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Energy Security in Changing Energy Markets

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What is energy security?

- Linked to national security
  - Military forces are large consumers of energy
  - Imported energy supplies can be embargoed or interdicted
- Energy is essential to a modern economy
  - Applies especially to electricity supply
- Cost of energy is important to households
  - Energy consumption also yields high consumer surplus
- Energy price increases have negative macroeconomic effects
  - Energy is an essential input to almost all production

Measures of energy security

- Diversity of primary energy sources
- Share of energy sources that have more volatile prices
- Share of imports in total supply of each energy source
  - Re-processed nuclear fuel analogous to domestic supply
- Geographic concentration of major supply locations
- Share of exports of one energy commodity coming from unstable/potentially hostile countries
- Sensitivity of the macro economy to energy price shocks
  - Related to share of energy in GDP
- Energy density is relevant to many of these measures

Non-fossil energy critical mineral inputs kg/MW

Mineral	Wind turbines	Solar PV	Nuclear	Major supplying countries
Aluminum		100		Smelter prod. China (56%) India (6%) Russia (6%) Canada (5%)
Boron	1			Turkey (39%) US (23%) Chile (14%) Kazakhstan (10%)
Cadmium		40	0.5	Ref. prod. China (33%) S. Korea (20%) Japan (8%)
Chromium	800		427	S. Africa (39%) Turkey (23%) Kazakhstan (9%)
Copper	2000	2000	60	Chile (28%) Peru (12%) China (8%) US (6%) Congo (6%)
Gallium		3		China (97%)
Indium		50	2	Ref. prod. China (39%) S.Korea (32%) Japan (10%) Canada (8%)
Lead		250	4	China (47%) Australia (10%) Peru (6%) US (6%)
Manganese	50			S. Africa (29%) US (17%) Gabon (13%) Ghana (7%)
Molybdenum	120		70	China (45%) Chile (19%) US (15%) Peru (10%)
Nickel	600		256	Indonesia (30%) Philippines (16%) Russia (10%) Australia (7%)
Niobium			2	Brazil (88%) Canada (10%)
Rare earths	188		0.5	China (63%) US (12%) Myanmar (10%) Australia (10%)
Selenium		40		Ref. prod. China (33%) Japan (28%) Germany (11%)
Silicon		15		China (64%) Russia (9%) Norway (5%) US (5%)
Silver		12	8	Mexico (23%) Peru (14%) China (13%) Russia (8%)
Tellurium		50		Ref. prod. China (62%) Japan (12%) Russia (9%) Sweden (9%)
Tin		450	5	China (27%) Indonesia (26%) Myanmar (17%) Peru (6%)
Titanium			1.5	China (28%) S. Africa (12%) Australia (11%) Canada (9%)
Tungsten			5	China (82%) Vietnam (6%) Mongolia (2%)
Vanadium			0.5	China (55%) Russia (25%) S. Africa (11%) Brazil (10%)
Zinc	5200	30		China (33%) Peru (12%) Australia (7%) India (6%) US (6%)
Zirconium/Hafnium			32	Australia (39%) S. Africa (26%) US (7%)

Some issues related to the table

- Precise inputs depend on details of the technologies used
- Many of these minerals are co-produced with other commodities the main output
- Recycling could reduce geographic concentration of supply
- Wind and nuclear also require substantial steel and cement
- The above inputs relate to generation *capacity*
  - Nuclear also has fuel inputs, although minor relative to fossil fuels
  - Wind and solar capacity factors are low relative to nuclear
  - Wind and solar plant life spans are also much shorter
  - Constraining capacity construction is less serious than constraining energy production

Three key characteristics of wind and solar

- Non-dispatchability
  - The *value* of the produced electricity depends on demand whereas the supply from wind and solar depends on exogenous weather
    - Often the correlation with demand is *negative*
  - Without *reservoir-based* hydroelectricity, storage is expensive
    - Backup capacity from natural gas turbines is less reliable/capable
  - Extra generating capacity can reduce capacity factors
- Intermittency
  - Frequency, voltage, reactive power must always be controlled
  - Rapid ramp-up capacity costs more than intermediate or base load
- Location of utility-scale facilities is often remote from the load
  - Long transmission links used at low capacity factors are expensive and more vulnerable to disruption

Average price effects of wind and solar

- General experience: Higher wind and solar generation has been associated with higher average retail electricity prices
  - Since these are zero marginal cost suppliers that might seem surprising
  - Indeed, subsides and mandates that apply to *production* appear to have resulted in occasional negative wholesale prices
- Some explanations for the paradox:
  - Costs of subsidies, mandates, and transmission expansions are covered by levies on electricity consumers
  - Increased need for backup that then is not used at high capacity factors
  - Extra generation in low demand periods disadvantages baseload generators
  - Likewise, wind and solar favor open cycle natural gas plants relative to combined cycle plants, but the former haver higher marginal cost
  - Covering fixed costs via volumetric charges encourages inefficient investments in rooftop PV, raising costs for those "left behind"

Larger electricity price fluctuations

- When renewable capacity is the marginal supplier, wholesale prices can be zero or negative as already noted
- At other times, prices are determined by the *net* load on the thermal system
  - Net load = total load – exogenous supply from wind and solar
- High variance exogenous output from wind and solar then leads to more variable net load on the thermal system
  - The result is much higher price variability

Transitioning other energy uses to electricity

- In 2018, the electricity sector:
  - Globally: consumed around 27.1% of primary energy and supplied around 23.7% of final energy consumption
  - OECD: consumed around 28.4% of primary energy and supplied around 26.5% of final energy consumption
- Other major uses were transportation, industry and agriculture, space heating and water heating
- Electricity generation typically relies on more primary energy sources than these other end-use sectors
- But transitioning these other uses to electricity would likely decrease the *overall* diversity of primary energy sources
- The electricity network may also be more vulnerable to physical and cyber attack than distributed physical supply points

Links back to dimensions of energy security

- National security:
  - Reliance upon supply of critical minerals, but the energy *source* is domestic
  - Vulnerability of the electricity supply network
- Maintaining a physical supply:
  - Increased risk of blackouts in a less stable electricity supply system
  - Possibly less diverse source of primary energy inputs
- Cost of energy:
  - Effects of renewables with backup/storage on average electricity prices
- Economic instability from energy price changes:
  - Increased variability of electricity prices
- Final comment:
  - Energy security is not the only issue we care about

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