Template version of 21.12.2020

Application for financial support

Energy research, pilot and demonstration programmes

1 General information

1.1 Type of project

☒ Research project ☐ Pilot/demonstration project (P+D) ☐ Preliminary study/ Monitoring of performance

1.2 Main applicant

Details of party bearing overall responsibility for the application.

Institution:	*Contact:*
HES-SO	Nabil Abdennadher
Address:	
4 Rue Prairie. 1202	
E-mail:	*Tel.:*
Nabil.abdennadher@hesge.ch	+41 22 54 62 534
Role (within project)	*Expertise (within project):*
Main Applicant, Project manager	Edge-To-Cloud technology, Context-aware and Self-adaptive applications, IoT

1.3 Project title

Project title in German, French, or Italian

Click here to enter text.

Project title in English (mandatory for research projects)

digitaL frAmework for SmArt Grid and reNewable Energies

Acronym (mandatory for research projects)

LASAGNE

1.4 Total project costs and SFOE contribution

Sums as shown on the Excel form "[Project costs, financing and non-amortisable supplementary costs]":

Total project costs:	807'620 (Swiss budget)	SFOE contribution:	**547 250 CHF**

1.5 Project duration

Start of the project[1]:	01.04.2022	End of project:	31.03.2025

1.6 Project location (mandatory for P+D projects)

Project location (full address):	*Canton:*
Geneva, Commune of Meyrin, Vergers ecoquartier	*GE*

1.7 Abstract

Brief description of the project in German, French, or Italian (max. 1000 characters including spaces; will be published):

Click here to enter text.

Brief description of the project in English (mandatory for research projects):

The energy transition calls for smart meters to support electric systems and microgrids. Indeed, apart from monitoring home appliances' power cycles, they will need to gather data about other households so as to predict/plan local and microgrid consumption/production. These novel smart meters, which we call **Grid Edge Devices (GED)**, will need to be managed in a collaborative fashion.

We want to develop GEDs enhanced with novel **AI algorithms and collaborative distributed models** which are the foundation to build **context-aware and self-adaptive "energy" applications**, such as rate negotiation, power transactions, grid stability. In essence, we propose to develop a **digitaL frAmework for SmArt Grid and reNewable Energies (LASAGNE)** and involve four "need owners": System Integrator, Independent Software Vendors, Edge Equipment Vendors and Need Owners.

To handle the energy transition in an acceptable way, we will consider both social and business perspectives in the development of our GED-based system.

1.8 **Keywords** (optional)

A maximum of 5-6 keywords, which describe the topic handled by the project:

Microgrid, social acceptability, context-awareness, self-adaptability, marketplace

[1] Applications must be submitted two (research projects) and three (P+D projects) months before the start of the project, respectively (Art. 61, para. 2 EnG).

1.9 Technology readiness

Estimate the scope of the technology readiness level (TRL) of the project (only applies to technical projects); classification according to the categories in Appendix I of the Directive):

From:	TRL 3: Analytic and experimental proof of the main functions and/or characteristic proof of concept	To:	TRL 7: Demonstration of a similar full-scale prototype system in a relevant environment

2 Project organisation

2.1 Project manager

Define the project management that bears the administrative responsibility and coordinates the project with the SFOE.

Institution:	*Contact:*
HES-SO//Genève	Nabil Abdennadher
Address:	
4 Rue Prairie. 1202 - Genève	
E-mail:	*Tel.:*
Nabil.abdennadher@hesge.ch	+41 22 54 62 534
Role (within project)	*Expertise: (within project)*
Main applicant & project manager	Edge-To-Cloud technology, Context-aware and Self-adaptive applications, IoT

2.2 Project partners

Name all parties participating in carrying out the project (in addition to the main applicant):

Institution:	*Contact:*
HES-SO//Valais	Emmanuel Fragnière
Address:	
Rue de Technopôle 3, 3960 Sierre	
E-mail:	*Tel.:*
emmanuel.fragniere@hevs.ch	Click here to enter text.
Role (within project)	*Expertise (within project)*
WP2 leader	Field Studies and Optimization under Constraints

Institution:	*Contact:*
University of Geneva	Giovanna Di Marzo Serugendo
Address:	
Centre Universitaire d'Informatique / Battelle Bât. A / 7, rte de Drize / 1227 Carouge (GE	
E-mail:	*Tel.:*
Giovanna.Dimarzo@unige.ch	Click here to enter text.
Role (within project)	*Expertise (within project):*

WP3 co-leader

Institution:	Contact:
CLEMAP	Pascal Kienast
Address:	
Lavaterstrasse 66, 8002 Zürich	
E-mail:	Tel.:
pascal@clemap.ch	Click here to enter text.
Role (within project):	Expertise (within project):
WP5 leader	Metering, edge device, data analytic

In addition to these three partners, the project involves two Swiss observer partners : SixSq (15’000 CHF in-kind) and Commune of Meyrin, Geneva canton (27’500 CHF, in-kind)

2.3 Organisational chart / Responsibilities

Show the hierarchical organisation in a diagram including indicating the responsibilities for each work package of all partners participating in carrying out the project (please take parties into consideration that may provide any accompanying measures, such as monitoring groups):

The goals of the project are detailed in Section 3.3 of this document and Section 1.3 of the Joint Call 2020 (MICall20) full proposal.

As shown in Fig. 0 and detailed in the Joint Call 2020 (MICall20) full proposal the project brings together three *full partners* from Switzerland and three from Sweden: a mix of SMEs, academics and “need owners” (see definition of “need owners” in the Joint Call 2020 -MICall20- proposal). Two Swiss *observers partners* are also involved: SixSq as Digital Platform Provider and the municipality of Meyrin as need owner. SixSq will provide the edge-to-cloud management and marketplace platform for hosting the energy applications targeted by the project. Meyrin will provide access to its Les Vergers microgrid infrastructure to use it as a field trial (WP5, Task 5.1)

The LASAGNE consortium will be assisted by an advisory board (AB) consisting of industry, technical, and interdisciplinary leaders who have access to not just current ecosystems but are influencing the ecosystems of the future. The AB will help the consortium in two critical areas: a) market trends and b) market opportunities, through technology, product implementation or business models. AB members are detailed in section 3.3, WP1 (Management, dissemination and Knowledge Community Standard), T1.3 (Communication, dissemination, outreach).

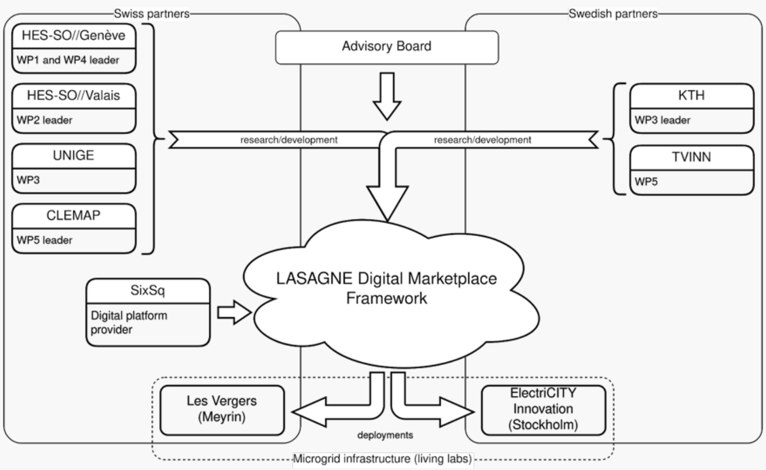

Fig. 0: Project organisation: partners and roles.

HES-SO//Valais will bring its know-how in the field of digitalisation of services, particularly in the user experience (UX) design; the approaches used to do this are both qualitative (survey, immersion) and quantitative (conjoint analysis, DCE). WP2 deals with this aspect. In particular in WP2, it will be in charge of the ethnographic field survey and the quantitative conjoint analysis survey respectively. The data collected will be used to feed the discrete choice optimisation model to identify the social acceptance attributes to be integrated with the technical attributes of the microgrid management.

HES-SO//Geneva will bring expertise if the domain of developing and deploying *context-aware* and *self-adaptive* applications on IoT-edge-Cloud solutions. Context-awareness is important in the case of IT applications that target smart Grid and renewable energies: the behaviour of the application depends on its context: country, regulation, social environment, climate, etc. WP4 deals with this aspect.

UNIGE brings its expertise and know-how in developing *coordination* models and their implementation supporting distributed adaptive software, working as digital twins and interacting in collective mode in various scenarios (smart grids, humanitarian, sports events, ecosystems of services, identification of hazards in industrial warehouses, services composition in IoT). In WP3, UNIGE will define and develop the part of the LASAGNE digital infrastructure relating to the coordination model and its support for intelligent digital twins (interactions, communications, collaboration, adaptation). The distributed collaborative ML algorithms of WP3 will rely on the coordination model. These algorithms will in turn be used to develop context-aware, self-adaptive energy applications (WP4, T4.1).

CLEMAP's specialties are metering and evaluation of energy data through their proprietary IoT Edge Devices and Cloud solution: through a combination of edge devices in the low voltage range, a cloud environment and Machine Learning analytics modules, CLEMAP will contribute developing a context aware application for energy flexibility and peak shaving, providing a Linux based GED and playing the role of ISV and EEV in the marketplace ecosystem which will be set up within the project. .

As for the Swedish partners, KTH will develop the *collaborative* ML algorithms applied to smart grid as described in WP3 TVINN and ElectriCITY Innovation will be for Sweden what CLEMAP and Commune of Meyrin are for Switzerland: Software developer of the context-aware application and need owner (microgrid infrastructure). Further details of the contribution of the Swedish partners are provided in the joint Call 2020 (MICall20) full proposal.

3 CONTENT OF PROJECT

3.1 Motivation / Preliminary studies

Describe the reasons/motivation for carrying out the project and the context in which the undertaking lies. Show why there is a need for research or field trials and to what extent the project can deliver solutions to the current challenges. Also indicate what preliminary studies have been carried out and the expertise possessed by the project team.

3.1.1 Motivations

Smart Meters are called smart but in reality are just digital meters. While the *current* generation of smart meters is designed to remotely monitor the overall electricity consumption of a measurement point, the *next* generation will hold a much wider role that ranges from measurement, gateway to controller in different grid applications. In addition, future smart meters will support extra smart capabilities at both local household and microgrid levels:

- Monitoring and forecasting appliances' power consumption (heat pumps, EV charging stations, HVAC etc.)
- Planning for optimal renewable power generation (in particular PV Systems) and storage, through consumption predictions.
- Providing communication channels to exchange data related to the above monitoring and planning activities.
- Enacting power negotiation and transactions within the microgrid and with the power grid.

Endowed with above functionalities, we define these new smart meters **Grid Edge Devices (GED)**.

With the complete liberalisation of the power market, it is expected that stakeholders (listed below) will request access to the functionalities of GEDs in order to guarantee the objectives they aim at. At present, there is no proposal on how these stakeholders can use the smart meters and GEDs *collaboratively*. Regulations and diversity of stakeholders complicate the mass-market roll-out.

Microgrids (Fig. 1) offer the regulatory framework and the economic incentive to support decentralised renewable energy sources and provide neighbourhoods with solutions to actively engage in energy economy. Intelligent microgrids (microgrids empowered with GEDs) would be based on AI mechanisms capable of forecasting power usage/production. These algorithms will be the foundation to build end-user context-aware and self-adaptive energy applications such as power network stability services and power transactions/flexibility negotiations. **Unlike other projects like MuLDeR, where the intelligence is confined in the GEDs, LASAGNE aims to develop context-aware "ecosystem" where the intelligence is provided through networked Low-GED (L-GED) and Mid-GED (M-GED)**, as shown in Fig. 2.

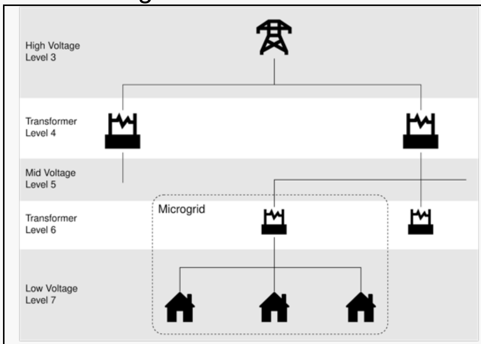

Fig. 1: A microgrid is deployed within a grid cell and spans mid- to low-level voltages (level 5 through 7). A microgrid with households and factories employing several power sources (solar, wind, geothermal) and appliances (heat pumps, EV charging stations, HVAC, etc.).

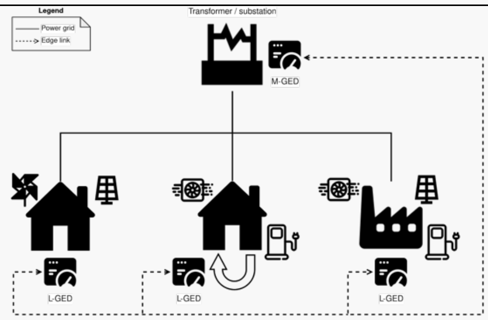

Fig. 2: L-GED and M-GED are able respectively to act on behalf of households and microgrids. L-GEDs and M-GED learn and anticipate the consumption/production of electric power at low (household) and mid (microgrid) levels and are then able to trade within the network of GEDs for energy exchange.

The added value of context-awareness is that the intelligence can self-adapt to changing operating conditions. Context-awareness will rely on collaborative ML algorithms which allows GEDs to adapt their intelligence according to their context.

We propose to develop a ***digitaL frAmework for SmArt Grid and reNewable Energies*** **(LASAGNE)**. The LASAGNE project's vision and contributions are schematised in Fig. 3. The project targets the three main areas of the call: energy & ICT infrastructure, social sustainability and energy marketplace. In the first area, LASAGNE aims to develop a framework based on *collaborative ML-based algorithms applied to low and mid power production/usage forecasts.* These algorithms rely on a coordination model. While such prediction tools already exist for high voltage levels, they have not yet been explored for medium/low voltage levels (microgrid, household).

The outcome of this research will be a toolset for building *end-user context-aware, self-adaptive energy* applications. To validate this toolset in a real concrete use case, CLEMAP and TVINN will develop a specific application that will completely detailed for disseminationOn the social sustainability side, a programme acceptance study will inform a communication campaign to empower end users, so that they will engage consciously in the renewable energy transition. This dimension of social acceptance, which is a strong point of our project, is crucial to ensure its success. Indeed, the classic business model called B2C (business to consumer) will be completely called into question in the years to come, and will be replaced by business models that will become C2C (consumer to consumer) since these consumers will also be producers. These new and very numerous players in the electricity grids are today called prosumers. This is where social acceptance comes in. It is to enable these prosumers to adhere to the management rules of the micro-grid and to encourage strong joint collaboration, without which this type of project is doomed to failure. The purely technical aspect of the project is therefore a necessary but not sufficient condition. The sufficient condition is possible thanks to social acceptance.

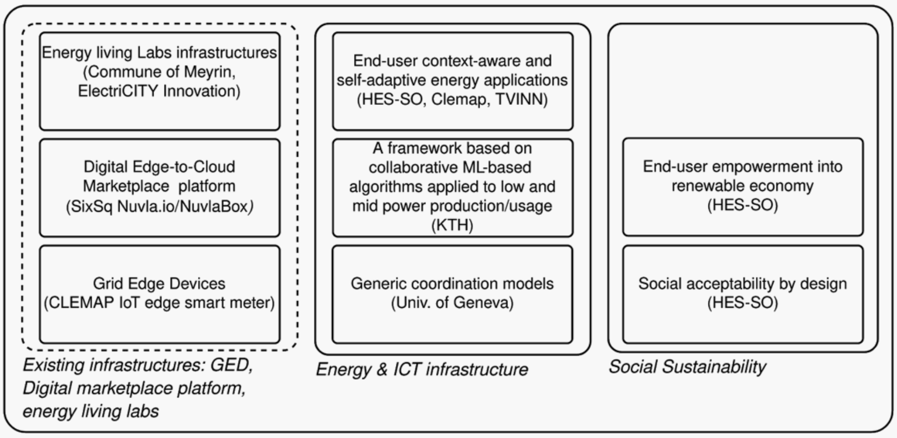

Fig. 3: Project's vision and contributions.

To evaluate the LASAGNE framework, we rely on existing infrastructures (the dashed-line box in Fig. 3):

1. The CLEMAP IoT Edge smart meter as GEDs,
2. The Nuvla.io/NuvlaBox edge-to-cloud marketplace developed by Sixsq, as Digital platform,
3. The existing microgrids infrastructures: ElectriCITY Innovation in Stockholm and Les Vergers Ecoquartier, in Geneva.

LASAGNE will involve four stakeholders:

1. System Integrators (**SI**) such as utility companies and microgrid admin.
2. Independent Software Vendors (**ISV**): developers of context-aware and self-adaptive energy applications.
3. Edge Equipment Vendors (**EEV**): GEDs providers.
4. Need Owners (**NOW**): households and microgrid owners/administrators.

For the 4 stakeholders to work together seamlessly, a **digital marketplace platform** is needed. The LASAGNE project will rely on the Nuvla.io edge-to-cloud platform which provides the desired market-place features and the mass-market scalability. In addition to its edge-to-cloud functionalities, the digital Nuvla.io/NuvlaBox platform will provide a federating backbone where the four stakeholders can easily interact and implement their legal agreements and financial flows.

Finally, stakeholders are also under obligation to handle the transition in an economic and socially accepted way. For GEDs to spread out, they must be accepted by actors. Whether these actors would tolerate such appliances is far from obvious and acceptance constitutes a potential barrier for the adoption of this new technology. The success of the energy transition depends on a mix of technological improvements and behavioral adaptations. **Our goal is to take into account both social and business perspectives when designing GEDs based systems**.

Our project is driven by 5 questions which are developed in the following:

Why are Smart meters not enough?

Existing smart meters are not yet ready for a resilient and future-oriented grid configuration due to low processing resources, no remote update functionality, data integrity and connectivity issues. In addition, smart meters cannot predict consumption by themselves, they must send collected data to the cloud for further analysis. This oversimplified approach has a number of shortcomings: the size of generated data is substantial, making the centralised cloud model ill-equipped to cope with the data volumes.

Why Edge-To cloud solutions ?

Edge-To-Cloud solutions will decrease the latency of communications, save bandwidth, lower data management costs and enhance data privacy. GEDs can boost the performance and the security of applications by offering real-time AI-assisted processing and anonymising data. In LASAGNE, Edge-to-cloud solutions will provide mechanisms by which the edge intelligence can be automatically adapted over time.

Why context-awareness & Self-adaptability? Why the collaborative learning and coordination model ?

Dynamic spatio-temporal changes in connectivity, technologies, electricity usages, environmental conditions require GED to provide intelligence that interacts with technical surroundings in a context-aware and self-adaptable way. These features call for AI and ML techniques.

A microgrid, employing several power sources and appliances (heat pumps, EV charging stations, HVAC, etc.), involves several distributed sources of heterogeneous and imbalanced data that are difficult to collect timely. To avoid high-latency data transfers and processing at central locations (Cloud), we need optimal forecasting ML algorithms that run collaboratively among the distributed sources at the Edge.

To favour collaborative power forecasting, we use a coordination model and its implementation middleware. It supports collective interactions, as well as coordination of the activities among GEDs. We use the concept of intelligent digital twins, equipped with the above learning and autonomous capabilities, to represent the various entities (appliances, services, other GED) within the coordination model.

Why Social Acceptability by design ?

In the energy sector, prosumer-oriented digital platforms are gaining momentum. It is crucial to consider the social factors affecting the acceptability of these systems by stakeholders. In the scientific literature, it is generally agreed that, for a technology to be successfully implemented, its performance is assessed according to the well known Technology Acceptance Model (TAM). Our project involves such radical social change that we need to go beyond TAM: namely, identify any social barriers that might undermine the implementation of our innovative energy platform. We will thus take into account all dimensions of social acceptability: at community, socio-political acceptability and market levels. These elements identified upstream will then be quantified to feed our Discrete Choice Experiment (DCE) model.

Why a marketplace platform ?

The multidisciplinarity of the problem calls for a marketplace platform to support the financial/technical interactions taking place between the four stakeholders listed in section 1.1: SI, SIV, EEV and NOW.

3.1.2 Preliminary studies

Every partner in LASAGNE is contributing pre-existing knowledge:

1. Edge-to-Cloud solutions: HES-SO//Geneva and SixSq
2. Social acceptability: HES-SO//Valais
3. Coordination model: UniGE
4. Business perspective and energy market: TVINN and CLEMAP.
5. Artificial intelligence applied to energy: KTH.
6. Need-owners perspective and technical aspects related to the power grid: ElectriCITY Living Lab, commune of Meyrin.

HES-SO//Geneva has been involved in several projects related to Cloud, edge and IoT and is currently working on 3 projects that aim to develop architectures for self-adaptive applications deployed on IoT-Edge-Cloud infrastructures: MEDInA, InTERiM and NORA. HES_SO//Geneva is currently initiating preliminary studies with CLEMAP and two municipalities in the canton of Geneva (Meyrin and Chêne-Bougeries) to connect the CLEMAP IoT edge smart meter to energy assets installed in several administrative buildings.

HES-SO Valais is doing research related to the digitization of user experience has acquired expertise in all aspects of the digital transformation of inclusive modes of e-participation, but also in general for any type of digital transformation of physical processes in the fields of democracy, mobility, tourism and sustainable development in particular. It has recently obtained the Innobooster (Innosuisse) "Technology and User Needs" and is specializing in the universal design of digital experience. Related to this latter point, it is also to be on the board of the FRH (Fondation pour la recherche en faveur du handicap Bureau | FRH Fondation). We are also an active member of EASPD, European Association of Service Providers for Persons with Disabilities. Regarding energy research, we have developed the SOCIO-MARKAL model for the modeling part and algorithmic part, which integrates technological improvement and social change that has been adopted by the ETSAP modeling group of the International Energy Agency (https://iea-etsap.org/).

UNIGE started research and development in coordination models and their related middleware implementation in 2010, through the EU funded SAPERE project. Since then, UNIGE developed several coordination models and corresponding middleware, in various settings and with various capabilities (learning-based, logic properties, enriched with a semantic knowledge) and for various applications (smart grids, services compositions in IoT, industrial warehouses, sports events, humanitarians scenarios). Two PhD thesis resulted from this work, one on learning-based coordination models and on logic-based coordination models. More recently, UNIGE started a collaboration on the concept of intelligent digital twins related to smart grids (to be presented at CIRED 2021) with Schneider Electric, one of the major specialists in energy management in France.

CLEMAP addresses the importance of electricity grid edge applications for a sustainable and resilient energy system and has around 150 proprietary edge devices deployed on the european energy market, monitoring and managing energy in real-time for the Smart Grid and Smart Building market, some edge devices are installed within microgrid environments such as Überbauung Stöckmatt. An additional 200 edge devices will be installed nationally and internationally under the umbrella of two research projects: Social Power Plus, and CleverGuard. In particular the Social Power Plus project investigates the interaction of households with energy and through living labs and energy challenges over smartphones the users interact with real time energy consumption. Numerous studies have already been published [link] and LASAGNE will build upon the findings when it comes to sustainability and social interactions.

As for the Swedish partners:

1. KTH has a major research history within ML, IoT, and energy systems. KTH partners are leading three major research projects within fundamental research for ML and IoT systems sponsored by the Swedish Research Council. The KTH researchers are also sitting on the Energy Platform of KTH.
2. Tvinn runs a unique Smart Charging project in Sweden with the purpose of creating both technical and commercial solutions that can enable a large-scale conversion to electric transport vehicles.
3. ElectriCITY Innovation has been involved in national and international projects like ERANET IntegrCities and SamSpEl. The most current project is a Microgrid project where the aim is to find and disseminate business models for microgrids and a flexible energy-market.

3.1.3 Expertise

LASAGNE will involve the following competencies: social acceptability, Machine learning techniques applied to energy, coordination models, edge-to cloud technologies & self-adaptive applications and edge devices for energy markets.

- Social acceptance will rely on transdisciplinary approaches. Typically, mathematical approaches (e.g. optimization, Markov decision process, conjoint analysis) are combined with behavioral approaches (e.g. conjoint analysis, ethnomethodology, quantitative survey). HES-SO//Valais will use these approaches to combine technological innovation and social change.

- There are numerous scattered nodes present in smart-grid where the enormous amount of data and information flow. Hence to monitor and supervise these entities, an essential component will be ML that uses data generated by these entities. Currently, the theory and algorithms for ML over IoT for energy systems are at the infancy. KTH will greatly contribute to the extension and application of these methods, based on the recent research results within distributed and collaborative ML.

- Collaborative ML algorithms will rely on a digital twin based coordination model deployed at different levels: L-GEDs, M-GEDs and Cloud. This expertise will be provided by UNIGE who has long experience in developing coordination models with digital twins. UNIGE will extend its most recent coordination platform with specific coordination mechanisms, algorithms and digital twins, in order to work at different levels (household, neighbourhood), exchange information about production and consumption, satisfy requests for energy, maximise the consumption of produced energy, minimise energy not consumed, negotiate energy exchanges, and integrate learning capability.

- ML based prediction modules are generated in the cloud and deployed on the edge. They are continuously improved thanks to the feedback loop explained in Fig. 4. HES-SO//Geneva will extend this functionality to edge-to-edge collaboration. This extension will rely on the coordination model

  In addition to these expertises, the participation of CLEMAP and TVINN in the project will ensure that it is in line with the real market and owners needs (present and future).

  The participation of SixSq as an observer partner will allow LASAGNE to take advantage of its Nuvla.io/NuvlaBox edge-to-cloud platform and its operational marketplace that has already proven itself in several applications.

  Finally, the GEDs based IT systems must abide by the laws of physics to which any power grid is subject: voltage control, frequency and inertia control, constraints imposed by TSO and DSOs, etc. The Advisory board and the involvement of the "need-owners" partners (ElectriCITY Innovation and Commune of Meyrin) will provide this relevant experience.

3.2 Project goals / Research questions

Formulate measurable targets to be attained by this project and specific (research) questions that will be studied to reach these targets.

LASAGNE will target three generic objectives:

- O1: Empower and motivate NOWs to engage in local green-economy business models, via GED's atomisation and personalised configuration, monitoring and reporting functions. Building upon learnings in the area of social engagement from Social Power Plus project and QuartierStrom project. This objective covers the *Social sustainability* challenge of the call.

- O2: Based on the outcomes of O1, develop a digital framework embedding: (1) collaborative machine learning based services to forecast power usage/production at low and middle voltage levels; and (2) collective interactions and coordination among GEDs. This framework will be used as a toolset to develop end-user context-aware/self-adaptive applications. Thanks to Nuvla.io, this framework will support the foundation of the governance policies that regulate technical, contractual and financial interactions among the four stakeholders. This objective covers two challenges of MICaLL2020: *Energy & ICT infrastructure* and *Energy marketplaces & business models*.

- O3: Deploy the LASAGNE framework in 2 field trials: ElectriCITY Innovation living lab in Stockholm, and Les Vergers Ecoquartier, in Geneva. The goal is to validate the reproducibility/replicability/interoperability/scalability of the framework in two different contexts. The considered application will use the LASAGNE framework to develop a power and flexibility negotiation tool which allows (1) the NOWs to earn and/or save money (and thus redeem their original investment: acquisition of GEDs) and (2) the SIs to guarantee the stability of the grid.

Starting from the three generic objectives detailed above, the scientific and technical goals of the project can be broken down as follows:

1. **Social acceptance by design**. In our context, social acceptability is more than the acceptance of a technology, it is about redefining the rules of exchange between actors whose social and economic role becomes more complex than in a classical situation. Indeed, these actors become prosumers. This objective will be done through a sociological survey. On this basis of social acceptance, design elements can be taken into account and allow us to integrate an analysis of electricity grid physical and technical attributes early in the project. Finally, we will be able to define a design which will come from a conjoint analysis integrated with an optimisation model (Discrete Choice Experiment). WP2 will target this objective.

2. Developing a **digital framework** for collaborative learning among GEDs: Forecasting power usage/production faces noisy and unbalanced measurements, and data sets distributed over IoT devices via Edge solutions, where coordination and computation procedures of ML are hindered by bandwidth limitations, latency and message loss. This needs a collaborative ML approach among the different data sources and computational units. To address this problem, we use a coordination model that provides a coordination media and mechanisms, allowing the GEDs (via intelligent digital twins) to exchange information, about production/consumption, and to collectively and in a decentralised manner smoothly reach varied objectives linked to context-aware/self-adaptive applications. WP3 targets this objective.

3. Setting up the **digital marketplace edge-to-cloud** platform: We aim to integrate the outcomes of objectives 1, and 2 and test them in the real concrete case of an end-user context-aware/self adaptive energy application as described in Section 4.1 of this document The LASAGNE framework will rely on the CLEMAP technology for the edge device and the SixSq Nuvla.io/NuvlaBox for the edge-to-cloud platform. Nuvla.io/NuvlaBox will also provide the required functionalities to support the marketplace ecosystem to setup within LASAGNE. **The project is mainly based on Swiss technology**. WP4 targets this objective.

4. **Use-case deployments**. Our goal is to develop and deploy the use-case application on two different microgrid infrastructures: ElectriCITY living lab in Stockholm, and Les Vergers Ecoquartier, in Geneva. These two deployments involve different contexts and stakeholders. WP5 targets this objective.

3.3 Detailed project description (maximum 5 pages)

Describe in detail the project approach, dividing it into work packages. Define the designated work steps, the followed methodology and – for SSH projects[2] – the data employed as well as the activities that will arise throughout the project. Complete the description by adding suitable illustrations, such as images, sketches, diagrams, plans, etc. For SSH: Show how access to the data required is secure and how the data compilation strategy is clearly defined.

[2] Projects of the SFOE research programme «Social Sciences and Humanities».

WP1: Management, dissemination and Knowledge Community Standard

The LASAGNE Management team is composed of 6 members, one from each partner, responsible for WP1: **Management, dissemination and Knowledge Community Standard.** This WP includes four tasks: "Management", "Quality Checking", “Communication, dissemination, outreach” and “Marketplace governance policy”.

T1.1 Management includes the deliverables to the joint call initiative, as well as the periodic management meetings, reporting and other external updates. We plan for two interim and one final work status report; two state of innovation and business application reports which will demonstrate the readiness to deploy the LASAGNE platform.

Additionally, the consortium management will be responsible for reporting on the financial pulse of the project.

T1.2 Quality checking concerns the milestones/deliverables of the project: Early in this work package, the consortium will determine the parameters of data governance and define how it will be applied to the LASAGNE platform. Critical questions must be answered in accordance with all applicable data privacy regulations all along the data pipeline; such as a) What data is collected and where and by whom? b) What about anonymizing and other data preparation steps? c) For what purposes will cloud storage be limited and how will the edge-cloud transfer/security of the data be managed.

T1.3 Communication, dissemination, outreach refers to all the foundational work which needs to be carried out to communicate information about LASAGNE and its results to stakeholders, energy community and the public. It also involves activities to secure the trust and goodwill of end-users and create enthusiasm among them to accept and adopt the LASAGNE platform. A critical external-facing component of Outreach is the strategic partnerships we must establish with different stakeholders, in view of further exploitation of the LASAGNE results. Along the same lines, LASAGNE consortium will get in touch with other initiatives and projects to understand and make progress on social acceptance, business models, regulations related to microgrid and smart grid. In addition LASAGNE will organize three workshops (WS) as part of the annual project events, required by the joint call initiative, with potential stakeholders. All these activities are detailed in Sections 2.4 and 2.5 of Joint Call 2020 (MICall20) full proposal.

For this purpose, the consortium will be supported by an Advisory Board (AB). The AB will play an important role in informing the consortium of trends and developments in two areas which have potential impact on the success of the project- a) market trends and b) opportunities to enable the partners through technology, product implementation or through business models. Hence, it is important that the advisory board consists of industry, technical, and interdisciplinary leaders who have access to not just current ecosystems but are influencing the ecosystems of the future. Here is the list of institutions that have confirmed their interest in being part of the AB:

- **From Switzerland**: Maurus Bachmann from the Smart Grid Switzerland Association, Frédéric Gross from Commune Chêne Bougeries, Thorsten Steinmetz from HITACHI Power Grid. Luca Dalessandro, Vice chair from IEEE Switzerland
- **From Sweden**: Per Kallner from Vattenfall , Marcus Nystrand From Region Uppsala, Stina Rydberg from Johanneberg Science Park.

T1.4 Marketplace Governance policy: The proposed LASAGNE architecture includes a marketplace, powered by an edge-to-cloud platform. While this approach brings flexibility and agility in the way the LASAGNE solution is packaged, deployed, operated and maintained, it also needs a strong level of control and governance. This task will focus on defining a reference governance policy applicable to the energy sector in general and microgrids in particular, focusing initially to Sweden and Switzerland. The approach will then be extended to other countries. The advisory board will be an invaluable resource to guide this task to ensure we propose a pragmatic, yet comprehensive, governance policy for the project. Initially, this task will consider the following aspect of the LASAGNE solution in its governance policy: Application certification, Data access, processing and categorisation, Access rights and Regulations. This list will be revisited and updated during the project execution.

The intellectual property rights (IPR) management and exploitation issues are part of this task. It will be handled by an Innovation Board, chaired by Dr. Qian Wang (KTH) who has wide experience in such matters, and has access to internal and external specialists in patent and legal affairs.

WP2: Social acceptance by design

WP2 aims at ensuring that the development of LASAGNE includes the notion of social acceptance by design. The TAM (Technology Acceptance Model) currently focuses only on ergonomic and usage aspects of new technologies. In our context, it is more than the acceptance of a technology, it is about redefining the rules of exchange between actors whose social and economic role becomes much more complex than in a classical situation. Therefore, more than a technological acceptance, we have to evaluate the social acceptance in order to remove the social barriers and give people a maximum chance to adhere to this project. It is articulated in 3 tasks:

T2.1 The ethnographic survey is a sociological approach based on semi-directed interviews with the project stakeholders. The transcripts of the interviews will then be analyzed using NVivo text analysis software. The objective will be to identify the most important social attributes that allow the social acceptability of our project. The chosen research strategy is based on the principles of ethnography. The objective here is to describe and explain the social context of the respondents as they describe it. This is an appropriate strategy for the management field if one is seeking information about a particular context, to better understand and interpret it from the perspective of those involved. An inductive approach was therefore preferred as the most appropriate for this research.

T2.2 Following T2.1, we will evaluate how the social acceptability attributes will be combined with more technical attributes related to the laws of physics of a power network.We will assess how social acceptability attributes will be combined with more technical attributes related to the physics of a power system. Indeed, in a classical relationship of several generators and often a single power utility supplying electricity to a large number of consumers, the logistical and management elements of the network are therefore provided by a single actor. Here, we find ourselves in a much more complex case where the multiple consumers also become producers, also called prosumers. Thus all the technical constraints linked to the electricity network must be taken into account as well as the social acceptance attributes that will make them collaborate together, otherwise there is no chance that the project will work. Just look at the problems encountered in California, which is very advanced in this area.

T2.3 Conjoint analysis is a market research tool used to determine which attributes are important in a product or service by studying the trade-offs consumers are prepared to make. In the field of social or psychological sciences, conjoint analysis has been widely used to determine the consumers' preferences and estimate consumers' utilities for different services. By conducting a survey and then applying the theory of conjoint analysis, utility function can be computed. The study estimated "part-worths" (i.e. utility functions) using the non-metric conjoint analysis procedures, adapted to qualitative scales, for each respondent and for the entire sample. Finally, this utility function is incorporated in a Discrete Choice Experiment (DCE) whose solution provides the optimal service design as well as an optimal pricing. Indeed, according to the constrained optimization theory, the shadow price, also called dual value, represents the change in the objective function of the optimal solution due to a small change in the constant of a given constraint. Consequently, the utility functions produced by conjoint analysis will feed a discrete choice experiment model in order to optimise the weight of the selected social attributes which will be at the basis of the algorithms delivered in WP3.

WP3: Coordination model and intelligent digital twins

WP3 aims at defining collaborative, distributed ML algorithms providing robust predictions of power usage/production. They rely on coordination middleware and intelligent digital twins providing support for distributed interactions specific to smart grids. Data used to develop these algorithms comes from several sources such as Groupe-E DSO/TSO and research projects such as DomOS.

The outcomes of WP2 will be used as input to develop the collaborative ML algorithms targeted by this WP.

T3.1 Distributed learning methods for energy. We develop ML methods for forecasting power usage/production from distributed, incomplete, and noisy data sets. We extend our preliminary work (curing the data sets, compressing data, and refilling missing time series by using deep neural networks that generate synthetic but highly realistic data). We consider all the representative energy data that can be available at IoT devices attached to energy production and distribution units. These new distributed collaborative ML methods do not need to transmit data to centralised ML computing units, instead they rely on distributed and collaborating training and inference methods.

T3.2 Coordination middleware and intelligent digital twins. Coordination provides support for context-aware distributed interactions (information exchange, propagation, or queries). We will adapt our most recent coordination middleware with distributed algorithms and mechanisms specific to smart grids (energy consumption, production, forecasting, and the applications developed in WP4). Working on behalf of corresponding physical assets, intelligent digital twins, actively engage into these interactions. This task provides intelligent digital twins for collaborative learning (T3.1, T3.3), as well as specific digital twins for implementing the context-aware self-adaptive applications (WP4, T4.1).

T3.3 Coordination rules and digital twins - algorithms and implementation. We implement the methods (T3.1) into performant distributed algorithms (e.g. Federated Learning), handling noisy and missing data, despite bandwidth limitations over IoT networks. We implement digital twins for learning; for representing entities (appliances, other GEDs); and for serving applications (WP4).

WP4: Edge-To-Cloud marketplace platform

This WP will be responsible for the development of the context-aware, self-adaptive “flexibility and power trading/aggregation” application developed by CLEMAP and TVINN (T4.1) and its deployment on the Nuvla.io/NuvlaBox edge-to-Cloud platform (T4.2). The Clemap IoT Edge devices will be used as GEDs.

T4.1: Development of the context-aware, self-adaptive "flexibility & power trading/aggregation" application.

The application to develop in T4.1 has two main functionalities :

1. Aggregating resources (e.g EV chargers, Energy Storage, solar energy production, etc.) and flexibility at low and mid power level (Fig. 1 and 2). The ultimate objective is to enable Systems Integrators (SIs) to improve the “conditions” of flexibility negotiations, excess or lack of resources thanks to reliable forecasts, at low and mid poser level, offered by LASAGNE. This is an important business case to SIs since they can create revenue streams and energy savings.
2. Peak shaving : Thanks to the reliable forecast provided by LASAGNE at low and mid power level, SIs can prevent peaks of usage/production by negotiating resources and flexibility transactions with other actors (SIs, households, etc.). This functionality is particularly related to the stability of the grid

The added value of this application, compared to other existing similar applications is detailed in Section 4.1.

T4.2: Deploying the flexibility and power trading/aggregation on the Nuvla/BuvlaBox platform.

This task aims to deploy the application developed in T4.1 on the Nuvla/NuvlaBox edge-to-cloud platform. The Clemap IoT Edge devices will be used as GEDs.

In essence, the Nuvla.io platform is an edge-to-cloud management platform as a service, allowing users to manage, monitor and update applications and edge devices across edge and cloud infrastructures. The platform permits application developers to register their applications into the platform’s app store. The platform also allows users to install and register edge devices, using the NuvlaBox software, also distributed by SixSq, which transforms any compatible computer (i.e. x86 and ARM hardware platform able to run Linux and Docker: The Clemap IoT Edge devices in our case) into an edge device connected to and secured by Nuvla.io.

Nuvla.io will also be used to deploy all applications on the GEDs. These applications will be integrated as applications in the Nuvla.io app store as private applications.

T4.3 Integration of edge-to-cloud and energy marketplace functionalities

This task will deal with setting up of a Nuvla.io based marketplace platform for the energy market, in particular the context-aware, self-adaptive energy applications running on edge-to-cloud infrastructures.

Nuvla.io is currently the only service offering a marketplace of applications targeting edge computing. While other platform operators offer such service for the cloud, Nuvla.io is currently the first to extend this concept to the edge. Several edge-to-cloud solutions (AWS-Amazon, Microsoft Azure, Google, Balena) exist, but none of them support marketplace functionalities.

The participation of SixSq as observer partner will allow the project to take advantage of an edge-to-cloud platform and an operational marketplace that has already proven itself in several applications. This task aims at applying this concept to the context-aware, self adaptive energy applications. This will provide a route to market for ISVs, such as CLEMAP and TVINN, and lowers the barrier to entry for SIs. An attractive aspect of the marketplace is its ability to establish a simple digital contractual framework, such that purchases and fund distribution is automated, simple and secure.

Section 4.3 provides an overview of the marketplace concept, how it applies to edge and cloud architectures in general and how this concept will be leveraged in the energy sector by the LASAGNE project.

Two configurations related to the two deployments described in WP5 will be created on Nulva.io.

WP5 – Deployment & evaluation

This WP will be responsible for the deployment of the application described in WP4 and Section 2.1 on two microgrid infrastructures: commune of Meyrin in Switzerland (T5.1) and electriCITY Innovation microgrid in Sweden (T5.2). As the GED hardware is already available, installation happens as early as the project starts, it follows the remote deployment of software and implementation of connection to appliances. Over the duration of WP5 the applications are being monitored, where necessary performance will be improved via remote updates.

The infrastructure that will be used in Meyrin (Geneva) under T5.1 is composed of:

1. The housing buildings of the “Vergers” eco-quartier;
2. The four public facilities buildings in Vergers (school, gym, specialized school), all equipped with photovoltaic roofs;
3. The school in La Golette, which already has a 30 kWp photovoltaic installation and whose renovation will be completed in the summer of 2021. It will include the installation of a heat pump with a thermal output of around 80 KW.

The infrastructure that will be used in ElectriCITY innovation (Stockholm) under T5.2 is composed of:

The infrastructure that will be used in ElectriCITY Innovation (Hammarby Sjöstad, Stockholm) is composed of:

1. 8 Housing associations with approximately 670 apartments, most of them have already heat pumps and solar panels.
2. The installed capacity of photovoltaic is around 390 kW
3. The installed capacity of heat pumps is around 2.4 MW
4. Investments in sensors for microgrids will be done through joint procurements.

In both microgrid infrastructure,at substation level M-GED with Rogowski coils will be installed and at housing level L-GED with current clamps will be installed. The L-GED will serve as a gateway and control heat pumps, PV- and EV-Converters either via local Modbus configuration or via API.

3.4 Schedule

Illustrate the schedule for carrying out the project in a diagram (e.g., as a table or a GANTT chart). Define the content, the chronological order (dates for the start and end), the milestones to be attained and the deliverables of each activity and/or work package:

	Y1				Y2				Y3			
Quarters	1	2	3	4	1	2	3	4	1	2	3	4
WP1 – Management, dissemination and Knowledge Community Standard (HES-SO//Geneva, all)												
T1.1 Management												
T1.2 Quality Check												
T1.3 Communication, dissemination, Outreach												
T1.4 Marketplace gouvernance policy												
WP2 – Social acceptance (HES-SO//Valais, Clemap)												
T2.1 Ethnographic survey												
T2.2 Technical feasibility of attributes												
T2.3 Conjoint analysis survey and DCE optimization												
WP3 – Coordination model and intelligent digital twins (KTH, UNIGE)												
T3.1 Distributed learning methods for energy												
T3.2 Coordination middleware and intelligent digital twin												
T3.3 Coordination rules and digital twins - algorithms and implementation												
WP4 – Edge-to-Cloud marketplace platform (HES-SO//Geneva, Clemap, TVINN)												
T4.1 Developement of the context-aware, self adapative "flexibility & power trading/aggregation" application												
T4.2 Deploying the flexibility and power trading/aggregation on the Nuvla/BuvlaBox platform												
T4.3 Integration of edge-to-cloud and energy marketplace functionalities												
WP5 – Deployment & evaluation (Clemap, all)												
T5.1: Commune of Meyrin deployment (Clemap)												
T5.2: ElectriCITY Innovation deployment (TVINN)												
Milestones				M1				M3				M5
				M2				M4				

LASAGNE work plan: GANTT diagram and milestones (M1 to M5)

Milestones

- M1: Comprehensive study based on ethnographic techniques to identify salient attributes that will be accurately assessed during a quantitative conjoint analysis survey to finally feed a discrete choice optimization model..

- M2: Coordination model, digital twins and design of distributed collaborative ML methods are implemented on an experimental edge-to-cloud architecture. Outcomes from WP2 are not yet supported

- M3: The context-aware, self-adaptive "flexibility & power trading/aggregation" application developed and deployed on an experimental edge-to-cloud architecture

- M4: Edge-to-cloud marketplace supporting WP2 and WP3 outcomes is functioning as a lab model. Edge devices have a running prototype of the "flexibility & power trading/aggregation" application, cloud application and edge devices are connected with Nuvla.io infrastructure.

- M5: Edge devices are installed, power and flexibility application is uploaded, marketplace is known and used in the two Microgrid field trials (Meyrin and electriCITY Innovation)

Deliverables:

WP1:

- D1.1: Management intermediary and final reporting (including report for Joint call initiative)
- D1.2: Data quality governance (including privacy)
- D1.3: Report on all communication/dissemination/outreach activities conducted during the project
- D1.4: Marketplace reference governance policy

WP2

- D2.1: A complete database analyzed and synthesized proposing the main attributes of social acceptance to take into account to ensure maximum public support.

- D2.2: A configuration design of the micro-grid including both social acceptance attributes and technical attributes related to its logistical and physical aspects.
- D3.2 An optimization code implementing the discrete choice modeling algorithms whose design solutions will directly feed WPs 3, 4 and 5.

WP3:

- D3.1: Design of distributed collaborative learning methods
- D3.2: Coordination model and middleware extended with distributed algorithms and mechanisms specific to smart grids. Design of digital twins.
- D3.3: Implementation of distributed collaborative learning. Implementation of intelligent digital twins.

WP4:

- D4.1: The context-aware, self adaptive "flexibility & power trading/aggregation" application developed and ready for the deployment
- D4.2: The context-aware, self adaptive "flexibility & power trading/aggregation" application deployed on Nuvla/NuvlaBox experimental infrastructure with Clemap IoT Edge device as GED.
- D4.3: Adapting the marketplace functionalities of Nuvla/Nuvla to the energy market

WP5:

- D5.1: Installation location of GED and appliances to be directly connected to cloud have been identified
- D5.2: GED have been successfully installed, appliances have been integrated in cloud application
- D5.3: Power and flexibility application deployed on GED
- D5.4: Report on functioning application and results, comparison before and after

3.5 Dissemination / Accompanying measures (knowledge and technology transfer)

Describe how the results/solutions/experience gained from the project will be processed and communicated to potential recipients from the economy, society, politics, etc. (e.g., through communication, publications, lectures, protection of intellectual property, exchange of experience monitoring groups).

We target 4 types of stakeholders: need owner (NOW), System Integrator (SI), Independent Software Vendor (ISV), Edge Equipment Provider (EEV).

Dissemination related to Swedish energy community is described in detail in section 2.5 of the main *ERA-NET proposal*. We focus here on dissemination in Switzerland:

- Unige and HES-SO are both members of the Data Innovation Alliance, an association gathering academics and professionals on digital topics, in particular through expert groups. HES-SO is currently setting up a Smart Energy expert group, gathering interested academics and professionals, SMEs and utility companies. Target: 4 types of stakeholders.
- Smart Grid Switzerland Association: represents the interests of the distribution network operators in Switzerland. Preliminary contacts with its president show the interest to join the LASAGNE project. Target: SI.
- LASAGNE will be presented to the “Pôle Energie” initiative which involves University of Geneva, HES-SO//Genève, “Services Industriels de Genève” and “Office Cantonal de l’Energie”. Collaboration is planned to synchronise and avoid overlapping projects.
- The project will be presented in the Swiss Smart City networks, in particular Smart City Alliance and Smart City Program of SFOE as a Microgrid pilot project.
- Energy Lab is an Innosuisse funded network providing an innovation ecosystem gathering more than 200 partners aiming at boosting energy transitions through joint innovations. LASAGNE will benefit from exploitation and funding opportunities through this network.

- We will organise three workshops (WS) targeting Advisory Board members, presenting the LASAGNE concepts and design (WS1), the prototype (WS2), and the final version (WS3). Feedbacks received during the workshops will help refine and tune the LASAGNE platform to meet stakeholders expectations.
- *EU projects community:* the european domOS project, led by HES-SO, is working on a formal and semantic representation of the smart grid (i.e. a type of digital twin). We plan to use these results within LASAGNE to represent the two fields trial in Meyrin and electriCITY Innovation.
- *General public and society*: Based on UNIGE and HES-SO expertise in developing specific activities towards general public (schools, families, journalists, etc.), LASAGNE will target the general public, professionals of the area, and interested stakeholders (see Section 2.4 of main proposal for more details).

Exploitation of results

- **Research projects:** Developing projects exploiting further the findings and the results of the LASAGNE projects, through various funding bodies, such as Innosuisse funded research
- **Commercial exploitation from CLEMAP (and Tvinn)**
  - LASAGNE will enhance GEDs with context-awareness, self-adaptability and collaborative learning. This will strengthen both CLEMAP and Tvinn positions as an Edge Equipment Provider and Independent Software Vendor in energy grid application towards Metering Providers releasing certified smart meters and System Integrators implementing microgrid solutions.
  - LASAGNE will increase the knowledge base within the SmartGridready initiative on local intelligence application and its interaction with appliances and context.
- **Reaching out to stakeholders**:
  - EXNATON developed, the QuartierStrom project, a centralised microgrid power management system based on real-time analysis of power consumption data. LASAGNE will go beyond this approach, by 1) distributing the power negotiation process over L/M-GED, which will act cooperatively under a coordination protocol, 2) optimising the overall microgrid's energy resources by forecasting power consumption at both household and microgrid levels via advanced ML models. However, we are interested in QuartierStrom's blockchain-based approach to handling the transactions for power negotiation via smart contracts. Indeed, preliminary contacts show an interest from EXNATON for the collaborative and decentralised solutions provided by LASAGNE, as its services could be deployed as an instance of LASAGNE's end-user context-aware and self-adaptive energy applications. EXNATON would then play an ISV role.

  - Hive power developed the MuLDeR project. It employs some level of intelligence in the edge, but does not target self-adaptability or context-awareness. In NuLDeR, intelligence is confined to the edge. Hive power can play the role of an ISV.

  - Groupe Hitachi ABB. Already part of the LASAGNE Advisory Board, they can act as EEV for further exploitation of the LASAGNE results.

  - The Canton Geneva city of Meyrin is part of the LASAGNE project and will act as a NOW. This partnership will provide commercial exploitation. Indeed, Meyrin recently developed the "Vergers" eco-neighborhood and has an interest in further increasing its energy-neutral aspect of that neighbourhood as well as renovating a series of public buildings according to these principles.

  - The Canton Geneva city of Chêne-Bougeries is interested but not part of the LASAGNE project. Results on the Meyrin city will likely be reproduced at Chêne-Bougeries. It will play the role of NOW (as a city). The microgrid infrastructure proposed by Chêne-Bougeries is the following:

    - On the site of the Rigaud building (55 rue Jean-Jacques Rigaud) managed by the CODHA. This site is equipped with photovoltaics and particularly adapted to a self-consumption model. It is set up in collaboration with Mr Guillaume Kaiser of the CODHA. This site, identified as perfectly corresponding to the needs expressed by LASAGNE, seems to be the best municipal candidate to experiment LASAGNE outcomes.

- On the “Belvedere” school, currently with a capacity of 2300 KWh/year.
- On other administrative municipal buildings that will be equipped with photovoltaic panels from 2021 onwards, such as “Gradelle” school (potential 100,000 KWh/year) and “Chêne-Bougeries” School (39'000 KWh/year potential)

4 RELEVANCE & POTENTIAL

4.1 Strategic relevance

Indicate to what extent the project is strategically, politically and/or scientifically relevant. (For research projects: Does the project contribute to a priority of the SFOE energy research concept and is it part of national or international cooperation?)

An energy system with a high share of renewable energy is a socio-technical system composed of a series of complex and intertwined elements: infrastructures, technologies, societal and behavioural aspects, economic and financial aspects, and regulatory aspects. See SWEET Call 1-2021. The transition in Switzerland to a more sustainable energy infrastructure with heat and mobility being electrified and energy being produced renewably, is a necessity. In an interview on 7 April 2020 in the context of the COVID-19 epidemic, the President of the Confederation stated that “Switzerland must reduce its dependence on energy from abroad. More than ever, Switzerland must strengthen the production of local renewable energy”. But this transition is also a threat to the energy system as it could increase grid instability and generate the need for grid expansion.

A successful transition of the Swiss energy system that meets climate and sustainability policy requires a highly networked system with trends toward decentralisation, local energy production in and out of Microgrid configurations. This energy system requests an intelligent and resilient digital meter infrastructure.

The functionalities of the application that CLEMAP will develop (with the Swedish industrial partner) as part of LASAGNE (WP4, Task T4.1) is a perfect example of the project's impact.

From the user perspective, the application offers two main functionalities that provides a higher value than current flexibility and microgrid stability solutions:

1. **Aggregating resources (e.g EV chargers, Energy Storage or solar energy production) and/or flexibility for future negotiation**. Thanks to the low voltage forecasts and context-awareness capabilities of LASAGNE, aggregation and negotiation are expected to be more efficient than the status quo approaches. For example, the solar trading approach has been proven by the Quartierstrom project in Switzerland. But this solution is centralised and relies only on real time data. Thanks to the collaborative GED’s intelligence, market additional revenues can be generated (Details about additional revenues in different market constellations of the project to be found out in the project). This aspect of aggregating/negotiating resources and flexibility with microgrids and/or DSOs is an important business case to microgrid owners/admin, DSOs,TSOs, aggregators companies since they can create revenue streams and energy savings.
2. **Reducing peak consumption/production and distributing the load** over the duration of the day. This functionality will increase the Grid stability and avoid expensive grid expansions. Thanks to collaboratively enhanced information, these load shifts are expected to be better managed and organised. For example in the EV-Charging environment, context awareness and forecasting methods could allow to improve load management and charging control of up

to 50% compared to the status quo approaches resulting in savings for all involved users. (Details about these savings in different market constellations to be found out in the project)

These two “enhanced” functionalities will be possible through the features brought by LASAGNE.

But this application is just one of several context-aware, self adaptive energy applications that can leverage LASAGNE. Many others can be considered such as:

- Implementing a Balance Service Provider platform. This is a new role in the energy industry and it will be important in future grid connected microgrids. In fact, power usage predictions are easier and in the microgrid context the knowledge about both production and consumption will be more important than before,

- Improve consumption/production scheduling of the accessible appliances (such as heat pumps and, water boiler, solar panel, e-car charging station) and negotiate local flexibility and power transactions among households of the same microgrid and/or other actors. This is a step further in the process of democratisation/liberalisation of the energy market.

LASAGNE will provide a framework to foster and promote this new family of applications that place the user at the heart of the future energy ecosystem, thus becoming direct beneficiaries of a liberalized energy market. This vision of intelligent and adaptive grids is not new and several projects have been initiated since early 2000, but this trend has become more realistic and efficient thanks to digitalization and edge device technologies.
From a Swiss political point of view, this project is also very relevant. Switzerland, with its system of direct democracy, has always relied on the empowerment of its citizens and their personal involvement in the social and political issues of the country. The notion of citizen participation in such a micro-grid project is therefore obvious. This project will allow everyone to contribute to the implementation of the ambitious policy that the Federal Council has set for itself in terms of sustainable development. The political dimension of this project, in addition to its obvious scientific character, is therefore of primary importance.

4.2 Potential for implementation and multiplication

Describe the potential for implementation in Switzerland and worldwide of the technology/solution/process to be studied. Estimate the market prospects of a later product/service and describe how and by whom the future implementation of the knowledge gained will occur. Name existing competitors and solutions (optional for SSH projects).

4.2.1 Potential for implementation in Switzerland and worldwide

As a generic and flexible software framework, LASAGNE will democratise the development of context-aware, self-adaptive energy applications. The context-aware capability will accommodate a variety of scenarios, by taking into account different contexts: weather conditions, regulations, social environments, etc. On the other side, self-adaptability has the advantage of letting the framework adapt over time: to this purpose, the edge-to-cloud platform and the coordination model will provide mechanisms to update the GED intelligence at any time.

From a business perspective, our marketplace will enable flexible collaborative dynamics, such as introducing and swapping stakeholders, without any disruption to the platform’s operations. The two deployments (WP5) planned in the project will involve two groups of stakeholders with different interests and problems.

Designing for social acceptance will have a customer multiplier effect: by seeking different stakeholders’ satisfaction, it will drive up the interest for smart microgrid solutions. The social acceptance study will inform our engineering choices. Thus, we will look for the technically feasible and economically viable solutions that receive the highest social acceptance. This approach should guarantee the replicability of LASAGNE in different social contexts: from small rural communities to large metropolitan areas.

From a technology perspective, to ensure replicability and interoperability, LASAGNE will leverage open-source-software technologies based on established industry standards. Indeed, our edge-to-cloud platform (Nuvla.io) is cloud-neutral: as such, it supports different cloud/edge service providers, as well as any kind of GNU/Linux-based edge hardware equipment. The open-source choice will boost the market scalability potential by fostering a community-based development effort, while ensuring the project's survival beyond its bootstrap phase. Exploitation measures towards grid edge providers will be performed immediately after the completion of the project.

We will extensively trial our solution in two deployments:

- **Switzerland.** Commune of Meyrin, with:
  1. **ISV:** CLEMAP + Tvinn
  2. **SI:** SIG + Commune of Meyrin (as microgrid's admin)
  3. **EEV:** CLEMAP
  4. **NOW**: Commune of Meyrin (as microgrid's owner)
- **Sweden.** ElectriCity Innovation living lab with:
  1. **ISV:** Clemap + TVINN
  2. **SI:** ElectriCITY Innovation living lab (as microgrid's administrator)
  3. **EEV:** CLEMAP
  4. **NOW:** ElectriCity Innovation living lab (as microgrid's owner)

4.2.2 Existing competitors and solutions

We compared the LASAGNE offering "prediction, flexibility/power negotiation and marketplace" capabilities against existing products/platforms:

1. **OPOWER** by Oracle: a customer engagement platform; tailored to utility companies.
2. Local Energy Market by **EXNATON**: a software billing platform for energy providers. It allows prosumers to exchange real-time surplus energy.
3. **Patagonia Energy Applications** Smart Meter platform by NES selling to IWB (Industrielle Werke Basel) customers. Delivers condition monitoring and response.
4. **GRIDEYE** digital grid (generation/consumption) optimizer and IoT communications platform for power distribution networks by DepSys.
5. **GRIDBOX** provides a platform for applications intended for distribution grids; for condition monitoring. It seems to be at a preliminary stage and not a market offering yet.
6. **Connected Life at Home** by Cisco is a platform connecting intelligent home-appliances. A potential upstream data collection point for LASAGNE platform.
7. **ABB Smart Grid** : an infrastructure to optimize charging and reduce range anxiety; a potential upstream and data source for LASAGNE.
8. **Smart Meter Toolbox** by **BEN Energy**, is a device gathering usage data at customer's site in standalone mode or linked to Smart Meters.
9. **Sunny Home Manager** is a household energy and power monitoring with visualization capability.
10. IDSPECTO: a metering information structured around a central data and process hub, by Görlitz.
11. **Swisscom** Infrastructure and connectivity solution for smart metering. It offers reliable connectivity, secure data management and modular services.

12. Hive Platform: A fully software based platform covering numerous applications from real-time energy management to microgrid applications. For example in the LIC project in Lugaggia they run a microgrid interface with Landis+Gyr's smart meters.

Smart meter providers, emerging companies serving smart grid and systems integrators as described in our marketplace model could be viewed as competitors. However, the LASAGNE consortium prefers to see them as potential partners. For example:

1. We can picture ABB Grid Edge Solutions and Cisco Connected Life as an upstream consolidator of Edge data for LASAGNE since it pulls together connected devices in the charging network.
2. Clemap, EXNATON or Hive Power could cooperate and be edge equipment vendors according to our marketplace strategy.
3. OPOWER, GRIDEYE and the Connected Life platform provide real time condition monitoring. This is a starting point for the predictive analytics and trade functions offered by LASAGNE.

In addition, most digital platforms targeting smart grid and renewable energies are still in pilot stages across Europe. Digital platforms for the smart grid market which hold the promise to scale securely, powerfully, and fast in production are in high demand. We foresee LASAGNE being competitive in this context. That means this is necessarily a collaborative space, and players depend upon one another’s strengths.

Modern business is making the traditional narrow definition of “competitors", redundant. In think tanks and among business leaders, the future is seen increasingly as a multi-dimensional collaborative space and less as a binary competition. LASAGNE aligns with this view because even if some stakeholders could develop their own LASAGNE-like capability, this is not their core business. Our federated approach to partners (and market) is strategic, pragmatic, and progressive: the four families of actors presented: Systems Integrators (SI), Independent Software Vendors (ISV), Edge Equipment Vendors (EEV) and Need Owners (NOW) will benefit from our capabilities that would be difficult for them to develop, while they bring to us access to the targeted markets. Together, as partners, we generate economic benefit at all levels of the collaboration.

4.3 Energy potential

Quantify the anticipated energetic benefit that will result from this project (or technology/solution/process), by estimating the anticipated production of renewable energy, the anticipated energy savings or any other benefit (economic, political, etc.) derived for the energy system for a single undertaking as well as the total potential through the multiplication of the undertaking. Compare the energy balance of the examined system with the current state of technology/knowledge. For SSH projects: Evaluate the contribution to a safe, sustainable and economic energy supply as well as to an economical and rational energy consumption.

Smart Geneva is a Canton Geneva initiative aiming at supporting smart city projects with a sustainability aspect. The LASAGNE deployments contribute to this initiative with a more sustainable energy production schema. Preliminary contacts with Smart Geneva representatives show the interest and the pertinence of our project and its impact for a smart and sustainable city.

As the electrification of the mobility and heat progresses and new energy intensive applications penetrate the market (e.g. server infrastructure) a natural reaction could be to increase the grid capacity. Nevertheless, numerous social, economical and environmental benefits are given when instead of a capacity increase the intelligence of the grid is increased.

Economic benefits of self-consumption

Whereas in typical microgrid configuration aims at increasing the self-consumption this is not automatically given by the technical infrastructure. Depending on how well the appliances and the renewable energy production are configured and interlinked the self-consumption and peak shaving can be additionally improved. Due to the context awareness and self-adaptive energy applications we expect to further increase the self-consumption by at least 10% in standard mixed use microgrids compared to current state. Energy providers have a large interest in reducing peak load and many take the role as

SI when it comes to developing microgrids and self-consumption communities. Peak load reduction means to save on expensive infrastructure and electricity grid expansion maintaining low the grid tarifs. This paper for example models a capital expenditure reduction of 22% when flexibility approaches are implemented compared to no implementation at substation level. The reduction is even higher (up to 90%) closer to the household main switchboard. For a typical household connection this can be of around 500CHF of saving per year.

Economic benefits of marketplace

The aggregation of resources for flexibility purposes generates income for SI and ISV. But these applications are reasonable if a large set of resources are bundled (with or without edge devices) and controlled and if the predictions are correctly set, moreover until today they are accessible only to a few energy market players (e.g. flexibility providers). Thanks to the LASAGNE platform with the marketplace and IoT edge device, new players (e.g. SI, ISV, EEV, NOW) to deal with flexibility and generate income. The market becomes open and transparent.

The Nuvla.io marketplace has a simple pricing scheme, based on a pay-as-you-go pricing model.

Two main items are charged:

1. Edge management: fee charged for managing each connected edge device

2. Edge applications: fee per deploy application

The edge management fee is driven by the pricing model of SixSq (https://nuvla.io/pricing) The edge application fee is defined by the ISV and is collected by Nuvla.io and goes to the ISVs (CLEMAP and Tvinn). SixSq as operator of Nuvla.io keeps 20% of application fees. Table 1 provides a possible scenario of these two items for the targeted market : context-aware, self adapted energy applications running on GEDs baset IT systems. Taking the form of a subscription, for each household (**we only consider here the L-GED market, not the M-GED**), a fee of 27 EUR per quarter is expected. Using the Nuvla.io marketplace pricing structure as a reference (https://nuvla.io/pricing), this translates into two main items: edge management (9 EURO) and edge applications (18 EURO) per quarter in Table 1. The marketplace will automatically split the fee per household to the three main stakeholders: SixSq, ISV and SI.

Since all transactions are automated, billing and invoicing are directly submitted to the SI and once payments are made, the Stripe payment system, integrated in Nuvla.io, distributes the funds.

		SixSq (Platform provider)	**ISV**	**SI**
Cost to serve (COGS)		7%	10%	
Cost of quarterly edge management	€ 9.00	44%	0%	56%
Cost of quarterly edge apps	€ 18.00	20%	80%	0%
Cost of quarterly	**€ 27.00**	**€ 7.60**	**€ 14.40**	**€ 5.00**
% Share of each stakeholder (Platform, SI, ISV)	100%	28%	53%	19%

Table 1: Distribution of costs between edge management and apps management. Share of each stakeholder (SI, ISV and the Platform Provider

This preliminary study (conducted by SixSq and HES-SO in 2020 and early 2021, with several Swiss stakeholders) applies the fee structure introduced above to the three commercial roles in the LASAGNE ecosystem, namely, System integrator (SI), edge-to-cloud marketplace platform (SixSq) and the Independent Software Vendor (CLEMAP and TVINN). The preliminary study gives an estimated volume of households that are likely to install and use L-GEDs, it does not address the M-GED market. The study was also completed by market insights provided by CLEMAP for the Swiss market and Tvinn for the Swedish market and extrapolating this to a neighboring market: Germany. The study also details the business model of the three commercial players : System integrator (SI), marketplace platform provider (SixSq) and the Independent Software Vendor (CLEMAP and TVINN).

Multiplication
In 2028 Switzerland aims at upgrading the electricity meter infrastructure to at least 80% of smart, digital meters. As the learning from the LASAGNE project, and in particular edge computing and negotiating capabilities, are upscaled in certified grid edge devices, flexibility resources become abundant and accessible to energy market players and the grid infrastructure is maintained instead of continuously expanded.

4.4 Project environment / Innovation / Added value

Make a list of current undertakings and existing solutions (national and international) and describe what distinguishes this project favourably from these, where the innovative aspects lie in terms of the current state of knowledge and what fundamentally new knowledge can be generated by the project. Describe which technical and/or scientific advantages will result from the new technology/solution/process and to what extent new knowledge, know-how and value creation can be generated.

The project has three key innovation elements: social acceptance by design, the framework with context-aware & self-adaptive prediction capability, and the marketplace concept.

Social acceptability by design

While engineering studies and social acceptance studies have been conducted independently so far, LASAGNE intends to merge the two approaches. **Social acceptance will be investigated using inputs from engineering calculations, and conversely**. Therefore, the findings of this project will provide indications about the solutions that receive highest social acceptance, among the solutions that are technically feasible and economically viable. Recall that participants are primarily involved in social interactions. So, identified social goals must be accepted from the beginning, such as community, socio-political and market goals. Thanks to this original contribution, LASAGNE will be properly contextualized and makes sense to all participants.

Framework for developing context-aware and self-adaptive energy applications

"Context-awareness" means here that GEDs are able to collectively self-adapt according to the "context" where they are deployed. The GED context depends on spatial/temporal conditions: appliances, weather, country regulation, social aspects, type of neighbourhood (residential, industrial, commercial), etc.: the intelligence is customised according to the context.
Self-adaptability is supported by a coordination model (deployed on GEDs) and prediction modules that are continuously improved using a feedback loop: **Fig. 4**. The goal is to minimise the prediction error. While such prediction tools already exist for high voltage levels, they have not yet been explored for medium/low voltage levels (microgrid, household).

Similar projects/products provide prediction functionalities that hint at those of LASAGNE. However, these do not cover self-adaptive, context-aware or distributed aspects. Unlike other projects like MuLDeR, where the intelligence is confined in the GEDs, LASAGNE aims to develop context-aware "ecosystem" where the intelligence is provided through networked Low-GED (L-GED) and Mid-GED (M-GED), as shown in Fig. 2.

The approach proposed by LASAGNE can be used to extend the QuartierStrom project, a centralised microgrid power management system based on real-time analysis of power consumption data. LASAGNE will go beyond this approach, by 1) distributing the power negotiation process over L/M-GED, which will act cooperatively under a coordination protocol, 2) optimising the overall microgrid's energy resources by forecasting power consumption at both household and microgrid levels via advanced ML models.
Concretely speaking, the LASAGNE platform will be composed of a:

- digital infrastructure with 3 layers: home appliances (heat pumps, boilers, EV charging stations, etc.), GEDs and a cloud platform.

- a digital framework providing collaborative ML based algorithms relying on a coordination model supporting collective interactions and coordination of activities among GEDs. The digital framework provides the backbone on which to develop context-aware/self-adaptive applications.

The framework is composed of couples <Learning, Prediction> modules, each is responsible for managing a particular aspect: local/global forecasting, forecasting peak loads, etc.

The prediction modules are self-adaptive: they are continuously improved using a feedback loop (**Fig. 4**). They gather real time data from the household or microgrid and attempt to forecast power consumption/production. When the performance of the prediction module drops, they send the data they failed to process to the learning module which collects these datasets and triggers a new learning cycle, resulting in a new deployed prediction module.

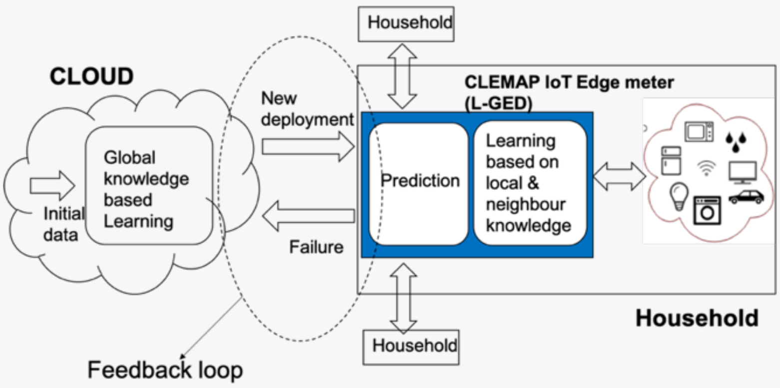

Fig. 4: Cooperative, self-adaptive forecast services applied to microgrid. In case of M-GED, communication is held with L-GEDs of the same microgrid and other M-GEDs.

Marketplace edge-to-cloud platform

The LASAGNE solution will leverage the marketplace provided by the Nuvla.io service and customize it to the energy market. Nulvla.io offers an agile mechanism to bring together the four stakeholders of the LASAGNE ecosystem. Finally, the ability to deploy a range of apps from independent software vendors, will ensure the solution can evolve, such that system integrators (SI) can continuously deliver innovation to their customers.

The Nuvla.io marketplace was released by SixSq in December 2020. An attractive aspect of the marketplace is its ability to establish a simple digital contractual framework, such that purchases and fund distribution is automated, simple and secure.

For example, Nuvla.io allows an ISV to set the price it wants for each app registered in the app store. The ISV can also either accept to follow the standard terms set by SixSq, or bring its own terms. Then, when a SI deploys an app on its customers' edge infrastructure, it accepts the terms and price, and the platform executes the app deployment. Since all stakeholders have accepted the terms of the platform, it can then issue invoices and payment instructions. Upon reception of payments, the platform then redistributes the payments to the ISV (typically 80% of the app store price) and the platform operator (SixSq).

With this level of automation in place, ISVs can be added to the platform, and SIs can choose which app and ISV to use. In agreement with the regulation and End-Customers, the SIs put in place a governance policy, such that only apps having been certified are allowed to be deployed.

4.5 Sustainability

Indicate to what extent this project supports the federal Sustainability Development Strategy in the dimensions of society, economy and environment on the national and the global plane.

The Federal Council has identified the three themes of "sustainable consumption and production", "climate, energy, biodiversity" and "equal opportunities" as priority issues, and has set targets for the period up to 2030, as well as strategic domestic and foreign policy guidelines for the federal government. Our project is fully in line with this strategy and fully integrates the three themes mentioned above. Within the framework of our project we want to encourage more sustainable energy production and consumption by making it possible for all citizens to become prosumers (i.e. both consumers and producers) in a logic of short cycles and therefore of local production and encourage local actors in promoting prosumer infrastructures. The globalisation of energy exchanges has indeed reached its limits and, as indicated by Federal Councillor Simonetta Sommaruga, Switzerland's autonomy and independence in terms of electricity is at stake. Moreover, the aim of these local productions is to produce electricity from renewable energy and here in particular from solar energy, which will have a positive effect on the climate and biodiversity. Finally, in terms of equal opportunities, which touches on the social aspect and more precisely on the social acceptance of our project, our approach is based on cooperation logics within the developed marketplace, which even if it keeps the economic element of skills, is oriented towards the notion of "coopetition".

4.6 Safety risks

Explain the risks to people and the environment that may arise through the project or through implementation of the corresponding technology/processes, and state which measures are planned to minimise such risks.

Does not apply to LASAGNE

4.7 Further federal contributions

Has (or will) an inquiry or an official application for further financial contributions been made to another federal funding institution (Innosuisse, SNSF, FOEN, FOT, FEDRO, SwissEnergy, etc.) for the current project or a related project?

☒ Yes ☐ No

If so, give the date of submission, the name of the funding institution and the decision and/or evaluation received.

Bridge SNSF/InnoSuisse. Will be submitted before May 17th. Partners: HES-SO, UniGE, HSLU.

5 Information for P+D projects

5.1 Measurement concept / Monitoring of performance

Describe the method with which the attainment of the project goals can be evaluated. Define the methodology, the tools employed and the duration and frequency of the planned measurements.

Click here to enter text.

5.2 Non-amortisable supplementary costs

Calculate the non-amortisable supplementary costs (NASC) of the project in comparison to a conventional system generating equivalent benefit, production or services. Complete the corresponding table in the Excel form "Project costs, financing and non-amortisable supplementary costs". Describe here how the capital costs, the annual operational and energy costs as well as any anticipated income or savings will arise for the conventional system and this project (if possible with cited references). The total capital costs (I_P) must concur with the total cost of the project (cf. paragraph 1.4). Examples of completed NASC forms are available at www.bfe.admin.ch/pilotanddemonstration

Click here to enter text.

5.3 Permits

List any permits required for the construction and operation of the plant and/or for carrying out the project, together with the status of the authorisation process and the date by which permits should be received (if not already authorised).

Click here to enter text.

6 Remarks

Click here to enter text.

7 SIGNATURES

This application has to be signed by all project partners who will actively participate in carrying out the project. By signing this application the project partners declare that the information given in this form and in the attached documents is truthful. Further, the project partners declare that they also agree to the publication and publicising of the results gained from the project in accordance with the Energy Ordinance (SR 730.01), Art. 61. In particular, project reports (interim and final reports) and the main project information will be published on the ARAMIS information platform (http://www.aramis.admin.ch) and, if applicable, the federal geoportal (http://map.geo.admin.ch).

Main applicant (institution):

HES-SO//Geneva

Place, date:	*Forename surname:*	*Signature:*
Geneva, 10th May 2021	**Nabil Abdennadher**	

Project partners (institution)

HES-SO//Valais

Place, date:	*Forename surname:*	*Signature:*
10th May 2021	**Emmanuel Fragnière**	

Project partner (institution):

Univ. of Geneva

Place, date:	*Forename surname:*	*Signature:*
10th May 2021	**Giovanna Di Marzo**	

Project partner (institution):

CLEMAP

Place, date:	*Forename surname:*	*Signature:*
10th May 2021	**Pascal Kienast**	

Project partner (institution):

Click here to enter text.

Place, date:	*Forename surname:*	*Signature:*

8 ANNEXES AND SUBMISSION OF APPLICATION

8.1 Research projects

The following documents must be attached to the application for financial support

- ☒ *Completed form "Project costs, financing and non-amortisable supplementary costs" (table "non-amortisable supplementary costs" not required) to be submitted as an Excel file.*
- ☒ *Written confirmations or declarations of intent stating the proposed financial participation of parties who have no active role in the project and participate exclusively in financing the project (third-party funds: cantons, building owners, foundations, associations, etc.).*
- ☐ *List of relevant sources/references on the topic (if available)*

The completed and signed application in German, French, Italian or English (digital signature or scan of the signatory page) including all the mandatory and optional annexes is to be submitted in digital form to the responsible programme manager

8.2 P+D projects and preliminary studies/monitoring of performance

The following documents must be attached to the application for financial support

- ☐ *Completed form "Project costs, financing and non-amortisable supplementary costs" to be submitted as an Excel file.*
- ☐ *If the SFOE funding contribution requested exceeds the sum of CHF 500'000, the most recent annual accounts and auditor's report (if applicable) of all project participants (apart from public organisations).*
- ☐ *Written confirmations or declarations of intent stating the proposed financial participation of parties who have no active role in the project and participate exclusively in financing the project (third-party funds: cantons, building owners, foundations, associations, etc.).*

The completed and signed application in German, French, Italian or English (digital signature or scan of the signatory page) including all the mandatory and optional annexes is to be submitted in digital form to pilot-demo@bfe.admin.ch.