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In collaboration with TexelEnergie

Cloud Power

Harnessing energy from renewable sources for self-sufficient electricity communities

People matter, results count.

Introduction

This paper introduces the concept of Cloud Power: an energy community striving for a self-sufficiency for electricity based on energy from renewable sources. The concept is currently under development at Capgemini in cooperation with TexelEnergie in the Netherlands. Cloud Power provides the advantages usually associated with smart grids but starts from the consumer's point of view.

The concept of Cloud Power is based on a community of consumers who share common ideas on their electricity supply. These ideas can be based on multiple drivers including: economic, environmental and social drivers that are reflected in, for instance, improved energy efficiency, reduced emissions and preference of locally generated electricity. A Cloud Power community resembles the concept of a cooperative in which members own and operate the organization to their mutual benefits. This offers the additional advantages outlined table 1.

Current plans to implement Cloud Power actually involve a cooperative energy company, TexelEnergie.

The concept of Cloud Power fits within the current regulatory framework of most liberalized markets although the implementation details will differ between markets. Still, it can be implemented swiftly as there is no requirement for large-scale investments.

Challenges for to the industry

The energy industry currently faces a number of challenges that require it to change. These challenges are driven by climate change, dependency on foreign fuel, fuel depletion, and the increasing electrification of society. The industry thus has to reduce its carbon footprint by using alternative sources of energy while increasing its overall output. The energy industry

Table 1: Differentiators for Cloud Power

Opt-in	An important advantage of Cloud Power is the simple fact that consumers have the choice to 'opt-in'. This freedom of choice has an important implication: participants in a Cloud Power community are motivated to participate. As a result the investments in Cloud Power can be expected to be utilized effectively whereas the effectiveness of investments in schemes that have a captive audience is typically found to be low.
Customized products and services	Energy supply companies have struggled to provide new products and services to the market. The underlying reason for this is that it is difficult to develop a meaningful/actionable customer segmentation. The Cloud Power concept's approach to segmentation is consumer led - consumers define their community themselves, and the community's definition provides opportunities for energy supply companies to offer customized products and services.
Multiple drivers	It is widely accepted that the financial benefits of energy efficiency will only motivate a small proportion of customers. There is, however, a group of consumers that is driven by environmental considerations. This group is willing to invest even in situations that have a negative financial return. The concept of Cloud Power enables participants to choose from both economic and environmental drivers. Furthermore, the concept supports and benefits from social drivers such as community building/cooperation/cohesion.
Flexibility	The fact that most of the solutions involved in Cloud Power are situated 'behind the meter' provides consumers the opportunity to choose the solution that fits best and to determine when these solutions are implemented. This approach is fundamentally different from circumstances where consumers have to adapt their behavior or individual situation to the solution that others provide.

Source: Capgemini

"Pieter de Vries: Island of Texel, part of the World Heritage Site Wadden Sea; courtesy of TexelEnergie" has gone through a number of changes throughout its history but in the past the industry itself was setting both pace and direction of change. These days the political agenda seems to determine both pace and direction. The pace is set by political ambition and the direction is largely determined by the subsidies allocated to whichever technology is currently favored by the authorities. These political signals are picked up by society, leading to increased energy awareness. Energy-aware consumers no longer take their energy supply for granted but wish to participate actively in the supply of energy.

To cope with the above challenges, the industry presented the notion of smart grids as a generic solution. This explains why the definitions for smart grids used by various bodies differ to a large extent. The obvious reason is that the challenges take different forms in different geographies and the importance put on various parts of the solution differs too.

The generic solutions envisioned are based on a number of assumptions:

- all consumers prefer the lowest possible cost for electricity
- all consumers prefer an abundant and uninterrupted supply of electricity at all times
- all consumers prefer to be protected against fluctuations in electricity prices.

It turns out these assumptions are no longer correct in all circumstances. Some people are willing to pay a higher price if this reduces the environmental impact of their electricity consumption. Some consumers are willing to accept a reduction or interruption of supply given a fair remuneration. Still others think they are well equipped to manage the risk of price volatility themselves. Nonetheless, the industry is developing generic smart grid solutions based on the above-mentioned assumptions.

Cloud Power aims to unite a relatively small group of consumers that have a common approach to their energy supply. It enables the group to define and jointly pursue their individual goals.

Cloud Power

As long as the costs and benefits of smart grids are unclear for consumers, it seems legitimate to look for small-scale solutions that present tangible results to consumers at a reasonable price. The solution shall provide choice in the sense that consumers can 'opt-in' when they think fit and 'opt-out' if not. Finally, the solution shall be democratic in the sense that it enables individuals and communities to define their own objectives.

Local electricity solutions have been proposed as micro grids before. These solutions, however, assume that the grid is owned by the community that uses it. Besides the problems of raising capital for such a grid, however small, micro grids require the community to be co-located and are based on the 'all-in' tenet.

Cloud Power, however, is based on the assumption that the grid is available and owned by a regulated body that has the obligation to serve those connected. This means that participants in Cloud Power pay the regular fee for utilizing the grid under the market conditions but do not invest in new infrastructure. As the grid is considered ubiquitous there is no need for co-location of participants either.

Each Cloud Power community has a broad choice of objectives regarding price, reliability, fuel type, sustainability, self-sufficiency etc. The profile of each community is defined by these common objectives. Individual consumers in the community may have additional needs particular to their circumstances. Cloud Power enables the deployment of both common and individual assets for generation, storage and load control.

> **"Cloud Power brings considerable advantages for TexelEnergie with respect to the local generation and usage of sustainable energy."**
>
> **Brendan de Graaf**
> **(Managing Director TexelEnergie)**

Segmentation

The Cloud Power community revolves around the common objectives which de facto determine the identity of the community. The objectives form the basis of the long-term plan for the community. Potential participants can take notice of the plan and determine if the plan fits their individual objectives and their available resources.

The long-term plan can be considered the equivalent of customer segmentation in marketing terms. The plan is based on the needs of a specific segment of consumers and reflects the perceived needs for energy supply for this group. A long-term plan can be compiled for either existing communities (e.g. small-scale energy companies and housing corporations) or can be designed for a completely new group of consumers. The long term-plan can be based on multiple aspects of energy needs including:

- cost of electricity and associated services (including the willingness to participate in demand side management or demand response programs)
- energy sourcing (fossil, nuclear or sustainable)
- utilization of individual distributed generation, load control or storage capacity (including micro-combined heat and power (CHP), solar, photo voltaics, smart homes, electrical vehicles)
- development and utilization of common assets for generation or storage (wind turbines, CHP, large-scale storage).

Synergy

A typical Cloud Power community can be economically feasible for several hundred participants. A community of this size will not achieve the economies of scale of traditional energy companies. To achieve competitive price levels other means have to be utilized. The community therefore strives for synergies from technology and participants.

Based on the objectives defined in the long-term plan, a medium-term plan specifies the optimum mix of technologies for generation, storage and load control. Besides the planning for technologies, the medium-term plan addresses the development of the portfolio of participants and takes into account the effect of individual participants on the overall goals of the community.

This medium-term plan states the needs for technology and participants that will deliver a positive synergetic effect for the community. For technology this means that both common and individual assets are considered. For participants the medium-term plan can promote a type of consumption/generation pattern, certain geographical locations or specific individual objectives.

Internal market

A well-known issue with respect to the integration of distributed generation (especially of renewable energy) is the fact that in most markets individual consumers have to sell their surplus of energy for prices that are far below the actual price levels in the market. To overcome this problem Cloud Power is based on an internal market where electricity is exchanged between participants of the community for prices that reflect the actual balance of demand and supply. As an additional advantage, the internal market for Cloud Power does not involve any transactional costs for the exchange of energy between (individual) participants.

The internal market also offers advantages with respect to value-added and energy taxes as most Cloud Power communities take the form of a cooperative energy company. Although tax regimes differ between markets, a cooperative company tends to have a positive effect through the reduction of energy related taxes.

Real-time pricing

The traditional electricity market adjusts the generation of electricity to the demand for electricity. To satisfy demand at all times, a considerable amount of generation capacity has a low utilization. This leads to higher prices for electricity generated by these assets. The reason for these high prices is that the fixed costs of the assets have to be recovered over a relatively small number of operational hours. The utilization of these generation assets leads to price fluctuations and this effect is exacerbated by the integration of renewable generation. Currently consumers are protected from price fluctuations by energy supply companies. For this protection they pay a considerable premium.

The generally accepted solution is demand response, where demand is adjusted to generation (instead of the other way round). Generic smart grid solutions address the issue of adjusting demand and generation through demand response programs and demand side management.

Cloud Power also incorporates these mechanisms, albeit in a different way, as follows: Every day a forecast for the day ahead is created, based on expected demand and generation within the community. Based on this forecast hourly prices are determined and distributed among the participants. The participants then adjust their demand for the day to come accordingly. In most cases the adjustment is handled automatically through a home energy management system. The objective of Cloud Power is to reduce exchanges with external parties to a minimum thus making optimal use of energy generated within the community and reducing transaction costs.

Carbon intensity

For participants of Cloud Power, pricing is not the only incentive. Some communities or individual participants consider the environment an important driver. Therefore, the day-ahead forecast does not only produce hourly prices but also calculates the carbon intensity of the energy that is available on an hour-to-hour basis. The carbon intensity informs the demand pattern of the Cloud Power participants in the same way as hourly prices do.

Energy balancing

The main objective of operating a Cloud Power community is to maintain the energy balance, i.e. adjusting demand and supply within the

Table 2: Energy entities

Category	Type	Description
Dispatchable generation	Supply	This group is based on fuel-based generation capacity. Entities in this group provide flexibility with respect to the output level which can be increased and decreased on command. This category may include biomass-fired CHPs.
Non-dispatchable generation	Supply	This group includes renewable generation capacity. As sustainable energy prevails within Cloud Power, this type of generation is considered non-dispatchable and will always be utilized to the maximum level available.
Stored energy	Supply	This group represents the electricity that is stored within the community and that can be recovered as electrical energy when demand exceeds supply.
Non-controllable load	Demand	This group of entities represents the load within the community that cannot be reduced or increased at short notice. As such it can be considered as the system's base load.
Controllable load	Demand	Controllable loads constitute the loads within the community that can be reduced or increased more or less instantaneously.
Storage capacity	Demand	This group represents the amount of storage capacity that is available. Storage capacity can be used when the amount of energy generated exceeds demand. Instead of disposing the energy surplus to external parties, the surplus is stored within the community.

Source: Capgemini

community. The balance is determined by a number of entities which are classified as described in table 2.

Balancing is conducted using multiple horizons. The long-term horizon involves capital intensive assets for generation and storage. The medium-term plan involves the attitude/behavior of participants with regard to the use of electricity. The short-term is concerned with the willingness of consumers to adjust their actual consumption to the availability of electricity within the community.

Cloud Power at work

The previous sections presented the primary business processes within a Cloud Power community. To support these processes a Cloud Power implementation relies on the following main components:

- home energy management system (HEMS)
- smart devices
- energy management system (EMS);
- assets for distributed generation and storage (individually or commonly owned)
- smart meter.

The components and their interaction are depicted in diagram 1.

The participants configure their HEMS according to their individual preferences. These reflect the participants' attitudes to electricity prices and carbon intensity. Once the HEMS receives the day-ahead plan, it determines how the smart devices are utilized during the day to take advantage of low prices or low carbon intensity. The plan may propose to postpone operating a washing machine or dryer to a time when abundant electricity is available (times of high winds or intense sunlight, for example).

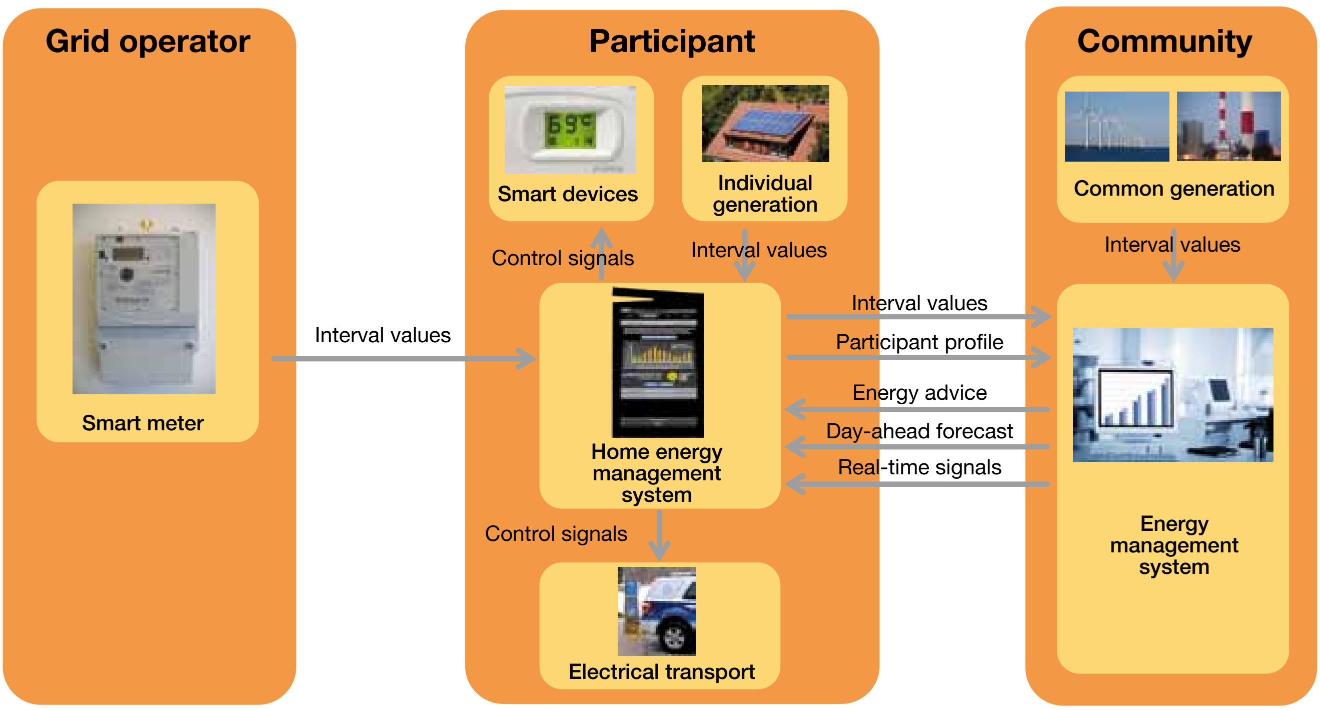
Throughout the day the HEMS receives hourly adjustments of the day-ahead forecast for prices and carbon intensity. Based on these hourly signals utilization of devices in the home may be adjusted. The HEMS thus takes care of the individual preferences of the participants but also contributes to the energy balance within the community.

The smart devices within the home are not restricted to domestic appliances only but also include thermostats for cooling and heating, and storage devices including electrical vehicles which can all be operated by the HEMS.

The day-ahead forecast is calculated by the EMS based on the meteorological forecast (for renewable generation), the capacity of dispatchable generation assets available within the community and the expected load within the community. During the day the EMS monitors load, storage and generation through smart meters, adjusts prices and carbon intensity, and distributes this information to the participants.

The approach taken in Cloud Power empowers participants to achieve their

Diagram 1: Cloud Power overview



Source: Capgemini

goals on an individual basis but also promotes participants to pursue their common goals as they are co-owners of the cooperative.

Organizational aspects

It is important to point out that a Cloud Power community is not an energy supply company. Consider the example of a housing cooperation that offers Cloud Power as a service to its tenants. In this case the housing cooperation will probably delegate the day-to-day operation to another entity, possibly an energy supply company. This energy supply company may operate multiple Cloud Power communities on behalf of multiple external parties. In some cases the energy supply company will also operate Cloud Power communities of its own. This clustering of communities provides the obvious advantages of shared resources.

Technical aspects

In contrast to most smart grid schemes Cloud Power does not depend heavily on any specific technology. Besides smart meters that will be installed by a third party, the concept can be implemented using multiple types of solutions from multiple vendors. This freedom of choice has a positive effect on the acceptance of the concept by potential participants. It also prevents participants from feeling caught in the community as they can easily change from one community to another.

Innovative aspects

From the consumers' perspective the innovative aspects of Cloud Power do not include any functional benefits over the smart grid approach pursued by traditional energy companies. The innovations incorporated in Cloud Power focus on what functionality is implemented, how it is implemented and when the functionality is implemented.

The fact that participants of Cloud Power can 'opt-in' to a community of their choice gives them the opportunity to choose the functionality they require but also gives them a choice with respect to costs. As such, Cloud Power represents a 'democratic' energy supply system.

Apart from the functionality implemented, Cloud Power enables consumers and communities of consumers to define their own preferences with respect to energy supply and determine their own approach to fulfilling their goals.

For the implementation of Cloud Power it is important that the concept reduces the reliance on third-party investments. This means that Cloud Power does not require additional investments in transmission and distribution networks and that investments are restricted to the domain 'behind the meter'. In this domain the participants can decide for themselves which investments are required and when they should be made.

The fact that Cloud Power will in most cases be implemented as a cooperative energy company overcomes the difficulty that individual consumers have with the cost-effectiveness of their investment in (generation) assets. The internal market and the envisioned synergies will reduce the recovery time of fixed costs significantly. Calculations on theoretical models for Cloud Power also show that the concept can meet the objectives of various communities in a large number of different configurations at competitive electricity prices.

Conclusion

The concept of Cloud Power presents a number of advantages over the smart grid approach. Cloud Power reduces the issue of split incentives because participants voluntarily enroll and have freedom in how to engage. As a result, the utilization of equipment will be more effective than in situations where consumers are confronted with a fixed solution presented by another party.

Due to the relatively small-scale and the fact that there is no need for large infrastructural investments, Cloud Power can be implemented swiftly when compared to smart grid approaches proposed by grid operators. As most of the investments for Cloud Power are located 'behind the meter' and are therefore not in the regulated domain, the concept also reduces the regulatory risk. This risk is very much felt by regulated entities like grid operators and contributes to the reluctance to invest in the infrastructure.

The integration of electricity from renewable sources in networks can cause problems in cases of a high percentage of renewables. As a Cloud Power community need not be co-located, the influence of the renewables from a community is dispersed and will not cause any disturbances in existing networks in the near future.

Preliminary calculations on the economic feasibility of Cloud Power show that competitive prices for electricity within a community are achievable using multiple configurations of assets for generation. These calculations were based on simulations using multiple models and will be verified during pilot projects.

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