INTERACT

Integration of Innovative Technologies of Positive Energy Districts into a Holistic Architecture

D3.3 *LINK*-ICT structure with communication guidelines between the actors within the electricity community

31st of August 2022

Leader: TU Wien

Dissemination Level

PU	Public	X

History

Version	Description	Lead author	Date
V1	Table of Content	Albana Ilo	04.03.2022
V2	*LINK*-ICT Architecture	Albana Ilo	05.07.2022
V3	Draft Definitions and Hardware	Albana Ilo	01.08.2022
V4	Communication Strategy and Interfaces	Albana Ilo	04.08.2022
V5	ICT Structure Großschönau	Helmut Bruckner	15.08.2022
V6	ICT Structure Fyllinge	Markus Olofsgard	18.08.2022
V7	Definitions and Review	Helmut Bruckner	25.08.2022
V8	Principles and Policies of the INTERACT-EC CT structure	Albana Ilo	30.08.2022
V9	Executive Summary and Review	Helmut Bruckner	31.08.2022
vFinal	Final Formatting and Review	Marketa Adamcova	31.08.2022

Disclaimer

This project has received funding in the framework of the PED Programme, which is implemented by the Joint Programming Initiative Urban Europe and SET Plan Action 3.2. The project is supported by the Austrian Ministry of Climate Action, Environment, Energy, Mobility, Innovation, and Technology (BMK), Technology Agency of the Czech Republic (TAČR) and Viable cities, a research program funded by the Swedish Energy Agency, Formas and Vinnova.

Executive Summary

Within this deliverable "D3.3 *LINK*-ICT structure with communication guidelines between the actors within the electricity community" we focus on the necessary information and data exchange within INTERACT Energy Communities, based on standardized interfaces in accordance with the holistic *LINK*-architecture.

After a short introduction into the document in Chapter 1, we highlight in Chapter 2 essential definitions, mainly the difference between information and communication.

In Chapter 3 we describe the currently existing ICT infrastructure in the two demo-sites of the project, Großschönau in Austria, and Fyllinge in Sweden. For the existing municipality in Austria, history, strategy, and services of the existing ICT structure are shown as well as the infrastructure itself is described. For the greenfield project Fyllinge, existing ICT infrastructure in the neighborhood is described, as well as how the potential real estate-developer of this area, company Tornet, is creating ICT infrastructure in similar other projects.

Chapter 4 is focusing on the general Communication Strategy of INTERACT ECs: How can we communicate? What architecture is recommended? What data needs to be exchanged how often? What actors are involved in the communication structure? What services, principles and policies will the communication structure follow. In Chapter 5 conclusions are summarized.

The structures developed and information gathered within this deliverable will be used in the final Deliverable 6.1 - "Roadmap for the implementation of the designed INTERACT energy community in general and for the specific local perspectives". It is also the final deliverable of Work Package 3 – "Characterization of current & expected future state of the specific energy communities" which aimed to describe the current available and designed future technologies and ICT-structures of both demo sites of the project.

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List of Abbreviations and Acronyms

BaU	Business as usual
CP	Customer plant
CT	Communication Technology
DMP	Data management plan
DSO	Distribution system operator
EC	Energy Community
ECC	Energy Community Coordinator
FTTH	Fibre to the house
GDPR	General data protection regulation
HV	High Voltage
ICT	Information and communication technology
IOT	Internet of Things
IT	Information Technology
LV	Low voltage
MV	Medium voltage
OLTC	On-load tap changer
PLC	Programmable Logic Controller
PV	Photo Voltaic
REC	Renewable energy community
RED	Real estate developer
RPD	Reactive power device
SME	Small or Medium Enterprise

Table of Contents

1 Introduction

1.1 Purpose of the document

This document aims to provide an overview of the required LINK-ICT structure with communication guidelines between the INTERACT- Energy Community (EC) actors.

Two distinct types of regions are considered:

- Existing neighborhoods shall be upgraded to function as a LINK-based REC properly.
- Greenfields, where the EC shall be built up from the scratch

The principles for the required ICT structure will be similar for both types of regions, but since the existing conditions differ, different considerations need to be made

1.2 Relation to other project activities

The GAP analysis in 3.2 serves as input to the design of the *LINK*-ICT structure. Results of the *LINK*-ICT structure will contribute to developing the technical section of the roadmap, which will be drafted within the WP6 of the project. Also, potential barriers to implementing a *LINK* ICT infrastructure are identified.

1.3 Structure of the document

This document has four main chapters apart from the executive summary and introduction.

In the first chapter, the definitions of essential concepts are played out. These definitions of commonly used terminology are to avoid misinterpretations later in the document.

The following chapters describes the current situation and ICT infrastructure in Großschönau, Austria, as an example of an existing Neighborhood and the planned situation in Fyllinge, Sweden, as an example of a greenfield area.

The communication strategy for *LINK*-based ECs is described in terms of actors, principles, hardware, software etc. in the third chapter.

And finally, short conclusions summarize the ICT architecture feasibility regarding INTERACT Energy Communities.

2 Introduction to essential definitions

Information means facts or details about someone or something [1]. Information is purely formal and has no meaning. It is impersonal rather than interpersonal [2].

Communication is defined as the activity or process of expressing ideas and feelings or of giving people information [3]. In our context refers to the process by which messages or information is sent from one place or person to another. Communication can be seen in a linear, one-way process in accordance with the transmission model of communication (see Figure 1, [4]), more fitting to communication between machines, or as a more interactive, two-way process in accordance with the interaction model of communication, which is incorporating feedback (see Figure 2, [5]), better suitable to describe communication between humans and/or animals.

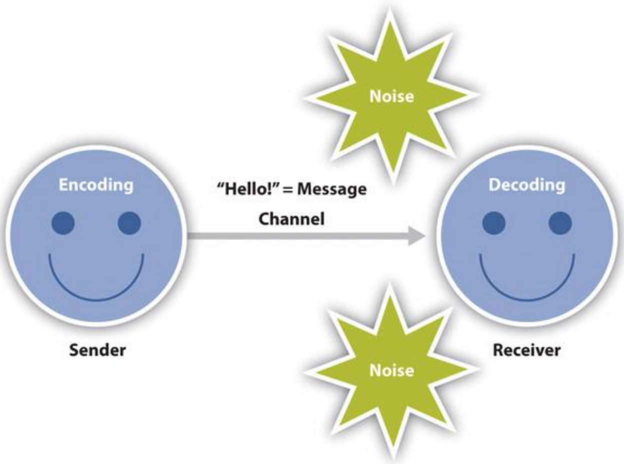


Figure 1 – More technical Transmission Model of Communication

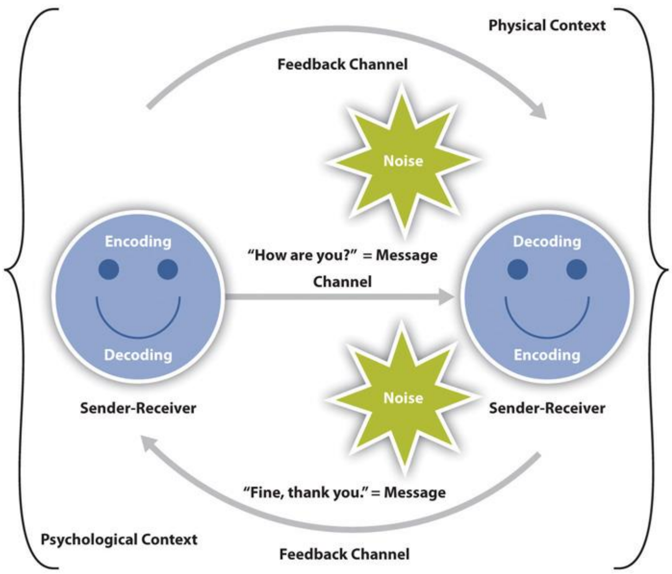


Figure 2 – Interaction Model integrating social realities

For the ICT structure discussed in this deliverable, we refer to the more simplified and technical transmission model of communication.

ICT refers to technologies that provide access to information through telecommunications. It includes the internet, wireless networks, cell phones, and other communication mediums [6].

Information technology architecture is a detailed description of the various information-processing assets needed to meet business objectives, the rules that govern them, and the information associated with them [7].

A **command** is an order to perform a particular action.

3 Investigation of the current structure of IT and communication

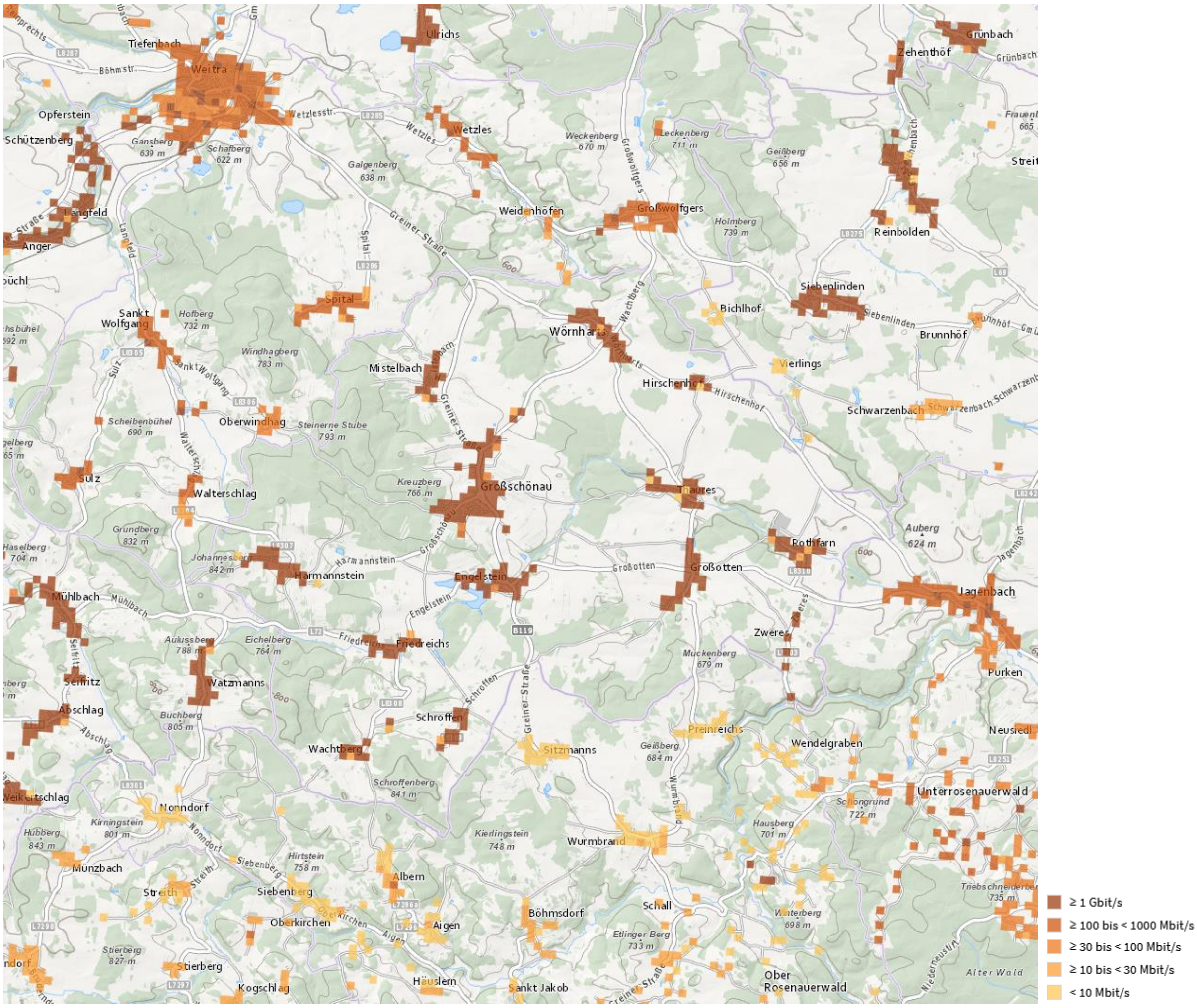
The following chapter looks at the currently available ICT infrastructure in the two INTERACT demo sites. For Großschönau, Austria, we mainly refer to the existing infrastructure. In contrast, for the greenfield project in Fyllinge, Sweden, we refer to most likely being built an infrastructure based on the neighboring city Halmstad and reference projects from the real-estate developer.

3.1 Pilot site Großschönau, Austria

The Austrian pilot site Großschönau is a rural municipality with about 1250 inhabitants living within 12 villages, whereas Großschönau itself is the municipality center with about 450 inhabitants. Given its location aside from major cities or infrastructure, ICT depended either on local initiatives or the priorities of the significant ICT providers. In the early 2000s, the municipality of Großschönau decided to invest itself in a revolutionary fibre optic network at that time. Thanks to the continuous enlargement of the network today, the municipality offers access to the fibre optic network to every household within the municipality area.

As the municipality owns this network, it was possible to realize different services related to the administration of the municipality, which is handled by the network; see section 2.1.2.

Figure 3, showing the map of current coverage of the Austrian landline network [8], confirms for Großschönau the best rating with FTTH (fibre to the house) technology and upload and download rates of 1000 Mbit/s. It also shows that larger cities in the surrounding (e.g., Weitra) have a lower rating, and similar-sized villages have by far lower ratings, partially with <10 Mbit/s only (e.g., Sitzmanns or Nonndorf).

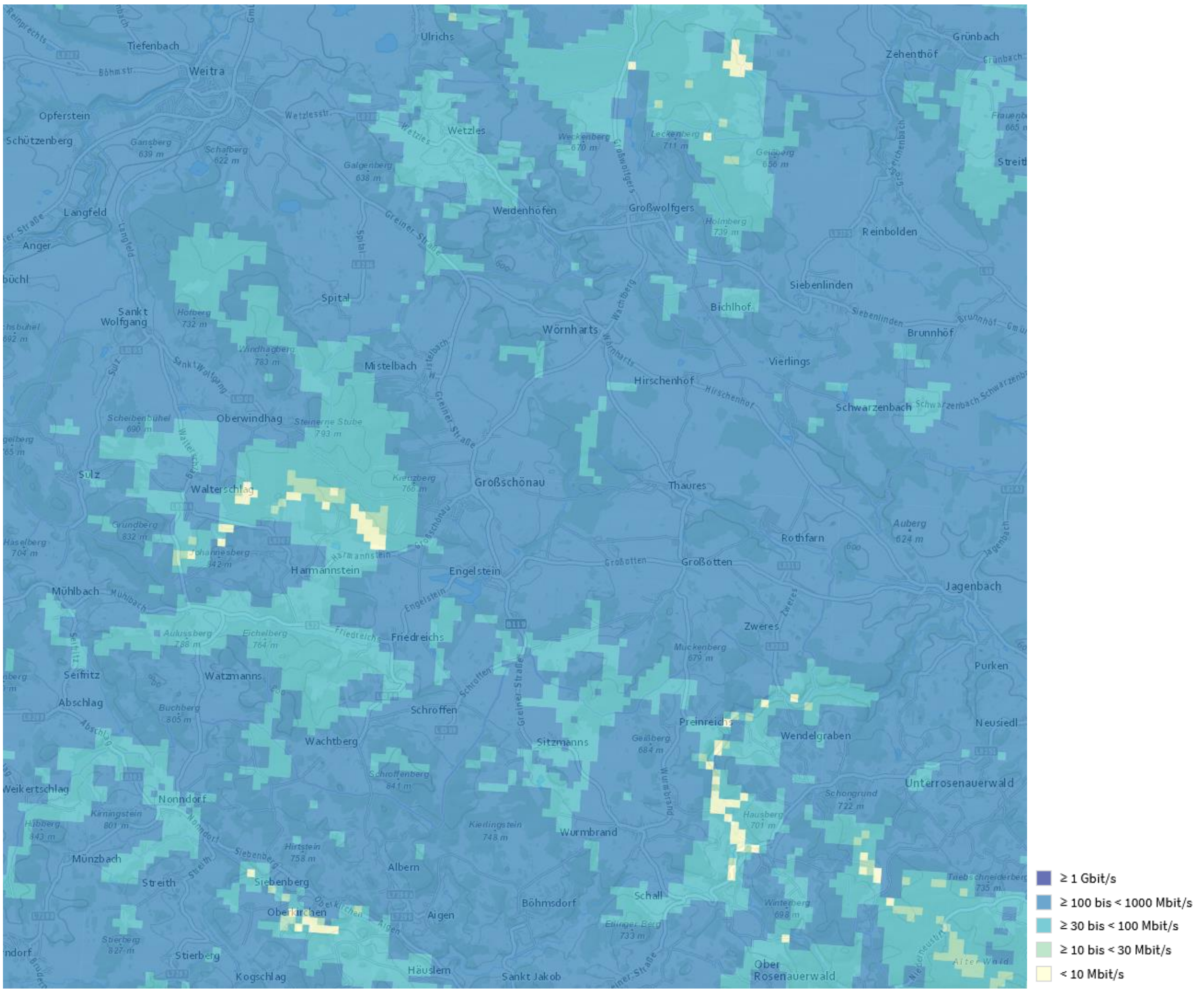


Festnetz

Infrastrukturanbieter	Technik	Download	Upload
Großschönau	FTTH	1000 Mbit/s	1000 Mbit/s
A1	xDSL	101 Mbit/s	22 Mbit/s

Figure 3 – Map showing the current Austrian landline network coverage

The second major communication network is the mobile phone network, offered in Austria by three different providers (A1, Drei, Magenta). All three providers have network coverage within the municipality to a certain extent. Modern technologies like 4G or 5G are currently not yet available. Figure 4 shows the map of the current coverage of the Austrian mobile network [9]. Depending on the operator, upload is currently possible with maximally 76 Mbit/s and download with maximally 251 Mbit/s.



Mobilfunknetz

Infrastrukturanbieter	Download	Upload
Drei	251 Mbit/s	35 Mbit/s
A1	169 Mbit/s	76 Mbit/s
Magenta	144 Mbit/s	35 Mbit/s

Figure 4 – Map showing the current Austrian mobile network coverage

Within Großschönau, ICT was, in general, a rather important topic in the recent decades, mainly as a means to improve the quality of life in the municipality and allow for better working possibilities. An IT training centre (Telestube Großschönau) was founded in 1999 to improve the IT skills of the inhabitants, and several IT-related SMEs / one-man-businesses have been founded since then.

In the following chapters, we focus on the municipality owned FTTH network, as this is the most likely infrastructure for INTERACT ECs.

3.1.1 ICT architecture

3.1.1.1 Hardware

The hardware part of the FTTH network of Großschönau follows a classic layout, whereas different services are also partially separated physically. External connections are secured by a physical firewall and then sent by a router with the help of various switches to the requested connection points within the network. Converters are used between the fibre optic cables of the main communication site and copper cables within the houses. Different servers are located in different buildings to offer redundancy and increase security.

For ECs the most important already existing ICT hardware is related to Energy Metering Services. These services are provided with the help of PLCs. For receiving metering data for example, regarding electricity, additional meters are installed in the relevant buildings and read by the system. There is no access to official metering information from the DSO-owned smart meters. About 30 different electricity meters are connected to the system at different levels, from complete and partial buildings up to single devices.

Used meter are for example regarding heat metering “Hydrometer SHARKY”, regarding electricity meters “DHZ 5/65” or “DVH 3113” or “eacDSZ-63A”, connected via “HYDRO-PORT Pulse” converters to the network.

Since 2022 a new battery storage is available to ensure continuous services during a blackout.

3.1.1.2 Software

This Energy Metering Service system is based on a Siemens visualization and evaluation tool and is powered by the regional specialist for public measuring systems Aramatic GmbH. The data evaluation is possible in a flexible way, and the software can be adjusted based on changing needs and/or regulations.

3.1.1.3 Protocols

The commonly used protocol within the metering system is M-Bus. M-Bus (Meter-Bus) is a European standard (EN 13757-2 physical and link layer, EN 13757-3 application layer) for the remote reading of water meter, gas, or electricity meters. M-Bus is also usable for other types of consumption meters. The M-Bus interface is made for communication on two wires, making it cost-effective. A radio variant of M-Bus (Wireless M-Bus) (circle-link) is also specified in EN 13757-4 [10].

Most energy meters connected to the system have an integrated network module, and the system automatically requests the measured values every fixed period. If no direct network module is available, the meters are connected to a HYDRO-PORT Pulse converter, which is converting the pulse signal to the M-Bus-Protocol. Some meters have an integrated log, allowing them to store values themselves and making the system more robust. We also tested optical meters reading the LED-pulse from the original electricity meter of the household. Due to non-reliable counting and bi-directional pulsing for buildings owning PV systems, these meters have been disregarded and exchanged.

3.1.2 Services: Provided functions and features

The key services and functionalities of the FTTH network of the municipality Großschönau are the following:

- High-speed internet within the municipality

As shown in Figure 3 above, without the own FTTH network current speed of the internet would be only about 5% of the actual speed available in Großschönau. Furthermore, high-speed internet was already available in such quality over ten years ago, when the actual speed of other providers was even lower. High-speed internet was seen as a key point to support businesses in the municipality and increase its inhabitants' quality of life.

- Publicly accessible WLAN

Around public buildings, a free WLAN was set up for all visitors as an additional service.

- Measuring data for the freshwater supply

The complete freshwater supply of the municipality is metered using the FTTH network. All tanks and pumping stations are connected, showing the functioning of the system. Automatic alerts are set to ensure a reliable working of freshwater supply within the municipality.

- Measuring data for the wastewater treatment

Like the freshwater supply, the wastewater treatment of Großschönau is monitored using the FTTH network.

- Energy Measuring Services (electricity, heat, water) of public and selected private buildings within Großschönau

As an extension of the water monitoring system, already in 2004, within the Intelligent Energy Europe funded project "SAVE - Intelligent Metering", public buildings within Großschönau got equipped with heat, water, and electricity meters to measure and analyze on a 15-minute level consumption data within the buildings in order to save energy. Based on the positive outcome of this project, further extensions of the Energy Measuring Services have been accomplished. Currently, about 100 different metering points are connected.

- Intranet of the municipality administration

The FTTH network connects all municipal public buildings, serving as a basis for the Intranet of the municipality administration.

3.1.3 Principles: Guiding ideas forming the architectural basis

As stated already above, the key idea behind the investment into an own FTTH network was to support the local businesses and increase the quality of life of the inhabitants of the municipality with high-speed internet.

Thanks to the investment and the now available infrastructure, the following key areas are covered by the network:

i. High-speed internet access for all businesses and inhabitants of the municipality

ii. Services for inhabitants and tourists: free WLAN, security services, webcams, etc.

iii. Services for the municipality administration: improved monitoring (freshwater supply, wastewater supply), communication (Intranet, data storage), security (blackout safety)

iv. Energy Data Services for interested participants (public administration, enterprises, private households)

Around these key principles, the current services are step by step enlarged and improved. Further additional services might be included if requested by inhabitants.

3.1.4 Policies: Rules enforcing the architecture principle

To ensure the proper functioning of the built-up network, specialized companies are assigned to secure its operations: The internet and IP-phone network is operated by company WVNET GmbH, a regional specialist in internet and telecommunication services. Company Aramatic GmbH operates the measuring and monitoring system. Within the municipality itself, dedicated persons are responsible for the system's administration, maintenance, and development.

3.2 Planned pilot site Fyllinge, Sweden

As Fyllinge is a greenfield site, there is no existing ICT infrastructure. Fyllinge is a part of the city of Halmstad, which has a long history of supplying an ICT infrastructure in the form of an open city grid since the beginning of 2000, thereby being one of the first municipalities in Sweden to do so.

Today over 97% of Halmstad households have access to a **fibre connection** with 100 Mbit/s or more. The city grid is, for natural reasons, not expanded into the greenfield area of Fyllinge, but all the surrounding areas have good coverage of the city grid, as shown in the Figure 5 below.

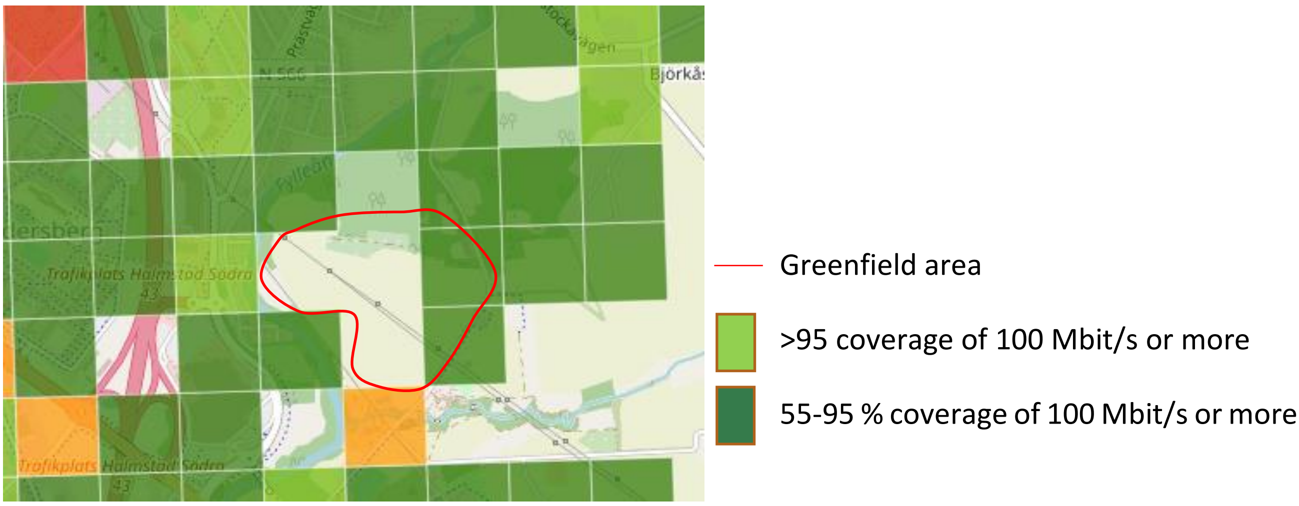


Figure 5 – City fibre optic grid coverage in proximity to the greenfield area in Fyllinge

Fyllinge is also totally covered by **5G mobile network** from several different providers. The speed of the 5G coverage is currently said to be around 60 Mbit/s. 5G networks have the technical capacity to increase to 1000 Mbit/s if demand arises.

3.2.1 ICT architecture

Since the ICT Architecture is yet to be built in Fyllinge, the following description is based on Tornets' current ICT architecture that is similar to buildings and the local prerequisites in Halmstad.

The Municipally owned company Halmstad stadsnät provides a connection point to the city-wide Fibre optics grid. Still, the real estate developer will be responsible for developing the ICT infrastructure within the multi-apartment buildings, which will make up a larger part of Fyllinge. In this case, the real estate developer can use either a 5G-based or a fibre approach in the buildings. Since fibre is the most common approach, this will be assumed to go forward. However, with the 5G development probably, this is deemed more favorable at the time of construction.

3.2.1.1 Hardware

The hardware will be built on two systems. The building external fibre optics grid and the internal building LAN, where there is a change from optic fibre to copper wire at the connection point to the building, as illustrated in figure below

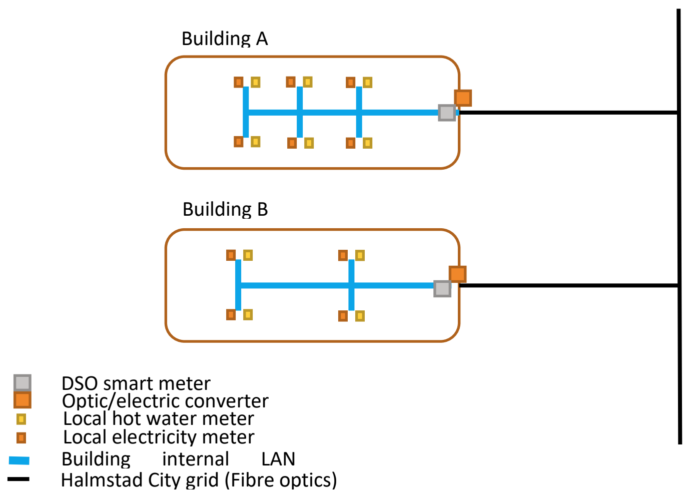


Figure 6 – Overview of ICT infrastructure for two example buildings in Fyllinge

The existing city grid is an open Fibre optic grid which means that there is a free choice between service providers for the customers. The overlaying fibreoptic grid is owned by Halmstad stadsnät but the connection from the property line into the house is owned by the real estate owner. Therefore, the converter from fibre optic to copper is owned and operated by the real estate owner.

All apartments are required by law to have separate measurements of electricity, and hot water. Sometimes other sensors and meters are connected to improve the energy balance and energy efficiency of the building and its operations.

3.2.1.2 Software

Data will likely be gathered and compiled with software specially designed for the purpose. As is the case in buildings and blocks today owned by Tornet where KTC is providing software for data gathering and compilation. Data is then used by KTC for building optimization and by Tornet for billing the tenants.

Tornet is currently developing a user interface for their tenants in form of an application called Torna where a lot of the energy data is visualized and used to encourage the tenants to a more sustainable energy use.

3.2.1.3 Protocols

Metering data from electricity meters and hot water meters will be gathered via an M-bus protocol based on EN 13757-2 and EN 13757-3; data is after that transferred to the servers of KTC. The metering is online and practically continuous.

3.2.2 Services: Provided functions and features

The main service provided in a business-as-usual scenario

- Internet availability both through LAN in buildings and WLAN in the surroundings
- Energy Measuring Services as a basis for individual billing for electricity and hot water even though several apartments share the same connection point to the grid.
- Providing data for specialized software (i.e. Tornets Torna) for services like energy optimization, learning the use patterns of tenants, adjusting choice of energy sources and use of energy to reduce energy use and costs.

3.2.3 Principles: Guiding ideas forming the architectural basis

The guiding ideas for ICT infrastructure are composed of two parts. The local City grid in the city of Halmstad is provided by Halmstad stadsnät, and the real-estate developer/building owner provides the building's internal LAN. Halmstad stadsnät aims to provide all inhabitants with reliable access to the local city network. It is not specified that it shall be a fibre optic connection, but in the present and near future, fibre optics is assumed to be the main technology in urban areas such as Fyllinge

3.2.4 Policies: Rules enforcing the architecture principle

The city grid is owned and operated by Halmstads stadsnät AB which is a municipality owned company. In the description of the company, it is stated that

"The company shall work for an active open local city network for residents, public activities and businesses. The company shall have an active role in developing and delivering Halmstad municipality's future digital community services and ensuring that the municipality's e-services can be offered to all residents" [11]

This shows that an open fibre will be available for all residents/commercial or other actors in Fyllinge, as long as Halmstad stadsnät is in operation.

4 Communication strategy in the INTERACT Energy Communities

Communication [12] is one of the fundamental pillars of all energy community activities and interactions. It is how the energy community passes the information to its members and other actors on the one hand and, on the other, data and commands to fulfil its operation processes and receive and interpret the feedback.

4.1 Communication types and channels

The INTERACT energy community uses formal and informal communication types combined with various channels such as non-verbal, verbal oral face to face, verbal oral at a distance, verbal written, and the internet.

Formal communication refers to official communication. Examples of formal communication are financial communication and legal expressions. It takes place via a predefined channel such as non-verbal (written) or verbal. The latter me be oral- face to face or at a distance, or verbal-written, all accompanied by protocols.

Informal communication is a fundamental pillar in the communication strategy of the energy community because it is "user-friendly". It serves very well to encourage positive opinions, ideas, and expressions without seeming like directives. It is oral and usually occurs spontaneously without protocol and structure, making it less reliable and accurate. The information spreads like wildfire because there are no formal rules to follow. All communication channels, such as non-verbal (e.g., flyers), verbal oral- face to face or at a distance, may be used. Moreover, the Internet (EC homepage) is another communication channel.

4.2 Communication between actors

INTERACT EC can interrelate with many actors or stakeholders in the energy sector [13], see also below Figure 7. They are DSOs (as a technical operator or wholesale market "Distribution" operators), authorities, and regulators. It can also interact with electricity producers and storage operators, vehicle charging operators, and customers (prosumers and consumers) that are not EC members.

Communication between the ECC and DSO as a facilitator of the wholesale market Distribution is mainly formal. They must exchange the day ahead schedules and negotiate the setpoints.

Communication between the ECC and DSO is formal. The DSO sends the negotiated set points (commands) to the EC members (CPMU).

Communication between the ECC and non-EC members (Customers, distributed StOs and CPOs) is informally using all possible channels.

Communication between the ECC and Authorities and Regulators is mainly formal.

Communication between the ECC and EC members is formally and informally and uses all possible channels.

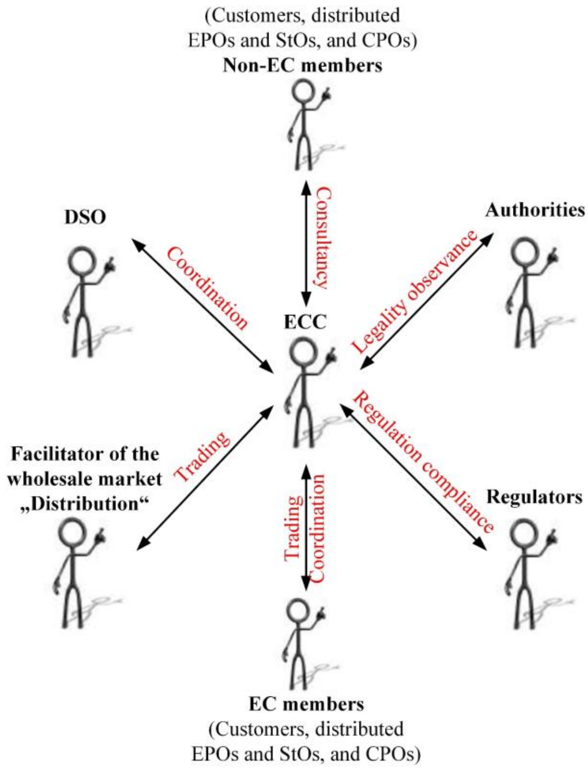


Figure 7 – Overview of the INTERACT EC interaction with various relevant actors

4.3 Communication technology architecture

A Communication Technology Architecture is a global model of the communication system. It usually consists of a structure of the various communication assets needed to meet the energy community objectives. It gives a detailed description of the properties of multiple assets and their relationships. Furthermore, it defines the frequency and credibility of information flow internally, between the energy community and its members, as well as externally. It helps structure how and when to communicate within the community and across processes.

4.3.1 Communication hardware

The communication hardware is the framework of the architecture. It is composed of servers, modems, and transfers media.

Power Line Carrier

The communication between the DSO and EC members for automation purposes or sending commands may be realized using power lines and **Power Line Carrier** or **Communication** modems. Here, existing power lines are used to superimpose a higher frequency signal and to enable communications along them. Normally, a Power Line Carrier can be implemented easily and quickly without additional infrastructure costs. The distribution system operators own the power lines (low voltage cables), thus eliminating third-party dependency, supply issues and leased line fees and allowing full priority and control over the data channel. They can be used in monitoring and control systems.

Fibre optic cables

Fibre optics is the technology used to transmit the information as light pulses through strands of fibre made of glass or plastic over long distances. In the power industry, they are used to communicate with protection, monitoring, and control devices.

Both technologies are suitable to be used for the establishment of needed communication of the energy community. The technology selection depends on the ownership of the technology, security of service and different fees.

Server

The server provides the basic computer power for the energy community and is typically centrally located.

4.3.2 Architecture

Figure 8 shows an overview of the CT architecture for the INTERACT Energy Community. DSO is the facilitator of the regional market, while the Energy Community is the facilitator of the local market. For the sake of data privacy and cybersecurity, the local market will be set up locally on the Energy Community server.

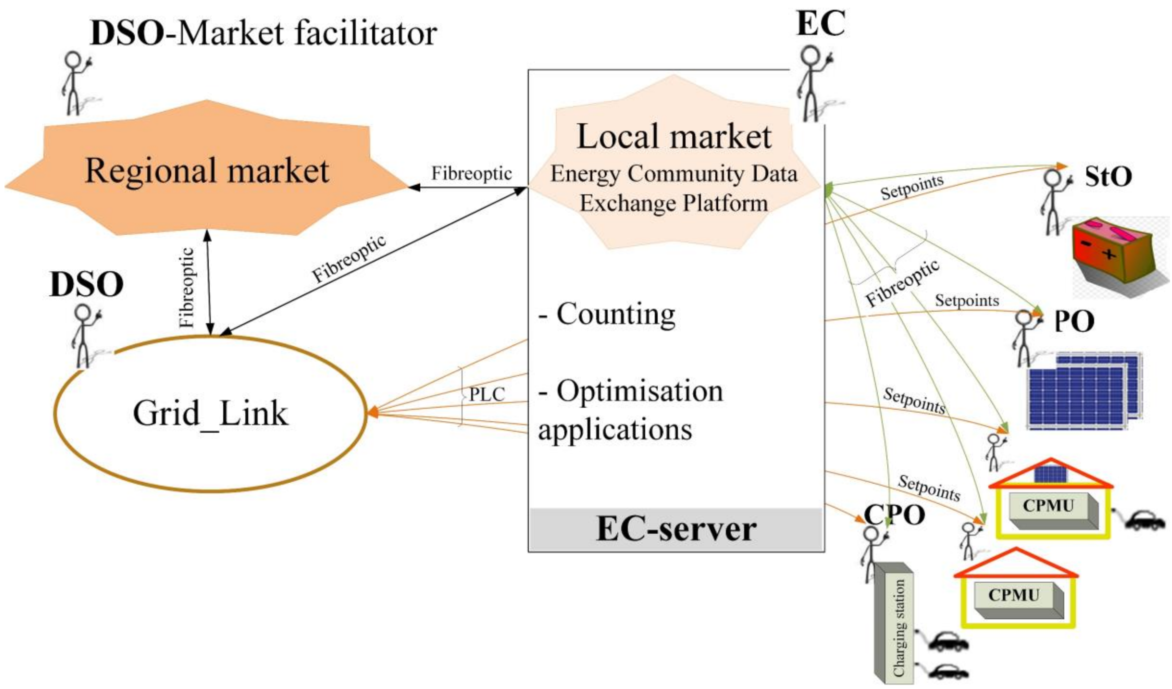


Figure 8 – Overview of the CT architecture for the INTERACT Energy Community

In this server will be performed optimization processes on the EC level. Each EC member will have two interfaces (see §4.3.4): one with information relevant to the market (green) and the other with technical information (orange). The market-relevant communication between all actors realizes by utilizing fibre optics. The communication between the DSO and EC members related to technical issues such as sending setpoints achieves by using Power Line Communication technologies. Thus, the reliability and security of the communication are guaranteed.

4.3.1 Energy Community Data Exchange Platform

Energy Community Data Exchange Platform (ECDEP) is a transparent communication platform that is non-discriminatory, independent, reliable, secure, stable, and cost-effective. It is protected from access by third parties by state-of-the-art solutions.

The exchanged data has a predefined format (structure) within the business process so that the members of the energy community involved in the process (or rather their CPMUs) can interpret the message from the other market partner (Energy Community Coordinator) in an automated way and vice versa. The sender and recipient are identifiable during data transmission, as are the encryption/decryption key and the transmitting protocol.

4.3.2 Technical and market communication documents

Technical and market communication documents are required to support the business processes of the energy communities.

The **Technical Document** details the energy community's processes and the data required for smooth market communication between the market partners, which are not explicitly dealt with in the regulations or laws and the documentation based on them.

The **Market Communication Document** describes the communication between market participants, market partners, and interested parties (for the respective use cases), which includes the data exchange procedures for handling the energy community's technical and business processes, including the required data formats and data transmission.

4.3.3 CPMU - The hub promoting the energy communities

How can residential customers and small businesses become empowered to engage and participate actively in the INTERACT energy communities? There are significant gaps in understanding the electricity-related behavior and rules that cannot be filled through seminars or simple education.

In the holistic *LINK* solution, the Customer Plant Management Unit (CPMU) is the hub also promoting the participation of residential and small businesses in the INTERACT energy communities. Besides optimizing all resources within the customer plants, CPMU also serves as the market and grid communication hub. To decrease the cyber security risk, it has two separate interfaces: the technical interface communicating via PLC with the DSOs (grid) and the interface with the market communicating through fibreoptics with the local market (energy community), Figure 9. Also, the control units of the Producers- and Storage-Links have separate interfaces.

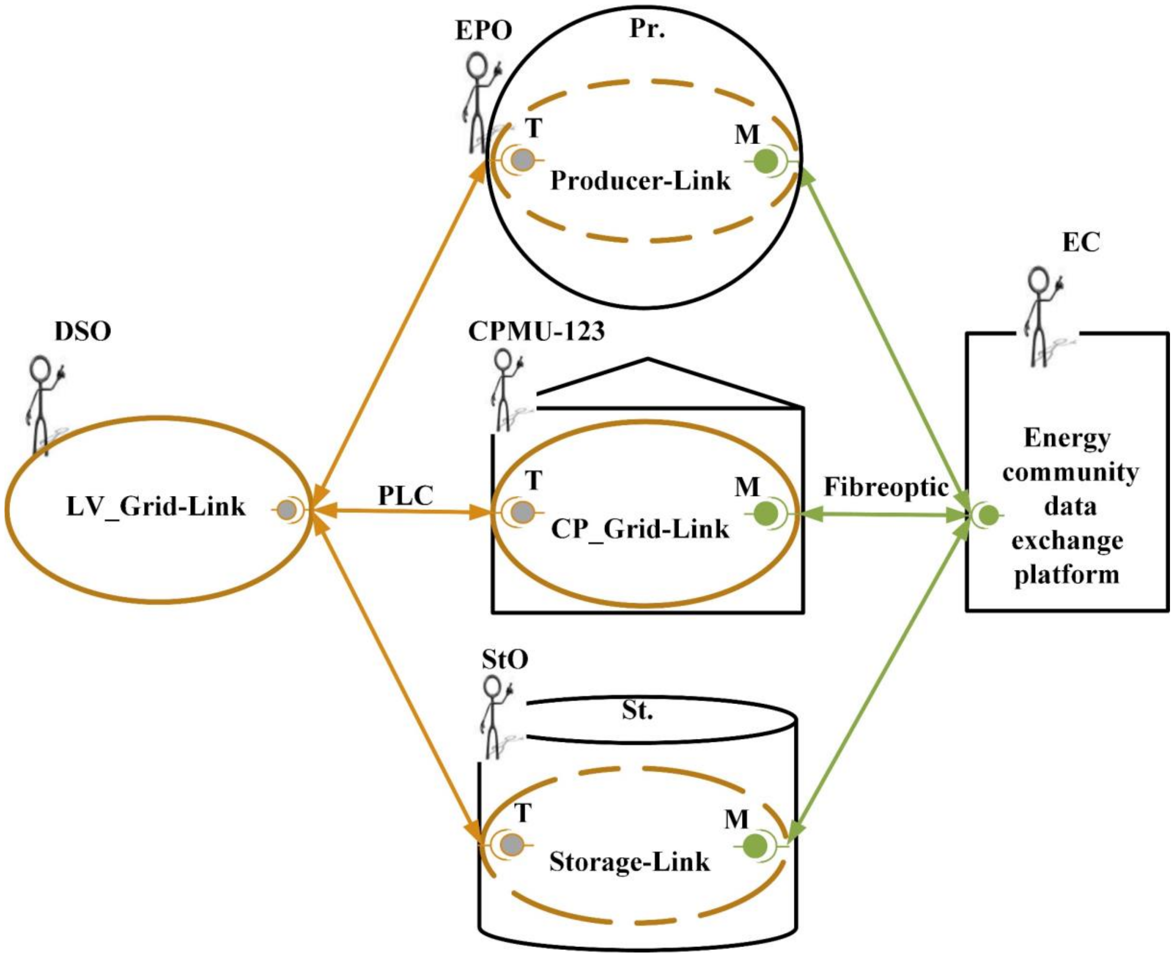


Figure 9 – Separate interfaces in customer plant, producer and storage level to protect the grid from cyber attacks

4.3.4 Exchanged data through the technical interface

The information required to enable feasible, reliable, and resilient operation exchanges via interfaces; one of the main elements of every *LINK*-architecture' component. There are three relevant interface pairs the Grid-Link/Grid-Link, Grid-Link/Producer-Link, and Grid-Link/Storage-Link. The relevant electrical entities to be exchanged are shown in Table 1.

The Grid-Link / Grid-Link Interface is the most extensive one. The day ahead $P_{Schedule}^{dayahead} \pm \Delta P$ and following hour schedule $P_{des}^{nexthour} \pm \Delta P$ exchanges to enable the load-production balance. ΔP is the active power capacity support (spinning reserve), which each Grid-Link should provide during contingency conditions. It is also relevant for the (n-1) security calculations. In this case, also the available reactive power resources should be known $Q_{Schedule}^{dayahead} \pm \Delta Q$ and $Q_{des}^{nexthour} \pm \Delta Q$. The dynamic data for the equivalent generator and the equivalent exciter, voltage regulator, turbine, and the governor are calculated in real-time and exchanged between Grid-Links to enable the angular and voltage stability calculations. Grid-Links can also offer services to each other employing secondary and tertiary reserve. The frequency f_{meas} is necessary to allow the synchronization process of Link-Grids, which have been operating in self-sufficient (autarkic) mode. Demand response is the most complicated process of Smart Grids operation. The request for load decrease or increase is included in the interface in the form of the desired instantaneous value, $P_{des}\pm\Delta P$, $Q_{des}\pm\Delta Q$. Depending on the interfering Grid-Link types, the following interface pairs are possible HV-HV_Grid-Link, HV-MV_Grid-Link, MV–LV_Grid-Link, MV- and LV– CP_Grid-Link. The latter is relevant for the INTERACT energy communities.

4.3.4.1 LV-CP_Grid-Link interface

This Grid-Link interface characterises the interaction between the LVG and CPG. The CP_Grid-Link is by definition modular and closed in itself, thus fulfilling the data privacy conditions. Unlike Kießling [14], where specific household devices should be turned on/off by network operators and energy suppliers, the CP_Grid-Link acts as a black box in the new functional architecture. The network operator interacts with the CP_Grid-Link through the CPMU interface, which gives information only about their exchange and their needs ($P_{des}\pm\Delta P$, $Q_{des}\pm\Delta Q$). No information over the household devices currently in operation is accessible from the grid operator or the energy supplier. The customer may wish to control the house devices by using the Internet of Things (IoT), but this is independent of the customer's interaction with the grid. The communication with the grid takes place only through secure channels, PLCs, thus protecting the power delivery systems from cyber-attacks. The LV-Grid-Link sends the negotiated set points P_{set_point}, Q_{set_point} to the CP_Grid-Link (CPMU). At the same time, the CP_Grid-Link's secondary control, the CPMU, supervises the real-time exchange with the grid. It generates the daily and hourly P and Q schedules. Theoretically, all entities for the Grid-Link/Grid-Link interface defined in Table 1 are necessary also for this link combination. Now and for the near future, it is not realistic to collect and prepare this kind of data. Firstly, the house electrical grid is not on the utility nomenclature, and practically they do not have access to it. Secondly, also the customer, as CP_Grid-Link owner, usually does not have the required information. Many research projects show that various automation solution will be necessary in LVG. Over time, this development trend will require more calculations and coordination, and therefore it makes sense to plan this interface with all the data described in Table 1.

4.3.4.2 Grid-Link / Producer-Link interface

This interface pair characterizes the interaction between the TSOs and the power supplier. It is well established at the transmission level, i.e., between the HVG and the electricity producer injecting through step-up transformers. Similarly, the same information exchange between MV_, LV_ and CP_Grid-Links, and the connected Producer-Links.

4.3.4.3 Grid-Link / Storage-Link interface

This interface pair characterizes the interaction between the TSOs and the storage. It is well established at the transmission level, i.e., between the HVG and the electricity storage (mainly pumped hydroelectric power plants). Similarly, the same information exchange between MV_, LV_ and CP_Grid-Links, and the connected Storage-Links.

Table 1 – Generalised electrical entities for all three technical interface pairs

	Electrical entities to be exchanged (*)	Grid-Link/Grid-Link	Grid-Link/Producer-Link(**)	Grid-Link/Storage-Link
Very fast	Operating mode***	√	√	√
	f_{meas}	√	√	√
	V_{meas}, C_{meas}	√	√	√
	P_{meas}, Q_{meas}	√	√	√
	P_{set_point}, Q_{set_point}	√	√	√
Fast	P_{des}±ΔP, Q_{des}±ΔQ			
	Delivered time	√	√	√
	Time interval			
	$P_{des}^{nexthour} \pm \Delta P$			
	$Q_{des}^{nexthour} \pm \Delta Q$	√	√	√
Slow	$P_{Schedule}^{dayahead} \pm \Delta P$			
	$Q_{Schedule}^{dayahead} \pm \Delta Q$	√	√	√
	Static and dynamic (lumped) load characteristic	√		
	k_{PV}, k_{QV}, k_{Pf}, k_{Qf} …			
	I_{equiv}, Z_{equiv}	√		
	Dynamic equivalent Generator parameters like x_d, x'_d, …, T'_{d0}, …	√	(****)	(****)
	Equivalent voltage regulator, static exciter parameters like K_A, T_A, …	√	(****)	(****)
	Equivalent governors, turbine parameters like K_1, T_{G1}, …	√	(***)	(***)
	Schedule for demand response capability	√		
	Reserves schedule (secondary, tertiary)	√	√	√

* Data related to the boundary node

** P and Q can have only one sign. Producers only inject power on the grid

*** Operating modes of the Link such as autonomous, autarkic or recovery (see D.3.2)

**** Static data should not be exchanged via interface

Many electrical entities listed in Table 1 may be considered unnecessary for operating in a low voltage grid. But depending on the degree of the automated interactive operation of the EC members, they may gain importance.

4.3.5 Protocols

Interface and protocol communication standards have the advantage that their use does not bind to a specific manufacturer, thus facilitating the integration of devices from different manufacturers and the system support. All protocols from the field of distribution grid automation are relevant for the INTERACT Energy Communities. The European Standard EN 13757-1 is suitable for meter communication systems and remote reading.

4.4 Services: Provided functions and features

The goal of the CT is to help the energy community to fulfil its mission; Democratization of the power industry by engaging all customers by offering services to it. Figure 10 gives an overview of the main energy communities topics to be supported through the CT architecture services, such as enabling the participation of its members in the local market, grid services coordination and accounting.

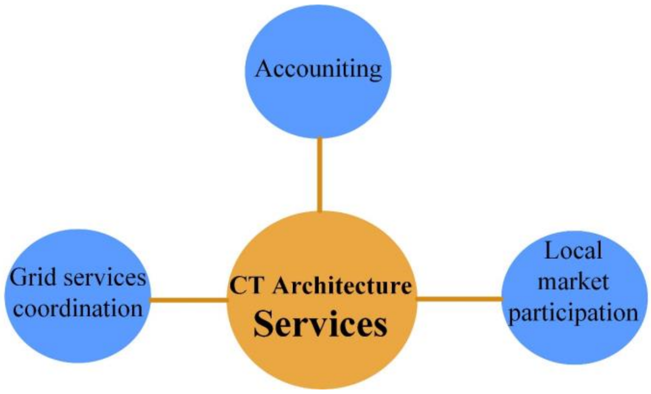


Figure 10 – INTERACT energy community services supported by the CT architecture

The CT used for INTERACT energy communities should have the following functions and features:

- Reliable infrastructure.
- Secure from cyberattacks and protected from access by third parties.
- Cost-effective.
- Transfer complex data structures for periodic transfer, transfer on request, one shot data transfer, etc.
- Transfer schedules, analogue measured values, status indications, text messages, commands, setpoints etc.
- Transfer accounting information.
- Encryption/decryption of the exchanged data.

4.5 Principles: Guiding ideas forming the CT for Energy Communities

INTERACT energy communities, designed based on the holistic *LINK* solution, promote distributed energy resources, and facilitate customer participation in power system activities on a large scale. They act harmonized with the entire power system. Therefore, the guiding idea forming the CT for energy communities is that any development should meet power system reliability, security, and feasibility standards.

4.6 Policies: Rules enforcing the CT for Energy Communities

Currently, DSOs own legally smart meters and only they are allowed to receive and analyze information about each subscriber's consumption and generation measurements. The municipality in Großschönau, Austria, was installing parallel measurement units to create their Energy Metering System. With the Austrian Energy Act (in German “Elektrizitätswirtschafts- und -organisationsgesetz” or abbreviated “ElWOG”) of 2021, this was updated, and as of 28th

of July 2021, the DSOs are required to measure at least every 15 minutes and to forward the measured values as soon as possible but not later than the next day also to the Energy Communities (ElWOG 2010, § 16e (1) 2.). The same paragraph also requires the DSO to provide this data both through a user-friendly web-interface as well as in a machine-readable format to the Energy Communities.

The same Austrian Energy Act also requires from the DSOs to calculate the allocation of used and produced electricity within the Energy Communities within 15 minutes intervals and provide this data to the Energy Communities for the invoicing (ElWOG 2010, § 16e (3)).

E-Control as regulator of the Austrian energy market was including these obligations into their ruleset, and in the other market rules electricity, information exchange, invoicing and clearing, version 4.0 [15], data exchange regarding energy communities was included, and access to the data by means of the standard electronic data exchange platform “EDA” enabled.

Thanks to this legal obligation, double metering infrastructure is avoided, and the grid owner (DSO) must share the metering data with the grid users (in our case Energy Communities) in way enabling automatization.

5 Conclusions

For the operation of an INTERACT Energy Community, data must be exchanged between the EC members and Energy Community for trading and settlement, between the EC members and DSOs for flexible customer control, and between the EC and DSOs for trading and harmonization with the grid. This data exchange is required partly during operation and partly at periodic intervals.

Ideally existing ICT infrastructure is used for the necessary data exchange. In Austria this data exchange is for certain metering information at certain intervals required by law since the Austrian Energy Act was enabling the creation of Energy Communities (28/07/2021). Technical realization of the legal requirements is nevertheless not as fast.

For more advanced services which require different data and/or more accurate data, such legal rules need to be updated, or additional ICT infrastructure must be installed by the Energy Communities.

For greenfield projects like Fyllinge, the implementation of the needed ICT structure needs to be considered during the planning stage to ensure lowest cost and optimal data exchange. All necessary data exchange for fully integrated Energy Communities can be realized either by setting up an own metering and ICT infrastructure from the beginning, or by agreeing on its technical parameters and shared use upfront with the local DSO when performing the long-term planning of the local power grid.

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