Energy systems and their transition

Filip Černoch

FSS MU

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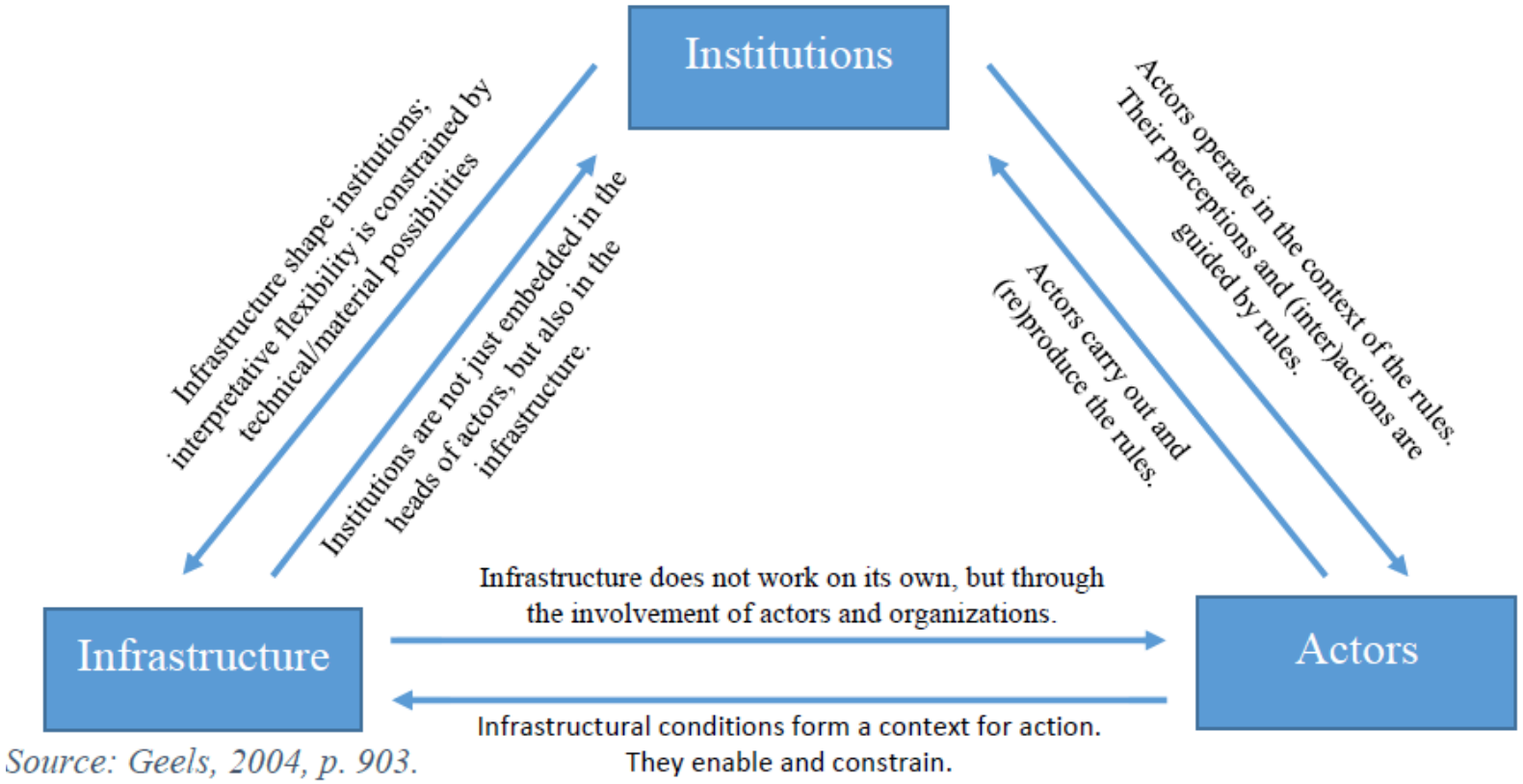
Socio-technical systems (MLP)



Source: Geels, 2004, p. 903.

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The dynamics of energy systems (MLP)

- System inertia – path dependence, locks-in, vested interests…

- Socio-technical transition theory - the change of a system is a result of niche innovations, taking advantage of external pressure and, in cooperation with or against the opposition of status quo forces, gradually transforming system into its new shape.

The dynamics of energy systems (MLP)

- 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

1) Technological substitution

- Sudden changes on the landscape level + developed innovation(s) on niche level.
- Innovations break in replacing existing regime.
- That triggers competition between status quo actors, being defensive, and newcomers representing change.
- Newcomers – new companies, activists, social movements, citizens, companies stretching their activities to new areas.
- Downfall of incumbent companies.
- Limited institutional change with innovations developed to fit into existing rules and institutions.
- Or rules and institutions are adjusted to accommodate niche innovations.
- Power struggles, social mobilization, counter mobilizations.

British ´transition from sailing ships to steamships´ example

- Sailing ship system with large and fast clipper ships stable and innovative in 1850s-1860s.
- Steamships confined to small niches (inland waterways, steam tugs in ports to maneuver large sailing ships).
- 1838 – British government created subsidized market niche for mail steamers to improve communication within the empire. Steamers expensive but faster and more reliable. New community created.
- Political revolutions (1848) and the Irish potato famine (1845-1849) formed landscape change that led to mass emigration to America. Steamships utilized that they are equipped with new technology – screw propellers, increased efficiency of engines, iron hulls enabling building of bigger ships.

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British ´transition from sailing ships to steamships´ example

Source: Lai Fong (Lai Fong of Calcutta, fl. 1870-1910) - Childs Gallery, Public Domain.

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British ´transition from sailing ships to steamships´ example

- Opening of the Suez Canal (1869) facilitating India and China trades – sailing ships are not allowed to Canal, continuing to going around Africa.
- Replacement of sailships accompanied by development of new infrastructure – world coal market, enlarging of posts to accommodate bigger ships, machines for loading and unloading ships…
- An effort of sailships producers to fight – bigger ships with more cargo.
- Transition with technology-push character, where adjustments in the sociotechnical system followed the breakthrough of steamships.

Actors	Infrastructure	Institutions
New firms struggling against incumbent firms, leading to incumbents' overthrow. Different kinds of "new entrants" (e.g. citizens, communities, social movement actors, incumbents from different sectors) that replace incumbents.	Radical innovation(s) substituting existing technology.	Limited institutional change, implying that niche-innovation needs to compete in the existing selection environment.

Transformation pathway

- Moderate landscape pressure + unfinished niche developments.
- Actors perceive the pressure and have desire to respond, but there is no technology available.
- Social pressure groups (incl. those from outside of the sector) voice protest, accompanied by experts, researchers and companies.
- New ideas to deal with the situation, accepted by actors as viable solution.
- Innovation activities are reoriented to these new solutions.
- New system emerges through cumulative adjustment and reorientation.
- Existing actors adapt but survive, with some damages and losses.
- Different level of institutional changes.

Dutch ´hygienic transition from cesspool to sewer systems´ example

- System insiders (city governments, city councils, Department of Public Works) vs. outside criticism from hygienist doctors (in 1850 correlation between infectious diseases and filth discovered, resulting from overflowing cesspools and waste-dumping on streets and in canals).
- Their demands downplayed, only incremental changes – dredging canals, pumping fresh water into them. Health seen as individual responsibility, not public issue (keeping taxes low for middle class population).
- 1870s – 1880s escalation of the problem – with industrialization more people in slums without sanitary facilities. Doctors cooperate with engineers, pressing for sanitary reform. Cities are changing their policies – implementation of dry-collection system. Scale still limited.

Dutch ´hygienic transition from cesspool to sewer systems´ example

Source: tvtropes.org: The Dung Ages

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Dutch ´hygienic transition from cesspool to sewer systems´ example

- In 1890s, cleanliness became a widespread cultural value – filth is no longer socially tolerated.
- New civic spirit calling for more involvement from public authorities. More importance of working class.
- Sewer systems implemented in The Hague in 1893, in Amsterdam in 1914.
- = transformation path with gradual adjustments in regime rules (perceptions of disease and wastes, role of public authorities…).

Actors	Infrastructure	Institutions
Incumbents reorienting incrementally by adjusting search routines and procedures Incumbents reorienting substantially to radically new technology or, even more deeply, toward new beliefs, missions, and business models	Incremental improvement in existing technologies (leading to major performance enhancement over a long-term period) Incorporation of symbiotic niche innovation and add-ons (competence-adding, creative accumulation) Reorientation towards new technologies: a) partial reorientation (diversification with incumbents developing both old and new technologies b) full reorientation, leading to technical substitution	Limited institutional change, or… Substantial change in institutions

Reconfiguration pathway

- Symbiotic innovations are adopted in the system to solve problems, based on their technical or economic superiority.
- System stays intact initially, but over the course actors are active in implementing and using given technology.
- This leads to major reconfiguration and system change.
- New entrants may both compete or cooperate with status quo actors.
- Since technologies are incorporated as modular innovations or add-ons → new possibilities and problems. Transition pathway has a strongly open-ended character.
- Limited institutional change is expected.

American ´transition from traditional factories to mass production´ example

- Factory production as a complex, distributed system with many technical and social elements. Sequence of smaller and larger component changes led to reconfiguration to mass production.
- In 1850s and 1860s new general-purpose machine tools (turret lathes, planners, boring machines etc.), operated by low skilled laborers. Line shafts with friction and inflexibility.
- 60s and 70s, processing industries (canning, meat packing, steel making) experimented with continuous movement in material handling (overhead conveyors, endless chains etc.). Small, battery-driven electric motors.
- 80s – 90s – special-purpose machine tools with interchangeable parts. Canning industry pioneered combination of machine tools and conveyor belts.
- Electricity.

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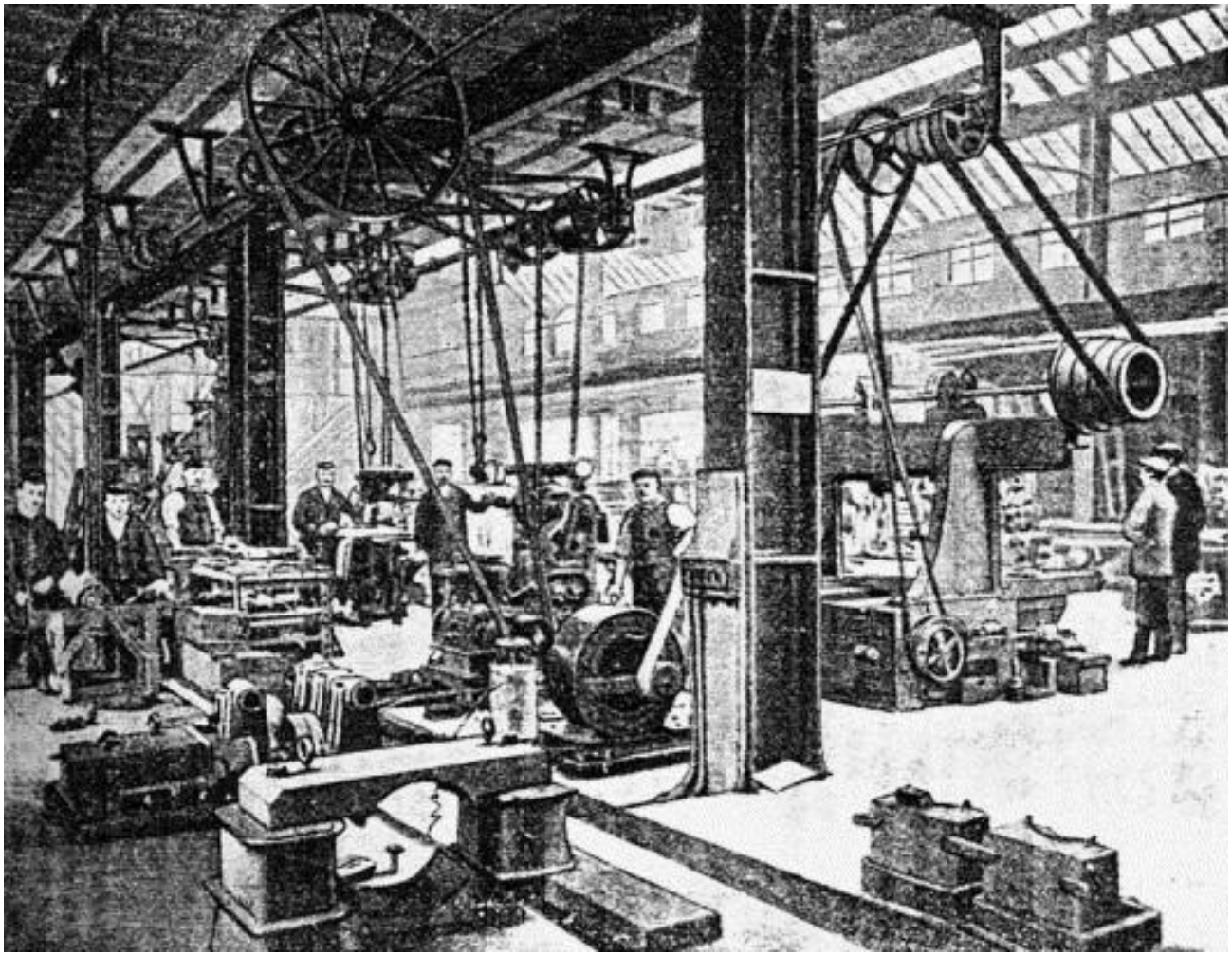
American ´transition from traditional factories to mass production´ example



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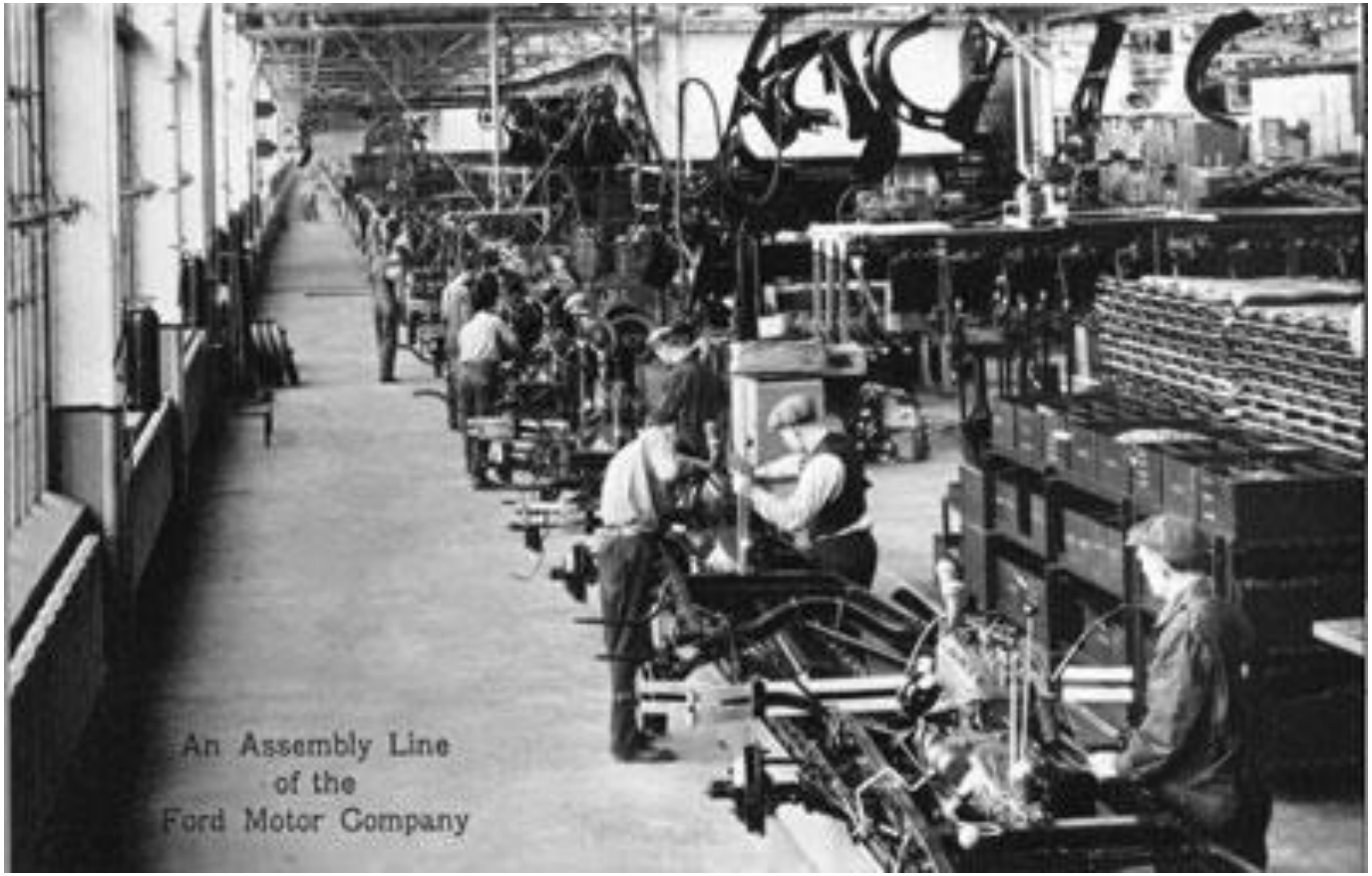
American ´transition from traditional factories to mass production´ example

- First decade of 20th century, industrial engineering, bigger companies (steel and reinforced concrete), more electric motors.
- Automobile industry perfecting new production system based on special purpose machine tools, division of labor, interchangeable parts, electric motors, assembly line – Ford´s factories.
- Impact of landscape development – national market, population and economic growth, rising purchasing power, the rise of engineers, electricity… .

= interaction between multiple component innovation and the system. Not one breakthrough innovation, but sequences of multiple component innovations.

American ´transition from traditional factories to mass production´ example



Source: Ford company

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Actors	Infrastructure	Institutions
New alliances between incumbents and new entrants.	From initial add-ons to new combinations between new and existing technologies; knock-on effects and innovation cascades that change system architecture.	From limited institutional change to more substantial change, including operational principles.

De-alignment and re-alignment pathway

- Sudden and major changes on the landscape level (wars, economic collapses), causing actors to give up on the status quo (de-alignment).
- System is not able to deal with problems, actors are looking for the solution at niche level.
- If there is no one → window of opportunity for multiple ideas, competing with each other. Eventually one wins, creating basis for a new arrangement (re-alignment).

American ´horse-drawn carriages to automobiles transition´ example

- Late 19th century America in flux – urbanization, immigration, hygiene movement, electricity, political reform movements, expanding middle class with more money and free time, new values such as fun and active sporting.
- Problems with horses – hygiene, longer travel distances, high costs of horse transportation.
- Competition between different engines – with ICE winning.

Actors	Infrastructure	Institutions
The collapse of incumbents because of landscape pressure, creating opportunities for new entrants	Decline of old technologies creating space for several innovations which compete with one another	Institutions disrupted by shocks and replaced, possibly after prolonged uncertainty

Transition pathways – reproduction

Actors	Infrastructure	Institutions
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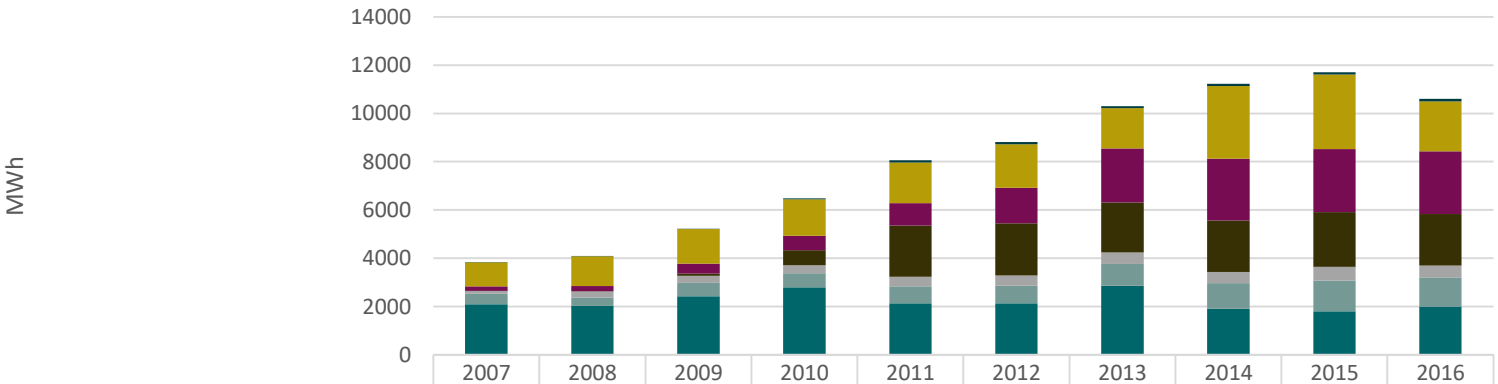
Czech ´renewable energy transition´ example

- Energy transition (decarbonization) is in immature phase – RES account for about 11% of gross electricity generation (2016). RES are not able to challenge to traditional system of electricity provision.



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Biologically degradable municipal waste	11	12	11	36	90	87	84	87	87	99
Biomass	993	1231	1437	1512	1683	1803	1670	3007	3092	2067
Biogas	183	214	414	598	933	1471	2241	2567	2614	2601
Photovoltaic	2	13	89	616	2118	2173	2070	2123	2264	2132
Wind	125	245	288	336	397	417	478	477	573	497
Pumped storage	434	352	553	591	701	731	905	1052	1276	1202
Hydropower	2090	2024	2430	2789	2134	2132	2856	1909	1795	2001

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Czech ´renewable energy transition´ example

Traces of ´substitution pathway´.

- 1) Vehement external pressure (→Act. No. 180/2005)

EU Accession Agreement (based on Directives 2007/71/EC and 2003/30/EC)	A greater renewable energy share in gross final consumption, reaching a level of 8% by 2010 and a level of 15% by 2030. A goal of a 5.75% share of biofuels in transportation fuel by 2010.
Directive of the European Parliament and of the Council 2009/28/EC	A greater renewable energy share in gross final consumption, reaching a level of 13% by 2020.
Directive of the European Parliament and of the Council 2009/28/EC	A renewable energy share of 10% in all forms of transportation according to gross final energy consumption in transportation in the Czech Republic by 2020.
A policy framework for climate and energy in the period from 2020 to 2030 (2030 Strategy)	At least a 27% share of renewable energy consumption (a target obliging EU as a whole, not binding Member States individually).

Czech ´renewable energy transition´ example

- 2) Resistance of status quo actors, hoping to outlast a challenging technology with partial changes of their behaviour and strategies.
  - MPO: „Only minimal effort and money should be invested to fulfill the EU´s RES goals.“
  - ČEZ: „the state is supporting it [RES], which means that from the business perspective it is a great idea. But people who do understand energy know what kind of energy nonsense it is.”
  - ČEPS: RES are a source of instability and incrased outlays in infrastructure and servising costs.

Target gross production in electricity in 2040 (SEPU). 2016 data in brackets.	
Nuclear-fueled	46-58% (29%)
Renewables and waste	18-25% (13%)
Natural gas	5-15% (9%)
Hard and brown coal	11-21% (55%)

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Czech ´renewable energy transition´ example

- 3) Struggles between status quo actors and newcomers
  - Rather limited, since newcomers are considerably smaller and less influential.
  - Also limited share of RES → traditional components of the system not challenged.

Czech ´renewable energy transition´ example

- 4) Existence of developed and employable innovative technologies.
  - They are available, but not in the Czech Republic.
  - Technology is primarily imported from abroad.
  - Limited R&D in the Czech Republic.

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