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D2.7 Smart Energy Supply and Demand with RES
WP2, Task 2.3

Transition of EU cities towards a new concept of Smart Life and Economy

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

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Abreviations and Acronyms

Table 1: Abreviations and Acronyms

Acronym	Description
mySMARTLife	Transition of EU cities towards a new concept of Smart Life and Economy
RES	Renewable Energy Solutions
EV	Electric Vehicle
OPV	Organic Photovoltaics
AFUL	Association Foncière Urbaine Libre : a free urban land association
MIN	Marché d' Intérêt National : a wholesale market
NMH	Nantes Metropole Habitat
CRE	Commission de Régulation de l'Energie: the French Energy Regulation Commission
BAPV	Building Applied Photovoltaics

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1. Executive Summary

This deliverable presents the mySMARTLife actions carried out in Nantes and focused on the development of renewable energy solutions (RES). Most of the actions are related to the integration of photovoltaics (PV) solutions. Some of the actions are also linked to the electric vehicle (EV) services, storage solutions, energy sharing solutions, and more general mobility services.

Each type of solution is described in one specific section:

- Collective PV projects.
- PV plants on public buildings.
- Organic PV production.
- PV production, storage
- Call for projects and new urban services based on a smart grid.
- Hydro power project.

In each section the strategy corresponding to the solution is described and then further details are given about its practical implementation. Finally, each section stresses the lessons learnt, mainly in the scope of potential dissemination and replication of the solution (advantages, barriers).

This deliverable gives an overview of how Nantes Metropole and its partners implement mySMARTLife’s main concepts (Smart Energy, Smart Economy, Smart People) through the development of RES. Most of the PV and grid solutions presented here tackle very operational issues (e.g. energy policy, regulation framework). Nantes Metropole’s RES solutions also present an interesting mix of mature technologies implemented in an original organisational context (e.g. self-consumption in multi-owner context), and advanced promising technologies (e.g. organic PV production).

The actions presented here can be a source of inspiration for any metropolitan area wishing to develop concrete renewable energy solutions, while being fully aligned with its urban transformation targets.

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2. Introduction

2.1. Purpose and target

The objective of this deliverable is to draw a feedback of the development and application of the actions linked with RES in the context of Nantes Metropole. Sections 2 to 8 presents the different actions (strategy, implementation, lessons learnt). Section 9 offers some general conclusions about the work done on these actions.

The strategy developed in Nantes, largely developed around PV RES, correspond to different challenges.

The need for **local renewable energy supply** is a key aspect in urban transformation, and the technologies associated to PV production offer a large range of solutions, presented in sections 3 to 7.

The need for **sharing the investment and benefits of PV plants**, through **self-consumption** approach and **citizen engagement** is illustrated in **section 3** through the examples of community PV projects.

The need to **make the most of the solar energy potential of the public real estate** surfaces is provided an answer with the initiatives described in **section 4**, on Nantes Metropole buildings.

The need to **test and demonstrate promising PV technologies**, in this case **organic PV**, which will allow more flexibility for the implementation on buildings and new architectural integration possibilities, is detailed in **section 5**. This step is crucial to anticipate the future development of this type of technology at larger scale.

The need to **consider PV energy as a vector for complementary and optimized uses**, such as storage and e-vehicle charges, is answered by the action described in section 6.

The need to **involve all the local stakeholders including companies**, is tackled in **section 7**. This section shows a solution to involve directly all the relevant actors in the urban transformation process, through an adequate call for projects.

And finally the work done on the preparation of the **hydro power project** is presented in **section 8**.

2.2. Contributions of partners

The following table depicts the main contributions from participant partners in the development of this deliverable.

Table 2: Contribution of partners

Participant short name	Contributions
NBK	Overall content production and deliverable leading
NAN	Overall content production and description of energy actions
ENG	Description of energy actions
CAR	Deliverable review.

2.3. Relation to other activities in the project

This deliverable focuses on describing actions developed in tasks 2.2 and 2.3. The development of these actions has been carried out taking into account the urban transformation method developed in the tasks of Work Package 1.

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3. Collective PV projects

3.1. General context

In 2016, Nantes Metropole launched the Great Debate entitled "Energy transition is up to us". Citizens and local stakeholders were mobilized throughout this democratic experience. This led to the building-up of a roadmap for energy transition with several commitments, some of them dealing with actions for energy consumption reduction and actions supporting local and renewable energy production. The goal of one of these commitments is to use 100% of the rooftops in Nantes Metropole territory; it includes solar power plants, but also green roofs. Moreover, Nantes Metropole supports the development of photovoltaic and thermal solar power plants through its "Sun plan", which consists of three main axes: the development of huge solar power plants; the multiplication of small power plants on rooftops and encouraging solar power plants by reviewing the local urban planning. So the effort is both about Nantes Metropole investing money on solar power plants but also about trying to make solar power plant projects easier to realise for private stakeholders or citizen communities.

Thus, all kinds of initiatives towards energy transition are supported. In the Nantes Metropole area, people are becoming more involved in environmental issues, including in the development of RE. Communities of citizens have emerged and are organizing themselves in order to bring out this type of project. Nantes Metropole has supported the development of Cowatt with subsidies. The latter received these subsidies through an association named Alisée, specialised in renewable energies and energy management. Cowatt was created to help citizens to carry out renewable energy projects; the company has an ambitious objective: fitting 1000 roofs with citizen-based solar power plants within 10 years. This initiative of Nantes Metropole supporting Cowatt is part of action 38 of mySMARTLife project.

Two projects described below illustrate this citizen-based approach of PV development on Nantes Metropole territory; in a third part, a collective project, supported by Nantes Metropole to boost the development of new ways of deploying RE production, is also described.

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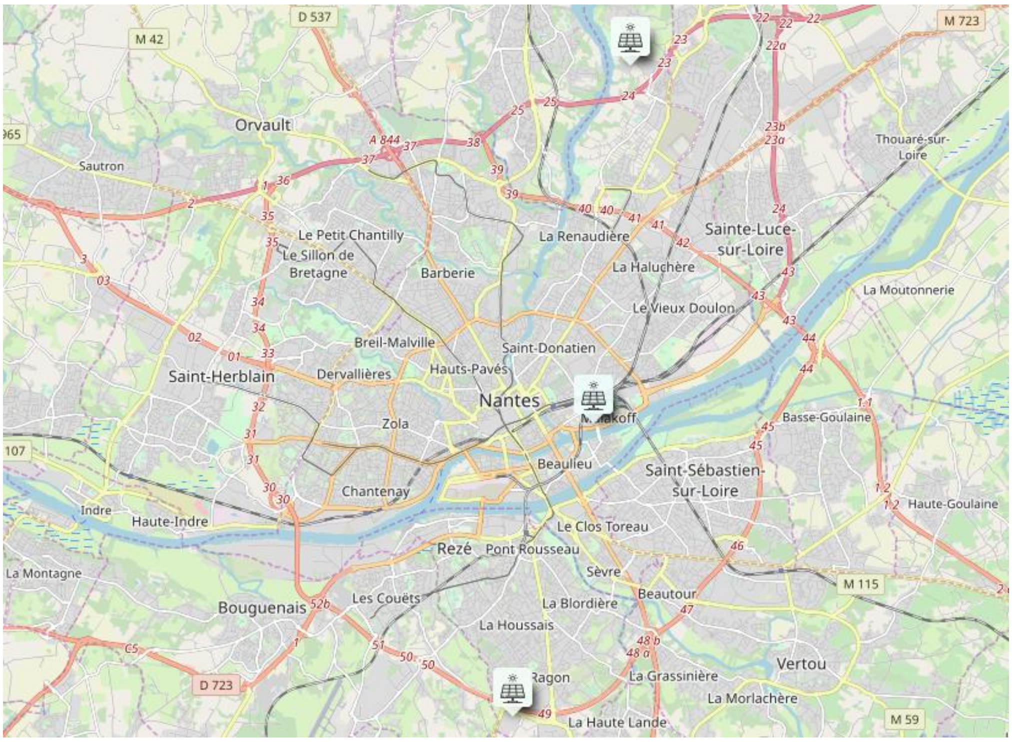

Figure 1: Location of the three solar power plants

3.2. MIN solar power plant

- **General overview of the project**

The MIN of Nantes (Nantes wholesale market) was first located on the “Ile de Nantes” (Nantes island) then transferred since a new hospital is going to be built instead. The new site of the MIN consists of several buildings and extends over 50 000 m² of retail areas. It represents 105 operators, 40 local producers, and 3500 buyers. In 2019, it is the second-largest wholesale market in France.

As the buildings were to be built and considering the surface available on the rooftops, it was the perfect moment for the installation of a solar plant on their roof. The idea was to have a solar power plant of which some of the funding would be of citizen origin.

The solar plant was divided into two parts: a 5MWp-solar plant whose energy production is sold and injected into the grid and a 500 kWp-solar plant whose energy production is directly used in self-consumption. The latter was funded by citizens through Cowatt, a company specialized in citizen renewable projects and is the one studied in this deliverable. Cowatt is also part of mySMARTLife through the action 38: this company received a grant from Nantes Metropole to enable its launch; Nantes Metropole wishes that other citizens’ initiatives are later developed by supporting this company.

This project marks one of the steps to meet the territory's energy objectives regarding the share of local and renewable energy production. Besides, this project is also a "first” on two points for Nantes Metropole:

– First integration of citizen funding in a PV project for Nantes Metropole
– First participation of Nantes Metropole as a shareholder in an energy production project

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Figure 2: The MIN buildings and the solar plants on the roofs (source: Nantes Metropole)

- **Technical implementation**

From design to contracting

Technical specifications were written by Nantes Metropole Energy Department. The power of the solar plant was not fixed but should respect the limits set in the technical specifications. These limits have been chosen according to the national call for tenders launched by the French Energy Regulation Commission (“CRE” in French). It was also stated that part of the funding of the solar power plant must be from citizen origin. The mode of citizen funding was kept open and it was up to the companies to come up with a solution. An option in the specifications stated that the company could also include an additional service to integrate the self-consumption of part of the electricity produced on-site for the cooling needs.

A call for tender was launched to choose the company that will install the solar power plant; through it, the companies had to present a business plan. Ten companies answered to the call for tenders. After a technical analysis and a bargaining process, the company selected was Armorgreen belonging to the Legendre group. The company has chosen to buy solar panels of the brand SYSTOVI which is a local producer located in the North of Nantes. Armorgreen offers consisted of developing two different solar power plants: the energy produced by the first and bigger one would be directly injected into the grid and the energy produced by the second one would be used in self-consumption and partly financed by citizens. As explained above in part 3.1, this analysis only concerns the latter solar plant.

A first study was made to determine how much energy could be used directly on site. In this document, the following elements were described: the power plant features, the simulation results of the plant production, details on the electrical connections and a comparison with cooling installations and their energy needs. Only the shared consumption (here the cooling needs) are taken into account. If the energy production were distributed among the various private operators of the MIN, the distribution process would be complicated and the number of actors involved would be multiplied, this is the reason why only shared consumptions will be supplied by the local production. A second study focused on the business model of the project.

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In France, before any construction work or installation of a solar power plant on a building, administrative documents must be submitted to the urban planning department of the city. These documents are analyzed by experts that give their validation for the project or ask for more details if needed. As soon as the validation from the urban planning department of the city was given, the project could be submitted to the national call for tenders for solar power plants in self-consumption.
Indeed, in France for solar plants of 100 kWp and more, the project should be among the laureates of the national call for tenders. The latter is launched at regular periods and different calls for tenders exist regarding the type of project: ground-based solar power plants, roof-mounted solar plants, integration of self-consumption or reinjection to the grid… Being a laureate of this national call for tenders meant being able to realize the project but it also entitles the owner of the plant to have an additional remuneration on the price of the sold electricity. The CRE has set up this procedure to support the development of renewable projects to reach the objectives of the national multiannual energy programming. In December 2017, the MIN project was designed laureate of this call for tenders.

Business model and contracts

Armorgreen was in charge of funding, developing, installing and then operating the solar power plant in the first instance.
To create a community of citizens to set up the project, a communication campaign was held, managed by a newly created company, called Cowatt. The latter has received subsidies from Nantes Metropole through an association named Alisée, specialized in renewable energies and energy management. Cowatt was created to help citizens to carry out renewable energy projects. For this purpose, this company provides technical and administrative assistance on the project set-up.
A simplified joint-stock company was created to manage the solar power plant; it is named **MIN à Watt à**. First, 11 citizens bought shares of MIN à Watt allowing the latter to acquire Sun Storage 1, the company in charge of the 500-kWp solar plant, which is a subsidiary of from Armorgreen. Thus, it allowed Cowatt to have the time to deal with its financial issues. Afterwards, the 11 citizens sold their shares to Cowatt, and they continued to take part in the project by reinvesting directly in Cowatt.
The company counts two other shareholders: Nantes Metropole and Energie Partagee Investissement, as shown in next figure.

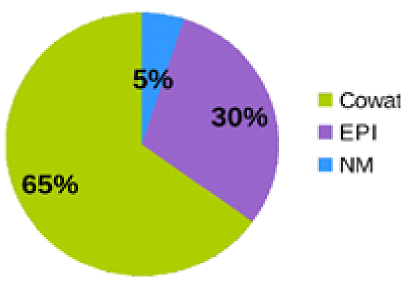

Figure 3: Shareholders of MIN à Watt

MINàWatt owns the 500kWp-solar plant; however, the latter is located on the rooftop of a public building belonging to Nantes Metropole. The rooftop use then must be regulated. The writing of the contract framing

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the use of a public building roof was undertaken by Nantes Metropole. A 30-year lease contract was drawn up for the use of the rooftops. This contract is between Nantes Metropole, the owner of the MIN buildings, and the owner of the solar power plant. The administrative and legal aspects are described in this 30-year lease contract:

- The boundaries of the allocated roof area and the specific and only use (installation, operation, and maintenance of a solar plant) allowed.
- The duration of the contract and the annual rent.
- Insurance and liability terms.
- The obligation for the user to provide information about the solar plant (production, interventions carried out or planned…) and to allow visits of the plant for Nantes Metropole.

The energy production of the solar plant is then directly sold to SEMMINN, which is the site operator. SEMMINN is linked to Nantes Metropole through a public service delegation contract.

Nantes Metropole teams worked on the possible legal options of self-consumption projects in third-party investors, in addition to the technical issues. The choice was made to deal with the energy sale through a different type of contract than the usual electricity sales contracts. Indeed, when the project was developed, the self-consumption with third-party investors was not entirely defined. It has then to be assimilated into a collective self-consumption project and has thus recovered the characteristics of this type of project. The MIN project was, therefore, subject to the "CSPE", the French contribution to the electricity utility, whereas the electricity produced does not use the public grid but is consumed directly on site. The energy sales contract between MINàWatt and SEMMINN is then similar to a rental contract of the solar power plant, the rent of which is calculated based on an energy price, as detailed in the next table.

Table 3: Rent costs

Period	Year 1 to 15	Year 16 to 30
Quarterly rent excluding tax	21 800 €	18 000 €
VAT (20%)	4 360 €	3 600 €
Quarterly rent including tax	26 160 €	21 600 €

The rent is reviewed quarterly based on the actual energy production of the solar plant. To do so, different terms are defined:

- Maximum availability (hours): theoretical operating time of the inverters, from the moment in the morning where the irradiance allows the inverters to run until the moment in the evening where it is no longer sufficient to allow them to operate.
- Guaranteed availability (%): ratio from which the rent adjustment mechanism is implemented.
- The number of hours of unavailability (hours): the sum of the number of inverter shutdown hours.
- Actual availability achieved (%) is calculated as follows:

$$Actualavailabilityachieved = \frac{Maximumavailability - Numberofhoursofunavailibility}{Maximumavailability}$$

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By billing period (quarterly), the rent is adjusted according to the actual availability achieved, using the following calculation formula:

$$Adjustmentamount = (Actualavailabilityachieved - Guaranteedavailability) \times Rentonthebillingperiod$$

If the result is positive, SEMMIN will pay the adjustment amount to MINàWatt. Otherwise, a reduction will be applied to the rent.

If we compare this rent to the potential electricity market cost evolution in France, it turns out that after a few years the self-consumption model becomes more interesting.

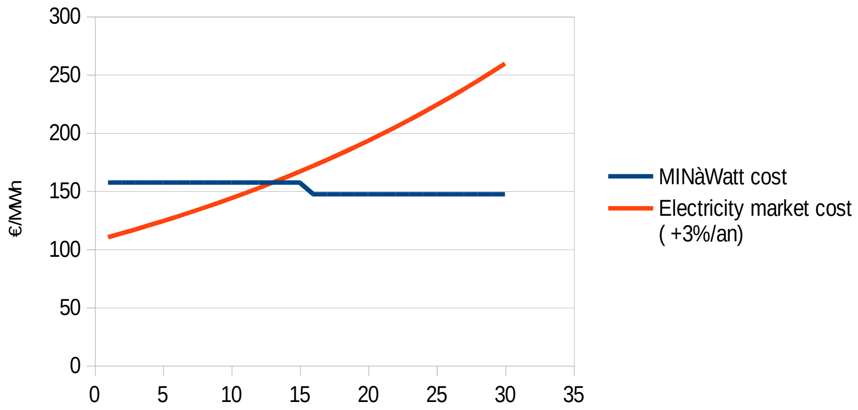

Figure 4: Evolution of the electricity price

The next figure summarizes all the procedures described above.

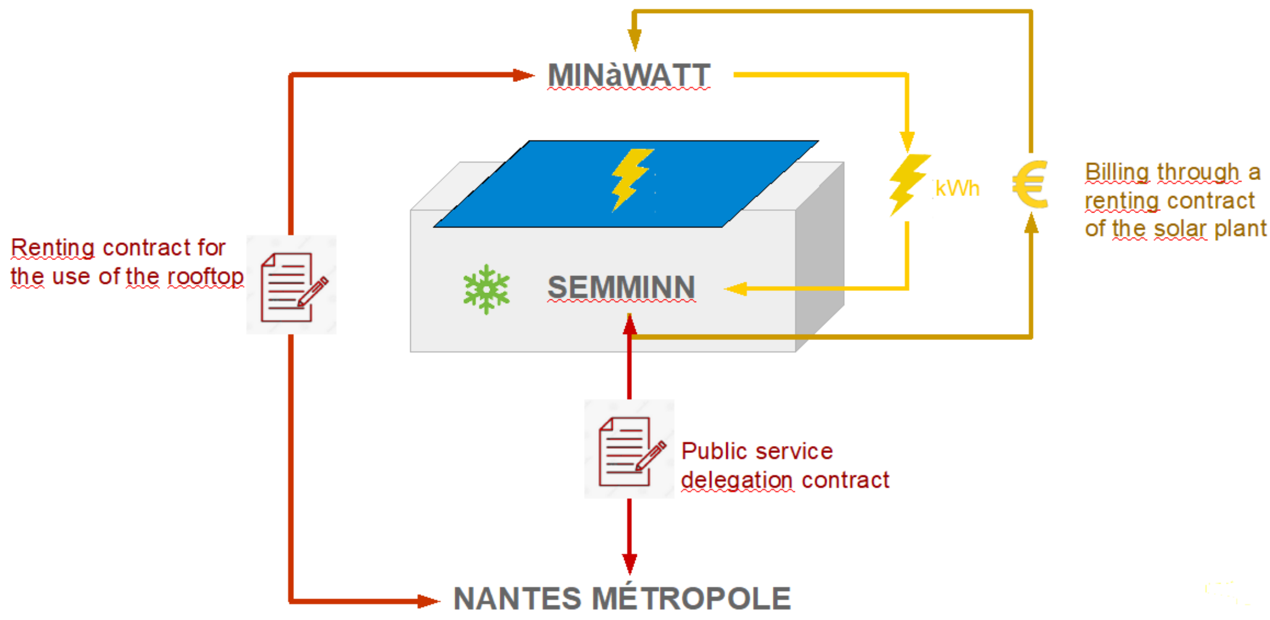

Figure 5: Operation of the solar plant in self-consumption

The following table describes the main key elements of the project and their progress over time.

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Table 4: Evolution of the MIN project over time

Key elements	Date
Call for tenders / Armorgreen selected	June – October 2016
Work on the legal, financial and insurance aspects of the project	2016 – 1st semester of 2018
Laureate of the CRE national call for tenders	December 2017
Involvement of the first 11 citizens	Beginning of 2018
Installation works of the solar plant	May 2018 – January 2019
Citizen fund-raising	September – beginning of November 2018
Commissioning of the solar plant	Spring 2019

The citizen engagement and funding is tackled in 2 different steps.

Step 1: engagement of 11 citizens

As explained above, the company Cowatt was created to support the development of citizen solar plant projects. They helped citizen communities to go through renewable projects in particular regarding the technical and administrative aspects.

Three types of citizen commitment can be defined for the MIN project. Firstly, 11 citizens have chosen to be involved in this renewable energy project in the first place; a call for mobilization was launched in early 2018 to bring together volunteer citizens and create this group. Several meetings were organized to promote and inform the interested citizens as described in the next table.

Table 5: Meetings for citizen mobilization (source: Alisée association)

Date	Subject of the meeting
26/01/2018	Meeting with the partner associations
31/01/2018	Preparation meeting for the mobilization of a project group with ECPDL[1]
01/02/2018	Communication within the ESS[2] and Energie networks and preparation of the project presentation tools
05/02/2018	First contacts with citizens, presentation of the citizen project
22/02/2018	Public mobilization evening co-hosted by ECPDL
27/02/2018	Private mobilization evening, at one’s of the future project leaders
02/03/2018	Information plenary meeting
08/03/2018	In-depth plenary meeting, development of a first planing, creation of working groups

1 ECPDL: Énergies Citoyennes en Pays de la Loire is a regional network provides support to the development of citizen renewable project and brings them together

2 ESS: Social and Solidarity Economy

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Their shares were then bought by Cowatt. However, they also choose to invest in Cowatt by buying shares of the company to remain in the project. Cowatt brought the professional skills to conduct this kind of project and dealt with all the aspects of the project development. However, some of the citizens are still involved: depending on the issue (legal, financial…) one citizen constitutes the point of contact for this specific subject, through the Cowatt community.

Step 2: a fund-raising campaign

Then, other citizens could also participate by financing the solar power plant and by taking part in its governance. A fundraising campaign was launched in September 2018, led by Cowatt, in which different communication tools were implemented:

- A website describing the project and the group leaders.
- Distribution of flyers.
- Information meetings with citizens: three citizen mobilization evenings.
- Public meetings in the different cities neighbouring the MIN.
- Organization of site visits of the MIN buildings or the solar power plant Beaulieu (located on the rooftop of a shopping center) with interested investors.

A MIN à Watt share represents 100€ and citizens could choose the number of shares they wanted to buy. Investing in MINàWatt even with a single share provides access to its governance. The solar power plant is directly managed by the citizens since they are shareholders as soon as they choose to invest in MINàWatt.

Originally the campaign was planned to start at the beginning of September 2018 and to end in early November 2018, but the enthusiasm for the project was such that in 6 weeks the amount set for citizen financing had already been reached. 120 000€ were required to launch the project but a large number of financial contributions from citizens has made it possible to go beyond this amount. The choice was made to stop the fundraising campaign and the final amount of citizen contributions comes to 142 000€ with 600 citizens engaged.

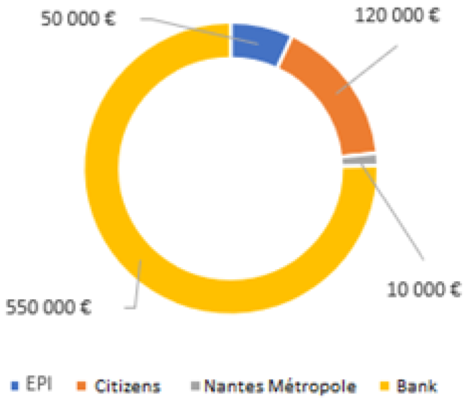

Figure 6: Funding contributions of MIN solar power plant (source: Cowatt)

Finally, one of the shareholders of MinàWatt, Energie Partagée Investissement, had also allowed citizens to invest in the project. The latter is a company limited by shares that enables citizens to invest in renewable projects; it is owned by 90% by citizens and 10% by a fund for the development of citizen projects. Citizens

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choose to invest their savings in Energie Partagée Investissement, which then reinvests these funds in renewable energy projects. These projects are chosen regarding their technical and economic relevance and their compliance with EPI charter.

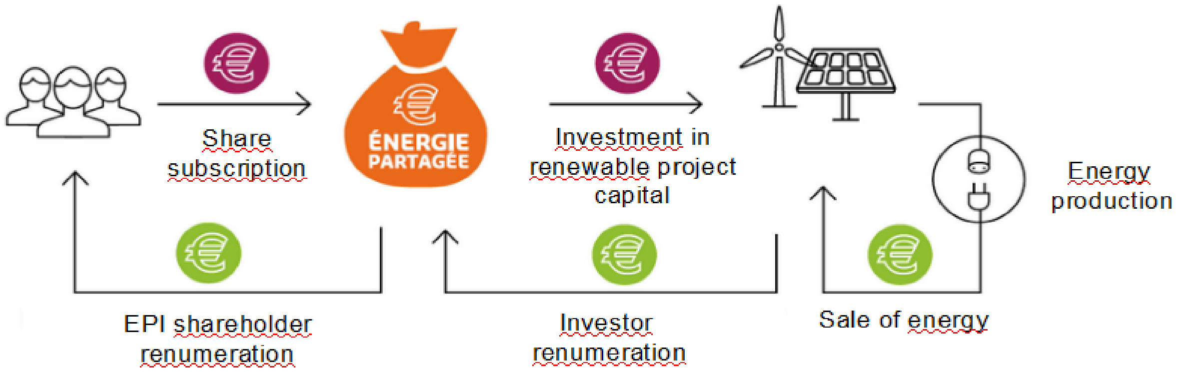

Figure 7: Functioning of Energie Partagée Investissement

The citizens who invested in the project take part in the decision and management process: the governance is citizen-based. Thus, citizen engagement is not only financial but also shows a willingness to work, by devoting one's time, for the energy transition.
On Nantes Metropole area, other citizen initiatives are emerging. A good example of the latter is the actions undertaken by the AFUL La Chantrerie, and in particular, the citizen-funded solar power plant developed in the last years.

3.3. Solar power plant led by AFUL Chantrerie

- **AFUL La Chantrerie**

La Chantrerie is an area located in the North of Nantes Metropole where some companies, universities but also housings are settled in. An association was created in June 2010 in order to allow the contractualization between the company Engie COFELY and several stakeholders of La Chantrerie site for the design, the construction and the operation of a biomass heating plant. A small district heating was created with this biomass plant, and the different stakeholders involved were connected to it so that their heating is now provided by this district heating. This association is named AFUL Chantrerie ("Association Foncière Urbaine Libre" which stands for free urban land association). The stakeholders involved are universities, private companies as well as public institutions, as shown on the Table 6.

Table 6: AFUL La Chantrerie members

Universities	Public institutions	Other
• IMT Atlantique • Polytech Université of Nantes • Ecole supérieure du bois • Design College of Nantes • ONIRIS	• Nantes Métropole Aménagement • Crous Nantes Pays de la Loire	• GIP INOVALYS • IMA Technologies • Schneider Electric • Microchip • Eurial

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Universities	Public institutions	Other
• CESI		• Le manoir de la Régate • Carrémand Gourmand • “Vivre à Gachet” (inhabitant association)

The association has managed to create a dynamic within its territory to involve stakeholders as well as citizens of the area, and nowadays actions are being developed among all the different subjects related to the ecological transition (energy, mobility, waste, local food production…).

Since 2019, another renewable energy project of the AFUL La Chantrerie has been operating: a 225kWp-solar plant installed on the roof of Polytech Nantes University, which trains engineers. The electricity produced is directly used on site.

The project leaders went all the way despite administrative and legal difficulties in the set-up of the project.

- **The solar plant: governance and citizen engagement**

The development of a citizen-funded solar power plant is one of these projects. The solar power plant is part of the MINERVE project. The idea of the demonstrator is to mitigate the intermittency of renewable energies such as wind and solar power, by storing it through this gas production. To do so, renewable energy production was needed. It consists of a power-to-gas-demonstrator made up of a small methanation unit transforming electricity into synthesis methane: the electricity feeds an electrolyser to produce hydrogen (H2); this hydrogen reacts with carbon dioxide (CO2) in a methanation reactor to produce synthesis methane (CH4).

Besides, work had to be undertaken on a 30-year roof. This roof is on a technical hall and belongs to Polytech University, an engineering college; it started to be derelict and retrofitting works should be initiated: it was the perfect time to consider the opportunity to fit the building rooftop with solar panels. Moreover, the director of this university was involved in the AFUL La Chantrerie and willing to study the opportunity of installing a solar power plant. However, the university did not have the required funds to undertake this retrofitting work. Thus, the retrofitting work of the roof was included in the project.

To be aligned with La Chantrerie approach, this project is citizen-funded and citizen-based. A simplified joint-stock company, SAS Energies Renouvelables Chantrerie was created to lead the project. It follows a cooperative principle (one person = one vote) and its shareholders are the AFUL Chantrerie, Energie Partagé e Investissement and two private individuals.

- **Technical and economic description**

Feasibility studies have been carried out by the engineering consultancy Belenn Ingénierie. The solar plant has a power of 225 kWp thanks to its 1250m² of solar panels. It will produce around 250 MWh per year and

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all the energy generated will be used by Polytech University. This electrical production represents a little less than 20% of Polytech University’s electrical consumption.

Figure 8: The technical hall
©Energie Partagée

A call for tender was launched to choose the company that will install the solar power plant. The selected company was Armorgreen. On this project, the company also used SYSTOVI’s solar panels, produced in the North of Nantes. The work was carried out during 2018.

Afterwards, the project was submitted to the French national call for tenders for solar power plant projects in self-consumption, and it was selected as a laureate. Being laureate allowed the project to have an additional remuneration on the sale of electricity for 10 years that amounts to 1c€/kWh.

A convention was written and signed with Nantes Metropole, who owns Polytech University buildings, and the SAS EnR Chantrerie for the use of the technical hall roof. The terms of the contract specify that the roof is provided free of charge by the University of Nantes for 22 years to the SAS EnR Chantrerie; by the end of this period, the solar plant will become the property of the University of Nantes.

For the solar power plant to be put into service, a connection agreement must be signed with the electricity grid operator, called Enedis. The latter had to refuse this request; indeed, it was not complying with the energy code on an administrative aspect. The issue was that the French Energy Code stipulates that for a self-consumption project, the company registration number should be the same for the producer and the consumer, which means that they should be gathered within a single entity. The grid operator Enedis could not take the responsibility to accept a project that was against the French Energy Code. La Chantrerie’s case was forwarded to the General Department of Energy and Climate, a department of the French Ministry of Ecological and Solidarity Transition. It turned out that this element was missing from the technical specifications of the French national call for tenders for solar power plant projects in self-consumption. Thus, the General Department of Energy and Climate asked Enedis to depart from the energy code and validate the project and the agreement, so that the latter could be developed as it is.

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- **Business model and financing**

The investment cost for the retrofitting work of the roof, the installation and supply of the solar panels, and all the electrical equipment amounts to 385 000€ ex. taxes. In addition to this amount, 15 000 € is added to cover the expenses related to the control office, the contracting authority assistance, and construction site insurance. The funding plan is distributed as follows:

- A loan of 250 000 € from the Banque Populaire Grand Ouest (BPGO);
- 20 000 € in the partner's current account provided by two natural persons;
- 130 000€ of citizen fundings brought by Energie Partagée Investissement.

Energie Partagée Investissement invests in several renewable projects and owns funds which allow it to commit to an investment in advance. Thus, Energie Partagée Investissement committed to providing a 130 000€-investment for this project. Its written commitment and the investment of 20 000€ by the two private individuals made the bank loan possible. The citizen funding is still open on Energie Partagée web platform and will be until the 130 000€ amount is reached. By the end of October 2019, 64 persons had invested in the project for a total of 94 579€. The compensation target is 4 % gross per year, for a minimum investment period of 10 years. It is also possible to enter the governance of the SAS Energie Renouvelable Chantrerie for companies, universities or CIERC (*Club d'Investissement dans les Energies Renouvelables Citoyennes*, a citizen investment club for renewable energy solutions).

Figure 9: La Chantrerie solar plant
Source: Energie Partagée Investissement

Regarding the sale of electricity, Polytech University committed to buying the electricity produced by the solar power plant through a public-private partnership. This kind of contract consists of a public institution to entrust a private service provider with the construction, financing or management of equipment necessary for the public service – here the roof work and the electricity supply – during a set period of time. The initial kWh cost is equivalent to the one from the current provider of Polytech University and is raised by 4% each year.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

The development of this project has thus been slowed down and made more complex by different elements. However, the will of the project leader made it possible to complete it.

The main key elements of the project are summed up in the following table.

Table 7: Evolution of La Chantrerie solar plant project over time

Key elements	Date
Feasibility studies	November 2016
Call for tenders / Armogreen selected	May – September 2017
The project is laureate of the national call for tenders	December 2017
Installation works of the solar plant	May – September 2018
Fund-raising campaign	2018 – Still on-going
Commissioning of the solar plant	Spring 2019
Inauguration of the solar plant	June 2019

3.4. Malakoff solar plant, a collective self-consumption project

In the French context, the term self-consumption is used when talking about a person or entity that produced and consumed its energy, whether partially or fully. Although self-consumption has recently extended more widely, it has in fact existed for some time now. Indeed, it has been used for specific or nomadic uses (military uses or isolated buildings). However, the current situation regarding climate changes and the energy transition, the rise in electricity prices and the increase in the energy efficiency requirements for new constructions and renovations in the French regulations have given self-consumption wider importance.

3.4.1. The French legal framework

Since 2015 and the French energy transition law for green growth, some support mechanisms to self-consumption have been implemented. As projects start emerging, different issues began to appear, and in particular regarding the **collective self-consumption model.**
A self-consumption operation is collective when the supply of electricity is carried out between one or more producers and one or more end-consumers linked together within a legal person. This is quite a new subject and the French regulations are not entirely set yet on it: the regulatory framework is still changing.
At first, the French legal framework was relatively restrictive. Before 2019 it has so far imposed that the extraction and injection points of a collective self-consumption project must be located on the same low-voltage antenna of the public distribution network. This means that when several buildings are involved in a collective self-consumption project, their electricity supply must come from the same low-voltage transformer.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

A decree is soon to be published and validated by the Ministry; it is aimed at extending the perimeter of collective self-consumption, on a trial basis for a period of 5 years. The decree will describe the new characteristics of a collective self-consumption project for this experiment:

- The withdrawal and injection points must be located on the low-voltage grid and contained within a circular area with a radius of 1 kilometre or less.
- The total power of the production facilities must be below 3MWp.
- The producer(s) and end-consumer(s) should be linked to each other within a single legal entity.

However, the French Regulation Energy Commission (CRE) gave a reserved opinion on the provisions of this decree. Even though its opinion has just a consultation value, it can influence on the final decision. The French Regulation Energy Commission highlights the fact that a geographical criterion (1 km of radius) does not necessarily correspond to the criterion of the dimensioning of the electricity grid that makes it possible to guarantee a balance in electricity flows. For the CRE, the suggested total power of production (3MWp) is too high for a simple experiment. It points out that collective self-consumption operations derogate from the common law rules applicable to the supply of electricity, in a less protective framework for consumers. For example, the legal entity responsible for a collective self-consumption operation is not subject to the obligation to offer a one-year contract; the consumer does not have the right to terminate his contract free of charge at any time and must comply with the termination conditions defined in the contract between the consumer and the legal entity.

At the time of writing the deliverable, the decree's release is still pending. Even if this decree opens new opportunities for collective self-consumption projects, the legal framework still stays restrictive on collective self-consumption operations. Institutions like high schools, supermarkets or retirement homes are often connected to the medium-voltage electricity grid. Thus, with these regulatory requirements, they cannot take part in a collective self-consumption project, whereas they may have interesting roofs or adapted consumption for the latter.

However, collective self-consumption projects are still emerging, such as Nantes Metropole Habitat’s operation in Malakoff district in Nantes.

3.4.2. Malakoff self-consumption project

- **General overview of the project**

Nantes Metropole Habitat (NMH) is a local social housing landlord, that represents 25 000 dwellings for 47 000 tenants on Nantes Metropole area. Together with the City of Nantes, they join forces to build up a photovoltaic project with a collective self-consumption approach. The aim is to create a collective self-consumption project in which electricity is generated through a solar power plant located on the roof of a residential building owned by the social landlord. The production will be used both by the buildings of the city of Nantes, operating on traditional office hours and by the landlord's residential buildings.

Several reasons motivated the launch of this project:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

- In the next years, new French building regulations will be implemented and they should encourage the installation of renewable energy production systems integrated into the buildings.
- Developing local sources of energy and encouraging short loops of production / energy consumption.
- The opportunity of the site itself with the proximity of buildings whose electrical consumptions have a different temporality.
- The will of Nantes Metropole Habitat and Nantes Metropole to be a driving force on this subject.

Before choosing the Malakoff site, Nantes Metropole Habitat had studied another site, located on the "Ile de Nantes" (Nantes Island) and composed of two residential buildings. The idea was to supply the underground car parks with electricity through two solar power plants located on each building roof. However, each building was connected to a different low-voltage transformer substation. This first project was then abandoned because of the legal framework. Indeed, until 2019 the collective self-consumption operations in France were limited to users, producers and consumers, whose withdrawal and injection points are located downstream of the same medium-to low-voltage electricity transformation station.
When the same issue occurred for the Malakoff site, Nantes Metropole Habitat, with the City of Nantes, chose to initiate the project anyway, expecting the regulations to change.

- **Technical description**

The building where the solar power plant will be installed is a huge 10-floor building, called Tchécoslovaquie building: its high rooftop is not subject to shading, which makes it perfect for this purpose. On the other side, the buildings that will buy the electricity from Nantes Metropole Habitat are smaller buildings and their rooftops situations are not very suitable for a solar power plant. However, they are operating during office hours, so they need electricity during the day mostly, that is to say during the production time of the solar panels. Based on this observation, all of these buildings are complementary for a solar collective self-consumption system. This led to the partnership between Nantes Metropole Habitat and the City of Nantes. The buildings involved in the project are detailed in the Table 8 and in the Figure 10: Malakoff site situation.

Table 8: Buildings involved in Malakoff project

Building roof on which the solar plant is located	Consumer buildings – NMH	Consumer buildings – City of Nantes
- Tchécoslovaquie residential building	- Communal areas of the Tchécoslovaquie building - Communal areas of the two Luxembourg towers (residential building) - Building office of NMH	- Bergson school, - The Haubans community center - The town hall annex building

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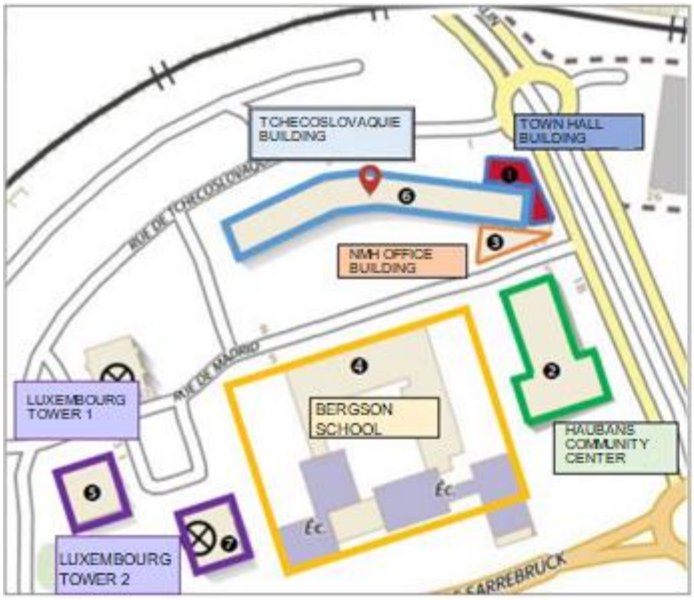

Figure 10: Malakoff site situation

(source: Pouget Consultant, technical specifications of the project)

As explained above one of the main technical issues of the project had been identified: the different buildings involved in the project were not located in the same low-voltage transformer substation loop. Indeed, these buildings are connected to two different low-voltage transformer substations, as shown in Figure 10. On the other hand, the legal framework requires that the producer and the consumer stay in the same loop of low-voltage transformer substations.

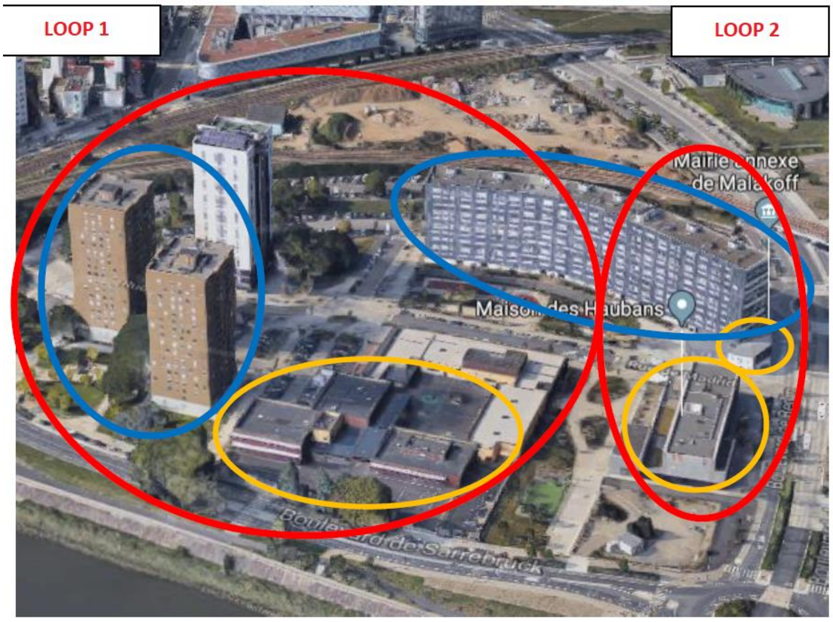

Figure 11: The two low-voltage transformer loops (source: Pouget Consultants)

A feasibility study has been carried out by the engineering office Pouget Consultants in order to define the technical characteristics of the solar plant and the financial aspect regarding the sale of energy between

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

Nantes Metropole Habitat and the City of Nantes. It was first realized when the legal requirement for the producer and the consumer to be connected to the same low-voltage transformer substation was still relevant. The electricity consumption of the future consumer buildings and especially the load curves were studied to define the proper power to be installed. To do so, some possible energy management actions were included in the life of the building (replacement of the ventilation system, of light bulbs…), to determine a planned evolution of the electrical consumption. Then the production potential was assessed regarding the available area on the roof of the "Tchécoslovaquie" building and compared to the consumption evolution. A layout of the solar power plant has been realized.

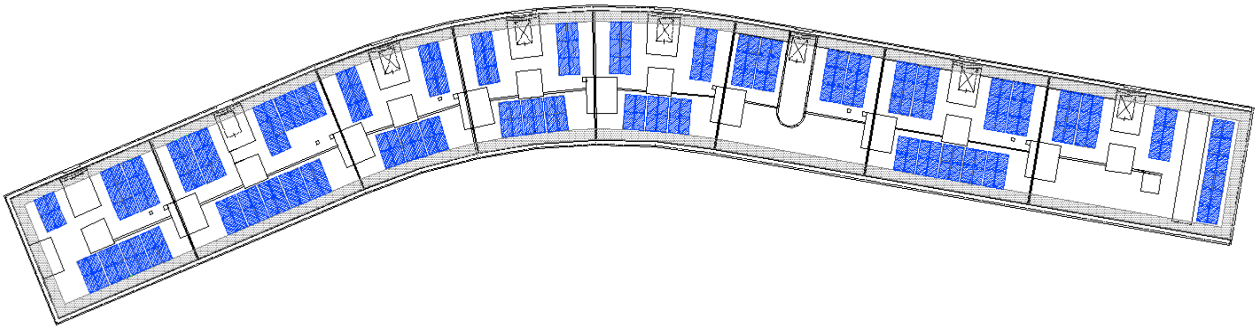

Figure 12: Layout of the solar panels on Tchécoslovaquie building roof (source: Pouget Consultants)

The solar power plant represents 416 m² of solar panels for the power of 69,3 kWp. The call for tender was launched during August 2019 so that a company may be selected by the end of November. Thus, the solar power plant will be installed at the beginning of 2020 and it will be commissioned in spring 2020.

- Electricity distribution process

Regarding the electricity distribution process, the energy produced by the solar panels is not directly transmitted to the buildings mentioned above. Indeed, the electricity produced is measured and then injected into the grid; the distribution between the different consumers is virtual and is integrated to the bills by the energy supplier, according to the coefficients defined by all the stakeholders in the convention at the beginning of the project.

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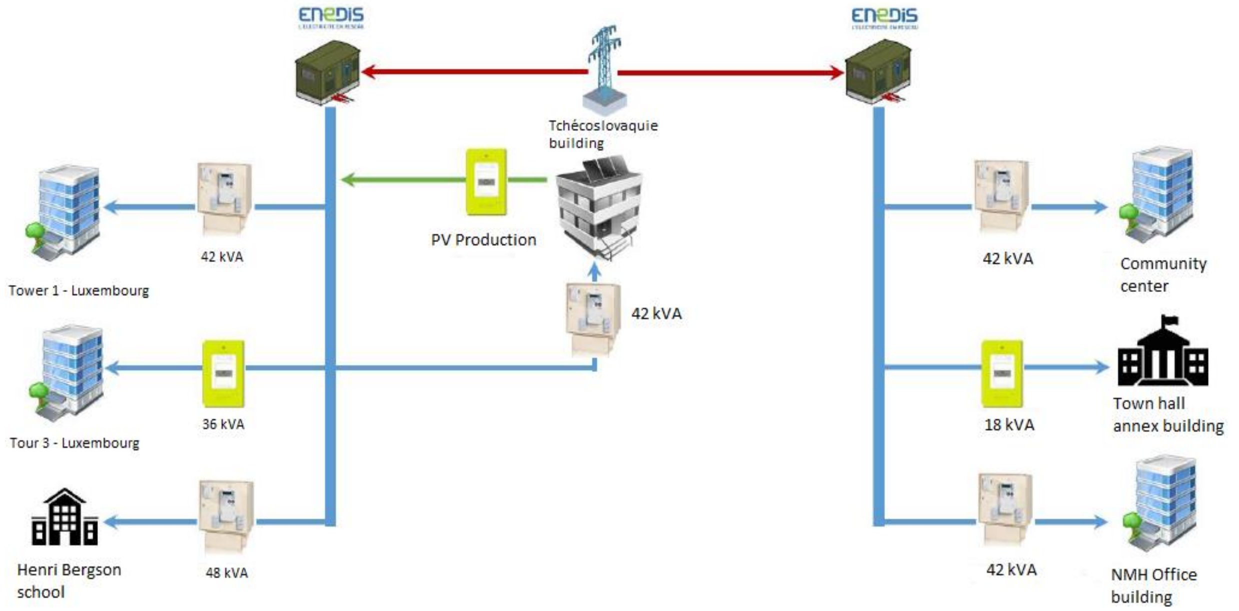

Figure 13: Distribution process between the different stakeholders (source: Pouget Consultants)

- **Creation of a Legal Entity**

To comply with the French Energy Code, the producer(s) and consumer(s) of the project must be gathered within a Legal Entity that will be in charge of organizing the collective self-consumption operation. However, an act to amend the energy code is currently under consideration. It states that for a social housing landlord in a self-consumption project, the creation of the Legal Entity would not be necessary and that the Legal Entity could be directly represented by the social housing landlord itself. However, Nantes Metropole Habitat and the City of Nantes have decided to initiate the creation process of the Legal Entity, to be ready and not to delay the project in case the bill doesn't pass.

This Legal Entity will be in charge of preparing and filing the collective self-consumption application to the public grid operator, ensuring that all the required electricity meters are installed and if it is not the case, it should request their installation to the public grid operator. Then the Legal Entity will sign a convention with the public grid operator. This convention sets different points and especially the electricity prices as well as the billing:

- The perimeter and project are described.
- The distribution coefficients of the self-consumed energy between the different consumers are detailed.
- The written agreements for all producers and consumers to participate in the self-consumption project.
- The public grid operator obligations are the following:
    - Calculate the various values relating to the electricity production, consumption and therefore billing.
    - Share these values to the different stakeholders of the project (if they are directly concerned by them).

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- **Financial and legal aspects**

The investment of the project is distributed as follows:

Table 9: Buildings involved in Malakoff project

Expenses	
Study phase	9 500 €
Work site management	10 000 €
Control office and safety and health protection coordinator	5 000 €
Insurance	3 000 €
Installation of the solar plant	136 000 €
Grid connection	4 000 €
TOTAL	**167 500 €**

Nantes Metropole Habitat received grants from the region, the national environment and energy management agency, and mySMARTLife for a total of 57 000€.

For projects with a power below 100 kWp, the prices for the use of the public distribution network are set by the French Energy Regulation Commission.

The collective self-consumption model is quite new and the applicable taxes still need to be reviewed to be entirely satisfactory and relevant. For now, the electricity produced with this solar power plant is subjected to 3 taxes:

- the **TURPE**, "Tarif d'Utilisation des Réseaux Publics d'Electricité" which stands for Rate for the use of the public electricity grid, still represents an important cost on the electricity price. Currently, any collective self-consumption operation can choose between a standard TURPE or a specific TURPE which is reduced for the self-consumed part and increased for the contribution of the network. For the Malakoff project, the final choice between the two solutions will be made prior to commissioning in accordance with regulatory evolutions.
- **CSPE**, "Contribution au Service Public de l' Electricité" which partly funds the electricity utility; it is applied to the final consumption of electricity. The possibility of an exemption exists but remains today subject to the interpretation of the tax authorities as to the quality of electricity producers on the same site. Thus, the exemption could only concern the consumption of the Tchécoslovaquie building, which is the production site, and not on the other buildings.
- **VAT rate**; The classification of a self-supply can be retained in this case and would allow an exemption from the part consumed by Nantes Metropole Habitat

The legal framework should evolve in the next months and years to achieve an easier and more favorable for collective self-consumption projects.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

The main elements of the project are summed up in the following table.

Table 10: Evolution of Malakoff project over time

Key elements	Date
Feasibility study by Pouget Consultants	March 2018
Legal studies on the project set-up (waiting for new French regulations)	2018 – 1st semester of 2019
Launching of the call for tenders	Beginning of September 2019
Creation of the Legal Entity	October 2019
Negotiations with the companies that responded to the call for tenders and choice of the selected company	October – November 2019
Installation works	January to March 2020
Commissioning of the solar plant	Spring 2020

Thanks to this first project, Nantes Metropole Habitat hopes to get knowledge on the project set-up to be able to replicate this kind of operation. The social housing landlord has the will to go further in the use of the rooftops of their buildings, whether it is for a collective self-consumption project or not. Thus, they have identified two other neighbourhoods that would be suitable for a collective self-consumption project: high residential buildings nearby smaller office buildings. Moreover, they are going further by carrying out a study over the solar potential of all their built assets.

3.5. Lessons learnt towards replication

Citizen-based projects

The first element that should be highlighted lies in the common point of these three projects: the location of the solar power plant, that is to say, the roofs. In each of them, they are used as a support for the solar power plant. It is an available area that does not use agricultural land or raises biodiversity issues. Moreover, depending on the buildings that are used, it can facilitate citizen participation. Indeed, if people are used to going to a particular swimming pool, supermarket or sports hall, it may mean more for them and may be easier to accept, to get involved or invest in a solar power plant project on these specific buildings.

For La Chantrerie solar plant, the fundraising is still ongoing at the moment but it is secured thanks to the functioning of EPI. The citizen mobilisation and fundraising of the MIN solar plant were quite efficient and did not take much time. However, these two projects are among the first citizen mobilisations for renewable projects on Nantes Metropole area, so that the citizens that have invested are already convinced of the need for this kind of project and aware of the stakes. If this kind of initiative becomes more numerous, the mobilized citizens will no longer be the same and it may become necessary to seek out citizens who might be less concerned by energy and environmental issues than the former ones. Thus, the communication around the project and for the fundraising should not be neglected.

These projects are among the first of their kind in Nantes Metropole area, so that some elements had to be determined and arbitrated, in particular regarding the project building, and the type of contract to be chosen for a public building roof. The main issue was to deal with a solar power plant project with a third-party investor. Indeed, in the French legal framework, this case is not yet defined, so that it is assimilated to a collective project. Thus, some taxes are still to be paid by the consumer of this kind of project, even though the tax in question is not relevant here. This is particularly the case for La Chantrerie solar project. However, the University of Nantes has chosen to pay the taxes and keep the legal set up chosen in the first place, counting on future regulation changes. For the MIN’s solar plant, the issue for one of the taxes have been bypassed by choosing an astute legal set-up that has required a lot of work and studies.

La Chantrerie solar power plant, on the roof of an engineering university, is also a pedagogical tool: Polytech University as well as IMT Atlantique, another engineering school of the area, can have access to the data of the solar plant and can use it. This project as well as all those of the AFUL Chantrerie is also a way to bring the different stakeholders of the area together, and to work together for the development of the territory they have chosen.

The collective self-consumption model

At the moment, collective self-consumption projects are still relatively scarce in France. Thus, the project leaders have to come up with new project structures to move projects forward as the regulations evolve. This is the reason why the latter implies project management on a relatively long-time scale. As a result, another issue the project leaders had to face was the relation with the energy distributor. Indeed, since the regulatory context remained unclear throughout the project, it was hard for the energy distributor to take a clear and precise stance. This is expected to stabilize shortly when the regulatory context is set.

A key point to be taken into account when developing a collective self-consumption project lies in the complementarity of the site's uses. Malakoff project is a good example of complementarity: on one hand a large and available roof area but a low consumption during the day, and on the other hand, buildings with shaded roofs and whose operation only extends over office hours, i.e. at simultaneously with the photovoltaic production. In the future for collective self-consumption projects to develop, it is essential for urban planners to have this requirement taken into account in their project, so that complementarity is created between the building consumptions and uses.

Difficulties for the collective self-consumption projects still lie in two aspects:

- The project set-up: regulations are quite new and the project leaders are still in a learning process
- The economic viability of the projects: the taxes that are still applied to the electricity coming from a collective self-consumption solar plant can be a barrier to their development, and are not always relevant for these specific projects.

The legal framework on this subject is evolving at the moment in France and progress on this subject may appear in the near future.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

4. PV plants on public buildings

4.1. PV projects for the buildings of Ville de Nantes and Nantes Metropole

PV plants projects are supported through several commitments:

1) Roadmap for energy transition

One of the commitments of the roadmap for energy transition is to make 100% of the Metropole rooftops useful: solar power plants, green roofs.

2) Public building plans

The department that deals with public buildings management has also set itself different objectives concerning energy management and renewables. Thus, specific energy-saving work bill be scheduled, the local renewable production will be increased and the use of digital technology to monitor the consumption and production of public buildings will be generalised. In particular, one of the targets consists of increasing up to 40% the share of renewable electricity in the total electricity consumption of public buildings in the Metropole area by 2030.

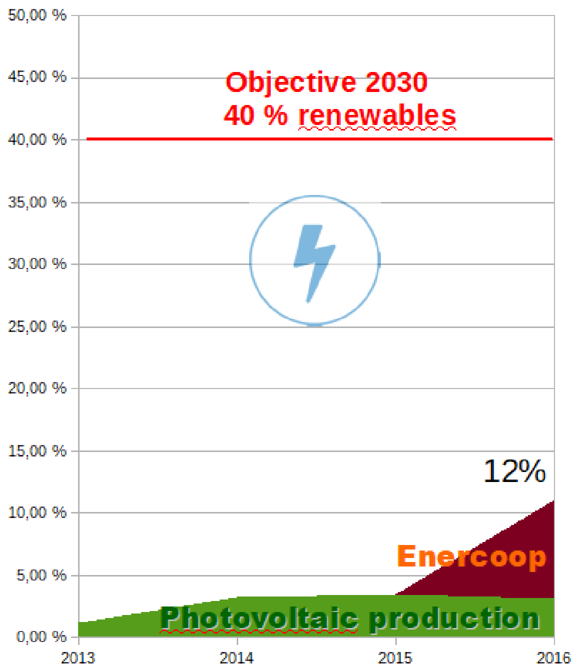

Figure 14: Consumption objectives of the building management department of Nantes Metropole

Currently, there is about 12% of the electricity consumption that comes from renewable sources for Nantes Metropole public buildings. It is either directly from photovoltaic production or by subscribing to renewable electricity supply contracts through suppliers such as Enercoop. This will be done on one hand by subscribing to green power contracts and on the other hand by installing photovoltaic power plants on rooftops.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

3) The solar plan

This follows also the solar plan of the Metropole and more precisely its 2nd goal: developing small solar plants all over the Metropole. The solar cadaster was part of the solution to encourage the development of solar power plants on private buildings; Nantes Metropole, as a public body and in its exemplary role, has to launch projects answering to this commitment. Moreover, the idea of this project was also for the Metropole to turn towards the self-consumption model. Considering the rise of the energy cost, it becomes more interesting to produce one’s energy.

Since this kind of project is supposed to increase in the following years, the Metropole building management department is willing to gain the skills to develop photovoltaic projects without the help of the Energy Department. Some feasibility studies have been carried out within the engineering consultancy of the Metropole for some of the buildings and for these buildings the site supervision will also be conducted by the internal staff of Nantes Metropole.

In order to comply with these commitments, a new financial envelope has been established from 2018 until 2030 by Nantes Metropole and the City of Nantes; this financial envelope is dedicated to the development of solar power plants on Nantes Metropole and the City of Nantes buildings.

This financial envelope constitutes a part of the answer to this commitment. The development of solar plants on public buildings also aims at increasing the renewable and local energy production which is also a commitment of the roadmap for energy transition: Nantes Metropole is committing to reach 50% of local and renewable energy.

4.2. Implementation of PV projects on public buildings

4.2.1. Study phase

During spring 2018, Nantes Metropole launched a call for tenders to appoint an engineering consultancy specialised in the solar power field. The call for tenders covered both feasibility studies and work site management. The selected company, System off Grid is an engineering office of the region. System Off Grid started by choosing around 20 buildings with a suitable roof allowing an easy installation of solar panels (orientation and tilt of the roof, construction material, roof condition). These 20 buildings are a preselected panel chosen among 800 available buildings. System off Grid did a site visit on all the buildings of this shortlist to determine whether the building should be included in the study or not. After that visit and after the study, a few sites were dropped for financial reasons.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

Figure 15: Location of the targeted buildings. In red: the buildings withdrawn of the study after a site visit. In blue: the buildings studied (source: System Off Grid)

The study aims at determining for each site, the right balance between the surface of solar panels installed, the financial investment and the economic impact on the building operation, whether the solar plant is used 100% in self-consumption, or if it is interesting to sell the remaining energy. Details on the estimated energy production and the savings on electricity bills are also calculated. The study also suggests a layout of the solar panels for each rooftop.

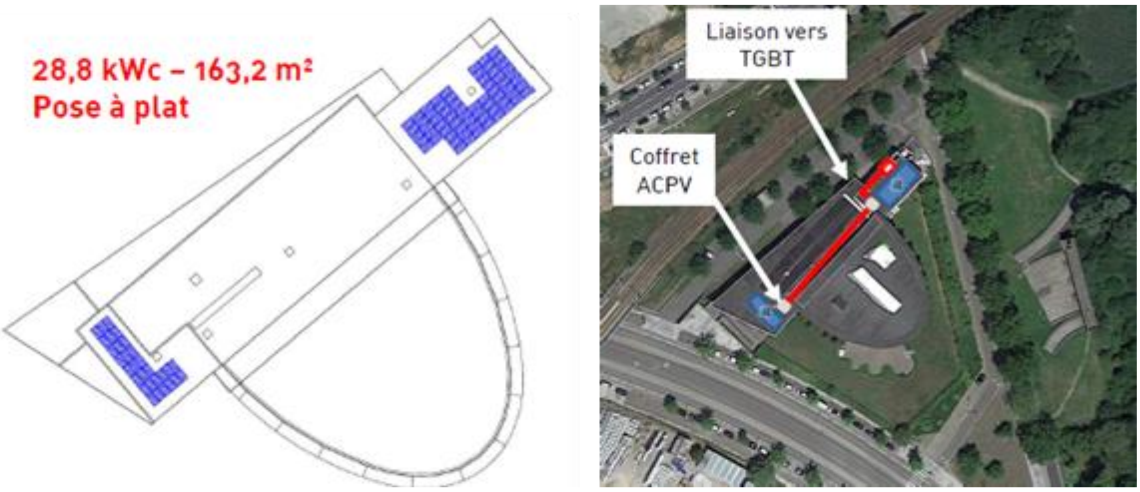

Figure 16: Example of panels layout for a building: swimming pool "Petite Amazonie" Source: System Off Grid

For each building, the structure of the roof is described, as well as if there are collective protections (such as guardrail) and if there are any shadowed areas on the roof. Then an energy balance and an economic assessment of the project is carried out for each building, as shown on the example below.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

Table 11: Example of energy balance & economic assessment – Swimming pool “Petite Amazonie” (source: System Off Grid)

Energy Balance		Economic assessment		
Site consumption	751 274 kWh/yr	Investment	48 914€ EXCL. TAX	
Peak power	28,8 kWp	Operating and maintenance costs	788€/yr for the first year, inflation of 1,5% per year	
Surface of panels	163,2 m²	Total costs	64 677€ over 20 years 1,5% discount rate included	
Theoretical PV production	28 248 kWh/yr, averaged over 20 years	Electricity suppliers	Comparison with two prices of the electricity	
			EDF: usual contract, 11,34 c€/kWh	Comparison price: 14,5c€/kWh
Specific producible	1019 kWh/kWp	Saving on electricity bills	3 177€ for the 1st year 73 305€ over 20 years (with +3%/year on the electricity cost)	4 065€ for the 1st year 93 783€ over 20 years (with +3% /year on the electricity cost)
Self-consumed PV production	28 248 kWh/yr, averaged over 20 years 100% of self-consumption	Project benefits (Net Present Value over 20 years)	8 627€	29 106 €
Coverage rate	4 %	Internal rate of return	3,2%	6,8%

Different assumptions and data were used for the techno-economic analysis, such as:

- The load curves were modelled,
- The producible calculated according to the orientation and tilt of each site thanks to a specialised software
- The aging of the solar panels, the maintenance cost and its growth have been taken into account
- A scenario for the evolution of the electricity price has been included.

Finally, after the feasibility study, a list of buildings with an optimal calculated power in terms of investment and economic benefits was established.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

Table 12: Summary of the selected buildings

	Building	Peak power	Installation cost	Use of the energy produced
Installation in the beginning of 2019	Communal social action center	21,6 kWp	28 028 €	Self-consumption
	Swimming pool “Petite Amazonie”	28,8 kWp	38 664 €	Self-consumption
	Blordière technical center (solar panels on a parking shade structure)	64,8 kWp	103 680 €	Study of a collective self-consumption system with surplus sale
	Confluences community centre	8,4 kWp	10 944 €	Self-consumption with surplus sale
	Contrie association centre	33,6 kWp	54 168 €	Self-consumption with surplus sale
	Trade union house	48 kWp	77 256 €	Self-consumption
	Champ de Mars	22 kWp	29 300 €	Self-consumption
TOTAL		**227,2kWp**	**342 040 €**	
Installation in summer 2020	Elementary school Plessis Cellier	30,3 kWp	98 239 €	Self-consumption with surplus sale
	Elementary school Contrie	33,6 kWp	145 968 €	Self-consumption with surplus sale
	Elementary school Longchamps	36 kWp	51 480 €	Self-consumption with surplus sale
	Elementary school Port Boyer	36 kWp	97 680 €	Self-consumption with surplus sale
	Conservatoire	30 kWp	44 420 €	self-consumption
TOTAL		**165,9 kWp**	**437 787 €**	

One site, Blordière technical centre is different from the others, for two reasons:

- The solar panels will not be on the building roof but they will be put on a parking shade structure.

Another study is underway to determine the relevance of extending the project to a collective self-consumption system with other buildings nearby.

Regarding the general technical solution itself, the choice was made to turn toward **ballasted solar panels.** This system is really easy to install: the photovoltaic panels are fixed on ballast tanks which are directly placed on the roof without any fixing, the weight being sufficient enough to hold the panels in place. The advantage of the solution, when implementing solar panels on an existing building, is that no roof restoration work is needed. On the contrary, if a solution with a structure fixed directly to the roof was chosen, the watertightness of the roof should be restored, resulting in significant additional costs.

Another solar plant on a public building is included in this action: the MIN solar power plant, funded by citizen. This 500 kWp-power plant is already operating and was developed in another framework.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

4.2.2.Monitoring

The monitoring process is an essential part of the project. It provides the necessary raw material for carrying a precise evaluation of this project, keeping track of performance, further helping to understand the impacts one intervention can bring; also, to relate to the city scale. As part of WP5 dedicated to the monitoring, some work has already been done and preparation was undertaken to be ready for M36, and to prepare for the monitoring.

The WP5 work is still ongoing, and projections are subjected to change; but first milestones have undoubtedly been reached upon the common work of WP5 T5.1, T5.2 and T5.3, such as the set of monitoring KPIs, shared between the three lighthouse cities and based upon reference sources ("SCIS" or "CITYKEYS" to name a few).

As for this deliverable and at times of writing, a monitoring schema and a refined set of KPIs have been consolidated to prepare the monitoring implementation. These documents are developed as part of the WP5 T5.3 for which an interim version of the deliverable D5.3 is due by M36, and the final one by M48; it is likely, therefore, they could be updated with a few changes.

An important part of this action was focused on making sure a proper data transmission method would be implemented in each and every public buildings PV plants. This transmission method should be interoperable so as to be adaptable for two main reasons:

- Foresee the future internal management of the solar power plants (monitoring and operation data). As explained beforehand, this kind of solar plants will become more and more numerous in the coming years.
- Deal with the integration of solar power plants data in the Urban Data Platform.

Therefore, these special features were described in the technical specifications and in particular the need for data loggers to be independent of the inverter manufacturers.

For this action, the monitoring part consists more specifically in gathering the production data and be able to see the evolution of the production over the weeks / months / year. The monitoring process is quite simple: thanks to the inverters or to the electricity meters, these data are directly transmitted and uploaded to an online platform and then aggregated.

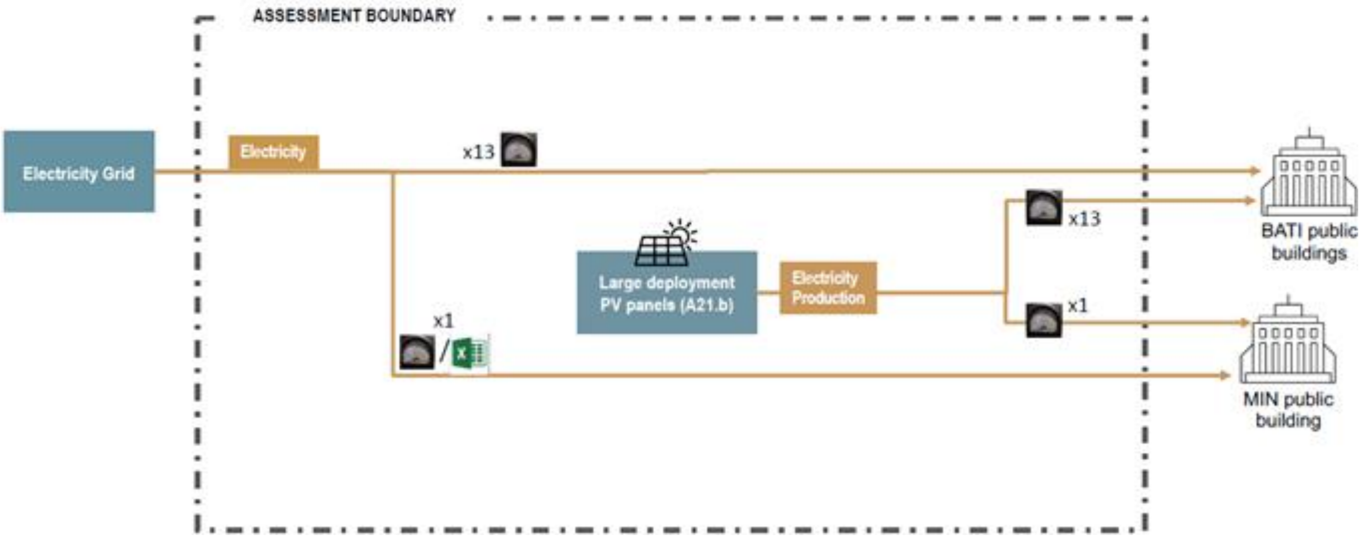

Figure 17: Monitoring scheme

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The data are formatted in tables and graphs and are used to calculate a series of indicators on a web platform: the producible (kWh/kWp), the average production per month, the self-consumption rate… This platform may be specific regarding the type of electric meters or inverters installed, but as explained previously the output must be in an interoperable format.

The platform is also designed to report alerts to the company in charge of the maintenance in case of a dysfunction or anomaly. To do this, the voltage, current and inverters alarm data are also transmitted to the web platform.

In mySMARTLife project, a list of shared indicators have been established so that the actions and their impact may be compared from one city to another. These indicators will be centralised in the Urban Data Platform. Below is an extract from a list of indicators monitored or calculated. As mentioned above, this table can still be updated in the coming months, as it is part of WP5 T5.3 and for which the final version of the deliverable is due by M48.

In this table, yellow rows highlight primary indicators, based on the collected data; blue rows show the secondary indicators which can be calculated straight from the primary KPIs; the green rows colour, finally, the secondary indicators for which a human evaluation is required (eg. evaluation of Greenhouse Gas Emissions reduction if emissions prior to the intervention need to be simulated).

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Table 13: List of KPI for the PV plants

KPI	Indicator	Type	Monitored?	Formula	Unit	Source	Urban Platform			Comments	Res-pon-sible
							Service	Integration	Open Data		
E2	Electrical energy consumption	Primary	Monitored	#	kWh/(m2.month); kWh/(m2.year)	Wattmeter	No	Yes	Yes		[NAN]
E4	Annual energy consumption	Secondary	Monitored	E2	kWh/(m2.month); kWh/(m2.year)	Calculation	No	Yes	Yes	Electricity only	
E19	Primary electrical energy consumption	Secondary	Monitored	E2 * primary electrical energy factor	kWh/(m2.year)	Calculation	No	Yes	Yes		
E21	Total primary energy consumption	Secondary	Monitored	E19	kWh/(m2.year)	Calculation	No	Yes	Yes	Electricity only	
E29	Total greenhouse gas emissions (electrical)	Secondary	Monitored	E2 * electrical energy emission factor	kg CO2eq/(m2.month); kg CO2eq/(m2.year)	Calculation	No	Yes	Yes		
E31	Total greenhouse gas emissions	Secondary	Monitored	E29	kg CO2eq/(m2.month); kg CO2eq/(m2.year)	Calculation	No	Yes	Yes	Electricity only	
E14	Total renewable electrical energy production	Primary	Monitored	#	kWh/year; kWh/(m2.year)	Wattmeter	No	Yes	Yes		
E15	Total renewable energy production	Secondary	Monitored	E14	kWh/year; kWh/(m2.year)	Calculation	No	Yes	Yes	Electricity only	
E17	Degree of energy self - supply by RES	Secondary	Monitored	(E15 * 100) / E4	% of kWh/year	Calculation	No	Yes	Yes		
E32	Reduction of total greenhouse gas emissions	Secondary	Monitored	100 - [(E31 after * 100) / (E31 before)]	% change in kg CO2eq/(m2.year)	Evaluation	No	Yes	Yes		
E16	Increase in local renewable energy production	Secondary	Monitored	[(E15 * 100) / (city installed PV)]	% of kWh/year	Evaluation	No	Yes	Yes		
E18	Increase of degree of energy self - supply by RES	Secondary	Monitored	Sum of installations	kWp	Evaluation	No	Yes	Yes	Sum of installed kWp because there was no self-supply before; no percentage can be calculated	

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4.2.3. Call for tenders and Installation work

All the documents necessary for the call for tenders had to be drawn up: the technical documents (technical specifications) but also all the administrative documents related to the French public tender procedure. The engineering office System Off Grid drafted the technical specifications which were then reviewed by Nantes Metropole departments.

The call for tenders was launched the first fortnight of July 2019 and the companies had until the beginning of September to submit their tender. A negotiation phase then took place with the companies shortlisted. The companies selected for each work package were then officially notified of the contract. A 6-week preparation period is planned in order to organize the work site and allow companies to benefit from a suitable supply period.

When scheduling the works, the buildings functioning needs to be taken into account, and actions such as the following must be implemented: if possible, installation works should be planned during holidays for schools; for an office building, noise pollution must be limited as much as possible during operating hours.

The following table sums up the evolution of the implementation of solar plants on the public buildings of Nantes Metropole and the City of Nantes over time.

Table 14: Evolution of the project over time

Key elements	Date
Feasibility studies	January 2019
Commissioning of the MIN 500-kWp solar plant	Spring 2019
Validation by the City board for the launch of the call for tenders	End of June 2019
Call for tenders	July – September 2019
Negotiation and choice of the companies	October – December 2019
Installation works of the other solar plants	January 2020 – August 2020

4.3. Lessons learnt towards replication

Building related issues

A first difficulty lied in the planning of works on the buildings and in particular roof renovation works. When deciding to install a solar power plant on a roof, it is first necessary to check that roof renovation work is not planned in the coming years. This was a difficulty because, at first sight, it did not seem too difficult to find roofs matching with the criteria (concrete flat roof) but in reality, some buildings could not be selected because either the roof was in poor condition or roof renovation work was planned in the coming years. The installation of photovoltaic plants should be in line with roof renovation works when scheduling the buildings retrofitting works.

Regarding the building itself, we had to face another issue: the building structure is not always strong enough to support the weight of the solar plant. The solution chosen for the solar panel consists in ballasted panels.

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They add 50 to 60 kg/m² to the structure of the building at most, but it could be less, around 30 kg/m². Existing buildings have not been developed in order to support this additional weight and for the solar plant to be installed, some structural works must be carried out. All of this leads to longer project times but above all to more expensive projects. Some of the first buildings targeted in the feasibility study had to be removed from the project because of this issue. The additional works were too expensive to fit within the budget allocated to the project. Even if this is not part of the action, the development of these solar plants taught us that when constructing a new building, the possibility of installing a solar plant on the rooftop must be studied beforehand so that the structure of the building is designed for the weight of the plant, so it may be "PV ready". For some buildings, the issue lies in the compressibility of the insulation that is not compatible with the load of the ballasted panels.

To finish with the building-related issues, some of them date back to a few decades, so it is possible to find asbestos in building materials. Given the age of these buildings, the files of the executed works were not found. It was therefore not possible to know whether or not asbestos was present, and diagnostics had to be carried out on those buildings which means additional expenses. There was indeed asbestos in some buildings: this implies having workers with specific training on the subject, a strict protection protocol and adequate site management.

Technical issues

As said before, the selected solution consists of ballasted solar panels. Since all the photovoltaic plants to be developed will be on existing building, choosing a solution with classic panels implies to build a structure to the concrete roof, which means restoring the watertightness of the roof. Once again it changes the stature and the expanses of the project, which was not conceivable. This is the reason why the choice was made to turn towards a ballasted solution. However, this kind of technology is quite recent and does not have a specific technical notice approved by the French national organisation (CSTB for Centre Scientifique et Technique du Bâtiment). There are several other types of technical notices in France that allow a product to be used but some building inspection offices find that this does not provide sufficient justification. Discussions were held before the work phase to reach an agreement with the building inspection office of the project.

Administrative and financial aspects

In the context of a photovoltaic roof project, one of the administrative obligations consists of submitting a prior declaration to the town hall. The instructor service then checks the conformity of the project regarding the local urban masterplan and gives its approval to the project if everything is in order. However, if the building is located in a heritage protection area, the project file must also be checked by the French architectural review board ("Architecte des bâtiments de France"). For now, the installation of a solar power plant on a roof within a heritage protection area is not yet easily accepted. Some of the files submitted were refused because of specific restrictions due to the location of the building in an area of this kind. To solve this issue, Nantes Metropole is currently working with the French architectural review board in order to establish the best practices for this kind of project: documents to add, things to avoid…

As for the financial part, a distinctive characteristic of this action is that the buildings selected belong to three different local organizations: the City of Nantes, Nantes Metropole and Nantes Communal Social Action Centre. These three local authorities each have an allocated budget for the development of solar power plants on their buildings. Thus, all invoices must be made separately for each of three local authorities regarding their

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allocated budget. Within the three local authorities, different buildings have been selected and their management is not carried out by the same person so that there is a multiplicity of interlocutors on the project. For the future photovoltaic projects managed by Nantes Metropole, this will be done in a different way : there will not be one big project gathering all the possible photovoltaic power plants, but in the works scheduling of each building, a feasibility study will be carried out to see if installing a solar plant is interesting and worth considering. A framework agreement for all kinds of environmental and energy studies facilitates the procedure to select an engineering consultancy quickly.

Another impact that could be expected from the deployment of these solar plants is the benefit for education and awareness. Some of the buildings targeted are schools, in this way, the solar power plant can be used as a means to raise awareness among pupils on a well-reasoned use of energy and to discover renewables in real life. The only issue is that it depends on the will of the teaching staff on this subject. Beyond schools, the selected roofs are on buildings that people are used to visit: music academy, swimming pool or association centre. In this way, some communication can be set up to raise awareness, such as a poster with information about the solar plant and the amount of energy produced in the past year.

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5. Organic PV production

The organic PV is a promising technology for PV production. This new solar system is developed by a French company named Armor. In addition to its friendly environmental production, this film is a solution to develop solar production on many locations where conventional PV system is not adapted. Indeed, the technology could be installed for example on curved shaves, zinc roof, metal roof, canvas roofs…

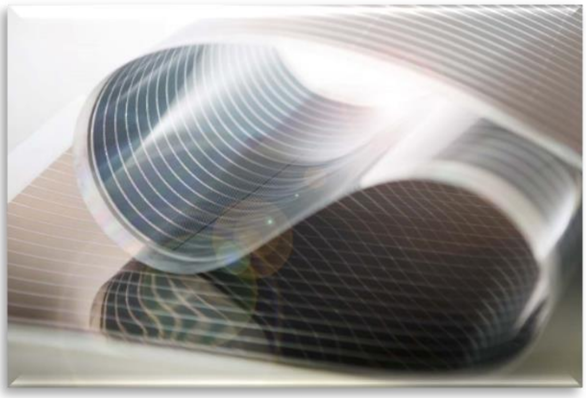

Figure 18: OPV film picture

On the congress Centre of Nantes, ENGIE installed a OPV film system to supply electricity for new services as charging point for mobile phone.

5.1. Organic PV: a promising technology for PV production

OPV is based on 3rd generation photovoltaics cells made of polymers including mainly chains of Carbon, Hydrogen and Nitrogen molecules issued from organic chemistry. They contain no silicon (Si) nor rare metal (such as CIGS – Cupper, Indium, Gallium, Selenium) nor toxic materials (such as CdTe, Cadmium Tellurite).

The **raw materials** constituting OPV bear major advantages comparing to other technologies:

- Raw materials (e.g. from organic chemistry) are available everywhere reducing third-party countries dependence as it is the case for rare metal.
- OPV manufacturing is a very low energy consumption process using the "roll to roll" method. On the opposite, manufacturing Si based PV panels is extremely power consuming involving blast furnace and extremely high temperatures cycles.
- "Roll-to-roll" manufacturing process allows for mass production and therefore can be processed at very reduced costs.

OPV films have **physical characteristics** offering competitive advantages comparing to other technologies:

- Light weight (between 450 g/m² to 800 g/m²) comparing to 2 kg/m² for thin films and 15 kg/m² for Si panels: Offering almost no limit to the choice of existing structures on which it can be installed, and which have not been designed to receive extra load
- Transparency (up to 30% today, 60% percent target within the next 3 years) due to the thinness of the polymers when other technologies are totally opaque: all transparent building surfaces could potentially be equipped with OPV films, playing two roles. On the one hand, activating glazed surfaces

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

and on the other hand lowering solar over heating thus reducing potential cooling energy consumption. Different colors can be achieved offering various architectural possibilities.

- Flexibility up to 5 cm in diameter and rolling and unrolling resistant up to 50 000 cycles: New usages can be foreseen such as rolling shutters or mounting on curb and flexible surfaces such as ETFE (Ethylene tetrafluoroethylene) cushions or textile surfaces. The most flexible existing technologies such as amorphous Si or CIGS (Copper indium gallium selenide solar cells) thin films cannot reach such bending performances without cracking or delaminating.

OPV offers **advantageous behaviour** regarding environmental parameters:

- Organic cells do not lose efficiency when submitted to high temperatures on the opposite of Si panel that reduce theirs by 0,4 to 0,5% per Celsius degree above 25° C. Therefore, OPV film is an ideal solution for direct application to, or integration onto building envelop materials such as Glass or Metal which temperature may soar up to 80° C when exposed to the sun.
- OPV is very sensitive to diffused light. When other technologies generate almost no current when not exposed to direct solar rays and no current at all below 1000 lux, OPV maintain its efficiency ratio even under diffused light and at very low luminous level, below 200 lux. Such characteristic allows for applications on all orientations, even vertical such as façades.

The OPV technology also offers local and European benefits perspectives. ARMOR is an international company based in Nantes. It is the world leader in thermal transfer films used for printing barcodes and etiquettes. 80% of its turnover is achieved internationally but 100% is produced in France. The OPV production line is located in the same premises as the thermal transfer film factory on the south outskirt of Nantes. Such strategy conveys the company societal commitment:

- ARMOR market is international. As ARMOR market share expands, local employment is growing. Besides, all levels of educational profiles are involved.
- OPV film is just one part of a whole PV system. PV electrical specialists and material integration partners are locally involved. Those companies will benefit from such disruptive innovation improving their technical know-how. Eventually increasing their value-added. Numerous building envelop and glazing world leaders are based in Europe and are potential partners.
- Beyond the companies taking directly part in the OPV system manufacturing process, all the stake holders involved in the value chain are benefiting from it. Public and private landowners, EPC's (Engineering, Procurement and Construction companies), installers, contractors, power producers… Even in this early development stage, this technology conveys a far-reaching message. Being the lowest carbon PV solution, with environmental low impact and locally produced.
- This message is also of a great interest for local communities such as Nantes Metropole wishing to attract economic operators by showing its dynamism and its commitment in renewables and sustainability.

Projects are also in the pipe with the education world. It is the case with the ICAM (Institut Catholique des Arts et Métiers) a network of technical and engineering schools. A pedagogical program all together with an industrial development program is being under discussion. Students will be exposed to this new technology.

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This point is all the more important since they will potentially become part of the OPV ecosystem as future prescribers or installers for instance.

5.2. Implementation of the organic PV project

5.2.1. Location of the project

The OPV project takes place on the Nantes City Congress Centre. The Congress Centre is located in the centre of Nantes. It’s an international city congress which welcomes 400 000 visitors per year.

Figure 19: Location of City of Congress of Nantes

The OPV modules will be installed on the sunshade of the south-south-east side of the building. “ready-to-glue” modules will be installed on metal shades, demonstrating its ability to be applied on existing surfaces without any structural reinforcement. On this location, conventional PV panels could not be installed.

ENGIE will engineer the electrical schematic design and install the modules as well as the electrical parts.

The power harvested through this installation will supply a rechargeable battery used by the City Congress Centre for boots temporary lighting.

Those shades are visible from the mezzanine of the City Congress Centre which is a very busy location. Communication wise, an informative pole will be erected close to the demonstrator. It will explain the technology and its potentialities.

The installation is described in the following sections.

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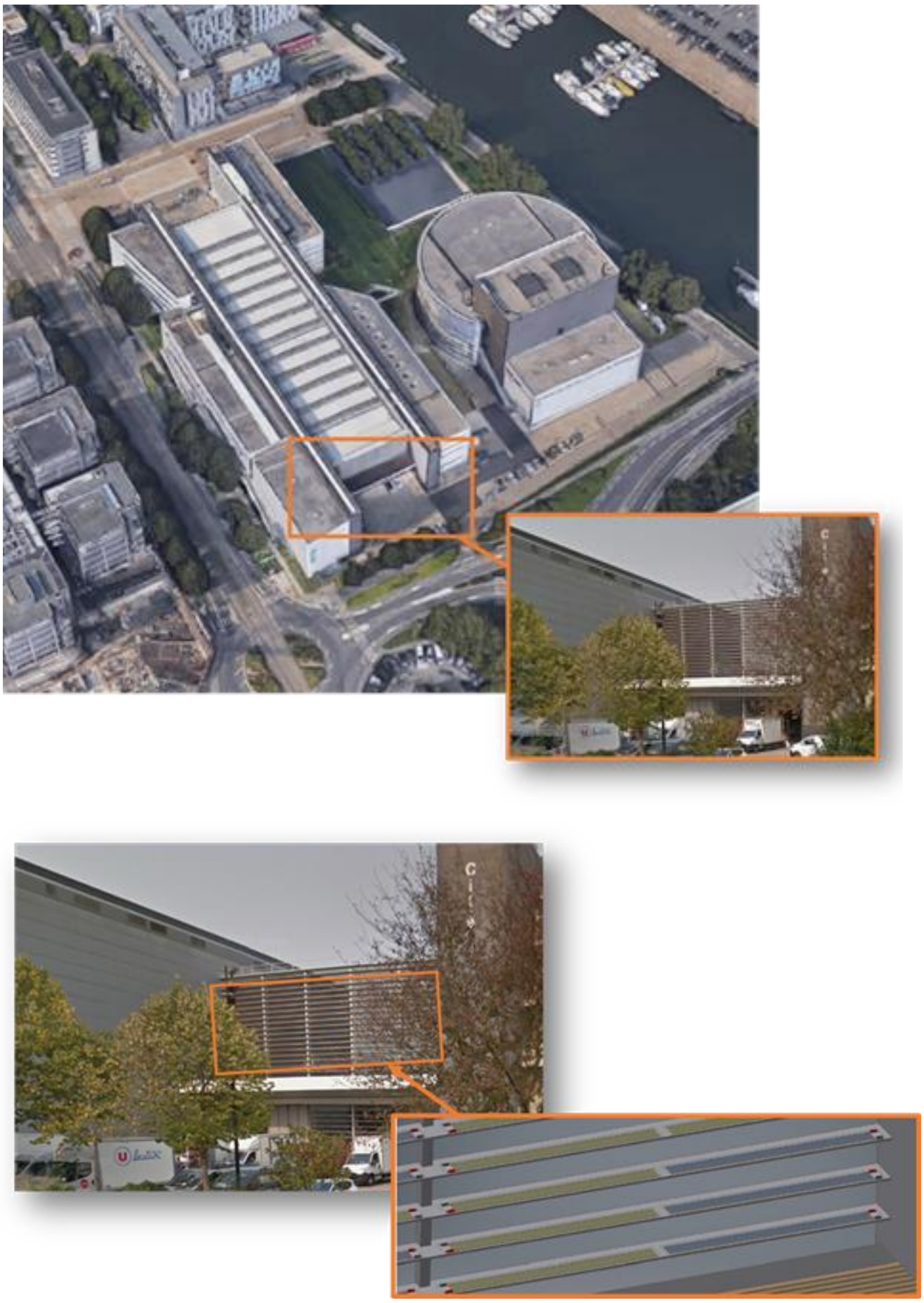

Figure 20: Location of the OPV plant

5.2.2. Technical details

The OPV films will be installed on the surface described below. The installation is very quick, less than one week.

- **Application surfaces**: Aluminium shades surfaces

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Figure 21: Outer view

Figure 22: Inner view

Figure 23: Shade detail

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- **OPV modules description**: 108 modules of 180 mm width and 2100 mm length.

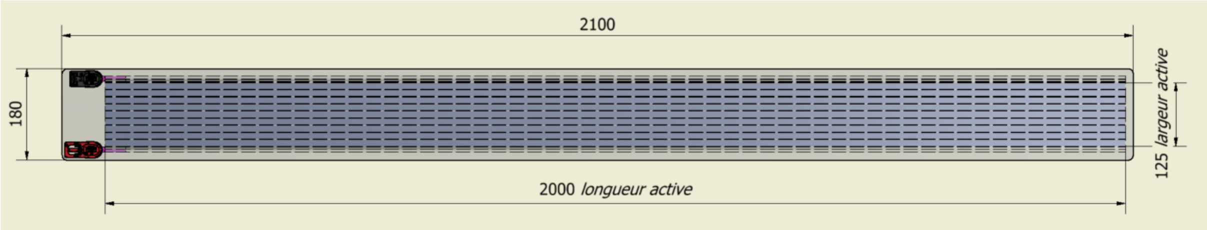

Figure 24: Module design

- The OPV modules are applied on metallic shades surface trough specifically developed adhesive.

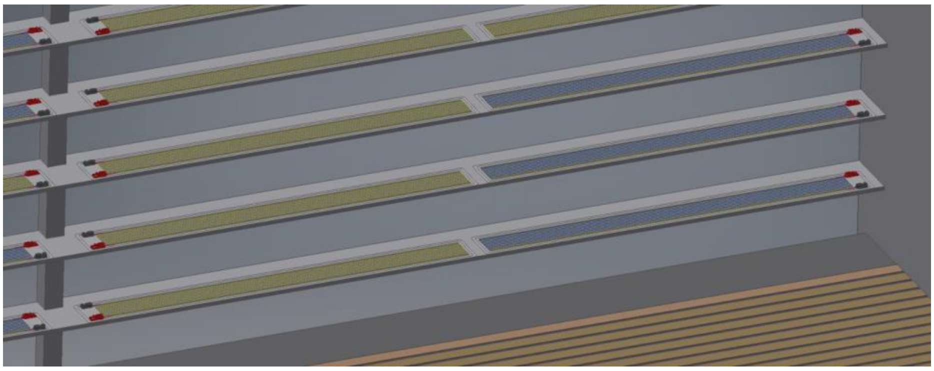

Figure 25: Adhesives on the metallic shades

The electrical characteristics are described in the next table and figure.

Table 15: Module characteristics

Voc	7,3V
Isc	2A
Vmp	5.6V
Imp	1.6A
Pmp	9Wc

- Total installed peak power: **972 Wp**

The installation will produce during the whole year, the estimated production is **410 kWh**. The estimated production is maximum during June and July.

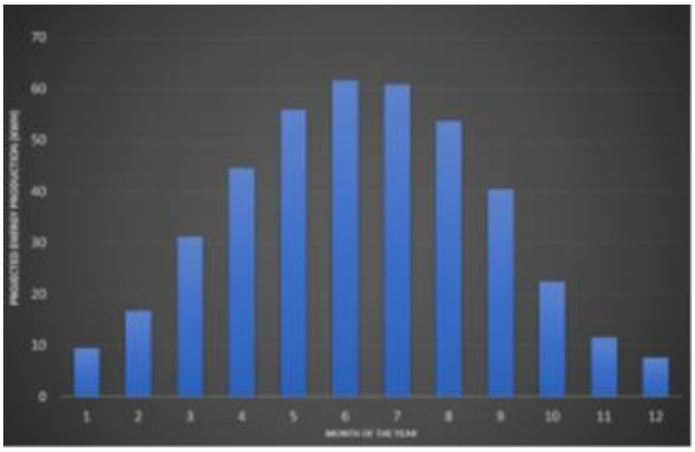

Figure 26: Monthly production

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5.2.3. Monitoring

As for the monitoring of the public buildings PV plants installation mentioned above, this action is part of the WP5 of mySMARTLife project and as such, the monitoring of this intervention may be subject to modifications as part of the monitoring & evaluation work package.

The schema for the monitoring so far is as follow:

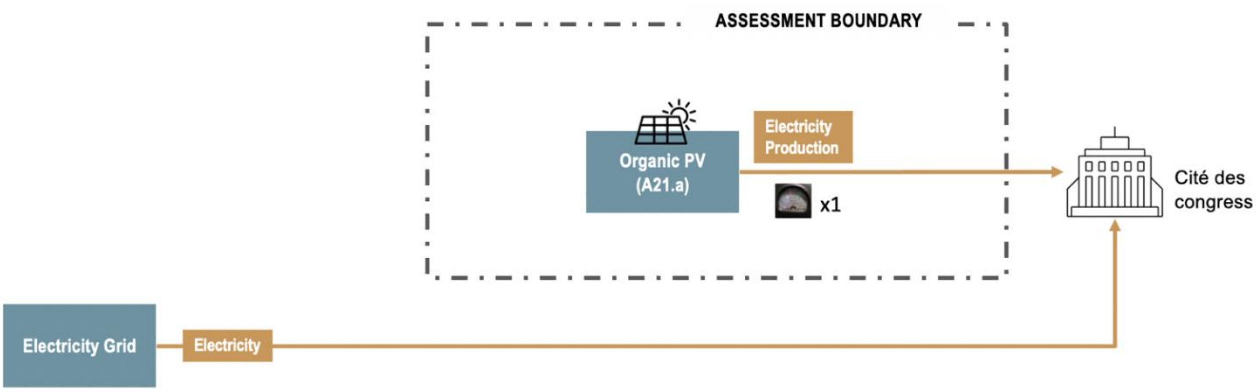

Figure 27: OPV demonstrator monitoring schema

In mySMARTLife project, a list of shared indicators has been established so that the actions and their impact may be compared from one city to another. These indicators will be centralised in the Urban Data Platform. The next table shows the list of indicators monitored or calculated with regards to the OPV demonstrator, in order to collect the necessary KPIs to evaluate this intervention. The yellow indicator is primary, while the blue one results from the former.

Table 16: OPV demonstrator KPI

KPI	Indicator	Type	Monitored ?	Formula	Unit	Source	Urban Platform			Comments
							Service	Integration	Open Data	
E14	Total renewable electrical energy production	Primary	Monitored	raw data	kWh/year or kWh/(m2.year)	Sensors	No	Yes	Yes	
E15	Total renewable energy production	Secondary	Monitored	E14	kWh/year or kWh/(m2.year)	Calculation	No	Yes	Yes	Only electrical

5.3. Lessons learnt towards replication

The OPV modules demonstration in Nantes City Congress aims at:

- Analysing OPV specific production behaviour when submitted to direct light, diffused light and shadow.
- Controlling production modelling regarding effective production.
- Validating electrical design.
- Improving installation process.
- Analysing the adhesive behaviour.

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Those parameters will be controlled through:

- Power production monitoring.
- Weather data analysis.
- Regular visual control.

This project will lead to a "ready-to-glue" product improvement that will eventually be replicated on divers' metallic surfaces. This product is a building applied photovoltaic system or BAPV.

According to Osseweijer, Van den Hurk, Teunissen and Van Sark, Elseiver (A comparative review of building integrated photovoltaics ecosystems in selected European countries – 2018), European building surfaces suitable for BAPV market represented more than 12 millions of km² in 2018 with a compound annual gross ratio (CAGR) of nearly 40% in throughout the next 6 years. This potential can be split into residential (70%) and non-residential (30%). Considering just this latter, about half of the potential surfaces are metal (mainly zinc, steel and aluminium) thus representing 1,8 millions of km².

As the traditional technologies (Si panels, etc.) are not suitable for existing surfaces application due to their weight and their poor production ratio when implemented for specific orientations, those available surfaces are not exploited.

The "ready-to-glue" OPV product that will be developed in this project will be the most relevant technology for BAPV application on those surfaces.

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6. PV production, storage and e-vehicle charge for service/office buildings

The action detailed in this section focuses on one location to implement a PV plant and a storage system by battery.

6.1. Combining various uses and technologies based on a PV energy source

This project is developed on a building of the CIC West Bank.

The objectives of this project are to:

- Validate an innovative economic model to finance the implementation and exploitation of renewable energy production for several tertiary buildings for self-consumption.
- Limit greenhouse gas emissions by optimizing the use of storage capacity based on peak hours, and times when demand is low.
- Optimize production in line with demand by storing the excess energy produced when the need is low and restoring it when demand is high.
- Propose an installation which can evolve for future deployment of charging stations at CIC’s parking.

The benefits to the community are:

- A support to the economy of sustainable development.
- A reduction of the carbon footprint (8910 $kgco^2$ per year).

Towards this project, the CIC will be able to control its energy consumption and reduce its CO2 emissions. By producing power for self-consumption, CIC will secure part of its consumption from the hazards of the distribution network and the evolution of electricity prices on the market. The customer CIC is engaged in a strategic approach in terms of Corporate Social Responsibility and wishes to develop actions in favour of the energy transition. The owner of the building, CIC, will consume renewable energy at the same price. The employees and user of CIC building will consume renewable energy during their work day. Besides, CIC will communicate on self-produced and consumed solar power to its customers through a digital screen. Employees and users of CIC building will have access to EV charging point, thus CIC encourage their employees to use electrical vehicle.

ENGIE finances, designs, builds and operates the PV system for self-consumption and the corresponding batteries for 15 years. The energy produced is self-consumed at the current price of the electricity contract subscribed by users. The economic balance is neutral for users. The annual fee that CIC will pay is almost equal to the actual electricity price.

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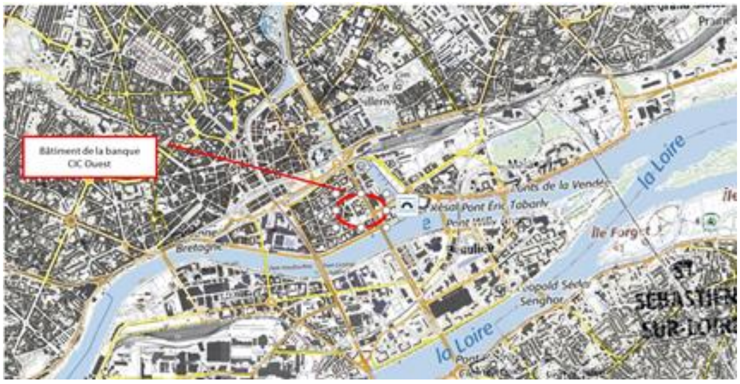
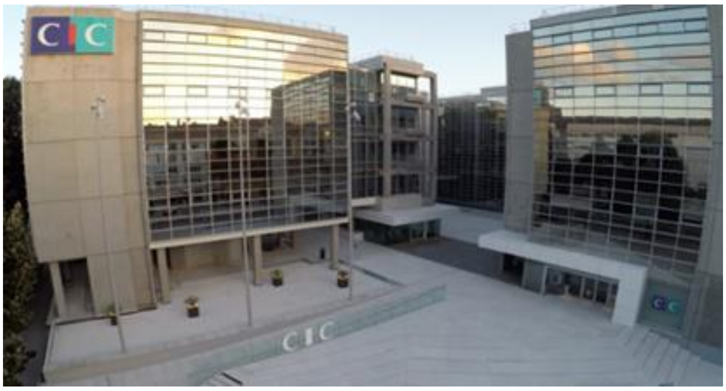
6.2. Implementation of the PV project

The project consists in implementing a 107 kW photovoltaic power plant associated with a 50 kWh lithium-ion battery storage capacity in order to produce electricity for self-consumption to power 3 buildings.

6.2.1. Location

CIC West Bank -2 avenue Jean-Claude Bonduelle - 44,000 Nantes; Latitude: 47.212210 Longitude: -1.544767 Altitude: 6.51 m.





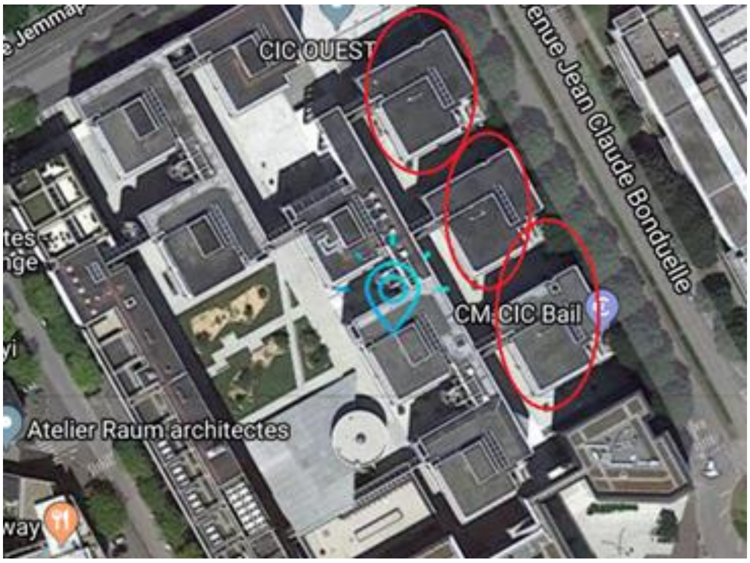


Figure 28: Location of the CIC building within its district

6.2.2. Methodology

To succeed in this action, the methodology is composed of the steps, as presented in the following Table 17 (next page).

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Table 17: Methodology of the installation

Collect data	Collect and analyse the electrical consumptions (based on average power's consumption called every 10 min during a year).Identification of available surfaces. Evaluation of the optimal PV power production profile with PVSYST and Meteonorm software •Identification of available surfaces.
Design the installation	•Design the power of this installation (depending on avaible surface, electrical consumption and profil...) Design the storage system Design the installation (localisation of each part of installation, electrical design...) Choice of materials and layout of the modules.
Financial and contractuals aspects	Techno-economic optimization calculations Prepare, propose and discuss about an contractual agreement with the owner and occupant of the building
Permits	•Prepare and submit a file for administrative authorizations
Works	Plan the work and install the equipment

6.2.3. Consumption and production

The first step of the study is to collect and analyze the profile of consumption of the building to design the installation (power of PV plant, size of battery…).

The profile of electricity consumption of CIC building shows on important consumption during the summer, probably due to the air conditioning system. Besides, the CIC building is an office building, thus the consumption varies during the week. A decrease in needs occurs every weekend. This is a typical profile of a tertiary site. Annual consumption represents a total of 2,632,767 kWh.

Nevertheless, there is a consumption stub due to data center.

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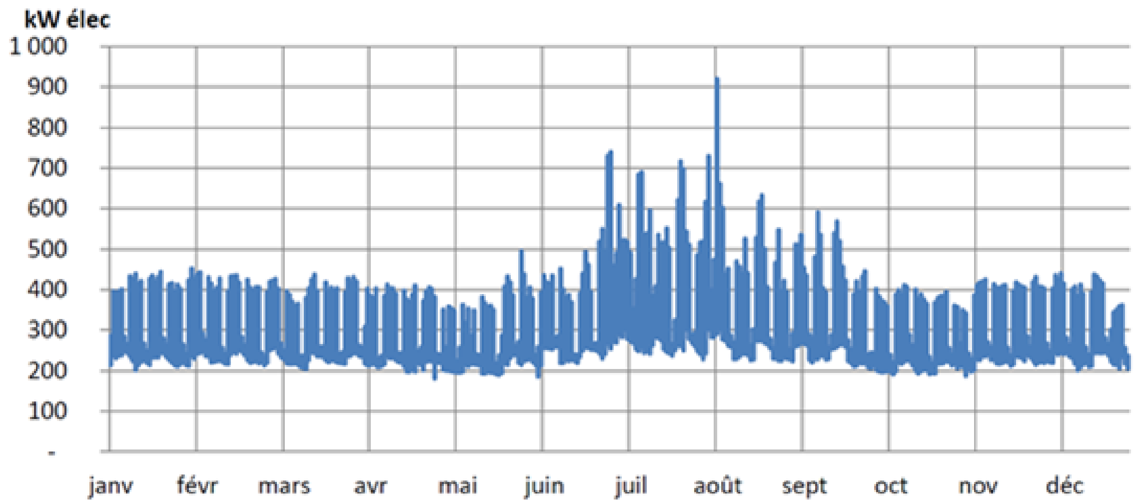

Figure 29: Electrical power load profile of CIC building

6.2.4. The installation of PV plant

The PV plant is composed by 334 PV modules of 320Wc installed on 3 roofs. To maximize the power, a landscape installation solution with an EAST/WEST orientation is used.

The modules are of crystalline technology. They are manufactured in France and have good carbon balances (less than 400 kg of CO_2 per kWp). Their weight is 11 kg/m². Their dimensions are 1.98m by 0.99m. Their power is 320 Wp.

Figure 30: Roof of CIC building

A low height weighted solution is recommended. No module will exceed the acroteria, which was a requirement to obtain the permit. The connections for electricity production are made on the distribution board of each equipped building.

Figure 31: Example of PV panels for CIC building

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6.2.5. The storage

The consumption and the production are not always simultaneous. The storage allows to use the excess of production during the period where the consumption is higher than the solar production. Thus, it allows to maximise the local use of renewable production.

A specific local will be created in the building. The installation planned has a capacity of 846 Ah and weighs 514 kg. This equipment is connected to bidirectional inverters.

Figure 32: Model of storage system used for CIC building

6.2.6. The EV station

An EVBOX brand charging station (22 kW) is available (see next figure). An all-in-one terminal, combining recharging with management software and e-mobility services. The EV station will be installed in the underground parking of the building.

Figure 33: EV charging station

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

6.2.7. Synthesis of the installation

Table 18: Main figures of the PV + storage + charging station installation

The building	**3 buildings – 3 roofs** **Annual energy consumption: 2,632 MWh**
PV plant production	107 kW 110 MWh/year
Size of battery	50 kWh
EV charging station	22 kW
Rate of self-consumption	100% of energy produced

6.2.8. Monitoring

Similarly to the other monitoring activities of the actions this deliverable covers, the monitoring of this global intervention on the CIC office building has been defined so far, in a first suitable version, but this will probably change as part of the monitoring & evaluation work package (WP5) for which the final version of D5.3 covering these topics (monitoring table & schema below) is due by M48.

So far, a global monitoring schema was designed to represent both the impacts of the different actions in the overall electrical system and how they will be monitored from an energetical point of view (cf next figure).

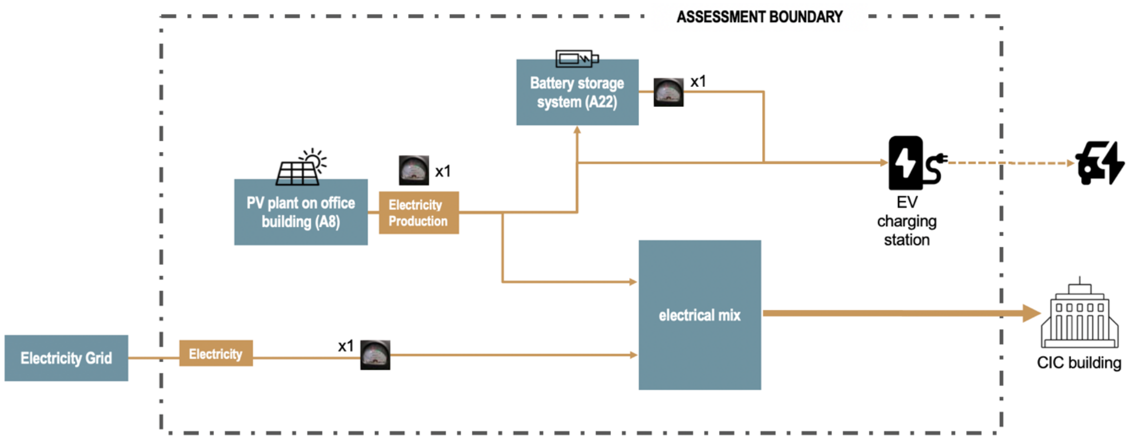

Figure 34: CIC office building PV production, storage, and EV charge system monitoring schema

The aim of this schema is to show where the necessary data will be measured to provide the raw material for the calculation of the monitoring KPIs.

Regarding the KPIs, a list of shared indicators has been established in mySMARTLife project so that the actions and their impacts may be compared from one city to another. These indicators will be centralised in the Urban Data Platform. The next table shows the list of indicators monitored or calculated to provide the necessary KPIs to evaluate this intervention: the yellow rows represent the primary KPIs, the blue ones are calculated from the former, and the green rows highlight KPIs for which some human expertise is required.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

Table 19: Main KPIs for the PV + storage +charging station action on the CIC building

KPI	Indicator	Type	Monitored ?	Formula	Unit	Source	Urban Platform			Comments
							Service	Integration	Open Data	
E2	Electrical energy consumption	Primary	Monitored	raw data	kWh/(m2 .month); kWh/(m2 .year)	Sensors	No	Yes	Yes	
E4	Annual energy consumption	Secondary	Monitored	E2	kWh/(m2 .month); kWh/(m2 .year)	Calculation	No	Yes	Yes	Only electrical
E14	Total renewable electrical energy production	Primary	Monitored	raw data	kWh/year or kWh/(m2 .year)	Sensors	No	Yes	Yes	
E15	Total renewable energy production	Secondary	Monitored	E14	kWh/year or kWh/(m2 .year)	Calculation	No	Yes	Yes	Only electrical
E17	Degree of energy self - supply by RES	Secondary	Monitored	(E15 * 100) / E4	% of kWh/year	Calculation	No	Yes	Yes	
E20	Primary electrical energy consumption	Secondary	Monitored	E2 * primary electrical energy factor	kWh/(m2 .year)	Calculation	No	Yes	Yes	
E21	Total primary energy consumption	Secondary	Monitored	E20	kWh/(m2 .year)	Calculation	No	Yes	Yes	Only electrical
E29	Total greenhouse gas emissions (electrical)	Secondary	Monitored	E2 * electrical energy emission factor	kg CO2eq/(m2.month); kg CO2eq/(m2.year)	Calculation	No	Yes	Yes	
E31	Total greenhouse gas emissions	Secondary	Monitored	E29	kg CO2eq/(m2.month); kg CO2eq/(m2.year)	Calculation	No	Yes	Yes	Only electrical
E32	Reduction of total greenhouse gas emissions	Secondary	Monitored	100 - [(E31 after * 100) / (E31 before)]	% change in kg CO2eq/(m2.year)	Evaluation	No	Yes	Yes	Only electrical

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

6.3. Lessons learnt towards replication

The project may evolve according to the demand in electricity in particular according to the deployment of the charging stations for electric vehicle or other electric mobility in the parking and their use by the users.
IN the perspective of replicating such a type of action the main barriers to overcome are as follows:

- 1st legal constraint = to obtain the signed agreement of the owner of the site.
- 2nd legal constraint = obtain the administrative authorizations.
- 3rd constraint = the legal framework related to self-consumption is changing, resulting in uncertainty about the associated taxes.

As concerns the analysis of consumption and production profiles, in order to correctly size a self-consumption installation, it is advisable to establish the electrical profile of the power demand.
From the top 10 mn file provided by CIC, a full year has been reconstructed. Exceptional days are not used in the study. Consumption is annually stable with an increase in power and consumption in summer due to cold needs. A decrease in needs takes place every weekend. This is a typical profile of a tertiary site. The annual consumption represents a total of 2,632,767 kWh.
The annual curve of needs is in full adequacy with that of a solar electric production whose production increases from May to September, in parallel of needs.
The site is ideally suited for a local installation of solar electricity production in self-consumption.

Another important challenge is to size the installation in perfect agreement with the type of energy contract, and to pay attention to the reinjection conditions.
A production profile has been generated from the PVSYST and Meteonorm tools. This file generated a "typical" production curve for the potential production plant of 125kWp from a typical year (base 15 years). This curve is then put on the consumption curve and generates a network requirements curve taking into account the site's self-consumption.
The locally produced electrical power reaches a maximum of 97 KW (July 8th). The annual production of self-consumed electricity is 110 MWh. The self-production of solar electricity does not reach the minimum consumption of CIC NANTES. Losses by reinjection on the network are zero. The rate of self-consumption is 100%. Annual consumption from the distribution network decreases to 2,500,759 kWh.

On this power photovoltaic self-consumption, the reinjection of electricity produced on the distribution network is prohibited for the considered contract. The proper sizing of the installation avoids it. A solution for regulating the power of the injection is provided in association with the monitoring. It will secure the 0 reinjection on the distribution network.
To allow to manage the power, we associate a storage of electricity and an electric vehicle charging station.
So we develop a solar solution of 107 kWp with a rate of 0% reinjection on the distribution network and 100% of self-consumption associated with a storage of 50 kWh and a charging station of 22kW.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

7. Call for projects: new urban services based on a smart grid

7.1. Transforming the city by developing a mobility hub

A multimodal hub was planned in the “Parking des Machines” located in the Island of Nantes. A renewable production with PV plant, wind turbines had to be developed on the roof of the park. A storage system had to be deployed to maximise the renewable production for local consumption.

The park had to be a site for new mobilities services as EV charging station.

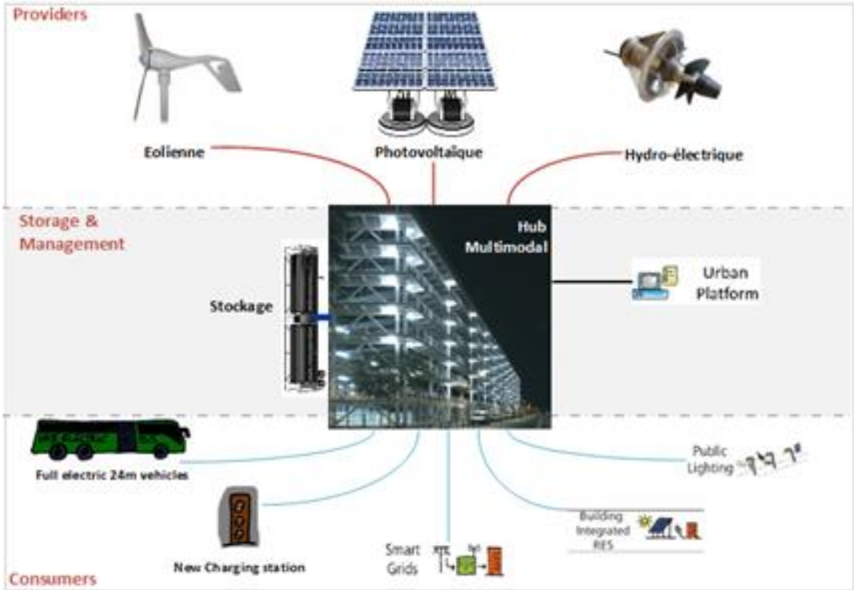

Figure 35: Initial project of multimodal hub

The hub multimodal was also a way to transform the area. Smart cities mean as well new services. In this way, a call for project was launched to find new innovative urban services.

This call for project named: “new innovative urban services based on a smart grid” was launched with local partners as ENGIE, Nantes Metropole, a local bank, a public investment bank (Caisse des Dépots), Nantes City Lab, and a local public development corporation (Creative factory by SAMOA).

This call was organized according various steps, presented in the next table.

Table 20: Main dates of the call for project

Launch of the call for projects	October 16th 2017
Deadline for response	December 5th 2017
Presentation of the proposals and analysis of proposals by the jury	January 16th 2018
Award ceremony	February 20th 2018

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

The call for projects was shared by the following ways:

- Publication on ENGIE website: https://innovation.engie.com
- ENGIE Innovation Newsletter in french (11500 registered) + in english (3500 registered).
- Publication on ENGIE social network: LinkedIn (6300 subscriber), Facebook (43000 subscriber) et Twitter (24700 followers).
- Creative Factory social network.

7.2. Implementation: Results of the call for projects

The proposed solutions had to deal with one or several of the topics below:

- Services to citizens, visitors and residents.
- New cultural or leisure opportunities.
- Services to local businesses.
- Transport and mobility, multimodal hub, multi-service, development of pedestrian and bicycle traffic, logistics of the last km.
- Management of parking flows, vehicles.
- New services for users to enhance the attractiveness of the district.

12 candidates proposed a solution, 10 were start-ups and 2 major groups. 8 solutions were about mobility, 2 about culture and 2 others on sustainable development.

The solution to be selected had to be a mature technology which required experimentation or deployment operation. The solution also had to offer a balanced business model.

6 solutions were selected for a presentation before the final decision.

Table 21: 6 projects selected for a presentation before the final decision

Name of the company	Summary of the project
CLEAN ENERGY PLANET	Multimodal charging station for electric cars and electric bicycles, which can be powered by renewable energies, and with intelligent charge management
LACROIX	Street lighting masts transformed into a real rallying point, in particular with a smartphone charging system via USB, wifi access point, semi standing seat
SHORT EDITION	Distributor of short stories via a terminal connected to our platform that prints 1, 3 or 5 minutes stories for free
KRYOLE	Intelligent electric bicycle trailer. Last meter logistics / postal delivery or refrigerated delivery.
LA POSTE	Solar powered cargo bicycles connected, with energy recovery
OBWSTREETSTYLE	Deposit for guarding and electric charging for AEV, gyropods, single wheels... Electric gyropod project for the disabled.

Finally, 2 projects have been selected: Lacroix and Obwstreetstyle.

For the Lacroix proposition, Nantes Metropole, Lacroix and ENGIE discussed about the implementation of this solution to adapt it to the specific site.

Unfortunately, the PV plant had to be installed on another site because the demands from the architect of the park required too much expensive works. Thus, the solution proposed by Obwstreestyle could not be implemented in the new location of the PV plant site. Discussions are ongoing to find alternative solutions.

7.3. Lessons learnt towards replication

The call for project presented here is a good example of the synergies between a private company and a municipality can stimulate the transformation of a district:

- Propose new solutions to satisfy the emerging needs in terms of soft mobility, connectivity.
- Integrate these solutions in the public space, favoring the social interactions and social well-being.
- Associate local renewable solutions for the energy supply.
- Support the creativity of local economic actors through the call for project process.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

8. Hydro power

8.1. Making the most of the fluvial power

The lock and its localisation

In Nantes, there is a lock called Lock Saint-Felix. This infrastructure separated the river La Loire and its affluent l'Erdre.

Figure 36: Lock Saint Félix – Connection between the river La Loire and the its affluent l'Erdre

The site is currently operated and owned by the Waterways Unit of the Loire Atlantique department. The unit has two main task to manage the dam:

- allow the navigation of ships by crossing the lock,
- regulate the water level of the Erdre.

The St Félix lock is composed of three distinct parts:

- Part 1: The Lock.
- Part 2: Flood Valving.
- Part 3: The Weir.

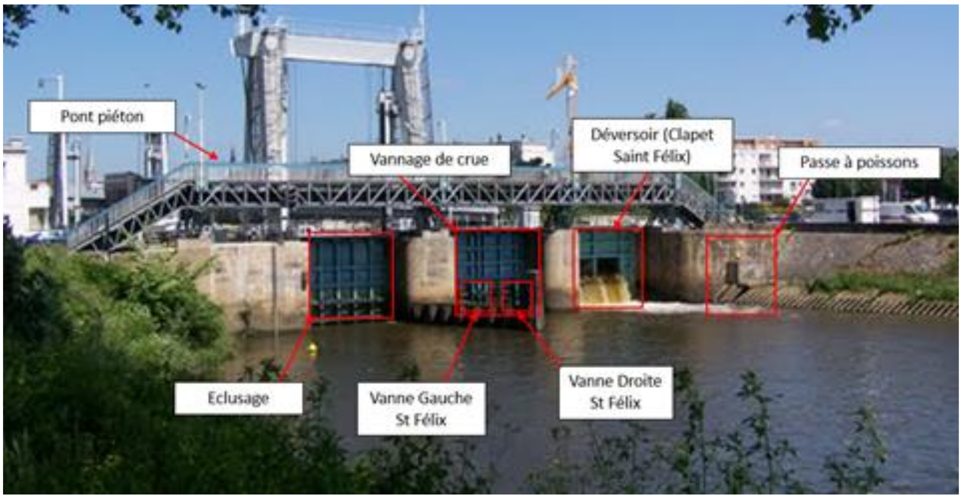

Figure 37: Illustration of the Saint Félix Lock

The principle of the electricity production

Navigating on the river l'Erdre requires a constant level of the water. Indeed, the level on La Loire varies greatly depending on the tides. Maintaining a constant level upstream of the Saint-Félix lock requires the passage of a water flow through a weir. This flow is highest during the winter period. Water falls gravitationally in the Loire. This potential energy can be exploited by installing turbines in which the water flow is turbinated, thus transforming the potential energy into electrical energy.

Figure 38: Photograph St Félix Weir at ebb tide - St Félix Lock - March 2017

The turbines would be connected to the electricity grid, enabling the entire hydroelectric production to be developed. As this production depends in particular on weather conditions and rainfall, the hydroelectric energy of this installation would be produced mainly during the winter period when consumption is at its highest. The maximum estimated production per year is estimated as presented in the next table (data collected from operators of the lock).

Table 22: Production capacity estimate

Year		2010	2011	2012	2013	2014	2015
hydroelectric Production (estimate) - kWh		636 102	442 669	571 893	827 631	774 465	555 658

Thus, on average the annual production is 515 MWh equivalent to the electricity consumption of more than 500 households. The power of the installation will be 240 kW.

The turbines are ultra-compact, each one has a unit power of 60kW. They are developed by the French SME company TURBIWATT. These turbines integrate the electrical generator. The rotating elements of these turbines are submerged and not visible, they are silent, and their design limits maintenance.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

8.2. Design of the hydro power project

The challenges of the project were to:

- guarantee the normal operation of the lock and in particular the passage of vessels,
- ensure ecological continuity,
- maximize power generation.

To guarantee the normal operation and the passage of vessels, the turbine will be installed in the opposite of the lock:

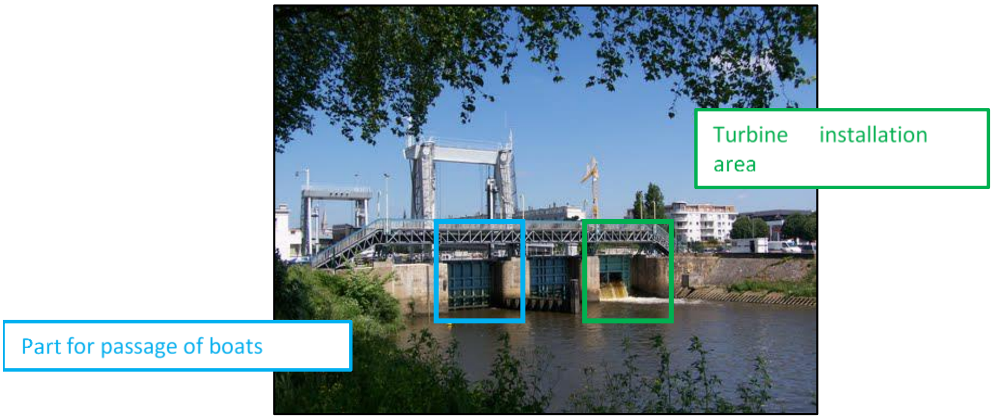

Figure 39: Position of the turbine installation

As concerns the ecological continuity, the lock is today described as a “potential disruption to ecological continuities”. Corrective measures are now being implemented by the Department's services. Besides, the site is very important and monitored because of presence of migratory fishes.

Today the lock is equipped with a fish ladder (next figure).

Figure 40: Example of fish ladder to ensure the ecological continuity

In order to preserve the ecological continuity of the site, for all the solutions, the micro-hydroelectric power plant must be equipped with a compatible ichthyo grid to protect fish. This will be installed on the upstream water chamber.

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Three alternative solutions have been designed:

Solution 1: The first solution consists in integrating the turbines into a water chamber downstream of the weir door.

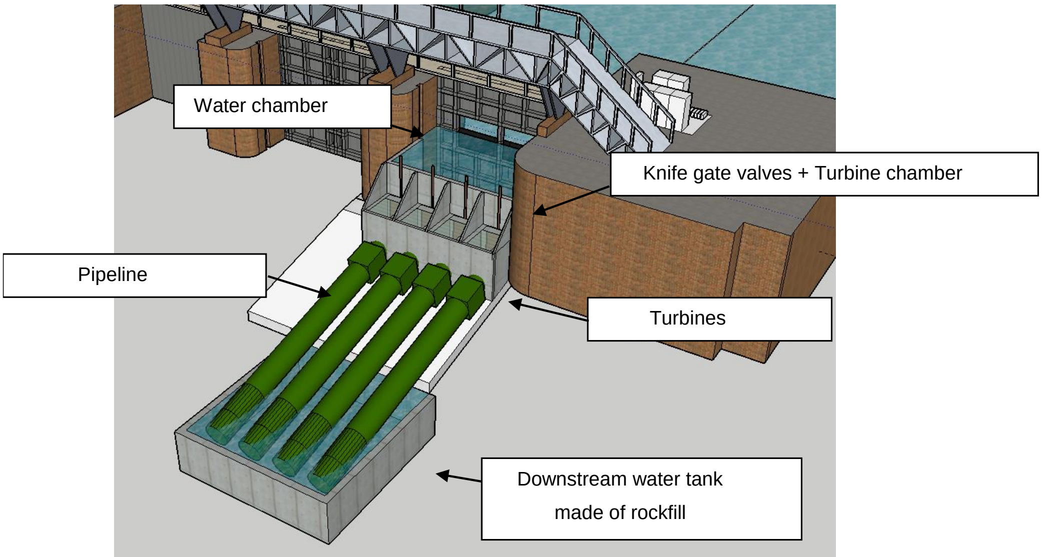

Figure 41: Solution 1: turbines in a water chamber

Solution 2: this solution consists of integrating the turbines on the weir door

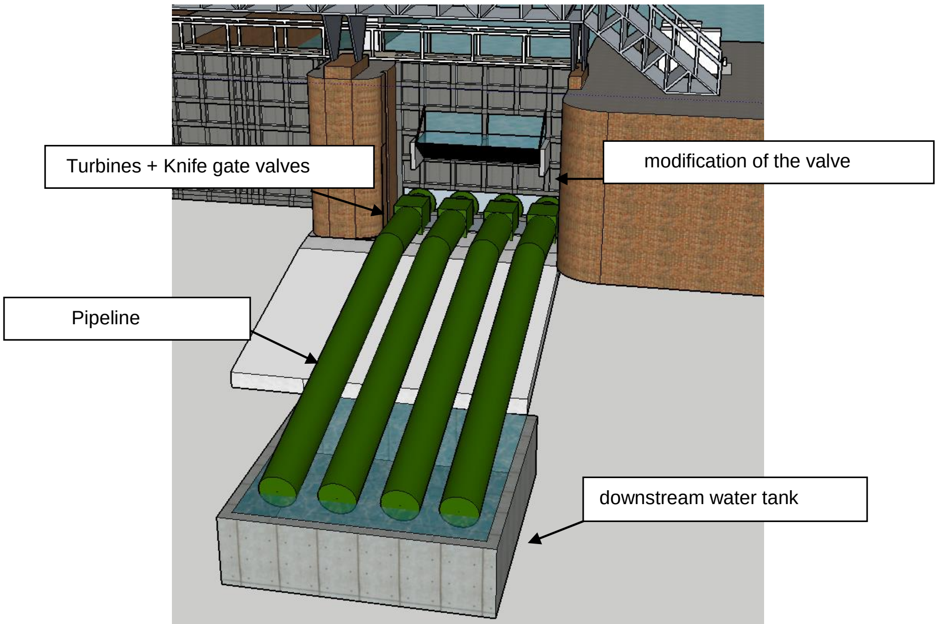

Figure 42: Solution 2: Turbines on the weir door

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<u>Solution 3:</u> The solution 3 consists in the integration of the turbines in the left bank of the St Félix lock:

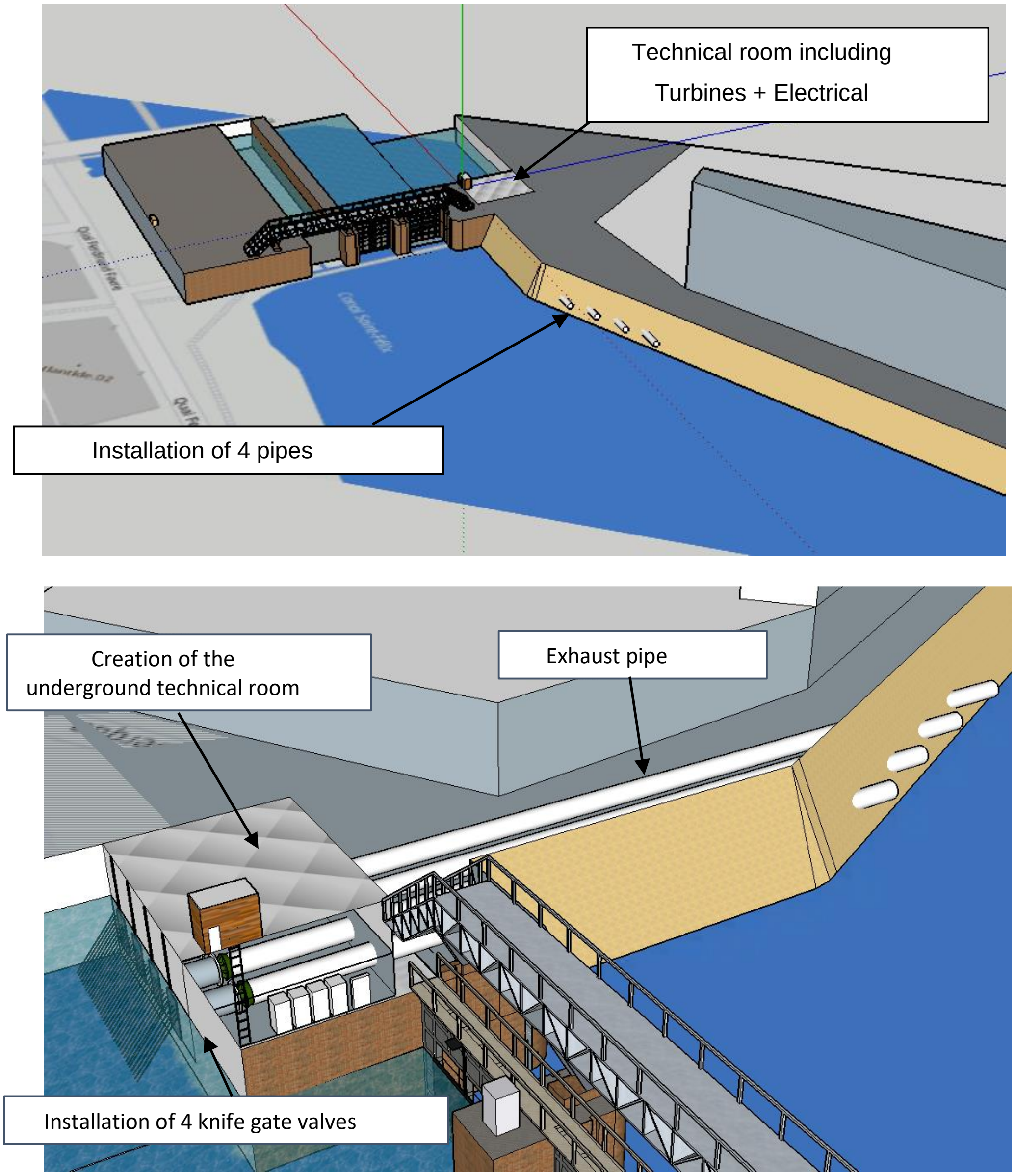

Figure 43: Solution 3: Turbines on the left bank

The electricity production output depends on several factors:

- drop height (H) (varying according to the level of the Erdre, the level of the Loire, the tides : level and time),
- instantaneous flow (Q),
- turbine efficiency.

It is calculated by means of the next formula.

P (W) = Q (kg/s) * H (m) * 9.81 * Machine efficiency (80% by hypothesis)

The estimate of the electricity production per year and per solution is then shown in the next figure.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.

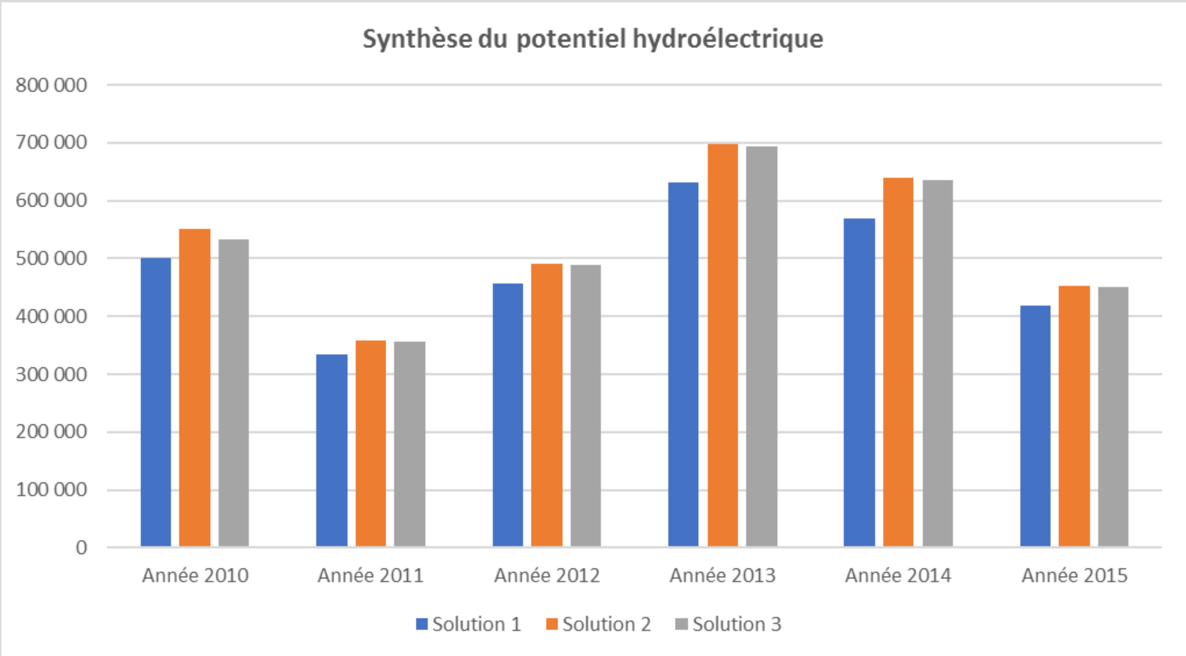

Figure 44: Hydro electric production potential per year, for each of the 3 proposed solutions (kWh per year)

The next table provides more technical details for each of the 3 solutions.

Table 23: Technical details of each of the 3 turbines solutions

	Solution 1	Solution 2	Solution 3
Technical description	• Creating a water chamber • Fixed travelling screen • Drainage pipe downstream of the weir • Creation of a downstream water tank with riprap • Technical room in a shelter on the wall	• Adaptation of the door • Automated screen travelling cleaning • Drain pipes downstream of the weir • Creation of a downstream water tank with riprap • Technical room in a shelter on the wall	• Disbursement of the left bank • Automated travelling screen cleaning • Exhaust pipes in the shoreline • Creation of a downstream water tank with riprap • Creation of an underground technical room
Time of work	4 months	1 month	7 months (work of riverbank redevelopment not including

Finally the next table shows the main advantages and drawbacks of each solution.

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Table 24: Relative advantages and drawbacks of the 3 types of turbines installation.

Solution	Easy to install	Work period	Cost	Impact during work	Visual impact	« Dismountability »
1 - With water chamber	+	+	++	0	- -	-
2 – Integration into the weir	+	+	+	0	-	+ +
3 – Integration in the left bank	- -	- -	- -	-	+ +	- -

8.3. Lessons learnt towards replication

The river lock is operated and owned by the Loire Atlantique Department. Many exchanges and meetings with the operator have been necessary to achieve this study. The Department has shared many data and figures (e.g. water flow) for the past years.

The business model is based on the sale of the whole electricity production. This revenue refunds the investment. (except in solution 3 because the investment is too high).

The solution was presented to the elected representative in charge of the lock. She has chosen not to proceed with our proposal. The low will change, and the Department authority would like to wait for the new regulation. Besides the solution 3 required an investment from the Department and it was not planned. The riverbank will be retrofitted, but it requires several years to define the urban transformations of the riverbanks

The solution could be deployed on any lock where there is a waterfall. It could also be installed in an area with continuous waterfall such as old mills. Each area is particular and requires a technical study to adapt the solution. The power could be adjusted for each installation, so that even a little installation could produce renewable energy.

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9. Conclusions

The RES developed in the context of Nantes Metropole are a shining example of the urban transformation approach developed in mySMARTLife:

- **Smart Energy**. Photovoltaics and PV related technologies (storage, e-vehicles) are defined as a strong direction of development for Nantes Metropole to implement an ambitious energy policy. Several types of implementations have been demonstrated in the context of mySMARTLife.
- **Smart Economy**. The techno-economic feasibility has been previously studied for each initiative and smart funding schemes have been adopted wherever possible, as for example: collective self-consumption in social housing context, or specific energy supply contract between ENGIE and CIC, MIN.
- **Smart People**. The involvement of the citizens has been crucial in the project about self-consumption. Moreover, Nantes Metropole will integrate in a systematic way the needed complementarity between the production and the use (production during daytime on residential buildings, consumption during daytime on the neighbouring service/office buildings). The involvement of local companies through innovative offers (e.g. action related to the call for projects) is also an efficient way to propose new services, well accepted by the citizens, and promoting the local stakeholders initiatives.

Beyond complying with the objectives defined in mySMARTLife, the solutions proposed here are also ambitious each one in its own way. They will serve as precious lessons and references for any municipality willing to replicate mySMARTLife’s solutions. Several barriers have thus been tackled:

- Regulation barriers. In a context of an evolving regulation context, practical solutions have been proposed, for example in the case of self-consumption buyer/seller obligations.
- Technical limits linked to the architectural integration of RES. For example the development of PV on the roof of public buildings made the most of the opportunity or absence of opportunity of the roof renovation calendar.
- Technological barriers. Very novel technologies are being implemented, such as Organic PV panels. This example of deployment is thus paving the way for a future adoption of this promising technology, once it will reach a higher readiness level for market applications.

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10. References

Commission de Régulation de l'Energie (2017), *L'autoconsommation dans le système électrique de demain – Ce qu'il faut savoir, available at:* http://autoconsommation.cre.fr/ce-qu-il-faut-savoir.html (accessed 30/10/2019)

Commission de Régulation de l'Energie (2019), *Délibération n°02019-215 portant avis sur le projet d'arrêté pris en application de l'article L.315-2 du code de l'énergie fixant le critère de proximité géographique de l'autoconsommation collective, available a*t: https://www.cre.fr/Documents/Deliberations/Avis/critere-de-proximite-geographique-de-l-autoconsommation-collective (accessed 23/10/2019)

FRANCE, *Code de l'énergie, articles L315-1 à L315-8, available at:* https://www.legifrance.gouv.fr/affichCode.do;jsessionid=7B4AE0CC94015ADD4E75213E0D4DFE8B.tplgfr37s_1?idSectionTA=LEGISCTA000032939883&cidTexte=LEGITEXT000023983208&dateTexte=20191030 (accessed 30/10/2019)

Ministère de l'environnement, de l'énergie et de la mer, en charge des relations internationales sur le climat (2017), *Décret n° 2017-676 du 28 avril 2017 relatif à l'autoconsommation d'électricité, available at:* https://www.legifrance.gouv.fr/affichTexte.do?cidTexte=JORFTEXT000034517272&categorieLien=id (accessed 29/10/2019)

Sénat, Commission Mixte Paritaire (26th of Sept. 2019), *Projet de loi : Energie et Climat, articles 6bisA, 6bisBA, available at:* http://www.senat.fr/enseance/textes/2018-2019/700.html#AMELI_SUB_4__Article_6_bis_A (accessed 30/10/2019)

SAS EnR Chantrerie (2018), *Centrale photovoltaïque à le Chantrerie, Elements de synthèse, available at:* https://web.imt-atlantique.fr/x-dg/aful-c/uploads/images/AFUL%20Chantrerie/PV%20participatif/Document%20pour%20souscripteurs_V2.pdf (accessed 24/10/2019)

Energie Partagée Investissement (2018), *EnR Chantrerie, available at:* https://je-souscris.energie-partagee.org/decouvrir-les-projets-epi/detail/enr-chantrerie (accessed 30/10/2019)
AFUL Chantrerie (2019), *L'AFUL CHANTRERIE : un territoire du "faire ensemble", available at:* https://web.imt-atlantique.fr/x-dg/aful-c/ (accessed 24/10/2019)

Cowatt (2018), *MIN à Watt - Aller plus loin, available at* : https://cowatt.fr/min-a-watt/min-a-watt-aller-plus-loin/#fonctionnementaveclespartenaire (accessed 30/10/2019)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731297.