Introduction

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Defining and assessing energy security

Complexity of and confusion in the field of energy security

- There are serious scholarly disagreements on energy security, particularly is it:
  - Security of fossil fuels supply OR an arbitrary collection of energy policy issues?
  - An issue of *human* security or of *conventional* security?
  - Objective property of energy systems OR a political construct?
  - Can be compared between different situations OR is entirely contextual?

Lack of rigorous science of energy security

- Attempts to simplify this complexity sometimes result in insufficiently rigorous approaches to dealing with energy security
- For example, the concept of the "5 As of health care" (Penchansky and Thomas 1981) was modified by arbitrary removing one "A" and became the "4As of energy security" (availability, accessibility, affordability and acceptability). Although initially it was proposed for describing energy issues in developing countries, its most widely-cited application relates to the future of European energy.
- Such concepts often lack empirical justification, theoretical rigour and practical applicability

The emerging science of energy security

- Most of the recent studies of energy security revolve around the definition that energy security = low vulnerability of vital energy systems

Vital energy systems

- Energy systems that support stability and survival of modern socieities
- System = set of energy resources, technologies, uses, etc. which, in case of disruption, can substitute one another but cannot be easily substituted by elements from outside the system.
- Can be divided by geographic (e.g. national, regional, global) and sectoral (e.g. oil and its products, electricity, liquid fuels, etc.) boundaries.
- Vital energy systems in some countries are energy exports

Three perspectives on vulnerabilities (Cherp and Jewell 2011)

- **Sovereignty:** links vulnerabilities to hostile intentions and power struggle. Represents the future as unfolding of competitive *plans*. Roots in political science and IR studies
- **Robustness:** links vulnerabilities to predictable natural and technical factors. Represents the future as a *forecast* (probabilistic unfolding of present situation and trends). Roots in natural science and engineering
- **Resilience:** asserts that risks are unpredictable and therefore focuses on the ability of energy systems to respond to (diverse) threats. Roots in complexity studies, ecology, economics.

Energy security assessment framework (Cherp and Jewell 2013)

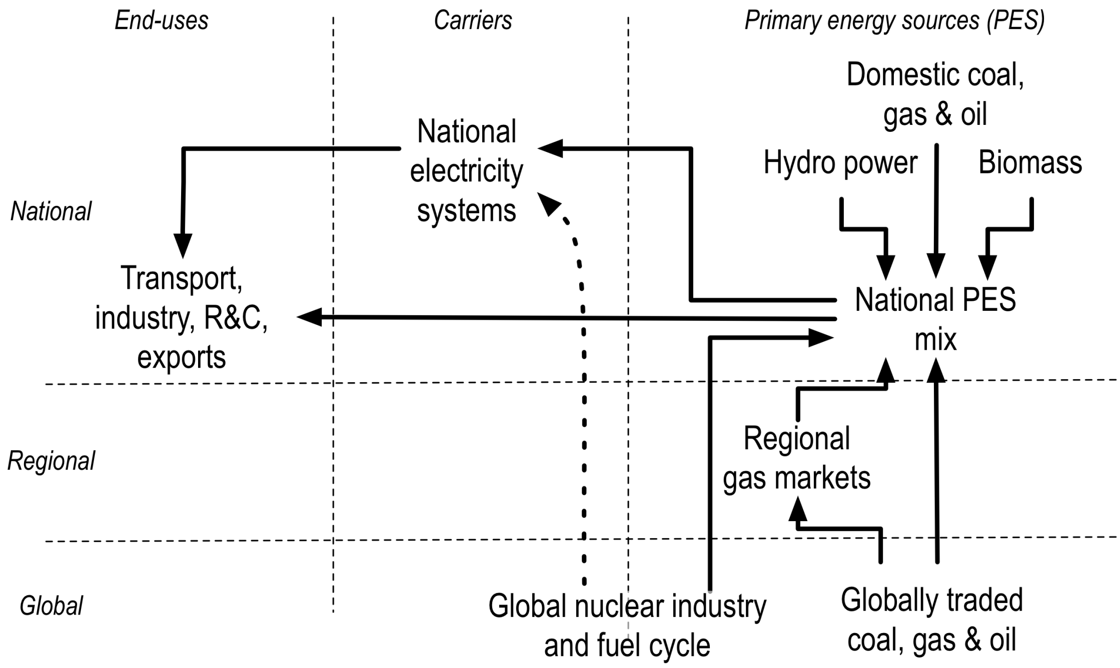
- 1 Delineate vital energy systems
- 2 Define their vulnerabilities
- 3 Collect and analyse data on individual systems and vulnerabilities
- 4 Aggregate and interpret the data as necessary

Setting the scene: present vulnerabilities of energy systems

Major energy systems (GEA 2012)

	Countries	People, bln
> 10% of total primary energy supply		
Oil	125	5,9
Coal	45	4,5
Gas	78	2
> 10% of total electricity generation		
Hydro	74	4,6
Nuclear	21	1,3
*Biomass**	*n/a*	*2,5*

Vital energy systems analysed in the Global Energy Assessment



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- **Oil as an illustration of global energy vulnerabilities**

Global oil today: sovereignty concerns (GEA 2012)

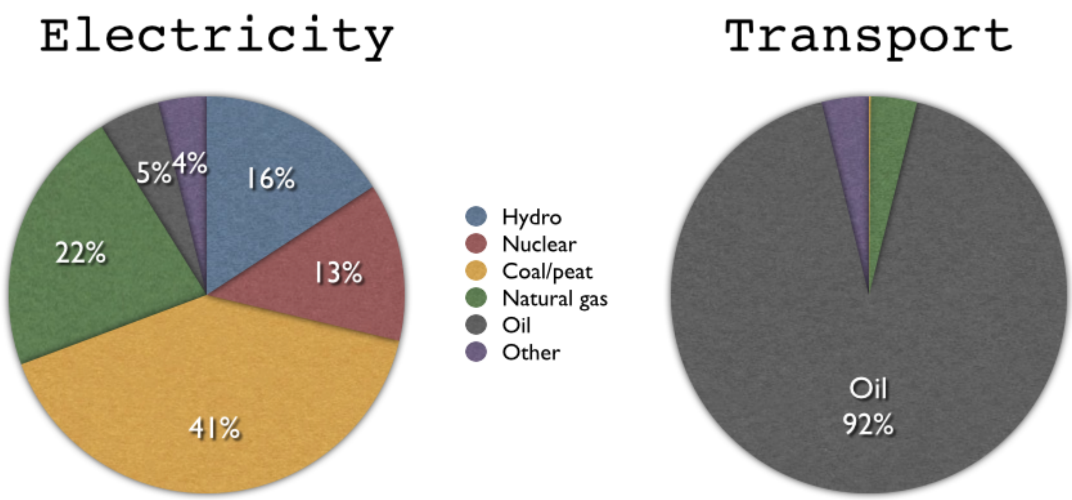
- Traded share of global oil production was 66% (29% for gas and 14% for coal)
- Geographic diversity of supply of tradable oil is also lower than that of coal and gas
- More than three billion people live in countries that import more than 75% of the oil and petroleum products they use. An additional 1.7 billion people living in countries with limited domestic oil resources (including China) are likely to experience similarly high levels of import dependence in the coming decades.

Global oil today: Robustness concerns (GEA 2012)

- About 1.7 bln people live in countries where transport energy use has grown faster than 8% annually over 1998-2007
- The global R/P ratio for oil is estimated at 30 years, for gas at some 80 years and for coal at some 150 years

Global oil today: Resilience concerns (GEA 2012)

Energy mix in transport and electricity



- Diversity = 1.75 Diversity = 0.04

Future energy security (Jewell et al 2013, in Press; Cherp et al in Press)

Which future?

- Future as forecast (can we deal with uncertainties?)
- Future as plan (do we have the capacity to implement?)
- Future as vision (does everyone share it?)

Future as a scenario

- Plausible (technically? economically? politicslly?
- Modelled by Integrated Assessment Models (IAMs) also used by the IPCC.
    - up to 2100
- The results reported below were generated by six IAMs: IMAGE, MESSAGE, WITCH, ReMIND, TAM-ECN and GCAM

Assumptions and constraints in scenarios

- Climate Policies (none, weak, moderate, strong)
- Demand-side technologies: high-, medium or low energy intensity
- Transport technologies

        - Conventional (liquid fuels)
        - Advanced (hydrogen and electricity)
    - Supply-side technologies:
        - No nuclear
        - No CSS
        - Limited renewables
        - Limited biomass
    - GDP growth: low, medium, high and 'high-conversion'
    - Fossil fuels reserves: low, medium, high and 'low oil'
    - Other assumptions: ensuring universal access, eliminating air pollution, import restrictions etc.

Future vital energy systems

- Energy security assessed at the global and regional (not national) level
- The present energy systems are supplemented by
    - Solar and wind for electricity generation
    - Hydrogen, synthetic fuels and liquid biomass as energy carriers

Sovereignty: global energy trade of the future

- **Without climate policies** global energy trade will dramatically increase, especially with respect to gas and coal
- The increase will be higher under high fossil fuel availability and high GDP growth assumptions
- **With climate policies** the increase will be much more moderate or absent. The trade under climate policies remains low even under high GDP growth or high fossil fuel availability
- No significant trade in biomass or hydrogen is expected even under strong climate policies

Sovereignty: importers and exporters

- Without climate policies the US is likely to become a major exporter and China the largest importer of fossil fuels
- With climate policies both 'traditional' and 'new' exporters will lose their revenues, but the significance and timing of this loss depend on many factors

Robustness: leaving resources in the ground

- In absence of climate policies the known oil reserves will be used up. (New technology
- With climate policies significant 'safety buffers' of all fossil fuels are left in the ground

Resilience: diversity of transport and electricity production

- Both with and without climate policies, the transport sector becomes less dependent on oil
- Under climate policies this change occurs earlier
- However, under climate policies some models project that electricity production may become entirely dominated by one technology (solar)

Nuclear energy, efficiency and energy security

- In 'no nuclear energy' scenarios energy security may suffer because of
  - high energy trade (if renewables are also limited)
  - low diversity of electricity production (if renewables are *not* limited)
- High diversity and low trade under all assumptions is possible only in scenarios with aggressive energy efficiency improvements.

Key messages and future research agenda

Key messages

- Defining energy security as '*low vulnerability of energy systems*' and taking into account the three perspectives on energy security allows assessing energy security at present and in the future;
- Climate policies would reduce global energy flows but may create new technological dependencies (e.g. in nuclear energy)

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Table 5
Selected energy security indicators in 2010, 2050 and 2100 in GEA pathways and the Baseline scenario.

Indicator	2010	2050		2100	
		Low-carbon	Baseline	Low-carbon	Baseline
total interregional trade	106 EJ	89–175 EJ	243 EJ	42–227 EJ	420 EJ
total interregional trade intensity	20%	10%–19%	21%	3%–18%	19%
Oil trade	82 EJ	21–71 EJ	135 EJ	0–8 EJ	179 EJ
Gas trade	9.4 EJ	28–68 EJ	47 EJ	7–98 EJ	94 EJ
Coal trade	1.1	0.8–1.1*	1.0	0.1–0.7*	0.8
Hydrogen trade	10 EJ	3–34 EJ	40 EJ	0–75 EJ	96 EJ
Geographic diversity of gas exports	1.6	1.4–1.5*	1.7	1.4–1.5*	1.6
Geographic diversity of coal exports	–	0–6 EJ	–	5–86 EJ	4
Geographic diversity of hydrogen exports	–	1.5–1.9*	–	1.1–1.6*	0
Electricity diversity	1.5	1.6–1.9	1.5	0.9–1.8	1.6
TPES diversity	1.7	1.8–2.1	1.7	1.1–1.9	1.8
Transport diversity	0.2	1.3–2.0	0.7	1.1–1.8	1.2

- * Only reports geographic diversity of exports for scenarios with high trade in that fuel or carrier (see Fig. 10).
- There would be winners and losers of strong decarbonisation policies

Future research questions?

- How does an energy *policy* issue becomes an energy security issue? (Leung et al In Press) - this can be explained by the theory of securitisation
- How are energy policy issues shaped by other national imperatives and capacities?
- What are the implications for politically realistic decarbonisation scenarios?

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