LOCAL ENERGY MARKETS: OPPORTUNITIES, BENEFITS, AND BARRIERS

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ABSTRACT

The "Clean Energy for all Europeans" package, which the European Commission presented in late 2016, opens way for a major transition of the European energy landscape towards customer empowerment and local energy. It states that consumers within the European Union shall be entitled to generate electricity for either consume it, store it, share it, or sell it back to the market. This paper takes on those promises to overview and elaborate on the concept of local energy markets, highlight the opportunities offered to various stakeholders, and discuss identified benefits and challenges/barriers to their further development.

INTRODUCTION

In November 2016, the European Commission (EC) presented the "Clean Energy for all Europeans" policy package [1]. Among its priorities are the empowerment of customers through more active involvement in the European Union (EU) energy system, allowing them a better control over their energy consumption and an improved response to price signals, by taking advantage of the local availability of renewable resources [2]. According to the EC, in 2030, half of the EU's electricity will come from renewable energy sources (RES), and by 2050, its electricity should be 100% carbon-free. Most of this new intermittent capacity will continue to be deployed on the customer premises, and must swiftly become fully market-integrated, to ensure RES cost-effectiveness [3]. These developments provide a framework for establishment of local energy markets (LEMs), which can be broadly defined as marketplaces that enable prosumers and/or other local generating entities to trade energy volumes of their choosing within local communities. The introduction of LEMs in the EU's energy system will take shape though revisions of both the Electricity Directive [4] and the Renewables Directive [5], which set legal and market participation principles for "local energy communities" and "renewable energy communities". Combined, the two documents advance that these communities:

- can engage in energy generation, consumption, distribution, aggregation, storage, supply/sales, including through power purchase agreements, and/or energy efficiency services;
- are entitled to own, establish, lease, and autonomously manage community networks;
- should operate on the energy markets, directly or via aggregators or suppliers, on a level-playing field without distorting competition;
- must benefit from non-discriminatory treatment in their activities, rights and obligations as final customers, generators, distribution system operators (DSOs) or aggregators;
- are subject to fair, proportionate and transparent procedures and cost reflective charges.

To address the above challenges, which also constitute opportunities, the DOMINOES project is designing and developing a transparent LEM architecture where customers interact and exchange energy and flexibility with other stakeholders such as DSOs, aggregators, retailers and/or other participating customers. (Figure 1). This paper, which is an initial deliverable of the DOMINOES project, elaborates on possible benefits that LEMs can provide to various energy system stakeholders, and serve as valuable input to the LEM concept design stage. Likewise, it examines barriers that may hamper their development. The identified benefits and barriers provide a checklist that may guide planners, managers, and decision-makers involved in local energy initiatives. In this paper, LEM benefits are organized into *Customer*, *Network operator*, *Service, technology and energy provider*, and *Society* levels. Identified barriers to LEM are divided into the *Technical*, *Regulatory & Legal*, *Economic*, and *Stakeholder* categories.

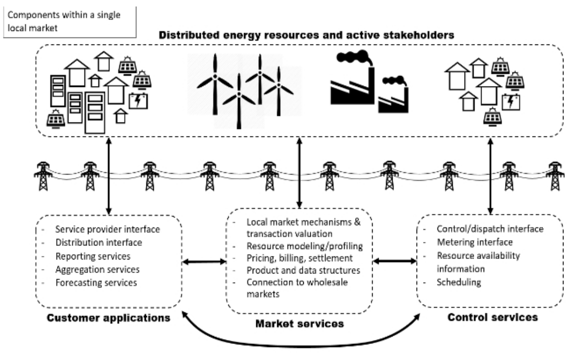

Figure 1 – DOMINOES project LEM concept components.

BENEFITS OFFERED BY LEMs

Customer level (Prosumer perspective)

In LEMs, customers with own generation will be able to consume self-generated energy by making an optimal use of local distributed energy resources (DER), including energy storage (ES) and particularly RES [6]; they become *prosumers*, who actively manage their energy affairs. This provides them with a higher level of energy independency and control, when compared to the traditional electricity "price-taker consumers", which are essential motivators for their engagement in LEMs [7,8]. They will also be able to trade their energy generation surplus within the boundaries of their local community, such as in a peer-to-peer – p2p – arrangement (see proposed local trading models in [9] and [10]). This enables the strengthening of the customer's position, i.e. from a passive to an active role, in the energy market/system. With greater involvement, customers also become more energy efficiency-aware, and may take part in innovative demand side management (DSM) and other customer-driven services [6], including electricity sales to the wholesale market. Customers can also provide flexibility capacity to network operators through intermediary market entities or aggregators [6]. By combining the available capacity from multiple electricity customers, aggregators can make offers in balancing and ancillary markets that comply with minimum capacity requirements, thus enabling the efficient participation of small prosumers that may otherwise not be possible. For these reasons, the connection to broader energy markets unlocks various levels of economic benefits to customers, which are not available to self-dependent isolated communities [6].

LEMs can also enhance security of supply if, for instance, these would be structured as microgrids (MGs) i.e. these could operate isolated from the distribution grid if outages occur [11,12). The avoidance of outage costs, particularly in rural areas where electricity delivery service is less reliable than in urban areas, is thus an additional benefit that customers can leverage in LEMs.

Expanding the broader energy market to the local level is a significant sectoral change that will drive disruption and innovation, but consequently also competition. Competition motivates companies to develop further their services and products in the interest of customers, in terms of both variety and price. More, the continued development of LEMs will increase pressure over traditional power industry players to adapt their operations towards more customer-oriented approaches.

LEMs will connect communities and drive their participant customers into achieving common goals, such as reducing costs of energy, emitting less greenhouse gas emissions, or becoming more energy self-sufficient [6]. This involvement and group-like behaviour, alongside a sense of "mission", contribute to a growing perception of transparency and trust in the energy system as a whole, which result in more engagement and commitment [11].

Network operators level (TSO, DSO)

The customer-owned DER generation present in LEMs will impact the everyday operations of distribution and transmission networks in various ways. It can reduce the network operators' need to make new investments and reinforcements in the distribution grid, not only because of DER capacity additions, but also due to increased flexibility and more efficient overall network operations [6,8,13]. These capacity additions at the grid edge also decrease stress in the distribution, due to a decrease in power demand. Network losses reduce as well, since there is less load at both the transmission and distribution levels. The aggregation of generation and demand capacity from multiple customers can help network operators in more efficiently balancing the grid's supply and demand [6]. For instance, DSM services increase the customer's energy efficiency, playing an important role in achieving this balance. Equally, balancing and ancillary services offered by customer-owned DER provide important support to the network operations. MGs can improve the distribution network's reliability by ensuring power supply in case of grid outages [11,14]. Furthermore, the optimized interconnection of multiple MGs (when accompanied by effective customer load management) could support the reliability, flexibility, and responsiveness of the overall power system and allow DER utilization at larger scales, generating widespread tangible and intangible benefits [6]. Power quality at the distribution level can be also be improved by the various flexible DER and the sophisticated power electronics present in MGs [12].

In general, the development of LEMs opens up new market opportunities driven by new business models geared towards value creation from the network operators' point of view. Different forms of value-added and real time services can be provided, as for example real-time energy monitoring and/or billing, DER asset management, customer generation/demand load aggregation, local balancing of supply and demand, distribution network leasing for customer-owned DER by DSOs, MG real-time energy management, etc. [7].

Service, technology and energy providers level

LEMs will rely heavily on modern technologies and on constant product innovation. In this context, opportunities will emerge for market stakeholders to reposition their strategies and to develop new products and/or services in line with new customer demands. New market actors will emerge due to changes in its models and governing structures. These actors will mostly operate as third-party intermediaries between customers, network and market operators. For example, aggregators are bringing advantages to both customers and operators, and can simultaneously generate profit by providing their core services. Another example are energy services companies (ESCOs), which can drive significant value to customers via reductions in their energy demand [13]. ESCOs offer various types of novel services, most typically by relying on performance contracting schemes

for invested capital recovery. ESCOs' revenues link directly to savings achieved for their customers, which is another step towards more transparent market practices.
Other business opportunities will arise in the domain of active information exchange between stakeholders – a key foundation of LEMs. Information and communication technologies (ICTs), the major enablers of a more efficient and flexible operation of the distribution network, will power this exchange. Significant business opportunities to develop and provide related flexibility and energy management services will drive the entry of new participants in existing LEMs.

Society level

The evolution from a traditional energy model to a new paradigm rooted in decentralized and customer-centric energy production and distribution is a massive undertaking with many positive societal repercussions. LEMs not only embrace this paradigm as take it steps further by providing greater market transparency and the promise of more fair distribution of power and more balanced allocation of systemic costs and benefits, which are arguably foundations to advancement of any society. LEMs facilitate the growth of clean energy generation, in particular from RES, which leads to lower local and global emission levels. This is in line with the EC's climate objectives and with the Paris climate agreement.

BARRIERS FACED BY LEMs

Technical barriers

Several DER technologies, which are crucial to LEMs, are not fully technical-mature and have not yet been widely adopted. Notable examples are various ES systems, such as metal-air battery systems, solar fuel cryogenic and synthetic natural gas and thermal systems, as well as different types of fuel cells [15,16,17].
Many technical challenges exist in microgrids that are subject to research by both academics and industry. For instance, the switch from grid-connected to island mode (decoupling), followed by a reconnection to the distribution grid (recoupling), is a challenging sequence of steps that requires high levels of voltage and frequency control, as the dual-mode operation causes imbalances between generation and loads [12]. This links directly to DER synchronization needs, whether in island operation or in reconnecting with the grid. Managing instantaneous active and reactive power balances between two grids is also difficult under various network voltage profiles [18]. Lastly, there are power and frequency control requirements specific to grid-connected MGs that can be difficult to achieve, since a significant extent of the generation in MGs comes from intermittent sources [12].
Smart metering is another key component to LEM operations and to market flexibility management [14]. Nevertheless, because smart meter rollout is at different stages in various EU-countries, there is need for increasing standardization in metering schemes [19].
Other barriers relate to communication and control aspects, which result mainly from the large variety of system management and control software options [12]. These options should be compatible with other components of MGs, so to enable appropriate connectivity, modularity, and thus efficient operation.
From a market standpoint, it remains unclear how should secure and transparent local trading platforms be established. For instance, it has been suggested the application of blockchain and related technologies to LEMs [11]. This could bring not only further transparency, as it would allow for a high number of distributed and secure transactions, as well as for the continuous tracing of even the smallest of these transactions. However, challenges are reported in [11], such as scalability issues, complexity of technical protocol and implementation with current components, which have not been thoroughly studied yet.
LEMs will incorporate the active collection and exchange of significant amounts of data, much of which of a sensitive and/or confidential nature. In this context, secure data handling and protection from various cyber security threats becomes a priority to address firstly by guaranteeing the clear definition of responsibilities as to the maintenance of the LEM data exchange systems.

Regulatory and legal barriers

In various countries, legislation barriers are hindering the development of LEMs by blocking the effective utilization of DER and/or RES. For example, it is not legal in some states to combine energy generation with storage in the customer premises or to feed self-generated electricity to the grid. Regulation also varies substantially in what concerns prosumer feed-in tariffs and the models that rule it [20]. In some cases, customer remuneration schemes for surplus electricity are inexistent. In other cases, it is not even possible to export local electricity to the grid, which keeps customers away from broader market participation revenues. Yet, the operation of LEMs will require well-established and balanced regulation geared towards allowing trading surplus electricity with grid operators or fellow customers. Furthermore, public policies must support local offer of customer-centric services, rather than discourage it. For example, the economic regulation of DSOs often incentivizes infrastructure expansion investments over demand response [23]. Such legislative frameworks vary significantly across the EU and globally, and will affect LEM developments at a case-by-case basis.
The legal context also often disallows MG islanding, typically due to voltage stability problems and safe operation challenges related to the small grids' size and bi-directional power flows [14]. To face this, regulators will have to push regulatory frameworks that facilitate compliance with bi-directionality requirements, particularly at the point of common coupling [12].
Taxation issues also persist. For example, in Finland, owners of electric storage assets pay taxes for the charging electricity. This leads to double taxation, as consumed electricity from storage is equally taxed [21].

The absent regulation of small-scale renewable generation in rural areas in many countries is likely to cause long administrative procedures and delays, including in getting project approvals and permissions. For example, it is not clear who pays for connecting DER to the distribution network and for possible grid reinforcements [22]. This uncertainty, added to an already unclear policy landscape, brings extra risks for investors that will negatively affect profitability analyses. Local energy systems need new distribution infrastructure, which will cross privately or publicly owned land. This raises legal issues that must be anticipated [14]. More, it may originate conflicts of interest, in cases where the new network intersects local distribution network rights-of-way, which DSOs hold under long-term leases. Equally, it is uncertain if only DSOs should manage and maintain these wires or if, to provide these services, they should engage in market competition. The same issues apply to the suitable entities to operate and manage the actual local energy systems, or the actual LEM operations. DER ownership is also difficult to define legally, for which further regulatory clarifications are highly required [14].

The direct control of customer loads can as well raise conflicts of interest and privacy issues. As various entities may use customers' flexibility for different applications, it becomes a necessity to define clear rights and obligations applicable to balance responsible parties.

Economic barriers

Local energy projects still bear high upfront costs, which affect their financial performance [6,22] and/or investor attractiveness. This is mostly (albeit not exclusively) related to high installed costs of less market-mature DER. Split-incentive problems can emerge in energy community developments, in cases where its benefits split between various stakeholders but its costs belong exclusively to investors [6]. This problem relates closely to the inadequate definition of DER ownership. For LEMs to reach its full potential, a fair distribution of value among its participants is a key requirement.

Increasing consumption of self-generated electricity can threat the DSOs' ability to invest in grid development and maintenance, if their revenues from grid fees decrease. This creates imbalances leading to increases in electricity prices and in grid fees for non-prosumer customers [20]. It is also likely that traditional energy market actors show resistance to the development of LEM because of fear of loss of market shares and positioning. On the other hand, new opportunities will emerge for these important and experienced players to provide new types of services to their customers. Additionally, the distribution network will remain a fundamental asset for LEM (needed, for instance, for energy trading). Innovative DER-based and customer-centric business schemes will continue putting pressure over traditional market players, such as centralized generation and operator companies, to change their commercial strategies and business models, until new market equilibria are finally reached.

Stakeholder-related barriers

Effective customer engagement is a vital step for the development of functional LEMs [12]. LEM and MG developers can face resistance from customers that do not possess enough information on the developments, or that do not have the understanding of highly innovative and technically complex concepts. This type of *resistance to change* may become more acute and sensitive to handle when projects take place in socially fragile areas. Another difficulty lies in the to a certain degree intangible nature, and/or in the difficulty in quantifying some LEM benefits, such as the lowering of emissions of global impact and the promotion of local growth, which are not easily perceived by individual customers [7]. In average, customers feel more attracted to benefits that are, immediately at a first glance, perceived as attainable, tangible, and easily quantifiable [7].

CONCLUSIONS

The ongoing trend towards local energy imposes an improved understanding of the opportunities, benefits, and barriers that LEMs may bring to various stakeholders. This paper takes first steps in that direction. Customer empowerment is behind a number of benefits that include the customer's more active and strengthened stance in the market, greater energy independence, more energy awareness, and growing perceptions of trust and transparency. Other important benefits relate to network operation improvements, such as the avoidance of customer outages, deferment of new grid expansions, lower network losses, beneficial redistribution and balance of loads due to added generation capacity at the grid edge, and power quality and reliability enhancements at both the transmission and distribution network levels. Network operators are the main recipients of the above benefits. The most populated group of LEM benefits links directly to market and business aspects, all of these largely driven by local innovation. These benefits are major drivers for service, technology, and energy provider stakeholders, who will welcome the emergence of new business models, market structures, and players, as a result from local and regional market growth and diversification. Amid market readjustments, network operators will most likely use their privileged position to embark in new business opportunities whether alone or by collaborating with third parties. Customers, on the other hand, will largely benefit from services they will become able to provide in the wholesale, balancing, and ancillary energy markets.

A fourth category of benefits relates to environmental improvements, which are essentially associated to lowering local and regional-to-global impact pollutant emissions, mostly as a direct consequence from the optimal exploitation of local renewable resources.

Various barriers to LEMs are technology-related, saying respect to DER and ICT. These have to do, for example, with techno-economic maturities, inadequate regulation, and with hard technical requirements, such as real-time metering and energy management, active information exchange, and DER problems such as synchronization, fault detection, microgrid islanding, etc. This links with user privacy and security issues that impose fast development of technical information science solutions that safeguard both the systems and its users. Other barriers lie with power network challenges of numerous kinds, to name a few interconnection issues, absent regulation for management of flexible resources, grid bi-directionality, maintenance of system power quality and reliability through coupling/decoupling cycles, and conflicts with DSO-owned franchises. Customer engagement activities will also continue to incorporate risks. For instance, resistance to change is especially likely to happen when projects address impoverished communities. Moreover, to develop LEMs that align the interests of its many stakeholders and that efficiently distribute value is a substantially complex challenge to tackle. Energy taxation issues are an unjustifiable bottleneck whose swift resolution and clarification urges. Lastly, several market and business-related barriers persist, strongly restraining the progress of LEM stakeholders. Well-defined, secure, and transparent local trading platforms are yet to be established. More, it is unclear who will be the regulating entities for such platforms, as it is for LEMs policy-making in general. The need for profound reinvention of business strategies and models also poses many difficulties. These models, with no past of practical applications, remove value from traditional domains and transfer it to novel ones, where much uncertainty exists. For example, split-incentives may happen due to undefined DER ownership and lack of understanding of value streams. Balance responsible parties, as well as their clear rights and obligations, are equally undefined in the context of LEMs, which is a necessity in the presence of ample customer flexibility.

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