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# ENHANCED ELECTRICITY MARKETS TO SUPPORT HIGH LEVELS OF VARIABLE RENEWABLE GENERATION: BRIDGING THE GAP BETWEEN ECONOMICS AND ENGINEERING

Chair of Energy Systems & Energy Economics

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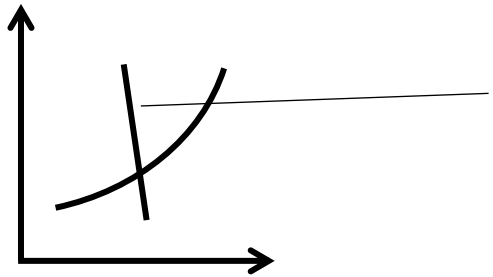
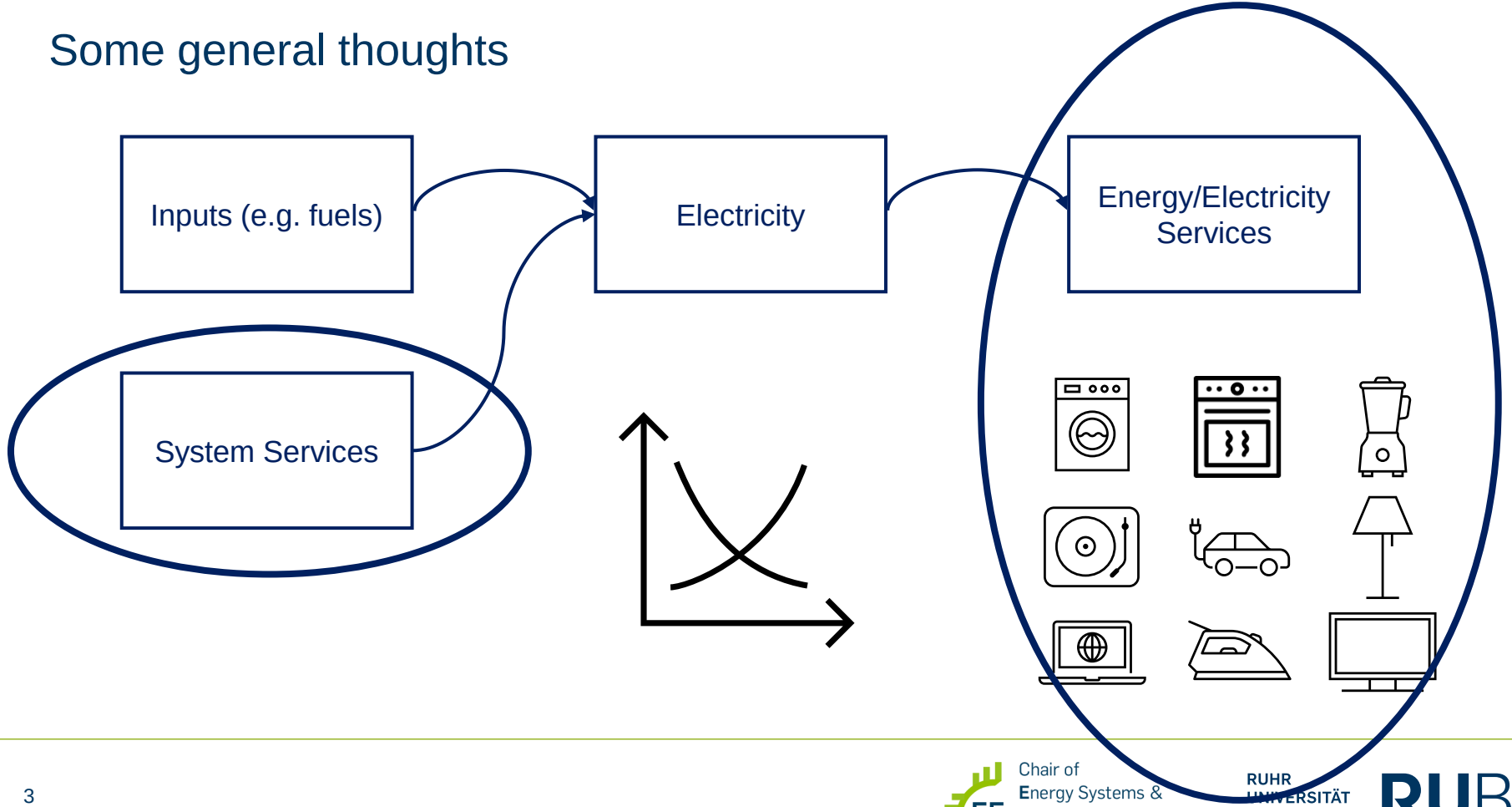
# Markets for electricity generation


Electricity markets designed…
… with a focus on the supply side
… for generation dominated by variable costs



Electricity considered…
… as an essential good
… as hard to substitute
… to have no/low elasticicy

# Some general thoughts



# On the way to 100% RES-E: some observations

- **Consensus: increased requirement for flexible sources of supply and demand**
- **Despite their value for the system, investments in such flexible sources on the supply or demand side (e.g., energy storage) are usually not economically profitable**
- **Typical discussion / "solution": separate revenue streams via dedicated markets or remuneration mechanisms explicitly targeted at procurement of system services**
  - → Practical, *ad hoc* approach
  - → Theoretical basis is weak without establishing in advance that there is indeed a missing market, rather than another potential source of market failure with a corresponding solution
- **Redesign of the EU energy market, prompted by the Ukrainian war and EU energy crisis is instructive: redesign is driven entirely by high electricity prices seen across EU markets, rather than by an examination of underlying fundamentals**
- **More generally, enhancements to market design to date have generally taken the form of "add-ons" to existing market designs**

# On the way to 100% RES-E: some observations (cont'd)

- **Dearth of a comprehensive theoretical framework for electricity market design**
- **Hypothesis: at least in part, this is due to the failure of economists to engage sufficiently with the particular theoretical economic challenges associated with efficient electricity market design with high levels of renewable generation and a failure of engineers and economists to collaborate on such topics**
- **This leaves engineers and system operators without the economic framework and tools needed to develop market mechanisms with sound economic fundamentals**
- **Four areas of importance for integrating energy economics and engineering research more closely:**
  1. Heterogeneity of system services
  2. Categorisation of system services as economic good
  3. Variable, fixed & zero cost provision of electricity and system services
  4. Multiplicity of markets

# 1. Heterogeneity of system services

- **Main purpose of system services: enabling system operators to operate their systems in a secure and stable way**
- **Under normal operating conditions, most services fall into one of two categories:**
  - Frequency control reserves (balancing services)
  - Voltage control reserves (reactive power services)
- **(Technical) characteristics drive type and volume of system services required, e.g.:**
  - size of country → demand
  - underlying power system and penetration of variable renewables
  - both affect system inertia and net demand in system
- **Reality:**
  - Markets and products and how they are procured and compensated for have developed historically over time at national levels leading to a highly heterogeneous landscape
  - Set of products much more diverse than the underlying power systems' characteristics

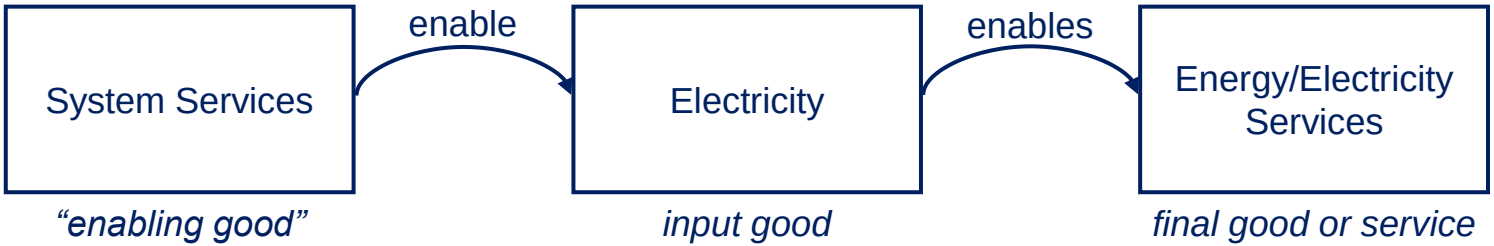
# System services: some “standard” products

| | Frequency containment | Frequency restoration | | Reserve replacement |
|---|---|---|---|---|
| Type/name of reserve product | Frequency Containment Reserve (FCR) | automatic Frequency Restoration Reserve (aFRR) | manual Frequency Restoration Reserve (mFRR) | Replacement Reserve (RR) |
| Control order | Primary | Secondary | Tertiary | Tertiary |
| Type of activation | Automatically | Automatically | Manually or semi-automatically | Manually or semi-automatically |

# Heterogeneity of system services

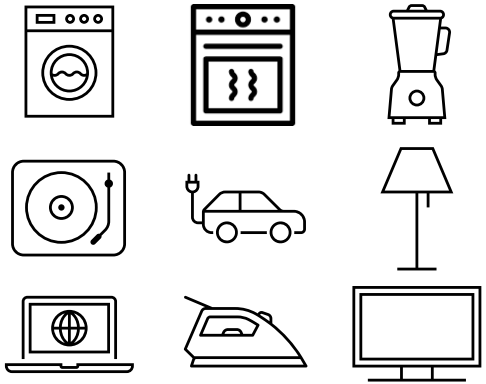
- **Observation: practice is moving faster than research in the area of system service design → ad hoc reactions**
- **Lack of sound academic literature in this space**
- **In contrast, much of the relevant documentation on system services is in the grey literature, (e.g., EirGrid and SONI, 2020; US Federal Energy Regulatory Commission and others, 1996; National Grid, 2017; KEMA, 2011; ENTSO-E et al., 2019; van der Welle et al., 2021).**
- **This lack of academic literature, at least from the perspective of economics, also driven by the national heterogeneity and practice-driven design of system services since it is challenging for economists to publish national-interest studies**

# 2. Categorisation as an economic good

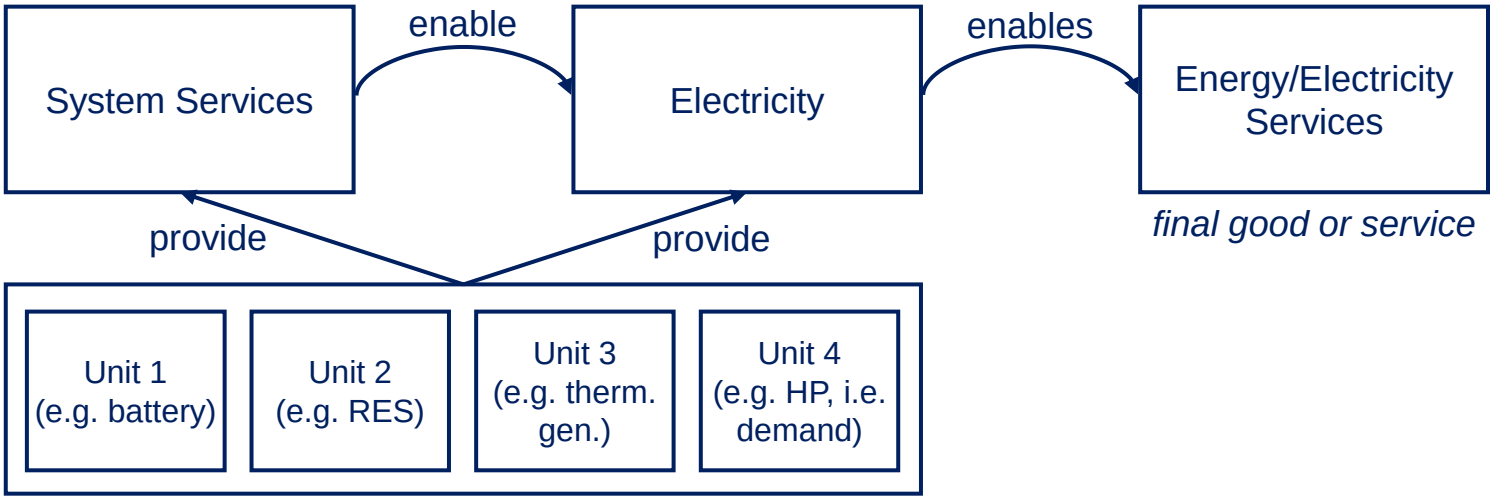



- Input good?
  - Demand depends not only on electrcity demand but on entire supply and demand portfolios
- Complementary good?
  - typically final goods
- Intangible asset?
  - Intangible: yes, but asset?
- Two levels of abstraction away from final energy service

- Electricity: pure input good
- Demand depends 100% on the demand for the final goods or services



# 3. Variable, fixed & zero cost provision of electricity and system services




- Electricity and system services inherently connected: same units provide both goods
- Unit that provides reserve capacity cannot bid this capacity into the electricity market

→Bidding and valuation of system services is typically based on opportunity costs

→Any changes in electricity market – e.g. related to increase in RES – have impacts on value of system services

# 3. Variable, fixed & zero cost provision of electricity and system services

- **Different units with very different (e.g. fixed vs. variable) cost structures compete for providing both electricity and system services → this situation is underresearched**
- **Electricity market:**
  - RES-E shift cost base away from variable towards fixed costs
  - Economic theory: marginal cost pricing will cover fixed and variable costs in an efficient manner, with possible market failures corrected by e.g. capacity markets
  - However, one can argue that, for electricity markets, fixed costs are best compensated via fixed revenues while variable costs should receive variable compensation
    - Same expected outcome as inframarginal rents in risk-neutral framework
    - Risk-averse agents: fixed compensation reduces risk, risk premia, and consumer costs
  - Analogy: consumer tariffs in the telecomms industry have moved from variable to fixed to become more cost-reflective
  - This may prove optimal for the energy sector, too, with a significant impact not only on electricity pricing but also on opportunity costs

# 3. Variable, fixed & zero cost provision of electricity and system services

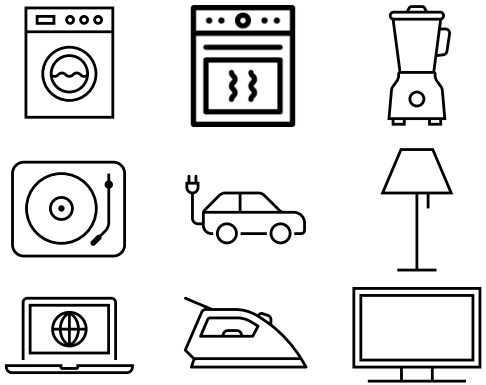
- **Different units with very different (e.g. fixed vs. variable) cost structures compete for providing both electricity and system services → this situation is underresearched**
- **System services:**
  - Some products cannot only be provided for a fixed or variable cost, but also at no cost by some players: e.g. large synchronous generators can provide reactive power and voltage support in tandem with the provision of electricity, with no change to either their fixed or variable costs
  - Such services can also be provided by synchronous condensers, with no variable cost but with a requirement for capital investment which cannot be recouped via energy or capacity markets (as synchronous condensers provide neither electricity nor capacity)
  - Variable speed wind turbines, in turn, can offer a short-term controlled response to system imbalances, which can provide an emulated inertial response; this response, however, entails an opportunity cost

# 4. Multiplicity of markets

- **Power system resources that can provide multiple goods can earn revenues through multiple markets, e.g. capacity market, day ahead market, intraday market, system services markets**
- **Integrated modelling approaches required for adequate assessment of profitability of system services providers**
- **Several papers consider multiple sources of revenue; however, they are often based on historical price time series from the corresponding markets, ignoring the strategic decisions of market participants and an active demand side, which both impact on equilibrium prices**
- **Fundamental challenge for designing an appropriate set of revenue streams**
- **Development of such models requires expertise of the engineering profession (to determine types and quantities of services needed), while economic modelling expertise is  required to capture strategic decisions made by profit-maximising agents**

# Energy retail markets and tariffs

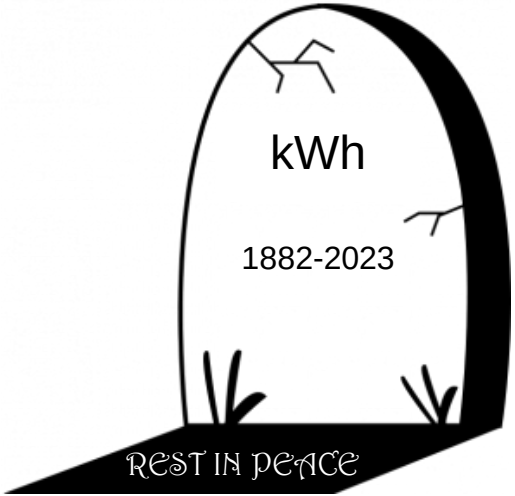

- **Lack of understanding of the demand side**
- **Retail tariffs typically include procurement costs from wholesale market plus a number of volumetric charges cumulating in a fixed ct./kWh tariff**
- **Creates incentives for self-consumption**
  - → System/grid cost recovery at risk and risk of spiral effects
  - → Distributional implications

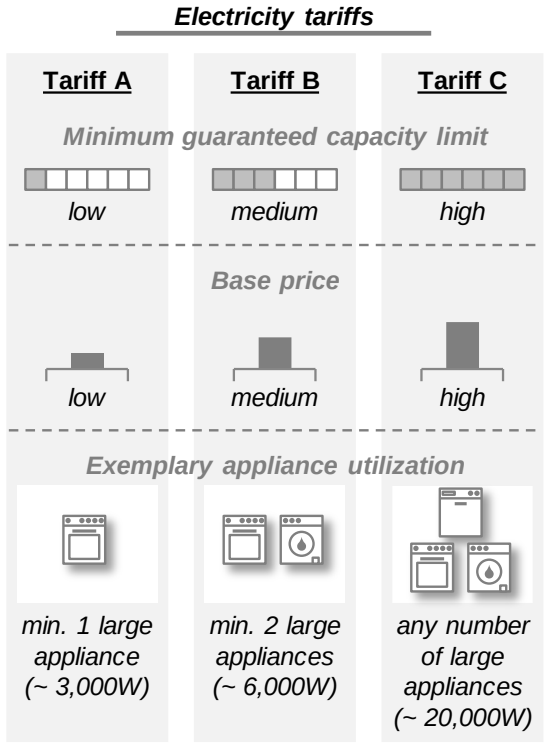




Kalt, G., Wiedenhofer, D., Görg, C., & Haberl, H. (2019). Conceptualizing energy services: A review of energy and well-being along the Energy Service Cascade. *Energy Research & Social Science*, *53*, 47-58.

# From energy delivery towards energy service provision




- **Introduction of a demand charge (can be done revenue-neutral) as well as further adjustments needed to ensure cost-reflectivity of retail tariffs and to allow for the definition of service level indicators and objectives**
- **Implications for electricity markets and system services…**

Source: Own representation based on Ströhle 2014

# Discussion and conclusions

- **Electricity markets require redesign**
- **Focus mostly on wholesale markets / in practice, market design proposals often take the form of “add-ons”**
- **Important to include system services markets and products as well as retail markets and tariffs in analysis and considerations**
  - Understand consumers’ willingness to pay / willingness to accept for electricity / avoiding the curtailment of electricity based on final services (beyond uniform elasticities…)
- **Collaboration between economics and engineering disciplines essential**
- **Educational system needs to be adapted to provide both engineers and economists with the tools and abilities to understand and contribute to this problem in a mutually complementary manner**

# Thank you very much for your attention!

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