RADIANT
ENERGY GROUP

Electric Vehicles & Carbon Intensity in Europe

November 2021

CONTENTS

INTRODUCTION

The IPCC has advised that, in order to keep carbon emissions from rising more than 1.5 degrees celsius above pre-industrial levels, the international community must achieve a 45 percent reduction in emissions from 2010 levels by 2030, and net zero emissions by 2050. The European Union, to meet this task, has set a target of 55 percent emissions reduction from 2010 levels by 2030.

Much of the early progress in decarbonization has come from reducing the use of fossil fuels in the production of electricity. However, as the electricity sector is only one way energy is sent to final consumers, major sectors such as residential and commercial heating, and transportation have been neglected until recently.

By taking currently off-grid energy uses, like heating and private automobile transportation, and putting them on the grid, progress on electricity decarbonization is hoped to be shared with those other sectors.

The transportation sector made up 23 percent of EU emissions in 2019, and within EU member-nations, this ranged from as low as 14 percent in Bulgaria to as high as 32 percent in Sweden. The electrification of passenger vehicles is thus seen as a major step towards carbon emissions

Not all European countries have the same amount of clean electricity, however. Further, the availability of clean electricity can vary widely depending on the time of day or season. As wind and solar electricity typically has absolute priority on today’s grid, with low levels of curtailment, essentially all increases in electricity consumption going to new electric vehicles comes from spare dispatchable power. In many European countries, this power will be from fossil fuels with emissions levels much higher than current average carbon emission levels. Hence, the amount of near-term carbon savings achieved by electrifying transport varies strikingly across Europe.

METHODOLOGY

The data is derived from the Transparency Platform of the European Network of Transmission System Operators for Electricity (ENTSO-E). Carbon intensity of electricity, or CO2 emissions per kilowatt-hour, was calculated using a volume-weighted sum of emissions intensity and hourly generation, for the period spanning January 1, 2021 through October 15, 2021. Emissions intensity by fuel used in these calculations can be found below.

For new registered electric vehicles, CO2-intensity is calculated assuming an electric vehicle with an efficiency of 15 kilowatt-hours/100 kilometers travelled. For new registered gasoline-powered vehicles, CO2-intensity is derived from the European Environmental Agency database for CO2 emissions of new passenger cars registered in 2020[1], as measured on the New European Driving Cycle (NEDC).

It should be noted that the European Union is in the process of phasing in a new emissions testing process for vehicles, the Worldwide Harmonised Light Vehicle Test Procedure (WLTP). The WLTP incorporates a wider range of road conditions and speed profiles said to more realistically reflect the average driving experience. For the average petroleum and diesel vehicle registered in 2021, the WLTP procedure reports values for CO2 emissions that are 18 percent higher than NEDC. Using the higher emissions factors of WLTP would show further improvements in E.V. carbon efficiency; our findings should be considered a lower-bound for the vehicle carbon tradeoff.

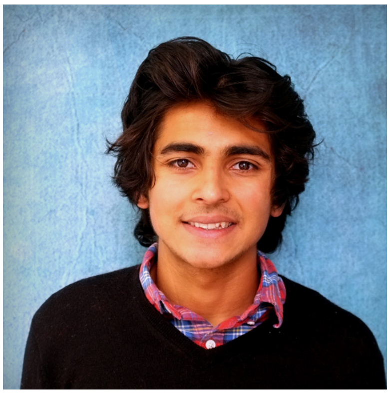
Emissions Intensities

The carbon intensity of generation depends on factors like weather, heat content of fuel, and thermal efficiency, which vary across power plants and countries. The standardized values used in these paper's calculations are approximated using the average power plant thermal efficiency of various EU member states, and fuel carbon content from "Default Emission Factors for the Member States of the European Union", from the European Commission.

Fuel Type	**CO2 Intensity** (KG per kWh)
Biomass	0.250
Gas	0.400
Lignite	1.050
Coal-Derived Gas	0.900
Hard Coal	0.900
Oil/Shale	0.700
Peat	1.050
Other Fossil	0.750

[1] *A value of 12.1 gCO2/km was assumed for countries which did not report to this database.*

AUTHORS



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KEY LEARNINGS AND INSIGHTS

1 *The carbon intensity of a country's electricity may affect its short-run incentive to encourage electric vehicle adoption.*

The average gasoline-powered passenger vehicle sold in the EU today would emit 12 kilograms of CO_2 per 100 kilometers, or around 40 kilograms of CO_2 to match a 330 kilometer range of a 50KW electric vehicle. For the vast majority of Europeans in the market for a new car, electric vehicles are the more eco-friendly purchase.

This is especially true for residents of countries which generate the majority of their electricity from hydroelectricity and nuclear power (Figure 1). Between January 1 and October 15, 2021, nuclear and hydroelectricity made up 40 percent of European electricity generation, but in nine countries, they make up a majority of electricity generation. This cohort of countries contains a population of 159 million people, around 28 percent of the total population within our group of countries. The average carbon intensity of charging in these countries is 0.84 $kgCO_2/100km$, a 93% carbon savings from petrol-powered vehicles. Within this category are Switzerland, Norway, and France, which have the three cleanest electricity grids in all of Europe. Indeed, western and northern European countries with abundant hydroelectricity and nuclear power have historically been the most successful at phasing out coal and lessening dependence on natural gas.

This category also includes Eastern European countries like Ukraine and Slovenia, which face a continued reliance on gas and coal, in spite of the availability of large amounts of low-carbon, baseload power. The challenge of electricity decarbonization for these countries is less in the form of construction of new capacity, as in many Western European countries, and more in the reorientation of the grid to prioritize existing low carbon resources. Possible mechanisms for decarbonization in these countries are financial, like the introduction of a merit order favoring clean energy, technological, like the equipping of steam-turbine gas generators to serve as dispatchable reserves, and political, like the imposition of clean energy standards on electricity providers. Clean baseload may afford countries the capability to decarbonize, but decarbonization-oriented policy must follow.

Countries with at least 50% Generation from Nuclear and Hydroelectric Power

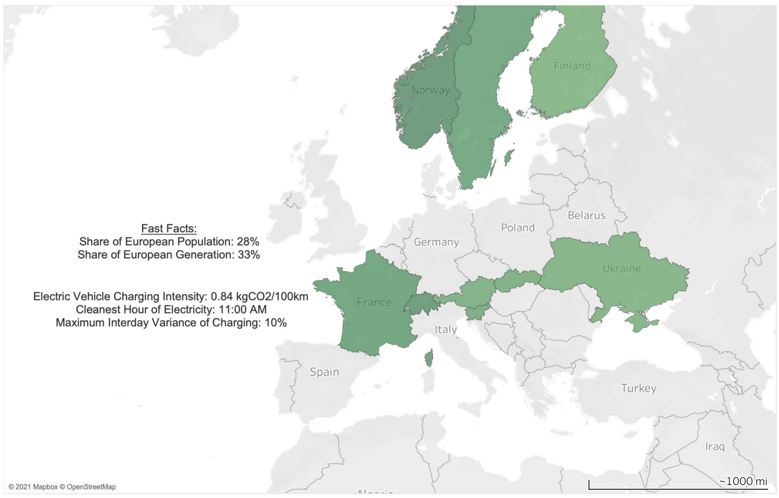


Figure 1

In the second category of Western European countries, which have seen the beginnings of an energy transition towards renewable electricity, but still rely on a mix of fossil fuels or hydro/nuclear for back-up power, the carbon calculus still favors electric vehicles, although more modestly so. Between January 1 and October 15, 2021, solar, wind, geothermal, and biomass made up 20 percent of European electricity generation, but in eight countries within our analysis, they matched or exceeded 30 percent of generation (Figure 2). This cohort represents 166 million Europeans, or 30 percent of the population of our sample of countries.

Countries with at least 30% Generation from Renewable Electricity

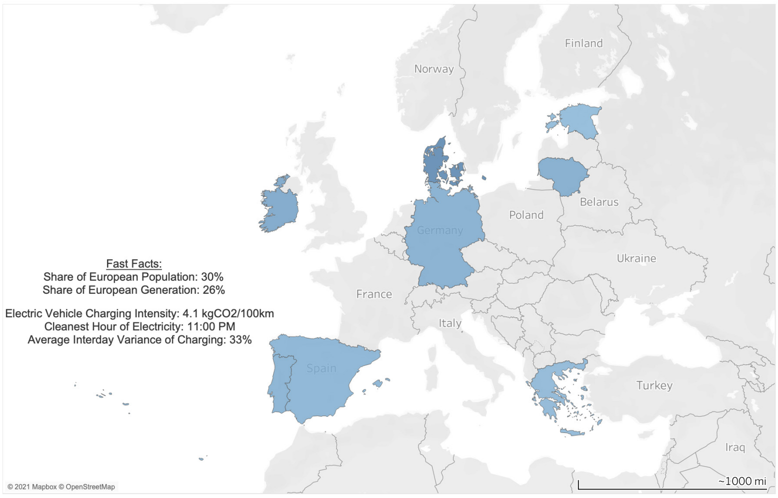


Figure 2

The average carbon intensity of charging in these countries is 4.1 kgCO2/100km, a 65% carbon savings from petrol powered vehicles. Between the countries within this renewable-heavy cohort, the amount of carbon savings depends not on the sheer amount of renewables, but instead on the content of the fossil fuel backup for these renewables. ([See Table](#)) For example, Ireland and Spain both generated 45 and 35 percent of their electricity from renewables, respectively. Spain, however, generated an additional 23 percent of its electricity from nuclear, and 15 percent from hydroelectricity, whereas Ireland gets about 13 percent of its electricity from oil, 9 percent of its electricity from coal, and 3 percent of its electricity from peat.The most extreme contrast within this group is between Estonia, which backs up its roughly 30% share of wind/solar with coal and oil, and Spain, which backs up a similar share of wind/solar with hydroelectricity, nuclear, and gas; charging an electric vehicle with Estonian electricity is on average 4.5 times more carbon-intensive than doing so with Spanish electricity. (Figure 3)

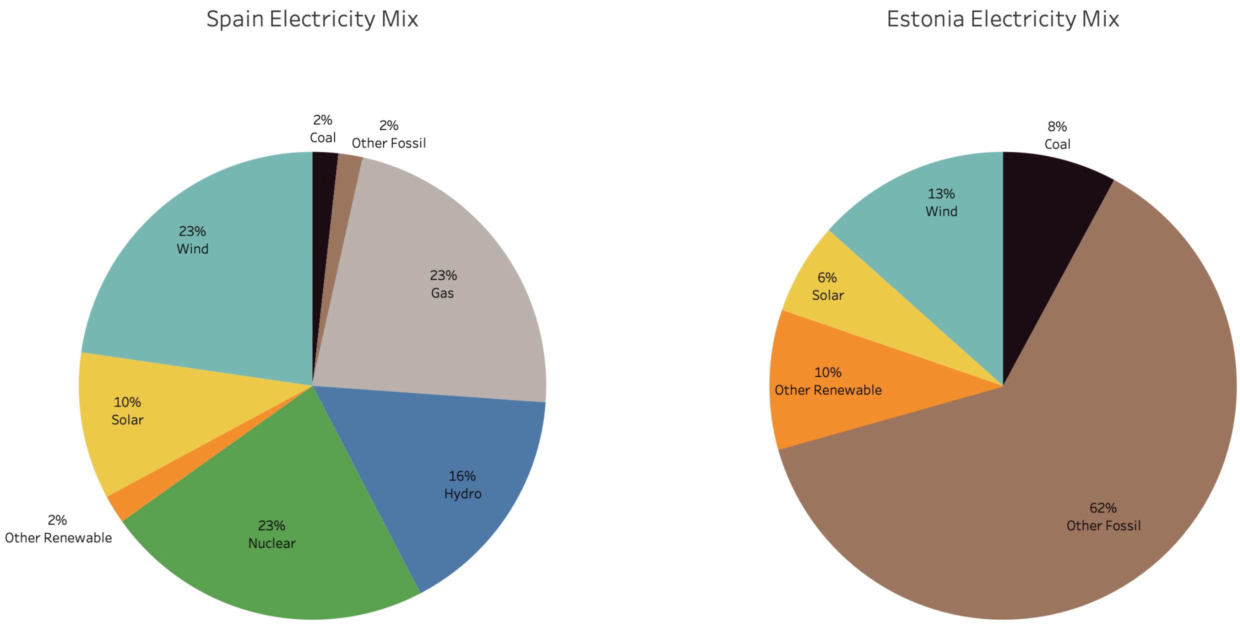
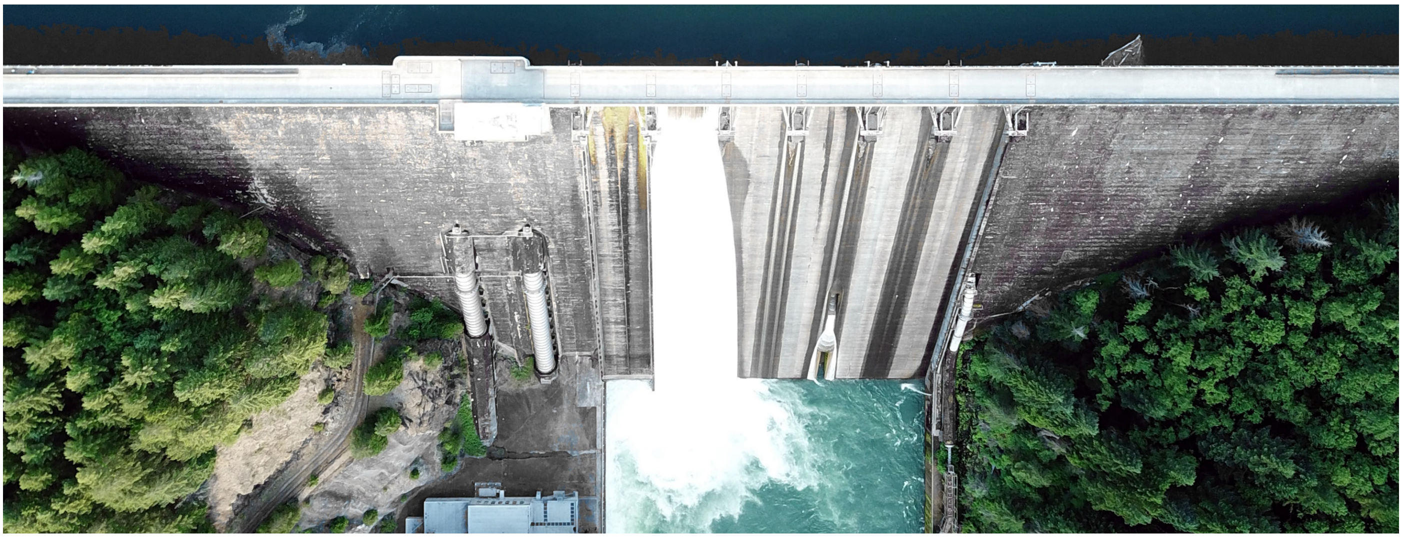


Figure 3



In the last decade, the favorable economics of natural gas and renewables allowed much of North America and Europe to phase out power-plants operated with relatively dirtier fossil fuels (see methodology). Some countries have been slower to make the transition. Power-stations operated by peat, oil, coal-gas, shale, lignite, hard coal, and unspecified fossil fuels made up 19 percent of European electricity generation, but in nine countries within our analysis, they exceeded 30 percent of electricity generation. (Figure 4) This cohort represents about 85 million Europeans, or 15 percent of the population of our sample of countries. The average carbon intensity of charging in these countries is 8.7 kgCO2/100km, a 65% carbon savings from petrol-powered vehicles.

Countries with at least 30% Generation from Coal, Oil, and other Fossil-Fired Power

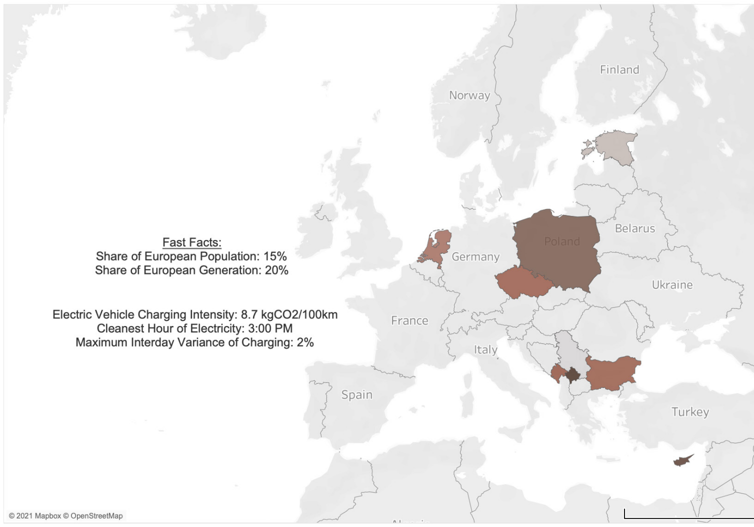


Figure 4

The challenges to decarbonization in this cohort of countries are varied. Bulgaria, Czechia, and Serbia all derive at least 30 percent of their electricity from hydroelectric and nuclear power. Czechia, the Netherlands, and Estonia each derive at least 10 percent of their electricity from renewables. Meanwhile, in Poland and Kosovo, lignite-fired power stations make up almost all electricity generation; in these countries, an electric vehicle is more carbon-intensive than a new petrol car. Several of these fossil-heavy countries have announced plans to phase out coal, shale, and oil in the 2030s; even Poland has recently [pledged](#) to complete the daunting transition from its only indigenous fuel source by 2049. `

Percent Reduction in CO2 from Electric Vehicle Purchase

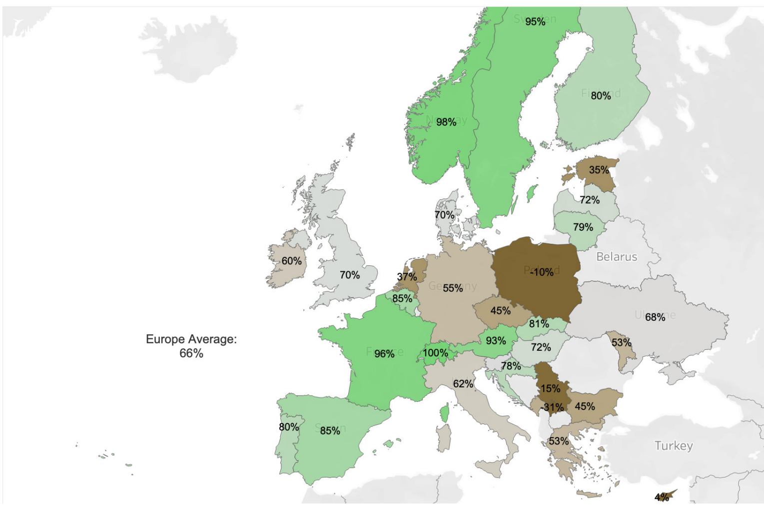


Figure 5

On average, throughout Europe the choice to purchase an electric vehicle represents a CO2 savings of 66 percent. (Figure 5)

KEY LEARNINGS AND INSIGHTS

2 *The carbon intensity of EV charging varies by time-of-day, by over 30 percent in some countries.*

For the average European, electricity is least carbon-intensive in afternoon hours and most carbon-intensive in night hours (Figure 6). Across Europe, the difference in carbon-intensity between these hours is 10 percent (Figure 7).

In the majority hydroelectric and nuclear cohort, an eight-hour charging cycle is on average cleanest at 11:00, when CO2 emitted per 100km is 0.79 kilograms, and dirtiest at 23:00, when CO2 emitted per 100km is 0.87 kilograms, a disparity of 10 percent..

In the renewable-heavy cohort of countries, an eight-hour charging cycle is on average cleanest at 23:00, when CO2 emitted per 100km is 3.4 kilograms, and dirtiest at 15:00, when CO2 emitted per 100km is 4.6 kilograms, a disparity of 33 percent.

In the dirty-fossil cohort of countries, an eight-hour charging cycle is on average cleanest at 15:00, when CO2 emitted per 100km is 8.6 kilograms and dirtiest at 12:00, when CO2 emitted per 100km is 8.7 kilograms, a disparity of 2 percent.

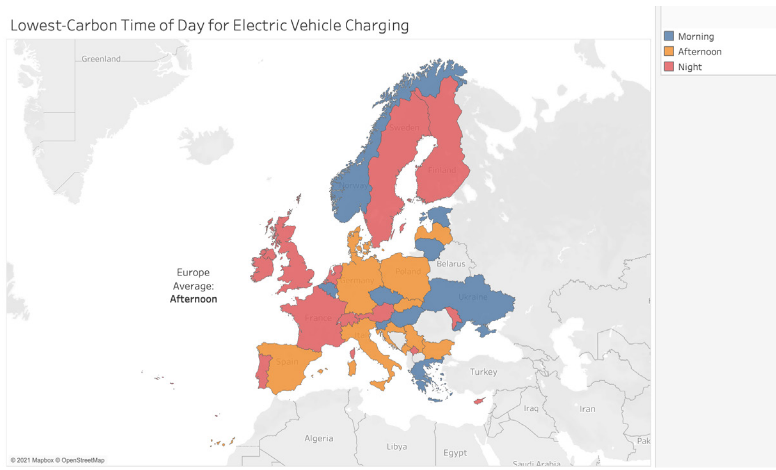


Figure 6

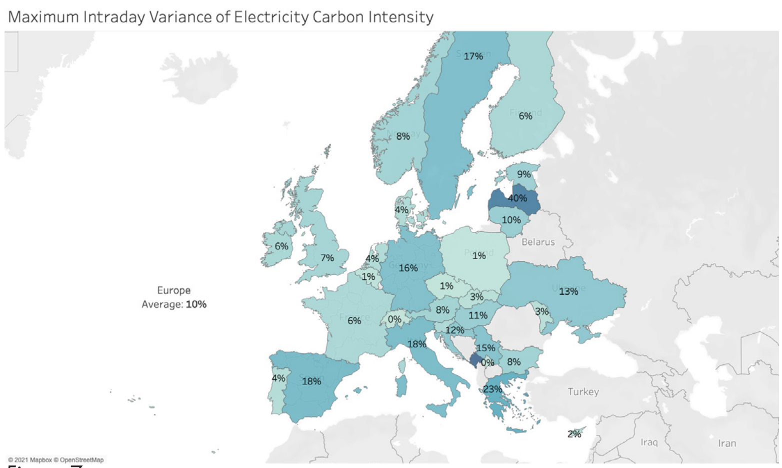


Figure 7

3 *Marginal fuel type is a better indicator of carbon savings*

As recently as 15 years ago, the carbon calculus for purchasing a new vehicle almost always favored electric cars. Between 2006 and 2016, due to EU regulation and industry innovation, the carbon intensity of new gasoline-powered passenger vehicles fell by about 25 percent. Today, tail-pipe emissions per kilometer of a new gasoline-powered passenger vehicle are about twice as high as that of an EV powered by natural gas-derived electricity, but between 16 and 35 percent lower than those of a coal-powered EV.

Thus Far, we've treated a country's average electricity mix to be the same as the mix of new electricity induced by new electric vehicles. This may be true in the short-term, while electric vehicles remain a relatively small share of total electricity demand. Yet, as growth continues, countries will have to procure new power plants to meet this new electricity demand. As a rule of thumb, electric vehicles demand about three and a half terawatt hours per year (the electrical output of 1000 wind turbines, one coal-fired station, or one-third of a nuclear reactor) per 1 million vehicles[2]. In international commitments and domestic policies, almost all EU countries currently project that the majority of their new electricity capacity build will come from zero-carbon sources of electricity. However, these zero-carbon projections sometimes belie a reality of reversion to fossil-fuels in times of political or climate-induced energy crises. Drought-stricken California, for instance, included fossil fuels in its 11.5 GW clean electricity procurement in response to a severe hydroelectricity drought, and in response to energy-shortages caused by their phaseout of 12.1 GW of nuclear power, Germany has connected 9.2 GW of coal capacity and 4.2 GW of natural gas capacity since 2011. Germany has been unable to push forward its 2038 target to phase out coal, setting it apart as a laggard among European states; in fact, Germany has brought online new coal capacity as recently as 2020, the same year that Sweden and neighbouring Austria completed their phaseouts. If coal also replaces the significant nuclear retirements planned for December 2021 and December 2022, serious questions should be raised about feasibility of the country's electric vehicle targets.

[2] Based on vehicle-kilometers-travelled per passenger vehicle among EU-28 countries of 23,000 km in 2018, calculated with data from Odyssey-Mure and EU. Assumes a nuclear reactor of nameplate capacity 1300 MW with 93% capacity factor, coal power-station of nameplate capacity 600 MW with 67% capacity factor, and wind turbines of nameplate capacity 3 MW with 40% capacity factor.

KEY LEARNINGS AND INSIGHTS

4

Regardless of the extent of short-term and marginal power-related carbon emissions, electrification is almost always good.

Even in countries like Poland and Kosovo, where short-run electricity emissions exceed those of gas powered vehicles, building EV infrastructure is the right long-term move. Electricity has the capability of decarbonizing transportation in a way that internal-combustion engines never will. But the variability of electric vehicle emissions across time-of-day and country illustrates that the details of vehicle electrification are of great importance. Clean firm energy sources are important if current public preferences of night-time charging are to continue. Grid stability and electricity rates will also be important to an EV purchasing public. This is not the time for nuclear retirements in countries which have yet to procure replacement power. If the retirements expected in Germany in 2021 and 2022 go through, the loss of firm low-carbon power, most helpful in securing nighttime and winter EV charging, and worsening charging conditions for their new EVs, such as time of day restrictions or ballooning costs, could completely undo the climate benefits of electrification, and turn the public away from EVs at a critical moment for their future adoption. In short, countries must adopt credible and achievable electricity decarbonization strategies if the electric vehicle transition is to be a success.

CONCLUSION

Although European countries have long treated the transportation and electricity sectors as separate domains with separate policies, with the rise of electric vehicles they are merging. Thus, decisions that may have been acceptably costly when considering only electricity supply, like closing clean, firm power plants of unpopular types, could become unacceptably damaging to climate ambitions when combined with rising, all-year loads from electric vehicles.

When power plants are being closed or being planned, it is now important to check not only what the effect will be on the grid load of today, but also the marginal effect on electric vehicles being purchased today and tomorrow.

Our work suggests that on-demand power, which either comes from hydro-electric dams, fossil fuels, or nuclear, will rise in importance as electric vehicle loads increase, especially outside of daytime business and commuting hours. The change in the carbon pollution levels of this power for electric vehicles must therefore continue to be quantified to determine whether Europe is on the right track for its climate goals.