D3.3 REQUIREMENTS FOR TOOLS FOR LOCAL ENERGY COMMUNITIES

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About ERA-Net Smart Energy Systems

ERA-Net Smart Energy Systems (ERA-Net SES) is a transnational joint programming platform of 30 national and regional funding partners for initiating co-creation and promoting energy system innovation. The network of owners and managers of national and regional public funding programs along the innovation chain provides a sustainable and service oriented joint programming platform to finance projects in thematic areas like Smart Power Grids, Regional and Local Energy Systems, Heating and Cooling Networks, Digital Energy and Smart Services, etc.

Co-creating with partners that help to understand the needs of relevant stakeholders, we team up with intermediaries to provide an innovation eco-system supporting consortia for research, innovation, technical development, piloting and demonstration activities. These co-operations pave the way towards implementation in real-life environments and market introduction.

Beyond that, ERA-Net SES provides a Knowledge Community, involving key demo projects and experts from all over Europe, to facilitate learning between projects and programs from the local level up to the European level.

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LIST OF ABBREVIATIONS

CEC	Citizen Energy Community
CLUE	Concepts, Planning, Demonstration and Replication of Local User-Friendly Energy Communities
EAG	Renewable energy expansion act (Erneuerbare Ausbaugesetz)
DSO	Distribution System Operator
LEC	Local Energy Community
REC	Renewable Energy Community

EXECUTIVE SUMMARY

Local energy communities bring together consumers, producers and prosumers of electricity and sometimes also heat to optimise their common energy system at the local level. The goals are usually to achieve a climate-neutral energy supply with the highest possible share of locally generated renewable energy and at the same time to achieve the lowest possible energy costs.

Energy communities introduce a new, additional organisational level in the electricity market. In the traditional electricity system, it is the task of the DSOs to supply an energy supply area completely with the required electricity as efficiently as possible. The generation and distribution of electricity is designed to fulfil this task.

Membership in the energy community is voluntary, which means that only some of the consumers and producers in a closed supply area (and sometimes beyond) are members of the energy community, and they independently optimise their energy system in terms of components (assets) and their operation according to a freely chosen business model.

This has the following consequences:

1. in order to successfully implement and operate an energy community, the appropriate structure with a corresponding business model must be found and the associated energy components planned and built, as there are many design options.

2. a new, independent organisation with appropriate structures must be established.

3. as the energy community is only virtually connected, smart metering systems, data platforms and data management systems need to be built.

4. in order to implement new business models such as energy sharing, peer-to-peer trading or trading of flexibilities, appropriate trading and billing tools must be created.

All 4 points can only be implemented efficiently with the help of digital tools, which underlines the importance of digitalisation for the implementation of LECs.

The development of LECs can be divided into 5 phases: LEC concept development, LEC energy system design, LEC implementation and organisation, LEC energy system operation and LEC transaction accounting. Different digital tools are needed for all 5 phases. These are described and characterised below. Finally, the digital tools developed within the CLUE project are presented.

1 INTRODUCTION

The Renewable Energy Directive (REDII) and the Internal Electricity Market Directive (IEMD) introduced Renewable Energy Communities (RECs) and Citizen Energy Communities (CECs). Both together are named Local Energy Communities (LECs) in this document. These concepts aim to involve citizens, local municipalities and small and medium-sized enterprises in the energy transition. RECs allows local citizens and local authorities to participate in renewable energy projects because this can add significant value in terms of local uptake of renewable energy and access to additional private capital and thus local investment, as well as more consumer choice and citizen participation in the energy transition. Such local participation is seen as very important in the context of renewable energy capacity development. In this context, participation in renewable energy projects should be open to all members of the community on the basis of objective, transparent and non-discriminatory criteria. And renewable energy communities, according to the EU Directive, should be able to share the energy generated by their community-owned installations among themselves. CECs offers an inclusive option for all consumers to have a direct stake in producing, consuming or sharing energy.

The EU Directive has so far only been partially implemented with regard to RECs in the various member states, and in different forms in each case. The countries represented in the ERA-Net project CLUE (Concepts, Planning, Demonstration and Replication of Local User-Friendly Energy Communities) also show very different levels of implementation. In Austria, for example, the Renewable Energy Expansion Act (Erneuerbaren Ausbaugesetz EAG) has made renewable energy communities possible in Austria since 2021, which largely comply with the EU Directive. In Germany, citizen energy communities have been known for many years. However, their scope for action has so far been limited to the joint operation of renewable energy plants. Energy sharing of electricity quantities between members via the public electricity grid has not been allowed so far. Energy communities can also be founded in Sweden, but the framework conditions have so far only led to limited demand.

The CLUE project consortium consists of leading European research institutes, industry and local partners working together to advance the local energy community agenda through cross-national analysis and validation of meaningful proof-of-concepts through pilot demonstration projects. The project includes five demonstration sites (two in Austria and three more in Sweden, Germany and Scotland) working on different technology and market solutions for their respective countries.

The objectives and goals of the project are to.

1) To learn about the different challenges, prerequisites and approaches for the development of Local Energy Communities (LECs) and to understand the potential

and flexibility of the five demonstration sites, their integration into the ICT architecture and interaction with the surrounding energy systems.

2) Develop and validate tools to support the creation and operation of sustainable local energy systems and fill the gap of missing tools considering sector coupling, flexibility, local and coordinating cloud capabilities.

3) Derive tailored transition pathways for selected groups of LECs through stakeholder interaction in workshops to identify relevant drivers, success factors and barriers.

LECs are exploiting new business models in a rapidly changing energy market. Therefore, it is a major challenge to identify a suitable and attractive business model, to plan the most useful energy assets of the members, to optimally manage the operation of the assets and to efficiently carry out the accounting of the community's activities. Digital tools have been and are being developed for these various tasks and will be discussed in the following chapters.

Since different types of LECs with different business models are possible, which can differ significantly from country to country due to the respective legal framework conditions, and many different tools from the traditional energy market can be adapted to the LEC market, the overview of the tools cannot be complete, however, but can only provide an introduction to the topic.

2 ACTIVITIES OF LECS AND RELATED TOOLS

LECs need very different tools depending on their activities and regarding their development steps. To illustrate this, this chapter first presents an overview of the different types of LEC activities and then the development steps of the LECs, for which different tools are required in each case. Peer-to-peer trading and the provision of flexibilities are then presented as examples of different requirements for LEC tools.

2.1 Fields of activity of energy communities

Energy communities can carry out traditional activities in the energy market as well as take on new roles, so far energy communities often carry out the following activities (Babilon et al. 2022):

- **Generation**: Energy communities jointly use or own generation facilities whose energy they do not consume themselves, but feed into the grid or sell to energy suppliers or traders.
- **Supply**: Selling energy to customers. Energy communities can supply customers in their vicinity, participate in aggregation activities and combine loads and flexibilities, and actively participate in electricity trading.

- **Consumption and sharing**: Energy produced in the energy community is distributed and consumed within the community.
- **Distribution**: Owning or operating their own distribution networks for electricity or heat or biogas. Energy communities may own and operate if they have grid infrastructure.
- **Energy services**: Energy communities may offer services such as energy efficiency, energy saving, consumption monitoring, e.g. in the building sector. The spectrum also includes flexibility, energy storage, grid services or financial services.
- **Electromobility**: This includes offers in the area of car sharing, operation and management of charging stations or comparable offers to members.
- **Other activities**: Offers related to the development of energy communities, such as campaign implementation or offers to reduce energy poverty.

This list shows the wide range of possible activities and associated business models.

2.2 Categorisation of tool types for energy communities

The tools for LECs differ according to their stage of development. Tools are needed to support LECs in the following tasks, among others:

1. identification and conception of the energy community, evaluation of the different business models.
2. planning of the energy system of the energy community and dimensioning of the energy assets involved.
3. management and organisation of the energy community.
4. management of the energy systems to optimise the operation of the participating energy assets in the interest of the LEC.
5. implementation of business models such as trading of energy services and aggregation of resources as well as monitoring and billing of transactions by providing data and trading platforms.

A distinction must always also be made as to whether the tools are used to support or manage activities only within the energy community, i.e. between the members and their plants, or also the interactions between the energy community and the external energy system and its actors.

2.3 Peer-to-Peer trading platform as a LEC business model

Peer-to-Peer trading can be defined as a contractual model that will enable short-term electricity exchange on a regional or national scale between multiple peers such as 'prosumers' or/and small to medium power generators or/and electricity appliances located at the end of distribution networks, i.e. distributed energy resources. The P2P trading will normally be based on contractual rules and electricity prices determined by the market or the contract, as well as predetermined conditions governing the automated execution and settlement of the transaction. Especially the automated execution and settlement, will require extensive use of digitalization. In most pilot or full business schemes existing to date, blockchain is used for this automated execution and settlement, but there may also be other software solutions for implementing it. (Ninomiya et al. 2020)

Peer-to-peer trading with intermediaries requires a digital platform solution for implementation that provides an open space for joining buyers and sellers, creating a two-sided market. The platform operators can take on different roles here. If the platform operators act as intermediaries, they buy energy and deliver it to the end customers, as in the traditional energy supply. However, platform operators can also act as pure service providers, i.e. they only support and handle the deliveries between the actors in the background. (Babilon et al. 2022)

2.4 Provision of flexibilities for external actors as a LEC business model

The provision of flexibilities, which are provided within the energy community, to and marketing towards external actors can be very diverse. The following potential flexibility services to prosumers (Olivella-Rosell et al. 2018):

- **Time-of-use (ToU) optimization**: to use flexibility from high-price intervals to low-price intervals.
- **kWmax control:** to reduce prosumer consumption peaks within a predefined duration.
- **Self-balancing:** to use the price difference for consuming, producing and selling electricity favorably.
- **Controlled islanding:** to maintain electricity supply behind the meter during grid outage situations.

With the targeted control of generation and consumption, energy communities can offer flexibility products and contribute to system stability through grid services (frequency maintenance, control energy backup, provision of flexibility areas and black start responsibility). Flexibility markets can provide incentives to control demand-side consumption behaviour (demand response) as well as local generation units and storage systems on the supply side. The goal is economically efficient trading transactions that at the same time serve the grid in order to be able to compensate for instabilities in the electricity grid. (Babilon et al. 2022)

Studies show that within energy communities, activating flexibilities and demand-side management can increase resilience and, if configured appropriately, maintain the community grid in the event of a grid failure. However, the energy flexibility of the community members and their buildings can not only be used to avoid supply disruptions to the community, but can also be used to reduce energy prices. (Mar et al. 2021)

2.5 Digital core technologies

Digital core technologies for the operation of the aforementioned fields of application of energy communities are smart metering systems, platforms and data management systems as well as distributed ledger technologies (e.g. blockchain) and associated smart contracts. Other digital tools for energy communities are tools for actual maintenance (digital maintenance) and for predictive maintenance, as well as modelling tools for generation, consumption, grid and storage forecasts. In addition, Big Data technologies for real-time data analysis, artificial intelligence such as machine learning and robotic process automation will be relevant in the near future. (Babilon et al. 2022)

3 TOOL TYPES FOR SPECIFIC STEPS OF LEC DEVELOPMENT

The development, implementation and operation of LECs takes place in 5 steps, each of which has very different tasks. For each step, digital tools are available or desirable to significantly facilitate the development and implementation of LECs. In some cases, the tools are also a prerequisite for successful implementation of the LEC. Figure 1 shows the 5 steps and exemplifies some digital tools that belong to each step. The types of tools are then described below.

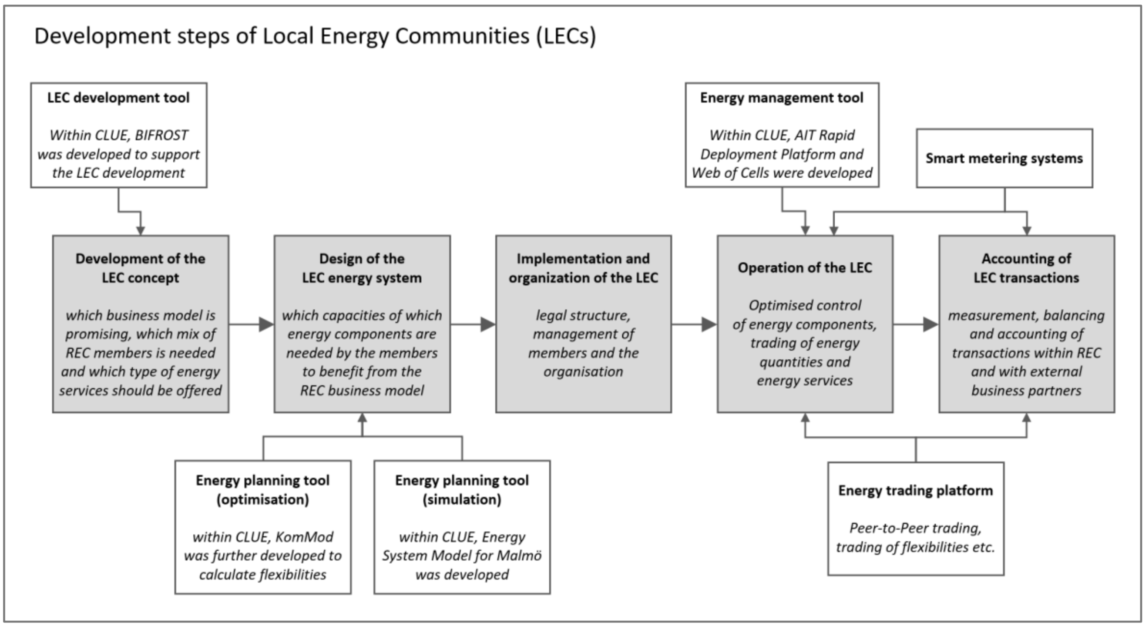

Figure 1: Development steps of LECs and related tools to support the implementation of the steps

3.1 Tool type 1: LEC concept development

The first step for the implementation of a LEC is the development of a concept with an objective regarding the type of number of members, the perimeter in which the members should be located, which conditions the members should fulfil with regard to the generation, storage and consumption of energy (electricity, possibly also heating and cooling) and the controllability of their individual energy systems, as well as the business model to be implemented within the LEC. For this purpose, the national legal framework conditions that enable or restrict the business activities of the LECs must be taken into account. However, the prosumers present in the region under consideration and their energy needs as well as the possibilities of renewable energy generation and much more must also be taken into account.

For the development of LECs, it is necessary to simulate different business models in order to assess whether they are economically attractive under the expected framework conditions. Appropriate simulation tools are needed for this.

3.2 Tool type 2: LEC energy system planning

In the LEC, the energy systems of the individual members (generators such as PV plants or biogas CHPs, electricity and possibly heat storage, controllable loads such as e-mobile charging points or heat pumps, etc.) must be optimised on the one hand so that the energy supply of the individual members meets the respective expectations, and on the other hand so that the expected energy services can be provided by the LEC. For example, energy sharing is only advantageous if larger generation plants are operated jointly or if there are members in the LEC with different, preferably complementary energy generation and load profiles. If external flexibilities are to be provided, sufficient storage, controllable generators or controllable loads must be available within the LEC.

It is recommended to use energy planning tools to dimension the energy system of the LEC (and thus also of its members) in such a way that the optimal capacities of the individual energy components are known and can be provided for the intended business model and the planned energy services.

Depending on the number of members, this modelling can be very detailed or only rough. For example, similar LEC members can be grouped together, e.g. the private households of a district with comparable load profiles, PV systems and electricity storage on the one hand, and the commercial members on the other hand, as well as the community facilities of the LEC. The modelling calculation must have as a result, for example, what total electricity storage capacity must be available in the LEC under the assumed generation and load profiles in order to be able to provide flexibilities to a certain extent.

With regard to the tools, a distinction must be made between simulation tools and optimisation tools. In simulation tools, a model of the energy system to be investigated is created with the corresponding parameters and the tool simulates the behaviour of the system over time and calculates, for example, the annual energy demands, the full load hours, the shares of the different generators, etc. The capacities of the different energy components are predefined. The capacities of the different energy components are predefined and are not changed during the simulation run.

In optimisation tools, on the other hand, a model of the energy system to be optimised is also created, but the capacities of the individual components are not specified, but are the result of the optimisation calculation.

Simulation models can also be used to optimise energy systems by systematically varying the configuration of the energy system and comparing the simulation results for the different variants, but this is more time-consuming and with more complex energy systems there is a risk that the global optimum will not be found.

3.3 Tool type 3: Operation of the LEC organization

The organisation of non-profit and membership organisations such as cooperatives involves many administrative and communication tasks that can be simplified by digital tools. LECs are likely to be little different from other similar organisations for which digital solutions already exist. Therefore, this type of tool will not be discussed further here.

3.4 Tool type 4: Energy management to support LEC operation

The energy systems of an energy community can be operated in different ways, whereby optimised operation depends heavily on the implemented business model. In the simplest case, the joint energy plants of the LEC are operated in such a way that they achieve the highest electricity yield in order to either sell the electricity on the electricity market or supply it to the members. In this case, the energy plants of the individual members can be operated independently of each other. However, if the LEC's objective is to achieve the highest possible self-supply ratio with energy from its own generation facilities, it is advantageous to operate the controllable generation facilities in such a way that their generation matches the energy demand profiles of the members as closely as possible, and to operate the storage facilities and controllable loads of the LEC and its members in such a way that they reduce the mismatch between generation and consumption.

This requires that the expected energy production of the non-controllable energy generators (photovoltaic and wind power plants) are known as well as the expected energy demands within the LEC and the states of charge of the available energy storage and the possible load shifts. Therefore, an intelligent measuring system is required at the LEC members and plants. Furthermore, a data transmission system is needed that collects the data of the distributed energy plants in real time and sends it to the management tool and the control signals of the management tool back to the energy plants. This must be done at least at the frequency of the time steps for which a new schedule is to be created for the plants.

Energy management tools are available for a wide variety of energy plant configurations and for different business models and tasks, and are continuously being developed further. Increasingly, new methods such as artificial intelligence are also being used, for example to predict generation and consumption as well as the attainable energy prices on the market, as the marketing of surpluses is also intended to generate the highest possible income.

3.5 Tool type 5: Trading and accounting tools to enable LEC operation

The operation of the energy systems and the physical provision, storage and physical use of energy quantities is controlled by the energy management system. The bookkeeping distribution and allocation of the generated or provided energy quantities within the energy community requires a trading and accounting tool that organises, records and settles the allocation according to the agreed rules. The energy quantities can not only be distributed according to rigid rules, but also traded on a local market, either within the energy community or also with external partners. Possible flexibilities of the energy communities can also be traded. This requires trading platforms that negotiate the transactions between the trading partners as automatically as possible. There are various approaches for this (e.g. peer-to-peer trading), which are often based on blockchain technology in order to achieve a high level of security in the execution of the transactions. The prerequisite for the trading platforms and billing platforms is the availability of the energy data of the individual actors in a sufficiently temporally resolved form.

4 TOOLS DEVELOPED AND USED IN CLUE

Within the CLUE project, the following tools in particular were developed and used in the participating countries. Other commercial tools were also used, which are not listed here.

LEC development tools
AUSTRIA
BIFROST (developed by Siemens in the framework of CLUE) BIFROST is a web-based tool for the construction of visually engaging settlements, communities and quarters backed by Smart Infrastructure. External modules can interact with the BIFROST data model and simulation engine to emulate complex distributed automation setups and create compelling stories. For energy communities BIFROST should address non-experts who are interested in the topic, maybe want to found an energy community and need help in decision making for this process. **BIFROST External Configuration Tool** (dev. by TU Wien in the framework of CLUE) The tool provides a web frontend for changing the configuration of single-family houses in a BIFORST settlement. During configuration, the data of the building

model is adjusted. The current scope includes photovoltaics, electric vehicle charging infrastructure and the setting of alternative load profiles. Different simulation scenarios for an existing BIFROST settlement have been created and configurated.
SCOTLAND
CARES Tool Kit A toolkit developed by local Energy Scotland that provides a guide through the process of developing a renewable energy project. This tool provides a reference to the requirements for planning and setting up local energy system projects in Scotland. The tool is used as a guide in understanding how to setup of local energy systems in Scotland.

Energy planning tools for LECs
AUSTRIA
NEPLAN® NEPLAN® is a high-end power system analysis tool for applications in transmission, distribution, generation, industrial, renewable energy systems, Smart Grid application and is used in more than 110 countries. It was used along with additional conventional tools like spreadsheets to plan the demo site in Gasen / Austria.
GERMANY
KomMod (further developed by Fraunhofer ISE in the framework of CLUE) KomMod (Municipal Energy System Model) is a modelling tool that can holistically optimise local energy systems of cities or city districts, taking into account sector coupling (electricity-heating-cooling-mobility) and the temporal dynamics of the energy system, especially solar and wind energy. It enables the cost-optimal design of climate-neutral energy systems. Within the framework of CLUE, it was further developed to be able to map a cold district heating network, which is being implemented in the German CLUE demonstrator. One aim of the further development is to calculate which external flexibilities the neighbourhood can provide for its surroundings.
SWEDEN
Energy system model for Malmö (developed by RISE in the framework of CLUE) The model represents Malmö's energy system including electricity and heat, production and demand, flexibility, and grid capacity. Flexibility potential is estimated by comparing the reference case and optimization case. Clustering and aggregation methods are used for capturing the demand/flexibility patterns of different customer segments.

The model is used to (1) estimate the flexibility potential in local energy communities from space heating, hot water preparation, EV charging, and stationary battery (2) enable an ex-ante analysis about the effects of energy communities on the local energy system in different scenarios concerning the population growth, electrification in transport/heating, regulatory setup, etc. and (3) allow a further analysis of the up-scaling effects in other regions.

Energy management tools for LECs
AUSTRIA
AIT Rapid Deployment Platform (developed by AIT in the framework of CLUE) The AIT Rapid deployment platform helps bringing Software used in simulations into the field or into Hardware in the loop (HIL) tests. By leveraging a microarchitecture, modules developed for simulations can be reused with minor modifications by adding interfaces which are compatible with the platform. This helps in combining different parts of the implementation: optimization and control algorithms, book keeping, storing historic data etc. With the platform the assets in the Austrian demonstrator in Gasen are controlled and measured.
GERMANY
E.ON Ectocloud / Digital District Heating (EON) See the description of Sweden.
SWEDEN
E.ON VPP (Virtual Power Plant) (EON) The VPP enables engagement in the flexibility market, local prosumers can modify their on-site generation or consumption to provide additional capacity when the grid needs it. The basis is to provide either savings based on capacity tariffs and/or generating new revenue stream by providing flexibility to capacity and/or frequency markets. The VPP supports operators of local energy systems (LES), aggregators and individual flex providers to manage flexibility in a optimal ways. The VPP creates the prerequisites for these actors to engage in the energy market to identify opportunities for local generation assets to contribute to the grid when it needs it most e.g. by optimizing the excess energy from distributed CHP, turbines, air conditioning, heat pumps and energy produced industrial processes. It can also manage flexibility by ramping down assets and using various demand side response (DSR) features. In the CLUE project, the VPP provides the logic and the user interface (UI) for executing the smart charging demonstration. **E.ON Ectocloud** / Digital District Heating (EON)

Ectocloud based control is achieved through cloud and IoT-based technology, computing system-wide steering in the cloud which is transmitted to Energy Manager IoT gateways. The Energy Managers integrate with suitable building assets e.g. heating loads, battery and PVs through the local BMS (Building Management System) or other control units and apply local control logic to influence the load outtake. Through Machine Learning technology, decision support information is generated and presented to the user to understand the benefit and impact of applied steering. The digital optimization and control platform ectocloud has been developed by E.ON to provide demand-side management (DSM) of various heating loads with different features for various systems e.g. district heating, LowEx grids and ectogrid. It is utilized to generate benefits from a production and distribution context, providing manually and automatically activated control capabilities to DSOs. Ectocloud based control is applied to circumvent needs of operating peak generation during shorter periods of high demand, or optimize based on other distributed assets, while having a neglible impact on customer comfort achieved through activation of building inertia.
SCOTLAND
Web of cells (developed by Catapult in the framework of CLUE) The web of cells groups related and fixed energy assets into cells. Each cell has distinctive properties, for example we have renewable generation cell which groups wind and solar generation assets in the community. Each cell works out the best approach to coordinate demand and supply within itself and provide this to the community while also considering how other adjacent cells are operating. The tool coordinates the power demand and supply between local energy community cells. A cell here is a managed group of one, or more, related and fixed energy assets within the community which are operated to achieve an objective or series of objectives. **Vector Integration Platform** (VIP) (Catapult) The LEC in the Scottish Demo is a multi-vector system that considers not just distribution of energy but also H2 gas in the gas network via green hydrogen from an electrolyser to be located at the Levenmouth wind turbine in the community. The VIP is a tool being developed in a tool that would decide how best to split gas and electricity distribution within the community. It coordinates how much electricity or H2 gas demand is provided to the community.

Monitoring, trading and accounting tools for LECs
AUSTRIA
AIT Rapid Deployment Platform (developed by AIT in the framework of CLUE)

The platform performs the monitoring by using well established technologies like Grafana (dashboards), Loki (logging), Jaeger (tracing), Docker (monitoring and managing the deployed modules), Prometheus (metrics), TimescaleDB (database for historic values). Due to the modularity of the platform, it is possible to replace or extend the tools used for monitoring (e.g. store logs in Elasticsearch). The AIT Rapid Deployment Platform monitors two parts in the community 1) the devices in the field (battery, electrolyser etc.) and 2) the health and functionality of the Software components of the platform. **BIFROST** (developed by Siemens in the framework of CLUE) In the operational phase of a LEC BIFROST will be used as monitoring tool to provide the same look and feel to the user as in the planning phase.
SWEDEN
E.ON Ectocloud / Digital District Heating (EON) Ectocloud provides monitoring data on the individual level of the LEC (LEC members), the community level of the LEC and the DSO / LES Operator. Real-time data on generation and consumption, storage, energy flows are provided and KPIs calculated e.g. self-sufficiency level, CO2 emissions, energy savings. Overview on assets and asset usage is provided to the operators and the relevant electrical data for the DSO.
SCOTLAND
Web of cells (ANM Element) (developed by Catapult in the framework of CLUE) At each energy asset there is a ANM element device located that monitors telemetry (power demand and supply profiles). This feeds information that web of cells uses to decides how best to operate the assets in the community. The tool monitors all local energy community energy assets used in the project.

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