Conceptualization of system-level transition(s) – how energy energy transitions unfold?

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Systemic perspective

- Energy transition: systemic change in the composition of primary energy supply, technology, and the way we use them.
  - Fossil fuels and industrial revolution.
  - Electricity.
- Decarbonization – a climate change driven transformation of fossil-fuels based system to low-carbon based system.
- Energy system: A complex network of elements necessary to fulfill societal function of the system - production, transport and use of energy.

The evolution of socio-technological systems

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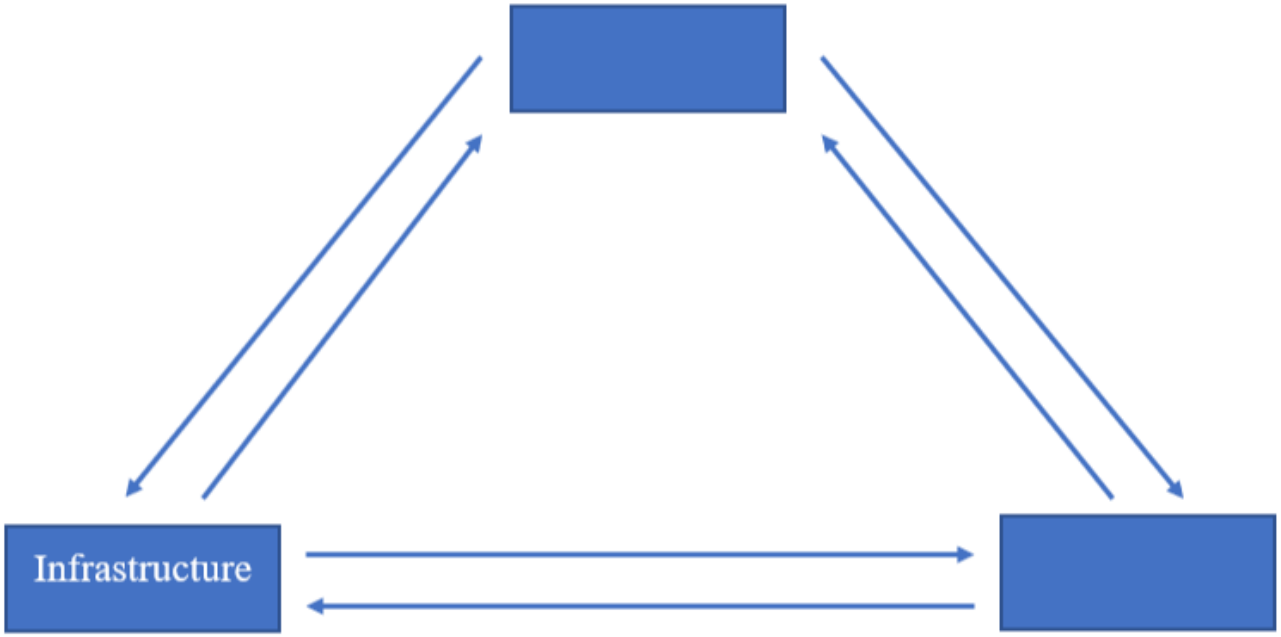
Components of the system



- What defines how different technologies emerge, are improved, and diffused in society? Why some technologies prevail and some diminish?

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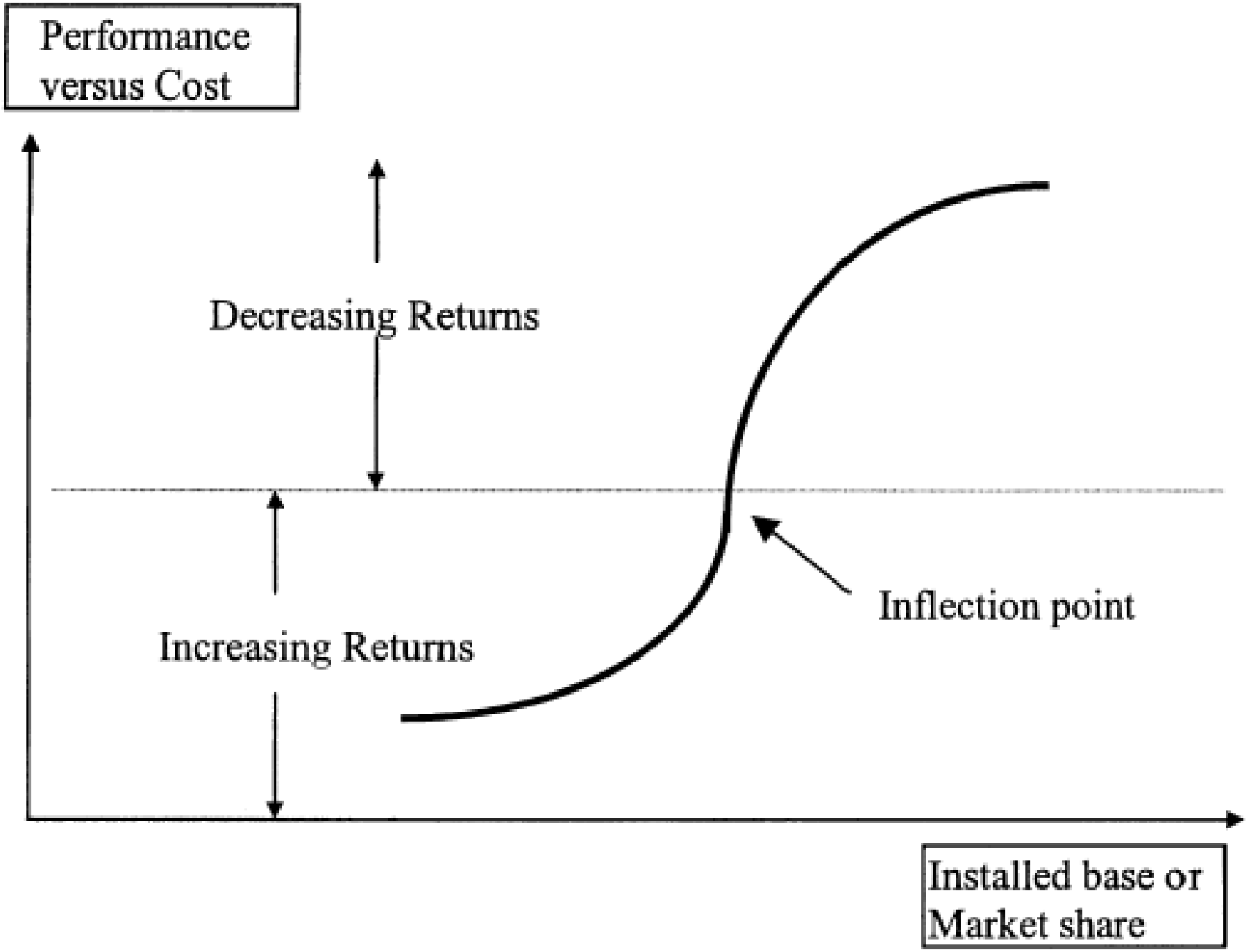
Techno-economic explanation

- Beginning of the 20th century - competition among steam-, electric-, and gas-powered vehicles to substitute horse and carriage. (noxious, noisy, complicated and dangerous vs cheap gasoline as a by-product of kerosene production).
- Then period of increasing returns to scale … locking internal combustion engine (ICE) as the dominant design.
- Other designs reduced – in 1890s, 1900 different firms producing over 3200 different variants of ICE vehicles in USA. By 1955 General Motors, Ford, Chrysler held 90 % of domestic and 80% of the global market.


Performance versus Cost
Decreasing Returns
Increasing Returns
Inflection point
Installed base or Market share

Techno-economic explanation

- Surviving oligopolistic firms shifted their focus from product to processes innovation, development of specialized knowledge = forming the basis of a company´s competitive advantage.
- General Motors divided engine development into 22 subsystems (ignition, fuels systems, lubrication etc.). That had lasting impacts on specialised labor and knowledge development.

= firms tend to focus on existing competencies and away from alternatives that could make their present products obsolete.

= capital investment goes preferentially towards projects that reduce production costs and perfect existing product.

Techno-economic explanation

= Invention and inovation create several technologial variants.

= Period of uncertainty – variants compete for performance improvements and market share.

= One of the variants captures a critical mass of the market and become de facto standard (due to the increasing returns to scale).

Societal factors

(Techno)-economic argumentation would suggest that the optimal technology is selected based on market forces and fully informed, optimizing agents – economically most efficient source (availability, price, convenience).

But this argumentation is incomplete.

There are some other factors (societal, cultural) affecting the people and company´s choices (setting the system).

Different electricity production choices of similar countries

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Different power production choices of similar countries

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Different power production choices of similar countries

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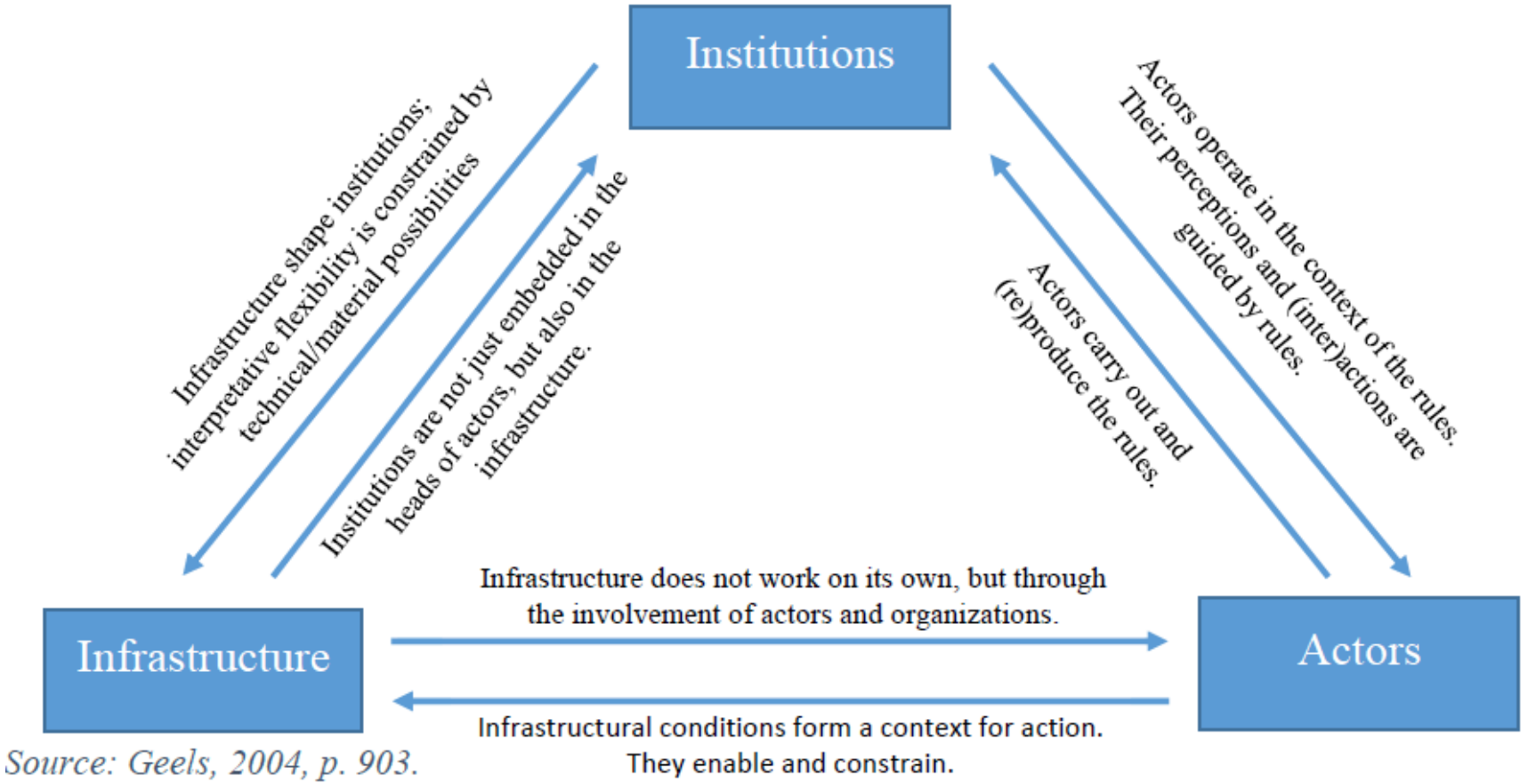
Socio-technical systems



Source: Geels, 2004, p. 903.

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Complexity of the modern systems

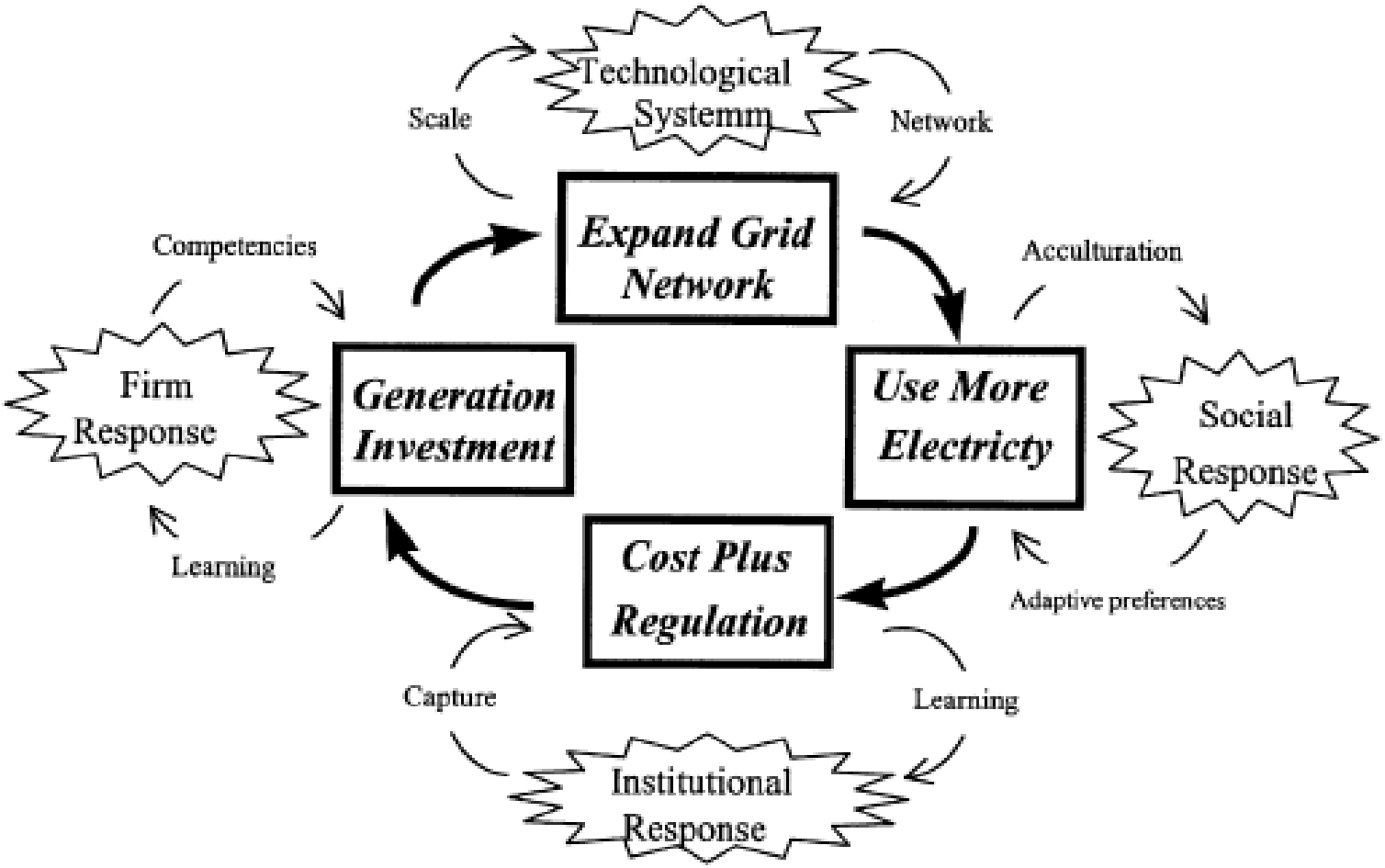
= Systems interact and get interconnected with other systems.

= Network externalities arise from systemic relations among technologies, infrastructures, independent industries, and users.

= Physical and informational networks can become more valuable to users as the grow in size (road network, telephone network).

= increased complexity and inertia of the system(s).

The techno-institutional complex



More on elements of energy systems

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Actors - governments

- Ability of institutional policy to override market forces. Government intervention can remove market uncertainty about the direction of technological development through policy (RES, PV car).
- Political inertia - changes could be very disruptive – risk of unexpected results. Big changes in policy regimes rare. Significant role of ideology.

Actors - Public

Atomausstieg

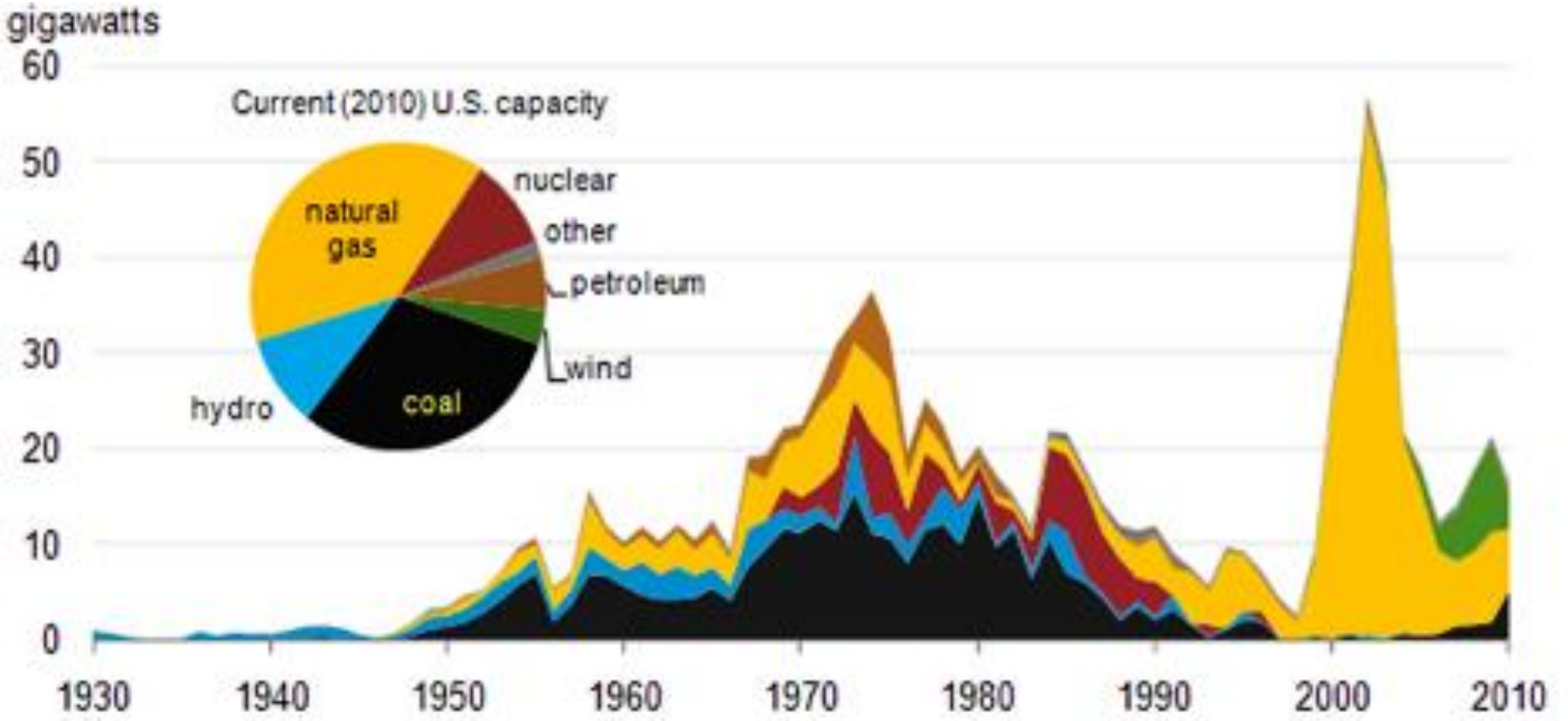
- Long and successfull tradition of nuclear industry in Germany – in 70s 17 000MW.
- German anti-nuclear movement – Ausserparlamentarishe Opposition in 60s (leftist students), environmental movements, local oposition.
- Three Mile Island in 1979, Chernobyl in 1986.
- 1998 Greens in federal govt (with SPD) – Germany´s plan to gradually withdraw from the atom.
- In 2010 the Atomic Energy Act amended – plant lifespan extended, production limits on nuclear electricity increased.
- 2011 Fukushima – phase-out by 2022.

Actors - Companies

- Newcommers, challenging the system, vs. status quo actors, defending it (and their positions within).
- ČEZ and renewables.
  - „The state is supporting it (RES), which means that from the business perspectiv it is a great idea. But people who understand energy know what kind of energy nonsense it is“ – M. Roman, CEO of the company, in 2005.

Infrastructure

Cost of durable capital



Institutions and their role in the system

- Path dependence in institutions.
- Superior technological variant doesn´t allways win out in dominant design frameworks. Inferior designs can become locked-in through a path-dependence proces.
- It is because of once the institutions (formal, such as legal structures, or informal, such as culture, norms and values) are established they tend to persit in their initial form for extended period.
- Some form of systematic barriers to the adoption of new energy systems (technologies).
- Czech emphasis on energy security (= energy autarky).

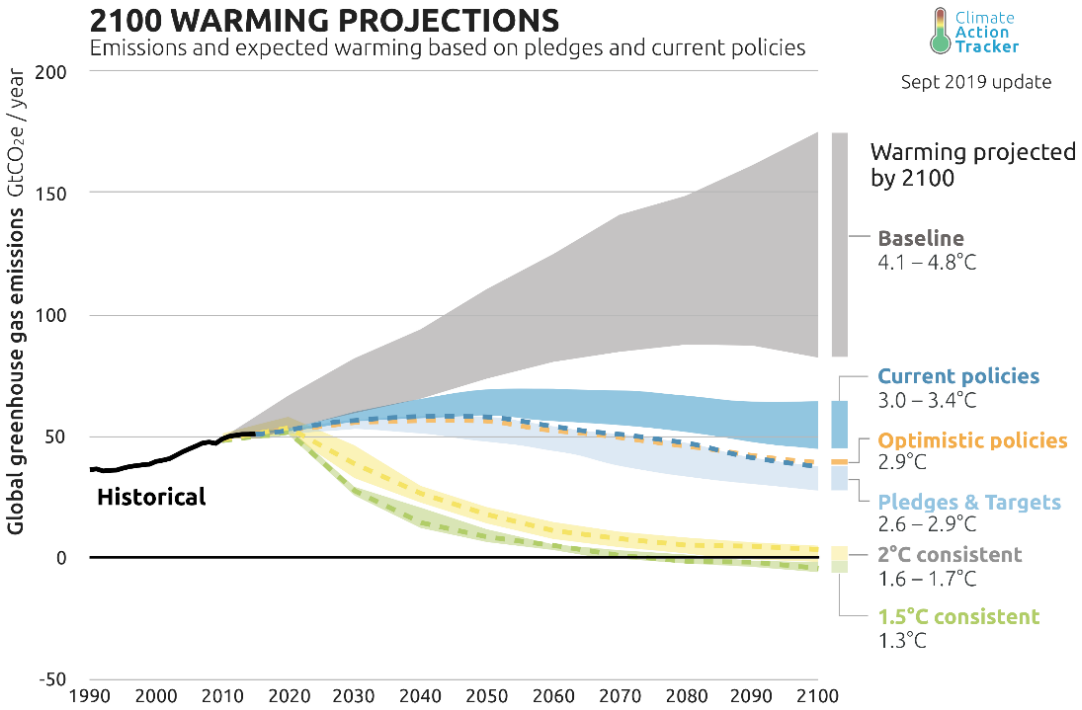
A unique nature of decarbonization?

Technological optimism

- Are we better equipped to deal with upcominig transition?

- Historically, problems with inadequate scientific understanding of the processes, lack of suitable high-performing materials needed for mass production (steel), manufacturing processes inadequate both in quality and quantity, uncomplete infrastructure, lack of large-scale competitive markets.
- Now, however – enormous wealth of information, no shortage of materials, advanced and fast manufacturing processes, highly competitive market delivering efficiency.

Urgency of climate change



- Decarbonization – deliberate and politically driven energy transition.
- Acceleration needed to stay below 2°C of global temperature rise.

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(Eforced) disruptions

- disruption in the system = a radical interference in one or more of the elements of a stabilised socio-technical system.
- Vs. incremental developments.

Dimension	Explanation
Technology	- Novel technology disrupting dominating technology and infrastructure by differentiated qualities. - Requires initial shielding from mainstream selection pressures.
Actors and ownership	- Emergence of new actors in production and supply. - Changing ownership of assets (in terms of kind of actors), with implications on justice and democracy. - Incumbent actors' reduced influence or fight back.

(Eforced) disruptions in the system

Dimension	Explanation
Markets and business models	- New value propositions and ways to capture value. - Reducing market share of incumbent companies. - New entrants and new business models from incumbents (connected to the actor dimension).
Regulation	- Dis-alignments between disruptive innovation and existing regulation, calling for regulatory change. - Regulatory interventions to intentionally disrupt non-sustainable systems.

A mini case-study of Germany

Germany´s Energiewende

- Aim of reducing GHGs by 80-95% by 2050, compared to 1990.
- 2010/2011 – Attomaustieg + Energiewende.
- In 1990, about 5% of RES electricity, in 2018 about 38% (wind 14%+3%, biomass 8%, solar PV 9%, hydro 3%...).
- RES transport and heating lagging behind.

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Technology

- Decentralized, not large scale (offshore wind, larger biomass) RES, challenging existing system + increasing role of distribution grid.

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- Storage

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- Cross-sectoral disruption in merging the electricity and transportation.

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Actors and ownership

- Start-up companies, individual households (PV), farmers, energy cooperatives (Emerging prosumers challenging the traditional roles of producers – customers). In Germany over 1000 energy cooperatives, around 51% of Germany´s RES capacity owned by farmers and citizens.

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- New type of actors in energy (as Google)

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- Cross-sectoral disruption in merging the electricity and transportation.

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Markets and business models

- Conventional sources struggle, low carbon technologies profit from merit-order-effect pricing mechanism. Splitting-up of E.ON, RWE.

- Business models reflecting increasing role of consumers – focus on services, instead of commodity.

- Cross-sectoral disruption in merging the elektricity, transportation, heating.

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Regulation

- Changing role of BNetzA, cooperation between grid operators (due to the re-dispatch)…

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- Gap of missing regulation for the non-dispatchable decentralized sources perceived as obstacle to development (Energy Industry act – EnWG - replacement?)

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- Cross-sectoral disruption in merging the elektricity, transportation, heating.

Political considerations

- Disruptions = rapid changes, with often painful and sensitive impacts on society. Politial management needed to avoid social disturbances?

Sources

- Gawande, A.(2009): Getting there from here.
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- Johnstone, P. et al. (2020): Waves of disruption in clean energy transition: Sociotechnical dimensions of systém disruption in Germany and the United Kingdom.