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ICE INTELLIGENT COMMUNITY ENERGY

Interreg France (Channel Manche) England

EUROPEAN UNION

DELIVERABLE ICE L3.1.1

DESIGN OF INTERVENTIONS AND TECHNICAL SOLUTIONS

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BRETAGNE DÉVELOPPEMENT INNOVATION

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Deliverable ICE L3.1.1

DESIGN OF INTERVENTIONS AND TECHNICAL SOLUTIONS

Syndicat départemental d'énergie et d'équipement du Finistère, Keynergie, Association des Iles du Ponant, University of Plymouth, University of Exeter, University of East Anglia, Pôle Mer Bretagne Atlantique, Technopôle Brest Iroise

About ICE

Supported by the Interreg VA France (Channel) England program, the Intelligent Community Energy (ICE) project aims to design and apply innovative intelligent energy solutions for isolated areas of the Channel. Islands and peripheral territories face specific energy challenges. Many islands are not connected to European electricity grids and are dependent on imported fossil fuels, especially oil-fired thermal generators. The energy systems on which they depend tend to be less reliable, more expensive and emit more greenhouse gases than on the European continental grid.

In response to these issues, the ICE project considers the entire energy cycle, from production to consumption, and integrates mature or new technologies to develop innovative energy solutions. These solutions will be tested and tested at two pilot demonstration sites (Ushant Island and the University of East Anglia campus), to prove their feasibility and develop a general reproducible method for other isolated smart energy systems. elsewhere. To transfer this methodology to other isolated territories, ICE will offer a global low-carbon transition commercial offer. This will include a comprehensive assessment of local energy resources and conditions, a tailor-made model proposal for the energy transition, and a set of low-carbon skills and technologies available in a consortium of selected companies. This ICE-certified consortium will promote this offer to other isolated territories in and outside the Channel area (5 territories initially). The ICE partnership brings together researchers and support organizations for SMEs and benefits from France – UK complementarity in terms of knowledge and technological and commercial development.

The involvement of local and European SMEs will help to strengthen competitiveness and transnational cooperation.

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1. Introduction

This document was written as part of the ICE project. It aims to provide methodological elements for the implementation of a "smart grid" or intelligent network as part of an isolated energy system.

The first part describes a methodology of reflection which can be applied to any isolated energy system, even for energy systems which wish to obtain an internal balance even if they can be connected to the continental energy system or to a local energy system of lesser size importance. Each energy system is unique and can present very different issues depending on its specific context. Nevertheless, the steps described in the first part are generic enough to find applications everywhere.

In the second part of the document, two specific energy systems are described, which makes it easier to see the application of the method in each case.

2. Methodology

2.1.A first diagnosis

The first fundamental step before embarking on a "smart grid" approach is to establish as complete a diagnosis as possible of the current state of the targeted territory.

The first of the criteria is to determine the number of inhabitants as well as its evolution over time (identify seasonal variability, an overall upward or downward trend). It is also necessary to characterize the activities present or to come in the territory. The resources to be devoted to this diagnostic phase will be directly proportional to the size of the territory studied.

This first step should make it possible to characterize the energy needs of the territory. If the energy system is existing, it is necessary to identify the various consumption items and obtain consumption statements. These generally fall into 3 categories: heat needs, mobility needs and electrical needs. For a system in creation, it is necessary to evaluate the needs to be satisfied. This analysis should also make it possible to identify the distribution over time of these needs and in particular to verify the seasonality but also the day/night or weekly distributions. It is also important to assess the degree of criticality of the consumption requirement. Certain consumption is essential for the inhabitants and their non-satisfaction prevents the maintenance of activities and populations: needs for heating or air conditioning, water supply, health or safety needs, emergency transport... Other needs are likely to promote social organization but are not essential, we can speak of “comfort” energy needs. Finally, certain needs aim to guarantee a lifestyle equivalent to the most developed areas of the planet and can be considered a luxury.

Depending on the size of the territory, the diagnosis may present different degrees of precision. In the case of a very small perimeter, the study may go as far as meeting consumers, especially the largest. Within the framework of a larger territory, the study will be able to content itself with characterizing the load curves of the different energies and reconstituting standard profiles.

In parallel, it is necessary to conduct a detailed analysis of the various local means of energy production and imported resources. To take into account the problem of climate change, it is important to find out what are the potential for local, renewable energy production that does not emit greenhouse gases. Document T1.1.1 Resource Assessment, also produced within the framework of the ICE project, provides methodological elements for this diagnostic phase. The satisfaction of energy needs can nevertheless be based on less sustainable means of production but allowing to guarantee the security of supply and the comfort of use, thus compensating for the fragility linked to isolation.

Particular attention will be paid to the climatic and geographical context of the territory considered. Indeed, sunshine, average daily temperatures over the course of a year, rainfall, prevailing winds, etc. are all parameters that will influence energy consumption and energy production and therefore impact the production system (typically the strongest winter / summer seasonality effect in temperate countries).

Another stage of the diagnosis aims to understand the functioning of the existing energy system or to put in place. Who are the actors involved? Who can make the decisions and steer the energy system? What are the possible resources? What value can we give to the energy that is or will be distributed in relation to the socio-economic context or in relation to public policies?

This diagnostic phase will also attempt to bring together consumption and production, thus making it possible to identify the critical points of the energy system, namely: Energy losses, periods of high and low demand, the responsiveness of the energy system to variations in demand.

Overall, the management of an isolated energy system risks being confronted with greater fragility and potential additional investment and production costs compared to a larger system which makes it possible to pool costs and resources, in addition to being able to count on an interconnection effect between different areas of the territory, making it possible to smooth consumption and production. This is why it is essential to conduct a special reflection to understand why the territory is currently isolated (geographic, political, economic reasons). From this base, different scenarios can be envisaged to get out of this isolation with the consequences specific to each one. What is the benefit of a connection to an existing network compared to the costs and the service provided?

The diagnosis can be deployed in several stages. A first summary diagnosis can lead to the next step in defining objectives. Nevertheless, subsequently, more complete diagnostics will probably have to be carried out to achieve an operational implementation of the smart grid.

2.2. Defining goals

Once the inventory has been carried out, it is then necessary to define the objectives of the energy system to be put in place. For this, it is necessary to carry out the broadest possible consultation to promote the adoption of the objectives by the population and by the local authorities. The question of the ambition of the objectives is a fundamental point. Unrealistic objectives are counterproductive because the efforts required of consumers, producers and the regulator of the energy system will not be accepted. Too restrictive objectives do not make it possible to build a strategy over time and a clear roadmap.

The objectives can relate to several aspects, but will be part of the general movement of reducing the impact on the environment (climate, biodiversity) with the final objective of moving towards a sustainable system. Among the various possible objectives, we can note the following:

- **Autonomy:** Full autonomy is an admirable goal but cannot be taken for granted straight away. The following questions must therefore be asked: To what extent is the autonomy of the territory considered materially possible and desirable? What would being autonomous actually mean? How to achieve this autonomy? In addition, the notion of autonomy can be considered depending on the energy sectors (heat, mobility, electricity) or on the overall energy system. What is the "price" of this autonomy in financial terms or in terms of adapting local activities? In particular, if the territory has a strong potential in renewable and sustainable energies, it is not more relevant to consider its connection to nearby networks, than to aim for autonomy.

- **Security of the energy system:** Depending on the territory, the degree of security requirements can vary greatly. The level at which the need for security is located directly impacts infrastructure (redundancy, storage, management), costs, maintenance, space. For example: Is it possible to accept exceptional announced power cuts (ex. 5-10 days / years) during periods of high demand? Or to set up an energy “curfew” to drastically reduce consumption during low production periods. How many power cuts and what duration are acceptable?
- **Resilience:** In an isolated territory, the resilience of the system is essential since it cannot, by definition, be helped or supported by an external network or benefit from rapid rescue resources. What are the choices to achieve significant resilience? Is the use of advanced technology, requiring specific parts and highly qualified personnel to be favored over a more robust technology, perhaps with a lower yield, but which in the event of a fault will be easily put back into service? In addition, the isolated nature of the territory considered further complicates the maintenance and repair procedures, which tends to exclude too “high-tech” solutions in favor of “low-tech” solutions.
- **Pollution:** Producing energy[1] leads to a change between an initial state and an end state, from a thermodynamic point of view. Therefore, it is impossible to produce energy without modifying its environment (since this energy comes from the environment). This means that in order to produce energy that can be used by humans, it must already be available in one form or another (wind, wood, tides, sun, etc.) on the territory. As a result, there will always be pollution and nuisances resulting from the energy system. You have to look at the “gain” / “constraints” ratio and compare it to the current situation. Also, it is important to have a global consideration of the impacts, and not only in the study area: in particular with the taking into account of the impact of imported / exported resources. Indeed, a new system making it possible to limit the importation of resources then makes it possible to reduce energy needs overall (reduction of transport) but this will lead to drawing more energy from the perimeter of the territory, therefore inducing more energy related impacts on the surrounding environment, the harmfulness of which needs to be quantified. Beyond the immediate and local pollution and its consequences on the environment and health, the climate crisis forces us to ask ourselves the question of greenhouse gas emissions, which are rather invisible and painless locally but have a global effect.

Basically, in an isolated energy system, setting goals can only be based on their acceptability by the community. This is where a lot of work needs to be done, because while many technical solutions exist, it is often the acceptance of the population of the territory that represents the decisive point. Due to a lack of communication, solutions that might prove to be effective may not be accepted. In addition, the temporal criterion must be taken into account (as much as possible), so a technique accepted today may no longer be so in 5-10-20… years (example nuclear reactors, incinerators), and vice versa. technologies not accepted today may be adopted by the local population (eg. wind turbine). The involvement of the population in the transition process can help speed up acceptance, in particular by promoting citizens' initiatives (ex. European project Interreg North West ECCO[2]).

These different points are all criteria to be defined as objectives in the establishment of a new energy system in an isolated territory, but for stronger reasons in any type of territory. In an isolated territory, it is above all the point of resilience of the system that is essential with acceptability.

[1] We cannot produce energy, according to the 1st principle of thermodynamics, but only convert it. By abuse of language, we use the expression "to produce energy" in this document, but its meaning is "to convert energy".
[2] http://www.nweurope.eu/projects/project-search/ecco-creating-new-local-energy-community-co-operatives/

2.2.1. Consumption reduction

According to the principle that the cheapest and least polluting kilowatt-hour (kWh) is the one that is not produced, any approach must begin with the search for reduced consumption.

Based on the diagnosis, we must look for possible reductions in each of the consumption sectors (heat, mobility and electricity), or even look for substitutions between types of energy suited to the defined objectives.

It is necessary to list the needs according to the consumption sector: residential, public buildings, tertiary activities, industries…. The second step is to identify the potential savings in volume and then characterize them in terms of ease of implementation and cost. An indicator makes it possible to prioritize the various interventions to be carried out: **the cost per kWh saved**. This cost is calculated on the basis of the necessary investments but also on the basis of the means required for implementation. For example, with regard to residential heating, insulation represents a very important source of savings but the implementation requires insulation work and means of animation to convince individuals to act.

A hierarchy of actions can then be planned in decreasing order of total quantities of energy saved, and / or in increasing order of energy costs. The selection of criterion will also depend on the timeframe for implementing the action.

This action plan must make it possible to define, at each deadline, the updated consumption needs and thus establish the load curves for the various energy needs. Based on these new data, a new action plan to reduce energy consumption can be defined.

2.2.2. Increasing renewable energy production capacities

In the energy mixes of isolated territories, we generally find a small part of renewable energy coming from the territory, and a very large part of imported fossil fuels because of their high energy density (or from a fossil deposit on the ground)[3]. territory, although this would probably involve its exploitation and therefore a probable “connection” of the isolated territory). In view of current global considerations on climate change and its causes and consequences[4], the use of fossil fuels should be reduced in order to move towards production of only renewable energies. Renewable energies are, by definition, "flow" energies, which have a strong need for space (use of diffuse energy, unlike fossil fuels which are "stock" energies, concentrated at one point).

The advantage of the development of renewable energies makes it possible to use the resources produced within the perimeter of the territory considered, and thus to reduce dependence on the "outside". This, for isolated territories, represents significant expenditure and a source of tension due to variability in supply (In times of crisis, the exporting zone can keep its energy and reduce its exports).

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[3] IRENA (2018), *Transforming small-island power systems: Technical planning studies for the integration of variable renewables*, International Renewable Energy Agency, Abu Dhabi

[4] IPCC, 2014: *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp

First of all, we must take stock of the resources currently available in the isolated territory. Renewable energies mainly coming from biomass (trees, crops), sun, wind, tides / rivers (if access to the sea), and geothermal energy. We must also look at the medium to long term, by carrying out a prospective study with scenarios including the implementation of new sectors in the territory to increase the potential for renewable energy production. Typically, the establishment of crops and field rotation to produce biomass, which can be mobilized for energy, then falling back into the old vision of agriculture and crop planning with: 1/3 for food, 1/3 for energy (wood or animal food) and 1/3 fallow (return to an initial state, ie. closing the cycle, and the definition of renewable).

The assessment of the quantities that can be mobilized for energy production must take into account existing technologies and especially their technological maturity. This point is particularly important in isolated territory. Robust and reliable technologies are preferred in order to strive for maximum resilience.

The technologies likely to be implemented in the territories must, however, meet the regulatory constraints of the territory, in order to limit the environmental and health impacts. The authorities must also be able and open to change. Indeed, the radical change that must be implemented to move towards a renewable society involves completely changing the habits taken over the past decades of abundant fossil fuels. It is therefore necessary to clearly identify the potential actors of this new production but also the decision-makers. The legal framework, inherited from past periods, may need to be modified or adapted. Public decision-makers should therefore be involved in the energy transition project for the isolated territory. The search for solutions can and must go beyond the current legal constraints.

In addition, these changes in habits from a legal framework point of view are all the more important as the establishment of a renewable production unit in the territory will in fact impact the direct environment and will have consequences. Instead of producing centrally on a very large scale, thus concentrating very locally a significant amount of nuisance and pollution, the production of delocalized energy on a small scale will make the nuisances and pollution more diffuse in the territory but also closer of each one. Typically, instead of a one-point fuel plant, you end up with 10, 100, or 1000 wind turbines / solar panels scattered across the land. One of the advantages is that it empowers the population by being in contact with the nuisances and pollution that it itself creates by its activity. From there, it then becomes all the more useful and effective to focus on reducing energy consumption, thereby reducing nuisance and pollution.

Finally, it remains to coordinate and harmonize the three aspects of the cost of energy production, security of supply, and the pollution generated. Security of supply requires additional infrastructure, increasing the cost of production. Pollution, and more precisely the limitation of pollution, requires the addition of infrastructure, increasing the cost. Regarding the cost following the implementation of new solutions in the territory, it is necessary to be able to compare its evolution with the previous situation.

Moreover, with the global ambitions of moving towards 100% renewable energy, it seems acceptable (even inevitable from a physical point of view) to have to pay more for renewable energy than for fossil fuels. From a technical point of view, we can be interested in the EROEI[5] indicator (for Energy Returned On Energy Invested) which characterizes the amount of usable energy over the amount of energy used for a given type of energy. The greater the value of the EROI, the more profitable the energy deposit. In addition, when EROI is less than 1, it means that more energy must be expended than what is recovered, then the deposit can no longer be considered as a source of energy. Fossil fuels showed very significant EROEIs at the beginning of the 19th century (petroleum> 100, coal> 80) but which are now dramatically reduced (petroleum ≈ 8, coal ≈ 2-17). This drop in EROEI can be explained because fossil energy is in the form of finite stocks, and the most accessible stocks were first extracted, then once empty, it was necessary to go to a little more difficult-to-access stock (therefore requiring more energy), then more and more difficult to access, etc.

[5] https://en.wikipedia.org/wiki/Energy_return_on_investment

On the contrary, renewable energies (if managed in a sustainable way) are flow energies which are renewed. Their diffuse characteristics mean that they show low EROEIs compared to fossil fuels from the beginning of the 19th century (biomass ≈ 3-5, wind turbine ≈ 5-20, geothermal energy ≈ 2-13, solar thermal ≈ 4-9, PV ≈ 1,7-10). On the other hand, if used durably, their EROEI will remain stable over time.

The overall idea of this step is to define, at different time horizons, the sources of energy production, renewable or not. It is also necessary to qualify the degree of intermittent production. Ideally, it is necessary to be able to constitute the production curve at different time steps (hour, day, season…) by integrating the intermittent characteristics of certain energies, as well as the predictable nature or not. The comparison with the consumption needs curve makes it possible to identify the critical points of the energy system which will have to be studied in the rest of the process to provide the elements of network intelligence necessary to reduce the total costs of the system.

2.2.3. Adding smart capacities

2.2.3.1. Adapting production to consumption

Currently in many territories, it is up to the energy production system to adapt to demand, but up to a point: when the demand is really too high, measures such as lowering the voltage or Power outages can be taken, forcing the consumer to adapt. Centralized production has therefore been the dominant model associated with energy choices during a period of plenty of "stock" energies.

Energy consumption fluctuates over the course of the day, and shows peaks of intensity associated with lifestyles such as, for example, in the morning (7 am-9am), noon (12 pm-2pm) and evening (6 pm-11pm) in a territory where the inhabitants work but the energy intensity of industrial activities is low (or constant). The fluctuations are also significant on the scale of a year, especially with the summer / winter cycle where demand in winter is particularly high because of heating or in summer because of air conditioning. In tourist sites, fluctuations are linked to the influx of people. Isolated areas are often contradictory very attractive from a tourist point of view.

Renewable energies are diffuse and, for the most part, are intermittent (wind, tidal, solar). In order for energy production to keep pace with consumption, we must have control means, but it is not possible to control the wind, the sun or the rivers. On the other hand, biomass is storable, its production can be planned for the years to come, and its use makes it possible to produce energy on demand (combustion, gasification, anaerobic digestion). In addition to wind, photovoltaic or hydraulic installations, a renewable energy mix that aims for production stability must then contain controllable means of production.

Energy storage means can also be used, but storage is always done with losses, and fairly low energy densities (0.2-4 MJ-e/L for current solutions against 36 MJ-th/L for diesel, i.e. around 10 MJ-e / L with 30% conversion efficiency) imply having to have space to store energy (valley for pumped-storage hydroelectricity, volume + quantity of metals for batteries, large tank for compressed air…). A storage capacity will be possible in an isolated territory, but its field of action will be rather limited, and will only allow the storage of a very small part of the total energy produced over the year. Instead, it will be necessary to invest in controllable means of production (biomass playing the role of storage as a reminder).

In addition, the wind does not blow at constant speed and direction, the presence of clouds obscuring the sun, it is necessary to be able to cope with the rapid variations undergone in the production of renewable energy. Rather, it is called "smoothing". The technical means of energy storage primarily play the role of smoothing than of storage itself, given the small quantities that can be stored.

National and international energy production systems, linked together, manage to adapt production to keep up with variations in demand. In particular by exporting areas of high production to areas of low production. However, in an isolated territory, by definition of relatively small size, there is no zone of high production and low production, but rather a single configuration. The homogenization of the flow of wind, sun and tides means that we cannot balance the variations in intermittent renewable energy production. This is why another pattern is emerging for isolated territories.

At this stage, the main lever are the storage facilities (short and long term) and smoothing. Depending on the technology, the cost can be very variable but generally leads to a significant increase for the energy system. The next step will be to reduce these costs thanks to the innovative technologies available in the case of a smartgrid.

2.2.3.2. Adapting consumption to the production

With the deployment of intermittent renewable energies and the intelligence of networks, a reversal of the pattern is proposed by adapting consumption to energy production. For example, we can try to shift consumption periods over time, towards a time when energy production is high. For example, domestic hot water (DHW) production equipment is now slaved to operate at night (off-peak period at a lower rate). They could be operated when demand is low and renewable production high, even if it means cutting the water heating cycle over 2 or 3 discontinuous periods over a day.

Another possibility is to substitute the ways of using energy. So instead of using electricity to heat water, solar panels can be used for hot water production during the day. This makes it possible to obtain the same service (water at 65°C) but with almost no impact on the electricity network. Substituting one energy for another can shift consumer demand towards the energy that is most available at a given time. However, this represents very few applications, and its potential remains limited.

Finally, a potential lies in the change of behavior of the inhabitants and the activities of the territory. This can be done through pedagogy, to help give everyone the meaning and implications when using energy. But it can also be mobilized by piloting technologies, which are relatively transparent for the user, or by pricing incentives.

For example, for electricity, rather than having a single tariff, we can also "encourage" and guide energy consumption over certain periods with tariff offers offering a range of tariffs ranging from very incentive to very dissuasive. On the other hand, it is necessary to be able to inform users of changes in price ranges, and also to be able to warn them in advance (how?) In order to be able to adapt and plan short-term consumption.

A global vision of the energy system is necessary in order to best guide these modulations, within the framework of the community of the territory, according to its values and the acceptability of the formulas adopted. The technology joins here the questions of social organization, of priorities of the general interest over the individual interest and therefore of the acceptability of the choices.

This step will have made it possible to define the potential for displacement of consumption or substitutions, but also the conditions under which these potentials can materialize. The first smart grid experiments allow us to estimate a potential of 5 to 15% of mobile consumption. In comparison to the potentials linked to energy savings, it is clear that intelligence is a significant complement, but cannot be the only solution for the sustainability of an isolated energy system.

2.3. Choose options

Depending on the specific situation of each isolated territory, certain solutions will not be possible. First, you have to be able to have the technical means to implement a solution. But acceptability will be the most important a priori criterion. Local actors will need to get involved in a coordinated fashion to come up with a solution and explain it. Once again, in isolated territory, the sustainability of the solution will have to be very important, on the environmental, economic and societal aspects.

The choice of an option will have to be made with full knowledge of the facts, and once final, its implementation will have to go to the end. Hence the importance of developing the project well and mobilizing all the partners.

It seems that the options must have relatively high reliability. However, it is necessary to be able to offer choices with an element of novelty, in order to develop and discover new applications in the case of isolated territories. This will depend above all on the capacities of the territory (or of the structure framing this territory) to absorb the consequences of a partial or complete failure resulting from a new choice. In addition, the climate change emergency means finding effective solutions quickly, which encourages trying a multitude of solutions, so that we can eliminate the less good quickly and improve those that seem promising.

Faced with uncertainties about changes in the energy system, it may be useful to favor options without regrets, that is to say those which provide a plus for the energy system at a lower cost regardless of future variations thereof. For example, acquiring the capacity to control domestic hot water tanks is useful today in an energy system powered by fuel oil, but will also be useful tomorrow in the presence of intermittent renewable energies, predictable or not.

The options allowing to reduce the energy bill of the territory should also be favored: reduction of external imports (fossil fuels or biomass), development of activities in the territory, reduction of consumption and therefore of the cost of energy for the inhabitants and activities of the territory…

Important additional information on the means of choosing the options is detailed in the document 2.1.2 General Methodology of ICE (part 6). The support of populations is a predominant factor in the success of the smart grid.

Finally, the availability of financial resources remains the sinews of war in determining options. What price are we prepared to put for an efficient and sustainable energy system? Who are the actors who may be interested in it? For an isolated territory that has developed a strong environmental awareness, it is possible to imagine that populations are ready to contribute with regard to the expected benefits. The idea of a structure involving local actors must be considered in addition to the resources that may come from energy operators or public authorities.

2.4. Selection of technological bricks

The choice of technological bricks must be made according to the technological maturity of these bricks and the cost/benefit ratio (based on the €/MWh-savings or €/fossil-avoided CO_2 indicator). Any technological brick put in place at a cost that should be compared with the expected benefits. Likewise, it is likely to have effects on the energy system and could risk, for example, increasing energy consumption, overall or during periods of high demand. For example, air-to-air heat pumps can greatly increase consumption during winter peaks even if they reduce overall consumption, or even large digital data management can increase electricity consumption and the need for air conditioning.

It is therefore very important to benchmark existing smart grids in order to verify the results obtained in other territories but also to ensure their adequacy with the local issues identified. A suitable solution on an isolated system is not necessarily transferable to another or may require adjustments.

The options selected may not yet have been developed. It should then be checked whether it is because the situation of the isolated system is unique or rare or whether it is a need that has not yet been identified but is likely to be reproduced elsewhere.

An important element of the choice is the capacity of the isolated territory to manage the identified technology. This management capacity is assessed on the degree of technicality that users must master and their motivation to use technological equipment, but also on the capacity of local professionals to intervene on the equipment or even the potential difficulties of implanting a technology on the site. a geographically isolated territory. We must also look at the economic interest of the territory: will it benefit from spin-offs in terms of economic activity or will a new external dependence be created?

The funds that can be mobilized also have an important weight in the choice decisions. Between two equivalent bricks in terms of potential savings in consumption or reduction in the price of production, the solution that can benefit from a subsidy will consume less of the available financial resources.

The existence of players who can offer technological building block solutions will also influence the choice of these building blocks. It is one of the objectives of the ICE project to identify potential players and get them to work for isolated energy systems by adapting their technologies to the specifics of isolation.

2.5. Deployment

Once the strategy has been well defined, with each action containing its technological bricks and the method of deployment, the action program must be implemented.

This step comes to concretize all the preliminary work carried out. The various actors in the territory who participate in the implementation of the action plan must get involved and consult each other on a regular basis. The quantification of the investments for each action must be well defined (financial, human, temporal).

At the same time, the search for funding should make it possible to cover the expenses to be incurred. As local players have an interest in reducing consumption, part of the funding may come from an investment on their part, ensuring them savings on the cost of energy with the new energy system.

Citizen funding could be offered to involve residents in the transition of their territory, some of them working themselves for local actors.

Finally, grants from the State or the Region to which the isolated territory belongs may be requested. However, the proposed new energy system must be able to function without the continuous influx of external aid, otherwise its very definition will have to be reviewed.

Once the project is being deployed, awareness-raising and communication operations must be carried out throughout the project, and even after the system has reached cruising speed.

Part of the population will not necessarily have followed the project closely, and we should also expect to have part of the population with reluctance or even clear opposition to the implementation of this new system. Explanatory workshops, debate sessions with different members of society can help to clarify the various points of doubt.

The implementation of a new system will face problems, which are of course expected and to be expected. A continuous improvement method should be well defined upstream in order to test the different actions, and assess their strengths and weaknesses. The link with users is to be maintained, making it possible to create trust and show interest in the opinions of users. Their feedback can help improve the protocols first defined.

3. Ushant Island

3.1.Context

The island of Ushant (Ouessant in French) is located twenty-five kilometers from the west coast of Finistère in France. Eight kilometers long and four kilometers wide, its area is 15.58 km^2 (Figure 1).

In the last census in 2015, the island had 846 inhabitants, or 54 inhabitants per km^2. In summer (July-August), the island's population can rise to 3,000 people/day.

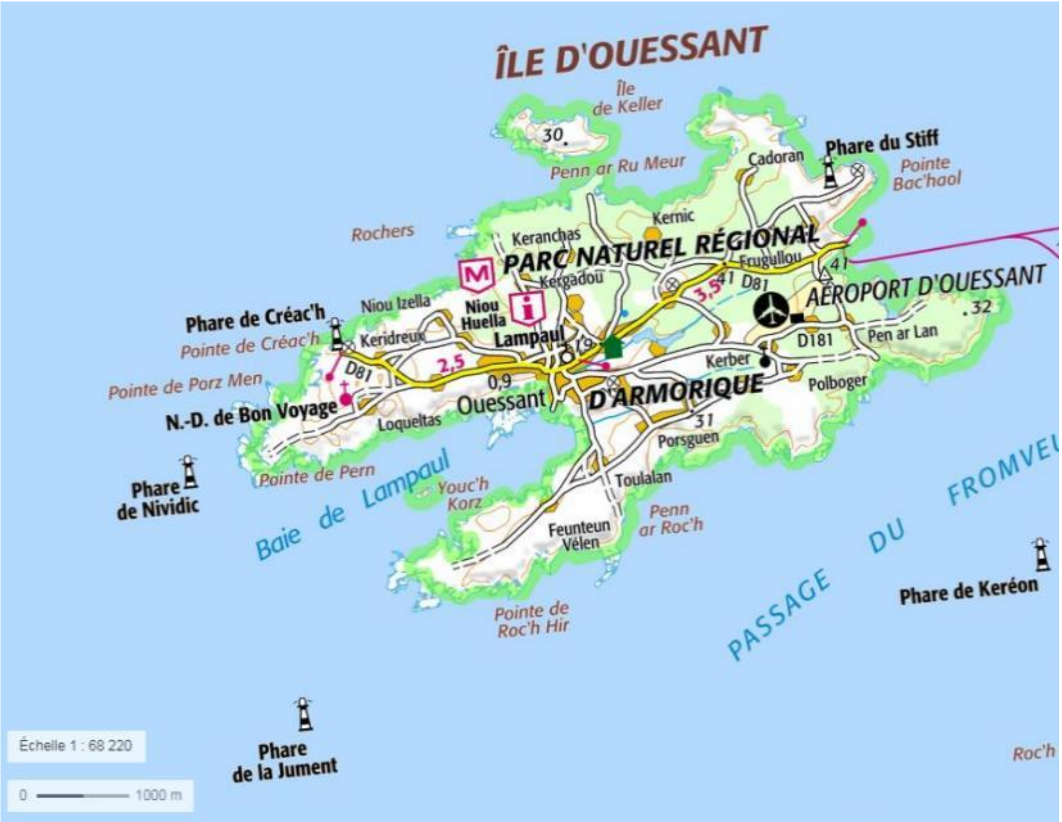


Figure 1 : Ushant map (source: IGN Geoportail)

The island of Ushant has an oceanic climate. The annual average temperature is around 12°C with relatively small temperature variations throughout the year, averaging between 6 and 19°C. Absolute records 29.4°C on August 2, 1990 and a cold record of −7.7°C on January 13, 1987. Average precipitation is 750mm per year, varying from around 80mm in winter and 50 mm in summer. Winds in Ushant are rather regular from year to year with monthly averages of 10-12 m/s in winter and 6-8 m/s in summer. The island enjoys moderate sunshine although it is significantly higher than in areas close to the mainland with an irradiance of 50 to 300 W/m² on average. The Passage du Fromveur has a very strong tidal current (8 to 10 knots) resulting from a local fault 60 m deep favorable to tidal turbine operation.

3.2. The challenges and constraints of the island

The island of Ushant is, like Molène and Sein, one of the few Ponant islands that does not benefit from any connection to the continental network. We are talking about a NIZ, a non-interconnected zone. Its electricity production is carried out from fuel generators, its fuels and other resources come from the continent (diesel, gasoline, gas, wood) with the exclusion of a weak wood resource used locally. Recently, the first photovoltaic installations and a prototype tidal turbine were installed in Fromveur. The energy transition objectives were set in the French "Multi-year Energy Programming" in a specific section dedicated to NIZs with 70% renewable energies in 2020 and 100% in 2030. To achieve this, a smart grid will be necessary in addition to the development of renewable energies and the reduction of energy consumption.

3.2.1. Energy consumption

In France, there is an equalization of electricity tariffs for citizens across the country. Consequently, and although the cost of electricity production is higher in Ushant than in mainland France, the inhabitants of Ushant pay for electricity at the same rate as those in the metropolis. Other sources of energy such as wood, gas or fuel oil contain additional costs due to importation.

As a result, electric heaters are the main heating devices in Ushant. In addition, there is no gas or heat network on the island of Ushant, making electricity the main energy carrier used on the island. This is why Ushant 's energy transition is currently mainly focused on electricity.

The island must import an annual total of 1,900 tonnes of petroleum products, of which 1,600 tonnes are for power generation and 300 tonnes for heating and mobility.

The key data on the use of electricity in Ushant are:

- The total electricity consumption is around 6 GWh / year.
- The residential sector (≤36 kVA) accounts for nearly 70% of total consumption, the tertiary sector and industry (> 36 kVA and HTA) for 10%, the professional sector for 20% (≤36kVA)
- The island has around 900 residential meters, half of which correspond to second homes, around a hundred professional meters, two industrial meters (only one before 2015) and less than ten tertiary meters.
- 40% of electrical energy is used for heating.

Most of the homes are equipped with electric heaters (75% for main residences, 85% for second homes). The residences can have a wood or fuel oil boiler, but above all they have additional heating with reclaimed wood. This is because the price of electricity is subsidized in such a way that it is the same as on the continent for the consumer (electricity tariff equalization). On the other hand, other energies (fuel oil, wood or gas) must be imported to the island, implying a higher cost, not subsidized.

Essentially, this is an old and traditional habitat with 75% greater heat-sensitivity[6] than on the continent despite a rather favorable climate. In practice, this means that for each drop of 1°C in the outside

[6] Heat-sensitivity represents the sensitivity of energy consumption for heating, as a function of the outside temperature.

temperature (below 12°C), the increase in energy consumption linked to heating is 75% greater in Ushant compared to the increase in energy consumption linked to heating on the continent.

By standardizing the electricity consumption at constant climate (calculation of the number of days UDD, for Unified Degree Day), we see that consumption between 2011 and 2015 is relatively stable.

Table 1 : Real electricity consumption at constant climate in Ushant

Year	2011	2012	2013	2014	2015
Real Consumption (MWh)	5 924	6 201	6 691	5 914	6 135
UDD	1 975	2 202	2 259	1 932	2 037
Consumption at constant climate (MWh)	6 242	5 860	6 164	6 370	6 268

- Average power consumed: 670 kW
- Minimum power consumed: 300 kW
- Maximum power consumed: 2000 kW

The cross-analysis between the demand for electricity in winter and the modeling of the housing stock (Figure 2 from INSEE) shows that the heating share is estimated at 40% of the island's total annual consumption, or 2700 MWh/year.

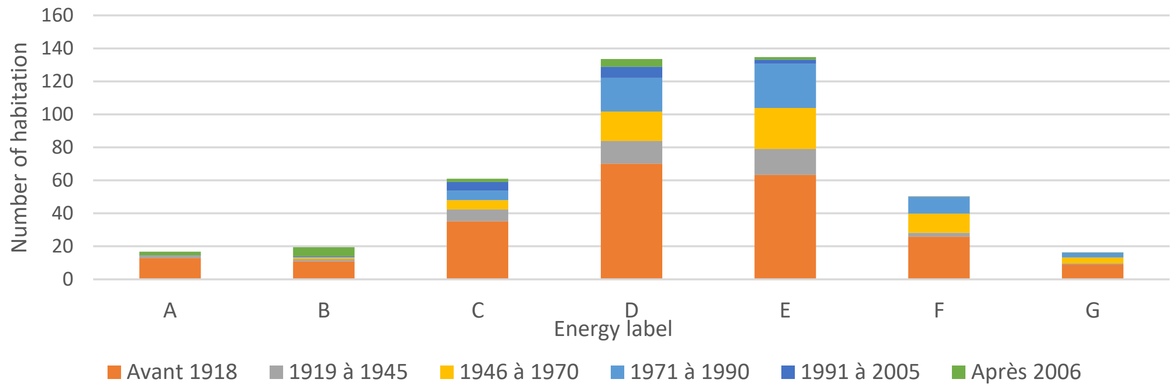


Figure 2 : Distribution of houses according to their energy label and year of construction

3.2.2. Energy production

The energy produced on the island is exclusively in the form of electricity. All fuel for vehicles is imported. A very small proportion of wood is used for heating either from the island or by importing logs or pellets.

The electricity production park on the island, before the ICE project, consisted of:

- 4 thermal groups running on fuel oil - 4,350 kW of total installed power
- 1 PV plant on the Gymnasium -50 kW of installed power

The fuel oil consumption for the production of electricity is of the order of 1600 t/year. Annual electricity production represents an average of 6,570 MWhe between 2011 and 2016, for annual final electricity consumption amounting to an average of 6,173 MWhe.

Table 2 : Production, consumption and estimation of electrical losses in Ushant

Year	2011	2012	2013	2014	2015	2016
Production (MWh)	6 146	6 614	7 011	6 370	6 468	6 808
Consumption (MWh)	5 924	6 201	6 691	5 914	6 135	
Estimated Losses (MWh)	222	413	320	456	333	

Electricity losses are of the order of 200 to 450 MWh/year, or between 3 and 7% of production.

Specific CO_2 emissions in relation to electricity consumption on the island reach 777 gCO_2/kWhe.

The deployment of photovoltaic plants on the roofs of public buildings continued in parallel with the ICE project. A total of three power plants were in operation at the end of 2020, for a total installed power of 94 kWp. Other projects are under study, notably on the roof of the Town Hall, the Aerodrome, a new agricultural hangar ...

In addition to these photovoltaic power plants on the roofs of public buildings, a project combining 3 types of renewable energy is being carried out by the company Akuo Energy, and bears the name of the "PHARES" project. It aims to deploy by the second half of 2023:

- 1 wind turbine of 900kW
- 500 kW of photovoltaic panels
- 2 tidal turbines of 500kW each, i.e. 1MW in total
- Energy storage in the form of a battery, of 1 MW.

These additional renewable and local energy production capacities should make it possible to reach a renewable electricity rate of 65% in 2023.

3.2.3. Variability

Electricity consumption variability on the island of Ushant is very high over one year, with a period of high consumption in winter (electric heating), and a period of low consumption in summer. The months of July and August show higher consumption than in June and September, due to a high influx of tourists (summer school holidays).

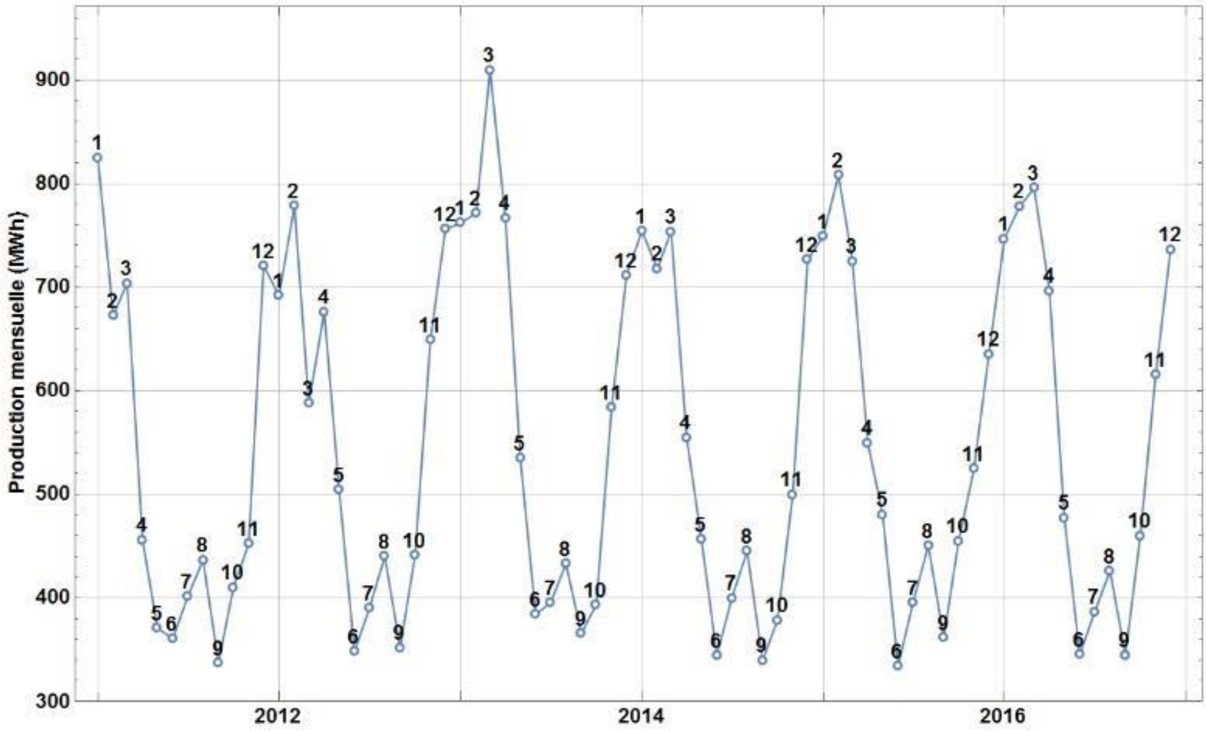


Figure 3 : Evolution of electricity production (in MWh) - monthly step in Ushant from 2011 to 2016

Consumption also varies on a day-long scale and shows periods of high electricity consumption in the morning and evening. In particular, there is a rapid increase in consumption in the evening at 11 p.m., which corresponds to the transition to off-peak hours, and which results in the start-up of domestic hot water production equipment.

Figure 4 : Evolution electric demand (in kW) for a typical winter day (orange), summer day (yellow), and Interseason (green).

The variability of consumption is therefore intra-day and seasonal. The production of electricity by an oil-fired generator is particularly suited to these variations and makes it possible to guarantee optimum security of supply but represents a very high cost and emissions of pollutants and GHGs. However, the energy and climate context leads to a complete revision of this energy model.

The development of intermittent renewable energies, predictable (tidal turbine, biomass, etc.) or not (photovoltaic, wind, etc.) necessary to replace fuel oil will lead to very significant over-sizing with excess periods, in particular excluding heating periods with also a non-cost. negligible.

Reducing energy consumption, in particular through the insulation of buildings, remains the essential avenue for achieving the objectives of 100% renewable energy by 2030 at a reasonable cost.

The magnitude of the variations can be reduced by storing, controlling or substituting energy.

3.3. Possible technical solutions

3.3.1. Energy Storage

Li-Ion battery storage was carried out in 2017 by EDF-SEI, with a capacity of 1 MW and 500 kWh. This storage made it possible to incorporate the first renewable energy production units into the electricity grid.

In view of the variability of demand and the importance of winter peaks, especially at the end of the day, the storage to be deployed, in the case of an energy mix according to the PHARES project, is estimated at 300 MW, with no savings made on heating in winter, and at 250 MW with 50% savings on heating in winter. Economically and with current technologies, the development of storage of this magnitude is not possible, and it is therefore necessary to combine a management capacity and dynamic consumption in addition to storage. Storage will limit the daily capping of renewable production, but will not allow storage over periods of the order of a season.

Additional storage is in preparation for up to 1 MW, within the framework of the PHARES project.

3.3.2. Control

The management of consumption on the island can allow better integration of current and future renewable energies. The objective is twofold: to reduce consumption by identifying unnecessary excess consumption (control of heating in buildings that are not permanently used) and by shifting consumption to periods when renewable production is the most important, this which makes it possible to limit the heating needs.

For Ushant, the idea is in particular to shift consumption to periods of tidal power production (intermittent but predictable) or to create new sources of controllable renewable energy production (gasification of wood waste).

For the displacement of these consumptions, several options are considered:

- Variable pricing : Tariff-based consumption control

Like the current “off-peak hour - full hour” offer available in France which allows consumption (mainly water heaters) to be shifted automatically by a signal sent to electricity meters, the idea is to define several tariffs for the electricity according to production. The construction of the tariff can be based on various criteria such as the production cost, or the CO_2 intensity per kWh consumed.

This system would make it possible to automatically shift consumption of water heater type, or even to shift, through the intervention of the consumer, consumption such as washing machines, oven, etc. The price argument in fact gives consumers an interest in consuming at the most appropriate times. cheaper.

- Automated control

This option is based on an automated control, based primarily on the rate of use of an equipment or a building, and can also integrate a concept of control according to the costs of electricity or an external signal coming from the production.

This involves, for example, adjusting the heating consumption on the schedule of use of a building (day / night, and week / weekend).

- Consumer information (non-financial incentive)

The idea here is to provide information to the consumer on the state of the power grid, identifying "good" and "bad" periods. Management is only possible through the voluntary action of the consumer, and without a priori financial repercussions, the lag in consumption not reducing the amount of energy consumed.

3.3.3. Substitutions

The reduction in consumption peaks can also be achieved by substituting energies.

In this context, for Ushant, substitution solutions from electric energy to other energies are being considered: wood heating, solar thermal for domestic hot water (thermodynamic water heaters).

These solutions are nevertheless strongly penalized by the equalization of electricity tariffs, the additional costs of equipment and the technical difficulties linked to insularity. Their contribution is therefore extremely limited.

Paradoxically, the quality of the energy system can even be improved with the extension of the electric perimeter to mobility. Indeed, the switch to electric mobility on the island only represents a low impact on consumption estimated at barely 2% but could be a good answer for the use of unpredictable renewable surpluses (PV and wind power) that either for recharging vehicles on the island or in connection with hydrogen storage allowing at least partial power to be supplied to the boats making the crossing in summer.

3.4. Selected solutions

3.4.1. Energy management system + Storage

- Industrial PC (redundant) which embeds control algorithms
- Interfaced (information exchange and management) with:
    - The various renewable producers and the thermal power station

        - The storage system
        - Future flexibilities
- Roles of the EMS:
    - Guarantor of the supply-demand balance
    - Ensures that system services are maintained at all times (in particular quality of supply and protection plan)
    - Maximizes the renewable energy share in the energy mix
    - May be required to restrict / disconnect the renewable energy producers (arbitration role between the producers according to the date of the connection request)
    - Scalable tool: addition of new producers, new flexibilities, improved optimization (consumption and production forecasts)

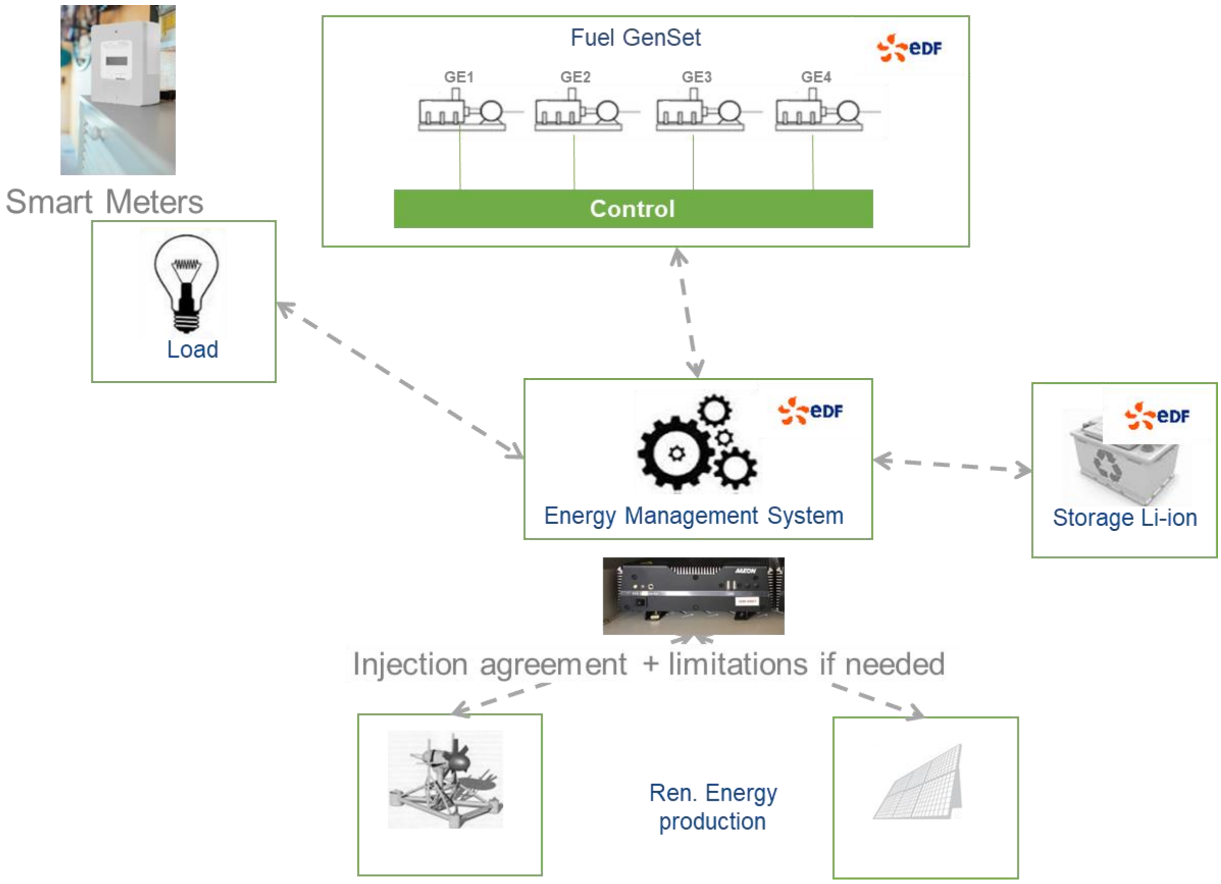


Figure 5 : EMS operating diagram within the Ushant electrical system

3.4.2. Smoothing out tidal turbine production

The smoothing of the electricity production of the tidal turbine is composed of a battery that can receive or give electricity. The constraints imposed by the network are to have power variations of less than 5 kW/s.

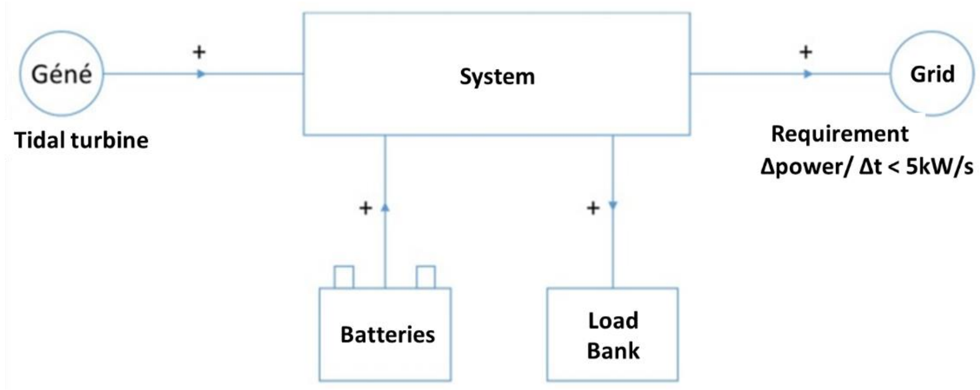


Figure 6 : Operating diagram of a tidal turbine smoothing system

3.4.3. Downstream management of smart meters

As the island is almost entirely equipped with "Linky" smart meters, consumption management can be considered and refined.

1°) Tariff-based consumption control

Equipping residences on the island with "Linky" smart meters (97% equipped) makes it possible to manage incentive tariff systems adapted to the island. In 2016, EDF SEI was able to shift the off-peak hours and cut them into 2 parts: one at night and in the afternoon. Therefore, instead of having the entire fleet of DHW equipment that goes off at 11pm calling for 300kW, we end up with 2 waves of power calls of lower intensities (approx 75-100kW). This also makes it possible to shift non-essential consumption to less busy periods. Thus, the same amount of energy is supplied but over less critical periods then offering a margin of flexibility for the network.

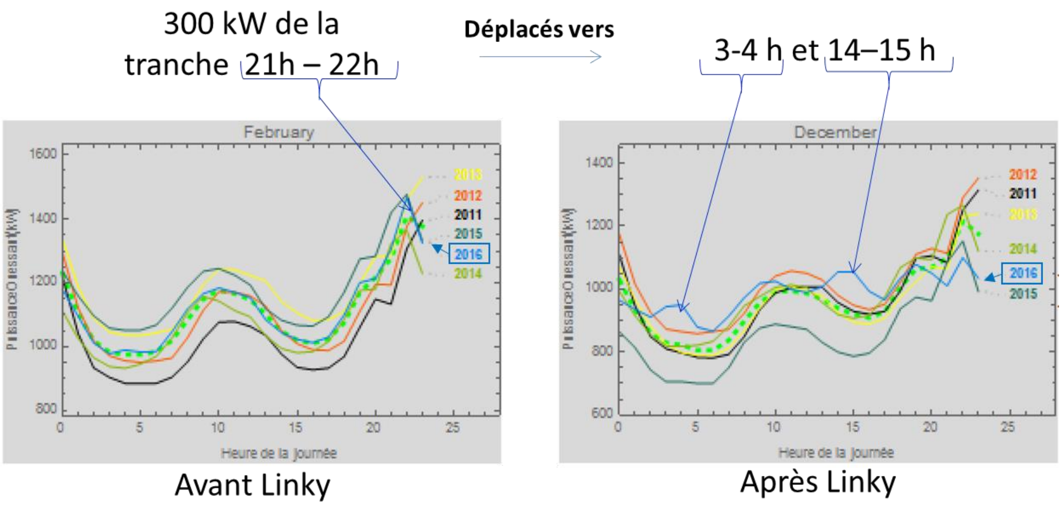


Figure 7 : Example of shifting consumption of Hot-water-boilers by shifting "off-peak hour" period

Likewise, EDF-SEI will propose a new distribution of off-peak hours in connection with tidal turbine production. The night range will therefore be floating according to the tides, allowing consumption to be triggered during the periods of tidal turbine production.

2°) Automated control

Within the framework of ICE, two automated piloting modes will be used. The first is to use the functions of the Linky meter to control more equipment and in a refined way. Communication between the meter and the equipment through the installation of a transmitter on the meter and receivers on the equipment.

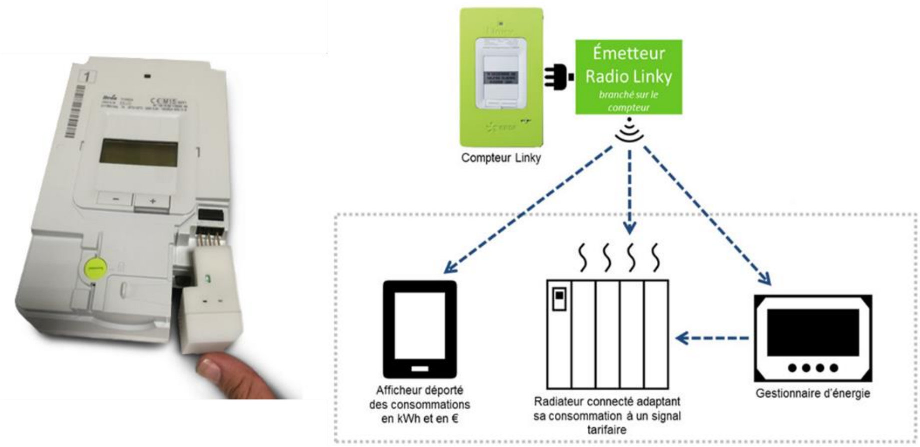


Figure 8 : Linky smart meter and a Radio transmitter (on the left) - Operating principle of the ERL on the connected equipment of the home (on the right)

The second is the installation on the island of a wireless telecommunications system based on LoRa technology. It makes it possible to intelligently communicate the Energy Management System and different equipment or applications through data processing on a platform. Such a system allows the establishment of smart city-type services through low-speed communications using stand-alone or low-consumption equipment. A proposal for the architecture of the downstream meter control system is shown in Figure 9.

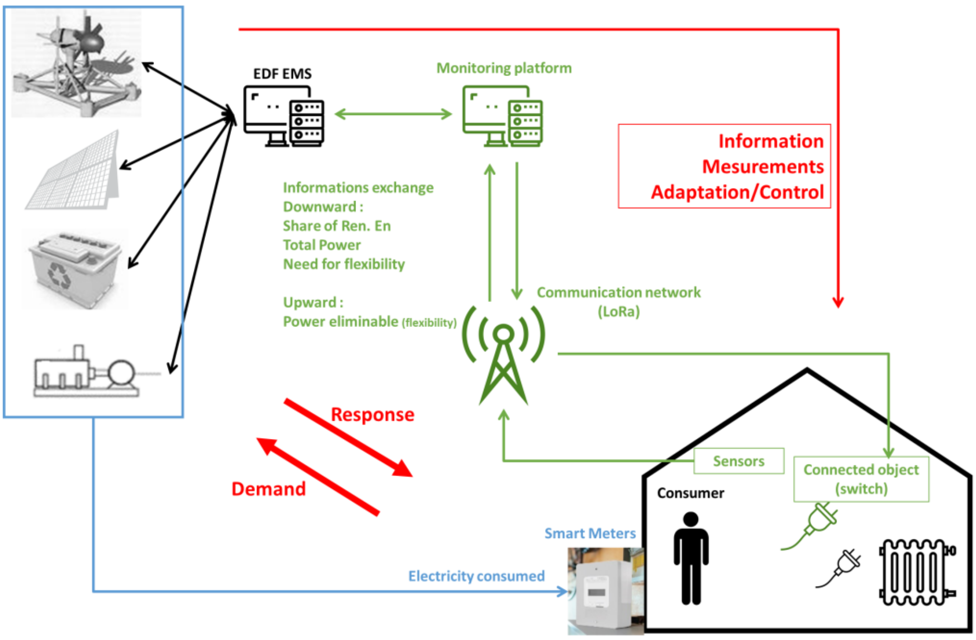


Figure 9 : Infrastructures and software making it possible to act on objects downstream of smart meters

The perimeter in purple includes the infrastructures and software that are included in the IoT project that the SDEF wishes to develop, eventually, at the level of the Finistère department. This project includes a focus on the energy efficiency of public buildings, which includes instrumentation to monitor buildings and produce a precise audit of consumption. The perimeters in sky blue represent the technological bricks specific to the ICE projects which must be added in addition to the IoT SDEF project, in particular with regard to actions with individuals or private entities.

3.4.4. From consumer to Prosumer

For this action, we proposed to set up several tools to provide information to residents, so that they can act on their consumption.

- Implementation of a smartphone / internet application on energy in Ushant: resumption of personal consumption, state of the Ushant network, eco-actions, EcoWatt-type alert services (in France)

- Deploy equipment in homes to measure and inform the inhabitants of their own consumption with regard to the state of the network. Eco-coaching.

Benefits:

- Savings for customers, more flexibility for the network

- Appropriation / awareness of energy issues

- Help the customer to understand and program his equipment

- Decrease of the tip

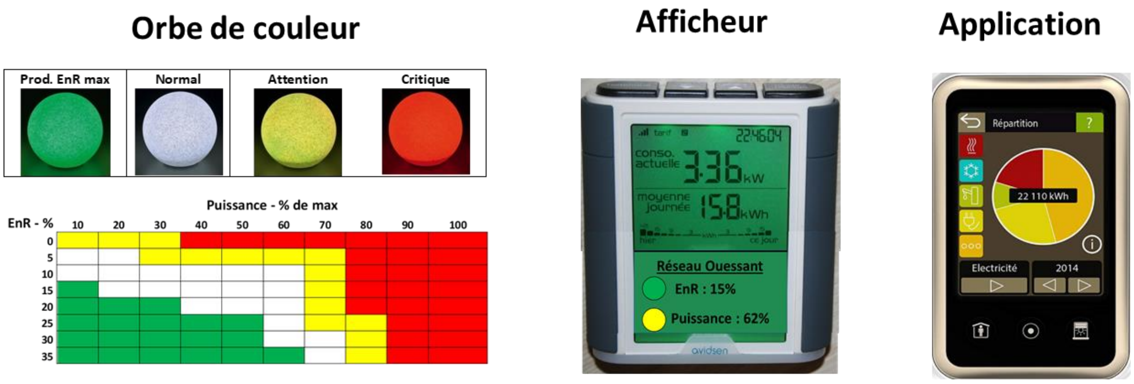


Figure 10 : Consumer information proposed technology bricks: colored orb (left), display (middle) and smartphone application (right)

We offer the installation of 3 types of equipment to provide 3 levels of information:

1. A colored orb: quick and easy information to understand

The orb changes color depending on two parameters: the total power drawn on the network, and the share of RE in the network. The colors are given a simple color code (green-yellow-red), giving the information of the network in order that the electrical consumption controllable by the inhabitants (washing machine, dishwasher) is preferably fixed on the green periods and avoided during red periods.

From a technical point of view, the order of the color change is done by a message sent through the LoRa infrastructure deployed on the island.

2. A remote display: detailed and instant information

The display shows the personal consumption of the home by taking information from the electricity meter, and it also displays the status of the network based on the selection criteria of the color of the orb.

This display takes up the objective of a remote display in energy-poor housing. There are displays for homes with an electrical installation to standards (class RT2012). On the other hand, there is no technical solution for older dwellings whose electrical installation is no longer up to current standards and would require a major upgrade.

3. The smartphone application: complete information and production of graphs and trend curves.

The smartphone application takes information from the display (personal consumption of the home, and network status) but also contains EcoWatt type messages with alerts or prevention during consumption peaks or even information messages.

4. University of East Anglia

4.1. Context

The University of East Anglia is a public research university located in the west of Norwich, East of England. It was established in 1963 on a 320-acre campus. It had 18,035 registered students for the 2019/20 academic year and over 4,000 full time and part time staff.

UEA comprises of a large number of buildings with varying age and technological readiness. The figure below shows the main buildings at the UEA campus. The main campus has been built in the 1960s and newer buildings have been built during the last 2 decades. There is also a historical building (Earlham Hall) of the 17th century which at present is used by the UEA Law School.

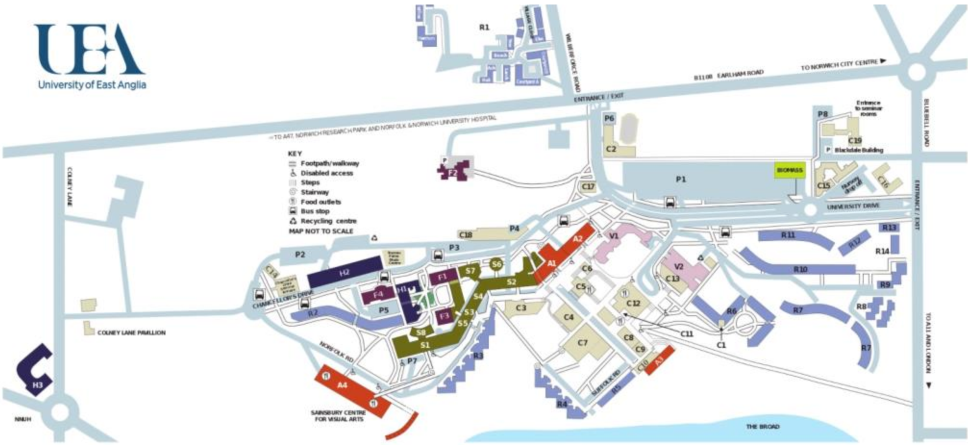


Figure 11 Main Buildings on UEA campus

Since March 2020 the University Campus has been used significantly less than normal due to COVID pandemic. This included most academic, administration and support personnel working from home and most teaching and research activities happening remotely. Going forward from the academic year 2021/22 UEA will embark on a large-scale, long-term project of deep refurbishment of the 1960's campus. This is an essential yet challenging decarbonisation step for the University. That older part of the campus is not built with modern efficiency standards and because of its unique brutalist architecture it is protected. As a result, its refurbishment is a particularly sensitive process, yet one necessary for UEA to achieve its ambitious emission targets.

4.2 The challenges and constrains of UEA

4.2.1. Energy consumption

There are three types of energy services at the main campus and student villages of the UEA, including heating, cooling and mains electricity supply, which in turn enables numerous uses as required. These energy services are mostly provided by natural gas through localised combined heat and power (CHP) plants, electricity imports from the power grid as well as localised electricity production with renewable energy sources. Additionally, a small fraction of heating and hot water services is provided by local gas boilers in buildings. In this section, we focus on the consumption of two energy sources that provide the above energy services at the UEA, namely natural gas and electricity.

4.2.1.1. Natural gas consumption at UEA

Natural gas is the main energy source at UEA. The annual gas consumption has been around 80,000 MWh since 2017. If optional plans for new buildings go ahead, it is projected that gas consumption will increase to over 90,000 MWh by around 2035 because of additional demand in electricity, heating and cooling. It is important, however, to mention that such plans (for new buildings) are not currently being considered, especially within the post-COVID space and work patterns assessment. At UEA, gas is mainly used to serve CHP plants that produce the majority of the electricity and heating at UEA. Other use of gas such as gas boilers at specific buildings, academic use, laundry, and catering account for about 5% of the total gas consumption. The figure below shows the existing and projected gas demand by building status. Gas capacity limit represents the agreed gas supply between UEA and its supplier. If additional gas capacity would be required, there needs to be new agreement on supply capacity between the UEA and its gas supplier (currently Gazprom as wholesaler) and possible upgrade on local gas infrastructure.

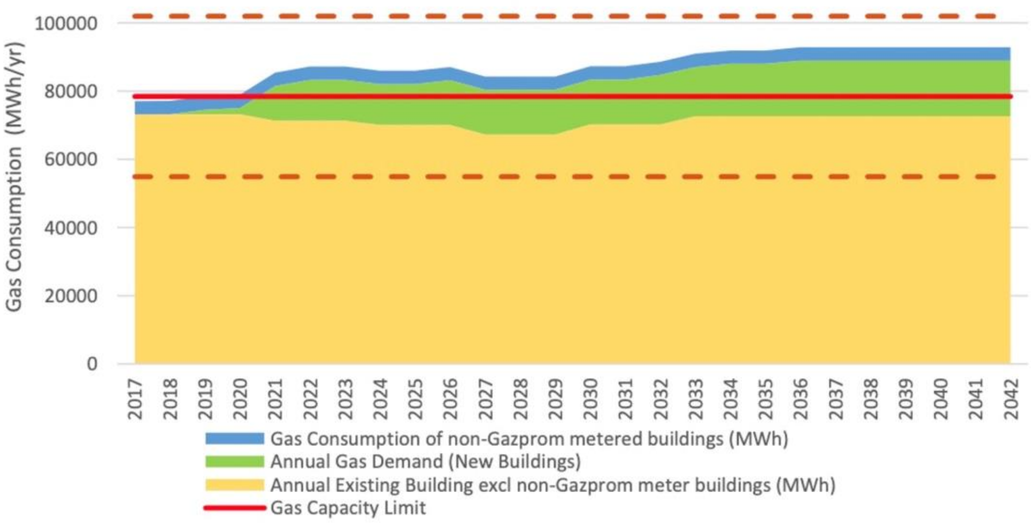


Figure 12 Annual gas consumption by building status

4.2.1.2. Electricity consumption at UEA

The other type of energy services is the use of electricity at UEA with the annual electricity consumption reaching over 27 GWh. The figure below shows a breakdown of annual electricity consumption by different uses: 63% of the electricity is consumed for academic purposes, including teaching, research, and other administration related activities. Residential electricity (for student accommodation) consumption accounts for 23% of the total electricity consumption. The Sportspark (UEA's sports facilities centre) is responsible for 8%, while support (4%) and catering (2%) represent the rest of the electricity consumption.

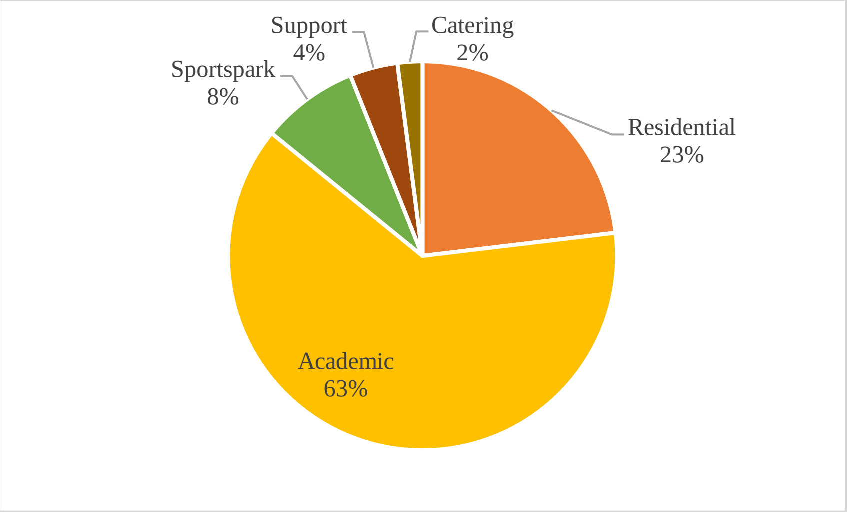


Figure 13 A breakdown of electricity consumption by different sectors

Both heat and electricity consumption have seen significant reduction in different types of buildings due to improvement in energy efficiency and adoption of new technologies. The table below summarises the changes in heat and power consumption in residential, academic, Sportspark, support and catering buildings during the last three years. It shows that in most buildings, heat and power consumption have been reduced by over 10%, apart from the heat consumption reduction in Support buildings (9% reduction).

Table 3 Changes in heat and power consumption in different types of buildings

	Heat	Power
Residential	-20%	-12%
Academic	-13%	-14%
Sportspark	-29%	-17%
Support	-9%	-32%
Catering	-30%	-22%

4.2.2 Energy supply

Energy supply at UEA is provided by three main sources in general, including three CHP units (two 2.0 MWe units built in 2017 and one 1.7 MWe unit with an earlier built year), 18 MW of gas boilers distributed in different buildings, and 225 kW of solar PV system. Apart from the domestic energy generation sources, the University also imports electricity and gas from the grid.

The average annual operating hours for its main energy generating units are 3,388 hours for the CHP units and 1,213 hours for the solar PV system, respectively. Their associated electricity generation is 19.3 GWh from the CHP and 0.273 GWh from solar PVs respectively and as is clear, the majority of electricity production is via the CHP system. The rest of the electricity supply is drawn from the grid (about 8.3 GWh or 30% of the total electricity consumption). The CHP plant essentially uses its main engines (internal combustion engines that operate with natural gas) to produce electricity. These engines, similar to all internal combustion engines, have a significant amount of heat losses i.e. energy from the fuel gas that is not converted to electricity, but instead is converted to heat which needs to be removed from the plant. This is normally achieved by a cooling system that can transfer the excess heat to the environment, however, in a CHP plant that excess heat is instead put into use. For that combination to be operationalizable electricity and heat demand must coincide.

On occasions, the CHP plant need to increase its electricity output to meet the daily peak demand. This is to avoid the additional 'Red Distribute Network Operator (DNO)' charge at that time of day; that is a penalty that the DNO charges to large consumers when they demand electricity during high overall demand hours. The increase in electricity supply can result in excessive heat production if heat is not required at the same time when electricity is required. For this purpose, in addition to the CHP, UEA has invested in heat storage technology in the form of hot water-based vessels. Therefore, part of the excessive heat production is stored in the Thermal Store on campus, but even with that system a significant part of the heat is dumped through the exhaust. The dumped heat usually represents over 5% of the total heat supply. For example, between November 2016 and October 2017, total heat production was 39.6 GWh with 2.3 GWh estimated to be dumped.

The University had a plan to install a biomass gasification plant as part of its carbon reduction programme. However, the woodchip gasifier has been decommissioned due to operational issues with the technology. Given the existing 5.7 MW of CHP units are considered sufficient to meet the existing demand and there is no plan to further expand the CHP fleet in the near future. However, it is projected that the maximum electricity demand will increase from 7.1 MW at present to 12.2 MW in 2050 in part due to the possible new buildings, the installation of EV chargers and possible heat electrification. The additional demand needs to be addressed through the development of alternative energy sources, such as renewable energy, hydrogen and batteries. At the same time the university will have to innovate in the coordination of energy supply and demand, given the stochastic production nature of low carbon energy sources. While storage technologies mentioned above (such as hydrogen, batteries and heat storage) are valuable, there is a requirement for controlling the demand for energy by the campus' energy users. UEA is already advanced in the broader demand response domain with significant experience of frequency response applications on campus. These, highly automated systems, allow for rapid identification of energy use reduction opportunities on campus when there is a requirement to balance energy supply and demand. Less automated systems are of equally high importance as the can be applied more widely but require better information flows and active agency by the campus energy users, students and employees.

4.2.3 Variabilities

4.2.3.1 Variabilities in gas consumption

Given the role of gas in heat supply there are significant seasonal variations in gas consumption. The peak naturally occurs in winter when heating demand is high, which accounts for about 70% of total annual heating demand through the year. For example, the highest hourly gas consumption was recorded on 24th February 2018. The total gas consumption reached 29,187 kWh[7] on that day. Consumption during summer holiday seasons (between mid-May and mid-September) is relatively lower since heating demand in the warmer months accounts for around 30% of the total heating demand in a year.

Although district heating provided by the CHP plants represents majority of the heating supply, not all buildings are connected to this system. This is why there are also local gas boilers installed in buildings to provide heating services. Figure 5 below represents gas consumption in each building on campus between 2016 and 2017. The Bio-Medical Research Centre accounted for about 50% of the gas consumption in buildings due to the steam boilers located in the building. Similar to the general consumption trend, gas consumption in buildings showed a significant seasonal variation, which saw a sharp decline from May before rising in September.

Although the majority of natural gas is used for direct energy purposes, a small proportion of gas is used for catering services at Restaurant Building, Sportspark, Village, Constable Terrace, INTO, Health and Community Centre and the Sainsbury Centre. It is estimated that the annual consumption for catering is around 415 MWh, which accounted for 0.5% of the total gas consumption at the UEA. As shown in the figure below, these buildings show slightly different consumption pattern, which does not follow the seasonal variations in total gas consumption.

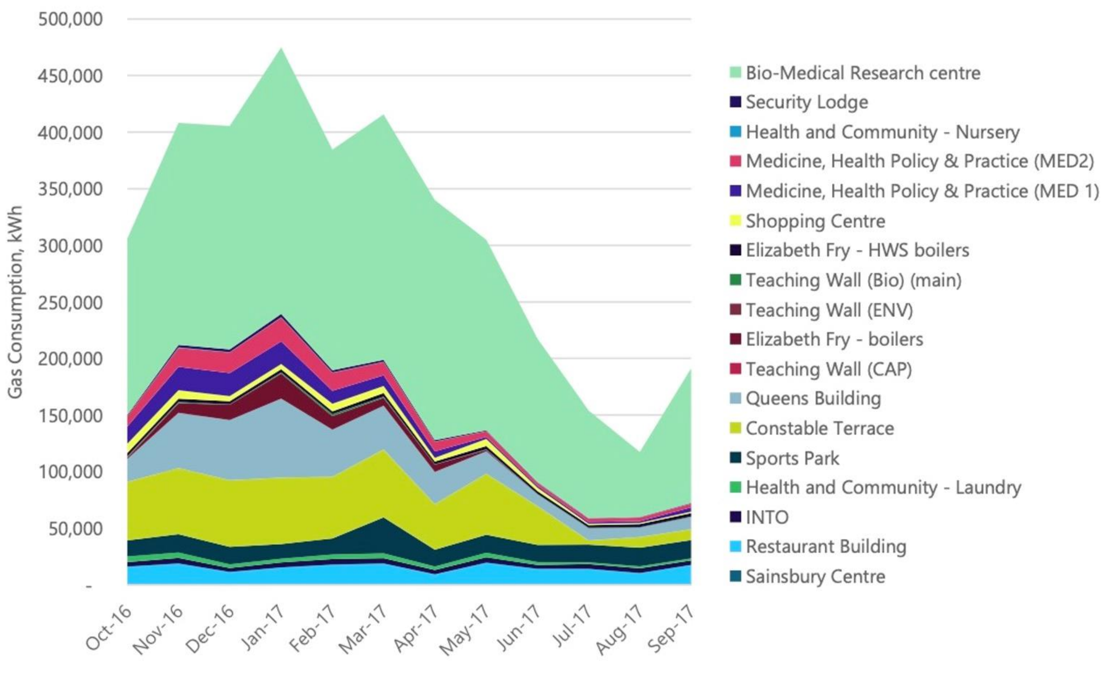


Figure 14 Building gas data – monthly 2016 - 2017

[7] Gas conversion: 1 cubic meter equals to 11.3627 kWh for gas consumption.

4.2.3.2. Variabilities in electricity consumption

The seasonal variations of electricity consumption are not significant comparing to gas consumption and are similar in pattern for all years. They are important in relation to the use of low carbon energy sources predominantly solar energy. This is because solar energy is highly seasonal and peaking during the summer months, when demand is lower. Wind energy on the other hand is peaking in winter months, which would fit with UEA's energy demand pattern. This could be exploited by separate contracts for wind energy procurement. On average, 52% of the electricity consumption happens in winter, whilst 48% of electricity is consumed in summer. The figure below shows the yearly electricity demand at UEA campus on a typical year (specifically between 2016 and 2017). A peak demand of 6.8 MW was monitored on the 20th of February 2017, partly due to the system maintenance of the CHP plants which reduced hot water supply and increased demand of electric immersion heaters in buildings. In general, all demand peaks over 5.5 MW happened in winter are more often attributed to unusual energy demand. Peak demand in summer is much lower and less frequent comparing to peak demand in winter. Notably, in the annual cycle, there is a significant demand drop during the Christmas and the Easter breaks and overall, there is higher energy consumption in winter than in summer. This reflects student numbers on campus and level of academic activity. While very little activity happens during the Christmas break and while a lower number of students and staff remain on campus during summer, the overall consumption is lower than during any other part of the year.

Figure 15 Measured Yearly Campus Electrical Demand in kW.

Apart from seasonal variations, electricity consumption also has daily (diurnal) variations. The figure below shows the daily peaking demand on a typical November day. These variation effects are particularly important for the increased use of renewable energy (both solar and wind) on campus. Matching demand with renewable energy supply is critical and challenging without the use of significant electricity storage capacity. Demand peaks between 4 and 8 pm, which is very similar to the power system's peak demand period in general (outside the university, at national level). Apart from the peak in the late afternoon, there was also a noticeable increase in the early afternoon between 1 and 2pm. The rise in demand is due to the large number of residential accommodations on campus. Most students finish classes and arrive home around that time. Home appliances such as televisions, computers and most importantly, cooking equipment are turned on. Besides, lighting services at the Sportspark also contribute to the increase in these peak hours. It is estimated that the spike is around 500kW on average. There are also significant differences in electricity consumption between weekday and weekends, with demand being around 20% lower on weekends during daytime.

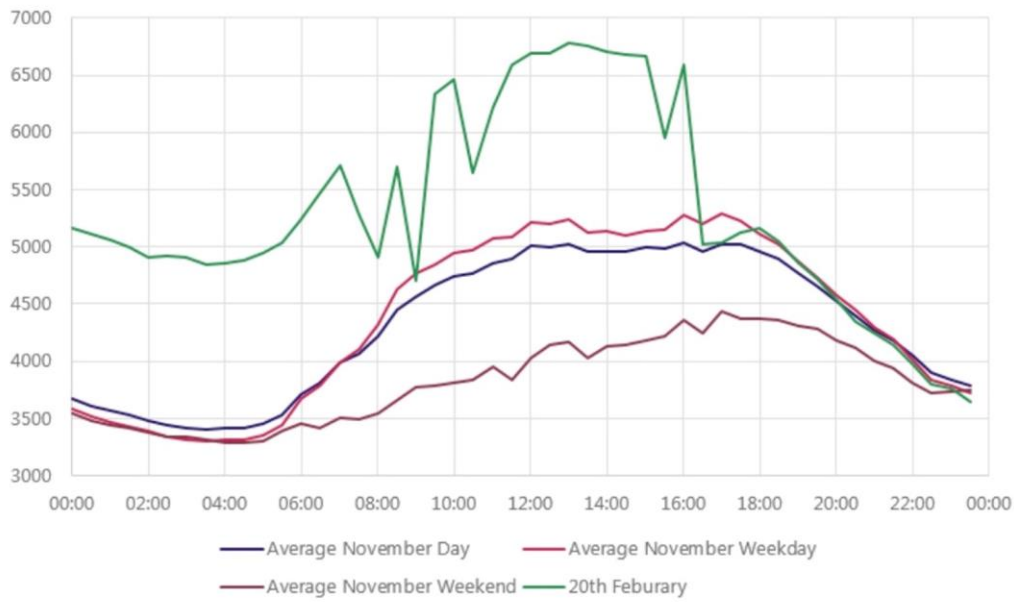


Figure 16 Campus electrical demand on a typical November day and on 20th February 2017 in kW

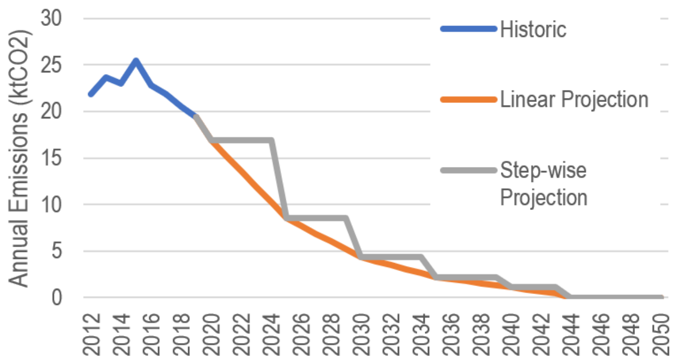
One additional aspect addressed in the figure is the electric demand curve for the 20th February 2017. It shows a very different demand pattern, in which electricity demand reached its peak around noon time and reduced significantly after 4pm. As is mentioned above, this was due to the CHP system maintenance that increased the need of electric heaters. While this example is relatively isolated, it highlights how much the UEA's energy system relies, at present, on the CHP system and is impacted by the behaviour of the campus-based energy users. A heat reduction by the normal CHP supply has meant a rapid increase in electric load to cover that heat demand. It raises the issue of the system's capability to not only control energy supply but also control energy demand through an automated or semi-automated protocol.

4.2.4. Other challenges and opportunities

4.2.4.1. UEA's carbon neutral target

UEA has been working on its low carbon strategy to become carbon neutral before 2050 (the Net Zero Plan). The Plan begins with an estimation of carbon budget to reach net zero, which is in line with the global carbon budget to limit temperature increase well below 2°C by 2050.

The carbon budget of UEA is estimated at 147kT of CO_2, including CO_2 emissions from students not living on campus (around 10,000 people). The estimation is based on the proportional distribution of its emission levels corresponding to Norwich's energy related CO_2 emissions (UEA represents 4% of Norwich's energy-related CO_2 emissions). The figure below shows the building-related historical emissions and recommended future emissions in order to achieve net zero at UEA before 2050. At present, building-related emissions represent four-fifths of total emissions at the University.



% Change in Annual Emissions	2015 Baseline	1990 Baseline
2025	-66%	-55%
2030	-83%	-77%
2035	-91%	-88%
2040	-96%	-94%
2045	-100%	-100%
2050	-100%	-100%

Figure 17 UEA's building-related energy use carbon budget projections

The implementation of a carbon neutral plan can have significant implications to its energy strategy. The university will need to implement measures to reduce its reliance on the CHP plant, increase the deployment of renewable energy sources, integrate more flexible units such as battery storage system, which will require significant investment and careful planning.

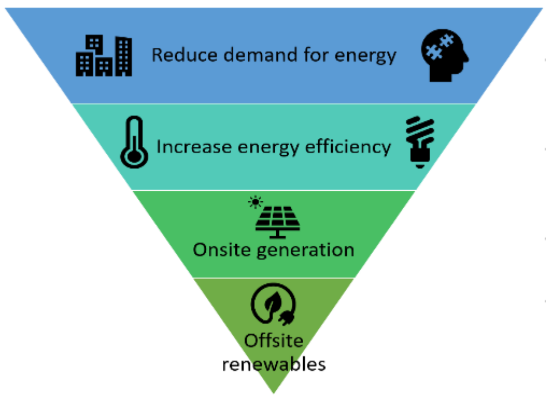
4.2.4.2 Building refurbishment – the opportunity

The University of East Anglia campus has just embarked on a major building refurbishment project. This concerns all the areas of the main teaching, research and office space on campus that was originally built when the university was established (1960s). All the buildings of that generation have received protected status by the UK Authorities for their unique modernist / brutalist architecture (overseen by Sir Denys Lasdun). As a direct result of their status these buildings' external appearance cannot be changed and UEA is responsible in maintaining them in good shape and appearance. However, these buildings are now over 60 years of age and in need of modernisation to current and forthcoming standards. This could not be more prominent than in the field of energy efficiency standards. Clearly, this situation presents both a challenge and an opportunity for UEA. Firstly, the challenge is that the buildings have single glazing windows, window frames which are not draft proof and there is no heating insulation alongside the main structures. At the same time, their aesthetic has to be preserved, including the size of the window frames and the bare concrete facets of the buildings. The university's policy for reaching net-zero emissions is entirely unachievable with these buildings at their current state. However, as the university has now adopted a plan for a major refurbishment, this presents an excellent opportunity for innovations that will help deliver top-tier sustainability standards for energy efficiency, smart energy design and beyond.

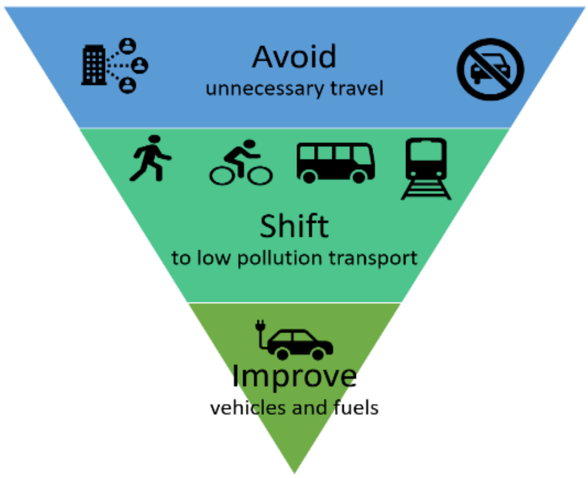
4.3 Possible technology solutions

UEA's net zero plan includes measures to fulfil the target of becoming carbon neutral by 2050. These measures are summarised in the figure below. Apart from building-related energy use (including electricity, heating and cooling demand), travel related emissions (including the use of private cars by employees and aviation travel), and biodiversity and land-use management (including opportunities to enhance the UEA's biodiversity and carbon sink) are also addressed in the key pathways to achieve zero carbon emissions.

For building-related energy use, UEA presents measures according to the energy management approach. Measures to reduce demand include space consolidation and behaviour change (a core element of the Intelligent Community Energy - ICE project demonstration work at UEA); measures to increase energy efficiency include building insulation, energy efficiency and temperature regulation (a core element of the ICE project at UEA); onsite electricity generation and storage provide additional means of reducing emissions are further strengthen the campus' capability to operate as an isolated energy territory; offsite generation of renewables can further contribute to achieving net zero, especially because they give access to offshore wind energy developments which are near the Norfolk coast, close to the UEA and Norwich.



Cutting emissions from campus buildings workshop



Cutting emissions from travel workshop

For travel emissions, UEA uses the Avoid-Shift-Improve framework. Measures to avoid travel include remote working and banning single occupancy and/or fossil fuelled cars, where the use of private vehicles is deemed necessary. Shifting to more sustainable modes of mobility includes encouraging walking, cycling and active travel. Additionally, increasing public transport access for commuting and shifting short-haul flights to rail where possible in UK and European trips. Improving vehicles and fuels broadly refers to increasing uptake of electric buses and cars on campus. Data is also crucial to allow both 'greener' travel choices and to monitor progress. It is particularly, the future provision of electromobility (private vehicles, bicycles and even buses) that will require some degree of campus charging that will require increased low carbon production.

For biodiversity and land-use management, several opportunities were identified to enhance the UEA's biodiversity and carbon sink, hence a significant means to reduce the campus' contribution to emissions. This primarily included ensuring adequate staff and resourcing levels; work with local partners and volunteer groups; identify opportunities for biodiversity offsets within the planning system; protect and enhance local habitats; manage access for competing users and uses, such as dog-walkers, recreational fishing and cycling; Access management could also be enhanced by increasing education and outreach to the wider community regarding the value and conservation of local biodiversity; Monitor progress through annual surveys is key to ensure implementation continuity.	 **Enhancing biodiversity workshop**

Figure 18 Summary of targeted areas in achieving net zero target at the UEA.

4.3.1 Building related energy solutions

Through consultation with key stakeholders, UEA has come up with several key measures for each of the three main targeted areas mentioned above. For example, in terms of reducing building-related energy emissions, it introduces the replacement of existing central plant by heat pumps and hydrogen for heating purposes. Such replacement can reduce gas consumption, which will be necessary for the UEA to achieve its net zero target before 2050. It also introduces the installation of solar PV and potentially wind turbines (or the direct procurement of wind energy) in combination with battery storage systems, which can effectively reduce gas consumption at the CHP plants and provide reliable electricity supply to buildings.

A narrative pathway for building-related energy use is shown in the figure below. Apart from the supply side measures, it also introduces measures on the demand side, including behaviour change and engagement in energy consumption, improvement in energy efficiency and adoption of smart energy technologies, as well as introduce the design of high efficiency and low energy demand buildings, an area in which UEA has been a pioneer in numerous opportunities before.

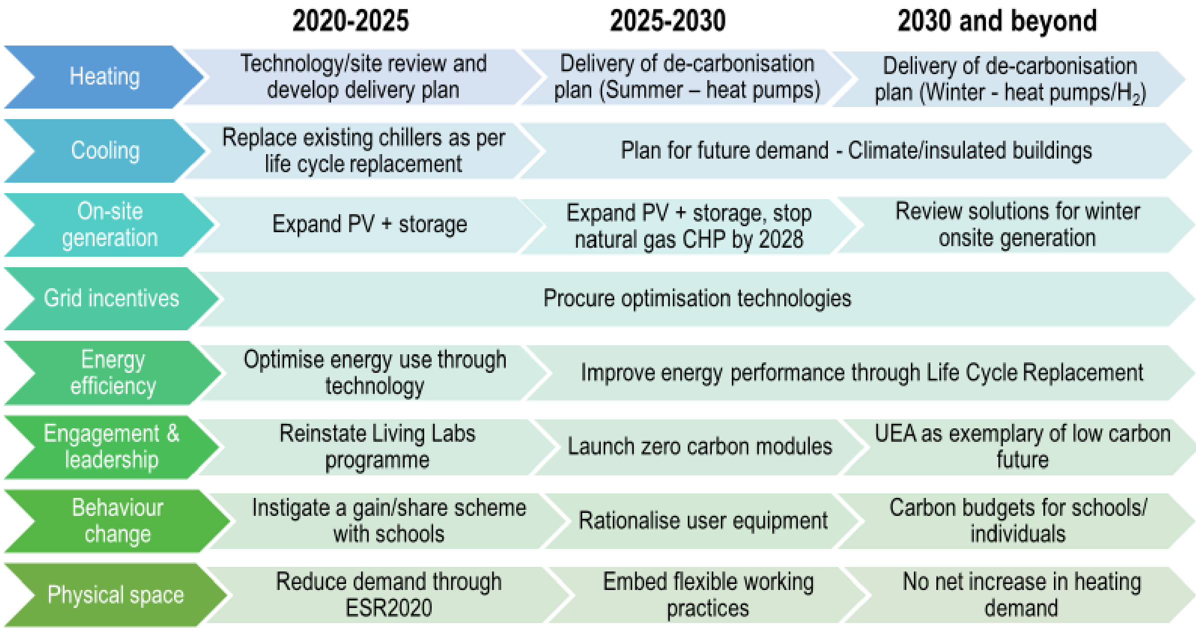


Figure 19: Narrative pathway for building-related energy use

4.3.2 Transportation related energy solutions

Apart from the building-related emission reduction, UEA also sets out plans for emission reduction in traveling, which accounted for one fifth of the total emissions in 2015. In 2018, over 55% of the UEA staff used private cars for their commute. In addition, the use of air transportation by UEA staff and international students accounted for a quarter of the travel-related emissions.

One of the most significant measures in reducing travel-related emissions is the adoption of electric vehicles. It includes both the private EV uptakes by UEA employees and the replacement of estates fleet with EVs. Such change will induce the requirement of new charging infrastructure. The university has considered of adding EV charging to one-fifth of its parking spaces, following the London Plan on planning policies related to EVs[8]. That means 220 new EV chargers will need to be installed by 2040. It is estimated that 15% of all EVs (or 93 EVs in total) will be charged on campus during peak demand period. With 20% of them on rapid charging (50 kW) and 80 % of them on slow charging (15 kW), it will lead to an increase in peak demand by approximately 2 MW. It is anticipated, however, that new business and pricing models can emerge in this area that can trigger a completely alternative picture. With night charging can be very cost effective with Time of Use (ToU) tariffs in the UK even sometimes paying customers to use electricity, it is expected that UEA campus users will charge their vehicles at home. Then their fully charged vehicles will be mobile batteries, available on campus for Vehicle to Grid (V2G) and Vehicle to Building (V2B) activities assuming an attractive pricing package. That would help support the campuses energy needs during the afternoon/evening peak.

[8] A London Plan is used as a reference since there is no similar plan in Norwich yet.

A narrative pathway is presented in the figure below. It shows eight targeted areas, which address the need of energy efficiency improvement, energy consumption reduction, as well as fuel switch to renewable energy sources.

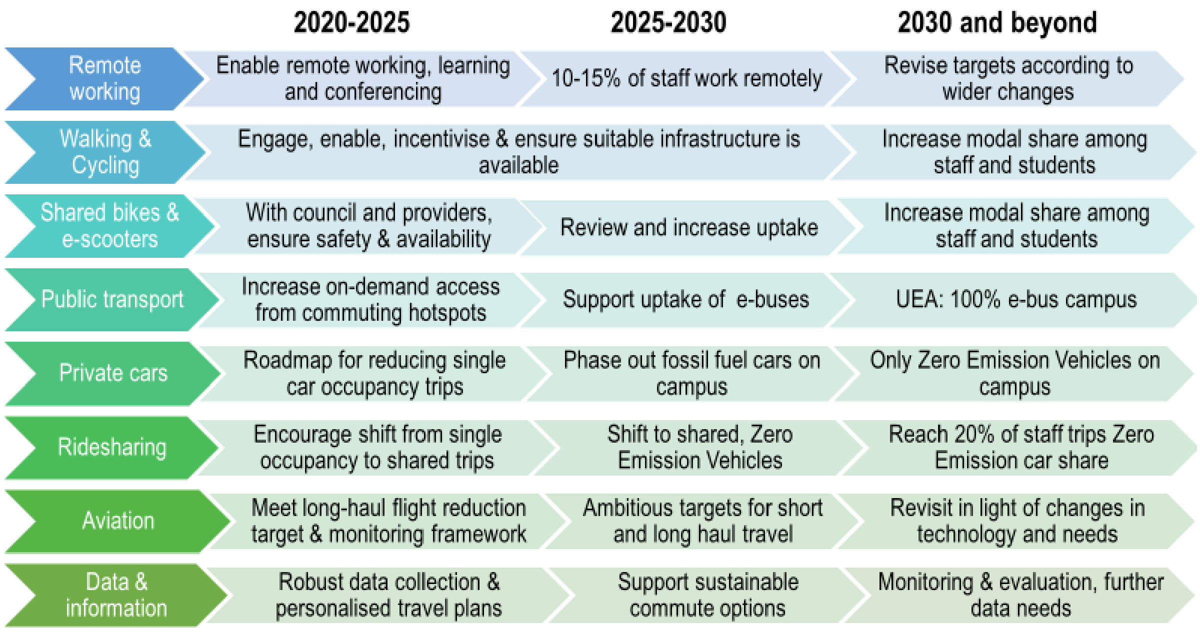


Figure 20 Narrative pathway for reducing UEA's transport emissions

4.4 Selected solutions

On a typical day, peak electricity demand happens between 1 and 2pm and between 4 and 8pm at UEA. When demand exceeds the agreed capacity limit during peak hours, UEA need to pay additional charges to consume electricity from the grid. The current solution is to increase power outputs from the CHP units to fulfil the rise in demand during the peak demand periods. However, CHP units can produce excessive heat when increase power outputs, majority of which is dumped into the atmosphere which resulted in loss in energy efficiency. One other solution is to engage consumers to reduce their demand during peak hours. This is most important, when that demand falls in either category of a. not being possible to be satisfied by renewable energy sources and b. not coinciding with heat demand that is being produced by the CHP system. Such incentives should be based on user consumption behaviour, information provision and relevant awareness raising and education.

4.4.1 The rationale for smart heating retrofit

Most of the attention of the technological options described that have been discussed belong in the broader category of top-down solutions. It is characteristic of these options that they are imposed by a central planning within the organisation and are very common in almost all attempts for low carbon energy transition. This is true for UEA and its localised energy systems as it is true of other transitional examples either in small communities or in larger regional or even national schemes. However, while the justification of central design in national planning may be justified for reasons of economies of scale, this is not necessarily true for smaller community systems. In such systems the connection between energy systems and their users (the community) can be a greater since infrastructure is more prominent. Additionally, the results of energy unavailability can be felt more since, in isolated systems there is a lack of alternatives. Therefore, that raises the argument for innovation that enables a different paradigm to the top-down approach i.e. a bottom up approach.

It is clear that reorganising a complete bottom-up campus energy system is capital intensive and has to be timed appropriately, to allow for existing facilities to reach the end of their lifespan. There is however, scope for innovations even if they do not provide a complete bottom-up solution, for as long as they help in re-balancing the overall system. On UEA campus, the student residencies provide with an interesting application case study. A major difference in relation to other university buildings is that the residencies present higher occupation, since they are actual living spaces for students. The most important energy demand in student residencies is in heating energy. As a standard design most residence buildings are operated centrally, with very basic on/off heating controls for the beginning and the end of the heating season in autumn and spring. There is no adjustment for rooms that have significant sun heating or for rooms that unoccupied for either short or longer time periods. The result is lack of optimisation in terms of energy use and user comfort since users have no control of the system.

4.4.2 System characteristics

A retrofit system would enable user engagement with the energy system, providing information, allowing for modular expansion, help reduce harmful emissions and improve energy efficiency. In this occasion the aim is to empower the energy users (students) to have agency on their heating system. Therefore, the traditional heat provision system is upgraded with a combination of temperature sensors, information provision for the user at room level, control units within the room and at aggregated level (figure below). Benefitting from the fact that the deployment is within a university and the targeted users are students the system is complement with training on its characteristics, its benefits for the user and the university and finally the importance of smart energy systems for the low carbon energy transition.

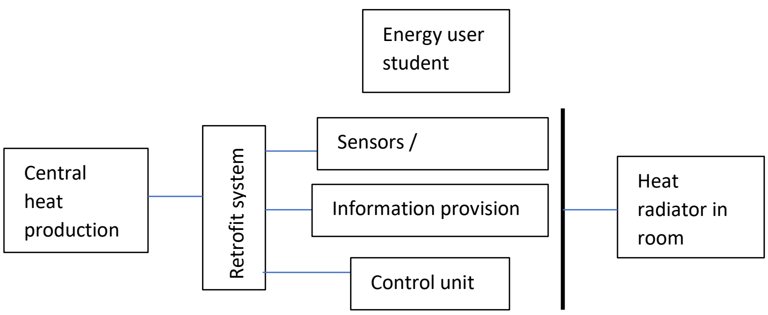


Figure 21 Modular system characteristics

The benefits of this approach can deliver:

- Reduced energy consumption and lower emissions which are necessary for low carbon energy transition
- Improved matching of energy supply and demand, reducing CHP heat waste through information

- Individual and centralised controls that empower the energy user (student), as a result raising awareness about low carbon energy within the new generation of citizens
- Improved comfort, since there is direct control of comfort parameters
- Integration within an existing heating system which is important for replicability for retrofitting other buildings that already have an older heating system
- Modularity for flexible growth according to requirements since there can be expansion on a room by room basis

5. Summary

Each energy system is unique and can present very different issues depending on its specific context. The design of technical solutions for isolated territories therefore depends on each situation, and is first and foremost based on an inventory of the territory's context and carrying out a diagnosis.

On the basis of this diagnosis, the short and medium-term objectives are to be defined on the various axes which are: Autonomy, Security of the energy system, Resilience, Pollution / Nuisance.

Consultation with the local population during the phase of defining the chosen axes is important, given that the impacts of the new actions will be directly felt by the population.

The order and importance of the actions taken should follow the following hierarchy:

1. Reduction of consumption: immediate reduction of dependence on external contributions, in addition to reducing local impacts and nuisances (eg polluting emissions)

2. Increase in renewable production: increase in energy independence and local valorisation of energy. Potential increase in impact on the local environment.

3. Add intelligence: adapt production to consumption as much as possible, and then adapt consumption to production (which potentially has more impact on consumer comfort).

Once the actions are well identified, it is necessary to move on to the concretization phase with the selection of technical solutions, allowing the objectives to be achieved. The selection and classification of technical solutions will be based on the costs and expected results over the lifetime of each technical solution.

The involvement of the population must remain important at this level, in order to present the various technical solutions, and their implications.

Depending on the actions, the population will be more or less impacted either by its involvement in the action (eg informative object) or by the impacts on its rhythm of life (eg punctual reduction in imposed or chosen consumption).

To conclude, as stated initially, each isolated territory is unique and there is no predefined method. This document proposes methodological elements for the implementation of a "smartgrid" or intelligent network as part of an isolated energy system, and an adaptation for each territory must be made.