Energy Perspectives on Sustainability

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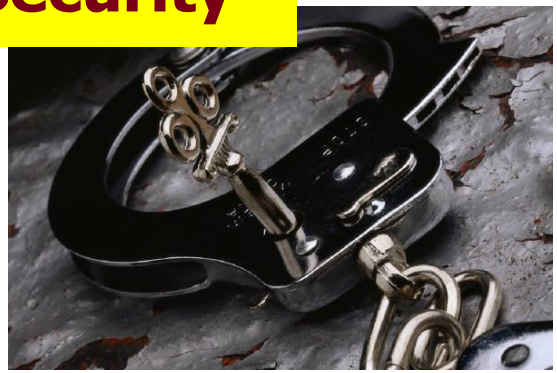
The Perfect Storm

Supply

- Energy supply and demand
- Energy and security
- Energy and the environment

Security



Impacts

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- Energy supply and demand
  - 450 EJ/year (14.2 TW)/16 T kWh-electric/year
  - Projected doubling of energy use and tripling of electricity use by 2050 in business as usual
  - 1.4 Billion people without electricity in 2030
  - 80+% fossil fuel/enough oil?
  - 50 year time scale for major shifts in energy

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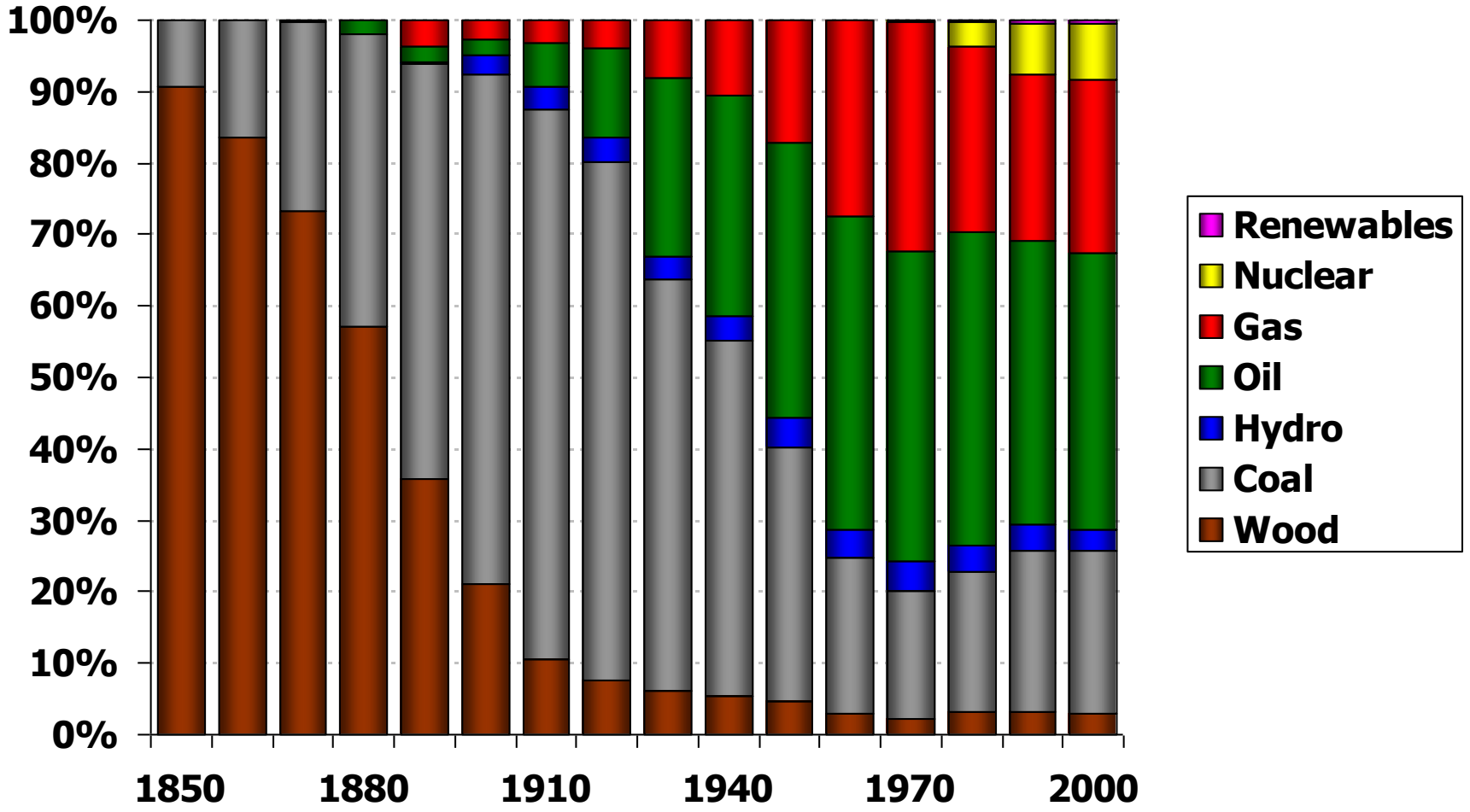
US Energy Supply Since 1850



Author: Koonin

Source: EIA

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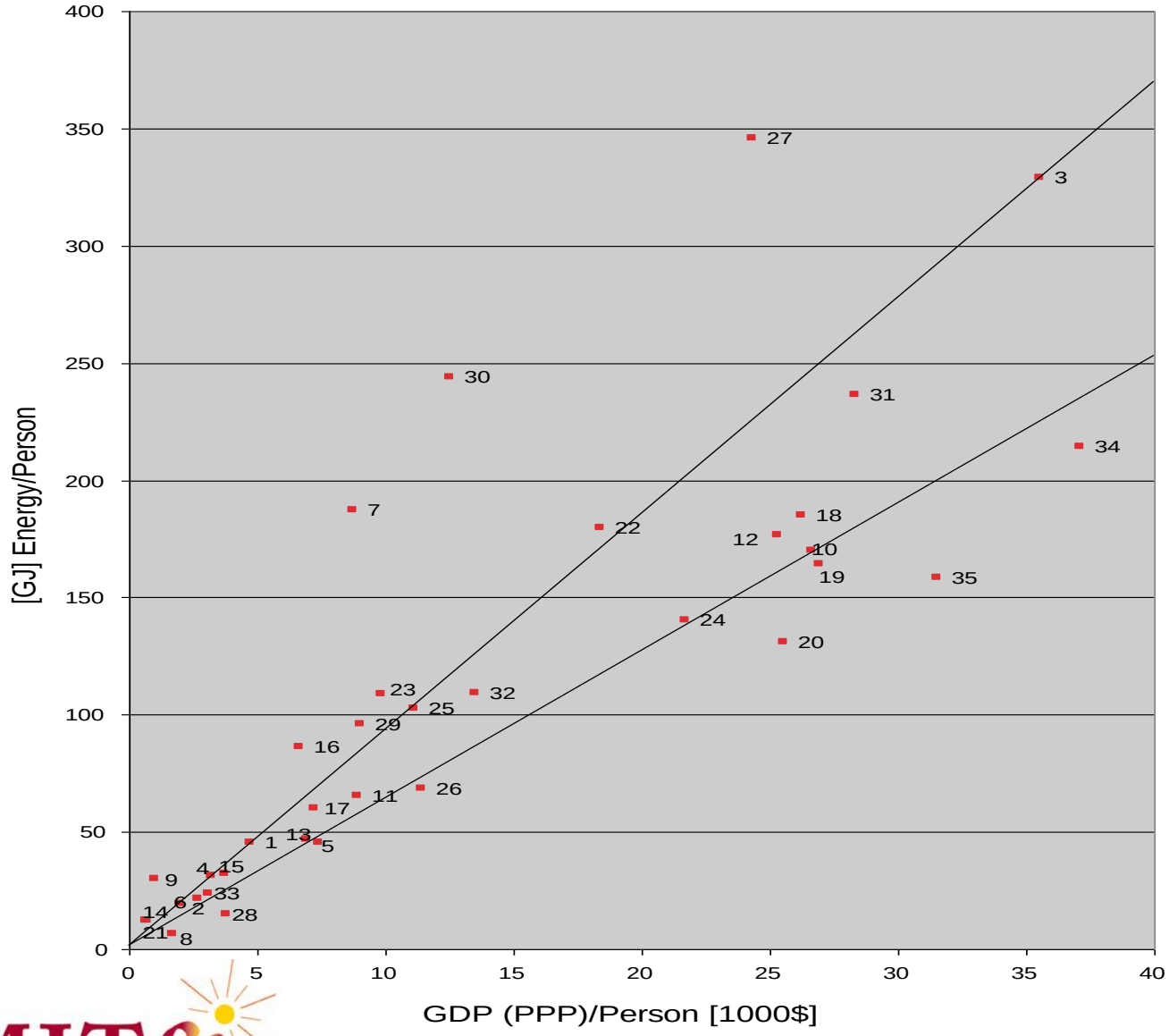
Primary Energy Use Per Person



1 China
2 India
3 US
4 Indonesia
5 Brazil
6 Pakistan
7 Russia
8 Bangladesh
9 Nigeria
10 Japan
11 Mexico
12 Germany
13 Turkey
14 Ethiopia
15 Egypt
16 Iran
17 Thailand
18 France
19 UK
20 Italy
21 Dem Rep. Congo
22 South Korea
23 South Africa
24 Spain
25 Poland
26 Argentina
27 Canada
28 Morocco
29 Malaysia
30 Saudi Arabia
31 Australia
32 Hungary
33 Nicaragua
34 Norway
35 Ireland

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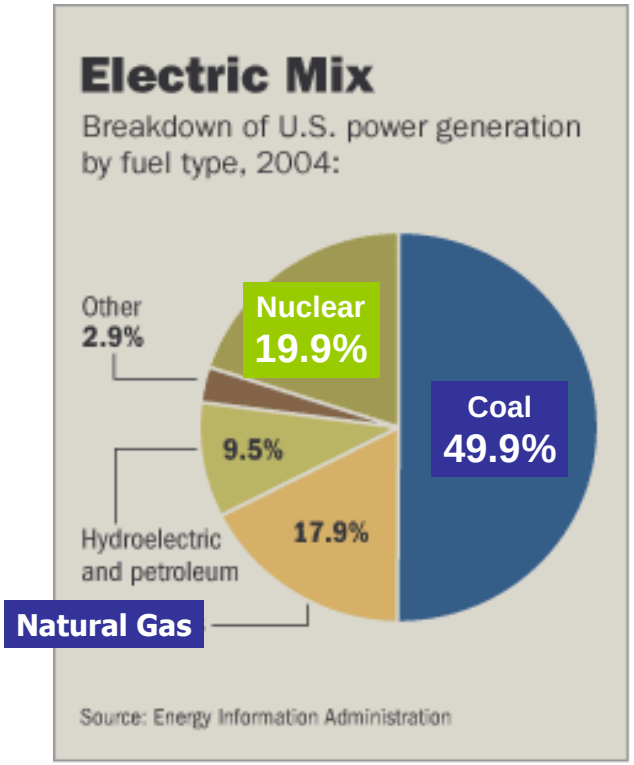
Scale Issues –Magnitude of Problem

- World wide consumption of oil ~ 1000 barrels per second
- CO2 emissions from coal is ~9 Giga Tons per year
- China currently building the equivalent of two 500 MW power plant per week
- China growth rate for coal consumption is twice the US rate
- Time constant for energy infrastructure changes in the US is O(50 years)
- Average age of US power plants is over 30 years



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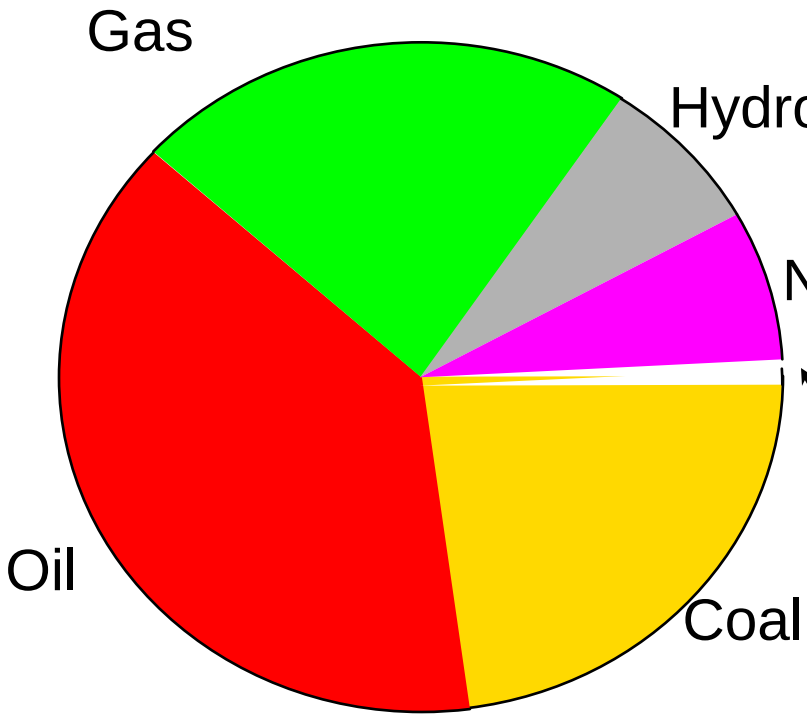
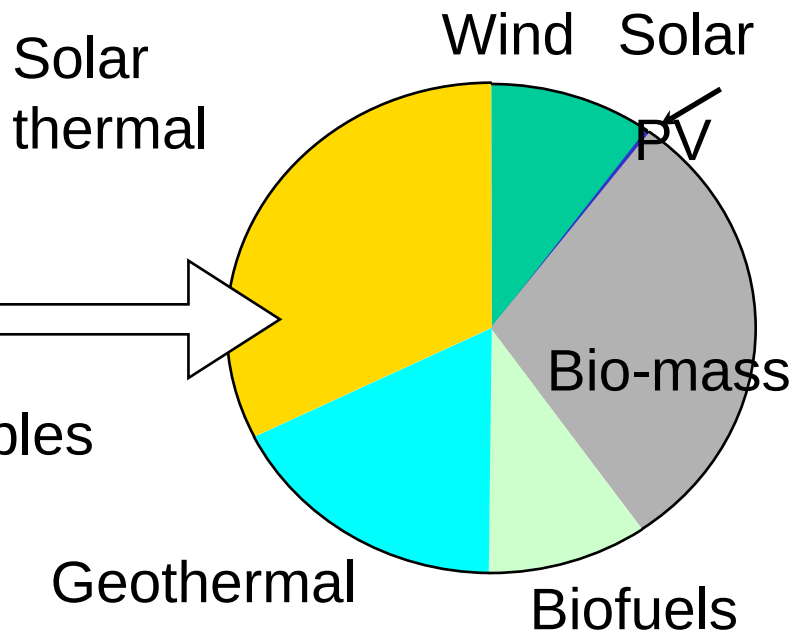
Scale Issues –Renewable Sources

Total primary energy: 410 EJ/year



Renewables: 4 EJ/year



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The "Perfe

- Energy and security
  - Geological and geopolitical realities of oil and gas supply
  - Oil (and natural gas) adequate and reliable supply
  - Vulnerability of extended energy delivery systems
  - Nuclear weapons proliferation facilitated by worldwide nuclear power expansion
  - Dislocation from environmental impacts, such as from climate change

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Oil and Energy Security

- Core Issue: inelasticity of transportation fuels market, together with geographical and geophysical realities of oil
- Addressing sudden disruptions
  - Strategic reserves
  - Well-functioning markets
- Increasing and diversifying supplies
  - Enhanced production from existing fields
  - Arctic E&P
  - “Unconventional” oil (tar sands,…)
- Weakening the “addiction”
  - Very efficient vehicles
  - Alternative fuels (coal, NG, biomass)
  - New transportation paradigm (electricity as “fuel”? H2?)

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The "Perfe

- Energy and environment
  - Risk of climate change
  - 50+ years of CO_2 "emissions budget"
  - "De-carbonizing" of energy?

Climate Change Technology/Policy Pathways

- Efficiency
- Low carbon or “carbon-less” technologies/fuels
  - Fuel switching, e.g., coal to natural gas
  - Nuclear power (fission, possibly fusion in long term)
  - Renewables (wind, geothermal, solar,…)
    - Note: scale matters
- Carbon dioxide capture and sequestration

Climate control policy is not new. As early as 1306 Edward I of England prohibited the burning of coal in craftsman’s furnaces. Later Elizabeth I banned burning of coal in London while Parliament was in session.

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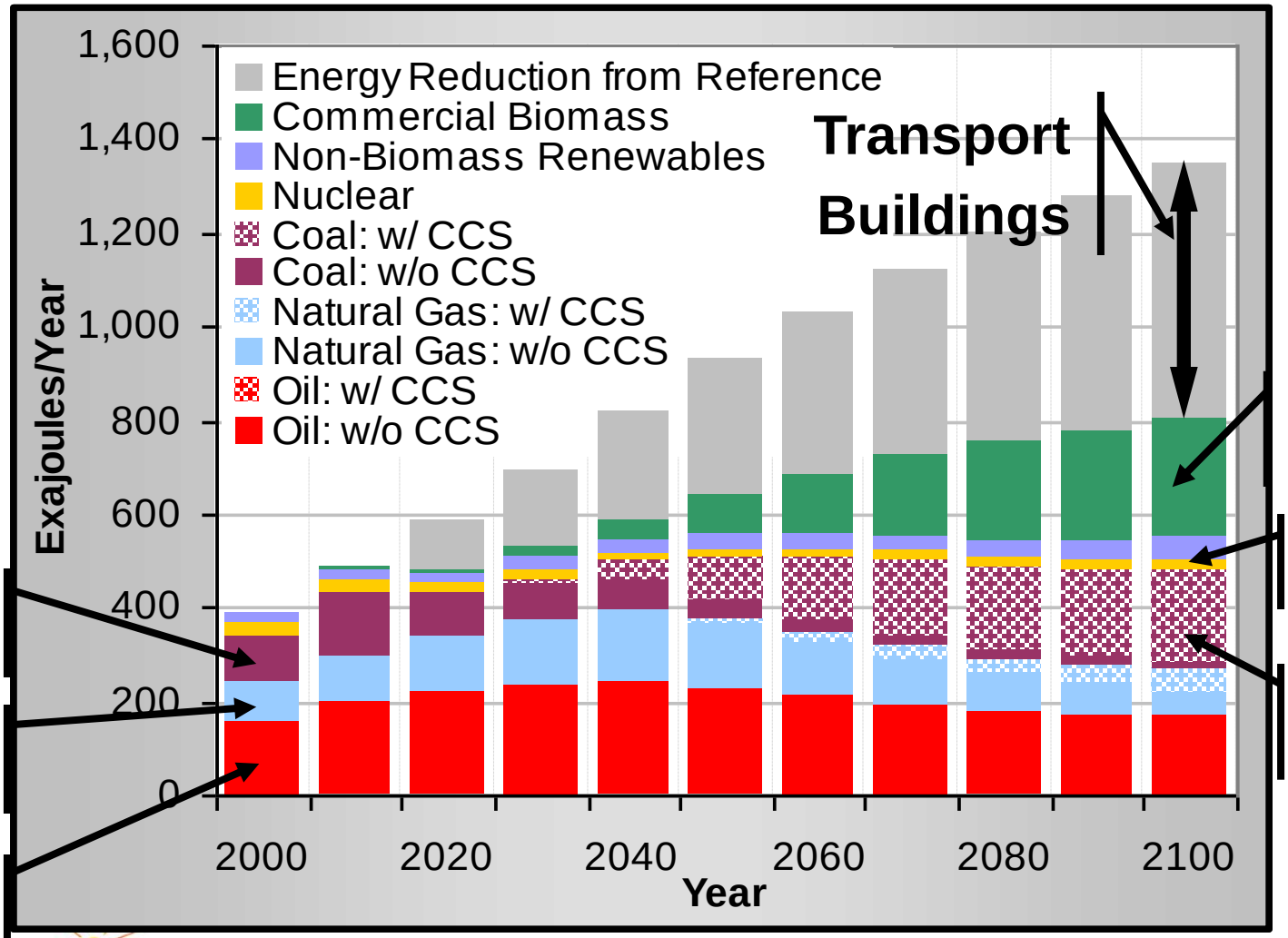
Global Primary Energy: 550 ppmv



Major technology and policy challenges to realization of this scenario - scale

Capture and sequestration of about 15 billion tonnes of CO_2 per year

- Billion barrels/50 yrs for 600 MWe
- About 200 million barrels/day of supercritical CO_2
- Alternatives? Nuclear, wind, solar,….

About 50 million barrels/day of biofuels (3.5 TW)

- Systems challenges (land, water, fertilizer,…)?
- Alternatives? Hybrids, electric vehicles, fuel cell vehicles/H2,…

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Uncertainty on a 50-year Time Scale

- Future scenarios highly uncertain on mid-century time scale
  - 50-year time scale characteristic of significant change in energy infrastructure, of greenhouse gas concentrations approaching twice pre-industrial,…
- Multiple uncertainties
  - Resource availability?
    - fossil fuels, land for renewables, effects of renewables at scale…
  - Science and technology advances?
    - technology breakthroughs, climate change impacts
  - Geopolitical considerations?
    - Middle East, climate protocol participation,…
- Broad response pursuing multiple technology and policy options is needed

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Key Technology Pathways

- Efficiency (buildings & cities, vehicles & transportation systems, supply chains, industrial processes)
- Alternative transportation fuels (biofuels, electricity, H2?)
- C-”free” electricity (nuclear, coal+CCS, renewables/solar)
- Unconventional hydrocarbon supply (EOR, heavy “oil”, ultradeep)
- Energy delivery systems (storage, high quality power, distributed generation)
- “Managing” global change (mitigation, adaptation, atmospheric “re-engineering”)

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Closing Thoughts

- This is an enormous problem both in magnitude and time scale
  - To provide 14 TW of carbon-free power by 2050 from nuclear sources
    - ~ 1 GW power plant needs to be built per day
    - What do we do with the nuclear waste?
  - A variety of technology options are needed
  - We must start now
  - At these magnitudes we must do our best to assess impact on our environment before we commit

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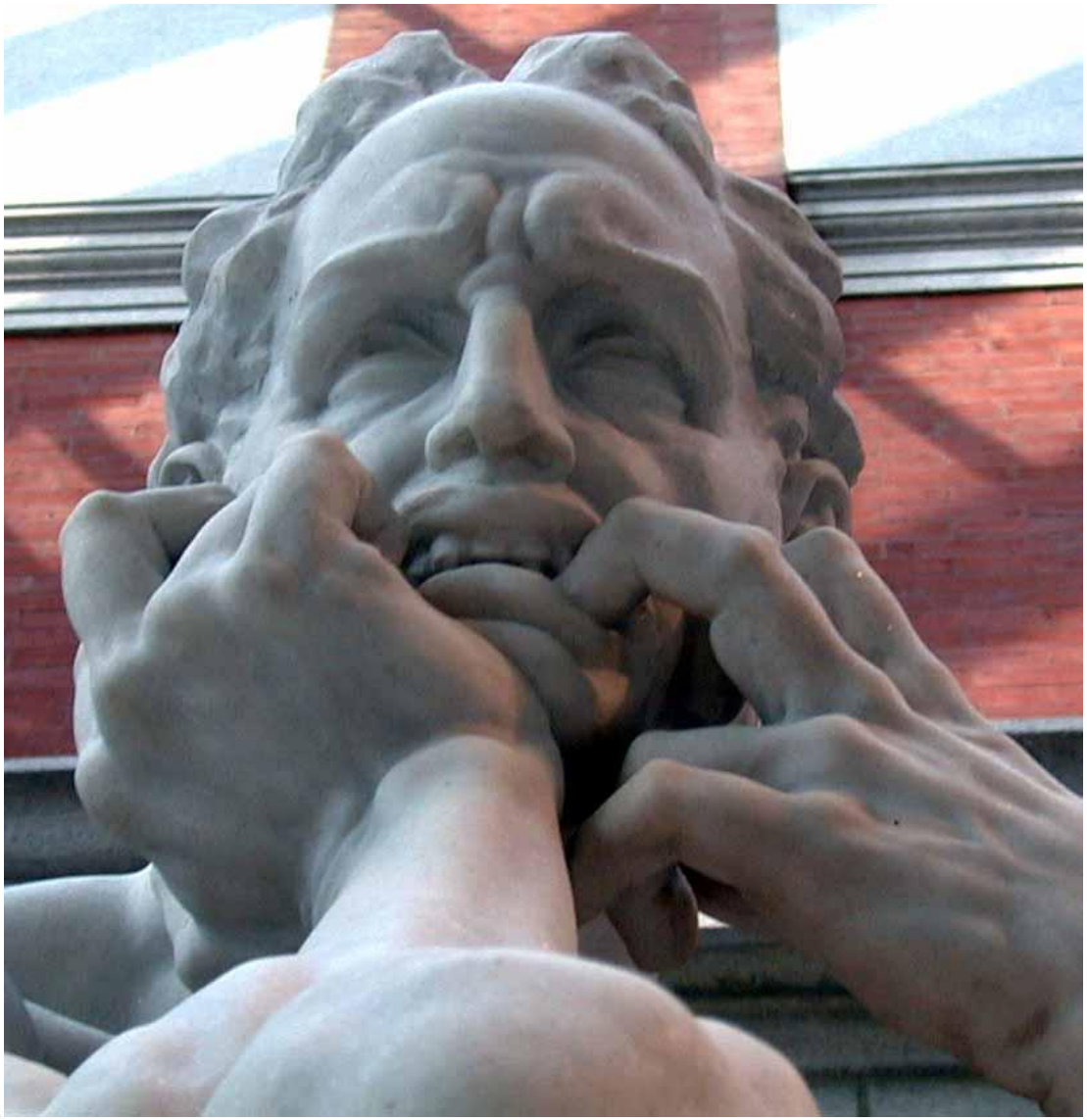

Thank You

Questions?