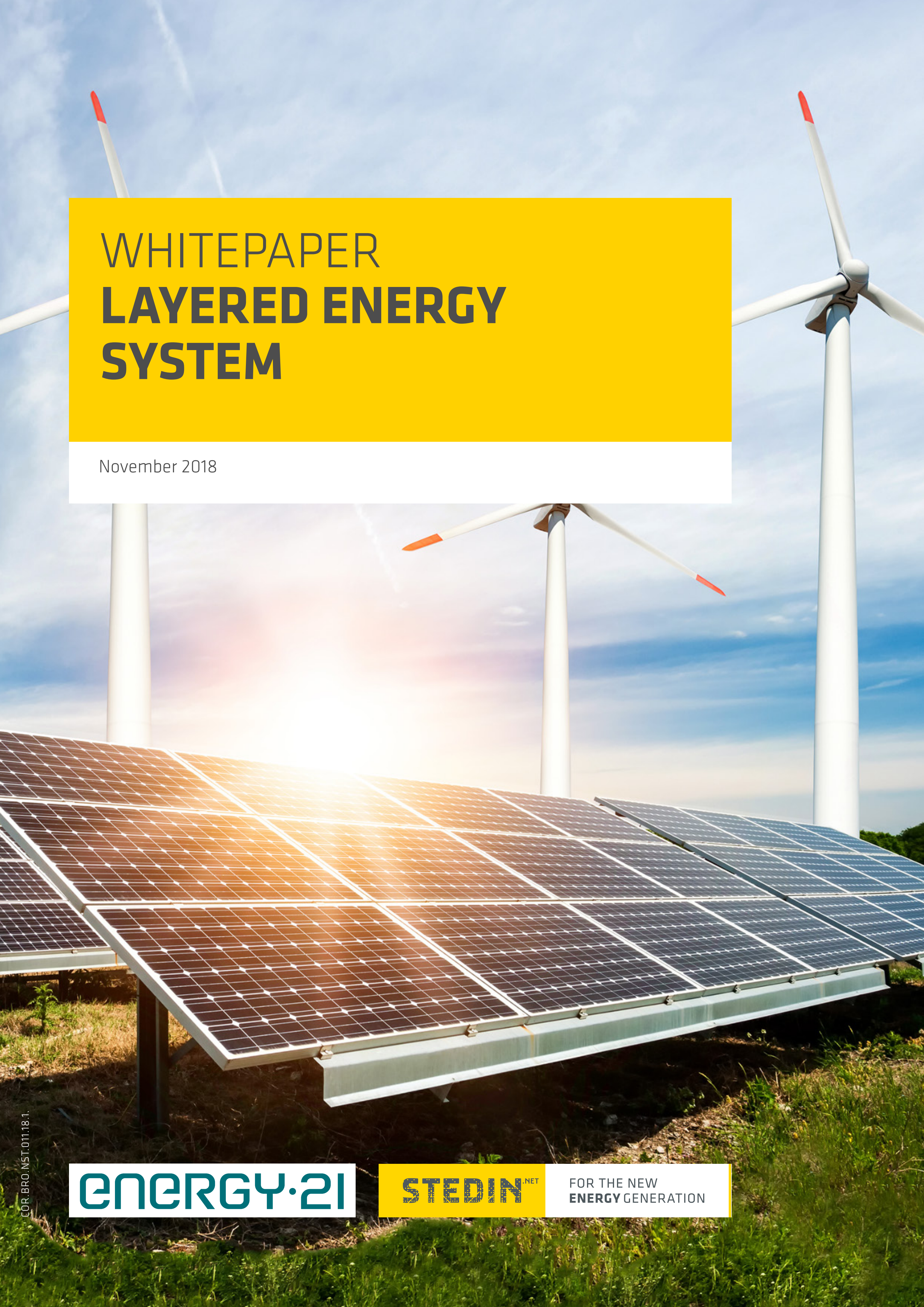

WHITEPAPER
LAYERED ENERGY SYSTEM

November 2018

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LAYERED ENERGY SYSTEM (LES): **INCLUSIVE ENABLEMENT OF LOCAL POWER**

PURPOSE OF THIS WHITE PAPER

In this white paper, we present a series of ideas and concepts that have been developed since 2017, in order to explore what a future energy system could look like. With this paper, we aim to align and express our thoughts on this fascinating topic and to inspire everyone actively involved in the energy transition.

In this white paper:

- we illustrate how these ideas come together as a framework for designing an energy system that consists of several layers on which many actors can interact, and in which the local level plays a leading role; and
- we explain how the Layered Energy System (LES) can result in a set of tools through which this framework can be implemented in local energy communities, as will be done by Stedin in their Hoog Dalem project.

This white paper was written with a forward-thinking mindset and should thus not be considered as our definitive viewpoint or the single possible route forward. Instead, it is meant to elicit new ideas among our readers, as an open invitation for further debate and co-creation. In doing so, we can learn and make this system evolve into a meaningful part of our energy future.

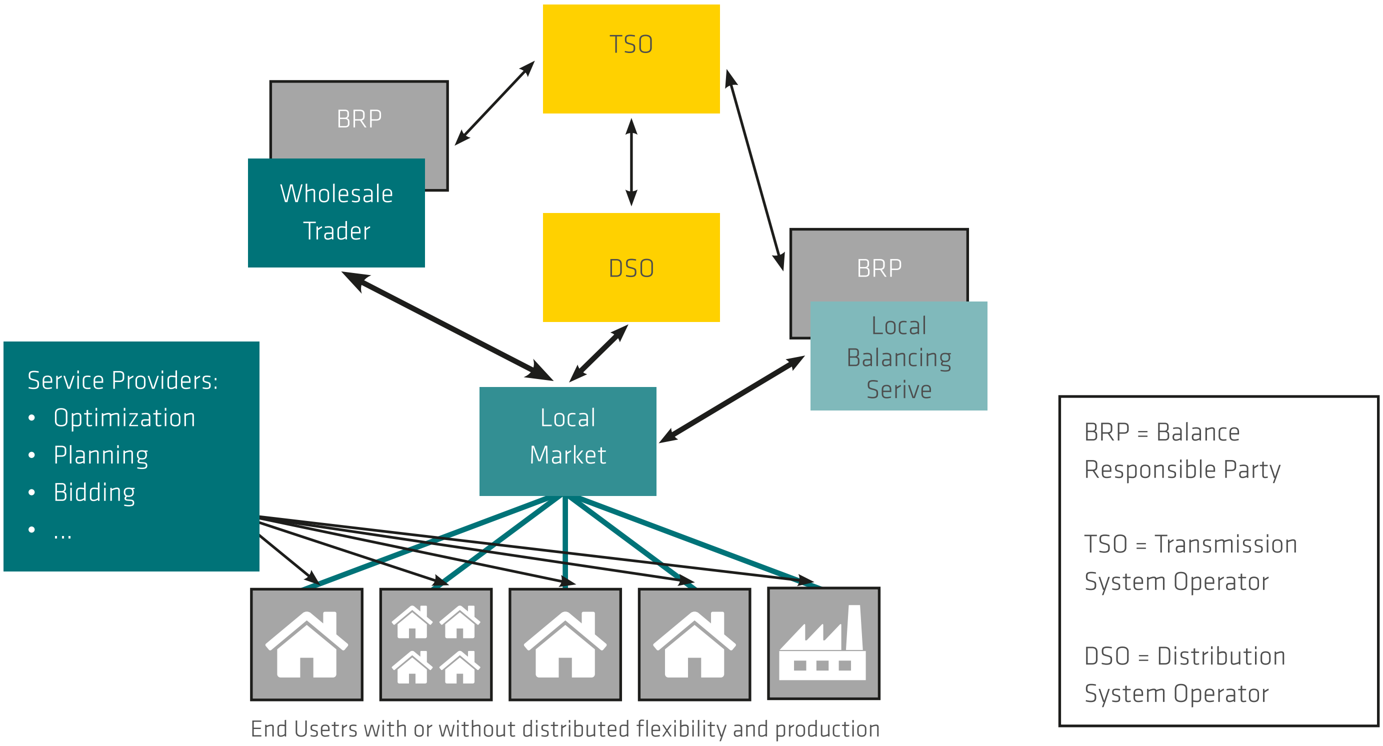
PART I – INTRODUCTION TO THE LAYERED ENERGY SYSTEM (LES)

The technologies to produce your own energy are widely available nowadays. Just like the means to know what energy markets are doing, and thus the ability to optimise your own smart energy system. At the same time, we all want to maintain the very high reliability of the energy system as we know it. The question how to enable the one without compromising the other proves to be not so easy to answer.

The Layered Energy System (LES) provides a way to have the best of both worlds. On the one hand, it enables households and enterprises to interact with and even provide energy to each other. On the other hand, LES gives market players access to distributed flexibility. At a price, because LES is driven by the rules of markets. Nevertheless, overall energy will probably become cheaper for everyone, even for those without their own solar panels on their rooftop.

A Layered Energy System is a system where local communities are organized in local markets. Trading energy within this local market is free in a sense that prices for infeed and take-off at the same moment in time are symmetrical. A community will probably not be able to supply all demand at all times, so the local market has an open connection with traders on a wholesale-level, who can participate in the local market as well. But this 'external' supply is subject to a premium; therefore, energy produced elsewhere has a disadvantage compared to locally-produced energy. All trade on a local level has to fit within the physical limits of the grid involved, managed by the distribution system operator.

This system has several advantages. First, local use of locally produced and shared (renewable) energy is stimulated, both technically (through a platform) and by providing the right incentives. Unnecessary grid investments can thus be avoided and it reduces transmission losses and enhances community building. Second, it does not compromise the freedom of choosing your own supplier: there is no obligation to join a local market. So it can exist perfectly next to the existing supplier model. Third, anyone can participate in the local market with a service provider of their own choice, even without any means of flexibility, or produce energy. Any stimulation measures like subsidies or feed-in premiums will be evenly distributed over all participants, thus opening up the benefits of the energy transition to everybody. Fourth, it prevents the disappearance of flexibility behind minimised connections. This partial grid defection, being a side effect of the current system, may result in a doom scenario for grid and system operators. And last but not least, for participants, the cost of energy will be less than or equal to what it is now.



LES is more than a white paper. At the moment, two pilots have been developed to test the LES concept. Therefore, the concept has been translated into user stories and a modular system based on blockchain technology and various apps. More information can be found on the Stedin website.

It will be explained how LES will impact and be beneficial for various roles in the system. In the following pages, this will be described per role.

Several key roles can be distinguished in a LES:
The End User: a residential consumer or Small and Medium Enterprise (SME) with or without the means to produce energy locally and/or the means to consume in a flexible manner. The End User hooks up with the Local Market.
The Local Market is an entity in LES that acts as an aggregator/supplier, by providing a Local Market transaction platform in the name of stakeholders that have an incentive to maintain a Local Market, varying from individual end users to local governments, entrepreneurs, energy suppliers, etc.

Service providers deliver services to the End Users to enhance their participation in the Local Market. These services can come with a device or an app.

The balancing service that is provided by a Balance Responsible Party (BRP) is pivotal for a local market to be able to connect with the wholesale markets: the BRP assumes the balancing responsibility for the local market and all its participants. This service will be offered by a regular BRP.

Wholesale traders can supply the net demand of local markets by generating or buying energy on a wholesale level and selling it in small ‘slices’ in local markets. They can also buy the excess energy or flexibility on the local levels.

The DSO operates and maintains the distribution grid and determines the technical boundaries for a local market to operate in. It may address distributed flexibility for local congestion management.

The TSO is responsible for system operation and balancing on a national level and may interact with local markets through market players.

LES was designed in 2017 by Energy21 and Stedin and first published in August 2017. This is the second version of the LES white paper as a result of several discussions with stakeholders.

PART II – LES FROM THE PERSPECTIVES OF DIFFERENT ROLES

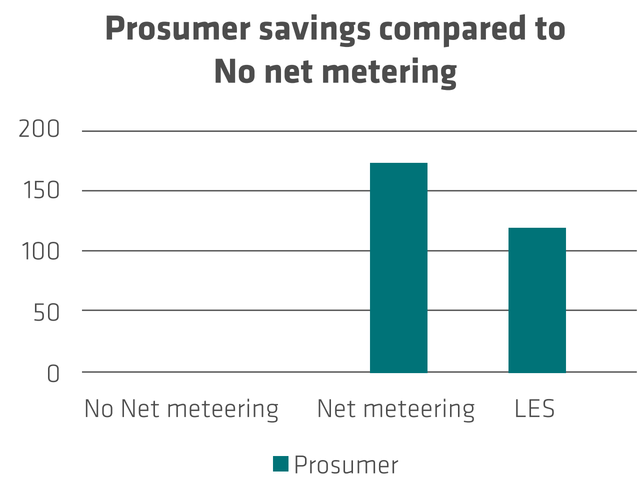
THE END USER

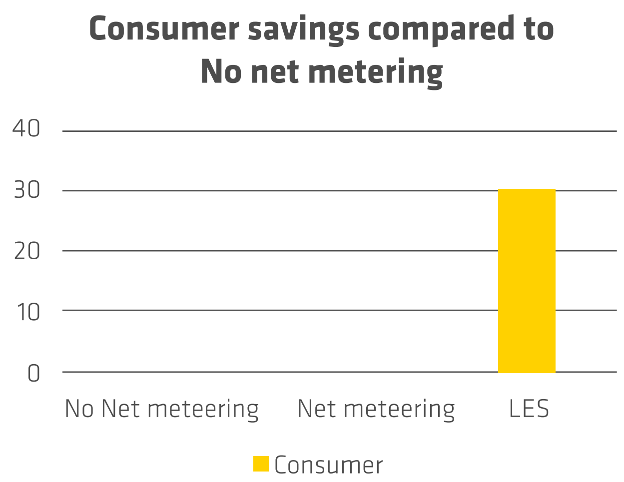
What does LES mean for an End User?
In a local market, End Users can sell their energy production and/or purchase their energy consumption. This demand and supply is matched locally. Any deficit of the local market is supplied by wholesale suppliers, so security of supply is not an issue. The local market in a LES offers the End User, both households as well as companies, a means to monetize energy flexibility and lower energy costs, but also a means to share the benefits of distributed renewable energy production with neighbours and an incentive to invest in renewable production and storage. An example business case is described in part IV, it shows that LES provides a positive business case for both prosumer and consumer if net metering is abolished.

How does it work for an End User?
Most End Users probably do not want to be bothered by the operation of a local market process or actively determine the amount of flexibility or forecasted energy demand for every moment of the day. It is very likely service providers will offer to do this in an automated way for a specific fee. This service can even be an app on your phone or a function of an EMS (Energy Management System). Flexible production and consumption can be made conditional, in other words, putting limits on what a user wants to get for produced energy or pay for consuming energy.

The local market mechanism determines a Local Market Price, based on the local input, the amount of additional external supply needed, flex prices, congestion issues etc. Every bid that falls within this Local Market Price is 'cleared', and this will be the basis for an operation plan for the End User. Again, there will be a variety of services possible to help the End User remain within the boundaries of this plan, ranging from fully automated operation of smart appliances to just sending a warning to a mobile phone. This will depend completely on the needs and desires of the End User.

What is important for the End User in LES?
End Users do not want to compromise their level of comfort just to save a few cents. When they turn on the light, the light should go on, whether it is according to their planned consumption or not. This means that the energy consumption pattern of the local community as a whole will usually differ slightly from the predicted one. In LES, these deviations are taken care of by an external party. This Local Balancing Service will charge a fee for this.
End Users can decide whether they want to participate in the local market, or stay with a traditional supplier (and thus keep paying the normal retail prices). The freedom of choosing your own supplier is not affected and there is no obligation to be part of a local market community. Furthermore, a LES local market is open to anyone, including consumers without solar PV panels or other means to produce energy or flexibilise their energy use.





THE LOCAL MARKET

What does LES mean for a Local Market?
In today's society there are a lot of initiatives to organise local renewable energy cooperatives and there are many communities that want to exchange locally-produced energy and optimise energy use. This is certainly not limited to residential end users. Small and medium-sized enterprises (SMEs) are looking for ways to monetise their energy flexibility or enhance their local significance by becoming a local energy supplier. Though the ambition of these initiatives is clear, it proves to be difficult to actually put it into practice. The energy system and its processes are complex and regulations make it even more so. The result is that local market initiatives are forced to let themselves be facilitated by the incumbent suppliers.
LES offers these participants a structured way to organise themselves in a Local Market Entity (LME) without the need of incumbent suppliers. The entity is the legal basis under the Local Market. It can be set up as a foundation or cooperative. The entity provides and operates the Local Market platform and acts as the supplier for the End Users who wish to participate.

How does it work for a Local Market?
The Local Market is a platform that is provided by the legal representation of the End Users it serves. This Local Market Entity (LME) can be formed by all its participants, but also by a consortium of facilitating parties such as, for example, the local government, local entrepreneurs, social housing associations, banks, etc. In USEF and in most regulatory documents nowadays, this entity is referred to as the 'aggregator'. The entity provides the IT-platform that facilitates the Local Market processes. This platform has to operate within the requirements of LES; however, some Local Market rules may be modified according to the specific local preferences. For example, when a Local Market wants to enhance renewable production and thus give local production without CO_2 emissions an advantage over energy produced in a different manner, it can be taken into account when weighing the production offers according to merit order.

The Local Market Entity is also the legal body that acts as the supplier of all Local Market participants. Please note that this will be a supplier without its own production: production will be filled in by local generators and wholesale traders respectively. The entity is only the legal gateway between local supply and the wholesale markets and will therefore also be responsible for the correct payment of taxes and levies.

Furthermore, the Local Market can have its own preferences, especially when it comes to the local merit order mechanism that is used. When a local community wants to assign a certain value to, for example, the 'greenness' of the energy (CO_2 emission involved) or the means of production, it can put this in the local merit algorithm.
What is important for the Local Market Entity in LES?
As the supplier, the Local Market Entity will be formally balance responsible for the End Users in the Local Market. In practice, the LME will contract a Balance Responsible Party for the balancing service in order to comply with the requirements of the national energy system. This balancing service is completely separate from the role of BRP for a wholesale trader or the BRP that independently provides ancillary services to a Transmission System Operator (TSO). Nevertheless, the local balancing service can very well be provided by such a 'regular' BRP.

THE DISTRIBUTION SYSTEM OPERATOR (DSO) OR REGIONAL GRID OPERATOR

What does LES mean for a DSO?
The DSO maintains and operates the distribution grid on the mid- and low-voltage level. When locally produced energy is also consumed locally this may reduce the peak load (especially on the mid-voltage level), load volatility and resulting congestion risks in the grid. A local energy system that is designed with the right technical grid characteristics in mind and that could reduce grid losses and postpone or even prevent grid reinforcements, may be in the interest of a DSO. In LES, the role of the DSO is threefold:

- The determination of the geographical boundaries of a Local Market is a prerequisite for a Layered Energy System. This can be defined by net topology or by another geographical criterion, for example the postal code area system in the Netherlands;
- The DSO is the party that determines the physical limits of the grid (the grid safety analysis), which defines the boundary conditions for the Local Market. If the transactions in the Local Market exceed these limits, the DSO could intervene. The DSO can also provide services for the market and its participants to help them avoid recurring congestion that could otherwise only be solved by costly grid investments (that are indirectly paid for by the community or society);
- The DSO may use flexibility that is available in the Local Market or that is contracted separately to mitigate congestion in the grid.

How does it work for a DSO?
A mix of market and limit orders are available on the local market, during regular operation. As bids are gathered and matched through the merit order mechanism, the market is initially cleared. The market result is communicated to the DSO. Based on the grid safety analysis, the DSO assesses whether this market result can be executed within the physical constraints of the grid. If so, the market will receive a 'go'. If not, a few options could be implemented:

1. A DSO that wishes to procure flexibility in real-time may purchase limit orders or bids that were not cleared in the initial market phase (soft intervention). A local market participant may, for example, offer the energy in his battery for a price that is higher than the usual market price. This bid will not lead to a cleared transaction in the initial market operation phase because a wholesale supplier will offer energy for a lower price and will be preferred. On the other hand, a participant can bid a demand at a price which is not initially met by any production offers. These kinds of bids could be called upon for solving grid problems.
2. As a backup, the DSO can limit the market as a whole (hard intervention). This would imply that constraints are imposed on the market volumes that can be exchanged in the local market, e.g. in order to avoid that market participants themselves suffer from severe local congestion issues. This way of working could be agreed upon with the local community.
3. A third option is that a DSO could address flexibility that was contracted beforehand outside the local market platform. This will lead to an adjusted market program of the local market.

The above are ways to solve a grid safety problem once it has occurred. Another approach is to try to prevent the occurrence of such problems. The DSO could provide a micro-service that publishes the expected congestion state of the grid, based on a mix of data from markets, weather, sensors, etc. Using 'traffic lights' this would work as a trigger for the market and its participants to limit their bids to a certain capacity depending on the expected grid congestion state. This variable limitation can be agreed upon up-front for the medium-to-long term, in exchange for a payment (less than investments in infrastructure), an allowance for extra capacity connected to the local (micro-)grid, a fee structure for every exceedance of the limit that is collected and used to buy compensating flexibility, or a lower risk of curtailment.

What is important for the DSO in LES?
Based on the grid safety analysis, the remaining flexibility offers can be passed on to the wholesale imbalance markets (see the description of the Transmission System Operator, TSO). When these bids can be met by the imbalance prices there, these bids will be cleared as well. When the total of remaining flexibility offers exceed the available local capacity only the most economical bids are passed on, up to the maximum local capacity.
Please note that the available local capacity can be limited on several levels. The DSO should take into account the bottlenecks on all possible levels in grid safety analysis: in the local grid, at the boundary of the local market as well as at higher (connecting) levels.
Furthermore, a DSO could be one of the trusted partners supporting the local market entity and ensuring metering of production and consumption.

THE TRANSMISSION SYSTEM OPERATOR (TSO)

What does LES mean for a TSO?
System operation of a power system requires a continuous balancing and management of possible congestion. Balancing actions to maintain the frequency of 50 Hz is a task of the TSO and preventing (partial) outages by means of grid safety analyses and congestion management is carried out by the TSO on the high voltage (transmission) grid. For balancing actions, the system operator (SO) uses flexibility offered by third parties: Balance Responsible Parties (BRP) through 'ancillary services'.

On a wholesale level, the mechanism of balance responsibility and balancing (capacity) markets remains the same with the introduction of LES. A local market is still within the balance responsibility of a BRP. However, the flexibility offered on a local market can be purchased by the TSO as additional flexibility on top of the regularly provided ancillary services.

In LES, the assumption is made that ancillary services provided by the local market will go through the BRP, so for now, in this version of LES, TSO is not a direct participant in the local market.

How does it work for a TSO?
Limit orders and bids for both consumption and production that are not cleared are "leftovers" of flexibility. The reason these limit orders are left out of the market can be due to extremely low-priced consumption orders (for example, for the non-critical charging of batteries) or high-priced production orders, even at prices higher than regular retail prices including taxes for production that will only run for balancing purposes a few times a year. These bids can be considered as free bids for balancing power for the TSO as long as they fit within the limits of the DSO network capacity.

Alternatively, the TSO can highlight the availability of power at very low prices and influence the merit order of a local market, though taxes and levies will apply. After operation, the local market is settled as cleared and operated, and all externally delivered flexibility is settled on a wholesale level between TSO and the local market operator. The local market operator will settle this further with the flexibility providers involved.

What is important for the TSO in LES?
Non-cleared local flexibility bids (in the form of non-cleared limit orders) are small. Consequently, the TSO will have to gather a large number of available bids from many local markets to add up to an amount of power that will significantly help the system.
When a customer or even the local market as a whole decides to participate in a flex-pool hosted by another aggregator, this flex capacity cannot be bid into the local market. How this is to be checked is yet unknown. Furthermore, the 'firmness' of the flex is something to consider: how can the TSO check whether the offered and purchased flex is actually available and will be delivered? The usual mitigation of these risks on a wholesale level with collaterals and technical pre-qualification studies is probably not feasible on the level of End Users in a LES.

BALANCE RESPONSIBLE PARTY OFFERING A LOCAL BALANCING SERVICE

What does LES mean for a BRP?
One of the characteristics of LES is that a local market is connected with the wholesale markets, so that parties active on wholesale level may interact with the local market as well. In other words: the local market has a role to fulfil in the system as we know it. Balance responsibility is a very important aspect in this regard.

In LES, the local market entity can be considered as the aggregator and the supplier for its participants, it consequently has to assume balance responsibility for the operation of the local market towards the wholesale processes. This can be organised by the local community itself in order to create an independent Balance Responsible Party (BRP). This would mean that a community has to comply with all obligations and market processes set for BRPs, which is probably a long stretch for most. It is more likely that the local market will pass balance responsibility on to another BRP. In LES, this is referred to as the Local Balancing Service. This role can be combined with the other activities of a wholesale BRP.

How does it work for a BRP?
The Local Market contracts a Local Balancing Service provider upfront for an agreed fee. This fee can be a fixed monthly fee or any other bilateral contractual form.
A possible model could be that any imbalance caused by the local market participants is paid for by the local market participants. The business revenue for the BRP providing the service can have different origins: a premium on top of the imbalance price, the possibility to compensate imbalances with opposite imbalances of other parties (e.g. other local markets) in a larger overall portfolio – referred to as the portfolio-effect –, or the use of a back-up facility that otherwise would not be used (for example, a not-committed capacity of a large battery).

The local market participants provide their planned demand and production, and all cleared transactions are communicated and turned into operational plans. This market result is input for the BRP in order to determine and communicate a balance position in the wholesale market process.

During operation, the energy produced and consumed will probably not follow the operational plans exactly. The net operational imbalance has to be compensated. It may be convenient to choose an operational time frame for the local market that is smaller than the Program Time Unit PTU of the balancing markets. When a local window of 5 minutes is chosen, it implies that there are three market clearances for each wholesale PTU of 15 minutes. This means that when a local market is in imbalance at the first 5 minutes, this position may be compensated by the other

two periods of minutes. This process can be coordinated by the BRP providing the Local Balancing Service or a locally applied algorithm.
The overall net imbalance over 15 minutes will be part of the balance position of the BRP that provides the service. The contribution to this position, either positive or negative, is to be settled with the Local Market according to the contractual agreement between BRP and the Local Market Entity. Any resulting cost for the Local Market can be distributed evenly over all market participants ('social-ized') or be proportionally settled by the causers of the imbalance. This is up to the local community to decide.

What is important for the BRP in LES?
A BRP that provides the Local Balancing Service is a distinctive role in LES and is not to be confused with the BRP, acting on the wholesale markets on behalf of generators, wholesale energy traders and suppliers. However, providing the service of a local BRP can also be part of the activities of a wholesale BRP. In order to emphasise the difference, this role could be given a distinctive name.

SERVICE PROVIDER

What does LES mean for a Service Provider?
The determination of the amount of flexibility with a market participant is not an easy task. It is the starting point of many 'smart energy solutions' offered by a range of suppliers of both IT, appliances, demand response solutions and domotica in general. Even more so, the determination of the supposed value of the available flexibility, while taking into account the end-user preferences and comfort settings as well as forecasted imbalance prices etc., is complex and difficult. Moreover, determining a bidding strategy in order to optimise the market result is yet another task most End Users will not be able to take upon themselves. This will lead to the offerings of several competing service providers that will unlock and monetise local flexibility on behalf of the asset owners.

Service Providers will offer their services directly to the End Users. The fees, contracts and conditions are open to competition and negotiation and are not part of LES as such. On the other hand, a Local Market Entity could possibly buy or provide a general service for all its participants. A local solar irradiance forecast can be an example of such a general service.

How does it work for a Service Provider?
The services are aimed at the optimisation of the actions of the End User in a local market. They can also be coupled with the assets of the End Users directly. Some services will be very dedicated focussing on just one aspect of the operation, like providing a very accurate forecast of the expected heat demand in the form of a web-app. Others

will offer complete end-to-end servicing of all in-house smart appliances including the HEMS (home energy management system), like the proposition of Google Nest or many traditional energy suppliers.

Which service provider is used is a bilateral agreement between the market participant and the provider. LES only requires that the standards of the local market communication processes are met. This is also a reason to develop these standards in an open, transparent and standardized way.

What is important for the Flex service provider in LES?
It is a great advantage for the End User that there is no lock-in with one service provider for all participants. If another provider can fulfil your needs in a better way, you can switch easily. It is even possible to develop your own services, as long as they meet the standard requirements of LES.

WHOLESALE TRADER

What does LES mean for a Wholesale Trader?
The local production in a local market will presumably not be enough to fulfil all local demand. This gives suppliers, that are active on a wholesale level, the opportunity to supply local markets. Wholesale traders purchase large blocks of energy on the wholesale market or, if they own their own generation units, they can produce large amounts of energy. These large blocks have to be sliced in (very) small bids for a local market so the offers can be matched with the local demand bids and a merit order can be established.

Every local market is open to any wholesale trader, so it will be a competition between these parties whose offers are to be cleared. The price of the energy provided by the wholesale traders is subject to all regular taxes and levies and thus will likely be the same as offered to other (retail) customers.

How does it work for a Wholesale Trader?
A local market can set its own market rules regarding how the merit order is to be determined. Consequently, it is not always the case that the wholesale trader that offers energy at very low prices will always be selected. If a local market decides to assign value to other aspects such as involved CO_2 emission or way of generation, these can be taken into account in the merit order as well. This may differ from local market to local market.

What is important for the Wholesale Trader in LES?
The slicing of energy blocks and offering them in local markets will probably be carried out by automated applications.

PART III – THE LES CONCEPT EXPLAINED IN MORE DETAIL

BACKGROUND: A TOXIC SITUATION

The means to produce energy by yourself and to participate in an energy market are becoming available for anyone. Information and data can be obtained and analysed with easy-to-use apps and increasingly (artificial) intelligent algorithms. At the same time, costs of solar panels, fuel cells and storage systems are plummeting, while the technical performance is being improved. In other words: Prosumers can assume a more active role in their energy provisioning; Energy is becoming democratised.

This transition is happening, whether we want it or not. At the same time, there is an unmistakable tendency within society that consumers want to be more in control of their own energy supply. Local communities organise themselves and are looking for ways to become more sustainable, using their own renewable energy generation and supplying themselves. Though this may be a sympathetic goal at first sight, most customers do not want to decrease their security of supply nor their level of hassle-free comfort. And financially, it should at least stay at the same level. Nevertheless, this customer empowerment is very much at the centre of the energy policies of the European Union.

The current energy system in North-Western Europe grew organically and was not designed for facilitating the energy transition. It is based on the principle of centralised production via transmission and distribution towards consumption and often assumes unlimited distribution capacity (i.e. the 'copper plate'). If demand fluctuated, the production would adjust itself accordingly. With a lot of solar and wind generated energy in the mix, production can be forecasted but not easily planned. The need for flexibility by means of storage, buffering and flexible ('smart') demand increases with it. An important part of this flexibility is to be found in the houses and small industries of the customers that are empowered. But the capacity of the distribution grids that connect these prosumers is very limited. If the copper-plate is to be maintained a lot of extra cables have to be put into the ground.

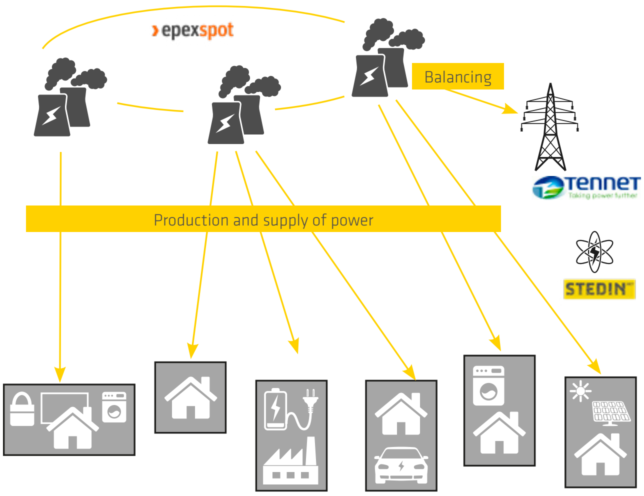
To add another notion to this introduction: for small consumers there is a huge price-asymmetry between selling their (solar) energy on the markets and buying it at another moment, when it is subject to taxes and levies. Though dampened by feed-in premiums and subsidies; all over Europe, the difference between selling and buying is large enough to make the business case for storage in your own house attractive. This may buffer the amount of distributed infeed and thus prevent grid reinforcements, but this flexibility is pushed out of the system and cannot be used for balancing or congestion management with causes elsewhere, for example windfarms at sea. TSOs and regional grid operators alike consider this effect very undesirable. As a side effect, this 'optimisation behind the meter' also has a social impact. The fruits of the energy transition can only be obtained by those that have the opportunity and means to invest in solar panels or storage assets, while the feed-in premiums are being paid by all. In other words, the energy transition in the current system causes the gap between the 'haves' and the 'have-nots' to widen.

Based on the above, it can be stated that the energy system is in dire need of a solution to the issues raised by the energy transition. This is recognised by stakeholders throughout the system and solutions are being devised as we speak. However, the difficulty is that a solution for one axis of the energy system (basically an energy system exists on three axis: transport (capacity), volume (energy) and system operation (balancing)) may have an undesired effect on another axis. For example: a grid operation system that reduces the amount of energy that can be fed into the grid has a limiting effect on the freedom of transaction. The question arises who is going to compensate for the transaction that was cancelled by the grid operator. Another difficulty is that a sudden overall revision of the whole energy system may cause serious problems in operations, not to mention the vested interests that it may collide with.

THE DEVELOPMENT OF A LAYERED ENERGY SYSTEM

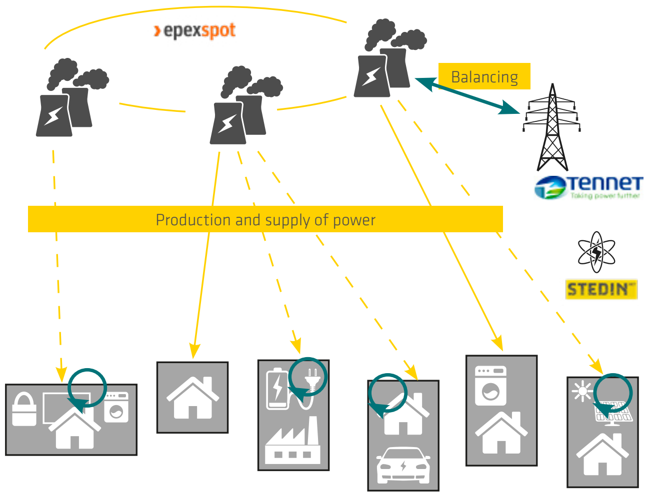
The energy system for electricity as we know it is based on centralised production by power plants that is supplied to consumers via transmission and distribution grids. These producers and suppliers trade with each other through a spot market or bilaterally (OTC). The system is balanced by the TSO in interaction with Balance Responsible Parties (BRPs) that, in most cases, are the same producers and suppliers. The following diagrams illustrate this for the Dutch situation, but can be translated to any European country.

Figure 1 - The energy system as it is now



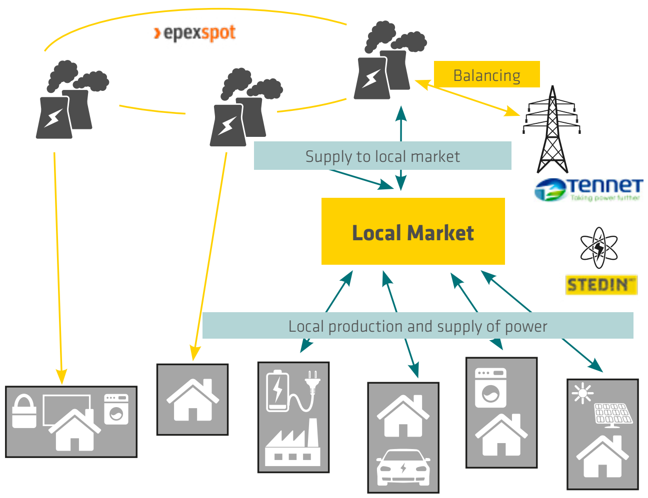
When households optimise their own energy use and enterprises use energy flexibility to optimise – ergo reduce – their capacity (connection) costs, the predictability of the consumer-side of the system decreases. At the same time, the distributed flexibility that is needed for the increasingly challenging balancing by the TSO is pushed out of the system, hidden behind very reduced connection capacities. This is illustrated in figure 2.

Figure 2 - Households and SMEs use flexibility for their own optimisation rather than supporting the balancing of the system



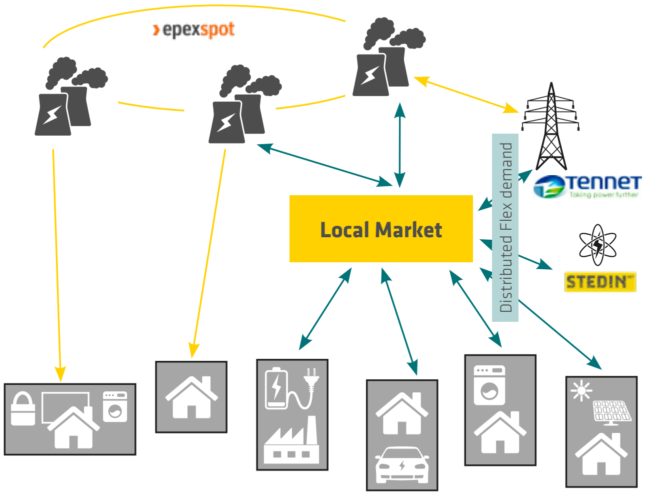
An alternative is creating a local market with symmetrical prices for prosumers, so the consumption or in-feed patterns of a prosumer will depend on the price, which in turn is a result of abundance and scarcity. When energy is abundant, prices are low and, for example, solar energy will be used directly or stored rather than added to the market. Wholesale producers can participate in the local market as well, though their supply is subject to an increase in costs compared to locally produced energy in order to provide incentives for local use before external supply (figure 3). It is important to note, however, that scarcity on the overall system level could occur at the same time as congestion at a local level. Therefore, implementation scenarios should consider energy and available capacity for all layers of the system.

Figure 3 - Introducing a local market layer between, on one side, prosumers and consumers and, on the other side, wholesale suppliers



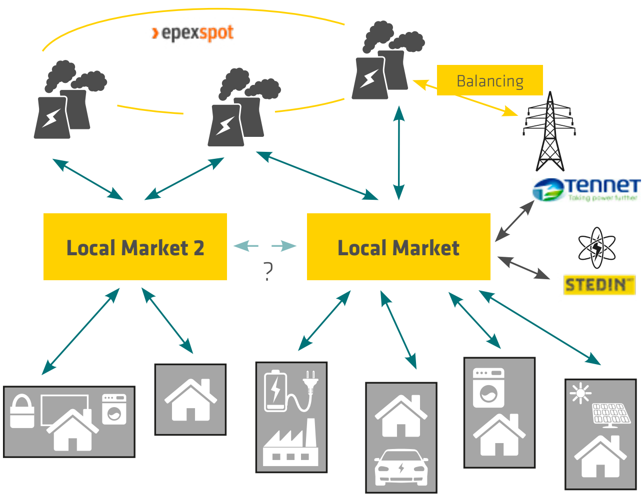
In case of a need for balance or redispatch capacity by the TSO or the DSO, the local market is also accessible for these parties (figure 4). After all, the flexibility is available on a market and by offering a higher price for that flexibility than others it can be obtained. In the case of congestion management, the geographical location of a local market can even be taken into account.

Figure 4 - A local market can also be accessed by a TSO and/or DSO



Taken one step further, another local market may come into existence parallel to the other. In a layered system, it can even be considered that there may be an exchange between local markets (figure 5). One community could provide the energy that is lacking in the neighbouring community at a better price than wholesale, or two communities could work together to solve a common congestion issue on their shared grid substation. These concepts are worth exploring further.

Figure 5 - Several local markets can exist next to each other



Depending on the prices of offers and demands within a local market, the local market results will differ. This implies that a form of zonal pricing will exist, though these will never exceed the existing retail prices as offered by the existing wholesale suppliers. Local markets with a low level of penetration of local production will result in a relatively high amount of externally supplied energy at retail prices, and will thus result in a relatively high local market price. This means that investing in distributed assets by, for example, housing cooperatives or investors would be the most rewarding in local communities that have little means of local production. In other words, it creates an incentive to spread the benefits of the energy transition more evenly.

THE MARKET PROCESS MODEL OF LES

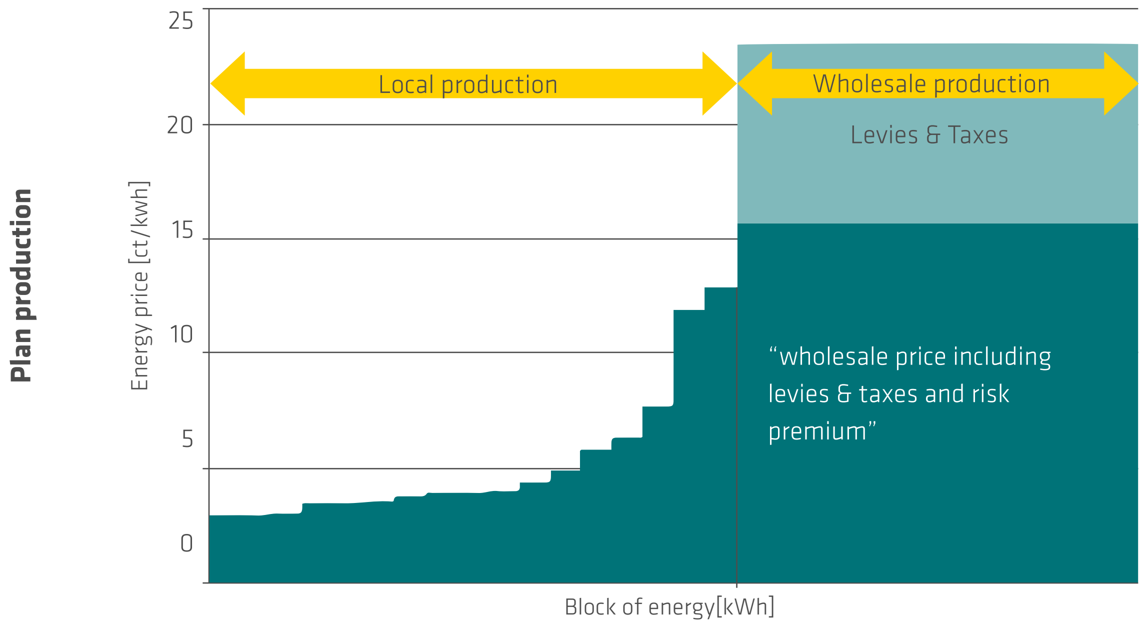
A widely recognized attempt to offer a framework for a system-wide-solution is the Universal Smart Energy Framework (USEF). The USEF foundation is supported by several European stakeholders in a joint effort to accommodate flexibility in our energy system. Stedin and Energy21 took this framework one step further and developed a market model that could:

- accommodate the customer's wish to produce and consume local;
- make use of the modern (information) technologies available;
- enable the end consumer to make his own decisions, but provide incentives to stay connected with the system;
- keep distributed flexibility accessible for purposes on a higher market level, such as balancing by TSOs;
- provide regional grid operators with a means to service the connected End Users in a most cost-effective way and facilitate the transition at the same time;
- distribute the benefits of the energy transition over all that want to participate.

This effort resulted in the Layered Energy System (LES). The basic principle of LES is that the aggregation and optimisation of distributed consumption, production and flexibility is to be based on a market mechanism. This local market should, on one side, be physically limited to a geographical area. To give the grid operator a tool to manage local grid congestion, this area is defined by the grid topology. On the other side, the local market should be open for other (wholesale) market participants to bid into the local market, though transactions between local participants should have priority over those with external parties. A simple way to achieve this is to impose added costs on any supply from outside of the local market.

On the other hand, prices for local production and use should be symmetrical. The net influx from external suppliers into the local market is then subject to, for example, taxes and levies, but other mechanisms are possible as well.
The local market mechanism follows the market phases as used in the wholesale energy markets and as described for distributed flexibility trade by USEF. In the plan phase, all market participants, both with and without production, bid their planned consumption and production. This can be done by the End User himself, but most bidding will be done automatically by smart apps or by a service provider that will do this on behalf of the customer. For production bids the distinction can be made between external production bids (which are subject to taxes and levies and these energy blocks will correspond with current retail prices) and local production bids with a limited price ("I will only inject when I can sell it for a certain price or above"). Consumption bids will consist of blocks of energy "for whatever the price, I just need that energy, even if it is against the old retail price" (referred to as consumption market orders) and blocks of energy "that I will consume only when the price is below a certain level, otherwise I will, for example, charge my battery later" (referred to as consumption limit orders). When all bids are collected, a merit order is established and a local market price is determined. All bids that fall outside the cleared market price will be "out of the market" and the corresponding consumption or production cannot take place during the operation phase.

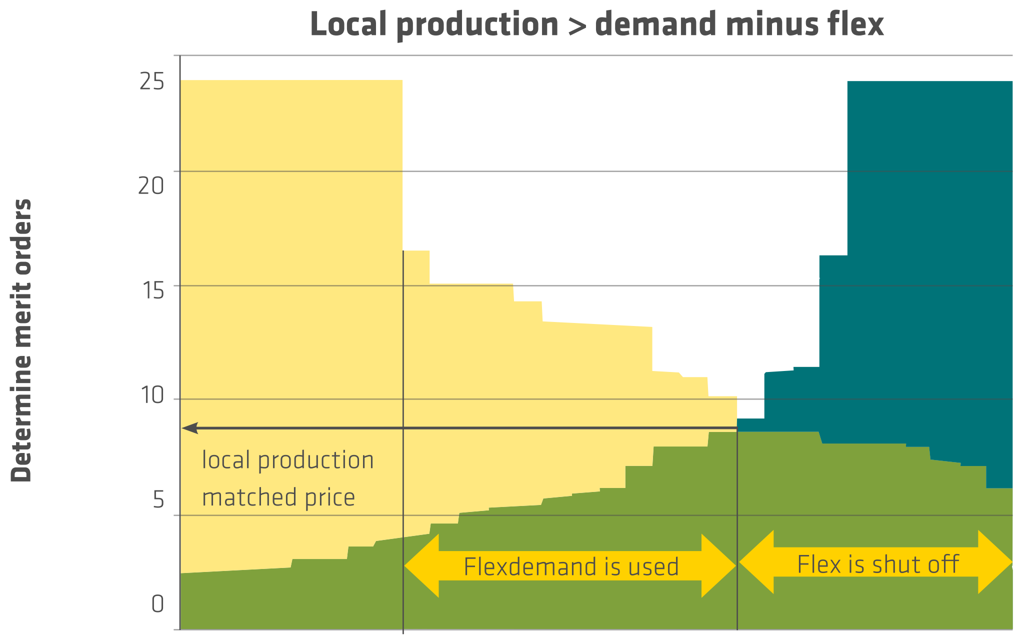
Production



Forecasted production for every interval (e.g. 5 minutes) will be bid into the market in blocks of energy for a certain price.

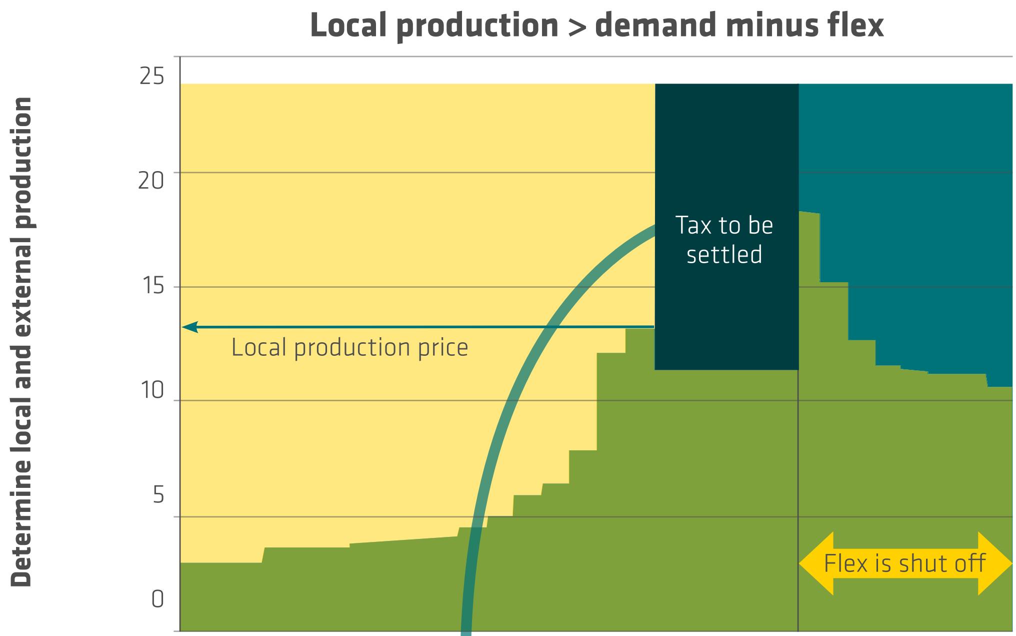
Demand and Flex

Forecasted demand for every interval (e.g. 5 minutes) will be bid into the market in blocks of energy for a certain (maximum) price.



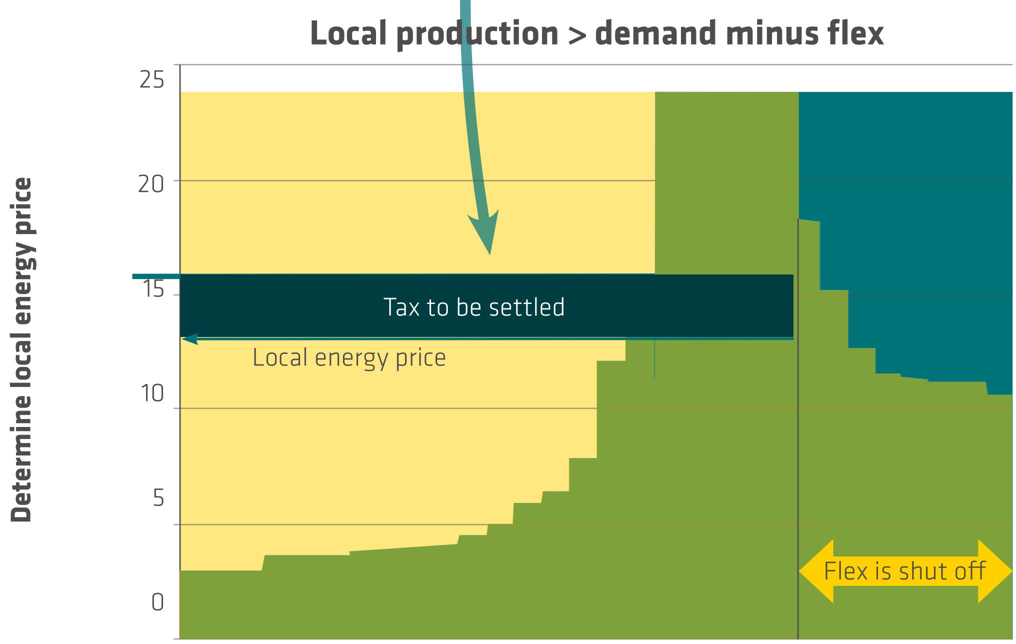
The blocks are sorted by the market operator into a merit order and a matched price will be determined for that interval. Any production with a price higher or consumption with aa price lower than the matched price is 'out of the market' and these transactions will not be cleared.

- Production
- Demand



Influx of energy from external (wholesale) suppliers is subject to taxes and levies.

- Production
- Demand



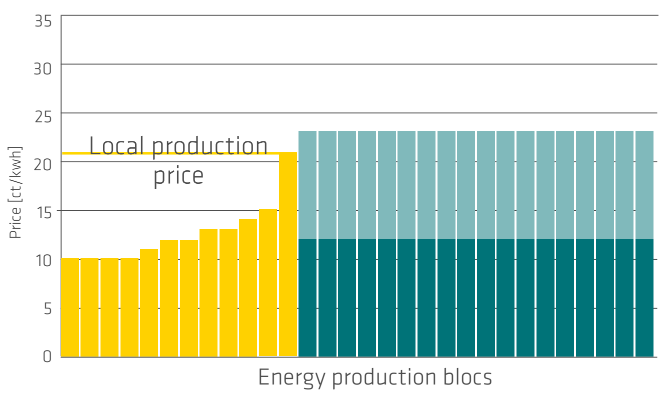
The taxes and levies due will be spread out over all transactions, resulting in a local energy price somewhat lower than the retail price of external (wholesale) suppliers.

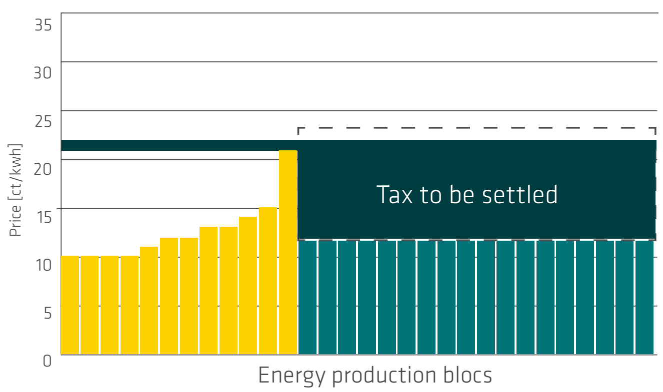
- Production
- Demand

Especially in the early development phase of a local market, the bulk of the energy consumed has to be provided by external producers, i.e. suppliers with access to wholesale markets and/or large generators. After all, local production will be limited and not sufficient to supply all local demand. Only the volume that is supplied by external parties is subject to taxes and levies and will be spread out over all local consumption. Consequently, the local energy price will be slightly lower than the standard retail price, and thus will provide an incentive to participate.
The lower local energy price can also be attained by a feed-in premium or flexible capacity tariffs, so the tax regime can remain as it is. As long as the price symmetry for consumption and production is maintained on the level of the End User, the mechanism or premium used for creating a local advantage can be freely chosen.

THE MARKET MATCHING ALGORITHM

The amount of locally produced energy determines the need for externally produced energy to be supplied. If local production can meet local demand, the influx will be zero. However, this will not be the situation in most cases. Let us assume the market needs external supply. The volume of externally provided energy leads to an amount of taxes and/or levies that are socialised over the consumption of the community as a whole. As mentioned above, it does not have to be taxes or levies that provide the financial advantage for locally produced energy – it can be anything –, but to simplify the description the term 'taxes' will be used here.





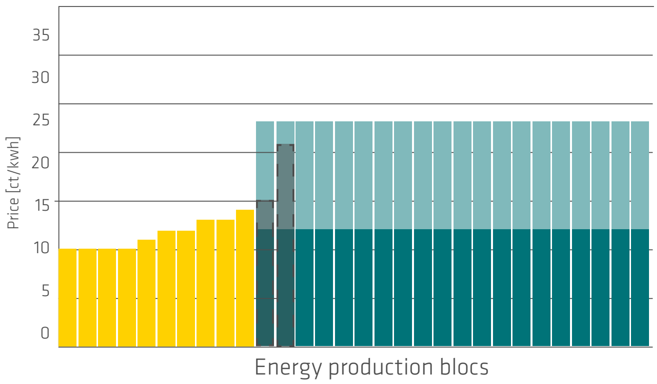
If a local production price is established that is relatively high, the situation may occur that, after socialising the taxes, the resulting local energy price is almost as high as the price for externally provided energy. This is especially important to consider because the local production price is a marginal pricing, meaning all cleared bids are settled at the highest cleared price. So even one small 'expensive' production bid may reduce the attractiveness of the local market significantly. On the other hand, you could say that this is the result of a market.

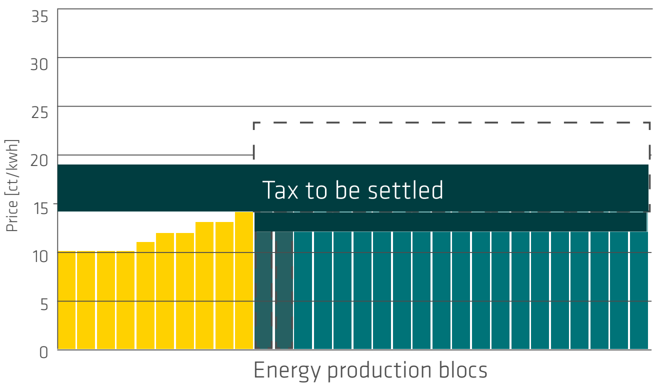
The above figures illustrate the undesirable market result when the local production price comes out very high due to one expensive production bid.

The objectives of the market matching mechanism are:
- The resulting local energy price is lower than the price for externally provided energy
- The use of locally produced energy is maximised

Keeping these objectives as prerequisites for the market-matching mechanism, you could argue that negatively influencing the marginal pricing mechanism with extreme prices of just a few bids should be prevented. In that case, a mechanism that provides a market incentive for local generators to keep prices at an acceptable level can be introduced. This mechanism removes the highest local bids if they deviate to certain degree (to be determined by the local market operator and its participants) from the mean or median of all local production bids and replace them with external production.

The market-matching mechanism follows the steps below:
1. Determine the production bids, both local and external that are needed to fulfil demand;
2. Determine the price for the externally supplied energy (wholesale price including fees, levies and taxes), probably around € 0.23/kWh;
3. Determine the marginal price for locally produced energy, being the maximum price for a local bid lower than the external price;
4. Optionally: Determine bids that are outliers, which are replaced by external bids;
5. Determine the amount of taxes to be settled and socialise this over all consumption, leading to a "spread tax" per bid;
6. Establish the local energy price (local production price + the spread tax) and clear the market.





The above figures illustrate that removing the two highest local bids and replacing them with external bids leads to a local energy price that is much lower than the external price. It should be noted that the total amount of tax to be settled is increased by replacing local bids, leading to a higher "spread tax per bid.

The effect of this alternative market matching is that local production that is relatively expensive is not cleared and 'manipulating' the market is therefore not rewarded. Furthermore, the price of a bid with a high likelihood of being cleared is not fixed but very much dependent on the amount of local production and the position of the bid in the merit order. This encourages competitive bidding strategies for local production.

THE OPERATION PHASE: ADDITIONAL ENERGY SUPPLY AND FLEXIBILITY

Once a local energy price is established and the cleared production and consumption bids are determined and communicated, each End User in the local market will use this as the basis for his operation. Deviations from the planned consumption or production during operation have to be compensated by other participants. This leads to the need for an incentive to stick to the plan as much as possible during operation.

Deviations have to be balanced. This balancing can take place on different levels:

- End-user Balancing: deviations from the plan of the End User can be compensated by the End User himself by using his own flexibility. Especially buffered appliances (e.g. batteries, buffered heat pumps) or non-time-critical appliances have the flexibility to compensate at any time. This can be highly automated, but can, for example, also be a manual action initiated by a warning sent by an app on a phone.
- Community Balancing: a deviation in one direction can very well be compensated by a deviation in the other direction by another End User. The net imbalance for the community is in that case zero. This statistical effect is called the 'portfolio effect'. However, the number of End Users in a local market is limited, so the effect will be limited as well. But unused flexibility from one End User can also actively be used to compensate deviations and balance the community. Again this can be automated.
- BRP Balancing: In order to fit into the existing market model, the community or local market has to appoint a Balance Responsible Party as its Local Balancing Service Provider. This BRP is presumably a party with a portfolio of clients. All these clients add up to a larger portfolio and, consequently, a larger portfolio effect where deviations are balanced by deviations in the opposite direction at other local markets or clients. At the same time, the BRP may actively manage flexibility in order to maintain a desirable balance.
- TSO Balancing: The TSO is ultimately responsible for maintaining the overall system balance. If the overall system is not in balance, the TSO buys ancillary services to restore the balance. Any expenses for balancing actions are recouped from the BRPs causing the imbalance. Different countries use different mechanisms for this.

The BRP of the local market will charge a premium or a fee for assuming balancing responsibility. How these costs are recovered from the local market participants – recovering it only from the causers of the local imbalance or socialising the costs over all local market participants – depends on the setup of the local market.

SETTLEMENT

Energy consumption and/or production in the local market is measured and the financial settlement of the involved transactions and imbalance costs is determined during the settlement phase. The basis for this settlement is always the measurement. However, which measurements by whom are considered valid for which settlement is open for debate. An important aspect in this is the difference between accountable data (on which final settlement should be based) and operational data. The latter can be data from a HEMS or a smart plug, and these can be very useful for operational information or even preliminary settlement but will not be considered accountable data in a legal sense. Key in any settlement process is transparency.

IMPORTANT ISSUES TO BE ADDRESSED

With the introduction of local markets, price differences will occur between local markets. Though energy prices will be capped by the normal prices for energy supply (it is the same or better), it is a political or even sociological debate whether this is acceptable. Though it might be accepted when it comes to consumer goods, price differences when it comes to energy is a sensitive topic.

Another issue could be that living in a rich neighbourhood where a lot of distributed generation is installed would be an advantage over neighbourhoods with fewer financial means to invest in assets. Though that might be the case in the beginning, it is still not a worse situation than before. And furthermore, a neighbourhood with fewer assets will result in higher local market prices and will therefore be more attractive for investors or housing associations to invest in as it will be a better business case. In the end, the mechanism of the market will lead to a levelling effect on the distribution of generating capacity and flexibility.

PART IV – EXAMPLE BUSINESS CASE

This example business case for the Layered Energy System (LES) is based on a broader analysis of data that was gathered by Stedin from a pilot containing an all-electric community consisting of both prosumers (with PV generation) and consumers (without PV generation). From the data, the consumption and production patterns for both the individual households, as well as the community as a whole, were determined. A comparison is made for three scenarios: the current situation with net-metering, a situation without net-metering, and one in which the LES is active.

The results show two clear benefits of the LES. Firstly, the incentives for investing in renewable generation remain intact, although slightly less than under net metering. Secondly, both prosumers and consumers within the same community can profit. Meaning that people who cannot afford to invest in renewable generation or do not have the right roof orientation can still participate and profit from the LES. The results show that prosumers in the LES will save on their electricity bill, when compared to a situation where net-metering is not possible. A consumer can save on their electricity bill compared to either the net-metering or non-net-metering situation.

The third (potential) benefit of the LES is that it will provide an incentive to match supply and demand in real-time. In other words, it will be cheaper for people to use electricity when there is generation in the community. However, in this example business case the potential incentive is relatively low (€22 - €55 annually). This low incentive can be explained by the type of community: a very high annual consumption and a relatively low PV penetration. Therefore, most of the electricity generated within the community (80%) is already used within the community.

If the type of community is different, for example with a higher PV penetration and/or a lower total consumption, the percentage of generated electricity that is used within the community will fall sharply. This will then increase the potential gains for prosumers and consumers to use the flexibility in their demand.