Transition towards an All-Electric System
A Merit-Order of Electrification

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Introduction

With most of the focus on the energy supply side, decarbonizing the energy demand-side is an often neglected key aspect of the *Energiewende*. A clear path towards an emission free energy demand-side has yet to be defined.
Under the precondition that in 2050, 80% of Germany's electricity will be produced by renewable energy sources, electricity will become an almost emission-free fossil fuel substitute. The electrification of applications such as conventional cars, oil and gas boilers or fossil fueled industrial processes could therefore become a viable path towards the decarbonization of the energy system.

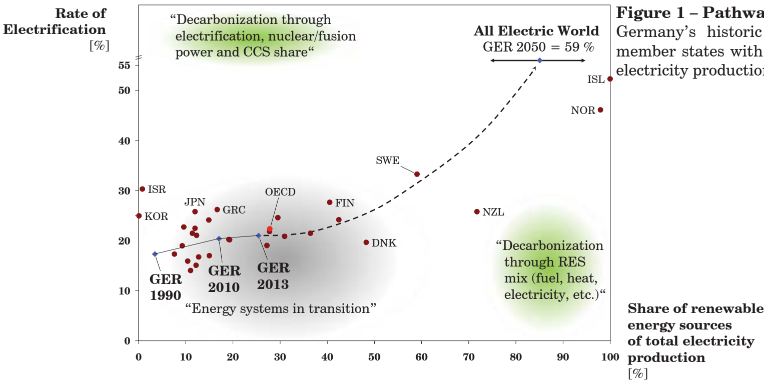

Figure 1 – Pathways towards decarbonization
Germany's historic development and current position of OECD member states with respect to share of renewable energy sources in electricity production and the electrification rate

Key Findings

A 142 TWh of electrification potential at avoided costs of ~1 bn €. This equals ~6 % of 2013 final energy consumption and results in 84 TWh of electrical final energy in 2050

B ~1100 TWh of fossil fueled final energy are displaced until 2050. This results in ~460 TWh of electrical final energy, additional costs of ~45 bn € and avoided costs of ~1 bn €

C Vehicles with below average driving costs have the highest specific electrification costs. Sectors are 'evenly' dispersed, no single sector proves especially suitable for electrification

The merit-order takes on a private investor cost perspective. Negative electrification costs, must not lead to immediate electrification. Other non-monetary costs exist, which can increase the „real" costs.
Benefits of electrification are highest when efficiency advantages of electrical technologies are realized (i.e. when energy consumption is highest)
The order of electrification processes is sensitive to changes in interest rates, energy prices and technology cost.

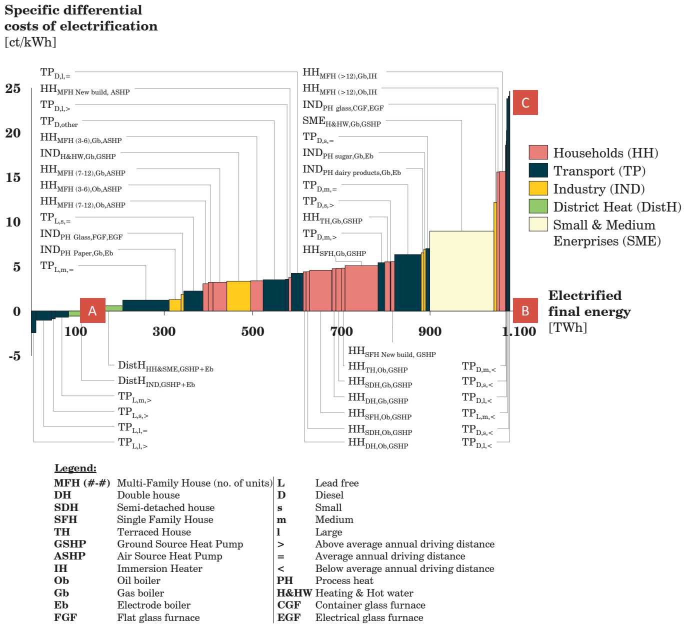

Figure 2 – Merit-order of electrification 2050
Each segment shows the difference in annualized total costs between a conventional reference and an electrical substitute technology, as viewed by the respective investor

Constraints

Tax effects are not considered
→ Taxes such as the vehicle tax lead to increased costs for conventional technologies and thereby trigger an overestimation of electrification cost

Energy prices, technology parameters and interest rates are held constant
→ Understatement of electrical technology cost development, leads to an overestimation of electrification cost

Other effects on final energy consumption (e.g. energy efficiency measures) are neglected
→ Leads to an overestimation of the electrification potential

It is assumed that sufficient charging infrastructure for electric vehicles exists, so that all journeys can be covered
→ Leads to an overestimation of electrification potential

Methodology

$$dc^{a}_{elec} = \frac{\sum_{r=1}^{n}\left(a^{elec}_{OPEX,r} - a^{ref}_{OPEX,r}\right) + \sum_{r=1}^{n}\left(a^{elec}_{CAPEX,r} - a^{ref}_{CAPEX,r}\right)}{FE_{elec}}$$

dc^{a}_{elec} = annualized specific differential costs of electrification
CAPEX = capital expenditure
OPEX = operating expenditure
ref = conventional reference technology
elec = electrical alternative technology
r = relevant cost set
FE_{elec} = electrified final energy

A suitable conventional reference and electrical substitute technology is defined for all analyzed processes. Costs for each electrification process are calculated using the formula above.

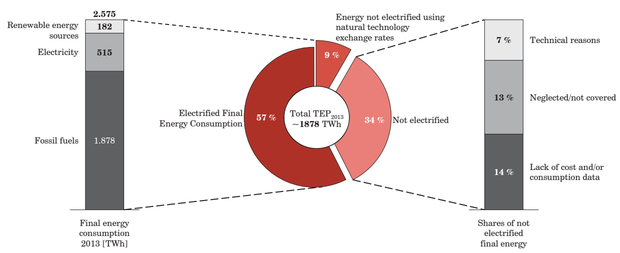

Figure 3 – Analyzed and neglected electrification potential
The theoretical electrification potential (TEP) is the final energy consumption 2013, excluding electricity and renewable energy consumption

Further research

- Expansion of the approach to include impacts of electrification on the energy supply side and network infrastructure
- Inclusion of learning curves and technology price scenarios
- Refinement of building model for household and SME sector
- Detailed industrial and SME process modelling and inclusion of further electrical technologies