energy consumption in the park. Additionally, only small effects of the installation of the five PV power plants on the local employment rate within the park and stakeholder involvement are expected.

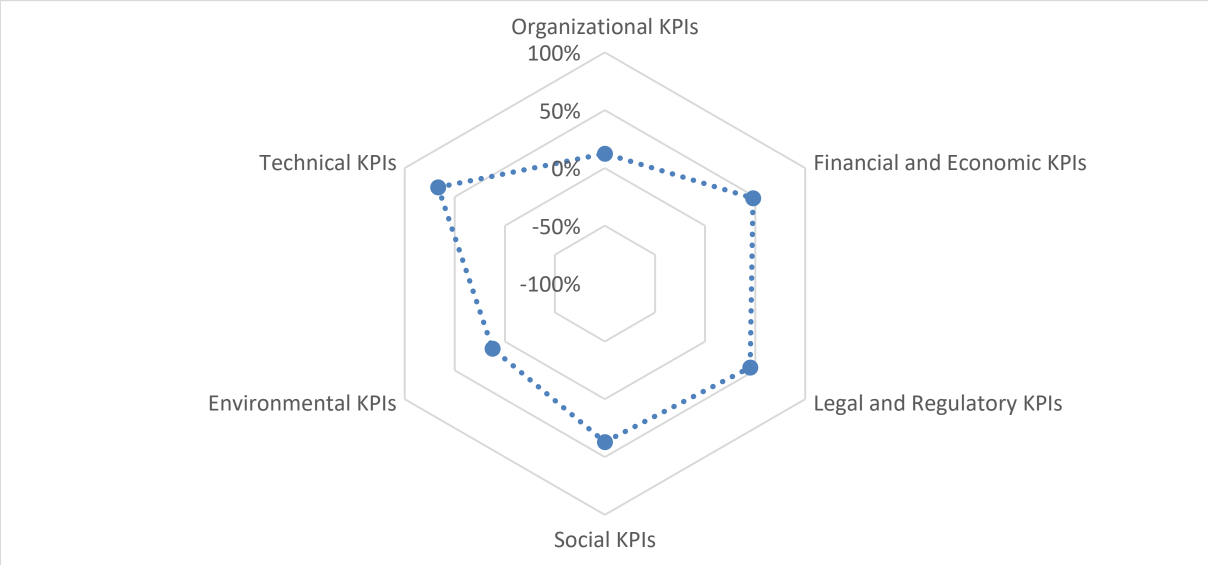

Figure 3-2: KPI evaluation joint PV power plants Ennshafen industrial business park. Source: EI-JKU

3.2.8 Conclusions and outlook

The local companies taken into consideration are all suited for the installation of PV plants with respect to high rates of self-consumption as well as competitive life-cycle-costs of electricity of the generated electricity. Financing through a joint power plant scheme provides a possibility to significantly reduce the amount of upfront equity capital necessary. Even though the 3-%-interest rate provided to the investors is higher than the current Euribor interest rates, price discounts for joint purchase of all power plants might (partially) compensate the high interest rates along with non-financial benefits such as strengthening e.g. employee and local community ties.

Following the positive results of the feasibility study, lack of legal impediments for the installation of the power plants as well as the environmental advantage of PV electricity over the average Austrian electricity prices, concrete price offers should be obtained, taking into consideration the local conditions for the installation of PV power plants as well as contacting potential (small private) investors and cooperation partners (e.g. vouchers for regional shopping) in order to set up a detailed financing scheme.

4 Chemiepark Linz, Austria

4.1 Waste heat feed-in to local DHN including decentralized building cooling

4.1.1 Background

Chemiepark Linz (CPL) is a multi-company park in the Austrian city Linz, which covers about 1 km². The 8 major companies in the park are all energy intensive and are primarily active in different areas of the chemical industry.

The park infrastructure and utilities are special, as the whole park formerly was part of one chemical company. When it was split up, the shared infrastructure, such as steam and cooling water (CW) supply, were maintained. One of the main producers of steam is Borealis Agrolinz Melamine, due to exothermal chemical reactions of the production processes.

For the feasibility study, it was assumed that Borealis and the local district heating network (DHN) operator, supplying the whole city, would cooperate in the utilization of waste heat. Underlying data and information were mainly taken from existing studies, public data and provided by Borealis. The DHN operator was not involved in the elaboration of the study.

4.1.2 Objectives and description of the Energy Cooperation

The idea is to reuse the waste heat from the CPL by feeding it into the DHN, thus replacing fossil fuels such as natural gas that is used as a primary energy source for the nearby DHN power plant.

The available waste heat has been calculated after a careful examination of the most suitable extraction points in the system for size and location, with the requirement to use heat exchangers and renounce heat pumps.

The identified waste heat sources amount to several megawatts with a temperature level being sufficient for the DHN throughout most times of the year, as the DHN temperature is regulated according to outdoor temperatures [26]. The waste heat is produced by Borealis and is emitted to cooling water or air today.

Two scenarios were evaluated: feed-in for building heating throughout winter time and an additional demand during summer, as heat-to-cold technology and district cooling is enforced by the local DHN [27, 28], which provides a good opportunity to utilize waste heat during summer time. Still, winter demand was estimated to be several times higher than summer demand.

The expected main beneficiaries of the cooperation are:

- Waste heat disposal, economic benefits, reputation: Borealis
- Increased capacities of CW system: all CPL companies connected to the joint system
- Substitution of fossil energy, economic benefits, reputation: DHN operator
- Positive impacts on the local environment

4.1.3 Economic and Environmental impacts expected

Economic feasibility is given, taking into account capital expenditure (assumption: operational costs are comparable to status quo of DHN) and assuming gas-based heat to be replaced with waste heat. The pay-back period is a few years; however, business models and contract design have not yet been evaluated in detail.

Taking into account that natural gas could be replaced by the waste heat – continuously throughout the year – several thousand tons of CO_2 emissions could be saved and the non-renewable primary energy demand reduced by several gigawatt hours, leading to significant environmental benefits.

4.1.4 Social / Legal / political aspects

As the centralized heat/cold generation leads to overall high efficiency and low maintenance effort for individual consumers, the specific heating/cooling effort and cost are estimated to be quite low for the consumers, resulting in social and economic benefits. Additionally, the transfer stations for district heating and cooling need much less space than alternative decentralized heating/cooling devices. This fact is important especially for large residential buildings with small/medium-sized apartments.

From a legal perspective, waste heat feed in to DHN is possible in Austria, but there are no specific regulations nor preferential treatment of waste heat feed-in. The DHN operator is not obliged to allow the feed in. The waste heat supplier and the DHN operator have to negotiate and set up a contract.

4.1.5 KPI overview

Suitable KPIs according to D4.1 [11] and D4.2 [12] have been calculated assuming the implementation of the proposed solution. As the technology is state of the art and no temperature conversion is needed, technical KPIs achieve good results, the same applies for economic KPIs.

The organizational KPIs are (a bit less) positive as well, as one CPL-internal and one external company would cooperate, while the number of directly engaged employees is assumed to be rather low. Regulatory KPIs are positive as well, however barriers mentioned in section 4.1.4 apply. Social KPIs are rated very positive, as the solution has a high replication potential and serves the local community.

The environmental KPIs are rated less positive compared to the others as the amount of utilized waste heat is rather small compared to the overall energy fluxes of the cooperation partners. Furthermore, some environmental benefits, e.g. reduced utilization of the open circle CW system are not represented by the KPIs.

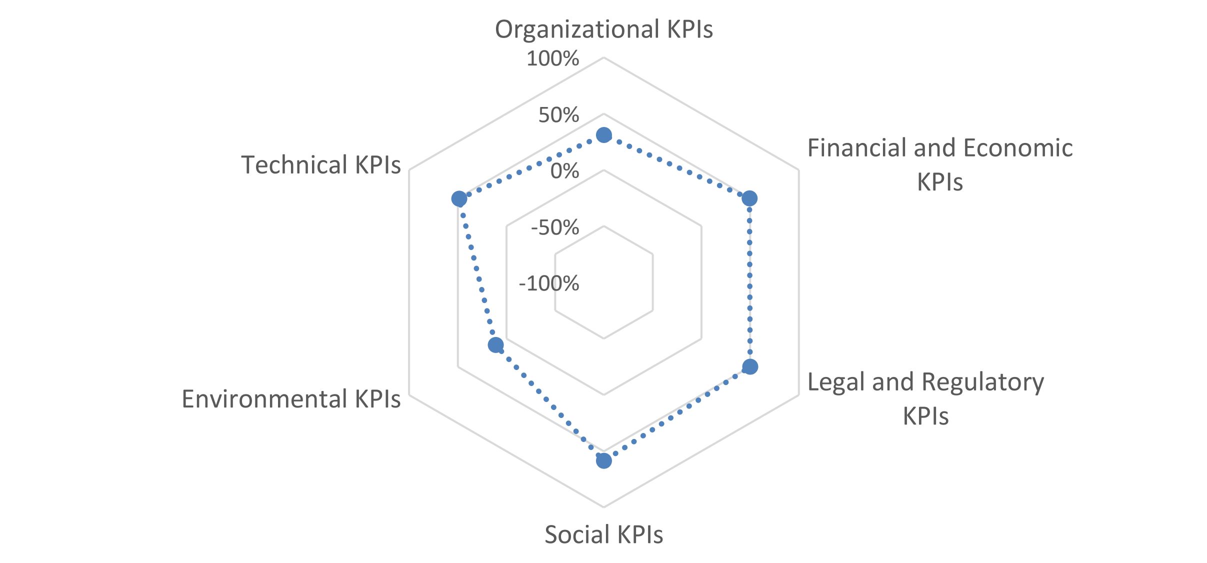

Figure 4-1: KPI radar chart for CPL waste heat feed-in to DHN Linz. Source: EI-JKU

4.1.6 Conclusions and outlook

As climate and environmental matters are of increasing interest in the City of Linz, the Chemiepark and apparently also for the DHN operator due to mild winters, hot summers and changed consumer habits, the basic idea of the conducted pre-feasibility study will be further discussed in order to elaborate satisfying collaborations. In order to do so, it is recommended that potential partners focus on joint project development, in order to cover aspects, which were not known when this study was conducted - such as detailed expansion strategies for the DHN, heat/cold demand development and contractual requirements. Furthermore, research on best practices and contractual solutions of similar projects could simplify further development steps and negotiations. As Chemiepark Linz is integrated into the City of Linz, close to a power plant by the DHN operator and in accordance with local, national and European climate goals, further intensification of collaboration is very likely, with the current study being of exemplary character.

5 Okamika-Gizaburuaga, Spain

5.1 Collaborative solar PV system

5.1.1 Background

Okamika park is an industrial complex with 26 companies. A detailed photovoltaics (PV) study for five companies, located in three different pavilions (P1B, P2, P3) at the same park has been carried out (from now on we call them **joint park**). Their main activities are mechanical engineering for third parties, manufacture of paper and cardboard containers and packaging and manufacture of rubber articles, synthetic rubber and latex.

Spain is one of the first members of the EU to adopt the European directive implementing one of the most ambitious regulations: Since April 2019 [29], the entry of the new regulation Royal Decree RD 244/2019, essentially allows the formation of energy communities, by allowing consumers to “connect” to a common renewable energy (RE) facility at the local level.

5.1.2 Objectives and description of the Energy Cooperation

The objectives were to carry out a feasibility study for PV installations for shared self-consumption among the different companies that exist in each pavilion and then analyse the case of shared self-consumption of the pavilions that compose the park, considering them as a single consumer.

Of the available options, "Subject to compensation" (the surplus energy is paid to the producer with an average market price of 0.047 euros/kWh) – was chosen. Within this modality of self-consumption, two scenarios have been studied both for the pavilions and for the park as a whole.

- Scenario 1: Dimensioning for self-consumption only (no electricity is fed into the grid)
- Scenario 2: Sizing for an annual net energy balance (total PV production = annual electricity consumption)

The study includes the calculation of photovoltaic production, economic calculations of export and/or self-consumption as well as dimensioning of the installations, technical viability of photovoltaic installation on roofs and techno-economic optimization of photovoltaic installations. Furthermore, an analysis of the impact of the installation on the park's electrical mix and an analysis of the environmental impact avoided were carried out.

5.1.3 Economic and Environmental impacts expected

To carry out the economic analysis and the staging of the two scenarios for each pavilion and for the park, the following prices were used: with regard to the economic compensation for the surplus energy fed into the network, it will be compensated with 0.047 euros/kWh generated (average price of the Spanish daily market) [30].

In addition, the prices associated with electricity consumption were collected. These prices are in accordance with distributor’s tariff 3.0A which is established in three periods (peak, flat, and valley) for the different times of the day according to [31]. A distinction is also made between the winter (November-March) and summer (April-October) periods (Figure 5-1 and Figure 5-2).

These prices will serve for both the cost of consumption and the savings that will be obtained by self-consumption thanks to the PV installation.

- 4 “peak” hours (orange) → approx. 0.147 €/kWh
- 12 “flat” hours (light green) → 0.125 €/kWh
- 8 “valley” hours (dark green) → 0.0905 €/kWh

Figure 5-1: Winter periods (Nov-Mar) [31]

Figure 5-2: Summer period (Apr-Oct) [31]

As far as the cost of the installation is concerned, prices[4] have been collected for the PV installation in terms of euros/Wp installed.

Table 5-1: PV System price (UNEF [32])

Hardware		
Modules	0.6	€/Wp
Inverter	0.2	€/Wp
Infrastructure, racking wiring…	0.2	€/Wp
Soft costs		
Installation	0.07	€/Wp
O&M	0.02	€/Wp year
Total initial investment	1.07	€/Wp

Studying the evolution of the price of electricity in the last decade, it shows a growing tendency of 0.75 % annually was assumed (data from Eurostat [33]). Nevertheless, great variations have been observed in the last decade and greater introduction of renewable energy in the system may contribute to price reductions [34]. Additionally, a discount rate of 6.7 % has been established for the analysis [35]. The following Figure 5-3 shows the relation between the install power and the internal rate of return (IRR). Table 5-2 shows the relevant results for the analysed scenarios.

[4] Obtained from the PSU (Photovoltaic Spanish Union).

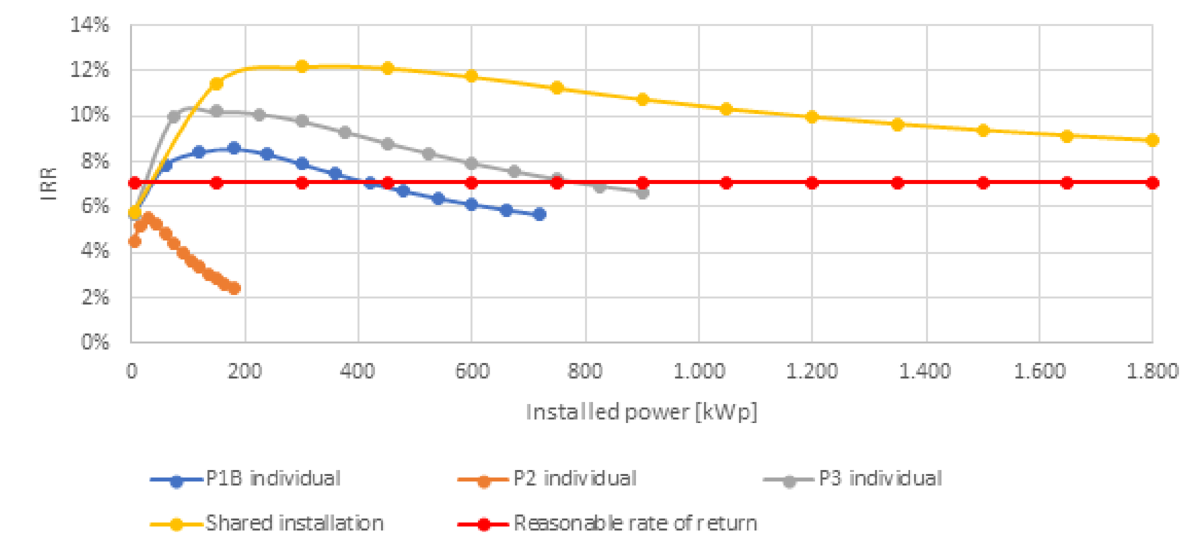

Figure 5-3: Internal rate of return (IRR) - Joint Park. Source: Tecnalia

Table 5-2: Results Joint Park. Source: Tecnalia

Self-consumption only (S.C) (1)		Maximum available surface (M:A.S) (2)	
Rated power	41 kW	Rated power	1 233 kW
Annual energy consumption	1 543 MWh	Annual energy consumption	1 543 MWh
Annual PV production	45.1 MWh	Annual PV production	1 346 MWh
Self-consumption rate	100 %	Self-consumption	46 %
Self-supply rate	3 %	Self-supply rate	87 %

- Investment cost for self-consumption only: 41 * 900 €/kW = 36 900 €
- Investment cost for maximum available surface: 1 233 * 750 = 924 750 €
- Investment cost for maximum IRR: 400 * 750 = 300 000 €

The **environmental impacts** associated with the PV system are dominated by the product stage, (i.e. components manufacture and PV system), which is the major contributor to the environmental impact throughout the life cycle.

The saving potential in total environmental impact is very large, due to replacement of the current energy mix with 100 % renewable energy, **reaching savings** of **85.5 %** in **CO_2 emissions** and **92.7** % in the use of **non-renewable primary energy**.

5.1.4 Social / Legal / political aspects

Considering the legal aspects, it is important to point out that legal and regulatory viability is high and that bureaucratic procedures have been greatly simplified in recent years.

Since 2007, the regulation concerning PV installations has undergone significant changes for the sector, going from very favourable situations at the beginning to instruments such as the "sun tax" which practically paralyzed the installation of solar panels for self-consumption. Finally, since April 2019, the entry of the new regulation allows the installation of PV systems for self-consumption, giving prosumers the possibility to adopt the following options [29]:

- **Without surplus**, which do not produce more energy than necessary and also have an ‘anti-dumping’ system installation to avoid feeding surpluses into the network.

- **With surpluses WITH compensation** of consumption in which the excess energy is fed into the network and through the prices established by the marketer, will be deducted from the bill.
- **With surpluses WITHOUT compensation**, in which the surplus energy is sold at the price agreed with the supplier.

In addition, one of the most relevant changes introduced by this decree is the possibility of making facilities for shared self-consumption. This change in the legal environment has opened the doors to a large number of new distributed generation facilities that seek economic savings in their electricity bills while promoting the generation of more sustainable energy.

The replication potential of this solution is also high, as it can be transferred to other parks in the same geographical area or with similar conditions.

5.1.5 KPI overview

Suitable KPIs according to D4.1 [11] and D4.2 [12] have been calculated assuming the implementation of the proposed solution. Technical KPIs achieve good results, the same applies for economic KPIs. Photovoltaic solar technology is highly adaptable to all types of environments, thanks to its modularity; it allows great flexibility and integration, is easy to install and has great potential for replication. The social KPIs are quite good, although the COVID-19 crisis situation has particularly affected the companies in the park and the total number of stakeholders in the park who have responded has been lower than expected. The legal and regulatory KPIs are also good as the Spanish government approved Royal Decree 244/19 which regulates the administrative, technical and economic conditions of self-consumption in Spain and provides greater security and certainty to users. This has also simplified the administrative procedures and the aids from the administration for this type of solutions have been activated.

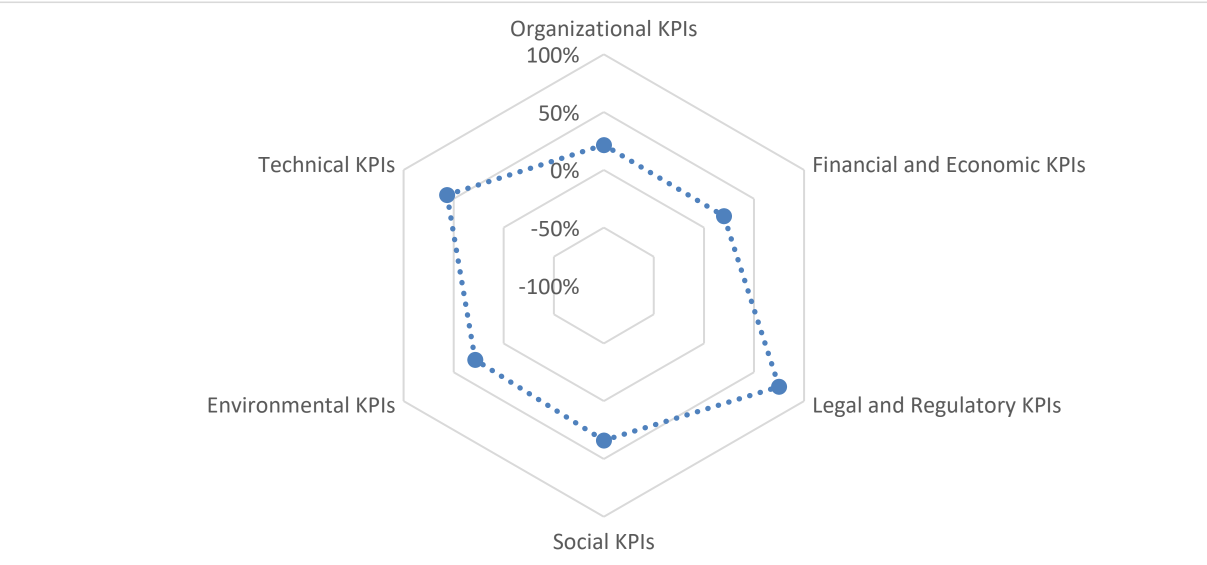

Figure 5-4: KPIs for collaborative PV power plant in Okamika-Gizaburuaga. Source: Tecnalia

5.1.6 Conclusions and outlook

After an analysis of the scenarios *self-consumption and annual energy neutrality* or *maximum available surface*, it was observed that the greatest benefit was attributed to the PV installations with 100 % self-consumption, although these installations would be very small.

Due to the low price of electricity and low consumption during the central hours of the day as well as higher solar yields in the summer months, larger PV installations are less profitable.

The results depend a lot on the evolution of the electricity price, since the variation that it has had during the last years has transcended in a very unstable behaviour.

The initial aim was to demonstrate greater profits through the joint production of buildings for shared self-consumption than individually. The study has demonstrated a good economic performance for the joint PV installation. The analysis shows that medium-sized PV installations are the most suitable for the proposal under consideration, due to good IRR values and the investment required.

The example for a joint installation, shows that profitability could be higher when PV installations are shared between the different pavilions and companies. It has to be taken into account that the calculation methodology has considered that PV production is shared between companies with an hourly balance, i.e. a 'dynamic distribution'. In practice, the actual regulation requires that companies pre-define a 'constant distribution' from the PV production that each would use through the year. Benefits from the joint installation could therefore be not so high as shown in the calculations.

The final conclusion for the analysis is that medium-sized PV installations in each pavilion are the most suitable for the proposal under consideration. A joint PV installation has currently limited additional benefits for the companies, but this could be improved if regulation would allow 'dynamic distribution' of PV production between different users from a joint installation.

5.2 Micro hydroelectric power plant

5.2.1 Background

The purpose of this study is to analyse the technical, financial and environmental feasibility of a micro hydroelectric power plant in the industrial park of Okamika (Spain). The park manages a gross land of 90 000 m^2 where several pavilions with a total area of 35 000 m^2 are located. The following outline is based on the techno-economic study of the possibilities of using the Bengolea dam, in the Lea River, located in the industrial park of Okamika in the municipality of Gizaburuaga, for electricity generation. Additionally, the environmental and social evaluation of the implementation is summarized.

5.2.2 Objectives and description of the Energy Cooperation

The objectives pursued with the study carried out are the following:

- Perform a feasibility study of a hydropower installation for shared self-consumption among the different companies of the industrial park and then analyse the case of shared self-consumption of the pavilions that compose the park, considering it as a single consumer.
- Dimensioning of the installation, technical viability of the hydroelectric plant considering the topographic and hydroelectric characteristics of the dam.

- Calculation of hydroelectric production. Economic calculations of self-consumption combined with the sale of energy to the grid.
- Techno-economic optimization of hydroelectric installation.
- Analysis of the impact of the installation on the park's electrical mix and analysis of its environmental impact.

Taking into account the current legislation and the national energy market, the following two production alternatives will be discussed:

- Self-consumption
  For this option it must be possible to contribute to a demand that exceeds the annual production. The estimated demand for the Okamika park is about 1.54 GWh in the year 2019 (including BSI and the five companies analysed) and therefore it is considered viable to use all annual hydropower production for self-consumption (0.28 GWh/year).
- Self-consumption with sale of surplus to the network
  This option is only considered in case that no company on the site is interested in buying locally produced renewable energy.

Taking into account the physical characteristics of the Bengolea dam, with a height of 4.6 m, an average flow rate of 1.61 m^3/s, and a total system efficiency of 0.73, the nominal power that may be obtained from this system is the following:

$$P[W] = 1.6 \cdot 4.6 \cdot 1000 \cdot 9.8 \cdot 0.73 = \mathbf{53\ kW}$$

The nominal power is the maximum power at which the installation can operate and is influenced by the nominal flow rate (average usable flow rate) defined above.

However, when analysing the change in flow throughout the year (remaining above the average usable flow for several months), the manufacturer (Landustrie, which collaborated to the present study) suggests slightly over-dimensioning the power of the machine, considering a usable flow of 2 m^3/s. In this way:

$$P[W] = 2 \cdot 4.6 \cdot 1000 \cdot 9.8 \cdot 0.73 = \mathbf{66\ kW}$$

As a result of these calculations, it is estimated that the Bengolea dam could work for about 4 200 hours/year at its nominal power and, therefore, generate 277 200 kWh/year.

5.2.3 Economic and Environmental impacts expected

The economic viability of this project will depend on three factors:

Initial investment (including the costs of equipment, transport and installation of the system): According to the data provided by the manufacturer, the initial investment is 306 066 euros.

O&M costs which include maintenance, equipment, personnel, insurance, payment of taxes, licenses, fees or payment to the bank. The annual operating and maintenance costs and annual payments for a hypothetical loan are calculated below.

According to the IDAE [36], the operation and maintenance costs of a mini-hydroelectric plant range from 2 % to 5 % of the initial investment. Considering the worst-case scenario, a value of 5 % is taken.

$$C_{O\&M} = 0.02 \cdot Investment = 0.02 \cdot 306\,066 = \mathbf{6\,121}\ \text{€}/\boldsymbol{year}$$

Revenues (profits generated by the sale of the energy produced in the plant): The prices to be obtained for the energy produced can vary as the legislation on this matter is currently undergoing a period of change. However, as analysed above, the following incomes are estimated through self-consumption:

<u>Self-consumption</u>

In this case, it is considered to supply the fixed consumption of the companies analysed in the park interested in the use of local renewable energies. The average price per kWh paid by BSI in 2018-2019 was 0.105 euros/kWh, so the current price could be maintained.

There is a possibility that the government will contribute through bonuses to this option (as is already done in other European countries). The viability of this option depends on how the Climate Change Act finally turns out. As mentioned, the estimation has been made considering values implemented in different European countries.

$$I_A = Selling\ price\ per\ Kwh \cdot Energy\ produced = 0.105 \cdot 277\,200 = \mathbf{29\,106}\ \text{€}/\mathbf{year}$$

<u>Self-consumption with sale of the surplus to the network</u>

The sale of possible 10 % surplus to the network is considered

$$I_{AVRE} = Precio\ venta\ kWh \cdot Energía\ producida = 0.0996 \cdot 277\,200 = \mathbf{27.610}\ \text{€}$$

The operation consists of the following:

$$I_{AVRE} = Precio\ venta\ kWh \cdot Energía\ producida = 0.105 \cdot 250\,000 + 0.050 \cdot 27\,200 = 26\,250 + 1\,360 = \mathbf{27.610}\ \text{€}$$

Conclusions

Taking into account some of the indices calculated before, the IDAE recommends the following ratios for a plant to be economically viable:

- Simple return period: 8 - 12 years
- Energy index: 0.4 - 0.7 €/kWh
- Power rating: 1 500 – 2 000 €/kW

Comparing these ratios with the results obtained for the Bengolea hydroelectric power plant shows that from a purely economic point of view, the project is not viable.

- Simple return period: 13 years (self-consumption) - 14 years (S.C with sale of the surplus to the network)
- Energy index: 1.104 €/kWh
- Power rating: 4 637 €/kW

However, the public support to micro-hydro generation, which could be decisive for the achievement of this project, has not been taken into account up to this point.

In 2017, the Basque Government Energy Agency (EVE), in its PAERPE document [37] established a maximum aid of 30 % and the reference for maximum cost per unit of nominal installed electrical power isolated (2 €/Wp) and grid connected (1.7 €/Wp), with a limit of nominal installed power (inverters) of 100 kW.

So, for an installed power of 66 kW, the maximum financial aids would be the following:

1.- Isolated: 0.3 x 2 000 x 66 kW = 39 600 €

2.- Connected to the grid: 0.3 x 1 700 x 66 kW = 33 660 €

Investments and simple return periods (SRP) with aids in self-consumption improved as follows:

1. Self-consumption (isolated system):
    a. Investment: 266 466 €
    b. Simple return period: 11.59 years
2. Self-consumption with sale of surplus to the network:
    a. Investment: 272 406 €
    b. Simple return period: 12.67 years

It is up to the administrations to consider this action favourably or not. It does not seem unreasonable to support it given its social and environmental advantages.

To this end, it is considered interesting to involve the companies that currently work in the park in the option of self-consumption, which is currently being worked on with the different stakeholders (local administration and ESCO).

5.2.4 KPI overview

The technical KPIs achieve good results for this energy cooperation. The same applies to the legal and regulatory KPIs as the Spanish government approved the Royal Decree 244/19 which regulates the administrative, technical and economic conditions of self-consumption in Spain and provides greater security and certainty to users. In this case, it must also be considered that the administrative procedures for obtaining concessions are complex and depend on several administrations. But there is aid available from the regional government for this type of solution. The economic KPI for this solution is not so good partially because the solution has a long payback time, more than 11 years. The organizational KPIs are a relatively low as the COVID-19 crisis particularly affected the companies in the park and the total number of stakeholders in the park who have responded has been lower than expected. In the case of the social KPIs, the advantages provided by mini-hydraulic energy are hardly known at a social level.

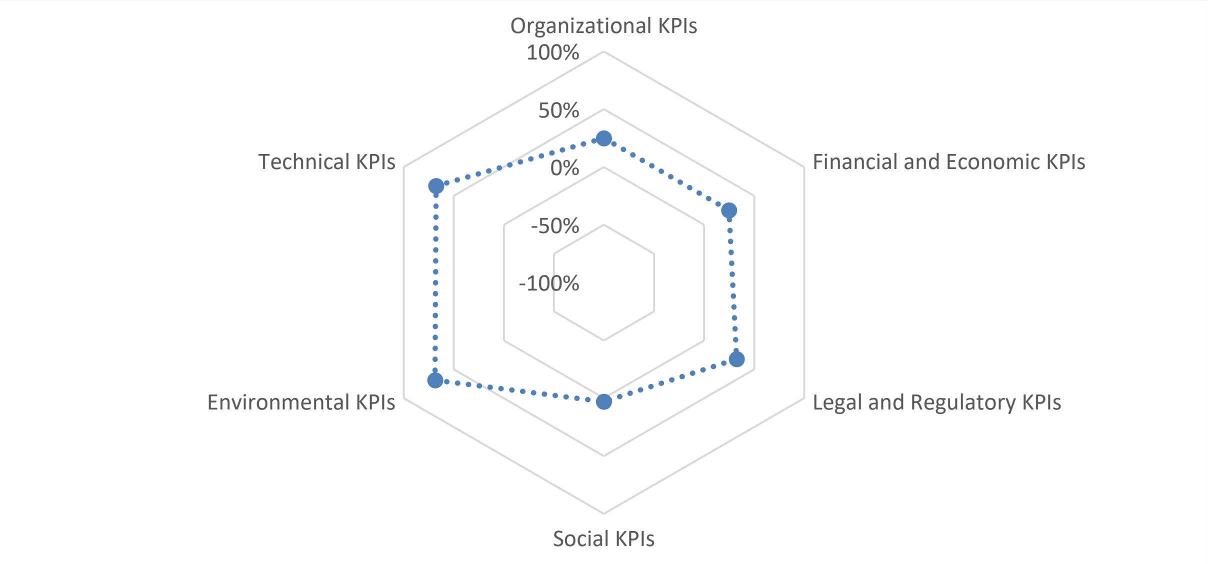

Figure 5-5: KPIs for small hydroelectric power plant in Okamika-Gizaburuaga (Scenario self-consumption). Source: Tecnalia, RINA, EI-JKU

5.2.5 Conclusions and outlook

Observing the trend scenario at a global level and opting for distributed generation with renewable energy sources, it is proposed to focus on self-consumption solutions. Therefore, only the economic viability of the two self-consumption solutions has been assessed.

Both solutions have proven not to be viable according to the three criteria recommended by IDAE for a plant to be viable: Energy index, Power rating and Simple return period.

This study has been developed in a preliminary phase, considering the consumption of the park itself and five companies. These companies, located in the industrial park, could adopt the option of self-consumption and make the solution viable if we consider the possibility of public support for microhydraulic generation, given its social and environmental advantages.

6 Bildosola-Artea, Spain

6.1 Micro hydroelectric power plant

6.1.1 Background

The purpose of this study is to analyse the technical, financial and environmental feasibility of a micro hydroelectric power plant in the industrial park of Bildosola-Artea (Spain). The industrial park has an area of 306 340 m² and is intended to cover the needs of companies in the Arratia region in Bizkaia (Spain). The work is based on the techno-economic study of the possibilities of using the old Bildosola dam, located in the municipality of Artea, for electricity generation, as well as the environmental and social evaluation of the implementation of this project.

6.1.2 Objectives and description of the Energy Cooperation

The objectives pursued with the study carried out are the following:

- Perform a feasibility study of a hydropower installation for shared self-consumption among the different companies of the industrial park.
- Dimensioning of the installation, technical viability of the hydroelectric plant considering the topographic and hydroelectric characteristics of the dam.
- Calculation of hydroelectric production. Economic calculations of self-consumption combined with the sale of energy to the grid.
- Techno-economic optimization of hydroelectric installation.
- Analysis of the impact of the installation on the park's electrical mix and analysis of its environmental impact.

Taking into account current legislation and the national energy scene the following three production alternatives will be discussed:

<u>Grid connection without premiums</u>

This is not considered an option for distributed generation through renewable energy sources because equal prices for all only benefit large plants and the centralized fossil model. It is not possible to move towards a distributed renewable model by giving priority to monopolies.

It is estimated that this energy that will pass through 400 m of distribution line will be paid at 0.050 euros/kWh and will be charged at 0.105 euros/kWh to the final client.

<u>Self-consumption</u>

For this option, it must be possible to contribute to a demand that exceeds annual production. The estimated demand for BSI's own contracts at the Bildosola park is about 111 000 kWh/year.

It would be necessary to be able to supply the fixed consumption of some companies on the site that have an interest in promoting the use of local renewable energy. The average price per kWh paid by BSI in 2018-2019 was 0.105 euros/kWh, so the current price could be maintained.

There is a possibility that the government will collaborate through premiums to this option (as is already done in other European countries). The viability of this option depends on how the

Climate Change Act finally turns out. Increasing the payment for the sale of local renewable energy to small installed powers (up to 100 kW) in Spain is being analysed, as is already happening in other countries (United Kingdom, Germany, Austria, among others). The estimations made in this report are considering values implemented in different European countries.

Self-consumption with sale of surplus to the network

This intermediate option is only considered in case that no company on the site is interested in buying local renewable energy.

It is estimated that the energy produced and fed into the public network will be paid for at 0.073 euros/kWh.

6.1.3 Economic and Environmental impacts expected

The economic viability of this project will depend on three factors:

Initial investment (including the costs of equipment, transport and installation of the system): According to the data provided by the manufacturer, an initial investment of 299 095 euros is estimated, broken down as follows:

O&M costs (maintenance, equipment, personnel, insurance, payment of taxes, licenses, fees or payment to the bank): The annual operating and maintenance costs and annual payments for a hypothetical loan are calculated below.

According to the IDAE [36], the operation and maintenance costs of a mini-hydroelectric plant range from 2 % to 5 % of the initial investment. Considering the worst-case scenario, a value of 5 % is taken.

$$C_{OyM} = 0.02 \cdot Investment = 0.02 \cdot 299\,000 = 5\,980 \text{ €/year}$$

Revenues (profits generated by the sale of the energy produced in the plant): The prices to be obtained for the energy produced can be very variable as the legislation on this matter is currently undergoing a period of change. However, as analysed above, the following incomes are estimated through self-consumption:

Self-consumption

This option means contributing to a demand that exceeds annual production. The estimated demand for Sprilur-BSI's own contracts at Bildosola is about 111 000 kWh/year.

It would be necessary to supply the fixed consumption of some companies of the park interested in promoting the use of local renewable energy. The average price per kWh paid by BSI in 2018-2019 was 0.105 euros/kWh, so the current price could be maintained.

There is a possibility that the government will contribute through bonuses to this option (as is already done in other European countries). The viability of this option depends on how the Climate Change Act finally turns out. As mentioned, the estimation has been made considering values implemented in different European countries.

$$I_A = Selling\ price\ per\ Kwh \cdot Energy\ produced = 0.105 \cdot 268\,800 = \mathbf{28\,224\ €/year}$$

Self-consumption with sale of the surplus to the network

This intermediate option is only considered in case no company in the park is interested in buying local renewable energy.

It is estimated that energy produced in this way will be paid for at 0.073 €/kWh.

$$I_{AVRE} = Selling\ price\ per\ kWh \cdot Energy\ produced = 0.073 \cdot 268\,800 = \mathbf{19\,622}\ \text{€}/\boldsymbol{year}$$

Conclusions

Taking into account some of the indices calculated before, the IDAE recommends the following ratios for a plant to be economically viable:

- Simple return period: 8 - 12 years
- Energy index: 0.4 - 0.77 €/kWh
- Power rating: 1 500 – 2 000 €/kW

Comparing these ratios with the results obtained for the Bildosola hydroelectric power plant shows that from a purely economic point of view, the project is not viable.

However, there could be the possibility of public support to micro-hydro generation, which could be decisive for the achievement of this project that has not been taken into account up to this point.

In 2017 the Basque Government Energy Agency (EVE), in its PAERPE [37] document, established a maximum aid of 30 % and the reference costs for isolated (2 €/Wp) and grid connected (1.7 €/Wp), with a limit of nominal installed power (inverters) of 100 kW.

So, for an installed power of 64 kW, the maximum financial aids would be the following:

1.- Isolated: 0.3 x 2 000 x 64 kW = 38 400 €

2.- Connected to the grid: 0.3 x 1 700 €/kW x 64 kW = 32 640 €

Investments and simple return periods (SRP) with aids in self-consumption would be as follows:

1. Self-consumption (isolated system):
    a. Investment: 260 695 €
    b. Simple return period: 11.71 years
2. Self-consumption with sale of surplus to the network:
    a. Investment: 266 455 €
    b. Simple return period: 19.53 years

It is up to the administrations to consider this action favourably or not. It does not seem unreasonable to support it given its social and environmental advantages. To this end, it is considered interesting to involve the companies that currently work in the park in the option of self-consumption.

The environmental assessment has been carried out according to the EN-15804:2012 + A2 - Sustainability of construction works – Environmental product declarations - Core rules for the product category of construction products [38].

For the analysis an estimate of total energy of 268 800 kWh/year generated by the Bildosola-Artea hydropower plant was used. The common electrical consumption of the Bildosola-Artea industrial park is currently supplied by the electricity network. This electricity has its origin in a mix of different energies among which those of fossil and nuclear origin predominate. The electricity generated in the micro hydroelectric plant, as it is 100 % renewable, will replace the electrical mix, avoiding many CO_2 emissions and reducing the use of non-renewable primary energy.

Savings during the use phase:

- Non-Renewable Primary Energy = 498 306 kWh/year (99.4 %)
- CO_2 emissions = 79.05 Tn/year (100 %)

The potential for savings in total environmental impact during the use phase is very high, due to the replacement of the current energy mix by 100 % renewable energy. The savings achieved have been 100 % in CO_2 emissions and 99 % in the use of non-renewable primary energy.

6.1.4 KPI overview

The achieved results are similar to the case of Okamika-Gizaburuaga. The technical KPIs achieve good results. The same applies to the legal and regulatory KPIs as the Spanish government approved the Royal Decree 244/19 which regulates the administrative, technical and economic conditions of self-consumption in Spain and provides greater security and certainty to users. In this case, it must also be considered that the administrative procedures for obtaining concessions are complex and depend on several administrations. But there is aid available from the regional government for this type of solution. The economic KPIs for this solution are slightly negative, partially due to the even longer payback time. The organizational KPIs are a relatively low, because the COVID-19 crisis has particularly affected the companies in the park and the total number of stakeholders in the park who have responded to the cooperation opportunity has been lower than expected. In case of the social KPIs, the advantages provided by mini-hydraulic energy are hardly known at a social level.

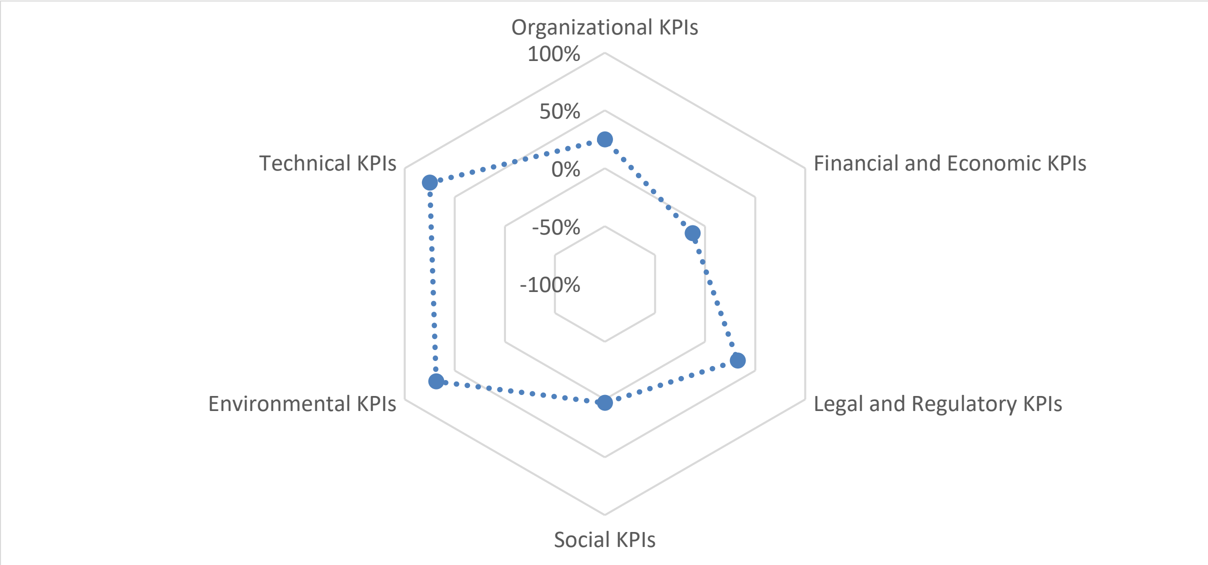

Figure 6-1: KPIs for small hydroelectric power plant in Bildosola-Artea. Scenario 1: Self - consumption (isolated system). Source: RINA, Tecnalia, EI-JKU

6.1.5 Conclusions and outlook

Observing the trend scenario at a global level and opting for distributed generation with renewable energy sources, it is proposed to focus on self-consumption solutions. Therefore, only the economic viability of the two self-consumption solutions has been assessed.

Both solutions have proven not to be viable according to the three criteria recommended by IDAE for a plant to be viable: Energy index, Power rating and Simple return period.

This study has been developed in a preliminary phase, considering only the consumption of the park itself. Some companies, located in the industrial park, could adopt the option of self-consumption and make the solution viable if the possibility of public support for microhydraulic generation, prioritizing its social and environmental advantages, is considered.

7 Conclusion

For all Lighthouse parks several feasibility studies of great diversity were elaborated – in terms of cooperative solutions but also with a focus on the barriers and instruments addressed and the impacts evaluated. Most feasibility studies lead to the conclusion that it is worthwhile to either carry out an even deeper analysis (e.g. with more data), potentially expanding the scope of the project (e.g. looking for additional partners) in order to achieve better economic results or to investigate potential investors and engineering companies in order to develop a detailed implementation plan.

The report summarized the work performed in Work Package 5 (WP5) of the S-PARCS project in the five S-PARCS Lighthouse Parks. Multiple feasibility studies have been elaborated and the key results of the most promising ones were outlined.

For all S-PARCS Lighthouse Parks potential joint energy projects were identified. Within other work packages of the S-PARCS project, the different solutions were analysed in terms of their identification (D1.1), the barriers that might arise (D1.2) and possible instruments to address them (D2.1, D2.3), whilst in the present document the approach focuses on a number of tailored solutions, which were studied in detail, applying the concepts developed in S-PARCS to the actual situation of the project-specific Lighthouse Parks.

Each feasibility study has been developed by the scientific and consulting partners in close cooperation with the respective Lighthouse Park representatives as well as the involved companies. The method applied is strongly oriented towards the PESTEL method that is a classic business environment/investment decision evaluation tool. Focus of the analyses differed depending on the evaluated solution and connected barriers, however, the main focus was generally put on technical and economic as well as environmental aspects.

The latter was considered for the most promising joint energy projects and life cycle assessments were carried out. The life cycle assessments were conducted including the product stage, the construction stage and the use stage according to EN 15804:2012 + A2.

Additionally, S-PARCS key performance indicators (KPIs) that allow the comparison and measuring of different energy cooperation opportunities for economic, sociocultural, environmental, legal and organizational factors, were calculated in order to complement the overall feasibility study.

Ponte a Egola is part of one of most important industrial clusters in Italy and internationally. In the study, the implementation of a combined heat and power (CHP) network based on three gas-based CHP plants was analysed. The concept would allow to supply the Ponte a Egola tanneries, Cuoiodepur as well as external partners with heat and electricity. Furthermore, in the future, locally produced biomethane based on tannery sludge could further increase the local economic and environmental benefits.

For the **Ennshafen** two feasibility studies are presented. As approx. 95 % of the employees in the park are car commuters, a future increase of e-vehicles is expected – for which an attractive charging infrastructure at the workplace could be conducive. Therefore, the first feasibility study evaluated the benefit of shared e-charging stations compared to a scenario in which the companies installed their own e-charging stations. Economic benefits are expected as the utilization factor of the e-charging stations would be higher and potentially lower electricity prices could be obtained. The second feasibility study evaluated the jointly organized installation of solar-photovoltaic panels (PV) on company roofs. Hence, suitable roofs and power capacities were evaluated and business models were developed, e.g. financing the PVs via small local investors, in order to reduce financial barriers and generate additional benefits for the companies as well as other local stakeholders.

The **Chemiepark Linz** in Austria is special as it maintains a steam and cooling water network that is jointly used by several independent companies located in the park. Although the existing system is constantly optimized, further optimization opportunities exist – e.g. when heat sinks outside the park are considered. In this study the waste heat utilization potential from Chemiepark Linz for a feed-in to the local district heating network (DHN) was analysed. The implementation could lead to economic as well as environmental benefits, furthermore it could serve the local community.

For the two Spanish parks **Okamika-Gizaburuaga** and **Bildosola-Artea** in the Basque Country, the joint investment into micro hydropower plants was evaluated. Focus was laid on self-consumption of the produced electricity by the local companies, still, (surplus energy) grid-feed in would be possible. For both locations environmental and social aspects are to be highlighted, economic feasibility is given when public subsidies are taken up.

For **Okamika-Gizaburuaga** the installation of joint PV was analysed additionally to the micro hydropower plant. Different scenarios were investigated, leading to different PV capacities and hence varying self-consumption, feed-in and consequently economic balances. It was shown that medium-sized PV installations designed for joint self-consumption of the companies generate the highest economic benefit. In case more companies with different load profiles join, the overall economic benefit but also the size of the PV system could be further increased.

In summary, in the course of the S-PARCS project the identification and analysis of several energy cooperation opportunities was achieved, proving that energy cooperation can be as manifold as described in theory in the previous deliverables. Most of the feasibility studies lead to the conclusion that it is worthwhile to either carry out an even deeper analysis (e.g. with more data), potentially expanding the scope of the project (e.g. looking for additional partners) in order to achieve optimal economic results or to look for potential investors and engineering companies in order to develop a detailed implementation plan.

Additionally, some of the cooperative projects owe their profitability mainly to their cooperative character, showing that energy cooperation can significantly expand the pool of sustainability, renewable energy and energy efficiency measures that are available to companies.

This is the case for the CHP network investigated for Ponte a Egola, which can only be energetically and economically balanced via the inclusion of several suppliers and customers. Some energy cooperation opportunities such as joint PV installations or e-charging infrastructure could be implemented by individual companies as well, however economic feasibility and the overall impact of the project (e.g. in sense of the local community) tend to be lower. In other cases, limits of internal energy efficiency optimization are close to be reached (at least for some energy streams) – in such cases energy cooperation with third parties can open up new economic and technical possibilities as was shown for Chemiepark Linz. Lastly, some projects would not be feasible at all in case an individual company would try to implement them – such as the Spanish micro hydropower plants. Although subsidies still would be needed in order to achieve economic feasibility, the joint investment and operation of the plants increases the overall feasibility significantly. I.e. otherwise no implementation at all would be possible, as risks would not be shared and the economically beneficial self-consumption not be optimized.

As this report summarizes the full feasibility studies and will contribute to the development plans of the Lighthouse plans, it closely relates to these two other deliverables:

- D5.3 "Feasibility studies for the most promising joint energy projects in the Lighthouse Parks", which is the confidential version of the present document that contains all studies and is the basis of the present report. [13]
- D5.5 "Energy cooperation plan per park", which is the natural prosecution of these feasibility studies and which will detail the strategy to achieve the most promising results.

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