

Electrification: EU Opportunities for Utility Growth

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I. Executive Summary

This paper presents a counter-narrative to what is often called the utility “death-spiral”, a vicious cycle of declining utility sales and rising electricity rates. Under the death-spiral paradigm, weak utility sales growth is exacerbated by increasing distributed generation (DG) penetration.² Given largely fixed network costs, rates increase to recover network costs from a smaller basis, further encouraging DG. At the same time, emissions reductions achieved in the electricity sector alone fall far short of those needed to reach longer-term economy-wide greenhouse gases (GHG) reduction targets. We present an alternative to this paradigm, in which utility sales break out of the death spiral and the European Union (EU) comes close to achieving GHG reductions targets, based on electrification of the transportation and heating sectors, coupled with decarbonization of the power supply mix.

Under this alternative scenario, the technical potential is for electricity sales in the EU³ to nearly double by 2050 (relative to a projected increase of only 28% without electrification) while achieving economy-wide carbon emissions reductions of 70%. Even with continued increase in rooftop solar penetration, this likely implies significant growth opportunities for electric utilities. Instead of a future where utilities cede volume to energy efficiency and distributed generation, even partial electrification of the transportation and heating sectors could therefore present a large opportunity for utilities to increase sales and be a major catalyst for reducing economy-wide GHG emissions.

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² We authored a similar paper examining the potential impact of electrification on the U.S. electric sector. See Jürgen Weiss, Ryan Hledik, Michael Hagerty, Will Gorman, Electrification: Emerging Opportunities for Utility Growth, The Brattle Group, January 2017

³ We use the term EU to refer to the 28 EU member states as of April 2018.

However, the transition to greater electrification also poses important challenges. For instance, who will bear the costs of this transition? How do those costs compare to alternative options for decarbonizing the economy? How will power grid operations be impacted by new, significant sources of load? How will these load impacts depend on parallel developments such as automated driving and the proliferation of car/ride sharing?

The pace and scale at which this transition occurs can likely be influenced by utilities. We explore a number of initiatives that could be pursued to nudge future industry developments towards (more rapid and perhaps more controlled) electrification. They include facilitating the deployment of vehicle charging infrastructure, charging rate design, effective engagement with regulators and policymakers, developing new programs to leverage the grid flexibility benefits that could be provided by more electricity-intensive end uses and lowering information and experience barriers.

II. Introduction

The electricity (and broader energy) industry is in a period of fundamental transformation. Increasing concerns about climate change risks, advances in cost and performance of alternatives to traditional fossil-fueled technologies, advances in battery storage, and the increasing ability of end-use customers to participate more actively in their energy production and consumption all suggest a profound change in the industry. In addition, advanced economies such as the EU continue to shift away from energy intensive activities and towards installing more efficient devices for providing similar services. The persistence of these trends is leading to a belief by some that the traditional utility model has become untenable. The combined emphasis on energy efficiency and proliferation of rooftop solar owned by individual customers in particular has led to a view that the role of utilities in the future energy system may be shrinking. In line with this view, the 2016 EU Reference Scenario⁴ projects net electricity sales between 2016 and 2040 will grow at an average annual rate of just 0.7%, significantly below the average of 1.1% per year over the previous twenty-five years.⁵ This same reference scenario only achieves GHG emissions

⁴ European Commission, “EU Reference Scenario 2016, Energy, transport and GHG emissions Trends to 2050,” 15 July 2016.

⁵ European Environment Agency, “Final energy consumption of electricity by sector,” 21 October 2015.

reductions that fall far short of the 80-95% economy-wide emissions reduction target the EU has set for itself.

The drive to further reduce economy-wide GHG emissions and ongoing transport and heating developments involving electric vehicles and autonomous shared driving as well as advances in heat pump technology suggest a pathway to an alternative future paradigm of economy-wide decarbonization through electrification.

In this paper we explore this alternative paradigm. Specifically, we explore: (1) if there is a compelling prospect for utility sales to reverse the current low/no growth trend and grow quite strongly over the next 30 years, and (2) whether such growth could be essential for achieving the deep economy-wide decarbonization needed to minimize the risk of catastrophic climate change. The driver of growth in this alternative paradigm would be the nearly complete, and possibly fairly rapid, electrification of transportation and heating, which together currently account for about 48% of the EU's 2015 energy related GHG emissions as compared to 33% for the electricity sector.⁶

Our modeling of upper-bound growth (i.e., the technical potential) in this scenario suggests that electricity sales in the EU could essentially double from 2015 levels by 2050 if the heating and transportation sectors were to switch from their current fuel mix to 100% electricity. Even if rooftop solar continues to increase its contribution to overall electricity supply, such a shift would imply annual electricity sales growth rates that significantly exceed recent growth and even growth in the decade prior to the 2009 recession.⁷ Coupling electrification of heating and transport with decarbonization of the power sector by 2050, to which the EU is already committed, could lead to more than a 70% reduction in EU 28's GHG emissions relative to 2015

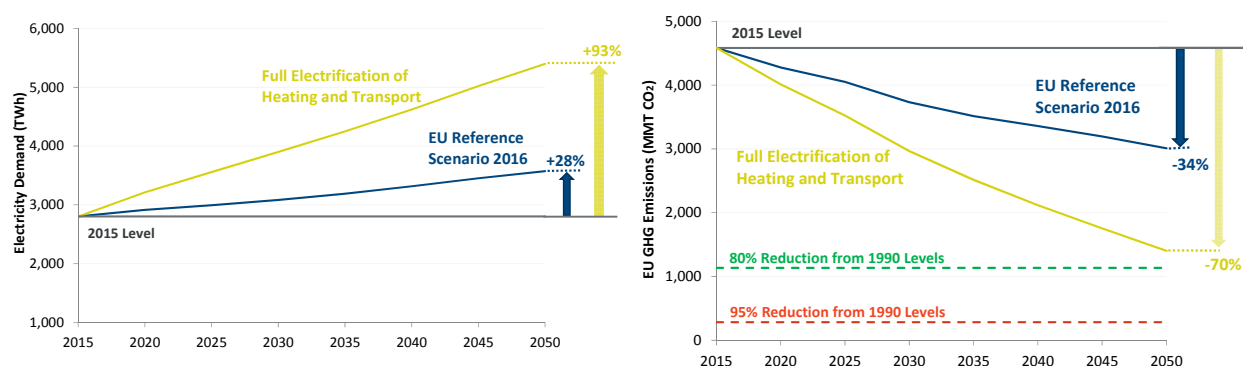
⁶ See EU Reference Scenario 2016, Energy, transport and GHG emissions Trends to 2050, European Commission, 20 July 2016.

⁷ For example, the maximum amount of electricity that can be generated from rooftop systems in Germany has been identified as 234 TWh, about 45% of current electricity demand. (Wegweiser Solarwirtschaft: PV Roadmap 2020, Roland Berger and Prognos, p.25) It is unlikely that more than 50% of this technical potential will be economically installed, so that the share of rooftop PV in an electrified energy system is unlikely to exceed 10-20%, which in turn implies that incremental electricity demand will need to be met with larger scale renewable installations.

levels and thus represent an important step towards overall economy-wide emissions reductions targets of between 80% and 95% by 2050.^{8,9} These two trajectories are summarized in

Figure 1.

Figure 1: Impact of Electrification Combined with Deep Decarbonization of Power Sector



Sources: The Brattle Group analysis. EU Reference Scenario 2016.

In the remainder of this paper, we first briefly lay out the challenges that lie ahead for utilities in the current slow growth paradigm, and we discuss the implications of long-term GHG reduction targets for the electricity supply mix. We quantify the impact that full electrification could have on electricity sales levels as well as GHG emissions. We also discuss some of the political and technical complexities associated with this transition. Finally, we explain and emphasize that this alternative paradigm is a foregone conclusion but will depend on many factors, including near term initiatives utilities can develop and implement. We describe several such initiatives.

III. The Deep, Economy-Wide Decarbonization Paradigm Explained

There is a broad political and technological trend toward decarbonization in the power sector. Beyond the need to mitigate climate change risks, significant declines in the cost of and increases in the performance of emissions-free technologies (primarily wind and solar) and their complements (battery storage) are leading to a widespread belief that the electricity industry will

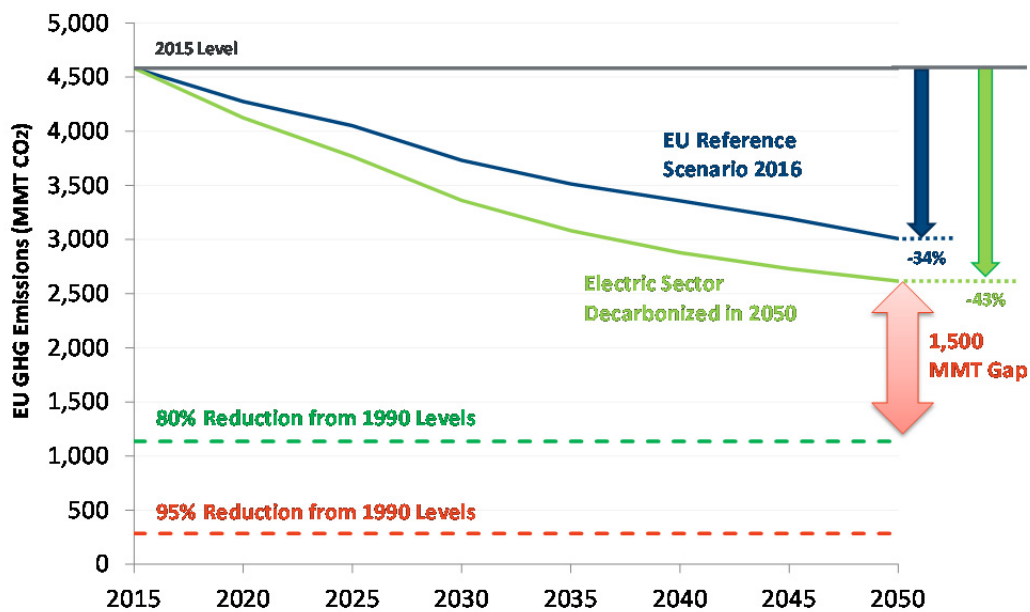
⁸ In 2015, energy-related GHG emissions accounted for 77% of total GHG emissions in the EU 28.

⁹ The EU has committed to GHG emissions reductions between 80% and 95% by 2050 relative to 1990. See https://ec.europa.eu/clima/policies/strategies/2050_en

become increasingly decarbonized, perhaps even without policies to reduce greenhouse gas emissions.

However, even if the electric power sector achieves full decarbonization by 2050, the EU will still be well above its long-term GHG goals as included in the Paris Climate Accord, absent other measures. Figure 2 shows that projecting a linear decarbonization trend between 2015 and 2050 still leaves the region 1,500-2,300 million metric tons short of a it 2050 GHG reduction goal.

Figure 2: EU-28 GHG Emissions with Fully Decarbonized Electric Power Sector in 2050



Source: The Brattle Group analysis. EU Reference Scenario 2016.

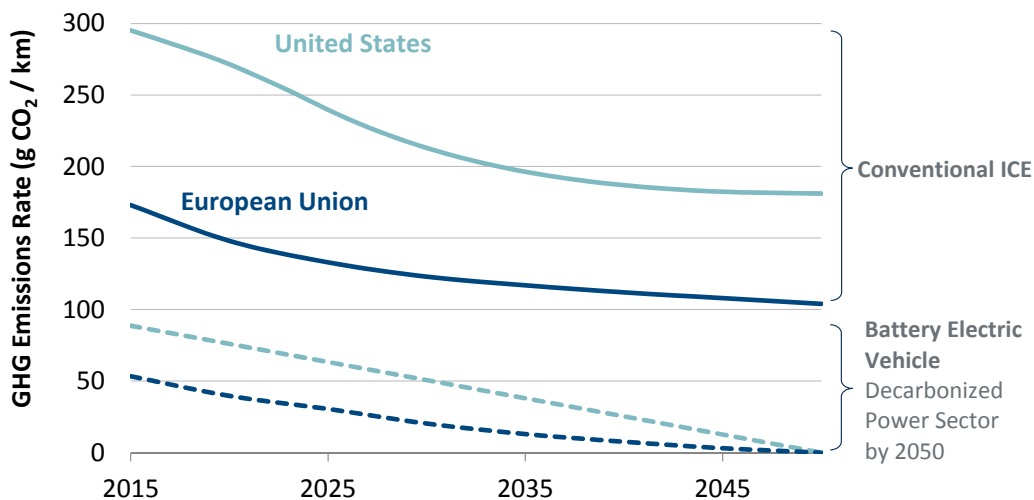
To achieve 80-95% reductions relative to 1990 emissions, further reductions are needed from the non-electric sectors, including in particular the transportation and the building sectors (space and water heating).

While some alternative pathways to decarbonizing these sectors exist, aggressively electrification of transportation and heating is one potential pathway, likely requiring fewer technological breakthroughs, cost declines and potentially less infrastructure development than other options.

A comparison of the emissions rate of different transportation technologies illustrates how vehicle electrification could lead to significant carbon reductions. Figure 3 below shows the

vehicle emissions rate from the EU 2016 Reference Case assumption for a gasoline-powered light duty vehicle (solid teal) compared to an electric vehicle powered by the electric grid with emissions also as projected in the EU 2016 Reference Case (dotted teal line).¹⁰ Using reasonable assumptions for future electric vehicle efficiency and carbon rates of the electric sector, battery electric vehicles (BEVs) provide a path for reducing transportation sector GHG emissions.

Figure 3: Emissions per Kilometer for Conventional and Electric Light Duty Vehicles



Source: The Brattle Group analysis. EU Reference Scenario 2016. U.S. Energy Information Administration, Annual Energy Outlook 2017.

As the figure illustrates, given the average current emissions rate in the electric sector, which is significantly below the corresponding emissions rate in the US, electric transport in the EU, on average, already provides a significant emissions advantage over conventional transport. It also shows that full (or earlier) decarbonization of the electric sector has the potential to further increase the emissions advantage of electrified versus conventional transport and allow for full decarbonization of transport where conventional transport does not. While not discussed in detail here, there are similar potential emissions benefits in the heating sector, due to the significantly higher efficiencies of electrified heating solutions, most notably air source and ground source

¹⁰ For our “greened” electric grid path, we assumed a linear decarbonization of the electric grid between 2015 and 2050. We note that this graph is based on an average EU view. The local and regional emissions rate could be quite different, driven by diverse electric generation mixes across the EU.

heat pumps, which achieve efficiencies several times higher than those achieved by fossil-based heating systems.

IV. Potential for Significant Electrification and Sales Growth

To demonstrate the potential for electricity sales growth and economy-wide GHG emissions reductions from electrification, we developed a high-level analysis of the gradual electrification of the transportation, residential, and commercial sectors.

Specifically, we developed an upper-bound estimate of the potential for electricity growth under deep decarbonization by assuming a steady conversion of transportation vehicles and residential and commercial heating devices away from burning fossil fuels and towards electric-powered alternatives, such that both sectors are fully electrified by 2050.¹¹ In other words, this analysis represents the technical potential for the electrification of heating and vehicle transportation.¹² For transportation, we assume that the projected volumes of fossil fuel used by light duty vehicles, commercial light trucks, and freight trucks are replaced by electricity demand for operating an increasing fleet of battery electric vehicles.¹³

For residential and commercial water and space heating, we calculate incremental electricity demand by assuming that appliances fueled by natural gas, propane, and distillate fuel (primarily water heaters and space heaters) are gradually replaced by heat pumps, electric water heaters, and electric ranges.¹⁴ For both sectors, the reduction in CO₂ emissions results from the decrease

¹¹ We used projections of future fuel demand from the 2016 EU Reference Case.

¹² We note that other developments in transportation such as autonomous driving, ride sharing etc. described in some detail later in this paper, could lead to an increase in total vehicle kilometers traveled and, if fully provided by electric vehicles, provide even additional sources of electricity sales growth.

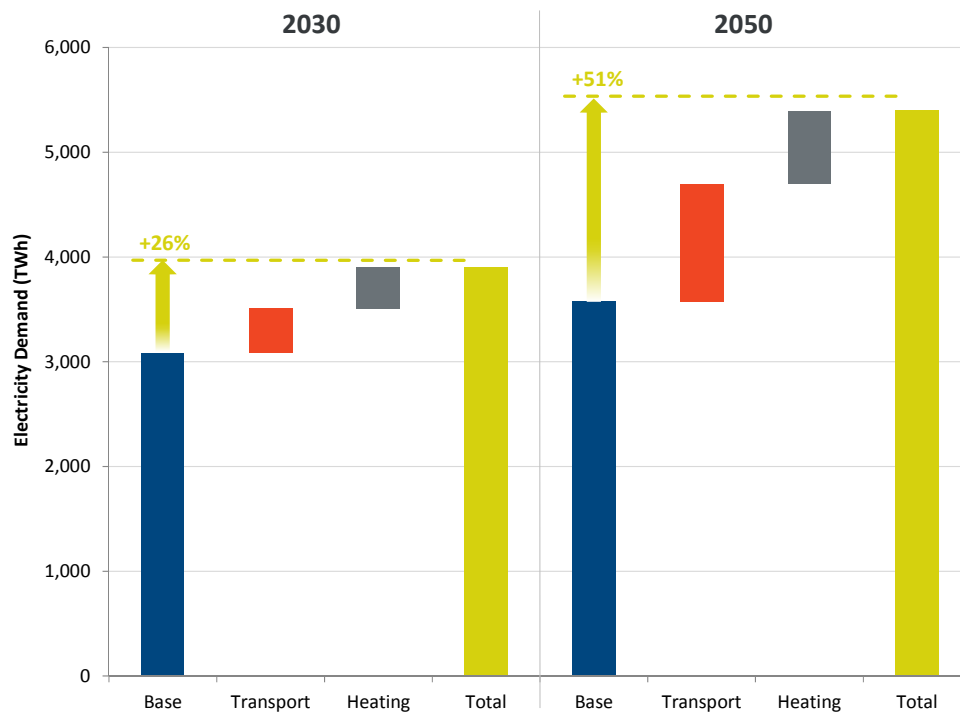
¹³ The analysis of the potential of transportation electrification in Europe is made somewhat more complicated by the absence of consistent data collection at the level of “vehicle kilometers” (vkm) traveled. Rather, in the EU data is reported as person km or ton km for passengers and freight, respectively. We used typical passenger and freight loads to convert data in vkm measures. Our assumptions of the efficiency of electric transport are based on typical electricity consumption per km traveled by vehicle class. By assuming a fixed ratio for each vehicle class, we are assuming that the efficiency of each vehicle type improves at essentially the same rate. We have not assumed a significant growth in fuel cell vehicles (FCV) that require more electricity to operate per kilometer than BEVs, but provide other benefits (including an extended range and fast fueling) that may result in significant penetrations in a full electrified scenario. We have also not included additional travel demand that may result from new models of personal transport, such as shared vehicles and shared rides.

¹⁴ We assume the heat pump coefficient of performance (“COP”) starts at 2.45 and steadily increases to 4.40 in 2050 for space heating, primarily based on a study from the U.S. Department of Energy. For water

in emissions from the burning of fossil fuels, partially offset by power sector carbon emissions, but the latter decline over time as the electric grid is decarbonized as per our assumptions.

With these assumptions, full electrification of land-based transport (light-duty, commercial, and freight vehicles) in 2050 would increase total electricity demand by about 1,100 TWh, or 40% of 2015 electricity sales if BEVs were to become the exclusive mode of transportation.¹⁵ The same calculation applied to heating suggests an increase of electricity demand in 2050 of about 700 TWh, or 25% of 2015 electricity sales. Figure 4 shows how full electrification could lead to an increase of about 1,800 TWh of new electricity demand by 2050 relative to the non-electrification BAU.

Figure 4: Incremental Electricity Sales due to Electrification of Heating and Transport



heating, we assume the COP begins at 1 and grows to 1.5 in 2050. The COP is greater than 1 because heat pumps act on a refrigeration cycle that is able to transfer more energy for heating or cooling purposes than is consumed to circulate the refrigerant.

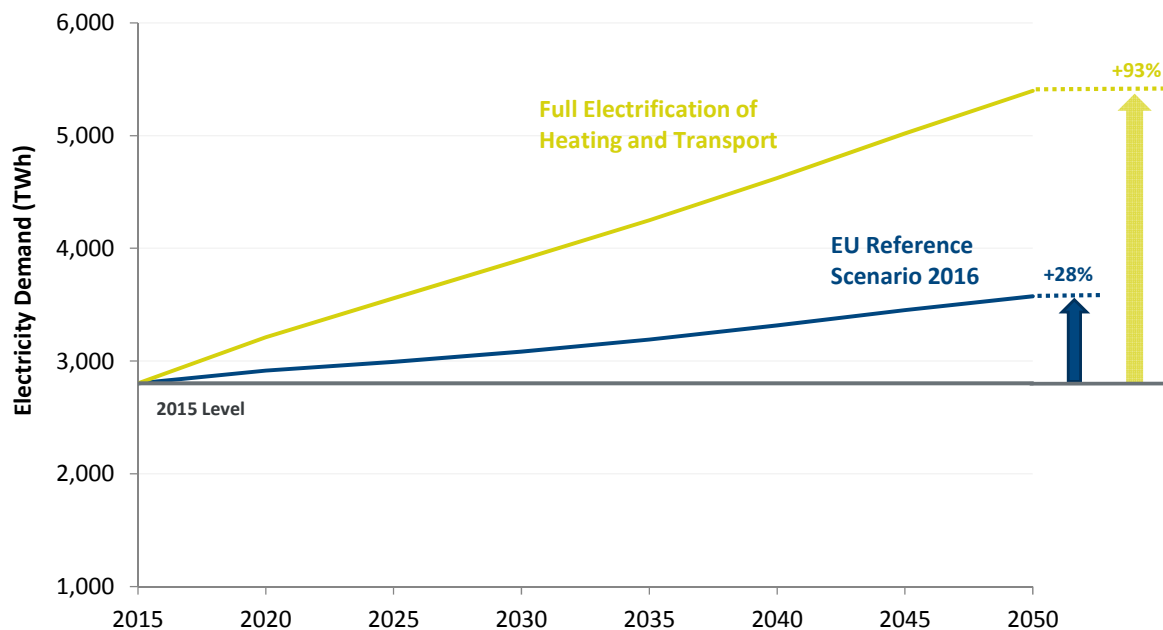
¹⁵

We did not examine the potential decarbonization other modes of transportation (including air travel, rail, buses, or shipping). An alternative decarbonization approach is the use of hydrogen fuel cells, which are potentially applicable to some of these other transportation modes. Several car manufacturers are embracing this approach over the BEV alternative. Projections for electricity demand under this approach are three to four times higher. For example, see Bossel, Does a Hydrogen Economy Make Sense?, Proceedings of the IEEE, October 2006, Figure 9, which shows that 100 kWh of renewable AC electricity would result in 69 kWh of electricity available to power an EV, but only between 19 and 23 kWh to power a hydrogen fuel cell vehicle.

Source: The Brattle Group analysis. EU Reference Scenario 2016.

To understand how such an increase in total electricity demand might impact utility sales, Figure 5 below contrasts the evolution of electricity sales under the EU's Reference Scenario and a case in which the energy sector is fully electrified by 2050. As can be seen, electricity sales would essentially double by 2050. This contrasts sharply to only a 28% cumulative growth of electricity sales between 2015 and 2050 in the absence of electrification. Assuming this transition takes place gradually through 2050 would result in an increase of electricity demand of approximately 2% per year between 2020 and 2050 compared to 0.7% per year under the EU's Reference Scenario. Even if some portion of this growth would be provided by more rooftop solar and perhaps other distributed resources, this would likely represent a significant increase over the average rate of electricity sales growth in the decade prior to the 2009 recession.

Figure 5: Projected Electricity Sales with Full Electrification

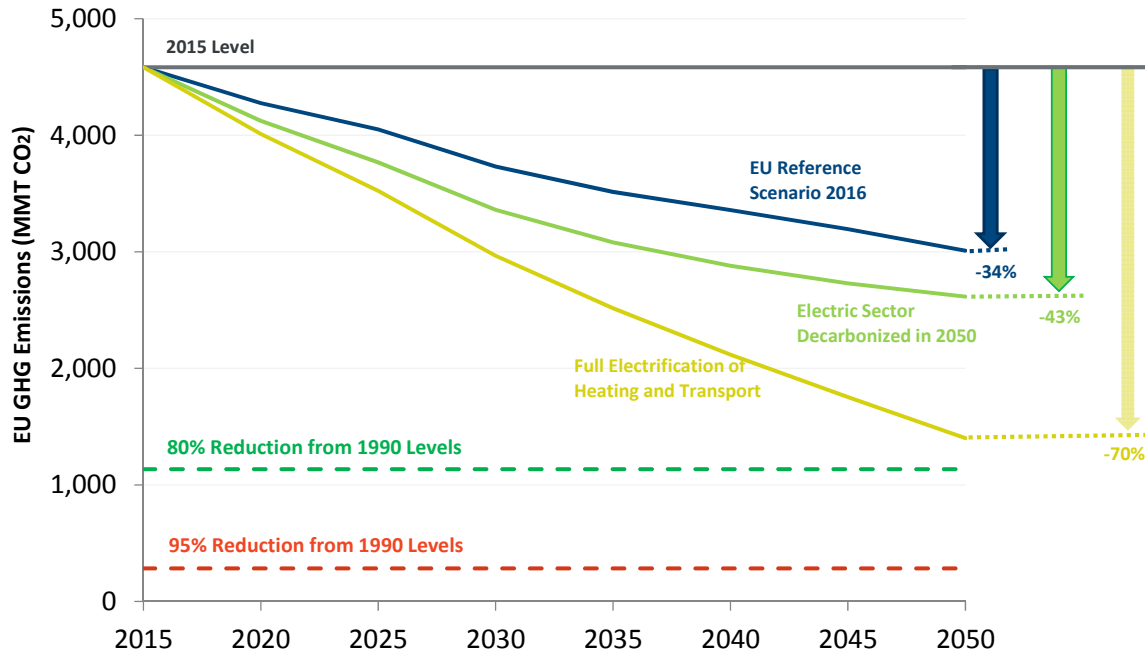


Source: The Brattle Group analysis. EU Reference Scenario 2016.

Figure 6 shows how full electrification of the heating and transport sectors, when coupled with 100% decarbonization of the electric sector by 2050, would reduce economy-wide GHG emissions by 70% relative to 2015 levels. This significantly narrows the gap to the 80%-95% decarbonization goal the EU has set for itself by 2050. More manageable reductions in other

sectors not modeled here could therefore allow the EU to meet its 2050 GHG emissions targets in this scenario.

Figure 6: EU GHG Emissions with Full Electrification in 2050



Source: The Brattle Group analysis. EU Reference Scenario 2016.

V. Operational and Institutional Complexities of Transport Electrification

In this section we highlight some of the challenges related to transport electrification. Our modeling above assumes that many of the factors shaping transport demand remain unchanged or are consistent with the EU's reference scenario projections. Both electric sales and GHG emissions ultimately depend on the total number of kilometers (km) driven by vehicles to transport goods and people. But the confluence of electric vehicles, autonomous vehicles (AVs), and shared transport services (even though the US based ride sharing services like Uber and Lyft are not as present in the EU as they are in the US, other concepts such as Car2Go, DriveNow, Autolib, etc. are growing rapidly) could lead to fundamental changes in how transportation will be consumed and thus change the number of total vehicle kilometers travelled (vkm). For example, it has been suggested that autonomous vehicles could lead to long-term increases in

vkm of up to 35%,¹⁶ which, given the size of electricity demand from electric vehicles (EVs), would result in further significant increases in total demand for electricity. However, predictions about the impact of autonomous vehicles are highly uncertain, given the large number of ways in which such vehicles could affect travel demand.¹⁷

The implications of rapidly evolving paradigms around electrified and autonomous transport are also significant for both the infrastructure for vehicle charging and the shape of electricity demand.¹⁸ The standard assumption about EV charging is still driven by a vision of individual car ownership, stable daily driving patterns and a gradual and relatively evenly paced increase in EV ownership. These assumptions lead to a dominance of home and workplace charging using “Level 1” and “Level 2” charging infrastructure.¹⁹ This evolution and resulting charging patterns lead to only modest and somewhat predictable changes to the shape of overall electricity demand. It is further often assumed that efficient pricing of EV charging, for example through time-of-use (TOU) rates, will lead to “benign” charging that produces a smoother electricity load shape with little or no growth in peak capacity needs. As a result, EV charging is often seen as a non-utility business, interconnection costs are relatively modest, and the effect of charging on peak generation capacity is modest or negligible.

However, the rapid emergence of autonomous driving and both car- and ride-sharing could materially alter this assumption of continued conventional individualized transport. The following are important considerations that are typically overlooked in studies of the impacts of transport electrification:

- The evolution of both autonomous driving and ride sharing may outpace the evolution of electric vehicles, as evidenced by the fact that several of the major traditional car manufacturers have recently made significant investments in both areas. With the commercial introduction of fully autonomous cars expected around or even before

¹⁶ See Bierstedt et al., Effects of next-generation vehicles on travel demand and highway capacity, January 2014, p.4

¹⁷ For a discussion of the various factors impacting vkm, see Todd Litman, Autonomous Vehicle Implementation Predictions, Victoria Transport Policy Institute, December 2015

¹⁸ See Faruqui, A. et al., “Smart Pricing, Smart Charging: Can time-of-use rates drive the behavior of electric vehicle owners?” October 2011.

¹⁹ Level 1 refers to slow (5-8 hour) charging with a 230V supply mostly overnight, *i.e.* off peak. Level 2 refers to relatively-quicker (3-4 hour) charging with a 230V supply. Both these levels tend to be easy to install at the household level.

2020,²⁰ even if vkm remained similar to current levels in a transportation world dominated by potentially shared autonomous electric vehicles, charging patterns and the infrastructure to support it could be significantly different.

- Today's individually owned cars have a very low utilization rate and thus sit idle for long periods of time, making low-powered charging over multiple hours possible. Shared autonomous vehicles, on the other hand, could well be used more like taxis, which often drive 250 to 400 kilometers per day,²¹ or close to ten times as much as the average privately owned car.
- While it is likely that travel demand will still be significantly lower during overnight hours, the more kilometers driven per day and the need to be available to pick up a ride likely creates the demand for fast, perhaps even for super-fast intra-day charging.
- The location of charging needed for AVs would change, with less charging "at home" or at the workplace, but rather either in centralized locations – autonomous vehicles could return to centralized charging points between rides – or as part of the public road infrastructure, for example through inductive charging embedded in roads themselves.
- Super-fast charging can currently occur at power levels of 100-150 kW, with significantly faster charging infrastructure already being deployed,²² as compared to Level 1 charging at up to about 2 kW and Level 2 typically charging at approximately 6 to 11 kW. Clearly, charging EVs at power levels 50-100 times higher than Level 1 charging over shorter and perhaps less predictable time intervals could create significant challenges to both electric infrastructure and electric system management, at least locally.

²⁰ See GM Executive Credits Silicon Valley for Accelerating Development of Self-Driving Cars, Wall Street Journal, May 10, 2016 (<http://www.wsj.com/articles/gm-executive-credits-silicon-valley-for-accelerating-development-of-self-driving-cars-1462910491>). See also Die Zukunft nach dem Abgas-Skandal, FOCUS Magazin Nr. 17 (2016), April 2016 (German) (http://www.focus.de/finanzen/news/wirtschaft-und-geld-die-zukunft-nach-dem-abgas-skandal_id_5457885.html), citing senior VW officials, who predict commercially available fully autonomous vehicles by 2019.

²¹ Average daily miles driven by Uber cars and taxis vary significantly. See <http://www.statisticbrain.com/taxi-cab-statistics/> (accessed 4/20/2018) and <https://www.quora.com/What-is-the-average-mileage-an-Uber-black-or-Uber-X-car-drives-in-a-day-in-San-Francisco> (accessed 4/21/2016) for some anecdotal evidence.

²² In the fall of 2017, several German carmakers formed Ionity, an entity committed to deploying 400 fast chargers with speed of up to 350kW across 19 European countries (see www.ionity.eu).

- High-power charging likely requires greater involvement of utilities, both because it may require significant upgrades to transmission and distribution infrastructure and controls, and because high-power charging in public spaces could well be considered a “public utility” rather than a private service, with implications for who should own and operate such charging infrastructure. There is some evidence that companies other than electric utilities are willing to make investments in fast charging infrastructure, such as through IONITY, the consortium of German car manufacturers rolling out 350kW fast charging infrastructure in many European countries.²³ Nonetheless it is possible that electric utility investments could complement these efforts to further accelerate EV adoption. Also, highway fast charging infrastructure may require significantly more “make ready” investments by distribution utilities, such as by increasing the capacity of existing distribution networks.

The rapid developments of autonomous driving technology and shared riding services suggest a potential revolution of transport occurring somewhat independent of the utility sales and decarbonization issues, which are the focus of this paper. That is, a transformation of transport seems increasingly likely whether or not the EU (and the world) is committed to achieving the deep economy-wide decarbonization targets, solely based on the other significant potential benefits of a transport system dominated by (shared) autonomous (electric) vehicles, such as vastly reduced accident and fatality rates, significantly expanded access to mobility to currently underserved populations such as the young, elderly or handicapped, significantly reduced space use (for parking and potentially road ways) in urban areas, reduced traffic congestion, improved urban air quality, and lower overall transportation costs.

Even though reports on autonomous vehicles often assume that such vehicles will be electric, this is not necessarily the case. An evolution toward more fleet-based transportation may make it easier to accommodate other fuels as well, such as hydrogen (which is likely also an electric vehicle in the long run unless hydrogen continues to be produced from methane, which in the absence of carbon capture and sequestration is likely incompatible with economy-wide decarbonization), compressed natural gas (CNG) facing similar long-term challenges or various

²³ More car makers including Tesla have expressed an interest in joining Ionity.

forms of biofuels. Some of these fuels will require new infrastructure, which in turn may be less costly if it does not have to be deployed to parallel the existing gas station infrastructure, but rather in a more concentrated fashion to allow fleet-level refueling. Therefore, to realize the full benefits of transport electrification, utilities will likely benefit from playing a pro-active role in identifying possible social and technical systems and transmission processes needed to achieve this development rather than just reacting to the developments of transport.

For example, a greener power supply provides a stronger argument for electrified shared autonomous vehicles, as does the provision of easy and ubiquitous charging. Given the discussion above, it is also possible that utilities can and likely should be an active participant in discussions about supporting infrastructure for a future of shared electric autonomous vehicles, since they may be a natural builder and operator of such infrastructure, and since the spatial distribution and sizing of charging infrastructure will have potentially significant impacts on total investment costs and the costs of reliable electric system operation.

VI. An Essential Role for Utilities through Electrification

Given that electrification of transport and heating implies increases in electricity demand that likely surpass any realistic expectation about the contribution from distributed energy sources, it would create a central and ongoing role for electric utilities to generate, transmit and distribute significantly more electricity to end users. This role involves the efficient and reliable operation of the power system relying on a mix of centralized and decentralized carbon-free electricity production. Electrification should therefore represent a positive business opportunity for utilities: continued growth of sales from centralized (i.e., non-distributed) generation as well as a crucial and likely significantly enhanced role for electricity network infrastructure and controls.²⁴

Even though beyond the scope of this paper, electrification could also make a fully decarbonized electric system easier to manage, by adding many layers of flexibility – in the form of thermally

²⁴ Even if DG could produce a significant share of the incremental demand, it is still likely that the role of transmission and distribution networks would increase.

storing heat or in the form of charging and discharging millions of batteries in future electric cars.²⁵

However, full or even significant electrification of the transport and heating systems is not a foregone conclusion. Even if deep decarbonization remains an important policy mandate, other options to decarbonize transportation and heating exist. And since electrification would shift significant revenues away from conventional fuels (i.e., gasoline, diesel, and natural gas), it is in the economic interest of those who would lose from such a shift to develop alternatives to electrification.²⁶ On the transportation side, the most obvious strategy is to count on further improvements of the performance of the internal combustion engine in combination with higher percentages of blended biofuels, hoping for the eventual emergence of a non-carbon emitting biofuel substitute for current transportation fuels. Such a path would leverage existing fueling infrastructure and result in less of an impact on the current delivery infrastructure for transportation fuels. Consequently and unsurprisingly, the transportation fuels industry is proposing a gradual decarbonization along those lines.²⁷

Given the significant uncertainties related to the costs and implementation challenges of various decarbonization pathways, there is no obviously superior pathway today from society's perspective and clearly different industries have much to gain or lose and hence are expected to advocate for their respective approaches. This means that the degree and form of electrification will likely depend on facilitative and preparatory actions taken early and along the way, including many actions under the control of the utilities. The options for utilities to catalyze electrification are many and a detailed discussion is beyond the scope of this article. Also, the options available to utilities likely differ significantly by activity. Below we focus on actions that might be taken by the regulated portions of the sector, most often the network portions of the industry, i.e. distribution and transmission system operators (DSOs and TSOs). We recognize

²⁵ Electric water heaters are a particularly attractive source of “flexible load” in the residential sector. See Ryan Hledik, Judy Chang, and Roger Lueken, “The Hidden Battery: Opportunities in Electric Water Heating,” prepared for NRECA, NRDC, and PLMA, January 2016.

²⁶ Incidentally, many utilities supply both electricity and natural gas, making the business case for electrifying gas-consuming services less obviously beneficial for utilities selling both commodities.

²⁷ See for example Roland Berger, *Integrated Fuels and Vehicle Roadmap to 2030+*, April 26, 2016, a study commissioned by a coalition of automotive companies and fuel suppliers that proposes such a largely fuel- and internal combustion engine based decarbonization pathway.

that there is substantial variation in how TSOs and DSOs are regulated and hence the ability to implement some of the suggestions highlighted below may differ country by country.

First, utilities can likely play an important role in facilitating and promoting the deployment of charging infrastructure. In the near term it is likely that “range anxiety” will remain a major barrier to BEV adoption. Ubiquitous and easy access to charging infrastructure will therefore likely be an important precondition for rapid wide-spread adoption of BEVs. Given that charging is generally considered a competitive activity in the EU, it will likely be challenging for regulated utilities (such as DSOs) to own charging infrastructure directly. However, utilities can be active in identifying segments of the charging landscape underserved by third party charging station developers. They could also promote a BOOT (Build, Own, Operate, Transfer) model when the unregulated build-out of critical charging infrastructure seems to be lagging behind what is needed for rapid EV adoption. DSOs could also ensure that they are not bottlenecks in facilitating third-party development of charging infrastructure, with simple application processes, pro-active identification of any network upgrades that are necessary to support in particular fast charging stations, etc. Also, since even the simplest BEV home chargers will be amongst the more electricity-hungry “appliances”, utilities could also play a role in making home charging easier, for example by providing financial incentives or installation and maintenance support. To the extent upgrades to electrical service are needed, utilities could provide financial incentives to help defray costs and encourage capabilities upgraded service.

Second and related, utilities should explore how modified network tariff designs could help remove disincentives for electrification. Some existing network tariff designs may create an economically inefficient disincentive to pursue electric end-uses. These include any tariffs that increase with increasing consumption, such as inclining block rates. Also, there may be a practical need to create a new tariff design for a subset of customers. For instance, price signals may be needed to incentivize charging during periods of surplus renewable energy generation or otherwise low demand. In the U.S. electricity rates for fast charging infrastructure including a demand charge component have emerged as a major issue and how they are addressed may impact the speed and scope of third-party development of fast charging infrastructure. Therefore,

network tariffs for fast charging providers that temporarily do not include demand charge may facilitate the third-party development of fast charging infrastructure.

Third, it will be critical to effectively communicate the benefits and complexities of electrification to regulators and policymakers. Electrification will likely create new challenges for electricity regulators. Actions taken by TSOs and DSOs to facilitate electrification would increase electricity use when regulatory incentives are traditionally focused on reducing electricity use, primarily through energy efficiency measures. As a result, existing regulatory mechanisms may make it difficult to increase investment in electrification-enhancing infrastructure even though many of the investments needed to facilitate electrification may be beneficial to customers and society even if they increase network tariffs or customer electric bills. Specifically, customers' *overall* energy bills might decline as a result, and society would benefit from lower greenhouse gas emissions.²⁸ In addition, widespread adoption of AEV fleets could have urban traffic, safety, and modernization benefits that are very attractive and valuable, but would be positive externalities in any utility-centric assessment and hence not naturally a part of a standard benefit-cost framework at the regulatory or political level. Thus, coordinated planning between urban managers and large industrial transport fleet owners may also be helpful.

For these reasons, DSOs and TSOs interested in facilitating electrification likely need to engage regulators and policy makers with the goal of broadening the tools used to assess investments and programs to foster electrification.²⁹ In the same spirit, a number of actions DSOs and TSOs can take to facilitate electrification may be considered “pilot projects” even if relatively large in scale, or could be larger than what can easily be justified based on current demand.

Fourth, utilities could be proactive in enabling (and incentivizing) the provision of new services that can be provided from behind-the-meter electric devices. For example, grid-

²⁸ In general it is possible that decarbonization will be costly relative to business-as-usual. In that sense, customer bills may need to go up, even without considering shifting energy use in transport and heating towards electricity. But it could be that electrification is cost-effective relative to other decarbonization approaches.

²⁹ For valuable discussion of policies that unintentionally discourage beneficial electrification, see Keith Dennis, “Environmentally Beneficial Electrification: Electricity as the End-use Option,” *The Electricity Journal*, November 2015. See also Keith Dennis, Ken Colburn, and Jim Lazar, “Environmentally Beneficial Electrification: The Dawn of Emissions Efficiency,” *The Electricity Journal*, 2016.

enabled water heaters can be controlled to increase or decrease load in real-time to provide balancing services. These balancing services could become increasingly valuable in markets with large adoption of intermittent sources of renewable generation. Electric vehicles could potentially provide similar services when plugged into the grid.

There are many options for promoting the use of electric end-uses in this way.³⁰ Customers could be provided with participation incentive payments, akin to conventional demand response (DR) programs. They could be exposed to more time-sensitive retail price signals and adopt automating technologies that allow them to respond to those price signals. Or they could participate through a third party aggregator, who would sign up customers and provide these services to the utility or grid operator. In any of these scenarios, customers benefit financially from adopting an electric end-use that displaces other fuels and utilizing it in a way that is beneficial to the power system. To demonstrate that the programs would provide meaningful benefits, it may be desirable to first offer them on a pilot basis.

Finally, utilities can reduce important information and experience barriers. It is well understood that the absence of information and/or experience with EVs are a major barrier to EV adoption. The same is likely even more true with heat pumps. On the transportation side, there is evidence that attitudes towards EVs improve significantly with information and experience. Utilities can play a key role in reducing these information and experience barriers. Among the measures utilities can take are making the installation of a home charger administratively easy, providing useful information (online and in hard copy) about the use of EVs and potentially creating opportunities for customers to experience EVs, such as through events that allow customers to drive an EV for some period of time. Given the potential move to autonomous and shared vehicle fleets, it is also likely that working with fleet operators to facilitate early electrification of those fleets could have the double benefit of a) early carbon reductions by making rides on shared vehicles electric early – such as is the case with Autolib in Paris, and b) exposing more customers to the use of an EV via the use of a shared vehicle or shared ride.

³⁰ Ryan Hledik and Jim Lazar, “Distribution Pricing with Distributed Energy Resources,” prepared for Lawrence Berkeley National Laboratory’s Future Electric Utility Regulation series, May 2016. <https://emp.lbl.gov/future-electric-utility-regulation-series>

VII. Conclusions

In this paper we provided a counter-narrative to the paradigm of a declining role for electric utilities in an EU that fails to reach mid-century economy-wide GHG emissions reduction goals. This counter-narrative involves electrification of transportation and buildings, mostly water and space heating, in combination with the decarbonization of electricity. While this paradigm does not fully meet the 80-95% decarbonization goals for the EU by 2050, it comes significantly closer than a paradigm that does not electrify both of those sectors. Evidence shows that efforts to reduce transportation emissions with more efficient engines and biofuels have so far not led to meaningful reductions in EU transportation sector GHG emissions. Similarly, given the vast stock of existing buildings in the EU, it seems at least doubtful that emissions in the building sector can be reduced enough with deep energy efficiency retrofits alone. And while further research into “renewable” versions of current fossil fuels – be it gas or liquids – should be conducted, it is at least doubtful that they can be produced in quantities sufficient to decarbonize heating (or transportation) without making use of electricity in their production, i.e. the use of P2G or P2L,³¹ both of which would further increase the demand for electricity relative to the potential for electricity sales growth we have estimated.

Electrification of transport and heating places the electricity sector at the center of the future energy system. Both getting to such a system and operating in it will require proactive engagement with numerous stakeholders, including customers, regulators and policy makers. We have outlined some options for the utility industry to nudge, facilitate and accommodate such a transition. It seems entirely possible that absent active engagement by the utility industry decarbonization will take other and potentially less efficient paths and/or will not proceed at the speed required under existing decarbonization obligations such as the Paris Climate Accord.

³¹ Power to Gas (p2G) and Power to Liquids (P2L).