Energy systems and their transition

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Transition of energy systems

- Energy transition: systemic change in the composition of primary energy supply and the technology.
  - Replacement of human muscles and occasional use of fire with domesticated draft animals and fire for production of metals and glass (300 000 years ago to 10 000 years ago).
  - Waterwheels and windmills.
  - Fossil fuels and Industrial revolution.
  - Electricity.

- Energy system: a complex network of elements necessary to fulfill societal function of the system - production, transport and use of energy.

Energy transition to low-carbon system

- Climate change results from the production and consumption patterns – satisfying consumer´s demands for goods and services through the carbon-based energy technologies and systems.
- Climate change mitigation is based on a switch to more efficient (low or zero-carbon) technologies and sources (RES).
- Decarbonization - deliberate process (energy transition) of switching from fossil fuels to low-carbon sources as a response to the climate change issue.

Energy transition to low-carbon system

- How the systems are created? What determines which energy source or technology will be used?
- How the system change? And how fast?

= Theoretical understanding of the energy transitions helps us to capture the process of decarbonization.

Issue No. 1 - what determines which technology will end up being used?

Economic argumentation would suggest that the optimal technology is selected based on market forces and fully informed, optimizing agents. But this argumentation is incomplete.

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

2) Once some choices are made they determine the future path (changing 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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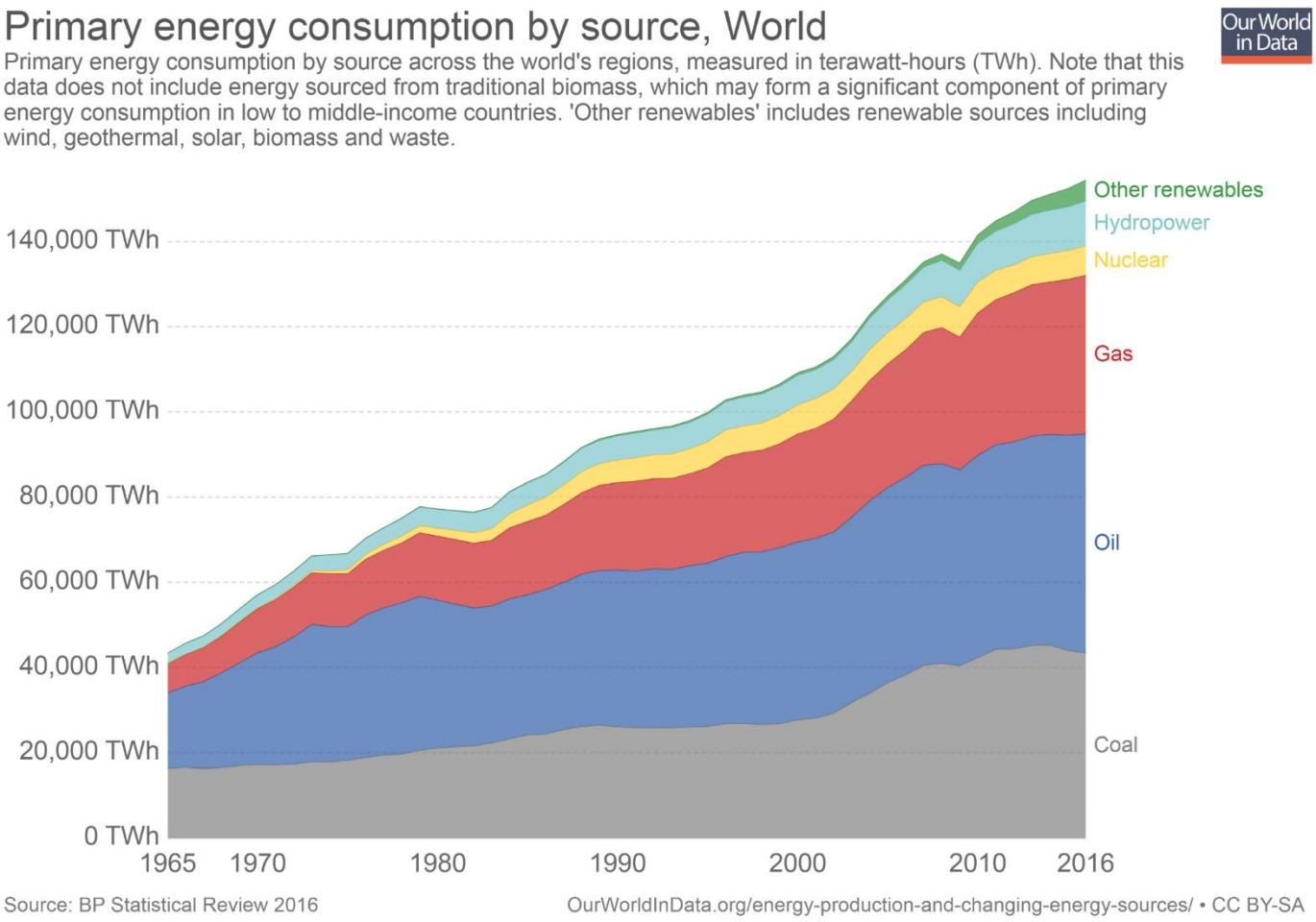
Issue No. 1 - what determines which technology will end up being used?

- Technically best choices from technologies available?
- But sometimes similar countries make different choices.

= It is not market decision only, people (individuals, collectives) make choices. Market just coordinate.

Issue No. 2 – pace of the decarbonization



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Technological systems – how do they develop?

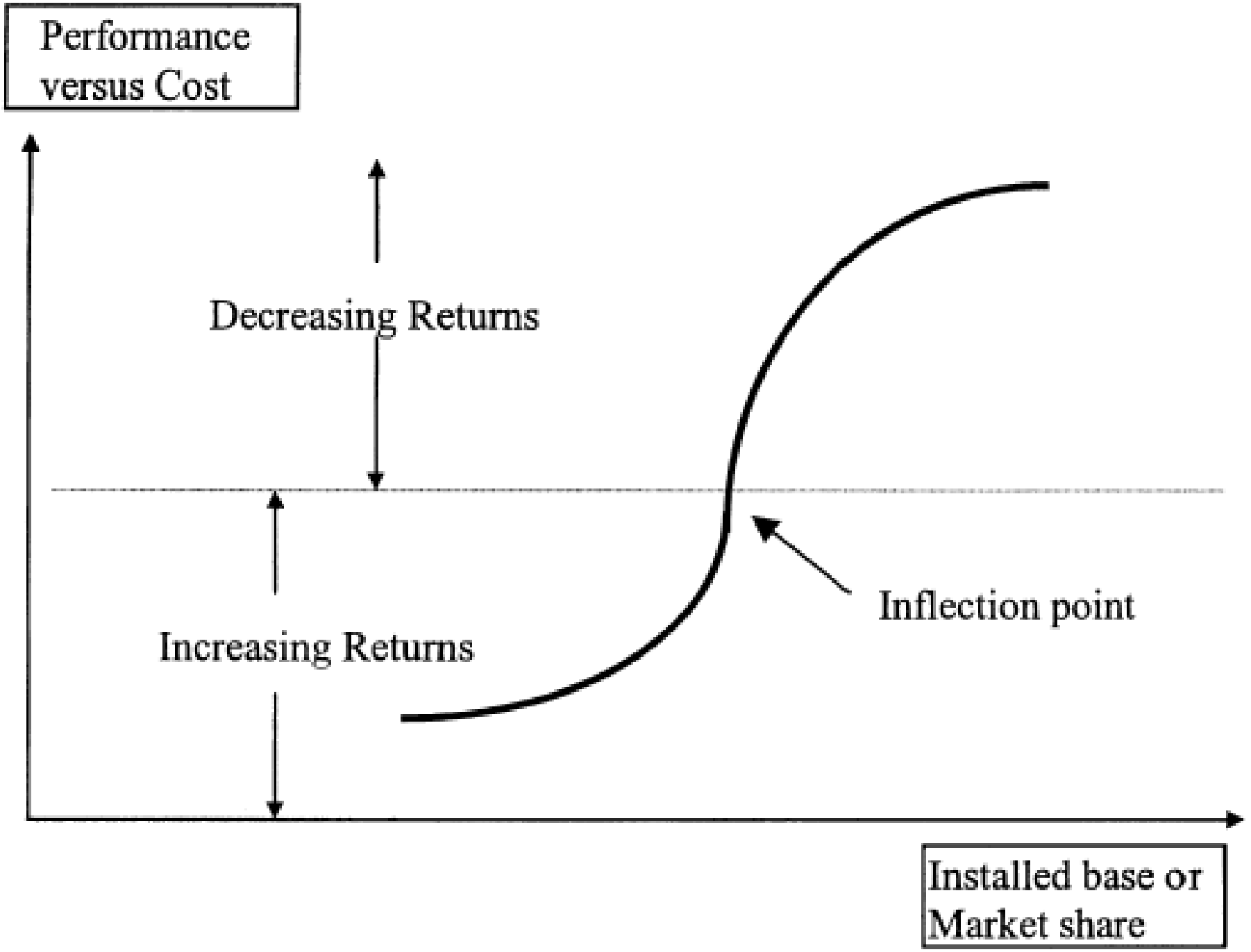
- Beginning of the 20th century, competition among steam-, electric, gas-powered vehicles to substitute horse and carriage. (noxious, noisy, complicated and dangerous vs cheap gasoline as a by-product of kerosene production).
- Then period of increasing returns to scale…locking internal combustion engine (ICE) as the dominant design.
- Producers of other designs are reduced – in 1890s, 1900 different firms producing over 3200 different variants of ICE vehicles in USA. In 1920s, a few dozens. By 1955 the Big Three (General Motors, Ford, Chrysler) held 90 % of domestic and 80% of the global market.

Technological systems – how do they develop?

- 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.


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

Concept of technological systems

- Technological system (TS) – inter-related components connected in a network or infrastructure that includes physical, social and informational elements.
- Changes in TSs are based on evolutionary framework with the dominant design models.
  - 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).

Lock-in of interdependent TSs

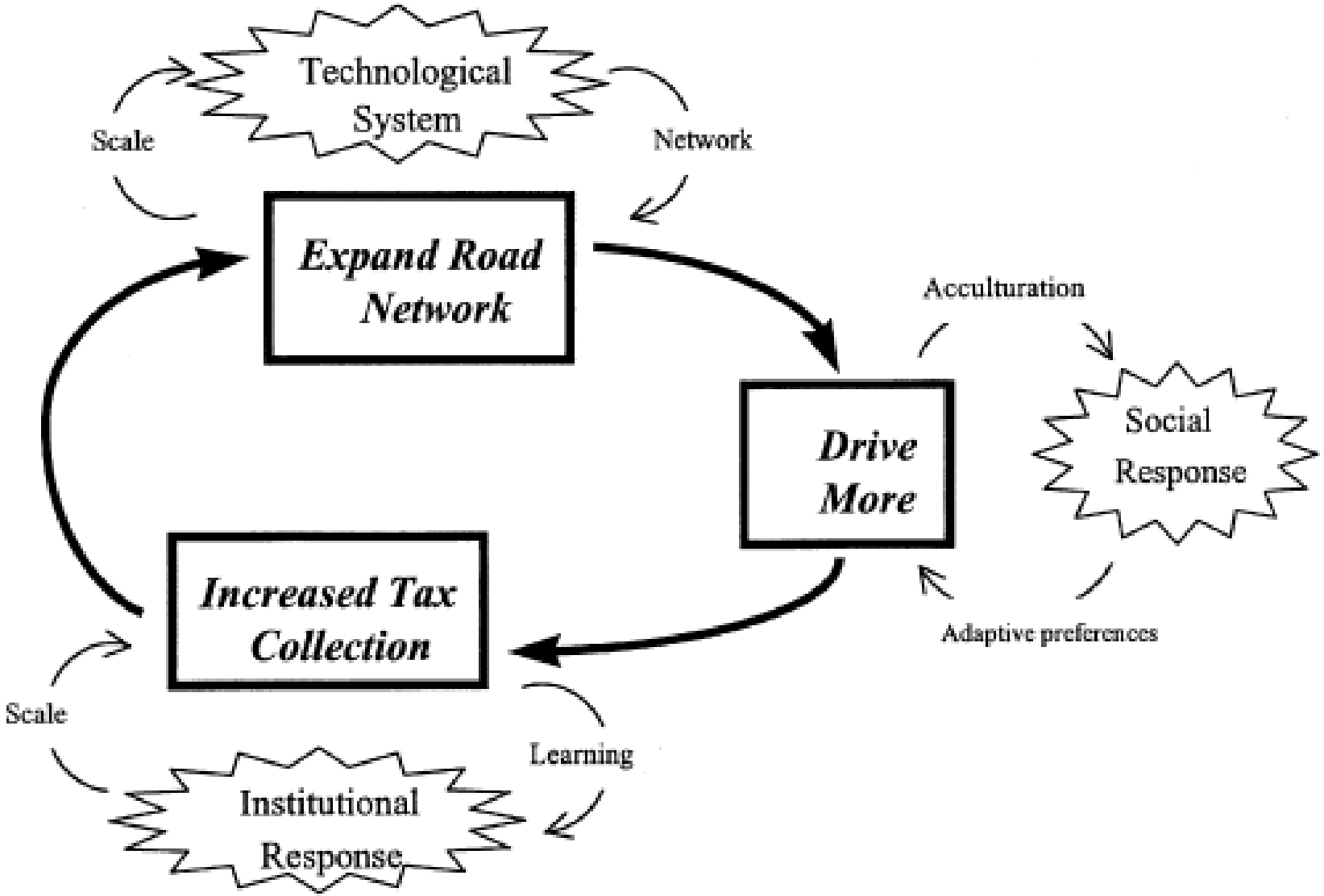
- Network externalities arising from systemic relations among technologies, infrastructures, independent industries and users.
  - Physical and informational networks can become more valuable to users as the grow in size (road network, telephone network).

= the viability of the automobile depends on the development of multiple supporting technologies and industries to create a functional system.

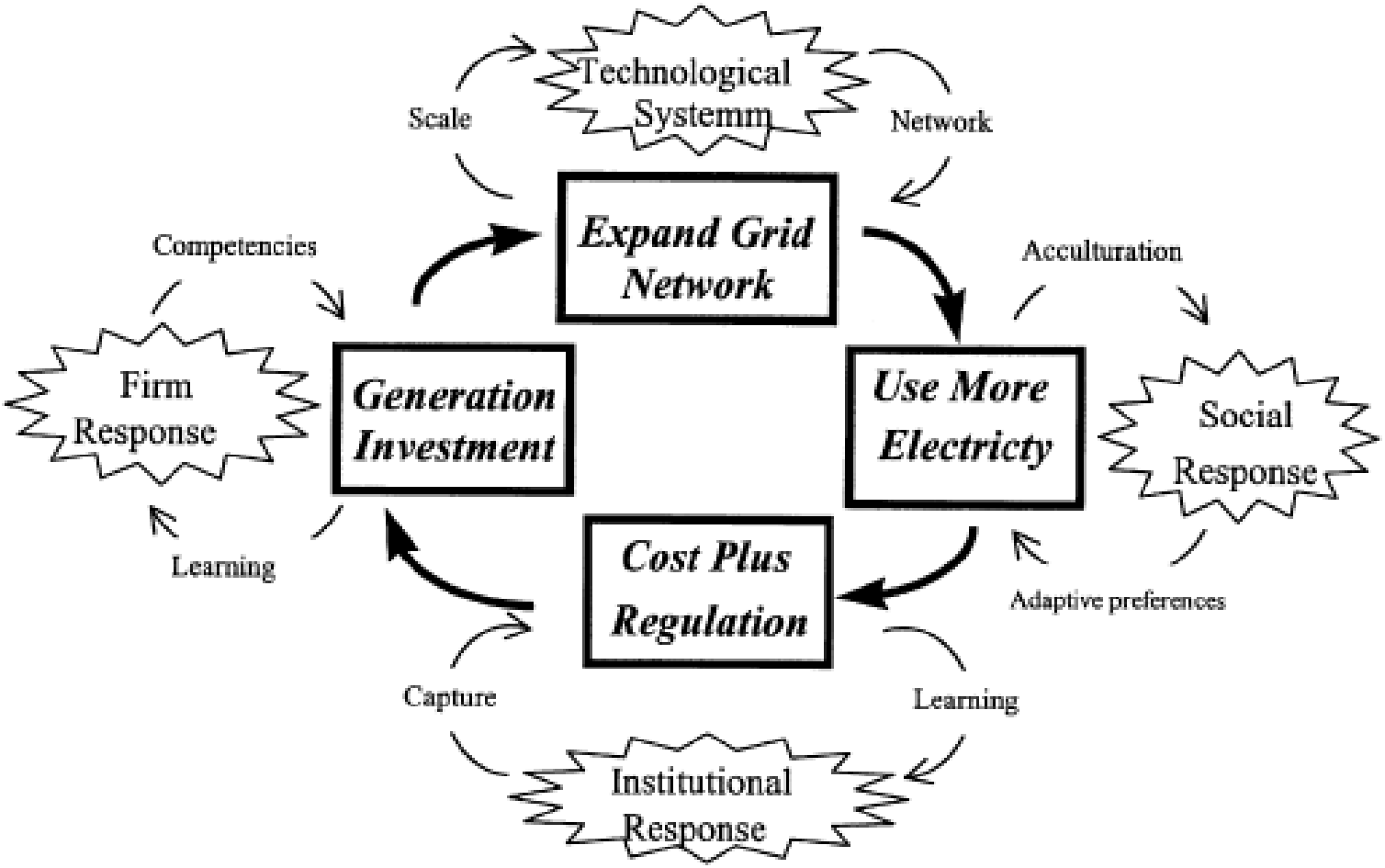
The techno-institutional complex

- TSs and institutions are inter-linked.
- Techno-institutional complexes emerge through synergistic co-evolution initiated by technological inreasing returns and perpetuated by the emergence of dominant technological, organizational and institutional design.

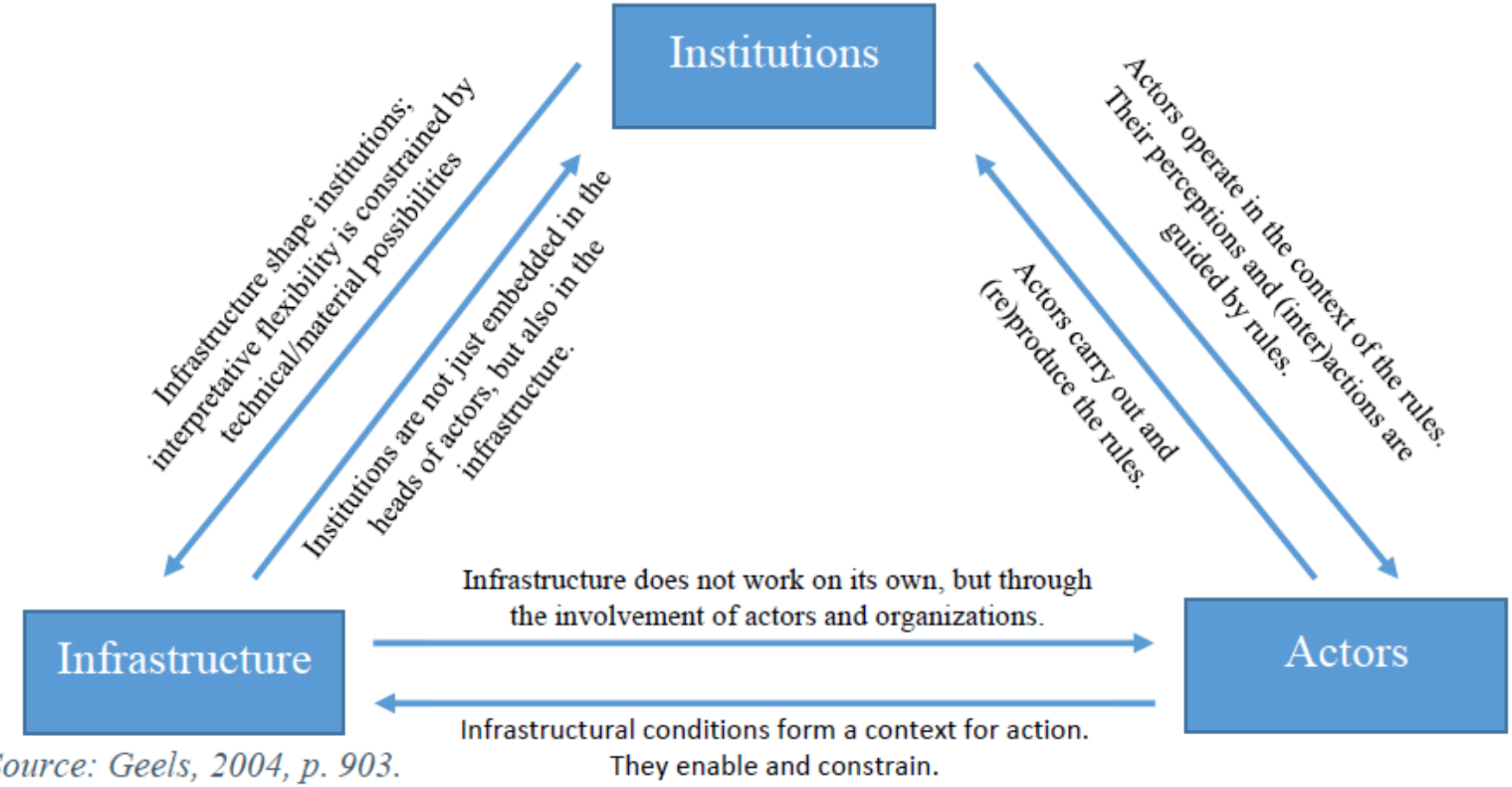
The techno-institutional complex



The techno-institutional complex



Socio-technical systems (MLP)



Source: Geels, 2004, p. 903.

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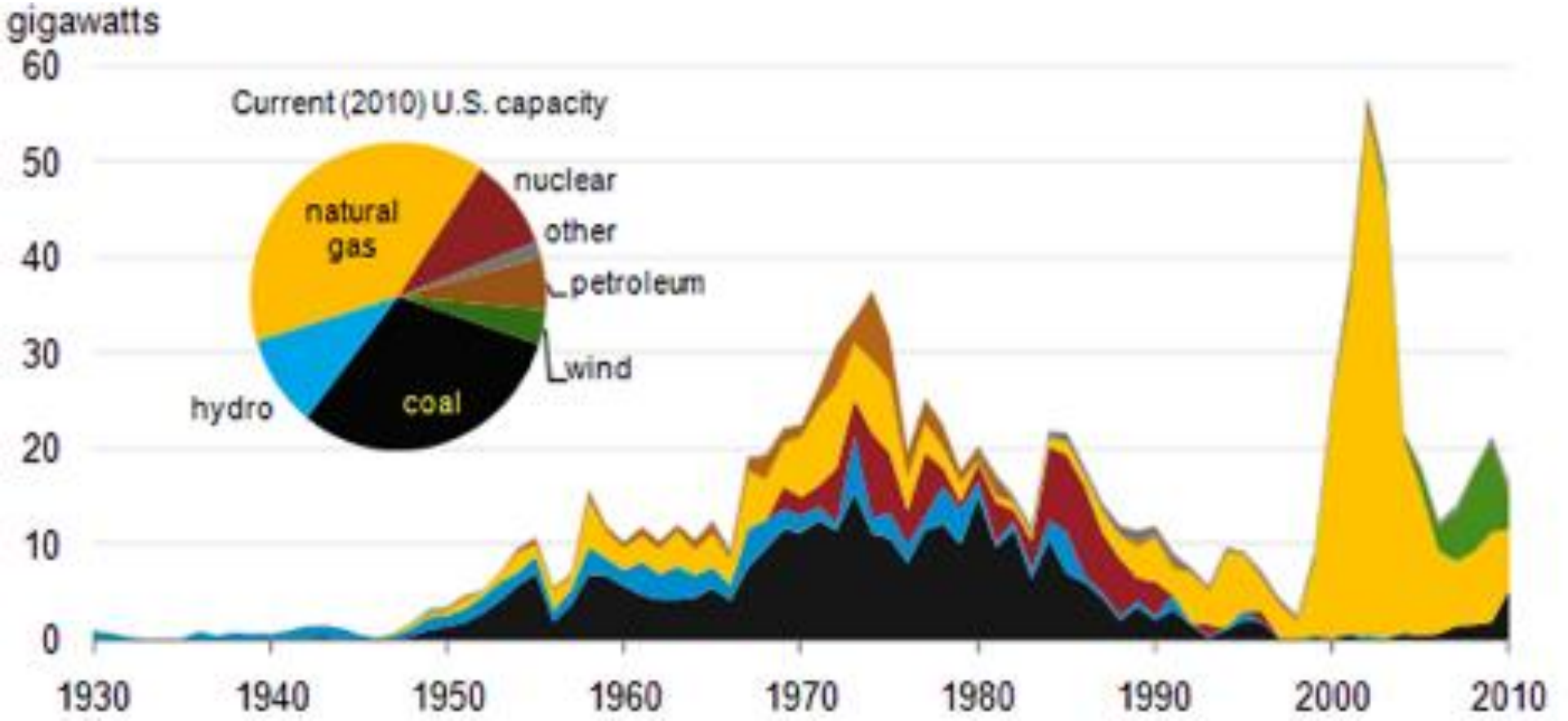
Actors and its role in the system

Example of government – its involvement is important for two principal reasons.

1) ability of institutional policy to override market forces. In the evolution of a technological system, government intervention can remove market uncertainty about the direction of technological development through policy (RES).
2) Political inertia - changes could be very disruptive – risk of unexpected results. Big changes in policy regimes rare (CAP of EU). Ideology matters.

Infrastructure and its role in the system

Example of the cost of durable capital



Cost of durable capital

Hazelwood power Station (1964-1971), Victoria, Australia.

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Institutions and their role in the system

- History (culture) shapes choices – path dependence (where we are now is the result of our decisions in the past).
- Superior technological variant doesn´t allways win out in dominant design frameworks. Inferior designs can become locked-in through a path-dependence process (Uber?, Airbnb?).
- 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).

= history matters.

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Institutions and their role in the system

Chinese navy

- From 1405 until 1433, Zheng He´s seven ocean expeditions (from China to Southeast Asia, India, Persian Gulf, Africa)
- Hudreds of ships (some of them 400 ft long, 160 ft wide), navy not comparable to anything in the world until WWI. Tens of thousands of sailors.
- Then the ocean-going ships intentionally destroyed.
- Financial bud also ideological and cultural reasons (Confucianism – isolationsm).

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

Sources

- Gawande, A.: Getting there from here, 2009.
- Unruh, G.C.: Understanding Carbon Lock-in, 2000.
- Schmalensee, R.: Energy Decisions, Markets, and Policies, 2012.

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