How should we think about the future of energy?

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How should we think about the future of energy?

1. Projected world energy demand growth
2. Qualitative characteristics of energy sources
3. Energy density
4. Energy security
5. The “valley of death” for new energy technologies
6. Is the current energy policy sustainable?
7. But what about CO2?

Projected world energy demand growth

- All energy demand projections forecast continuing strong world energy demand growth
- Key explanation: High population developing countries entering the “take-off” phase of economic growth
  - Modernization of agriculture
  - Urbanization
  - Industrialization
  - Infrastructure development
  - Increasing per capita energy demand is then translated into strong total energy demand growth

Desirable characteristics of energy sources

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- An abundant supply of *high-quality* energy is indispensable to a modern lifestyle
- Desirable characteristics of energy sources
  - Affordable
  - Reliable
  - Controllable
  - Storable
  - Transportable
  - Versatile
  - Environmental externalities
  - Energy security implications
- Currently, fossil fuels score more highly on many of these dimensions than do the alternatives
- The main criticism of fossil fuels relates to their emissions
  - Control technologies have substantially mitigated the problem of conventional toxic flow pollutants
  - We return to CO_2 at the end of the discussion

Energy density

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- Volumetric and gravimetric energy density can significantly affect the desirability of different energy sources
  - These affect the explicit costs of inputs:
    - labor, capital, minerals, land, water, transport services, etc
  - And the implicit costs of externalities
    - the costs of emission, accident, etc
  - *Per unit of energy services supplied*
- One reason for the high value of liquid hydrocarbons, especially for transport applications, is their relatively high volumetric and gravimetric energy density
- To support billions of people living a modern lifestyle, sources with high energy density will be essential

Energy security

- Energy security can be identified in part with national security concerns:
  - Reliance on countries that are politically unstable or geopolitical adversaries for energy resources
  - A need to defend vulnerable transport links for the import of essential energy sources
  - The reliance of modern military forces on substantial volumes of refined oil products
- Energy security also has economic dimensions:
  - Many recessions have been linked to sudden, large increases in energy prices
  - Higher prices and reduced growth from energy supply shocks raise difficult trade-offs for monetary policy
  - Higher energy prices also increase financial flows from net importers to net exporters of energy commodities
  - Energy price variability deters investment by increasing uncertainty about future energy prices
- Many measures to increase energy security are *public goods*

The "valley of death" for new energy technologies

- The "valley of death" for new energy technologies
    - A valley of death was thought to be a problem for *all* new technologies with high R&D requirements
    - This seems to be an issue for energy technologies, but not IT or pharmaceuticals, for example
    - Key distinction: Substantial additional investment is required to *deliver* energy services to customers *after* the R&D phase
- More general point:
    - The most successful new energy technologies are probably going to use a lot of existing infrastructure

Is current energy policy sustainable?

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- Current policy *assumes* a renewables/batteries-only system is the long-run target, but is that likely?
- Frequency control:
  - In traditional power systems, synchronized rotating turbines with high inertia resist short-term fluctuations in frequency
  - Wind, solar, and battery systems convert DC-generated power into AC using grid-following inverters
  - Micro-grids have a grid-forming inverter that can be transformed to and from grid-following mode (so the micro-grid can be “islanded”), but can multiple grid-forming inverters be synchronized into a reliable and resilient system?
- Wholesale market operation
  - Extra renewable generation operates at similar times to existing capacity, requiring expensive excess capacity, long-term storage and/or curtailment
  - If all supply has zero marginal costs, a competitive market will lead to zero prices most of the time, making it difficult to pay for fixed investment costs
  - Low elasticity of electricity demand can produce extraordinarily high prices when capacity constraints bind, but capping wholesale prices exacerbates the missing money problem
- Not all uses of energy can be electrified
  - Prominent examples may include aviation and many high-temperature industrial processes

But what about CO_2?

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- Contrary to popular sentiment, CO_2 is not the primary, let alone the sole, issue determining the future of energy
  - High-population developing countries will likely become more concerned about environmental issues, but conventional toxic flow pollutants will be their first concern, not CO_2
  - With them not controlling CO_2 emissions, what the developed countries do does not matter for CO_2 accumulation
  - Many anthropogenic and natural causes change climates, while *existing* climates have many extreme weather events
  - CO_2 is not directly hazardous, has positive externalities for plant growth, including agriculture, while changes in some climates resulting from increased temperatures are likely to be positive
  - Many uncertainties impede the effectiveness and therefore the desirability of a policy of reducing CO_2 emissions
- An alternative set of policies involves public defensive measures to reduce the harmful consequences
  - Global agreement is not required to implement these
  - Each country can tailor measures to the risks it faces, making the policies potentially much more effective
  - Public defensive measures allow retention of any beneficial effects from increased CO_2 accumulation
  - Some public defensive measures also reduce the costs of events unconnected to weather, such as volcanic eruptions, tsunamis, industrial accidents, terrorist attacks, or pandemics
  - Public defensive measures do not increase energy costs, and do not impinge on energy security
  - By reducing the costs of *current* extreme weather events, they begin yielding benefits immediately

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