Electrification decarbonization efficiency in Europe – a case study for the industry sector

M.Sc. Andrej Guminski[1]
M.Sc. Tobias Hübner[1]
Dr.-Ing. Christoph Pellinger[2]
Dr.-Ing. Serafin von Roon[1]
[1]Forschungsgesellschaft für Energiewirtschaft mbH, +49 89 158121-0
[2]Forschungsstelle für Energiewirtschaft e.V., +49 89 158121-0

Overview

In a variety of German energy system studies, the substitution of fossil fuels through electricity on the energy demand-side (electrification) has been displayed as a key deep decarbonization measure (cf. /RUH-01 18/). Also possible system interdependencies have been analyzed on a national level /GUM-01 18/. Such national analyses however do not consider possible changes in the energy system composition that could occur due to decarbonization through electrification in neighbouring countries. Neglecting these developments could lead to false conclusions about the resulting system effects in a European context, especially if extreme electrification rates are assumed. In order to assess the effects of a simultaneous increase in electricity demand in several European countries, an overview of the costs and potentials of electrification in these countries is required. Another key factor is the position of possible additional electrical loads in relation to the renewable energy sources wind and solar power as well as the grid. In this context especially large industrial loads are relevant. It is the aim of this paper to provide an overview of the electrification costs and potentials for Germany and its neighbouring countries. Furthermore, a consistent and regionalized European electrification scenario is determined for the industry sector in NUTS-3 resoution.

Methods

The implemented methodology combines two approaches. First, the energy demand of European neighbouring countries is analyzed and structured according to energy carriers, end-use sectors and applications. This step is performed based on a variety of energy statistics such as /ECE-01 17/, /ISI-02 16/ and /ECDGE-01 16/. The national Energy end-use balances are the starting point for the derivation of electrification costs and potentials in each sector. Based on the methodology laid out in /FFE-20 17/ technical electrification potentials and the costs for realizing these potentials are calculated for each country and sector and subsequently visualized in several national merit-order curves of electrification measures. Ultimately national curves are combined to provide a European merit-order of electrification which is then analyzed with respect to key points on the curve. Hereby the order of electrification measures, the total amount of energy which can be electrified and the totals costs associated with pursuing electrification are most relevant.

The resulting European electrification curve is furthermore interpreted with respect to the displaced or additional emissions resulting from electrification and the metric "electrification decarbonization efficiency" is calculated. The latter shows the decarbonization efficiency of electrification measures by comparing the additional amount of electricity entering the system to the emissions displaced by the measure.

In a second step, the national electrification scenarios for the industry sector are regionalized in NUTS-3 resolution to determine the spatial distribution of industrial loads. Basis for the regionalization of industrial loads are the European emission trading system and the European pollutant transfer registry databases, as well as several additional industry branch specific databases. Electrical loads are distributed according to the NUTS-3 level emissions for process applications covered by the mentioned databases and employee data from /ECE-02 17/.

Results

The results for Germany from /FFE-20 17/ do not indicate a certain sector which is especially attractive for electrification. Within each sector, there are classes which are prone to electrification and others for which electrification incurs higher costs. The high-priced end of the merit-order is dominated by electric vehicles with below average driving distances. The additional electricity demand for end-use appliances in 2050 is 339 TWh in Germany. Avoided costs through electrification total to €0.4 bn and occur solely in the paper industry and for large lead-free vehicles with above average driving distances. In total additional costs of €58 bn accrue for the electrification of 1265 TWh of fossil-fueled energy. The calculated annual additional costs due to electrification exceed the annual spending on the German renewable energy levy of €~24 bn by a factor of three. Pursuing the path towards electrification would consequently require a significant level of government support in Germany /FFE-20 17/.

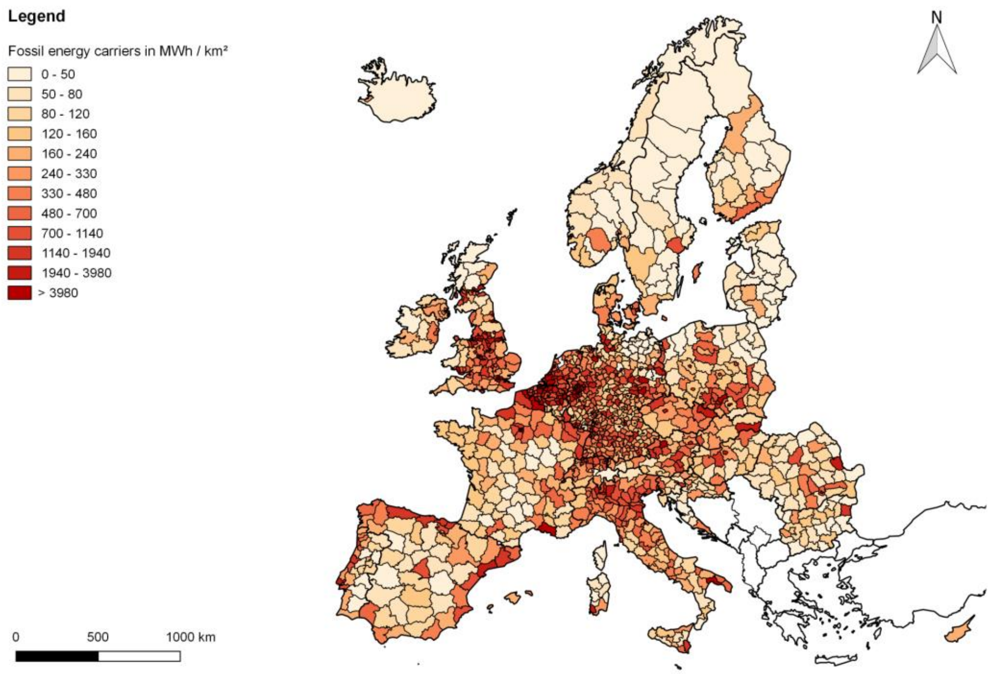

Figure 1: Regionalized theoretical electrification potential in Europe

Figure 1 shows the industrial electrification potentials for Europe in 2014, thereby building the basis for Europe wide electrification cost calculations and the regionalization of the electrification scenarios. The figure shows that high industrial electrification potentials outside of Germany mainly exist in the UK, France, Belgium, Italy and Spain. Depending on the sector and country specifc energy carrier prices, electrification cost results in these countries will differ significantly from the German values.

Conclusions

The preliminiary results show that electrification leads to a significant increase in electricity demand and system cost. Considering a Europe-wide electrification scenario will show how these costs compare to electrification in Germany's neighbouring countries and if there are countries and sectors in which decarbonization through electrification is likely to occur due to a clear cost advantage. The resulting regionalization is the first step towards implementing this scenario in a European energy system analysis.

References

ECDGE-01 16 Fleiter, Tobias et al.: Mapping and analyses of the current and future (2020 - 2030) heating/cooling fuel deployment (fossil/renewables) - Work package 2: Assessment of the technologies. Brussels: European Commission Directorate-General for Energy and Transport, 2016

ECE-01 17 Energy statistics - supply, transformation and consumption: Complete energy balances - annual data - nrg_110a: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=nrg_110a&lang=en; Luxembourg: European Commission - Eurostat, 2017.

ECE-02 17 Eurostat: Structural business statistics (SBS) data by NUTS 2 regions and NACE Rev. 2 - sbs_r_nuts06_r2: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=sbs_r_nuts06_r2&lang=en; Luxembourg: European Commission - Eurostat, 2017.

EEA-01 17 Trends and projections in Sweden 2017 - Tracking progress towards Europe's climate and energy targets. Copenhagen: European Environment Agency (EEA), 2017.

FFE-20 17 Guminski, Andrej; von Roon, Serafin: Transition Towards an "All-electric World" - Developing a Merit-Order of Electrification for the German Energy System in: 10. Internationale Energiewirtschaftstagung an der TU Wien. Wien, Österreich: Technische Universität Wien, 2017

GUM-01 18 Guminski, Andrej et al.: System effects of high demand-side electrification rates: A scenario analysis for Germany in 2030. In: WIREs Energy Environ. e327. New Jersey: Wiley Online Library, 2018.

ISI-02 16 Rohde, Clemens: Erstellung von Anwendungsbilanzen für die Jahre 2013 bis 2015 mit Aktualisierung der Anwendungsbilanzen der Jahre 2009 bis 2012. Karlsruhe: Fraunhofer-Institut für System- und Innovationsforschung (ISI), 2016

RUH-01 18 Ruhnau, Oliver et al.: Direct or indirect electrification? A review of heat generation and road transport decarbonisation scenarios for Germany 2050. In: Energy 166 (2019) 989e999. Philadelphia, USA: Elsevier, 2018.