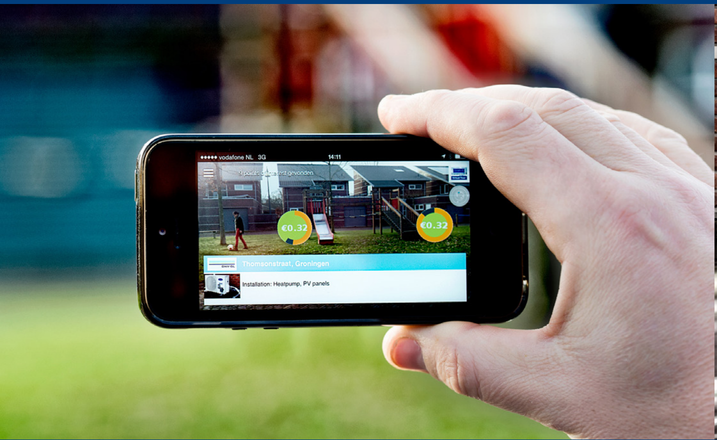
PowerMatching City



Living and doing business in the energy world of tomorrow

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POWERMATCHING CITY: PIT STOP IN THE ENERGY TRANSITION

We take a permanent supply of electricity for granted. Europe's energy supply is not only extremely reliable, it also affordable for all. But this is no longer enough. Today, energy has to be generated sustainably, and even the most state-of-the-art technologies must be able to be seamlessly integrated in the existing energy network.

Sustainable energy has become a natural part of our lives. Every day, we pass by wind turbines in fields and solar panels on roofs. Many of us are unaware that these technologies are part of a whole new and dynamic energy supply system. If the wind dies down, power stations automatically increase production to ensure supply. Likewise, as soon as the sun comes out from behind the clouds the solar panels will immediately start producing electricity, and the power stations will need to slow down. Wouldn't it be ideal if your washing machine automatically turned on to profit from the free solar rays? Or if you could share the excess power produced by your solar panels with your neighbours so they can recharge their electric car? Or could this power be used more effectively by the neighbours across the road, who have a heat pump? The key here is flexibility: the devices in this case need to be able to adjust the demand or supply of energy to the current conditions.

These are all ways that consumers can make an active contribution to sustainable energy targets, and because these combined households are responsible for about a third of the energy consumption, their behaviour can really make a difference. In fact, it is conceivable that communities in the future will be entirely energy self-sufficient or even net energy producers!

In order to give the transition to a sustainable energy system the best chance of success, it is important that consumers can actively contribute to this transition. But these people are not only consumers, they are also professionals. Once they have experienced how to live sustainably at home, they will use this knowledge in their work as well, and this could accelerate the energy transition considerably.

Many consumers find it difficult to determine which sustainable technologies best suit their needs.
The new devices have to be installed and they have to find out how they work. They also need to know how long it will take to earn back the initial costs of the system. These obstacles are challenging enough and it only gets harder if they want to implement several technologies at once or share their new source of energy with their neighbours.

Although we can paint a broad picture of what this future will look like, we have practically no hands-on experience with this new energy world as yet. This makes field trials of these technologies all the more important. How can we accelerate the energy transition? How can we stimulate consumers to take action? And how can we ensure that the new energy system will be sustainable, affordable and reliable?

PowerMatching City was built to find answers to these questions in practice. The participants in the pilot get to experience what it is like to live in a sustainable community in real life.

How do the residents experience the innovative devices and services? How would the Dutch economy benefit if this system was implemented throughout the country? And most importantly: how can we design tomorrow's energy world to meet the demands of a dynamic supply and demand so that all interests are taken into account?

POWERMATCHING CITY TAKE-AWAYS

PowerMatching City is the preeminent example of the sustainable energy community of the future. The implementation of this project has resulted in the following insights and recommendations:

Services

- The residents are motivated to build a sustainable community together. Flexible supply and demand in the community is facilitated by developing attractive services together with the community.
- Residents want to use the energy they produce themselves and are willing to change their energy usage habits. They prefer the devices to adapt automatically rather than having to adjust the devices themselves manually.
- The new energy service that focuses on concrete cost savings is more popular than the more abstract service that promotes sustainable energy consumption in the community.

Technology

- The devices required to enable the smart grid already exist, they can be integrated in existing housing and they are suitable for large-scale implementation. The households are connected and the energy flexibility is provided thanks to smart interaction between these devices.
- A combination of devices was chosen to make the most of the available forms of energy: gas, electricity and heat.
- A real-time operating system was developed that uses PowerMatcher agents with predictive capabilities that are compatible with existing energy markets and that can resolve bottlenecks in the local networks.

Value

- Flexibility provides value for all the stakeholders: the energy provider, the system operator and the consumer.
- The benefits of flexibility for the Dutch consumer market were calculated at between 1 and 3.5 billion euros on the basis of field measurements. These benefits are made up of deferred grid operation costs and the added value for the energy markets.
- The following bottlenecks were identified: smart meter allocation is required in order to make demand response economically viable. Smart meter allocation can easily be integrated in existing grid management processes and the social costs are relatively low.
- By connecting central and local energy systems using a smart operating system, we can achieve an affordable, reliable and sustainable energy supply, whereby both central and local energy sources can be used to their full potential.

Recommendations

- A new market model should be developed for the optimal distribution of flexibility and to make the most of the value this flexibility offers. The fair distribution of the benefits between the stakeholders is critical for a viable business case.
- This market model requires a single market party that can collect and redistribute the flexibility: the aggregator.
- Standardisation is required to reduce the cost-to-serve and cost-to-connect so that large scale implementation will become economically feasible.

LIVING IN POWERMATCHING CITY

Forty households are taking part in PowerMatching City. The residents are all tapped in to the energy system of the future. They have access to innovative equipment that is intelligently controlled and that ensures optimum living comfort. Electricity is generated by solar panels. Some of the homes have a micro CHP that can generate electricity and heat based on the demand. The heat produced can be stored in a buffer tank if necessary.

Other homes have a heat pump connected to a buffer tank in order to flexibly use the power and provide heat depending on the fluctuating demand. The residents can program household appliances such as washing machines to start at the most efficient time of the day. Finally, smart meters provide the residents with information about their own energy consumption and generation, which they can compare with the rest of the street.
To make all this possible, the researchers and the residents jointly developed two energy services to meet the residents' needs, although many other types of services are conceivable.

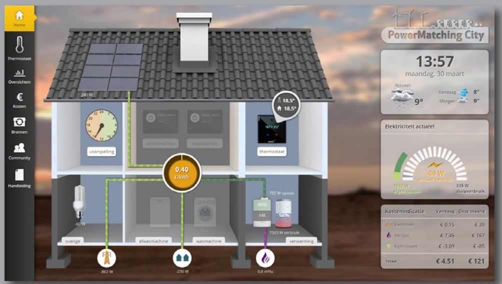
Two energy services were created: 'smart cost savings' and 'more sustainable together'.

The 'smart cost savings' service enables the residents to keep the costs of energy consumption and generation as low as possible, while the 'more sustainable together' service focusses on helping them to become a sustainable community. The two services are each other's opposites and were randomly allocated to the forty households. The project used three forms of control:

- Automatic control: of the heat pump or the micro CHP
- Semi-automatic control: of the washing machine
- Manual control: of the dishwasher, dryer, etc.

An energy monitor helps the residents to make the right choices, for example by offering suggestions for the correct use of a given appliance, such as the best time for switching on a dryer. It also provides feedback on the performance of the energy service. Using a specially developed invoicing system, the monitor can update the resident's energy bill every fifteen minutes. The monitor also enables the household to make investment decisions to bring down their energy costs, such as the purchase of solar panels.

In one of the streets in PowerMatching City, Thomsonstraat, there is a community monitor. This monitor provides information on the energy consumption and generation of the entire street. This helps the residents to become more aware of and compare the use of energy in their own household, in the community and at the national level.



WHAT DO THE RESIDENTS THINK?

What is it living in PowerMatching City like? The residents of the forty homes shared their experiences in trials, questionnaires, interviews and discussion meetings.

The residents were able to voice their own priorities before the new energy systems were installed. Their views on cost savings, sustainability, independence, technology and comfort were compared with a control group. This comparison revealed that the residents of PowerMatching City consider the themes of sustainability and technology more important than the average Dutch family, while they find cost savings and comfort less important.

The two energy services were developed with this information in mind. The residents were very positive about this approach; it made them feel more committed to PowerMatching City and the energy services.

To ensure objectivity, the residents were randomly allocated one of the energy services. The residents gave feedback on the service in general ('I'm happy with the service') and the various components of the service before and after they were allocated the service.

The 'smart cost savings' energy service proved the most popular.

The residents said that they found the information on costs tangible and motivating. The 'More sustainable together' energy service channelled the excess energy generated by the community back into the community. However, the leaf symbols on the monitor that indicated the level of sustainability were not appreciated as much as the 'hard euros', the reason being that sustainability gains were less tangible. The residents were also more interested in comparing the savings made in euros in the community rather than the sustainability score. Furthermore, the residents reported that they preferred being able to use the energy they had generated themselves as much as possible in their own homes.

Yet another interesting result was that the residents allocated to the 'Smart cost savings' service were more actively engaged in manually setting the start times of the dryer and dishwasher than the residents with the other service. The 'More sustainable together' customers simply turned these appliances on when it most suited them. The 'Smart cost savings' customers checked their energy monitor twice as often as the other group.

The residents all reported that they thought the automatically controlled devices contributed the most to the goals of the energy service. This equipment also cost them the least effort and this was therefore the most popular method of control. A precondition is that the users have to be confident that the devices and the service function correctly. Occasionally, the residents noticed that certain devices switched on or off at seemingly illogical times. Once the user has lost confidence in the device, it is very hard to win it back. But still, appreciation for the services was increased greatly by explaining things during the group discussions and residents meetings.

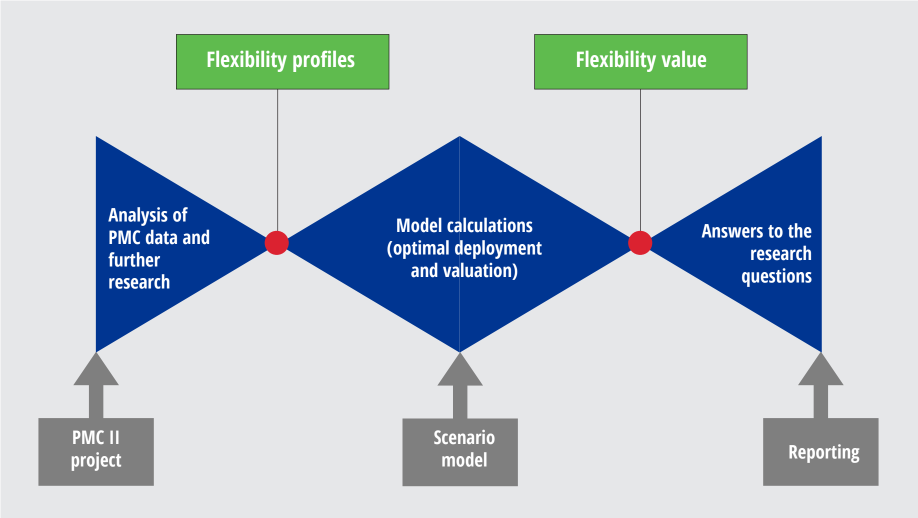
The residents reported that the manually operated appliances gave them a greater sense of satisfaction with and control over the system. They did require the help of the energy monitor to control these devices. In time, however, they learned what the right moment was to turn an appliance on or off. Once they had learned to do this, they also preferred to control the smart washing machines themselves.

The general conclusion is that energy services need to provide a simple and transparent service and that they can only be successful if they can adapt to the users' priorities. By the end of the pilot, two thirds of the residents said to prefer the 'Smart cost savings' model.

METHOD

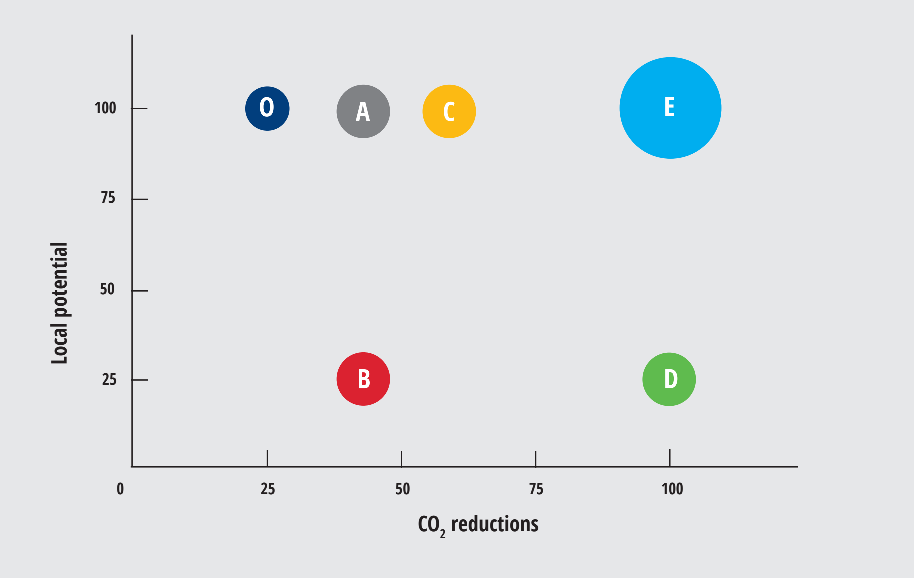
In PowerMatching City, the actual energy consumption and generation of all the devices in the home was measured over a period of seven months. The devices that promised the most flexibility were given extra attention, being the micro CHPs, heat pumps and the electric cars[1].

Flexibility profiles were drawn up for each of these devices (see the chapter Flexibility profiles). A flexibility profile is a curve that displays the average electricity consumption or generation over a 24-hour period. A broad band through this curve depicts the available leeway, i.e. the opportunities for energy flexibility.



The flexibility profiles were entered in a scenario model. This model was designed to value the available energy flexibility in the Netherlands on the basis of various future energy scenarios.

The scenarios were originally developed for Netbeheer Nederland[2]. The 'current policy' scenario was added for this research project. The scenarios are influenced by such things as the degree in which heat pumps, electric transport, micro CHPs and solar panels have been implemented, the energy prices and the costs of the CO_2 emissions.



Overview of future scenarios (2030). The surface area of the circles is a measure of the share of renewable sources in the energy supply. A, B, C and D = 25%, E = 100%, O = 18%, based on current policy.

[1] The data on electric cars were obtained from the Statistics Netherlands mobility survey and a study carried out by Enexis.

[2] CE Delft and DNV GL, 'Scenario ontwikkeling energievoorziening 2030' (Scenario development for the energy supply in 2013), Delft, 2014.

WHAT IS THE VALUE OF FLEXIBILITY?

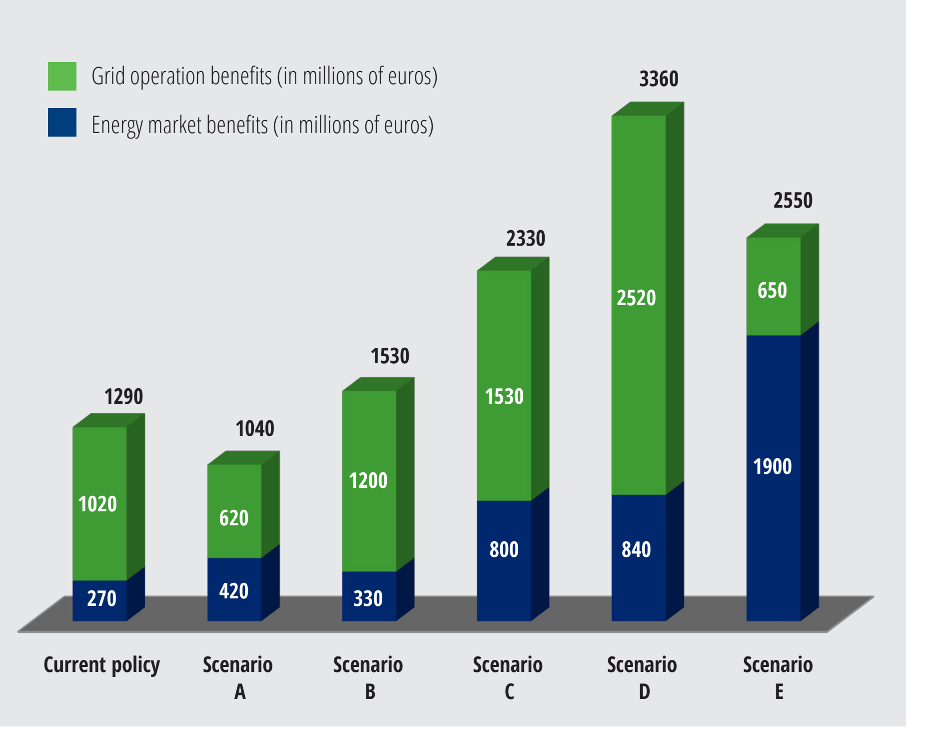
nalysis of the results from PowerMatching City reveals that the benefits of smart grids in the consumer market could be worth between 1 and 3.5 billion euros[3]. These are divided into benefits for the system operators and benefits for the energy market.

Where system operators are able to profit from flexible consumer devices and appliances they will need to invest less in the development of new networks and the maintenance of existing ones. This applies to all voltage levels and the intermediate transformer stations. Moreover, there will also be fewer energy losses due to long distance transport. The total value of flexibility for the system operator will depend on the outcome of the future energy scenarios.

The benefits of flexibility for the wholesale energy market mainly concern the fluctuations in market prices and the avoidance of energy imbalance costs. An energy provider can profit from variations in the wholesale price in order to purchase cheaper energy for their customers. This does require them to be able to manage their customers' energy consumption. This is currently the case for business customers, but not for consumers.

Alongside optimisation on the basis of price variations, providers can also avoid costs through the more efficient use of locally produced energy (where supply and demand are in balance). This saves the variable costs of centralised energy generation and storage and hence also the costs of compensating CO_2 emissions.

The supply and demand of energy needs to be continually in balance. The system operator is responsible for maintaining this balance and adjusting it where necessary. This is done by asking all energy providers and consumers to provide a forecast of their energy generation and consumption (their energy profile). They are fined if they deviate from their forecast. This stimulates the providers and consumers to meet their forecast targets and in doing so assist the system operator to maintain the balance of the system.
To this end, the energy providers guarantee the flexibility that is available to them.



The benefits of smart grids in the consumer market are worth between 1 and 3.5 billion euros.

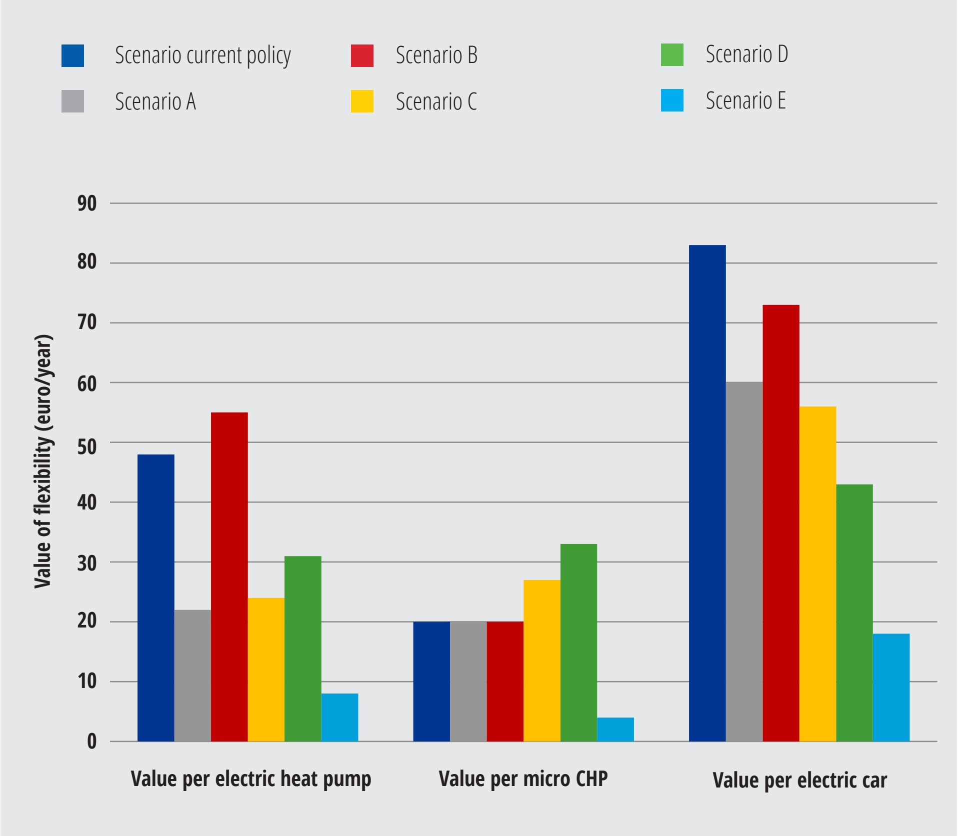
[3] CE-Delft and KEMA conducted a similar study in 2012. This study revealed significant benefits, ranging from 7 to 14 billion euros. These benefits were based on the added value of the smart grid itself and excluded the added value provided by the individual energy applications. The results of the PowerMatching City analysis cannot be directly compared with this earlier study because we only calculated the value of flexibility in the consumer market. Moreover, we used newer scenarios.

The benefits for the energy market are lower than those for the system operator. The reason is that the model is optimised towards levelling the grid load. The energy market would get more benefits if the model were optimised for this market. As this is not the case, the maximum value of flexibility for the energy market cannot be derived from this model.

The flexibility profiles can also be used to calculate the flexibility value of each device in euros.

A flexible micro CHP can provide savings of 21 euro per year, a heat pump 28 euro and an electric car as much as 58 euro.

These benefits apply solely to smart control of the device in an energy market with variable pricing. Additional benefits are obtained from energy savings or higher efficiency.



HOW CAN WE MAKE THIS VISION OF THE FUTURE A REALITY?

Energy providers currently purchase energy based on a standard consumer profile. This profile is based on the expected consumption of a consumer per hour, day and year. The actual consumption is only revealed at the end of the year after the meter has been read, when the profile is modified if necessary. The energy provider currently has nothing to gain from managing the supply and demand of consumers, as this cannot be measured and hence cannot be monetised.

This will change during the coming years as the smart meter is introduced throughout the Netherlands. This meter provides data on energy consumption and generation every fifteen minutes, providing the energy provider with information on the consumer's energy profile in real time. In other words, the effect of managing energy use will become measurable. The process of using real-time energy data is called smart meter allocation and is an absolute precondition for the implementation of energy flexibility.

In PowerMatching City we studied the effects of smart meter allocation on existing market processes. These processes proved to be more or less unaffected, with the exception of a number of minor adjustments. The system is also sufficiently resilient. Effective administrative procedures can be introduced to process errors and make reliable estimates when data is lacking. No complex system is required to make the requisite calculations as the system grows; the existing system operators' IT systems are sufficient. All processes have been fully described and validated: they are transparent, fair and verifiable.

The social costs of the implementation of smart meter allocation were calculated to be around 0,25 euro per customer per year.

These costs are negated by the potential value of the flexibility of a heat pump or micro CHP, which could be as much as €20 per year or more. But this is not the whole story: if an energy provider wishes to implement flexibility then they will be faced with additional costs for the integration of smart meter allocation in their own processes. This integration will only take place if there is a viable business case and the flexibility provides sufficient added value for the provider and their customer. Additionally, the provider will also face extra costs for data processing.

Of course consumers can choose to use the services of energy providers who propose to manage supply and demand. The providers will have the opportunity to offer consumers attractive terms to entice them to become as flexible as possible. Consumers who choose this option will no longer be standard profile customers, but instead will develop into 'smart meter allocation' customers in much the same way as the providers presently cooperate with business telemetry customers.

The PowerMatcher

The electronic heart of PowerMatching City is the operating system. The PowerMatcher matches the supply and demand of various providers and users in real time. The design is based on a so-called multi-agent system. Like every football player has his own agent, so each device in PowerMatching City, from the heat pump to the washing machine, is represented by a software agent. This agent offers to buy or sell energy for this device on the energy market. By adding up the various offers, the PowerMatcher can match the supply and demand of energy. This balance involves an equilibrium price, which fluctuates constantly according to supply and demand.

The smart management of the devices is based on shrewd comparisons of the various offers, which the Power-Matcher does at the level of the devices. However, not only can the offers be combined at the household level, it is also a simple matter to combine all the houses in a community or per energy provider.

Alongside the software agents that manage the devices, it is also possible to use so-called objective agents. These agents represent the interests of a certain stakeholder. Some of these partisan agents are active in Power-Matching City:

- The DSO agent represents the interests of the system operator. This agent responds to the actual status of the grid and the available flexibility in the homes.
- The 'Trade Dispatch Objective Agent' ensures that the energy generated by PowerMatching City is traded optimally. It bases its decisions on data from the energy market and the weather forecast. The objective of this agent is to ensure that the forecast targets are actually achieved.
- The Inhome agent represents the PowerMatching City residents' interests by following the energy services' performance. The Inhome agent thus either takes account of the expected prices or the forecast generation of sustainable energy in the community.

SMARTER GRID MANAGEMENT: CAPACITY MANAGEMENT

The system operator is expected to provide PowerMatching City with affordable and reliable energy, just as it would any other user group. Energy consumption will increase in the future and larger peaks and troughs are expected in the grid. In order to ensure that the electricity grid remains stable under these conditions, the system operator would normally need to increase the capacity of their network.

There is an alternative solution, however: the system operator can generate more electricity locally and manage the energy supply and demand of the community. This will enable them to postpone or even completely avoid unnecessary investment. The system operator of PowerMatching City has a clever tool to this end: the smart control mechanism. The transformer station in Thomsonstraat provides the DSO agent with real-time information on the available flexibility in the households.

The load on the transformer is measured continually. These measurements are used to compare the actual load on the power cable in Thomsonstraat with the ideal profile for the street. The agent will know when a peak load is approaching and attempt to reduce the imbalance by acquiring sufficient flexibility by means of price incentives. The available flexibility is based on the combined offers of the other agents. The DSO agent will then send a signal to the smart devices served by the transformer in order to use their flexibility.

The DSO agent bases these actions on informed forecasts. The advantage is that the agent and the system operator have more leeway to even out peak loads. If the system were only to take the actual transformer load into account, then the only option would be to delay the load until a later time. What makes Power-Matching City unique is that the system operator can actually prevent the peak load in their network or in any case proactively manage it.

Because the system operator can forecast that the energy demand will peak at a given momnet, they can ensure that part of this demand is called on earlier and so distribute the load more evenly.

It is as if a road manager were able to avoid tailbacks by making some cars start their journey earlier and so pass by a bottleneck before the queue builds up. Obviously, though, some forecasts will be wrong.
So what are the benefits for the residents? In the current situation, a household pays an annual fixed rate for the use of the network. In PowerMatching City, this rate is based on actual usage. The system operator offers discounts to residents who adapt the amount of energy they generate or consume according to its guidelines. If they will not or cannot adapt then they have to pay a higher rate, but never more than the standard rate. This means that the residents always benefit, regardless of their energy habits. This is only one of the ways residents can be rewarded for providing flexibility. Obviously there are other conceivable ways of rewarding them, for example by means of a fixed annual reimbursement. In PowerMatching City, the DSO agent was able to offer the residents the right price incentives at the right times in order to make them adjust their behaviour. This is advantageous for the system operator, who is able to put the available flexibility to good use and so needs to invest less in their network.

FLEXIBILITY PROFILES FOR DEMAND RESPONSE

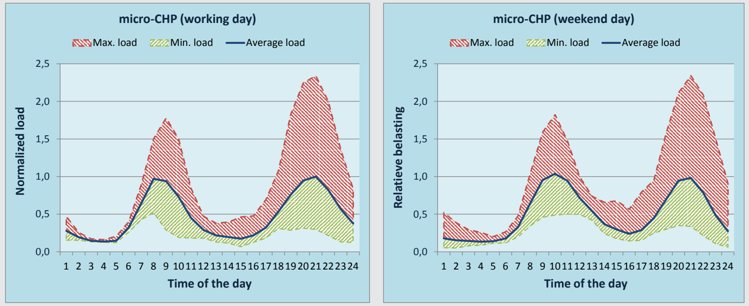
The analysis of PowerMatching City is based on the measured flexibility profiles of the devices. However the flexibility profiles themselves reveal interesting insights too. Take the example of a micro CHP on a normal weekday. If this device is not managed, then there will be two peaks in the power production.

In the morning, there is a peak when the device is powered up and at the end of the day there is another, when it is turned up higher and more water is used (blue curve). The buffer tank, that decouples the production of electricity and heat, provides flexibility (red and green areas). The micro CHP can be powered up to produce more electricity (red) or powered down to produce less (green) by the smart system. The extra heat is stored in the buffer tank. Because the net household demand for heat remains unchanged, the micro CHP can produce less energy later on. Because the heat demand does not change, the surface area under a profile curve will always be constant (and equal to that under the blue curve). The total area between the green and red curves is the measure of the leeway: the flexibility.

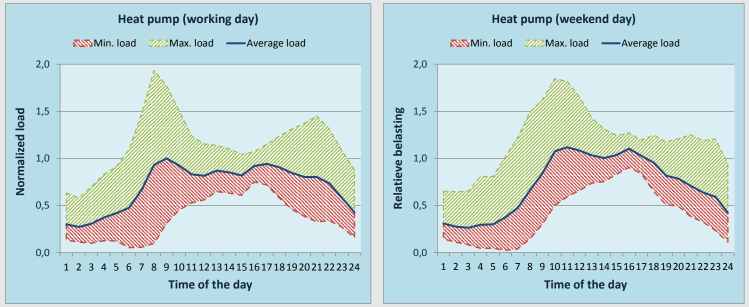
Heat pumps and electric cars consume electricity. In the case of these devices, powering them up entails using more power (green) and powering them down means they will use less (red). For example, if an electric car is not managed, it will normally be charged as soon as the owner gets home from work (blue curve). But by postponing the charging, the car will use less power (red). The charging cycle can be activated later on when it is more opportune (green). Less flexibility is available during the day because the cars will be away.

It is remarkable that there is more flexibility in practice than was expected on the basis of earlier studies.

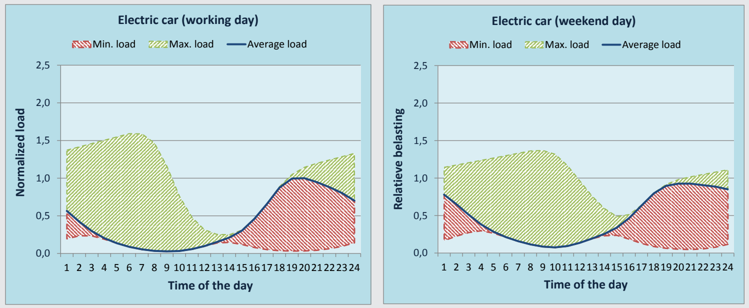
These studies[4] assumed a flexibility band of 5% to either side of the energy profile. The leeway in PowerMatching City is considerably larger. Each device provides a flexibility of approx. 1kW. Depending on the number of devices in a household, this amounts to a flexible power output of between 300 and 6000 MW for the entire Netherlands.



Flexibility profile for micro CHPs based on PMC II data



Flexibility profile for heat pumps based on PMC II data



Flexibility profile for electric cars based on an analysis of mobility data

4 *CE-Delft and KEMA, "Maatschappelijke Kosten en Baten van Intelligente Netten [in Dutch] (The Social Costs and Benefits of Smart Grids)", Delft, 2012.*

INTELLIGENT ENERGY TECHNOLOGY: SMART BY DESIGN

The homes in PowerMatching City are equipped with all manner of devices to integrate them in the smart energy grid. The right combination of technologies, the right choice between gas, electricity and heat and the use of the current gas and electricity grid all make PowerMatching City 'smart by design'.

All the residents of PowerMatching City have solar panels that convert sunlight into electricity. These generate 1400 Wp per household on average. The energy produced is distributed optimally within the community. Because the sun only shines during the day, the solar panels need to be combined with other sources of energy and any excess power they produce has to be able to be stored in order to meet the energy demand and facilitate flexibility.

Some residents of PowerMatching City have a micro CHP coupled to a hot water tank. A micro CHP (combined heat and power) is a gas appliance that generates electricity alongside heat. When this device is active it generates approx. 1 kW of electricity. The micro CHP generates power on demand.
The heat produced can be used at a later time to heat water or the house. This provides flexibility.

In other households, the hot water tank is coupled to a heat pump. A heat pump extracts heat from the outside air and uses this to heat the home, as a kind of reverse refrigerator.
Heat pumps are very efficient: they use only 1 kW of power to generate some 3 kW of heat. As with the micro CHP, a hot water buffer is used to decouple electricity consumption from heat production. This creates flexibility in the system.

Some residents of PowerMatching City have a smart washing machine. They only have to set the time they wish the cycle to be completed. The PowerMatcher manages the washing cycle so that the device makes optimum use of the cheapest or the most sustainable energy. A single washing cycle uses approx. 1 kWh of power. The time lapse creates flexibility.

All the households in PowerMatching City have smart meters that provide them with complete insight into their energy consumption. The meter measures gas and electricity consumption in real time and passes the readings on to the central system via the P1 port. This means that the supply and demand of the entire community can continually be balanced.

The households all received a tablet with the energy monitor installed on it. The energy monitor displays all the energy flows in the home and overviews of the historical usage. They can also use the monitor to adjust the thermostat. Finally, the monitor also suggests the best times for using the dishwasher, dryer or vacuum cleaner. The community monitor is located in a central spot. This monitor displays the energy consumption and generation of the entire community.

In Thomsonstraat there is a smart transformer station.
The loads on this local transformer are monitored. If the transformer detects peaks in the demand then the PowerMatcher will intervene and ensure that the load is reduced.
Thanks to this smart transformer, the community requires a lower capacity energy grid than a traditional neighbourhood.

A number of homes in PowerMatching City are fitted with a PowerRouter. The PowerRouter by Nedap combines locally generated energy with smart battery storage. The PowerRouter enables excess electricity from the micro CHP or solar panel to be stored and used to charge an electric car later, which makes it an optimum green energy application.

The electric scooters used in PowerMatching City are intelligently charged using sustainably generated energy. The scooters all have a built-in PowerMatcher which was especially adapted by NXP for PowerMatching City. All the requisite technology is built into a single chip and in principle it can be adapted to make any piece of electrical equipment a smart device.

THE BASIS FOR INTELLIGENCE

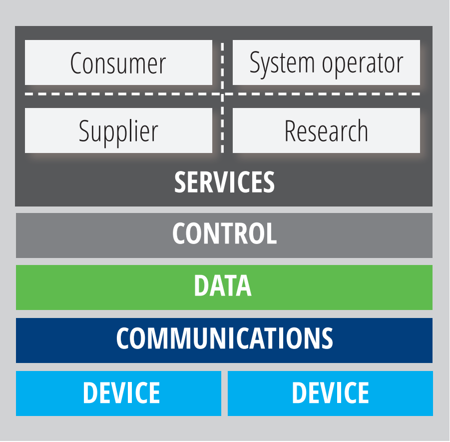
The backbone of PowerMatching City is a complete intelligent architecture. The IT architecture comprises a number of layers.

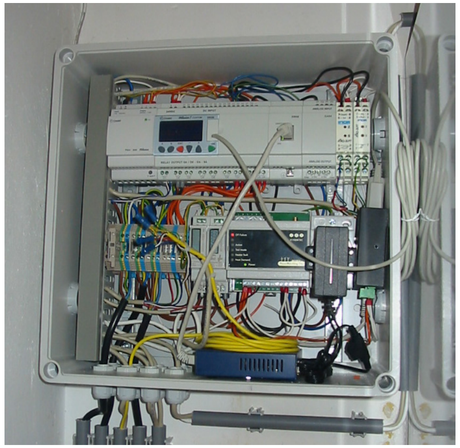
Devices

PowerMatching City has built experience in managing devices that were not initially designed for demand response. In some cases the device's operating system had to be adapted. The success of the smart energy world depends on the availability of devices that are suitable for on-demand control. This is why it is extremely important that the energy sector and the relevant knowledge institutes closely involve the manufacturers of these devices in this development and let them know what is needed to make the devices suitable for demand response.

Communication

Initially, the costs of the communication links played a subordinate role in PowerMatching City. There were separate ADSL connections and whole computer systems were installed in the meter cupboards. In order to keep down the costs of the connections (cost-to-connect) and the services (cost-to-serve), the connections were later replaced with the existing internet infrastructure in the residents' homes and the computers were replaced with cheaper built-in electronics.





Data

PowerMatching City is based on innovative cloud technology. This makes the concept more scalable, more reliable, more secure and easier to maintain. It also makes it relatively inexpensive and results in direct savings on the energy services. Because an important part of the control system was already in place, the modifications could be kept to a minimum and were set up as an Infrastructure-as-a-Service (IaaS).
This saves costs, but does not offer all the benefits of cloud technology.
The alternative, Platform-as-a-Service (PaaS), is preferable because the cloud provider will also have the responsibility for the maintenance, reliability and scalability of the system. The future PowerMatching City will then be able to make the most of the benefits offered by the cloud.

Control

The control of the system is managed by the PowerMatcher. However, the special agents, such as those that manage the devices, the trading agent and the system operators also have access to a lot of data. These agents occasionally have conflicting interests, so that they are not always easy to combine: a ‘prisoner’s dilemma’. The PowerMatcher was able to adequately control supply and demand, although we recommend making the IT architecture independent of a single algorithm. The PowerMatcher can then be used as a plug-in alongside alternative plug-ins.

Services

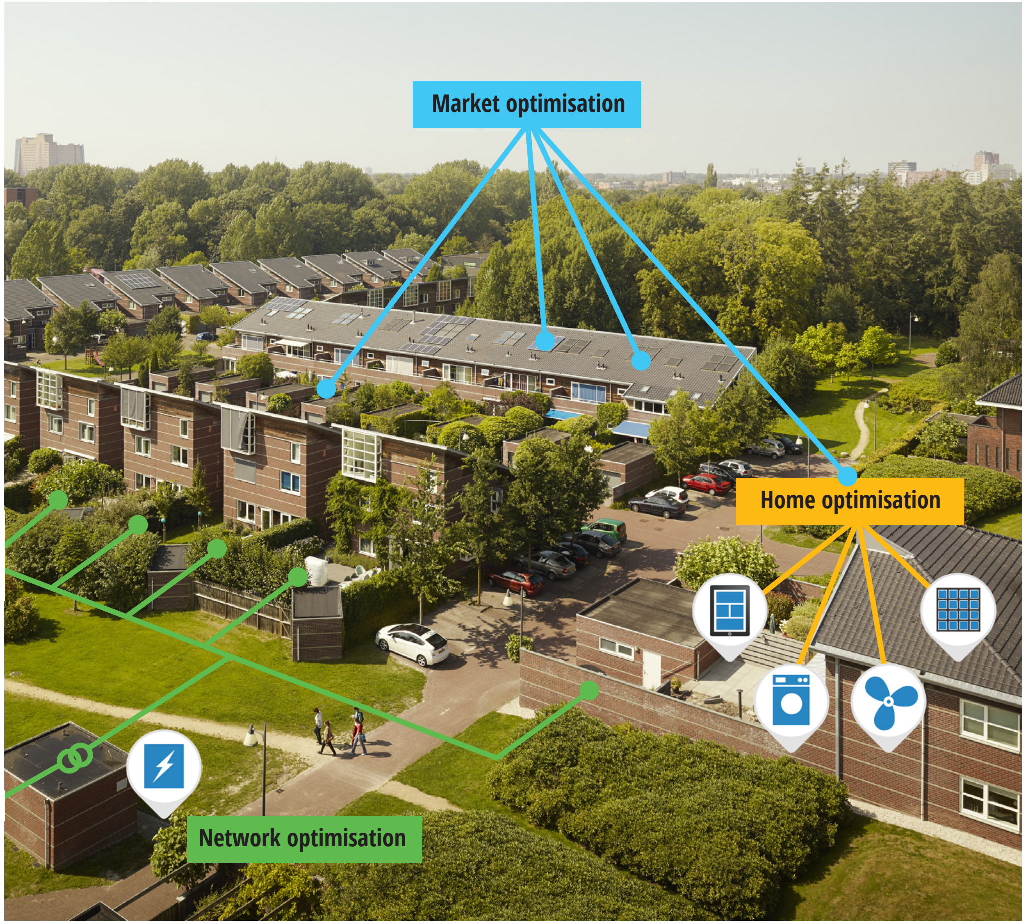
The residents can choose from two energy services: ‘More sustainable together’ and ‘Smart cost savings’. The choice of service does not only mean an alternative user interface, but also a different set of underlying IT processes specific to each service, such as the administration of certificates and a community service that monitors the energy balance of all the households. The system operator can use the ‘capacity management’ service. This service manages the PowerMatcher on the basis of the peak loads on the local transformer station. The most important advantage for the energy providers is the flexibility to purchase and sell energy thanks to smart meter allocation. Finally, there are services for the management and maintenance of the system and for the researchers to be able to extract the usage data from the database.

COST-TO-CONNECT
All the costs of the consumer’s network infrastructure, both one-off and recurring costs. Examples are home gateways, internet connections, etc.

COST-TO-SERVICE
All the costs of running a service. Examples are cloud subscriptions, maintenance costs, data storage, etc.

PRISONER'S DILEMMA

The devices in PowerMatching City deliver flexibility. The residents, the system operator and the energy provider can all benefit from this. Flexibility can be expressed in monetary terms. The biggest challenge is to fairly divide the benefits between all the stakeholders.



The PowerMatcher agents represent the interests of the residents, the system operator and the energy providers. These three agents operate at separate levels and do not communicate with each other. This means, for example, that the system operator and the provider do not share information about their demand for flexibility. The various interests are balanced more or less arbitrarily in PowerMatching City and each agent has been allocated a certain amount of flexibility. Although this principle works, it is not easy to provide hard proof that the system as a whole functions effectively. Often, stakeholders need to have access to all available flexibility, but in practice are only be able to use their own, or all stakeholders may need to access all the flexibility simultaneously.

An objective valuation is required in order to distribute the flexibility fairly. One option is to express the value of flexibility in euros per kW. This will also have to involve weighing the risks. Based on the experiences of PowerMatching City, we recommend allocating a single market party the responsibility of distributing the flexibility.
In PowerMatching City, the energy provider assumed this role by means of collecting all the required data. The provider's agent proved capable of converting market and energy demand forecasts into an optimised profile and also of monitoring this throughout the day.

A single market party is responsibel for distributing the flexibility.

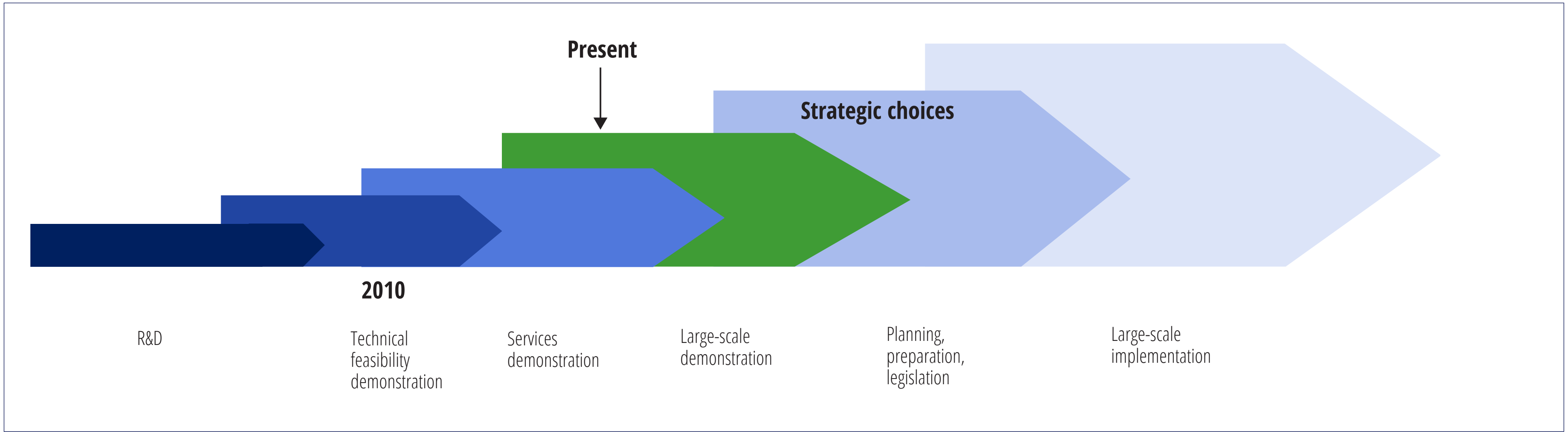
THE NEXT STEP

For many people, it is no longer the question of whether we need to implement smart grids, but rather of how.

PowerMatching City has demonstrated that:

- Smart grids are technically feasible.
- Flexibility has an economic value for the Dutch economy.
- Energy services can be created that meet the needs of consumers.
- Market barriers that impede the monetisation of flexibility can be eliminated relatively cheaply.

So what next steps are required in order to implement smart grids on a large scale? This is illustrated in the diagram below:



Development of smart grids

A number of conditions need to be met in order to facilitate large-scale implementation:

Acceptable distribution of the value of flexibility
The business case should benefit all the stakeholders. None of them will accept a burden of costs that is not proportionately offset by benefits.

Risk reduction
The current smart grids need to be scaled up. Neither the technology nor the underlying economic model has been sufficiently developed to be able to safely manage expansion to the European level.

Scale
The cost-to-serve and cost-to-connect will need to be reduced significantly for a viable business case. This can be achieved by opting for a solution that can be deployed at the European scale. This requires the development of:

- A standardised framework within which these systems can be developed.
- Standardised interfaces adn protocols within this framework.

Strategic policy choices
Policy choices will need to be made at the European level in order to bring about the desired legislative framework in the European member states. Critical to this process is a clear timeline so that the investment risk for the energy sector and the providers can be managed and the likelihood of disinvestments is reduced to a minimum.

The first concrete aggregator markets for demand response are currently being developed for the business sector in various European member states. This demonstrates that flexibility has a real value for the European energy market. Similar developments can also be observed elsewhere in the world.

At the same time, a number of large-scale demonstration projects are taking place. The size - and hence also the costs - of these smart grid projects are such that it has become necessary to utilise the value of flexibility. This entails creating temporary or permanent market conditions in order to balance the costs and benefits. At this scale, the products, services and solutions that were successful in PowerMatching City will result in a viable business case with an acceptable risk for all stakeholders.

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