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

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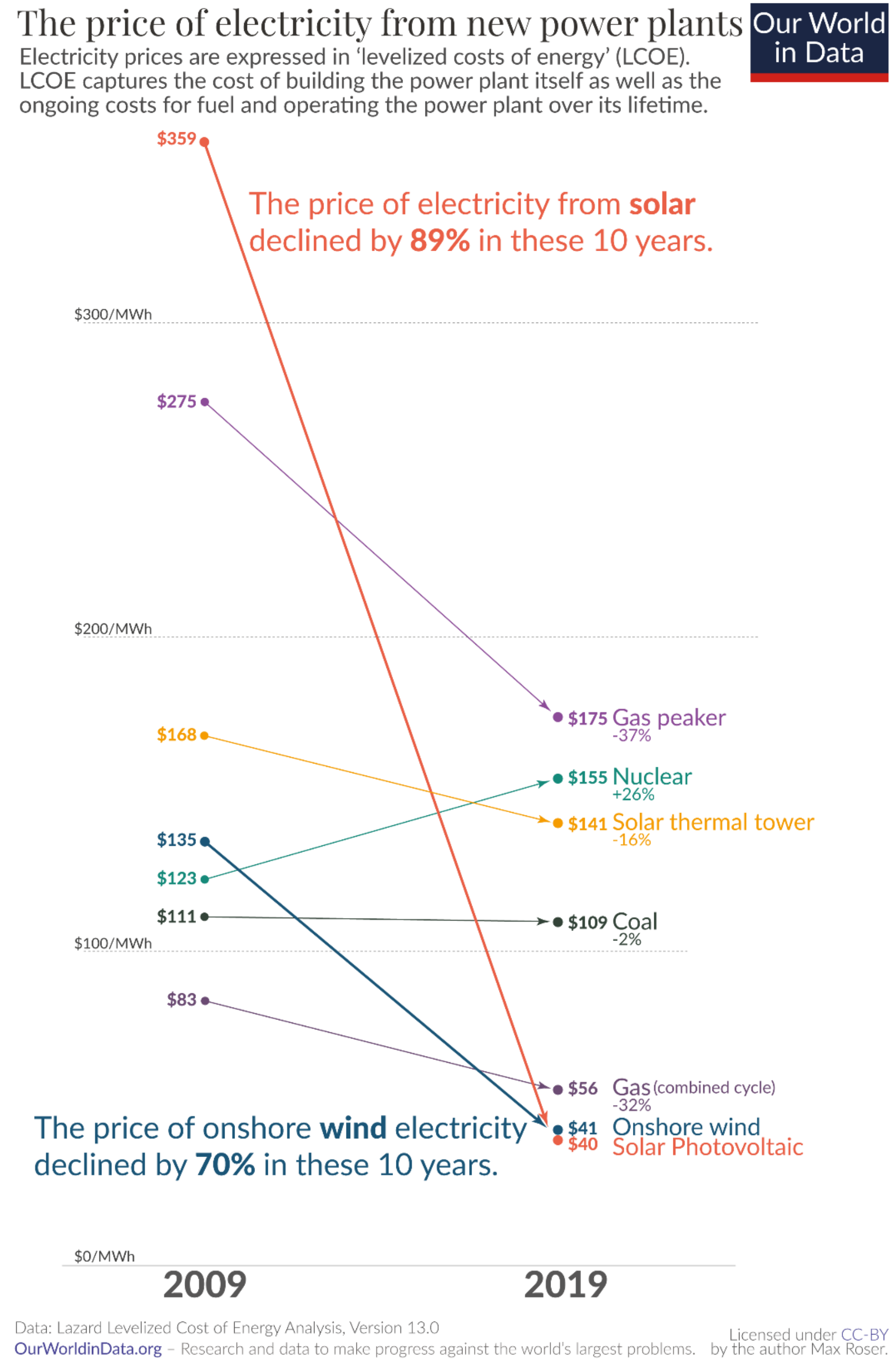
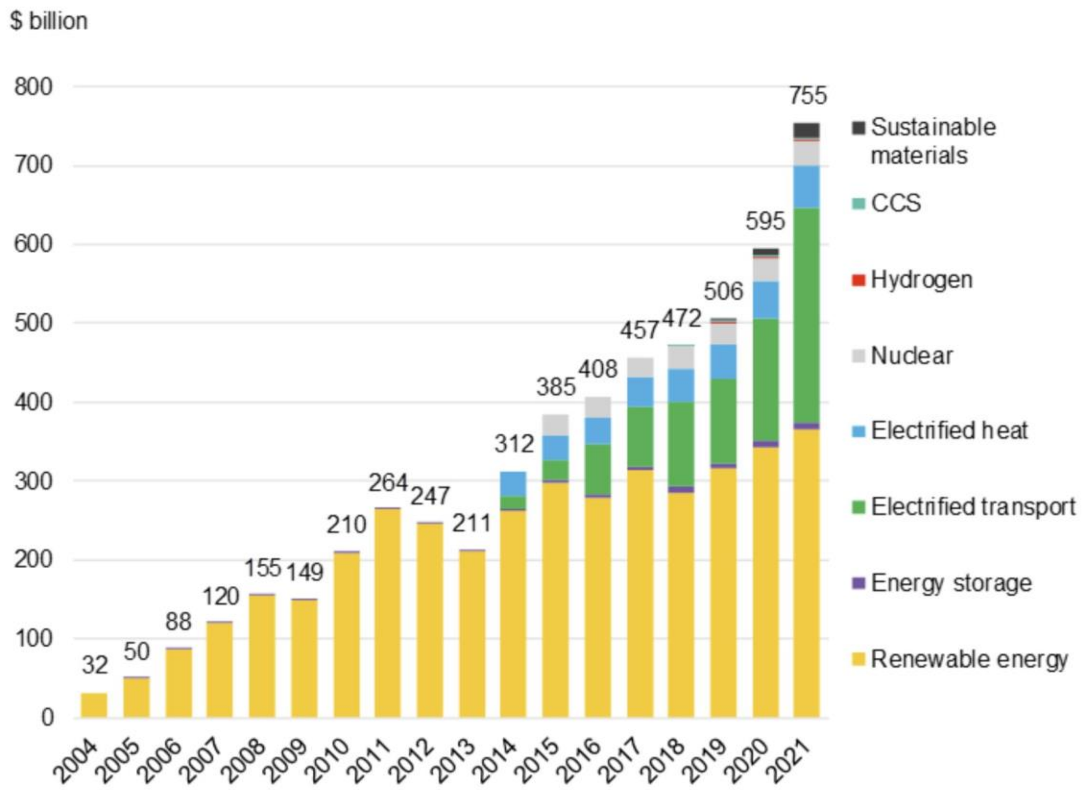
Technology development



RES investments



The flow of money to decarbonization has trippled to 0.75% of GDP in the last decade.

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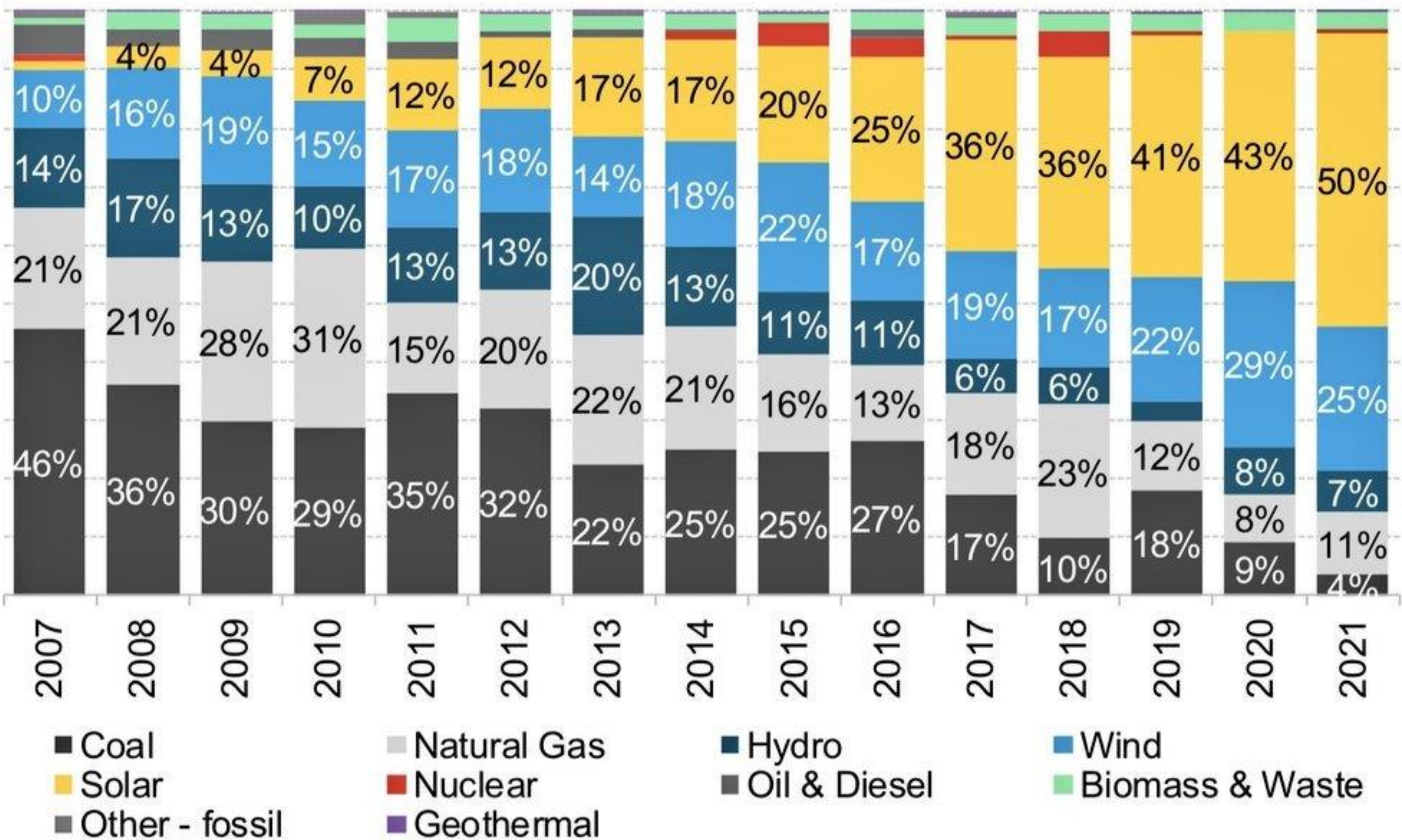
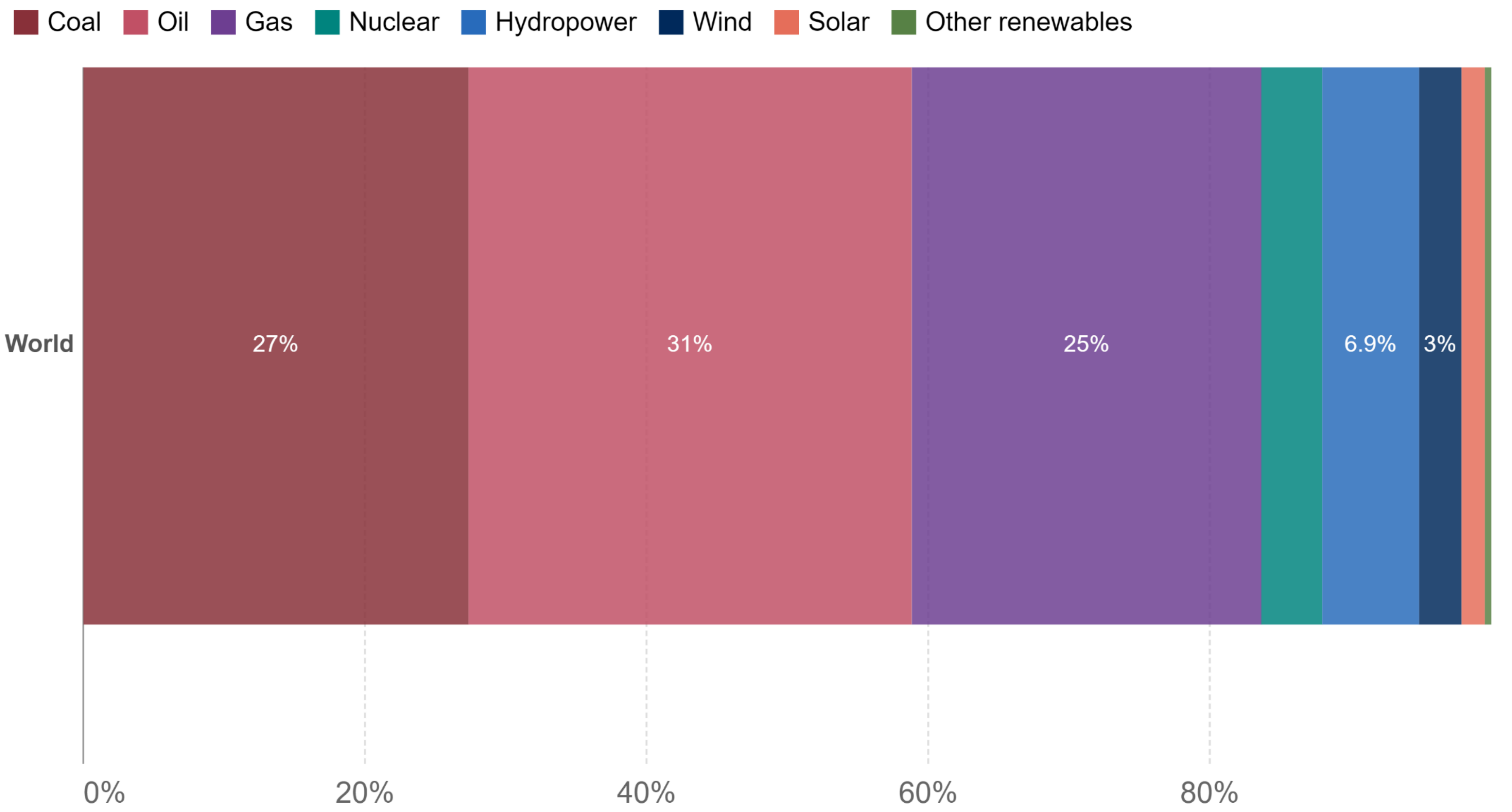
Share of global capacity additions by technology



Source: BloombergNEF. Note: Share of global capacity additions excluding retirements.

Primary energy consumption by source, 2021

Primary energy is calculated based on the 'substitution method' which takes account of the inefficiencies in fossil fuel production by converting non-fossil energy into the energy inputs required if they had the same conversion losses as fossil fuels.



Source: Statistical Review of World Energy - BP (2022)

Systemic perspective

- Energy system: A complex network of elements necessary to fulfill societal function of the system - production, transport, and use of energy.
- Energy transition: structural 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- to low-carbon based system.

The evolution of socio-technological systems

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Techno-economic explanation

- Beginning of the 20th century - competition among steam-, electric-, and gas-powered vehicles to substitute horses and carriages. (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.

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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 technological 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).

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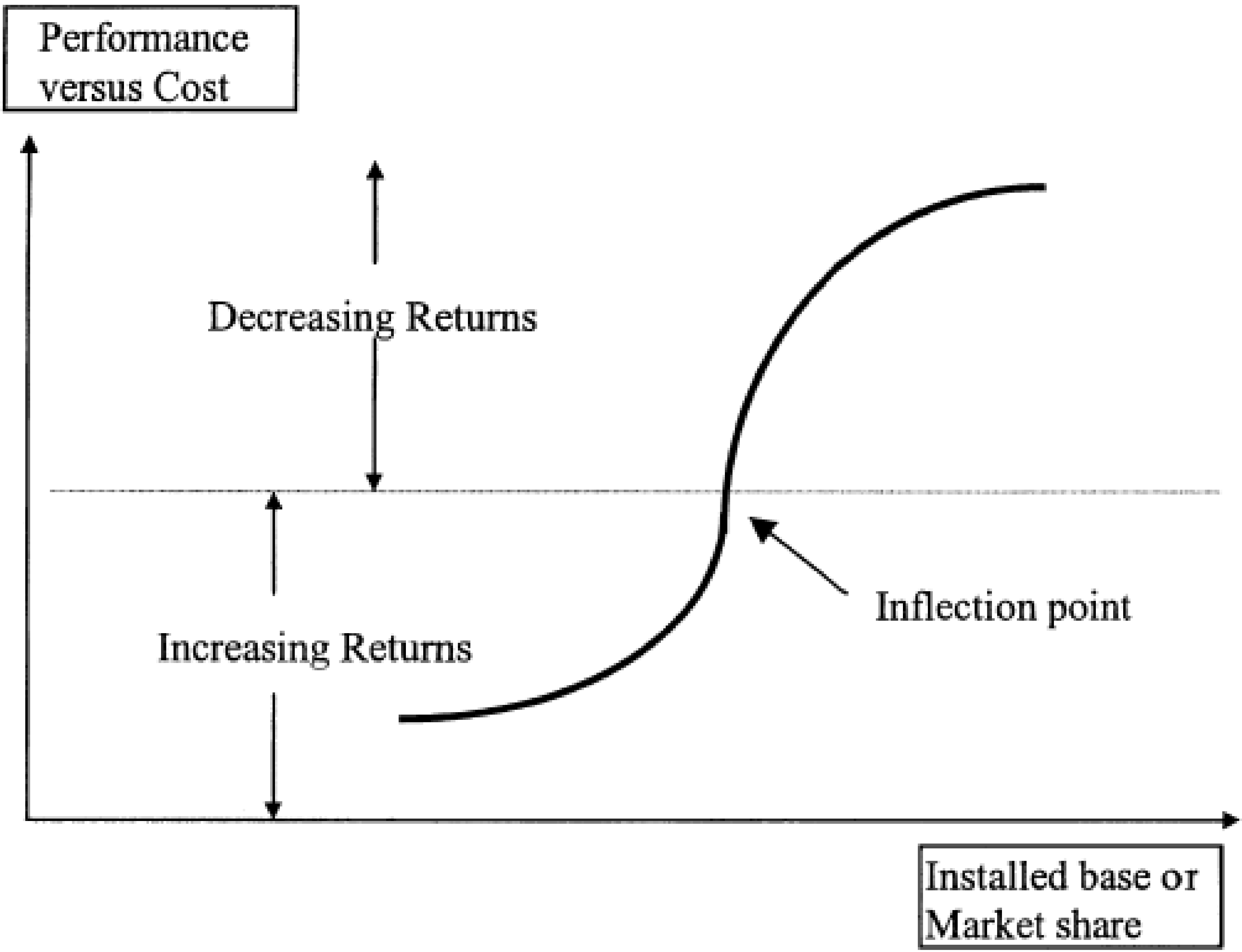

Performance versus Cost
Decreasing Returns
Increasing Returns
Inflection point
Installed base or Market share

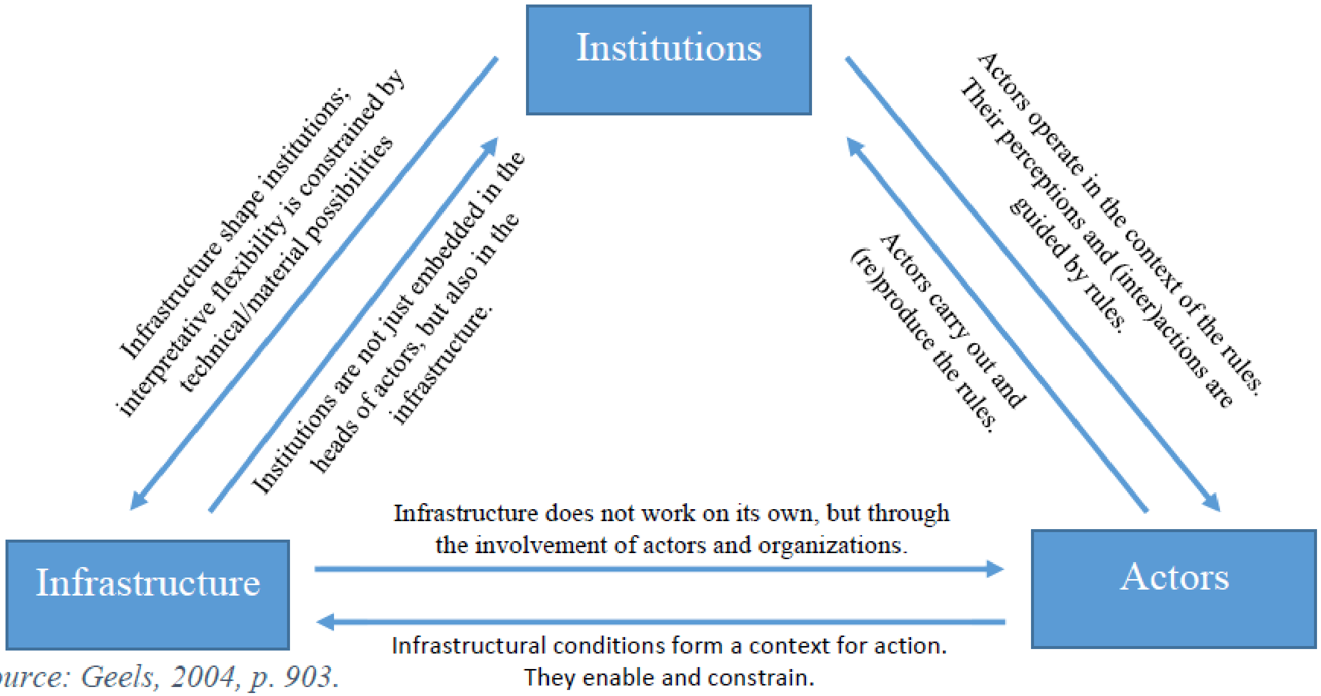
Societal factors

(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´s and company´s choices (setting the system).

Components of the system



Source: Geels, 2004, p. 903.

Different electricity production choices of similar countries

Different power production choices of similar countries

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Different power production choices of similar countries

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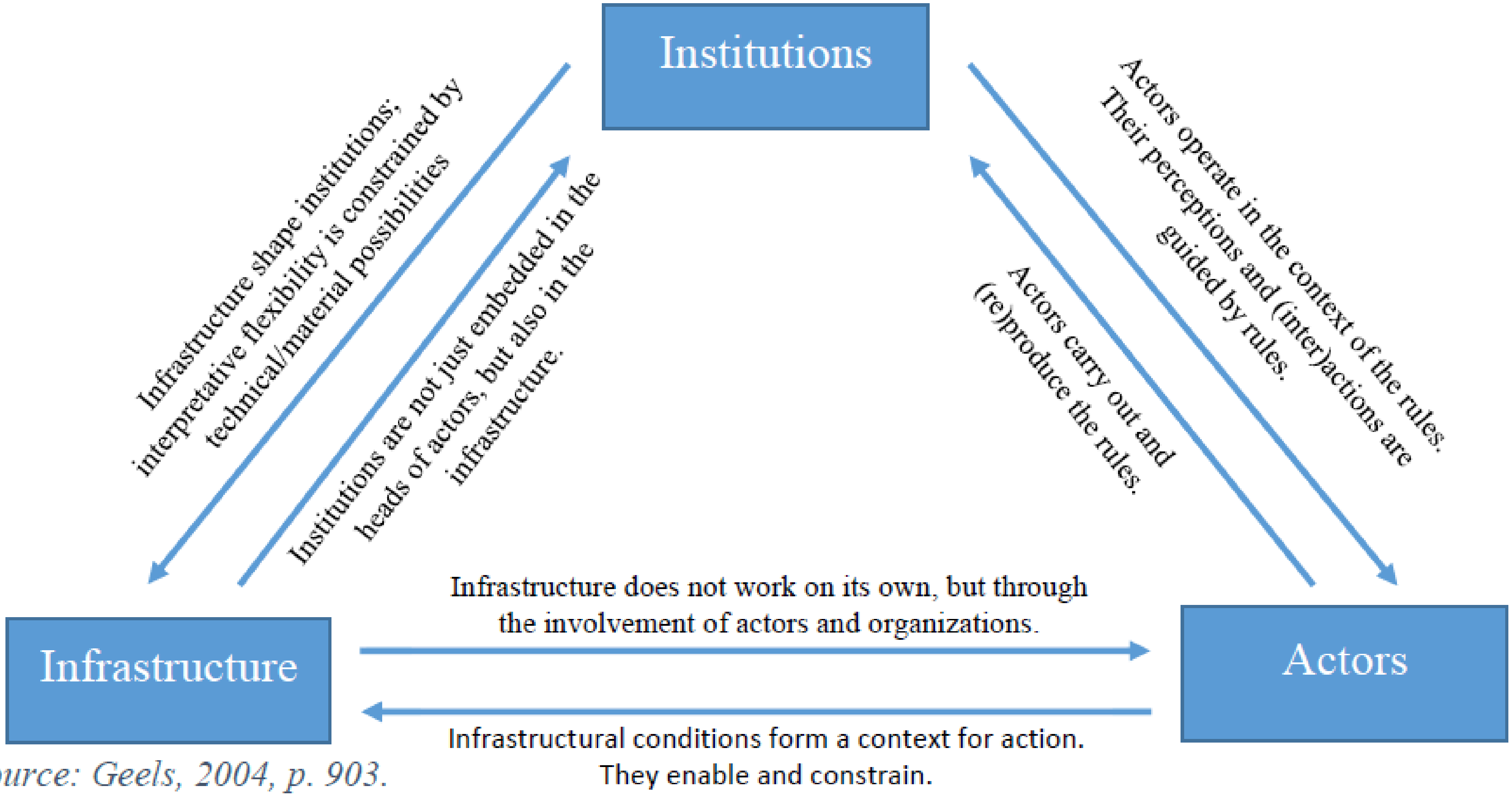
Social components of the systems



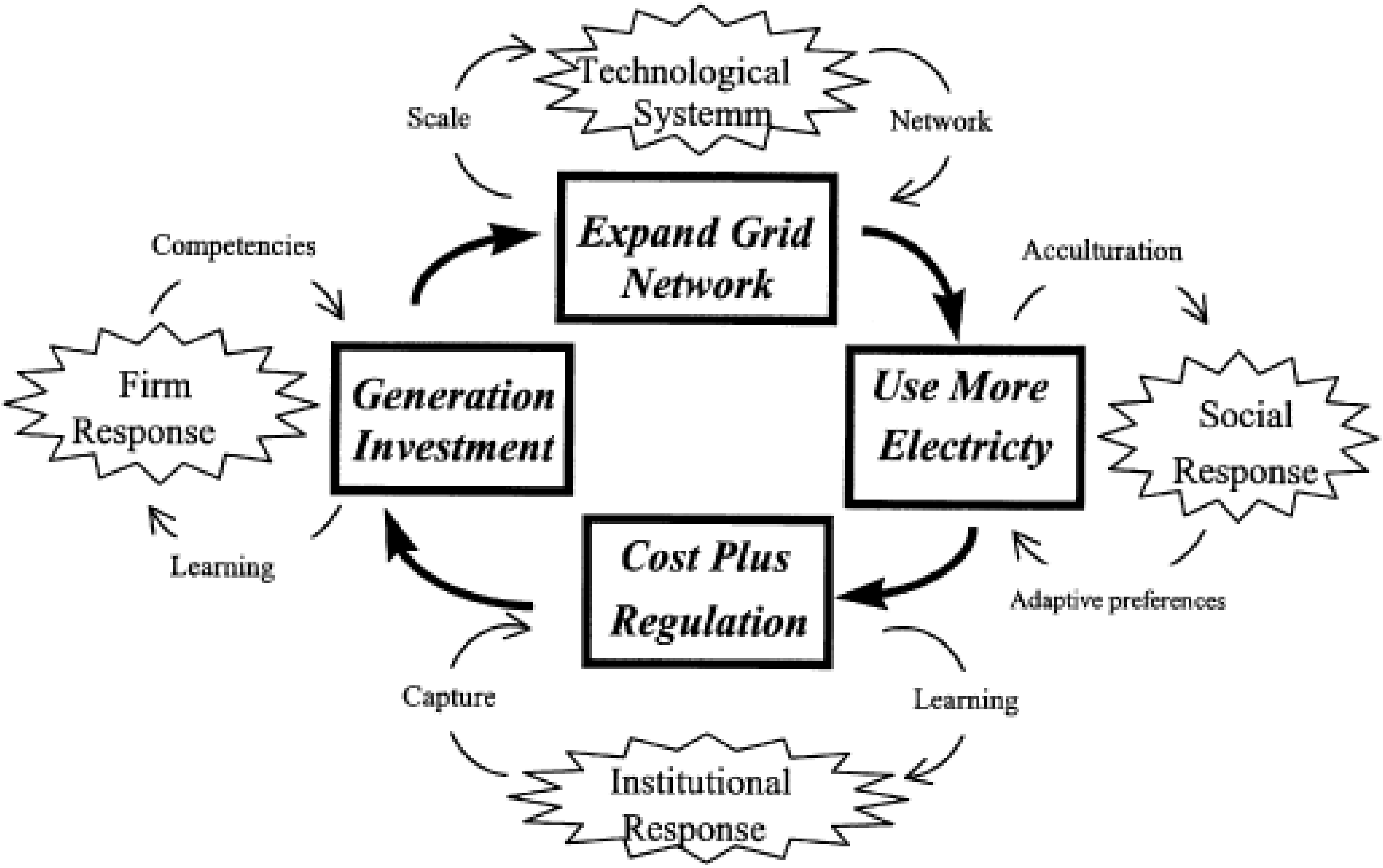
Source: Geels, 2004, p. 903.

Complexity of the modern systems

1) Physical and informational networks can become more valuable to users as the grow in size (road network, telephone network).
2) Systems interact and get interconnected with other systems.

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

The techno-institutional complex



More on elements of energy systems

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.

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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 perspective 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.

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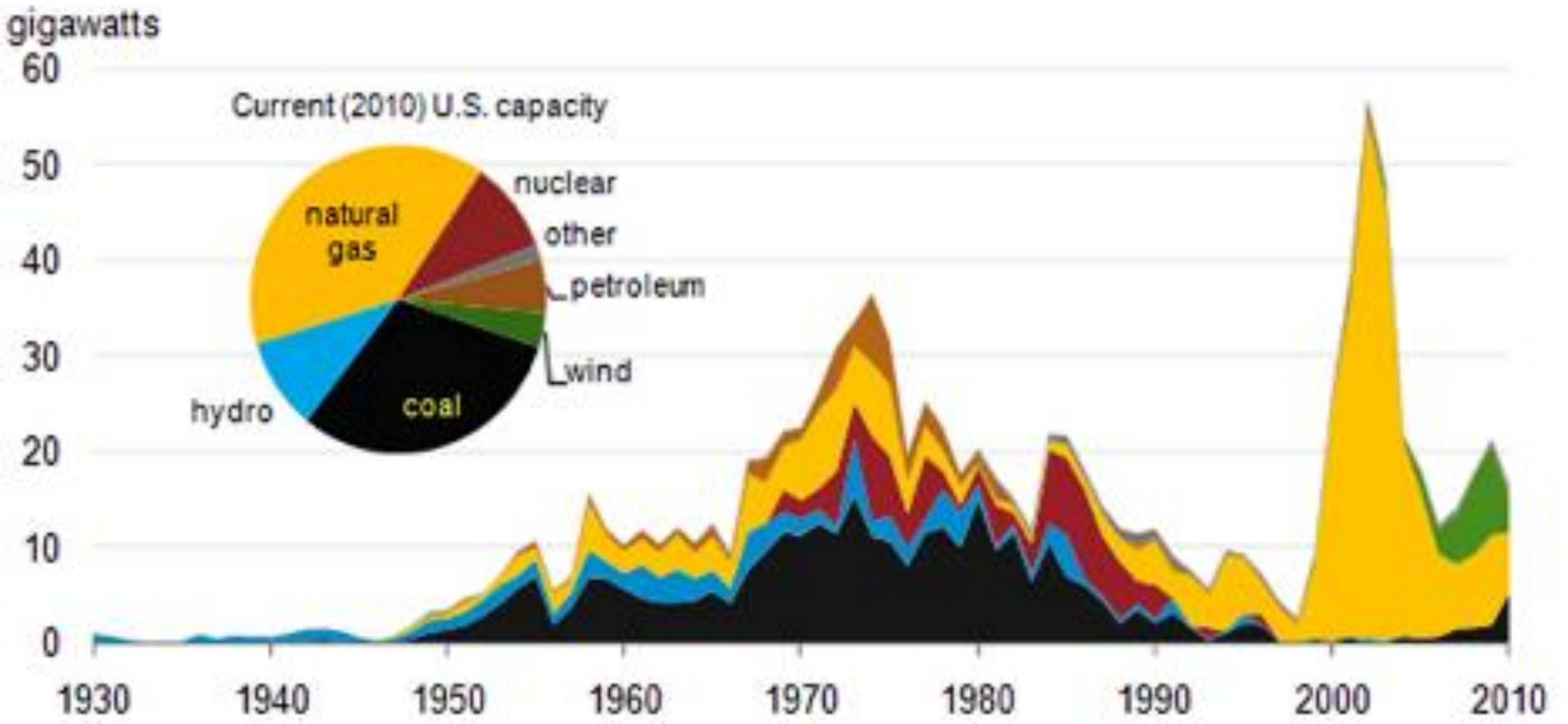
Infrastructure

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).

How systems change?

Meso-level of the system itself.

Meta-level of the landscape – external factors (economic growth, globalization, wars, systemic environmental changes etc.) that are beyond the controls of the actors of the system, changing slowly. They open the windows of opportunity for system change.

Micro-level of the niches – incubators for radical technology development. Here technical advances are protected from market forces and are able to develop to a competitive state.

→ Archetypal models of change

A unique nature of decarbonization?

Technological optimism

- Are we better equipped to deal with decarbonization?

- 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.

Changes in energy systems

1) Could be (and has been) done
2) Sometimes as evolution driven by social demands and technical development (sail to steam, coal to diesel locomotives)
3) Sometimes it takes changes in public policy – nuclear energy.
4) New systems face chicken-egg problem