**Discovery**

Project description

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**digiTal sELf-adaptivE smart-GRid platform(TELEGRAM)**

# Summary

The need for implementing an energy transition in favor of renewable and clean energy has become urgent and obvious. Many governments mention this issue as one of their top priorities and numerous programs, such as the Swiss “Energy Strategy 2050”, have been developed in order to maintain high standards of supply based on renewable energy sources while minimizing environmental damage.

Besides, new forms of electricity production and consumption are disrupting the market. Renewable energy sources (solar and wind) are by definition intermittent and distributed in vast numbers of small-scale decentralized energy producers, which affects grid management fundamentally. The decentralized production of electricity permits self-consumption of electricity (**prosumer**) and creation of peer-to-peer networks (**microgrids**). These are promoted by the Swiss Energy Law’s, 2018 revision. In parallel, consumption scenarios are shifting from fossil fuels to electricity in a series of domains.

In an interview on 17 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”.

We infer a growth opportunity for microgrids from these trends.

Functioning as enablers, digital transformation and new digital technologies (IoT, edge-cloud, ML/AI, blockchain, etc) are affecting production and consumption and reshaping the electricity market in fundamental ways. These technologies are pervasive in all aspects of the microgrid ecosystem: integration, systems and services, business models, and social acceptance. They are also mature enough to support smart energy management appliances (**SEMAs**) that can collect data, control devices, forecast consumption/production and negotiate energy transactions between stakeholders.

TELEGRAM aims to: a) Design and develop SEMA and b) Dynamically manage the microgrid infrastructure through the deployment of self-adaptive SEMAs that work collectively. This **“digitized layer”** that is in charge of managing the microgrid infrastructure is called the TELEGRAM Platform.

TELEGRAM will target three objectives:

1. Identify the economically feasible combinations of SEMAs and microgrids that receive the best social acceptance in the Swiss society. We will ensure that the proposed SEMA variants, (i) support the business regulations imposed by the different stakeholders, (ii) are in line with regulations, and (iii) respect the constraints and technical requirements of the microgrid installations, by optimizing through the application of Discrete Choice Experiment (DCE) procedures. This objective belongs to the socio-economic domain, but relies on simulation techniques to guarantee the best social acceptance of SEMAs and the TELEGRAM platform.
2. Learning and anticipating local and global consumption/production: an accurate forecast for consumption/production is necessary for ensuring reliable and stable grid operations. Consequently, this must be based on the development of suitable algorithms for appropriate global and collaborative learning across the TELEGRAM platform. This objective relates to global and collaborative machine learning in computer science.
3. A third pillar, needed to secure parts of the second objective, is a coordination model that makes collaborative learning between SEMAs possible. Our coordination model will leverage intelligent digital twins [[1]](https://paperpile.com/c/NKDwn1/eeaC), and guarantee the self-adaptation, reliability, robustness and stability of the TELEGRAM platform. This objective relates to self-adaptive systems in computer science.

Additionally, there are two technical objectives: Edge-cloud technology and negotiation. Our own expertise here will be amplified by our Advisory Board (AB) consisting of experts and business leaders. TELEGRAM and the after-project place a lot of importance on the role of the AB in the success and sustainability of our solution. Our ability to deliver a smoother, faster trading experience to the prosumer by means of Edge-cloud computing optimization and dynamic negotiation will be a key success factor for the TELEGRAM platform.

TELEGRAM is not about developing research in relation to physical electric constraints, since this is taken into account through existing technology. TELEGRAM leverages this technology, and is concerned with a digitized layer ensuring self-adaptive management of microgrids that takes into consideration dynamic needs of prosumers and social acceptance.

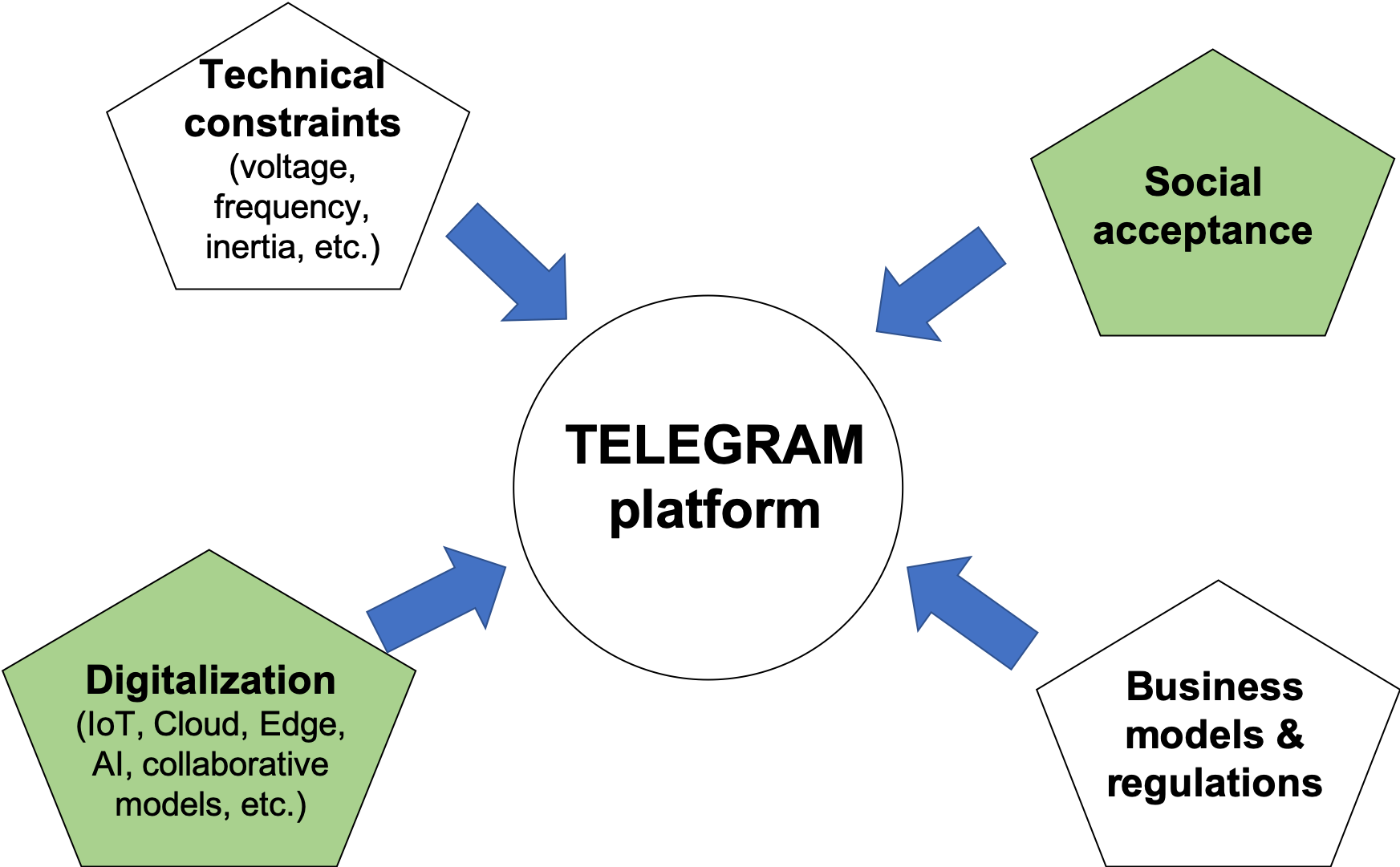
# Project description

To be able to build a viable and sustainable SEMA and TELEGRAM platform for managing microgrids in a collaborative manner as defined above, four cornerstones are needed (Figure 1):

1. Technical constraints: SEMAs must respect the laws of physics that govern a electric grid: voltage control, frequency and inertia control, constraints imposed by ***electric******energy companies***[[1]](#footnote-1), etc.
2. Business regulations: energy is a highly regulated market. SEMAs and the TELEGRAM platform are serving an emerging shift in the current business model and regulations. Rates, now set by electric energy companies, will be set more and more by peer-to-peer and decentralized negotiations in the light of new regulatory changes to come. The TELEGRAM platform respects them while allowing dynamic negotiations regarding prices and service level agreements.
3. Digitalization: to predict any production/consumption peaks at different levels, SEMAs and the TELEGRAM platform must rely on IT technology: Internet of Things (to collect and gather data), Artificial Intelligence (to set up predictive models and self-adapt), Cloud-Edge computing (to store and process data), collaborative models to ensure collaboration and negotiations, etc.
4. Social acceptance: for SEMAs to spread out, they must be accepted and used by the electric energy companies and prosumers; i.e. customers. Whether these actors would tolerate such appliances is far from obvious and acceptance constitutes a potential barrier for the adoption and diffusion of this new technology. The success of the energy transition hence depends on a mix of technological improvements and behavioral adaptations.

***TELEGRAM will rely on the two first cornerstones -in white in Figure 1- and will target elements of the two last ones: digitalization and social acceptance (in green in Figure 1)***. The TELEGRAM AB will help us ensure that the research and development carried out as part of the project are in line with the cornerstones of technical constraints and business regulations.

The TELEGRAM platform will be deployed on a fully operational electric microgrid infrastructure. As the main result from the project, electric energy companies can offer their prosumers (households, factories, buildings, and e-vehicle) the ability to trade surplus energy while optimising production and consumption and managing overall grid stability. This will be accomplished via the SEMA that we propose to develop during this project and deploy it as part of a self-adaptive digital platform (on top of microgrid infrastructures): the TELEGRAM platform.

**Figure 1**: The four cornerstones on which the TELEGRAM platform relies. The platform must take into account the two white cornerstones (as constraints) and target the green ones (as objectives)

Traditional power grids continue to be disrupted by the transformation from a centralized generation and distribution system to a fragmented microgrid-based market (Figure 2.1) and diverse mix of energy sources, some of which are intermittent by nature (e.g. solar power) and served by vast numbers of small scale, decentralized energy providers who both, consume and generate energy. With the lines between producers and prosumers of energy blurring and the additional consideration of energy being produced from a mix of traditional and renewable sources, our solution helps electric energy companies and prosumers manage production and consumption peaks while respecting the energy grid stability. Moreover, the end-user (prosumer) would like to trade “flexibility” or surplus energy production, thus saving money as well as potentially making money. Our project will establish a basic negotiation service only. It will be extended, during the post-project stage, to an economic model for peer to peer trading and negotiations.

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| Figure 2.1: Autonomous microgrids connected to the power grid and interacting with each other. | Figure 2.2: Zoom-in on a microgrid: Three configurations (colours) of SEMAs : m-SEMA, p-SEMA, c-SEMA |

We anticipate to deploy three types of SEMAs (Figure 2.2): **m**obile, **p**ersonal, and **c**ommunity SEMAs: m-SEMA (yellow), p-SEMA (blue) and c-SEMA (green). They are able respectively to act on behalf of e-cars, households and microgrids. Our goal is that SEMAs learn and anticipate the consumption/production of energy at local (mobile device & household) and global (microgrid) levels and are then able to trade within the network of SEMAs (TELEGRAM platform) for energy exchange. Our novel solution will create an economic opportunity for prosumers, electric energy companies and the SMEs developing and selling SEMA based solutions.

End-users (prosumers and electric energy companies) may be reluctant to adopt SEMAs and the TELEGRAM platform. This may slow down the rise of this new market if it is not supported by sociological approaches that facilitate its development and minimizes “non-adoption” risks. One of the objectives of this project is to explore the economically feasible combinations of SEMAs and the TELEGRAM platform that receive the best social acceptance. Because the design of SEMAs is evolving, many variants are conceivable, it is impossible to collect observational data (i.e., question actual SEMAs’ buyers). In such situations, stated preference approaches technique [[2]](https://paperpile.com/c/NKDwn1/3DdM), and in particular Discrete Choice Experiments (DCE) [[3]](https://paperpile.com/c/NKDwn1/GsFg), is the only possible way for conducting an investigation.

In TELEGRAM, SEMAs are autonomously and actively involved in both system-wide and local coordination tasks. Key elements to reach the TELEGRAM vision are a coordination model and intelligent digital twins. Together they will coordinate and support interactions of a large number of intelligent devices.

In this context, TELEGRAM will require expertise in the following four fields: (1) Machine Learning applied to Smart Grid, (2) Machine Learning deployed on resource constrained environments (edge devices: SEMA), (3) coordination model and intelligent digital twins and finally (4) social acceptance.

The next section will detail the state of the art and achievements already undertaken by the partners in these 4 relevant fields.

## Current state of research in the field

### 2.1.1 Machine learning applied to smart Grid

Accurate load prediction plays a very important role in the energy management of smart grids due to its impact on the reliable operation of power systems and on the economy. Many variables have an impact on the load forecasting, such as meteorological factors and consumption scenarios of individuals, buildings, transportation and infrastructures. The prediction of charging spatially dynamically changing consumers such as electric vehicles is an important aspect to consider in the future [[4]](https://paperpile.com/c/NKDwn1/qFW3) [[5]](https://paperpile.com/c/NKDwn1/gEPk).

A variety of artificial intelligence techniques have been used in research areas for electrical load forecasting. However, these prediction models have several weaknesses: low convergence, high computational complexity and local minimum problem [[6,7]](https://paperpile.com/c/NKDwn1/Z6UdW+tNzHo).  To tackle these problems, case studies have already been made with self-organization, self-configuration and multi-agent systems [[8,9]](https://paperpile.com/c/NKDwn1/6g1a0+hGxKP), but much more research is needed due to the enormous complexity and the numerous variables that must be considered.

Since ML techniques are not suited for execution on resource constrained edge devices such as SEMAs, the novel approach proposed by TELEGRAM is a collaborative machine learning (ML) technique embedded in smart appliances. We expect this innovative approach to cope with the high complexity of a decentralized and volatile environment.

### 2.1.2 Machine learning deployed in resource constrained environments

In the context of TELEGRAM, the SEMA is a resource-constrained edge device executing Machine Learning (ML) based algorithms. So far, ML techniques are not suited for execution on edge devices. Several research efforts aim to lighten ML algorithms in a way that saves computational resources but keeps good performance. [[10,11]](https://paperpile.com/c/NKDwn1/R49u+NhNTn)[[12]](https://paperpile.com/c/NKDwn1/q7Ia) tried to squeeze heavy ML techniques into edge devices by distributing the learning process. [[13]](https://paperpile.com/c/NKDwn1/O6LOV) worked on SVM techniques and managed to distribute learning over resources-limited devices containing each, a portion of the data.

[[12,14]](https://paperpile.com/c/NKDwn1/ctXXZ+q7Ia) reimagined popular ML techniques in a way that makes them less resources-greedy. The first, called Bonsai, is based on Tree algorithms used for efficient prediction on IoT devices. The second, called ProtoNN, is inspired by KNN (k-nearest neighbors).

State-of-the art ML models may need millions of parameters, e.g., the celebrated AlexNet has 60 million parameters [[15]](https://paperpile.com/c/NKDwn1/IhOz), occupying 240 MB of memory. Such a big model also needs high computational power to execute the prediction/inference task. It is then imperative to compress these models before deployment on SEMA. The existing works on model compression focus usually on image classification tasks and are not designed for complex interconnected cyber-physical systems like microgrid, where a lower decision accuracy at a few edge nodes (due to the use of a compressed model) may impact the entire network.

### 2.1.3 Coordination model and intelligent digital twins for microgrid management

Microgrids management involves a large number of heterogeneous entities (domestic appliances, smart meters, electricity storage or production) acting at different levels. A coordination model and intelligent digital twins are key elements for ensuring integration and collaboration of these heterogeneous decentralized entities.

Coordination models provide coordination media and mechanisms [[16]](https://paperpile.com/c/NKDwn1/xmV7), allowing entities to collectively and in a decentralized manner smoothly reach varied objectives linked with self-adaptive global or local management. Working on behalf of physical entities in microgrids, digital twins are “digital replicas of real-world devices” [[17]](https://paperpile.com/c/NKDwn1/68qF). In advanced settings “Intelligent digital twins” [[18]](https://paperpile.com/c/NKDwn1/Tw5B) become active alongside their physical counterparts [[1]](https://paperpile.com/c/NKDwn1/eeaC), physically connected at the infrastructure edge they are capable of learning and autonomy. Similar to autonomous software agents [[19]](https://paperpile.com/c/NKDwn1/KAMI)[[20]](https://paperpile.com/c/NKDwn1/wIvu) equipped with sensing and acting capabilities, they autonomously collaborate and interact with each other, erasing the underlying heterogeneity of their physical twin.

Even though digital twins gain interest in the power sector, their usage is still limited to modelling [[18,21]](https://paperpile.com/c/NKDwn1/Tw5B+2jfE), to simulations and real-time data analysis [[22,23]](https://paperpile.com/c/NKDwn1/q4Ic+rkcC). They are based on data-driven and real-time integration between digital and physical spaces [[24]](https://paperpile.com/c/NKDwn1/t0Hl). To cater for different and conflicting features of smart grids, [[25]](https://paperpile.com/c/NKDwn1/pYug) provides a holonic hierarchical coordination model, involving various bio-inspired decentralised patterns, e.g. stigmergy and collaboration. Unlike TELEGRAM, these proposals do not leverage the full potential of intelligent digital twins and do not support their interactions through a dedicated coordination model.

### 2.1.4 Social acceptance

To date, research on smart appliances for renewable energy management mainly focuses on technological aspects, but little information exists on the acceptance of such measures and on the end users’ preferences towards these new digital technologies. Only a few existing studies focus on the economic, social or behavioral barriers that prevent households from adopting technologies and management schemes (peer-to-peer trading, demand side management, storage capacities, dynamic pricing), that are interlinked with SEMAs.

Social acceptance is a sine qua non condition for smart grids [[26]](https://paperpile.com/c/NKDwn1/Hv1O). Indeed, a smart grid in the logic of participative management (C2C) and "prosumer" type actors [[27]](https://paperpile.com/c/NKDwn1/ggil) must be based on a strong commitment from the entire community. Section 2.4 details a famous example of this notion of acceptance applied to a real case, represented by the fully digital utility system OPOWER [[28]](https://paperpile.com/c/NKDwn1/u9gY).

A service acquires value once the client perceives the benefit of it [[29]](https://paperpile.com/c/NKDwn1/neBs). An attribute [[30]](https://paperpile.com/c/NKDwn1/hiUa) in a given service corresponds to a major element of perceived value in the eyes of the consumer. There are several kinds of attributes, some purely logistical (like recovery strategies for load balancing) and some more social-oriented (like trust building within the microgrid community). The latter are those we are primarily interested in, in order to achieve a goal of social acceptance for our system. Typically the selection of social-oriented attributes is based on Discrete Choice Experiment (DCE) optimization techniques [[31]](https://paperpile.com/c/NKDwn1/Cb1F) [[32]](https://paperpile.com/c/NKDwn1/X169) [[33]](https://paperpile.com/c/NKDwn1/pvvx).

## Own achievements in the field

The next four subsections present the areas of expertise of the three institutions involved in the project. These areas will be of great benefit to the project. For each section we highlight its relevance for the WPs.

### 2.2.1 Machine Learning applied to Smart Grid

HSLU has the expertise in machine learning, in particular in deep neural networks (DNN), to analyze power consumption data in order to identify individual loads or to make a consumption forecast for the total power consumption of an apartment or for individual devices. WP2 will be based on this expertise. HSLU has worked on several national research projects on Non-Intrusive Load Monitoring (NILM) using consumption data. The results of the NILM-algorithms serve as input for feedback systems that motivate people to save energy [[34]](https://paperpile.com/c/NKDwn1/OcKW) [[35]](https://paperpile.com/c/NKDwn1/wEhi) or indicate where devices offering flexibility are located and what the potential of flexibility is [[36]](https://paperpile.com/c/NKDwn1/wX4v). HSLU is currently working on a research project that aims to disaggregate industrial loads not only using overall consumption data but additionally using low-cost sensors measuring magnetic fields around supply cables for the machines [[37]](https://paperpile.com/c/NKDwn1/dyAo).

The second area covers the topic of consumption prediction where in a running project enerFACEpredict [[38]](https://paperpile.com/c/NKDwn1/Pmnu) HSLU analyzes historical data with DNNs to predict the future consumption to optimize the operating times of appliances to increase one’s own consumption. The prediction runs locally in a house. DNNs in other houses cannot benefit from what the local DNN has learned.

TELEGRAM will rely on the research work done in enerFACEpredict, and improve the DNN-based prediction algorithms so that they use a collaborative machine learning model supporting the exchange of learnings between different instances of a DNN. Additional information for enerFACEpredict can be found in the section “Further requested and obtained funding” in mysnf.

### 2.2.2 Machine learning deployed in resource constrained environments

This expertise is covered by HES-SO (HEPIA team)**.** WP4 (integration & deployment) and part of the research carried out in WP2 (Learning) and WP3 (Coordination model) will be based on this applicative expertise. The large scale distributed systems (LSDS) research group of HES-SO//HEPIA was involved in several projects related to Cloud, edge and IoT. These projects, funded by FP7, CTI, SEFRI, Innosuisse, and Swissuniversities are detailed in [[39]](https://paperpile.com/c/NKDwn1/ibtj).

LSDS is currently working on a research project that aims to develop a generic Intelligence as a Service (InaaS) architecture for IoT self-adaptive Machine Learning (ML) deployed on hybrid infrastructure (IoT devices, edge devices and cloud): MEDInA [[40]](https://paperpile.com/c/NKDwn1/IiG6). MEDInA targets smart city applications. If TELEGRAM is accepted, there will be a strong synergy with MEDInA. Additional information regarding this synergy is detailed in the section “Further requested and obtained funding” in mysnf.

LSDS is also working with a Swiss start up company on the development of a smart noise sensor coined *Real-Time Event Detector* (RTExD). By combining IoT, Acoustic and Artificial Intelligence technologies RTExD sensor offers a generic solution for traffic monitoring. The first prototype of RTExD, based on a Raspberry 4, uses neural networks to classify vehicles (cars, trucks, buses, motorcycles) [[41]](https://paperpile.com/c/NKDwn1/1HPU). Recently (April 2020), RTExD was used to quantify the road traffic during the COVID-19 confinement period and compare it to a “normal” road traffic [[42]](https://paperpile.com/c/NKDwn1/f9UW).

### 2.2.3 Coordination model and intelligent digital twins

This expertise is covered by UNIGE and provides the basis forthe research carried out in WP3. The Centre Universitaire d'Informatique of the University of Geneva (UNIGE) runs various EU, COST or Swiss (SNSF, Innosuisse) funded projects.

UNIGE develops coordination models and intelligent digital twins, coordination mechanisms and related design patterns since 2010 [[43]](https://paperpile.com/c/NKDwn1/r58j). UNIGE participated in the development of a highly-innovative coordination model and implementation (middleware) for the decentralized deployment of self-adaptive services provided by various entities [[44]](https://paperpile.com/c/NKDwn1/9kZn); and developed the decentralized algorithms supporting interaction, coordination and information flow among the entities [[45]](https://paperpile.com/c/NKDwn1/FCT9). UNIGE recently designed and deployed a *learning-based coordination model,* extending the original coordination model and the interacting entities with learning-based capabilities in order to provide necessary, pertinent and reliable services to the user [[46]](https://paperpile.com/c/NKDwn1/Fvnt).

These works leverage intelligent digital twins, that work on behalf of entities, such as connected objects, sensors or actuators and self-organize by interacting through a coordination middleware. The latter provides built-in features supporting decentralized interactions among digital twins [[45]](https://paperpile.com/c/NKDwn1/FCT9)[[43,47]](https://paperpile.com/c/NKDwn1/r58j+j616), and digital twin learning capabilities [[46]](https://paperpile.com/c/NKDwn1/Fvnt). UNIGE and HES-SO recently presented and deployed a set of use cases, like smart lighting [[48]](https://paperpile.com/c/NKDwn1/fYHq). Together with HSLSU they prototyped a coordination-based decentralized energy trading scenario [[43,47]](https://paperpile.com/c/NKDwn1/r58j+j616).

### 2.2.4 Social acceptance

This expertise is covered by HES-SO (Valais team). The research carried out in WP1 will be based on this expertise. The Institute of Tourism of the HES-SO Valais is specialised in various fields related to the notion of social acceptance of digital technologies in general in our societies. We have various specific themes related to social acceptance: firstly in tourism, where digitization is used to enable the creation of fluid and coherent customer journeys in a sector where typically many players work independently [[49]](https://paperpile.com/c/NKDwn1/pT37), secondly in e-society and e-democracy where people are reluctant to adopt electronic voting [[50]](https://paperpile.com/c/NKDwn1/gvCG) or e-participation technologies to take part in democratic debate, thirdly in the digitization of work where AI also creates a human risk and finally in energy and environmental planning by mixing social change with technological progress to reduce CO2 emissions[[51]](https://paperpile.com/c/NKDwn1/62YC). In relation to the 4 themes mentioned above relating to social acceptance we can mention the two following examples: 1. Innosuisse: Digitized governance tool to mitigate human-related risks where digitization is not addressed from a purely technological point of view, but from the point of view of the social acceptance as perceived by employees today [[52]](https://paperpile.com/c/NKDwn1/Ydgz)**.** 2. FNS: Design of a sustainable energy model by inclusion of behavioral and social parameters for Romania. Energy research shows that although technological progress should bring obvious efficiency gains, social change does not follow. Therefore, both technological and social aspects must be simultaneously optimized in order to have a real impact on the reduction of greenhouse gas emissions [[53]](https://paperpile.com/c/NKDwn1/QuHk)**.**

## 2.3 Scientific contents

TELEGRAM aims at developing a digital SEMA based self-adaptive decentralized platform to be deployed on a microgrid infrastructure: **TELEGRAM platform**: “Digitalization” cornerstone in Figure 1. The platform must take into account:

* The stability/reliability of the microgrid in a dynamic context. From a utility provider perspective, the TELEGRAM platform must respect the laws of physics: voltage control, frequency and inertia control. If some parameters are violated, the SEMA itself can initiate switching off/on some home appliances or invite the consumer to do so.
* The regulations and business models adopted by the electric energy companies.

These two constraints are represented by the two white cornerstones in Figure 1. In addition, the functionalities of the platform must be adopted by the different stakeholders (customers and electric energy companies). This aspect will be covered by the “social acceptance” cornerstone in Figure 1.

From an IT perspective (digitalization cornerstone in Figure 1), the TELEGRAM platform is composed of:

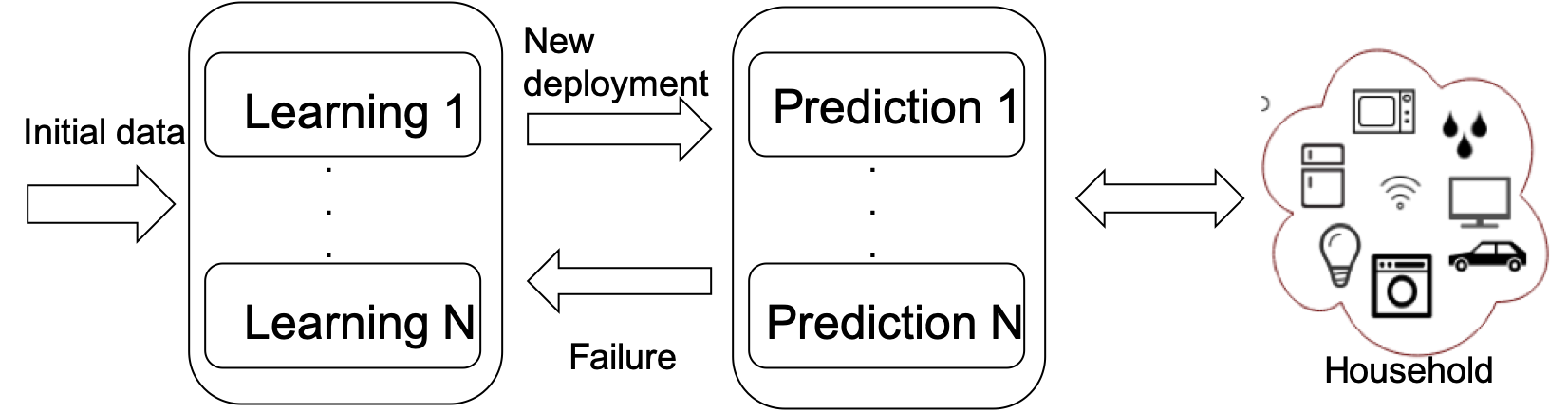
* A digital infrastructure with three layers:
  + home appliances,
  + SEMAs (edge devices)
  + cloud infrastructure.
* A self-adaptive application deployed on the digital infrastructure. The main aim of this application is to ensure self-adaptive management of microgrids while taking into consideration dynamic needs of users. This application is composed of a set of couples <Learning, Prediction> modules (Figure 3). Each couple of modules is responsible for managing a particular aspect of the TELEGRAM platform: predicting local consumption/production, predicting peaks of consumption/prediction, predicting the status of SEMAs with whom a negotiation could be successful, etc. 

Figure 3: The self-adaptive application of the TELEGRAM platform

There are mainly two families of Learning:

1. Global learning: this family relies on centralized data to generate prediction modules. This scenario is used, for example, to set up a plan for optimal operating times of household devices and provide this as “flexibility” to the grid in order to stabilize the grid. Flexibility here means, for example, to propose to the user an optimal time for switching on a device such as a washing machine. Other suitable devices are dryer, dishwasher, boiler or heat pumps. Further elements for flexibility are batteries located in a house, a microgrid or in electrical vehicles.
2. Collaborative learning: this family relies on local data of a single household (or microgrid) and data gathered from neighbor households (or microgrids). Because the real operating times of household devices depend also on users behavior, collaborative learning has to learn it locally. As an example, the collaborative learning scenario could be used during the negotiation process: a household decides whether it will consume, store, buy or sell energy based on local information and on information from the neighborhood.

The learning modules rely on data collected from the e-cars, home appliances, households and microgrids to generate predictions modules. If the gap between the prediction (estimated) values and the actual values becomes too large, corrective measures must be taken locally (e.g. release or request energy via neighboring SEMAs; switching off/on locally controlled consumers, compensation by inclusion of batteries). Besides, the prediction modules are continuously and automatically improved using a feedback loop to minimize the prediction error in the future.

This improvement follows a number of steps as shown in Figure 3: The learning module generates an initial prediction module from an initial set of training data. When deployed, the prediction module gathers real time data from the household and attempts to forecast electricity consumption/production in the future. The performance of the prediction module is continuously monitored: once the prediction is unable to make a reliable decision for a period of time, it sends the data it failed to process to the learning module. The learning module then collects these datasets and triggers a new learning cycle, resulting in a new deployed prediction module.

From a user perspective, the TELEGRAM platform will provide two functions:

* Learning/prediction function: the aim here is threefold: (1) respect the laws of physics: voltage control, frequency and inertia control, (2) avoid consumption peaks by synchronizing/coordinating consumers and producers, and (3) predict consumption/production at the three levels: e-cars (m-SEMA), household (p-SEMA) and microgrid (c-SEMA) in Figure 2.2. Although these three objectives are tightly linked, 1 and 2 are related to the electric energy companies perspective, while 3 represents the customer (prosumer and microgrid owner/admin) point of view. In order to fulfill 1, 2 and 3 , the SEMA will rely on a set of learning techniques: ***global and collaborative learning***.
* Negotiation function: The customer would like to trade flexibility or surplus energy production, thus saving money as well as potentially making money. Negotiation can be done at two levels: among p-SEMAs (within a given microgrid) or among c-SEMAs (inter-microgrid negotiation): Figures 2.1. A basic version will be deployed on the experimental platform that is set up as part of the project (WP4). A more advanced decentralized and peer-to-peer version is planned in the post-project roadmap.

The learning prediction function and SEMAs interactions will rely on a ***coordination model and intelligent digital twins*** providing built-in features for dynamic interactions, as well as learning and negotiations. Intelligent digital twins will work on behalf of physical entities such as e-car, smart meter, energy storage, home appliances, and SEMAs themselves.

Finally, the project will carry on a sociological study in order to guarantee the ***social acceptance*** of the TELEGRAM platform. For this purpose, the project will combine discrete choice experiment (DCE) to investigate social acceptance and simulation tools to ensure that the proposed SEMA functionalities (i) support the business models proposed by the different electric energy companies, (ii) are inline with regulations, and (iii) respect the constraints and technical requirements of the microgrid installations (white cornerstones in Figure 1). These functionalities are expressed in terms of “attributes” in DCE terminology.

To summarize, the project will target three scientific objectives: (i) global and collaborative learning, (ii) the design and development of a coordination model leveraging intelligent digital twins, with appropriate built-in features, to support the first objective and (iii) social acceptance in microgrid management. These three objectives will be detailed in the next subsections.

### 2.3.1 Global and collaborative learning

The goal of TELEGRAM is to deploy this self-adaptive application (Figure 3) on a set of collaborative SEMAs and a Cloud infrastructure. As explained earlier, two types of learning are to be considered:

1. Global learning (Figure 4.1) : Relies on centralized data to generate the prediction modules. For this purpose the algorithms are trained in the cloud and the resulting parameter sets (prediction module) are transferred to the SEMAs. Centralized data consists of the grid’s current state or conditions for managing the grid but also consumption/production data provided by SEMAs. In this scenario, even if the intelligence is pushed close to the data by deploying the prediction module on the SEMA, the SEMA intelligence is controlled by the cloud.
2. Collaborative learning (Figure 4.2) will propagate “knowledge” among neighboring SEMAs. SEMAs communicate asynchronously without having a global knowledge of the system. They support lightweight learning algorithms that can self-adapt without synchronisation with the cloud. To decide whether energy is consumed, stored, bought or sold not only a tariff signal is used but also the behavior and knowledge of other SEMAs. Based on its own and other’s knowledge, a SEMA switches devices on or off or makes corresponding proposals to users. This results in what we call SEMA’s collaborative intelligence.

**It’s worth reminding here that Figures 4.1 and 4.2 deal with the p-SEMA deployed at a household (Figures 2.2). The same goes with c-SEMA deployed at the microgrid level (Figures 2.1 and 2.2)** .

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| Figure 4.1: An Edge-Cloud architecture of the TELEGRAM platform (SEMA-controlled intelligence) | Figure 4.2 : SEMA-Collaborative intelligence (based on an Edge-Cloud architecture and a coordination model) |

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### 2.3.2 Coordination model and intelligent digital twins

In the TELEGRAM vision, SEMAs autonomously and actively engage in decentralized interactions and coordination with each other. They are also capable of sensing, acting, learning and negotiating. To reach this goal, we will consider:

1. Coordination model: at the heart of each SEMA, the implementation of a coordination model (in practice a middleware) provides: (i) a coordination medium allowing coordinated entities, in our case intelligent digital twins, to share information with each other, both locally and in a system-wide manner; (ii) coordination rules to dynamically process information flows among intelligent digital twins and system-wide across a network; (iii) built-in features for supporting intelligent digital twins for learning and negotiation.
2. Intelligent digital twins: working on behalf of their physical counterpart (smart meter, e-car, etc.), they physically reside inside a SEMA. They interact with their physical counterparts on the one hand (sensing, acting); and with each other through the coordination middleware on the other hand to organize their tasks both locally and system-wide (learning and negotiation).

### 2.3.3 Social acceptance

In order to offer a global assessment of the solutions that are both (i) technically and economically feasible/efficient and (ii) socially accepted, we will implement a three-step procedure:

1. In the first phase, which concerns the attributes of social acceptance, we will carry out an exploratory survey (semi-directive interviews, focus group and immersion episode) based on the principles of the ethnographic approach. The field phase will essentially be carried out among so-called prosumers under the supervision of the advisory board (in particular electric energy companies). The results will give us the most important social acceptance attributes. For example, these attributes may correspond to the local provenance of the energy or to the fact that the energy is of renewable origin.
2. In a second phase, based on simulation techniques (details are in WP1, Task 1.2), the attributes of social acceptance will be put to the test, allowing us to verify that the social attributes are in conformity/compatible with the physical constraints of the grid , the professional standards (SIA), and the laws in vigor (White cornerstones in Figure 1)
3. In a third phase, we will be able to feed a first DCE model in order to get a starting combination of social attributes with optimal weights that are at the same time feasible for the grid. This DCE approach will be later on reused in subsequent steps of the project in a dynamic manner in order to fine tune the overall social acceptance.

## 2.4 Innovative potential

As detailed in section 2.3 above, TELEGRAM’s research avenue is a decentralized self-adaptive platform which brings capabilities around global & collaborative learning, and negotiation at the microgrid level. It is designed from the outset to generate user trust and acceptance. We evaluated the hypothesis that the combination - Decentralization, Prediction, Negotiation and Social Acceptance by design- has unique innovative potential:

1. Decentralized architecture promotes scalability which allows the solution to grow from few dozens to few thousands of SEMAs.
2. Learning and prediction allows us to maintain a high level of reliability in the microgrid as well as allow prosumers automated flexibility of operation which is something they increasingly demand as well as come to expect.
3. Negotiation is an essential component for creating new market opportunities for us and other innovators. We can use this capability to create a revenue stream for prosumers, thereby increasing their satisfaction with microgrid participation. Increased user satisfaction can, in turn, speed up adoption of microgrids in new communities.
4. Social acceptance by design is an important consideration for us because new solutions must meet the increasing interest and evolving expectations of society around sustainable, self-sufficient energy systems and trust. Convincing households to accept smart appliances and capabilities is an important step towards achieving the objectives of the Energy Strategy 2050. Even the best technological solution would be rendered useless if people are reluctant to implement it. The success of the energy transition hence depends on a mix of technological improvements and behavioral adaptations.

### 2.4.1 Existing solutions vs. TELEGRAM platform

We compared our hypothesis (Decentralization, Prediction, Negotiation, and Social Acceptance by design) against 13 existing solutions that can be classified as a) products and b) platforms. These solutions are principally developed by three kinds of entities who serve the microgrid space:

1. Electric energy companies (as defined in the beginning of section 2)
2. Governments and research initiatives
3. Technology players (Artificial Intelligence and Machine Learning startups or specialists in large companies, IT and connected technologies, Data science).

Here are the 13 solutions:

1. [**OPOWER**](https://www.oracle.com/industries/utilities/products/what-is-opower.html) is a SaaS (Software as a Service) customer engagement platform for utilities, offered by a technology company (acquired by Oracle). It is feature rich and tailored for private utility companies operating in a fragmented and highly competitive market. Unlike OPOWER, TELEGRAM generates the potential for revenue for prosumers from automated energy trading.
2. [**Quartierstrom**](https://quartier-strom.ch/index.php/en/the-essentials-in-brief/) is Switzerland’s first local electricity market, consisting of 37 households, developed through the pilot, demonstration and lighthouse program of Swiss Federal Office of Energy (SFOE). Through a blockchain-based trading system (Local Energy Market platform built by EXNATON), PV-owners sold their locally produced electricity to their neighbors in Walenstadt. Quartierstrom is a collaboration between government, academic, and industrial partners.
3. **Local Energy Market** is a software billing platform, powered by a data analytics engine, for energy providers. It allows their customers to exchange energy directly and is offered by [EXNATON](http://www.exnaton.com), who built the software for the SFOE Quartierstrom pilot project above. There is a clear potential for EXNATON to expand their commercial footprint by partnering with TELEGRAM.
4. [**Patagonia Energy Applications**](https://osgp.org/en/news/press_details/Networked-Energy-Services-Expands-Smart-Grid-Market-Share-in-Switzerland) Smart Meter platform is offered by the US technology company NES (Networked Energy Services) in collaboration with local cooperative, IWB (Industrielle Werke Basel), to IWB customers. However, TELEGRAM takes the next step of prediction versus the condition monitoring and response focus of the Patagonia Energy Applications platform.
5. [**GRIDEYE**](https://www.depsys.ch/solutions/) is a digital grid optimizer featuring an IoT communications platform for power distribution networks, offered by technology company, DepSys, active in the energy market. The data analysis journey of Grideye - balancing of generation and consumption - makes them an interesting potential partner around our additional capabilities in prediction and negotiation.
6. [**GRIDBOX**](https://www.smartgridsolutions.ch/en/gridbox/) provides a self-adaptive application platform for devices in the distribution grid, developed through a collaboration between the SFOE and two local/municipal utilities. Whereas GRIDBOX focuses on condition monitoring, TELEGRAM moves beyond and integrates predictive capabilities and negotiation of automated energy trades.
7. [**Connected Life at Home**](https://www.cisco.com/c/en/us/solutions/service-provider/connected-life-at-home/index.html) by technology company Cisco is a platform offering at the intelligent home-appliance level. The SEMA could plug into its connected appliance platform at the household level for quicker deployment and usage data gathering.
8. [**Smart Meter Toolbox**](https://www.ben-energy.com/de/smart-meter-toolbox)by German AI company, [**BEN Energy**](http://www.ben-energy.com), is a physical device operating at the customer’s site in standalone mode or linked to other Smart Meter technologies. It gathers customer behavior insights, based on Smart Meter usage data.
9. [**Sunny Home Manager**](https://www.sma.de/en/products/monitoring-control/sunny-home-manager-20.html) is an energy and power monitoring and management device with visualization capability, at the household level from technology company, SMA.
10. [**Kapsch**](https://www.kapsch.net/) Smart Energy GmbH is an Austrian smart meter company which offers a flexible and meter independent system software, Meter Data Management.
11. [**IDSPECTO**](https://www.goerlitz.com/metering-information-system.html?&L=1) is a metering information system structured around a central data and process hub, by technology company, Görlitz. This looks to be a software application, not platform, modular set up for easy adding of additional functions.
12. [**Swisscom**](https://www.swisscom.ch/en/business/enterprise/offer/iot/smart-metering.html) offers optimal infrastructure and connectivity solutions for smart metering in Switzerland. The emphasis on reliable connectivity, secure data management, services-modularity all lend themselves to an uninterrupted meter data management at the microgrid level and hence, this makes Swisscom an attractive partner for TELEGRAM on the enablement of capabilities side (prediction and negotiation).
13. SOLOGRID-This project from Alpiq InTec established a generic box focussed on one application, i.e. stabilising the voltage band in the low voltage grid. The product is not available anymore after Alpic InTec was bought by Bouygues group.

A common theme we came across while examining existing solutions is a strong element of collaborative innovation. From among the 13 existing solutions, we narrowed down the comparator analysis to 6 platform offerings as being closest aligned with the functional purpose of the TELEGRAM platform. We compared them to TELEGRAM on 4 dimensions: Architecture (central vs. decentralized), prediction, negotiation and social acceptance (See Table below).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Platform offering** | **Architecture (de/centralized)** | **Prediction** | **Negotiation** | **Social Acceptance (by design)** |
| [OPOWER](https://www.oracle.com/industries/utilities/products/what-is-opower.html) | Centralized | No | No | Yes |
| [LOCAL ENERGY MARKET](http://www.exnaton.com) | Decentralized (blockchain) | No | Yes | Yes |
| [PATAGONIA APPLICATIONS PLATFORM](https://www.networkedenergy.com/en/products/smart-meter-applications) | Decentralized | No | No | Partial (local utility) |
| [GRIDEYE](https://www.depsys.ch/solutions/) | Decentralized | No | No | No |
| [GRIDBOX](https://www.smartgridsolutions.ch/en/gridbox/) | Centralized | No | No | No |
| [CONNECTED LIFE AT HOME](https://www.cisco.com/c/en/us/solutions/service-provider/connected-life-at-home/index.html) | Centralized | No | No | No |

It is worth noting that the product makers BEN Energy, SMA, and Kapsch as well as Swisscom are viewed as potential partners whose products TELEGRAM can help expand. We can involve them after acceptance and for a future market oriented project around commercialization (e.g. Eureka, Innosuisse, InnoEnergy, etc). See further elaboration in section 2.5.2. Furthermore, we have evaluated existing solutions for negotiation because it will be covered from a scientific perspective post-project.

### 2.4.2 TELEGRAM Unique Selling Point (USP)

Unlike the existing solutions we presented above, we claim that we cover the four dimensions detailed in section 2.4.1 and this is our unique selling point.

In addition, our approach is a combination of edge and cloud. It brings the best out of each and makes it possible to provide a seamless and reliable service to the customers. Indeed, several researchers agree that Edge computing (the SEMA in our case) can boost the performance and the security of applications. This is through offering real-time processing offloading the data computing services from the cloud, aggregating and filtering data, anonymising data in a privacy-preserving way.

### 2.4.3 Impact

Finally, a short tie-in to why TELEGRAM is timely and likely to succeed in Switzerland and beyond. Energy Strategy 2050 (introduced in the summary) puts priority on, a) Use of new renewable energy, b) Increased energy savings, c) Expansion of hydropower, d) Gas production and imports, only if necessary. This is relevant for TELEGRAM because the expansion in the use of renewable energy is viewed as a key offset to the drop in generation from the eventual petering out of nuclear generation. The country’s five nuclear power plants continue to run but will not be replaced at the end of their lifespan, the last of which is expected in 2034.

Further, the Swiss government acknowledges the need to develop self-sufficiency in key areas following the coronavirus pandemic of 2020. The Swiss President, Ms. Simonetta Sommaruga, spoke in an Apr 2020 [Le Temps](https://www.letemps.ch/opinions/petrole-masques-combats-suisse) interview emphasizing three key post-pandemic areas of changed focus: a) Increased self-sufficiency around medical supplies and energy, b) changes to basic supply chains and c) changing work styles. In her words, “More than ever, we must strengthen the production of indigenous renewable energy”. Our focus on providing novel user capabilities around indigenous energy production in Swiss microgrids is strongly aligned to the direction of energy the country wishes to pursue in 2020 and beyond.

### 2.4.4 Market outcomes

In addition to the positive social impact we outlined just above, we also anticipate positive market/economic impact. The design of the TELEGRAM platform allows for quick scale and adaptations for future growth. We anticipate that our solution, designed to engender trust and provide powerful capabilities, would create new opportunities in the microgrid market for new prosumer services and to support microgrid adoption throughout the country. We have developed these market outcomes further and we examined them in detail in section 2.5.2.

## 2.5 Project plan

### 2.5.1 Methods & Milestones

The project is composed of 6 WPs detailed in this subsection. Their organisation is also presented in the GANTT diagram (page 17)

**WP0: Management (HES-SO//HEPIA,** all**)**

The TELEGRAM project Management Team is composed of 4 members: Giovanna Di Marzo (UNIGE, coordination models and intelligent digital twins expertise), Andreas Rumsch (HSLU, Machine Learning expertise), Emmanuel Fragnière (HES-SO, social acceptance) and Nabil Abdennadher (HES-SO, edge-Cloud expertise). This team will be responsible for the management, communication, dissemination and quality checking of the project (Figure 5).

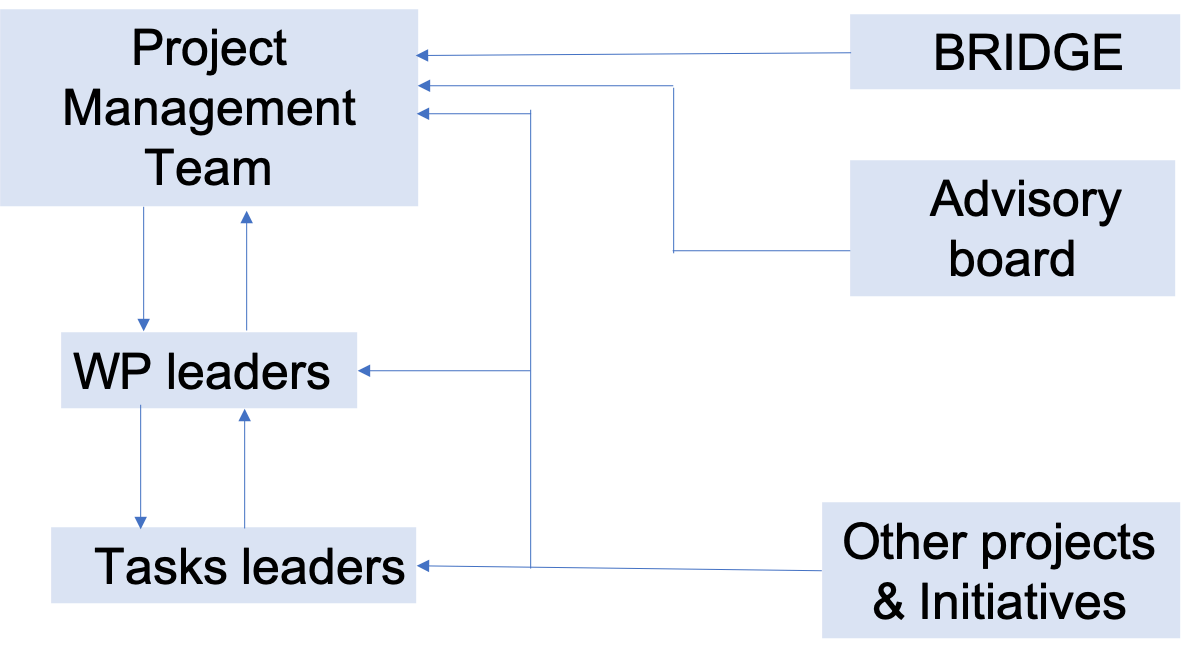


Figure 5: Project management organization chart.

**Task 0.1** **Management & communication:** Early in this work package, the consortium will determine the parameters of data governance and define how it will be applied. Critical questions must be answered in accordance with all applicable data privacy regulations all along the data pipeline. Communication includes the periodic management meetings, reporting and other external updates

**Task 0.2** **Advisory board meetings**: Manage the Advisory Board and kickoff the members engagement with an introductory meeting where they will learn about TELEGRAM in detail, including the Risks identified to date, exchange ideas on science challenges, the size of opportunities in the market, brainstorm on the ways in which future markets may be within the consortium’s power to advise or influence. The tone will be set in this initial meeting for the high level strategic roadmap of the project. At least 2 meetings / year are planned (Q1 and Q3)

**WP1: Social acceptance (HES-SO//Valais,** HES-SO//HEPIA**)**

The aim of this WP is to identify the main attributes that will make the community of prosumers share the same social values and therefore fully play the game of cooperation within the microgrid. The three following tasks are related to the three-step procedure detailed in Section 2.3.3.

**Task 1.1** **Ethnographic survey**: Initially, we will base ourselves on an ethnographic survey in order to identify the most important attributes of social acceptance for the future prosumer community (e.g. digital trust, sustainable development, energy independence, etc.).

**Task 1.2** **Technical feasibility of attributes**: This ethnographic analysis will be fire tested (simulation-based) in order to sort out these social acceptance attributes with regard to logistical attributes (physical attributes as well as regulatory and normative aspects). Concretely speaking, a simulation framework [[54]](https://paperpile.com/c/NKDwn1/GudZ) will be used for this purpose. This framework allows to simulate (i) the behavior of the power grid, household appliances and their physical effects, (ii) and the behavior of the people (how their electricity base consumption is and how they would configure their electric devices). The simulator will be extended to support a new device: the SEMA. The simulation will be calibrated on the basis of existing smart meter data from Swiss households available to the research team (see letter of support from Groupe-E and SI Nyon). This exercise will enable us to rank the attributes in terms of their expected technical efficiency.

**Task 1.3 Conjoint analysis survey and first DCE optimization.** The social acceptance attributes finally selected will be the subject of a quantitative survey based on the conjoint analysis and will feed a Discrete Choice Experiment model in order to determine the optimal weights of these attributes. This will be the basic model which will then be dynamically refined at the WP2 and WP3 levels.

**Deliverables**

D1.1 (Q1, Y2). Report consists of a detailed ethnographic study about social acceptance attributes regarding our specific fieldwork.

D1.2 (Q1, Y2) Deliverables consist of computerized data files resulting from DCE optimizations that will feed WP2 and 3.

**WP2: Learning and prediction (HSLU,** HES-SO//HEPIA**)**

In WP2 we address the prediction of consumption/production for an e-car, a household or a microgrid that is done on the 3 types of SEMAs. The WP comprises the processing of data, the investigation of global learning and collaborative learning.

**Task 2.1** **Data processing**: In this task we process consumption and production data from households and a microgrid to identify outliers and missing data. Anonymized data is provided by the two advisory partners, SI Nyon and Groupe-E (see letters of support). The result is a good quality dataset ready to use for the training of the machine learning algorithms.

**Task 2.2** **Global learning**: In this task, the intelligence is pushed close to the data by deploying the prediction on the SEMA. The global learning, meanwhile, is executed on the cloud (Figure 4.1). The parameter sets are the weights of the neural networks that run on the SEMAs. The training is triggered by the SEMAs when the performance of their prediction modules decreases. The main challenge we will face here is related to memory footprint and computational requirements of the inference step of the trained model. This task will rely on WP4 to (i) transfer the parameter sets from the cloud to the local networks in the SEMAs and (ii) send low performance data (low performance means here that prediction does not match with the real consumption/production) to the cloud where the global learning resides. The cloud then collects these datasets from different SEMAs and triggers a new learning cycle, resulting in a new configuration which will then be pushed back to the SEMAs.

A further aspect that we address in this task is the social attribute relating to digital trust. Therefore this task relies on findings of WP1, T1.2.

**Task 2.3** **Collaborative learning**: neighboring SEMAs will work together. To decide when a device should be switched on or off, a SEMA evaluates external data (tariff signal, e.g.), internal data (consumption data) and data from other SEMAs. To control household devices or get data from sensing devices the module communicates to intelligent digital twins[[2]](#footnote-2), which in turn communicate with the devices. The findings of this task will be combined with those of T3.2 and rely on T3.3. Effective integration will be done by Task 4.3.

We investigate algorithms for collaborative learning, mainly lightweight machine learning algorithms that can be executed on the constrained resources. We enable a single SEMA to interact with other SEMAs of the same type (p-SEMA - c-SEMA) or a different type. Therefore we will investigate how a SEMA can differentiate between the source of data from other SEMAs and how this inter-level knowledge can be integrated.

A further topic of research is the relationship between collaborative learning and the digital twins. It has to be investigated which information the digital twins need and how the information of the digital twins flows back to the collaborative learning. Additionally, collaborative learning has to adapt when the digital twins change due to updated models. This part of the task relies on the findings of WP3, T3.2.

**Deliverables**

D2.1 (Q3, Y1): First version of a self-adaptive application composed of prediction and “global learning algorithms”. The prediction module is not optimized to run in a resource constrained environment. It’s deployed and executed on the cloud.

D2.2 (Q1, Y2): A second version of the application with a prediction module optimized to run on a resource constrained environment (SEMA).

D2.3: (Q2, Y2): First version of collaborative learning running on the SEMA without interaction with the digital twins.

D2.4: (Q4, Y2): Second version of collaborative learning supporting interaction with the digital twins.

**WP3: Coordination model and intelligent digital twins (UNIGE,** all**)**

SEMAs engage in decentralized interactions and coordination with each other. This is done by intelligent digital twins residing inside SEMAs, autonomously and actively interacting and coordinating their tasks with each other locally and system-wide thanks to a coordination middleware. WP3 addresses these elements.

**Task 3.1 Coordination model and intelligent digital twin model**: This task aims to design a model for the coordination middleware and the intelligent digital twins to deploy on SEMAs.

The coordination model serves to coordinate digital twins tasks. It is made of 3 elements: (i) c*oordination media*, a shared repository serving to share information among the entities in asynchronous manner; (ii) *coordination rules* aggregating automatically and dynamically this information, including alerting the relevant digital twins; (iii) built-in features for collaborative learning (Task 2.3), negotiation (Task 4.4) and communication over a network.

The intelligent digital twin is based on various parts: a dynamically updated model of the environment and the corresponding physical twin; a dynamically updated model of social acceptance features (Task 1.3); interactions capabilities with the coordination middleware (injecting, retrieving information); interactions with its physical counterpart (sensing, acting); learning (Tasks 2.2 and 2.3) and negotiating capabilities (Task 4.4).

**Task 3.2 Coordination middleware and intelligent digital twins implementation**: The aim of this task is to implement (i) the coordination model elements as a middleware (coordination media, primitives to activate coordination rules, built-in learning, negotiation and communication features) and the elements of the digital twins as defined by the previous task.

**Task 3.3 Coordination rules - algorithms and implementation**: Information flow is driven by coordination rules processing messages and data exchanged among digital twins for collaborative learning and negotiation. Algorithms for information flow are crucial for decentralized coordination. This task will design and implement algorithms for coordination rules. They apply on information provided by the digital twins in the coordination medium to dynamically aggregate it, propagate it further, or remove it if outdated, and this both locally and system-wide. Algorithms follow decentralized patterns.

**Deliverables:**

D3.1 (Q4, Y1): First version of coordination model and intelligent digital twin model   
D3.2 (Q2, Y2): First version of coordination middleware and intelligent digital twin core implementation   
D3.3 (Q3, Y2): Revised version of coordination model and intelligent digital twin model  
D3.4 (Q3, Y2 ): First version of coordination rules - algorithms and implementation  
D3.2 (Q1, Y3): Revised version of coordination middleware and intelligent digital twin core implementation  
D3.4 (Q2, Y3): Revised version of coordination rules - algorithms and implementation

**WP4: Integration & Deployment (HES-SO, HEPIA team,** all**)**

The goal of this WP is to set up the whole TELEGRAM platform. Concretely speaking, WP4 aims to integrate all the deliverables developed in WP2 and WP3 and deploy the self-adaptive application (Figure 3) on an Edge-Cloud solution. This edge-cloud solution is enhanced with an intelligent digital twins based coordination middleware. WP4 will also develop a basic negotiation service to enhance the platform with a trading service. It’s worth reminding here that the goal is to prepare a Proof of Concept of the negotiation service in preparation for a more substantial post-project study. The expertise of EXNATON will be of a great help (see letter of Support). Finally the WP will deploy the TELEGRAM platform on a test-bed microgrid infrastructure.

**Task 4.1 Selecting and customizing an Edge-Cloud solution to the TELEGRAM platform** (HES-SO//HEPIA): In the MEDInA project, the HES-SO conducted a comparative study of the edge-cloud technologies on the market (Amazon, Google, Azure, etc.) [[55]](https://paperpile.com/c/NKDwn1/ZqPx). This study concluded that the NuvlaBox/Nuvla solution proposed by SixSq has several advantages: it is open source and offers an easily adaptable ecosystem for TELEGRAM. As specified in the LoS of SixSq, TELEGRAM will rely on the SixSq technology to set up the IT edge-cloud infrastructure and deploy the self adaptive application introduced in section 2.3 and developed in WP2. The SEMA hardware will rely on the NuvlaBox appliance. Nuvla.io will be used to deploy all applications on the SEMA devices. The aim of this task is to customize the Nuvla/NuvlaBox to the TELEGRAM platform.

**Task 4.2 Integration and Deployment of global learning on the Edge-Cloud solution** (HES-SO//HEPIA, HSLU): This task will deploy the feedback loop of the global learning process (WP2, Task 2.2) on the edge-cloud solution. this corresponds to the SEMA controlled intelligence explained in Figure 4.1

**Task 4.3 Extending the Edge-Cloud solution to support collaborative learning**: In this task, the selected edge-cloud infrastructure will be enhanced by the capability of having an edge to edge communication (SEMA to SEMA). This is done by integrating the coordination middleware and intelligent digital twins (Tasks 3.2, 3.3). The resulting platform will be used to deploy the collaborative learning (Task 2.3, Figure 4.2).

**Task 4.4 Negotiation**: This task will deploy a basic negotiation service on the TELEGRAM platform. This service will rely on the outcomes of tasks 3.1 and 3.2. Negotiations will be held between prosumers to exchange energy transactions, setup SLAs and rates.

**Task 4.5 Deploying and validating the TELEGRAM platform on a test bed microgrid infrastructure**: This task aims to deploy the TELEGRAM platform on an experimental lab microgrid infrastructure composed of at least 10 virtual households. There will be a dedicated SEMA installed in each household (living labs) of the microgrid. The SEMAs will be connected to a common Cloud infrastructure. We will be able to test the collaborative communications between SEMA as well as examine the data flow from ingestion to cloud learning and the learning at the cloud and edge and ensure that it is robust and functioning according to design.

**Deliverables**

D4.1 (Q1, Y2): An edge-cloud version of TELEGRAM platform for global learning

D4.2 (Q3, Y3): A collaborative (edge-edge) version of TELEGRAM platform for collaborative learning

D4.3 (Q3, Y3) : A basic negotiation service deployed on the TELEGRAM platform

D4.4 (Q4, Y4): A microgrid integrated system composed of a test bed microgrid infrastructure and a TELEGRAM platform

**WP5: Dissemination & Outreach (UNIGE,** all**)**

**Task 5.1. Industrial Workshops** (HSLU, HES-SO)**:** In order to reach out industrial players, identify trends, future use cases and partners, we will organise three industrial workshops in collaboration with the expert group “Swiss Intelligent Energy Systems Network” (being setup) of the Swiss Alliance of Data Intensive Services (Q4 of 2021, 2022, 2023). See LoS of D+S. We will invite the main Swiss industrial players of the energy sector as well as selected European ones (e.g. UK, Netherlands, etc).

**Task 5.2. Publication Plan and DMP** (all)**:** We will disseminate results to the research community through a variety of refereed channels such as international conferences, open access journals (transactions and magazines). We prepare collected and processed data, including software codes, according to the DMP and make them available through Yareta[[3]](#footnote-3), the research data repository of Geneva’s higher education institutions, in compliance with the FAIR principles

**Task 5.3. International Academic Workshop on microgrid management** (UNIGE - HES-SO):to reach out to the academic community, besides publications, we will organise a peer-reviewed academic workshop on the topic of adaptive solutions for microgrid management within a major conference of the area (energy conference). Proceedings will be published in a referenced book or online library.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **Y1** | | | | **Y2** | | | | **Y3** | | | |
| **Quarters** | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| **WP0 – Project Management (HES-SO//HEPIA, all)** |  | | | | | | | | | | | |
| T0.1 Management & communication |  |  |  |  |  |  |  |  |  |  |  |  |
| T0.2 Advisory board meetings |  |  |  |  |  |  |  |  |  |  |  |  |
| **WP1 – Social acceptance (HES-SO//Valais, HES-SO//HEPIA)** |  | | | | | | | | | | | |
| T1.1 Ethnographic survey |  |  |  |  |  |  |  |  |  |  |  |  |
| T1.2 Technical feasibility of attributes |  |  |  |  |  |  |  |  |  |  |  |  |
| T1.3 Conjoint analysis survey and first DCE optimization |  |  |  |  |  |  |  |  |  |  |  |  |
| **WP2 – Learning and prediction (HSLU, HES-SO//HEPIA)** |  | | | | | | | | | | | |
| T2.1 Data processing |  |  |  |  |  |  |  |  |  |  |  |  |
| T2.2 Global learning |  |  |  |  |  |  |  |  |  |  |  |  |
| T2.3 Collaborative learning |  |  |  |  |  |  |  |  |  |  |  |  |
| **WP3 – Coordination model and intelligent digital twins (UNIGE, all)** |  | | | | | | | | | | | |
| T3.1 Coordination model and intelligent digital twin model |  |  |  |  |  |  |  |  |  |  |  |  |
| T3.2 Coordination middleware and intelligent digital twins implementation |  |  |  |  |  |  |  |  |  |  |  |  |
| T3.3 Coordination rules - algorithms and implementation |  |  |  |  |  |  |  |  |  |  |  |  |
| **WP4 – Integration & deployment (HES-SO//HEPIA, all)** |  | | | | | | | | | | | |
| T4.1 Selecting and customizing an Edge-Cloud solution to the TELEGRAM platform |  |  |  |  |  |  |  |  |  |  |  |  |
| T4.2 Integration and Deployment of global learning on the Edge-Cloud solution |  |  |  |  |  |  |  |  |  |  |  |  |
| T4.3 Extending the Edge-Cloud solution to support collaborative learning |  |  |  |  |  |  |  |  |  |  |  |  |
| T4.4 Negotiation |  |  |  |  |  |  |  |  |  |  |  |  |
| T4.5 Deploying the TELEGRAM platform on a test bed microgrid infrastructure |  |  |  |  |  |  |  |  |  |  |  |  |
| **WP5 – Outreach & dissemination (UNIGE, all)** |  | | | | | | | | | | | |
| T5.1 Industrial Workshops |  |  |  |  |  |  |  |  |  |  |  |  |
| T5.2 Publication Plan and DMP |  |  |  |  |  |  |  |  |  |  |  |  |
| T5.3 International Academic Workshop on micro-grid management |  |  |  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Milestones** |  |  |  | **M1** | **M2** |  | **M3** |  | **M4** | **M5** | **M6** | **M7** |
|  |  |  |  |  |  |  |  |  |  |  |  |  |
| M1: Attributes technically feasible |  |  |  |  |  |  |  |  |  |  |  |  |
| M2: Attributes technically feasible (after DCE: weights, values) |  |  |  |  |  |  |  |  |  |  |  |  |
| M3: Global learning deployed on Edge-Cloud infrastructure |  |  |  |  |  |  |  |  |  |  |  |  |
| M4: Collaborative learning (supporting intelligent digital twins) |  |  |  |  |  |  |  |  |  |  |  |  |
| M5: TELEGRAM platform supporting (1) negotiation, (2) global & collaborative learning (with coordination middleware and the digital twinsg |  |  |  |  |  |  |  |  |  |  |  |  |
| M6: Deploying the TELEGRAM platform on the test-bed microgrid infrastructure |  |  |  |  |  |  |  |  |  |  |  |  |
| M7: Final report, implementation plan, DMP, white paper for thernational workshop |  |  |  |  |  |  |  |  |  |  |  |  |

**TELEGRAM GANTT diagram**

**The consortium**

The TELEGRAM consortium is composed of three full academic partners (funded by BRIDGE: HES-SO, HSLU and UNIGE) and 7 ***advisory partners*** (not funded by the project), who will compose the ***Advisory Board*** of the project. They are split into three families : end-user (electric energy companies), IT infrastructure and software integrators partners:

1. **Full academic partners**:
   1. HES-SO. Two teams are involved: HEPIA and Valais. The former brings its expertise in Edge-Cloud technology and deploying ML algorithms on resource constrained environments. The latter is specialised in social acceptance.
   2. University Geneva: coordination and communication modeling, designing collective and self adaptation, intelligent digital twins.
   3. HSLU: AI and ML techniques applied to smart grid and renewable energies.
2. **End-user partners** are electric energy companies. We are pleased to have [GroupeE](https://www.groupe-e.ch/fr) and [SINyon](https://www.sinyon.ch/) on board as key advisory partners. They will bring us grid expertise, access to smart grid relevant data for both training and validation of models, algorithms and simulations feedback that will help us validate technical functioning of the solution in the field, as well as the SEMA compliance with electric grid regulations. Further, their interface with prosumers affords us the opportunity to examine social acceptance in reality.
3. **IT Infrastructure partner**: [SixSq](https://sixsq.com/), based in Geneva, will provide the infrastructure for Edge-Cloud deployment. This consists of a) the Nuvla.io edge-to-cloud management platform offered as a service and capable of enabling remote management of the SEMA devices and b) the NuvlaBox® technology (hardware and software) that will be used as a baseline to design and develop the SEMA.
4. **Integrator, ML and data science partners**: This group includes 3 partners: KTH, EXNATON and the Swiss Alliance for Data Intensive Services (D+S). KTH will provide feedback to improve the inputs into research and training of the machine learning models, facilitating access to another market in Europe (that of Sweden). EXNATON provides expertise and brings us in contact with new potential commercial partners. Swiss Alliance for Data Intensive Services provides access to expertise within its member and partner base in industry and academia. In particular, the Swiss Intelligent Energy Systems (being setup) of D+S will be critical to us to gather market intelligence and benefit from the latest knowhow in data sciences.

The advisory board of TELEGRAM will play an important role in informing the academic partners of trends and developments in areas which could have a major impact on the success of the project: a) market conditions and b) opportunities for the consortium to enable the commercial partners through technology, product implementation or through business models. Hence, it is very important that the advisory board have access to not just current ecosystems but are themselves influencing the ecosystems of the future. This is an honorary position with no monetary compensation involved and a maximum of 2-3 meetings per year.

### 2.5.2 Innovation roadmap & implementation strategy

**2.5.2.1 USP of Telegram platform solution**

TELEGRAM allows current prosumers (*resp.* microgrid owners/admin) to automatically trade energy at the microgrid level (*resp.* power grid level) - See Figure 2.1. Its decentralized architecture and capabilities (negotiation, prediction), combined with social acceptance by design, makes it ideally set up to scale and expand into future services.

**2.5.2.2 The after-project and where we go commercially, from here**

At the end of this Bridge project and with the help of our Advisory Board, we aim to have answers to two key questions: (1) What is our modality of commercialization? (2) How will we finance it?

We foresee two options to commercialize: (1) establish a startup or, (2) establish partnerships that are governed by contracts. Either modality will call for a set of resources that need to be sustained and the finances to secure those resources. Hence, the project outcomes have to lead into a roadmap to commercialize the SEMA through the TELEGRAM platform.

For initial funding, the scientific work and progress made in TELEGRAM can feed into an [Innoenergy](https://www.innoenergy.com/), [Eurostar/Eureka](https://www.eurostars-eureka.eu/), [Innosuisse](https://www.innosuisse.ch/inno/en/home.html), or “[Pilot and Demo](https://www.bfe.admin.ch/bfe/en/home/research-and-cleantech/pilot-and-demonstration-programme.html)” (Swiss Federal Office for Energy -SFOE) project, the first two indicating a commercial reach beyond Switzerland. We are already in contact with two Swedish partners: [KTH](https://www.kth.se/) ([with Letter](https://www.kth.se/en) of Support included in the proposal) and [Vattenfall](https://group.vattenfall.com/). Select Advisory Board members could be the implementation partners.

After the end of the project, we plan to have access to a test microgrid infrastructure of around 500 households that will be setup by GroupeE, in 2023/2024 (Letter of Support included in proposal). Access to a test microgrid will be critical from a commercial perspective as well as to have sufficient data for the large-scale training of our models and algorithms. A successful field test would result in the platform solution ready for phased commercial roll-out. We will expand the Advisory Board and bring relevant members on board to secure expertise and guidance in founding a startup and securing venture funding, should this be the modality of choice.

**2.5.2.3 Existing market and competitive environment**

An estimate from our partner, GroupeE, puts the number of microgrids in Switzerland at 80 in 2024 and 120 in 2026 (1 c-SEMA = 1 Microgrid). The business model will be developed further during pre-commercialization. Here, we examine a business model for the p-SEMA. An average of 200 households per microgrid yields 16,000 to 24,000 p-SEMA (household-level) products to be installed in Switzerland in 2024 and 2026, respectively. We estimate an avg. monthly subscription of CHF 15 per subscriber. The revenue potential upon penetrating 24,000 households in Switzerland comes to CHF 4.3M anually and can be easily re-calculated to the shifting realities on the ground. An alternate revenue model is to impose a fee on every energy trade transaction, potentially 15%. We wish to emphasize here that the social acceptance attributes will help us decide on the business model, true to our commitment to securing the trust and buy-in of the prosumer.

Modern business is transforming and making traditionally narrow definitions of “competitors” redundant because the future is increasingly seen as a collaborative space. Further, even if our partners are capable of developing their own SEMA-like capability, this is not their core business. To exponentially enhance the value to the customer (and to their own bottom-lines), it would be in our partners’ interest to integrate our capabilities into their offering. We bring capabilities our partners would find time-consuming and expensive to develop and our partners bring market access and microgrid ecosystems within our reach.

**2.5.2.4 Market access and Go To Market (GTM)**

Independent of the modality or vehicle we eventually choose for commercialization, we need the collaboration of electric energy companies, IT infrastructure, AI software and data science companies. Through the electric energy companies, and on the basis of their already installed solutions, we deliver to the customers (prosumers) in a B2B2C format.

Our Go To Market plan is a classic “land and expand”. It starts with the establishment of commercial agreements between actors. The key efforts which will be needed for a successful and sustainable market entry include:

1. Identify electrical electric energy companies who are prospective commercial channel partners.
2. The electrical energy partners sell the new capabilities through their sales channels to prosumers.
3. The software and infrastructure partners will design and deliver the deployments and perform remote maintenance and upgrades.
4. A feedback loop will be established with the electric energy partners to ensure quality of service to the prosumers.
5. Steps 1-4 will be repeated in selected regions, starting with Switzerland and rippling outward to markets identified as high-potential.

Preliminary exploration with members of our advisory board has given us confidence in this model, with at least one country (Sweden) showing market promise right away: see LoS from KTH.

**2.5.2.6 IP & Regulatory Situation**

After the project and in collaboration with commercialization partners, the Intellectual Property (IP) will be set up with the help of [UNITEC](https://www.unige.ch/unitec/fr/). UNITEC is the University of Geneva and HES-SO technology transfer office aiding in the transfer of technologies from the lab to the marketplace. Its services are to provide expertise on topics of legal, licensing, IP, spin-offs.

**2.5.2.7 Scalability**

The TELEGRAM platform offering is designed for scalability on three fronts:

1. The decentralized architecture of TELEGRAM platform, together with the coordination model will guarantee its technical scalability.
2. Designing for social acceptance will increase the probability of a multiplier effect- satisfying different stakeholders, thereby driving up the demand for microgrid participation in general.
3. Open source software and standard IT technologies will enhance scalability of the market because a community of developers will be able to contribute to improve and offer SEMA-based solutions (see detail in WP4, Task 4.1).

**2.5.3 Risk management**

This section details the scientific/technical and implementation risks associated with the project. For each risk we specify the preventives and correctives measures (mitigations) as well as the indicators of occurrence and success factors.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Risk Description** | **Indicators of occurrence** | **Preventive measures** | **Corrective measures** | **Success factors** |
| Difficulties to find the right profile of people to conduct semi-directed interviews  **(WP 1)** | Behind schedule regarding the interview planning | Including more candidates to interview in the purposeful sampling strategy | Requesting the Advisory board for help in finding the targeted profiles to be interviewed | Having the semi-directed interviews transcripts loaded on the NVIVO software to conduct the synthesis of the fieldwork |
| Prediction models with good performance require large computational resources. They are too heavy to run on SEMAs.  **(WP2)** | Model size is larger than available RAM in the resource-constrained devices. | Start with simple models, with fewer parameters. | Use more complex models and then deploy knowledge transfer: Transfer Learning to train simpler ones. | A SEMA can take into account the knowledge of neighboring SEMAs and so benefits from collaborative learning |
| Coordination middleware uses memory, computing and networking resources. It does not execute properly on resource-constrained devices  **(WP3)** | Coordination middleware does not execute properly on SEMA | Start with coordination middleware in the cloud | Design a minimal coordination model to run in SEMA. | Decentralized interactions happen through information flow among and within coordination middleware executing on SEMA |
| Intelligent Digital Twins don’t interact with their physical counterpart  **(WP3)** | There are no API or communication links to access physical twins | Simulate physical twin activity | Provide physical twins with communicating capabilities. Develop API if necessary. | Intelligent twin interacts with physical twin |
| The edge-to-cloud feedback loop (Figure 5.1) is too complex to implement.  **(WP4)** | Unable to close the loop between the edge and the cloud shown in Figure 4.1 | Use the InaaS platform of the MEDInA project (see details In the *“Further requested and obtained funding”* section on mysnf) | Deploy the self-adaptive applications (learning & prediction modules) on a centralized cloud. | The overall edge-to-cloud learning process in place, with as many steps automated as possible. |
| The collaborative learning’s need for data exceeds capacity of communication technology  **(WP4)** | Data to be transferred exceeds bandwidth of communication technology | Start using communication technology with high bandwidth and  start with algorithms that need few data | Improve algorithms and use compression to reduce amount of data to transfer between SEMAs | The required data for collaborative learning can be transferred between neighboring SEMAs |
| The collaborative learning’s need for data exceeds capacity of communication technology  **(WP4)** | Data to be transferred exceeds bandwidth of communication technology | Start using communication technology with high bandwidth and  start with algorithms that need few data | Improve algorithms and use compression to reduce amount of data to transfer between SEMAs | The required data for collaborative learning can be transferred between neighboring SEMAs |
| Risks with respect to the technologies used  **(Implementation)** | Technology access falls through. | Two electric energy companies, two IT Infrastructure partners. | Switch over to the redundant technology | Ability to make a switch with minimal outage. |
| Not receiving approval from the public sector in a highly regulated market (energy sector)  **(Implementation)** | Our compliance is deemed insufficient | With OCEN (Cantonal office of energy) on our AB, we are mitigating risk of non-compliance. |  | Approval from relevant public bodies. |
| Scaling: Not being able to scale in a commercial implementation due to downtime and malfunctions.  **(Implementation)** | Repeated downtime, manual maintenance. | Decentralized architecture and open-source software is our built-in first line of defense to guarantee scale. | Remote maintenance of the entire edge-cloud infrastructure. | Minimal downtime during growth phases. Fast response time during regular operations. |

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1. **In the remainder of this document “electric energy companies” include all stakeholders involved in the generation, transport and distribution of electrical power: Transport System Operators (TSO), Distribution System Operators (DSO), microgrid installers, etc.** [↑](#footnote-ref-1)
2. In the rest of Section 2.5, for the sake of simplicity we will use the term digital twin to stand for intelligent digital twins [↑](#footnote-ref-2)
3. https://yareta.unige.ch/ [↑](#footnote-ref-3)