Transitions in Electricity Distribution: Insights from the Multi-Level Perspective

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As more nations are committing to decarbonize their electricity sector fuel mix, the electric grid must transition from a centralized fossil-fuel based system to an electric power system. This new system will be cleaner, more distributed and interconnected, opening the doors for customers to produce (prosumers), consume and save energy in numerous ways (Glitman et al., 2019). The objective is clear: provide affordable, reliable, sustainable and modern energy for all, while fostering innovation and making cities inclusive, safe and resilient.

The Decarbonization of Electricity Distribution Networks

Until very recently, cost-competitiveness was the major obstacle concerning renewable energy sources. But with wind and solar reaching grid parity and representing more than eighty per cent of new capacity in 2018 (IRENA Renewable Capacity Statistics, 2019), the challenge of clean energy has now shifted from the cost of new generation to the subject of how to integrate these clean but variable and intermittent resources into the grid (Golden et al., 2019). Moreover, in this rapidly changing context, transportation electrification, although offering an opportunity to provide flexible demand and increasing the integration of renewables, which can contribute to power system efficiency, can also lead to grid congestion (Glitman et al., 2019).

To successfully decarbonize the electric sector, utilities will need to tackle the growing load shape challenges driven by the variability of many renewable resources. Behind-the-meter solutions (anything that can be done to reduce the amount of energy being purchased from a utility), namely energy efficiency, demand response, electrification and storage, will play a crucial role providing stability to the grid. Still, these measures will only be effective if they can deliver changes in demand acknowledging the time and locational needs of the grid. Thus the importance of decentralization of energy supply, which in turn generates new needs at the distribution level (Hayes et al., 2020; Golden et al., 2019; Silvestre et al., 2018).

In fact, new innovative architectures are arising (for instance, microgrids or blockchain solutions) and market design and regulatory mechanisms are expected to evolve in order to support and facilitate this transformation. As noted by Glitman et al. (2019), even though the technology necessary to decarbonize, for instance, land transportation exists today, an affordable and reliable transition will require a focus on policy and regulatory changes. Thus, low carbon innovations have the potential to trigger the necessary transition towards new or durably reconfigured socio-technical systems. However, many of these innovations are small in terms of market share and investment, while facing barriers from existing socio-technical systems. Current government interventions focus mostly around cost structures, information provision and regulation, which may be insufficient to generate non-marginal change. Also, these innovations should not not be studied isolated, but in the context of their harmony with and clashes against existing socio-technical systems, as their diffusion does not happen in an 'empty' world, but in the context of existing systems that provide barriers and resistance (Geels et al., 2018).

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Multi-Level Perspective

The most common approach for socio-technical systems is the multi-level perspective (MLP). This heuristic approach combines ideas from social construction of technology, regarding social networks and interpretations, with evolutionary economics, that recognize economic dimensions and conflicts between radical innovations and existing systems. Literature concerning socio-technical transitions has been mostly developed by the Dutch school of transitions studies, as a governance approach for sustainable development (Jenkins et al., 2018; Kemp et al., 2007a; Kemp et al., 2007b). This attention on governance means that the socio-technical literature acknowledges the political dynamics present in the process through which innovations scale, diffuse or are established, since, historically, energy transitions emerge together with parallel developments of technological innovations (Hess, 2018; Guidolin and Guseo, 2016).

The MLP identifies three distinct levels: the niche innovations - novelties that deviate from existing systems; the regime - the incumbent socio-technical system; and the landscape - aspects of the exogenous environment (e.g., cultural preferences, demographics, short-term shocks such as macroeconomic recessions or oil shocks) (Geels et al., 2018).

The niche level is usually characterised as the lowest but most dynamic stage, and it is typically considered to be the domain where radical and revolutionary innovations emerge. The innovations generated can have several dimensions, for instance a new behavioural practice (e.g., car sharing), a new technology (e.g., battery electric vehicles), or a new business model (e.g., energy service companies) (Geels et al., 2018; Jenkins et al., 2018; Shum, 2017).

The regime level, also known as the meso-level of the MLP, contains the dominant institutions, policies, consumption patterns and technologies of the current socio-technical system (for instance, infrastructures and energy markets). It changes slowly and, typically, under the influence of niche dynamics (Geels et al., 2018; Jenkins et al., 2018). As noted by Fouquet (2016), transitions encompass not only the decline of incumbent industries but the rise of new ones also. However, as noted by Geels et al. (2018), existing systems may be rearranged through the adoption of multiple innovations, which together lead to broader changes. Car-based systems, for example, can be reconfigured through self-driving cars, congestion charges, on-board navigation tools, dynamic road management, and electric vehicles providing back-up capacity for electricity grids (via power stored in batteries, a practice known as vehicle-to-grid, V2G). Thus, instead of mapping the diffusion of single technologies, it may be more pertinent to ask how multiple innovations can reconfigure existing systems.

The third stage of the MLP model, the macro-level landscape, refers to slow changing, but large-scale, aspects of the exogenous environment. The socio-economic, environmental, and cultural context, within which actors and institutions are situated, as well as

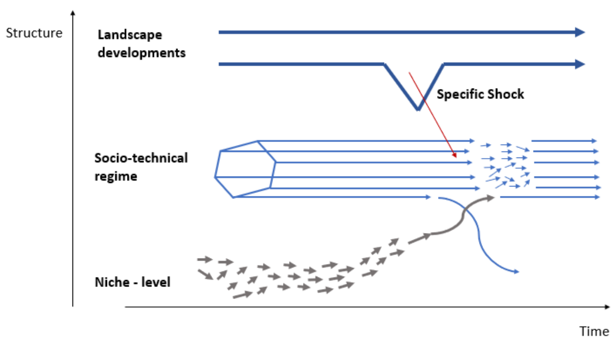

Figure 1: Technological substitution pathway in the multi-level perspective (based on Geels and Schot, 2007)

broader trends and global events, are considered. Accordingly, this level represents the broader political, social and cultural values and institutions of a society (Bataille et al., 2018; Jenkins et al., 2018; Shum, 2017).

Figure 1 depicts the technological substitution pathway in a general conceptualisation of the MLP process.

The intersection of the three stages, socio-technical systems, niche innovations and exogeneous slow-changing developments, is what determines the decarbonization progress.

Conclusion

New societal demands, for instance carbon neutrality, can be originated by exogenous factors such as global warming. These have the ability to push the current socio-technical and innovation systems into change to accommodate the new needs (Wesseling et al., 2017). The force and impact of the new societal demands, coupled with the stability of the system where they occur, influence whether a transition through prevailing technological trajectories arises (for instance, innovations regarding energy efficiency) or a transition to a new system configuration occurs (for instace, innovations in microgrids).

Niches are typically associated with the start of transitions and the major force for change occurs between regime and niche levels. Still, a transition takes place only when shifts in the three levels occur simultaneously. By the same token, the dynamics between the three levels is what creates or restricts technological transitions (Jenkins et al., 2018).

Thus, in order to transition to a decentralized and clean power system, an overall change needs to take place, not only in new businesses and technologies, but also in dominant institutions and in the socio-economic, environmental, and cultural context. While most energy system decarbonization focus is on supply-side opportunities (e.g., renewables), nations should also focus on demand-side drivers and create a diversity of mechanisms, institutional support frameworks and regulations to support them (Barido et al., 2020).

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