# COMMUNITYWARE SMARTGRID

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## *ABSTRACT*

*One of the key promises of the smartgrid is the multitude of benefits it will bring to all of the involved parties, especially by actively integrating the end-user. Since standalone and non-coordinated user participation may have limited impact, we believe that focusing on dynamic communities and enabling them with innovative ICT tools, can unleash the true potential of the smartgrid. The communityware smartgrid will need to support advanced business services that provide in real time information to all parties, and enable them to interact and transact in an open, secure transparent and market-driven environment. We discuss on the service paradigm and the service support for communityware.*

## MOTIVATION

Integration of renewable, minimization of losses, optimal usage of locally produced energy are some of the motivating factors that push the smartgrid vision [1] towards operating over a very dynamic and decentralized future energy network, where electricity will be produced in a distributed way; where customers will be not only consumers but also producers (hence called prosumers); and where bidirectional interaction between producers, consumers and other entities will be possible. These prosumers are expected to interact with each other via Internet services in a very timely fashion. Typical examples are price signals that can be sent to the end users so that they adapt their energy behavior in order to e.g. avoid network-wide peaks. Typical incentives investigated are mostly of monetary nature, however it is expected that other ones will also play a significant role e.g. preference to alternative energy resources (irrespective of price) etc.

The smartgrid is a system of systems i.e. it is a complex ecosystem of heterogeneous (possibly) cooperating entities that interact in order to provide the envisioned functionality. Advanced business services are envisioned that will take advantage of the near real-time information flows among all participants. These real-world energy services will go way beyond the existing ones and enable us not only to become more energy aware, but also to optimally manage it.

In order to realize the promise of smartgrid, a key element would be to have timely monitoring and control; a task that will heavily depend on ubiquitous networked embedded devices and ecosystems of them. For instance smart meters are the key for monitoring energy consumption. However in parallel the bidirectional interaction is pursued i.e. that there is an adaptation on the behavior of the prosumer device based on the information that it receives e.g. electricity price.

## TOWARDS A SERVICE DRIVEN SMARTGRID

Energy data collected from existing monitoring devices such as the smart meters, is communicated via wired and wireless channels either directly to a metering service or via the usage of in-network intelligent data processors. At some point the data reaches the enterprise system where today mainly billing is done (as shown in the left part of Figure 1). However in the future we expect that to change. Following the software-as-a-service (SaaS) model, we expect the rise of new applications (as well as feature enhancement) simply by rapidly combining cross-enterprise services to deliver customized functionality.

As depicted in Figure 1, various new services are envisioned such as real-time energy monitoring, real-time billing, direct asset management, customized information services, marketplace interaction etc. This is a significant change for the energy domain, as we move away from heavyweight monolithic applications towards much more dynamic, up-to-date and interactive ones utilizing local capabilities. By increasing visibility via near real-time acquisition and assessment of the energy related information, providing analytics on it and allowing selective management, we expect the emergence of a new generation of customized energy efficiency services.

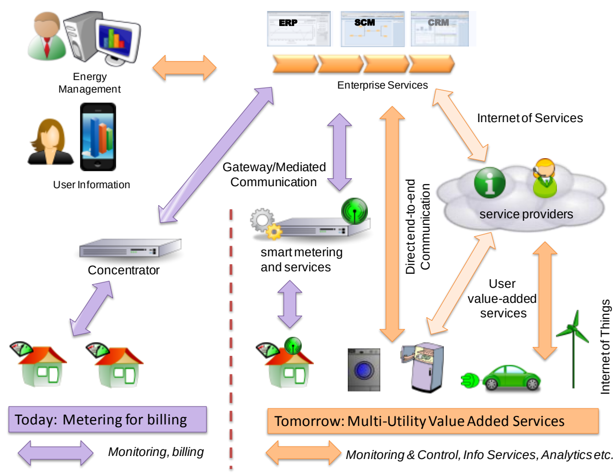


**Figure 1 – The multi-utility service-driven smartgrid**

For most of utilities today the smartgrid is synonymous to smart metering and the visibility it can offer. As such business cases are laid out where the user vs. the utility monetary benefit is calculated, however mostly considering existing business interactions among them but often failing to see beyond and towards innovative services that may arise. Today each house hosts a meter and its consumption is reported and paid for. However this will drastically change in the future! Not only the integration of renewable and local energy generators will introduce additional complexity, but the number of devices that can report their energy consumption will increase expodentially. As depicted in Figure 1, with the introduction of e.g. smart appliances any kind of device (e.g. fridge, computer, electric car, air condition etc.) will be able to measure and report its energy consumption or production; effectively acting as a smart meter. Since these devices may be also mobile, new challenges arise as most of research today still considers the meters as static ones residing in homes and with limited cooperation capabilities.

Current efforts focus on engaging the users to actively participate by adapting their energy behavior. Most approaches focus on rescheduling in order to move loads to different zones during the day, while others deploy automatic systems that react to real-time price signals. The majority of the approaches assume that the user will be motivated enough to install and actively operate in long term energy management optimization techniques. However initial results show that the monetary benefits may be low and therefore user's interest may decrease over time. As such it is crucial not to focus on single use case and exploit broader business cases that take into consideration several value added services that can be hosted once a common smartgrid infrastructure is in place. Considering the analogy with the telecom domain and usage of advanced services with smartphones, we expect similar services to flourish in the energy domain and be bundled with additional benefits; energy billing is expected to be only just one of them.

Prosumers in the smartgrid may take into account real-time information and even engage in short-term contracts, buying and selling energy online as well as adjusting their behavior according to their goals. The service-driven smartgrid makes it possible to empower the communities with new capabilities on managing themselves and their external interactions. The emergence of communities may provide both the motivation and the critical mass to enable interactions among the smartgrid actors with significant impact, something that is hardly realizable today.

## COMMUNITYWARE EMERGENCE

The emergence of Internet and its services enabled users to not only be better informed but also overcome location and communication barriers. Partial goal of these communities is information flow among their members but also possible common actions. In communities, intent, belief, resources, preferences, needs, risks, and several other conditions may be present, all of which have an effect on how the community's members behave internally and how the community as a whole appears to interact externally with others in a highly networked world.

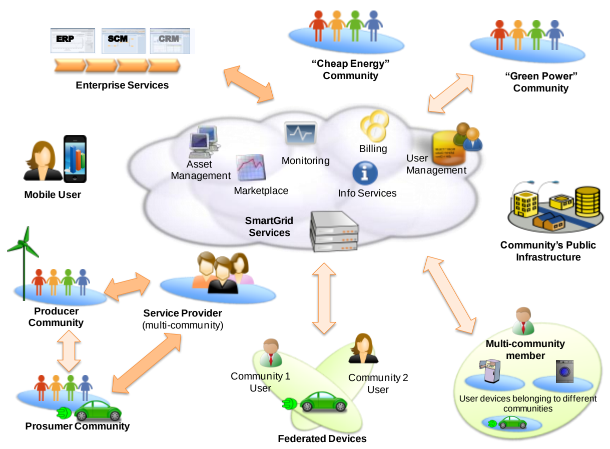


**Figure 2 – Communityware empowered smartgrid**

Community member interactions may lead to the emergence of more intelligent global behavior, unknown to the individual members. Typical example from the math and computer science domain is the swarm intelligence; the collective behavior of decentralized, self-organized natural or artificial systems. Since the smartgrid is seen as a very complex system of systems, emergence i.e. the way complex systems and patterns arise out of a multiplicity of relatively simple interactions, is of extreme importance. Potential goals such as prediction of prosumer groups' energy behavior may assist in better planning and achieving targets e.g. energy efficiency. Additionally from the economic domain we have a perspective on how behavioral attitudes depend on incentives and expectations, while from the social science we get insights on interactions among communities and populations. Since the smartgrid domain is not only a multi-disciplinary one but will also be driven by multi-dimensional networks operating over a sophisticated cyber infrastructure, integrating lessons and ongoing research targeting highly interconnected communities [5] may be of help in understanding the complex emerging phenomena.

Today most efforts involving end-users in the smartgrid focus on individuals, which in our opinion may have limited impact due to uncoordinated reactions, degrading interest over time, high expectation on continuous user involvement etc. We believe that what could unleash the true power of smartgrids would be the consideration of communities i.e. multi-level groups of users and their assets. Focusing on communities will definitely give the critical mass to have some impact on any transaction envisioned in the smartgrid era.

As depicted in Figure 2, prosuming Virtual Power Plants (that could produce or consume/store energy when needed) could be realized by integrating distinct communities of users with high flexibility towards altering their energy signature. Similarly a user may take part in several communities, while devices such as electric cars or common appliances in house may even be federated. Communities will interact with eachother and possibly be part of other bigger communities or interact with coordinating entities. The result is a very dynamic ecosystem of cooperating actors each of which is striving towards achieving his goals.

The existence of heterogeneous communities could enable the emergence of third party service providers that would serve/assist such communities and adopt new roles in the energy domain. Similarly for the user participating in such communities, more benefits might be achieved, as he is acting as part of a group in comparison to acting alone in an uncoordinated way. A community of thousands users offering their electric cars to be charged at any time, may offer a service to the network for storing excessive energy, or even buy energy based on cheap/negative prices [2] in the energy market. Similarly on a high demand time they could feed-in energy in the network, acquiring monetary benefits for the members. Impact is the key, and consideration of communityware smartgrid can provide the critical mass to achieve it.

## COMMUNITYWARE SMARTGRID SERVICES

For the communities to emerge and be able to meaningfully interact with the envisioned smartgrid infrastructure, several services have to be in place. Some of them are anyway considered to be deployed as core part of the smartgrid, some already exist in other context (e.g. social networking sites), while others will need to be developed; additionally integration among all of them will have to be realized with the energy as target focus area. Such services are currently under investigation within the scope of the NOBEL project that focuses on energy efficiency for neighborhoods [4].

**Community Management**: The communityware smartgrid must support the creation of dynamic communities where the (mobile) user may connect and participate. These communities may be motivated by several aspects e.g. environmental, economic, social etc. It should be possible for users to easily create such ad-hoc groups, as well as join them while getting some guarantees on security, trust and privacy issues involved when affiliated and/or transacting in this context. Support for intra- but also inter-community collaboration is wished in order to increase networking effects.

**Energy Brokering:** Enabling the prosumer communities to be able to buy and/or sell energy on online marketplaces as standalone community or part of larger communities should be possible. Proxy agents may automate the negotiation process and take into consideration constraints and goals e.g. when negotiating with other communities. Existing marketplaces could be used with expanded functionality to accommodate community behavior or others can be set for geographical communities, cities, regions etc. Transacting and clearing should be done in real time and with trusted parties.

**Real-Time Energy Monitoring**: Several efforts today target real-time discrete energy monitoring, however this should be done in a way that the user has more control of it and can provide fine grained access to this data to third party service providers. This will enable the users to provide policy controlled access to subsets of their data (and possibly revoke it later) in order to empower the community's functionality. Typical examples we start seeing today are energy efficiency reporting in social networking sites e.g. Facebook or online energy awareness e.g. Google power meter. The key part is to be able to share data in a user-controlled way via interoperable technologies.

**Real-Time Analytics:** Assuming that the real-time monitoring is in place, being able to provide analytics for the user and communities may provide the necessary timely assessment for sophisticated automated strategic decisions. Additionally energy and third party providers may be able to better understand the dynamic behavior of communities and the way they interact, and develop better business models.

**Community Behavioral Simulation:** Simulations on the behavior of dynamic communities internally and when interacting with others may be proven valuable in better understanding and even planning and predicting future actions. With the emergence of communityware smartgrids it is expected that a very dynamic infrastructure will emerge where goal-driven groups will compete for resource availability; better understanding them can provide a business advantage.

**Energy Prediction:** Energy prediction may assist the user to associate with the right community as well as the community itself to better plan and negotiate in the global energy market. Since in the mid and long term it is expected that the energy prosuming devices will be able to provide very detailed information for their energy status, solutions are needed that take into account this vast information and derive customized models based on community's historic or profile data. Real-time complex prediction should be possible by assessing market, community, and context specific data.

**Real-time Energy Optimization:** The goal is to be able to better manage the energy prosumed. This does not necessarily imply e.g. less energy consumption, but better overall consumption based on given target behavior (e.g. adhere to a given target energy curve). As such energy efficiency can be enhanced. Typically these services will consider as input the current energy prosumption and the prediction and apply strategies to optimize community-wide the usage according to community's key performance indicators. Possible inter-community collaborations may assist towards reaching this goal. This will enable us to tackle at global level issues such as minimization of energy losses, peak reduction etc.

**Energy Info Services:** Communities will provide ground (as also done today) for more interest-oriented groups of people to be active. As such more targeted informational services can be developed that address their needs. These services can take into consideration voluntary info that the users or their community (e.g. overall analytics) provide in order to be even better assist them. Typical examples may be news, advertisements, energy contracts fitting to community's needs, energy prices, location based information (e.g. cheap electric car charging), house profile evaluation, social networking site integration and many more.

**Energy Management:** Being able to do monitoring can only assist partially on predicting the emerging behavior of a community; complementing it with real-time management capabilities is needed. In that sense the user's infrastructure could be actively tuned in order fit with the community's goals. Typical example functionalities envisioned (in interaction with the other services) include in-band (direct) management (control) of the devices/appliances, interaction with energy management systems, information for out-of-band user integration (e.g. via instant messages to take action) etc.

**Asset Management:** Future appliances are envisioned as networked embedded systems that can communicate [6] locally (over protocols such as, ZigBee, Bluetooth, 6LoWPAN, WiFi etc.) and over large distances e.g. over IPv6 etc. As such it is possible to have appliances cooperating [3] locally e.g. in-house as well as globally in order to achieve the community's goals. Being able to provide very detailed information about their operational status and scheduling plan, may come handy as typical business processes associated with e.g. installment of a new appliance, connection/disconnection of the user, device-health status etc. can be done more efficiently. Additionally new business models may emerge since now the fine-grained visibility within the community's infrastructure (e.g. appliances) exists, and value added services such as remote maintenance or appliance upgrade rebate programs may emerge. Enhanced asset management has the potential to empower business practices related to approval process, procurement management, life cycle management, (re)deployment and disposal management. However, special attention has to be given to the privacy since such detailed information may open the door for misuse.

**Energy Application/Service Store:** The trend towards mash-up rapid application development and the expectance of a large number of generic energy related services to be developed poses the need to have an online energy application/service store. This could provide a catalogue of available applications and services, which can be downloaded and installed e.g. on mobile devices or even links to their (online) implementation, search and matching functionality etc. The communities can use these services and easily build customized mash-up applications that could empower their users. Similarly the business world may be able to offer more innovative services to communities by rapidly combining communityware functionality. Additional services like rating etc. may provide peer review on quality, availability, performance and privacy offered by applications, services and communities.

## CONCLUSION

The smartgrid envisions active user participation in order to achieve its goals; however we believe that the critical mass can only be reached by considering goal-driven communities, the interaction with which may have significant impact rather than addressing each prosumer individually.

Taking into consideration the communities formed by multi-dimensional networks operating over a sophisticated cyber infrastructure is a challenging task. In order to empower communityware smartgrids, the open service-driven paradigm must be adopted and communityware auxiliary services must be designed, implemented and integrated with the current business practices and envisioned innovations. Mobility, and real-time information access and interactions are needed. Additionally security, trust and privacy need to be considered from day one and not be added later as an afterthought. Finally the policy and regulatory framework must make possible all envisioned interactions and support disciplinary actions against misconduct.

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