Technology Session 2: Operations and Planning

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Future Grid Forum
June 27-28, 2012
Washington D.C.

Outline

- Operational challenges
- Planning challenges:
  - Planning via rolling 100-year explorations
  - Multi-sector modeling to capture interdependencies
  - Multiobjective assessment
  - Resilience metric: op-cost increase to events
  - Flexibility metric: adaptation cost
  - Handling uncertainty
  - Public education and policy
- Concluding comment

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Operational challenges

- Frequency, regulation, load following, reserves:
  - What, besides UFLS settings, drives the need for bounding frequency deviation and duration?
  - How to properly evaluate cycling of fossil-fired units?
  - How to determine the right portfolio of ramping capabilities?
  - What technologies should be used: CTs, wind/solar, demand-side, storage, HVDC?
  - How should markets be designed to achieve the above?
  - What should be the size of the balancing area?
- Monitoring and controlling system stress:

  ➔Need "lever" to smoothly control system stress (controlling flows exceeding limits does not accomplish this)
- Capability to respond to high-consequence events

  ➔Need software to provide decision support for operators.

  ➔Need to account for "cost" of excessive technological complexity.

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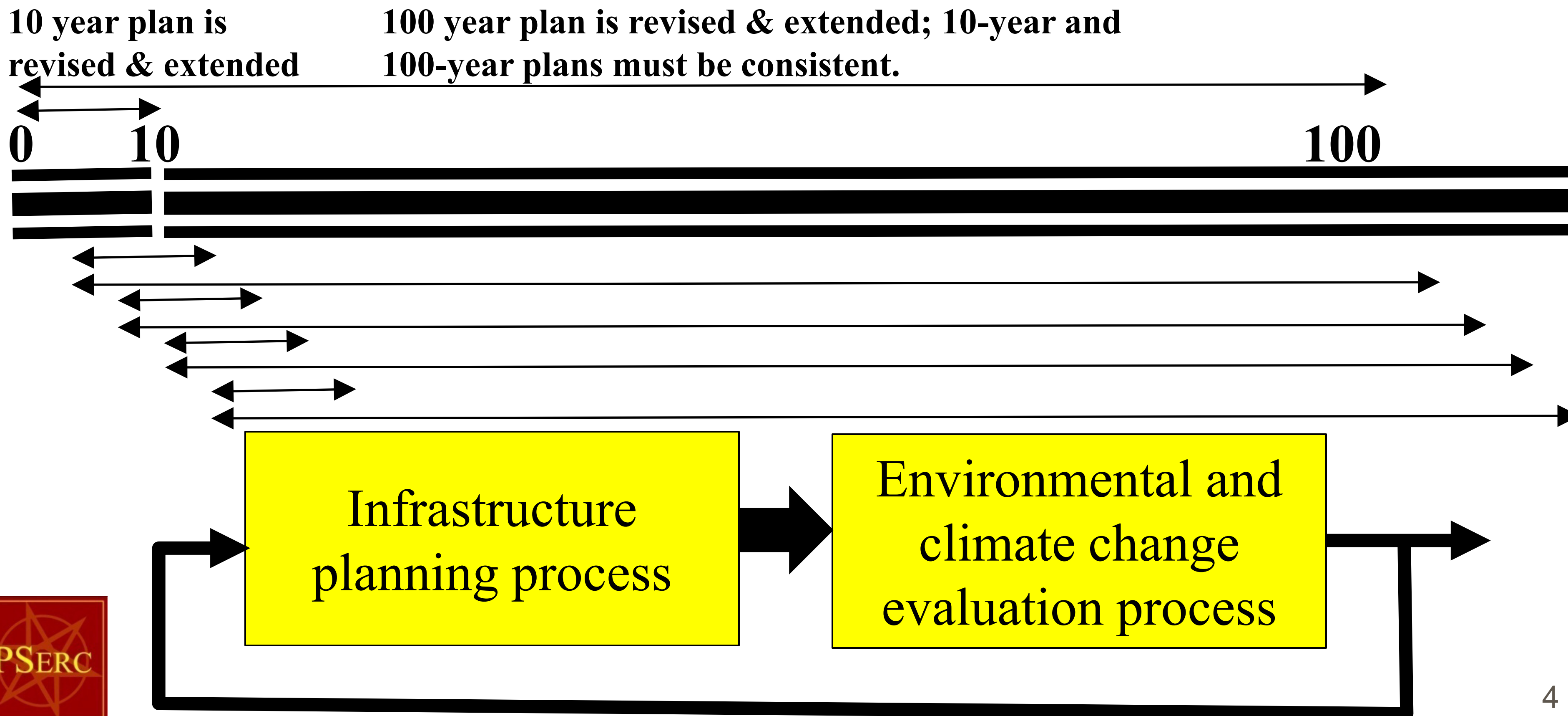
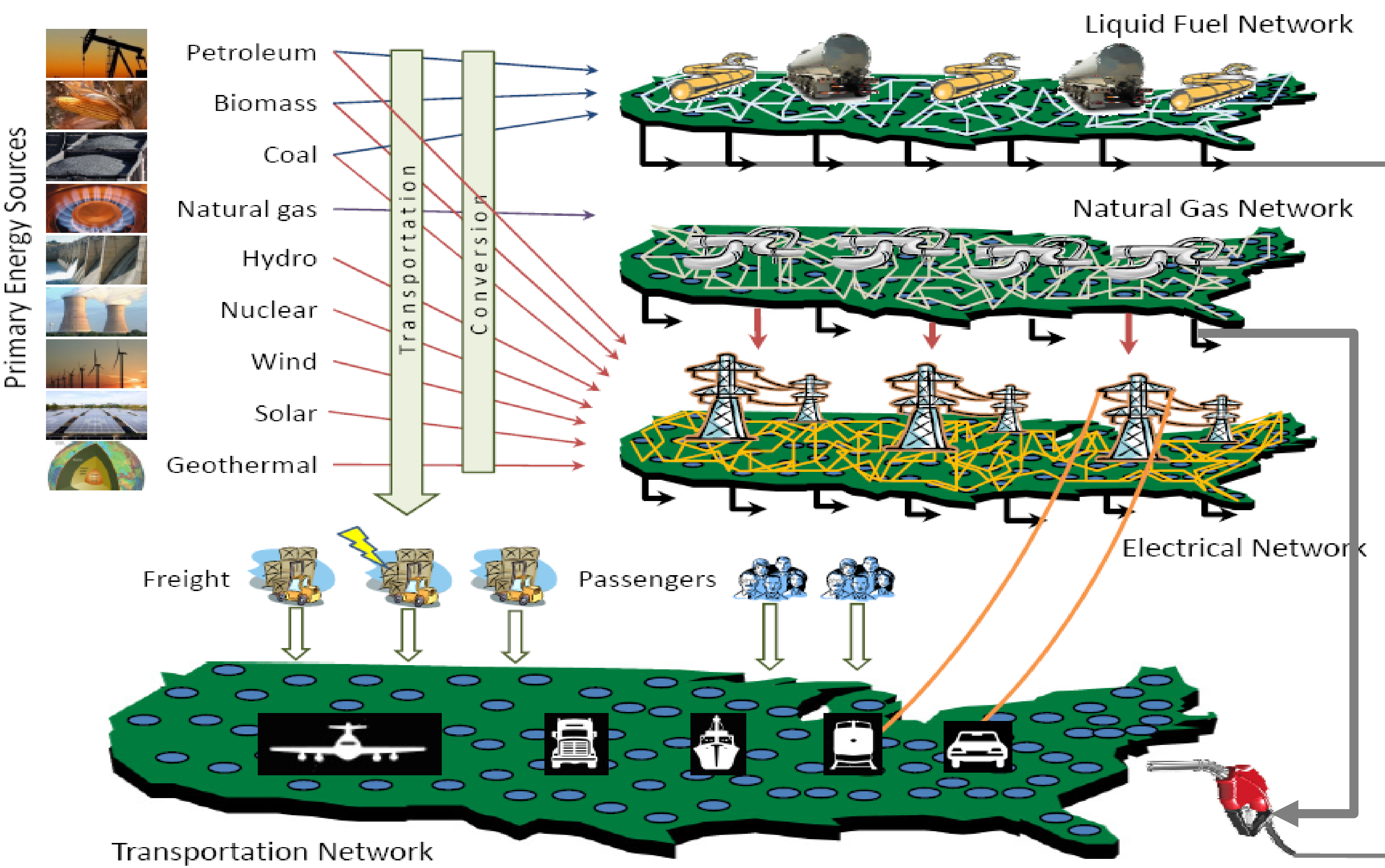
Planning via rolling 100-year explorations

- Equipment lives 40-70 years
- Greenhouse gas effects on climate take decades
- Major infrastructure build requires 5-10 years



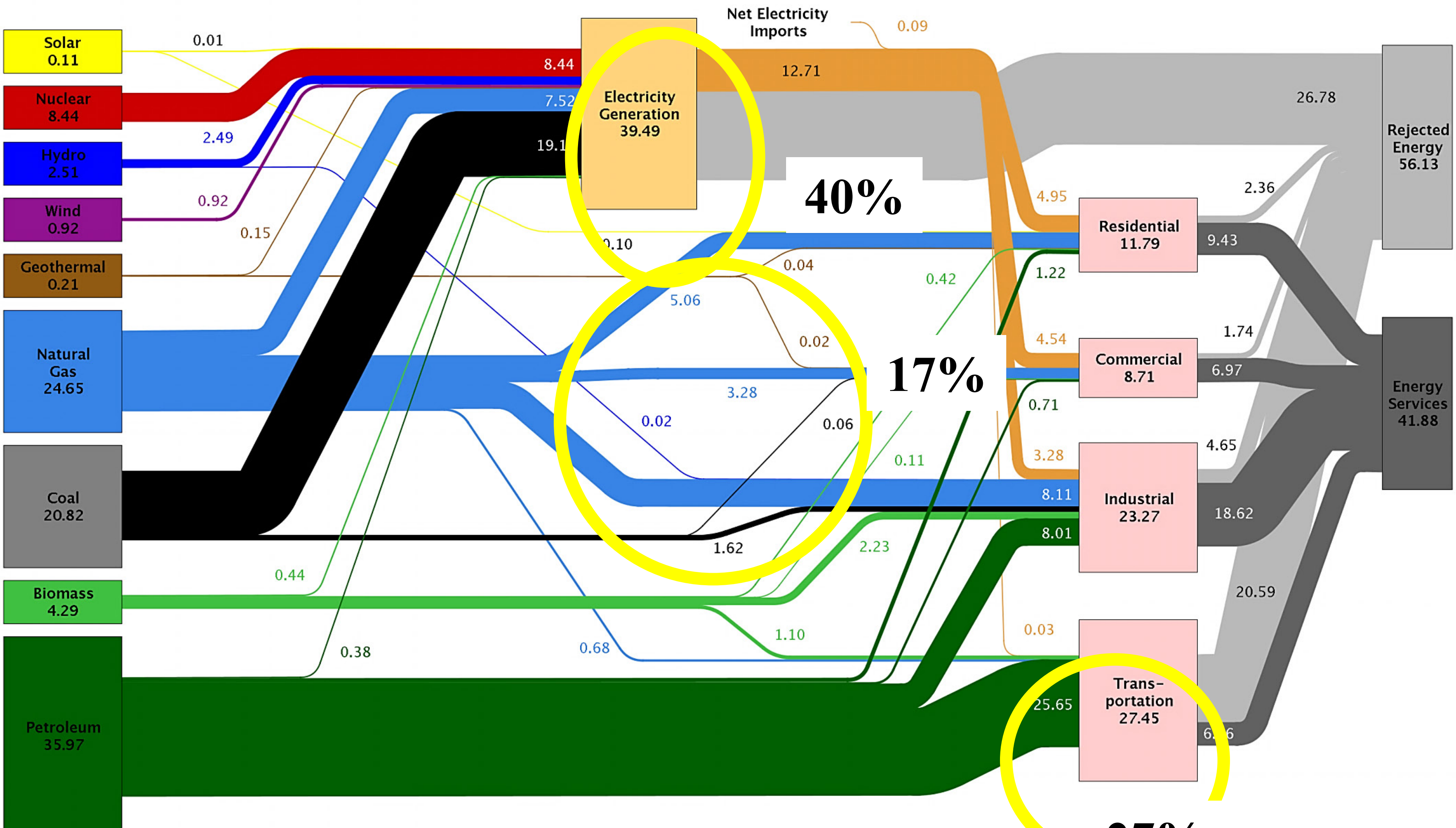
Multi-sector modeling to capture interdependencies



Multi-sector modeling to capture interdependencies

Sankey diagram **Estimated U.S. Energy Use in 2010: ~98.0 Quads**

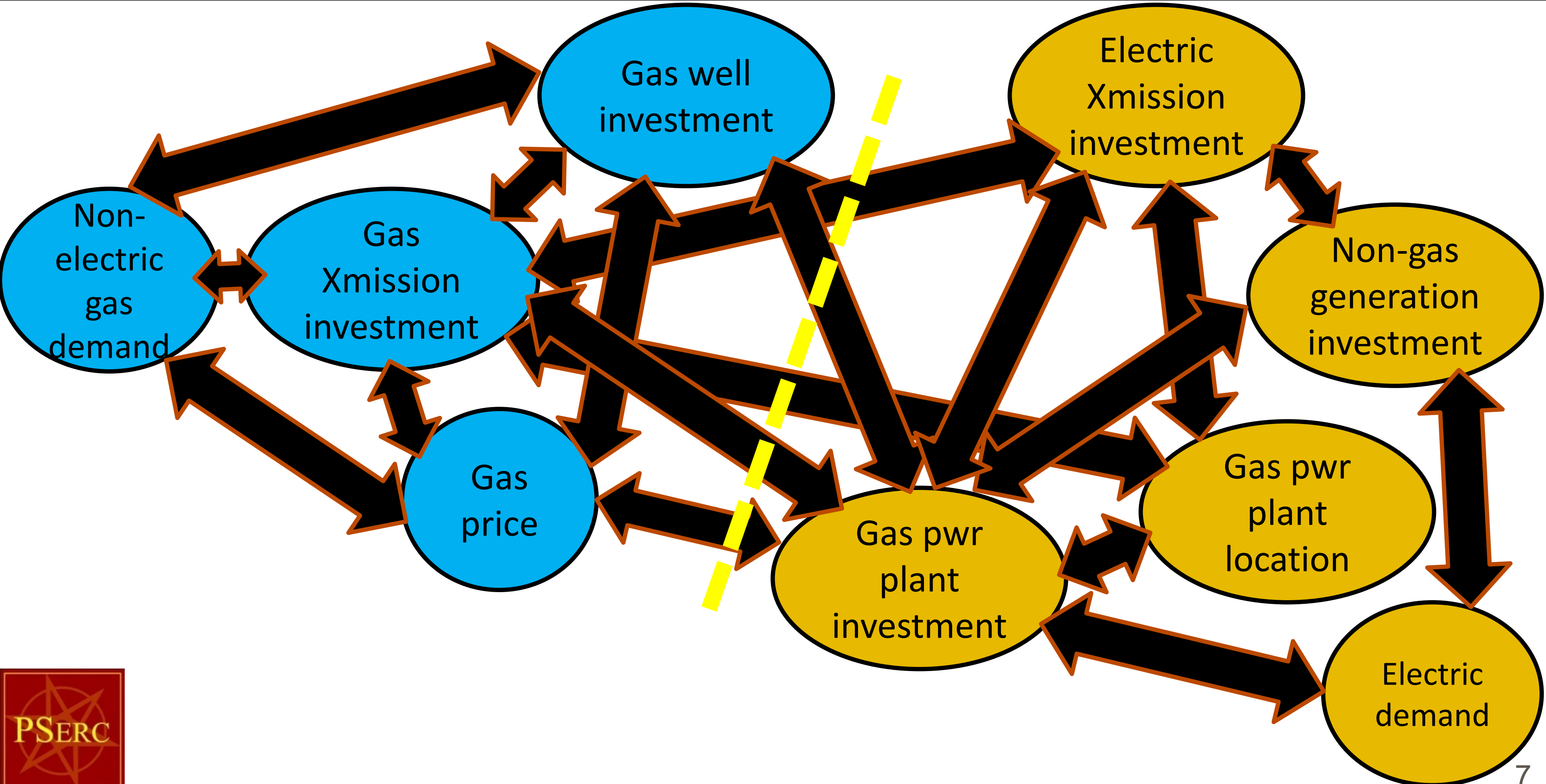
Lawrence Livermore National Laboratory



Source: LLNL 2011. Data is based on DOE/EIA-0384(2010), October 2011. If this information or a reproduction of it is used, credit must be given to the ... ational Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and do... neration. EIA reports flows for hydro, wind, solar and geothermal in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." (see EIA report for explanation of change to geothermal in 2010). The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Multi-sector modeling to capture interdependencies

Cooptimized analysis informs investment decisions on bulk electric & natural gas systems, accounting for interdependencies between them.



Multi-sector modeling to capture interdependencies

- Food, water, biofuels and steam power plants:
  - Water withdrawal=41/39% agrcltre/power; consumption=85/3%. How to utilize our limited land / water resources to achieve good balance between energy production & human consumption?
- Passenger transportation and energy:
  - What is the best technology portfolio (ICE, PHEV, CNG, metro-rail, high-speed rail) & fuel portfolio (petroleum, electric, natural gas, and biofuels) for future passenger transportation systems?
- Freight transportation and energy:
  - How should location of electric resources and transmission be balanced with the cost and impact of transporting fuels?
  - Are there attractive combinations of geographic relocation for energy-intensive industries AND growth in technology / location of electric infrastructure? Could reduction in coal usage free freight transport to move products of relocated industries?

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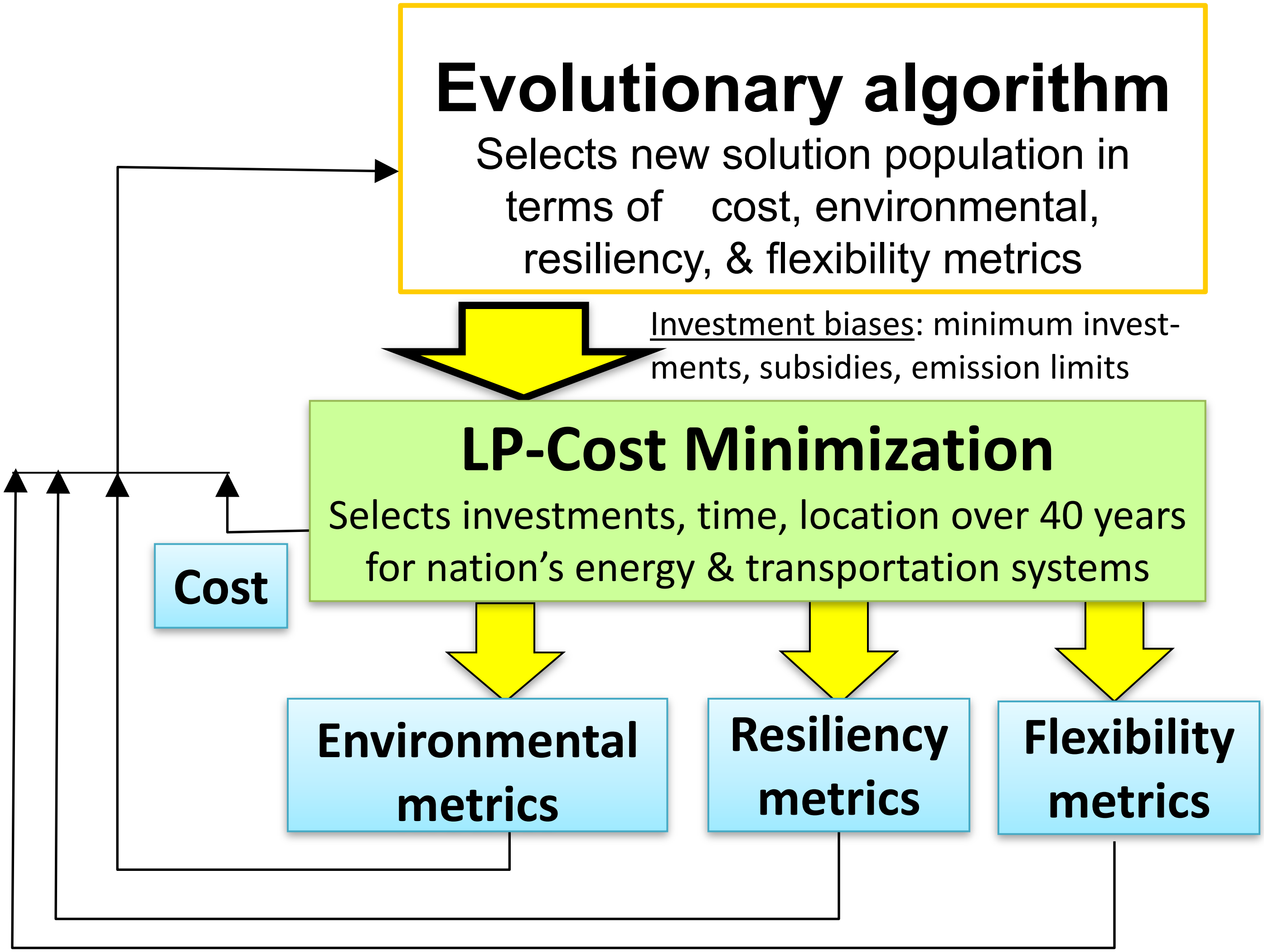
Multiobjective assessment



➔FINDS SOLUTIONS WITH GOOD TRADEOFFS BETWEEN DIFFERENT METRICS.

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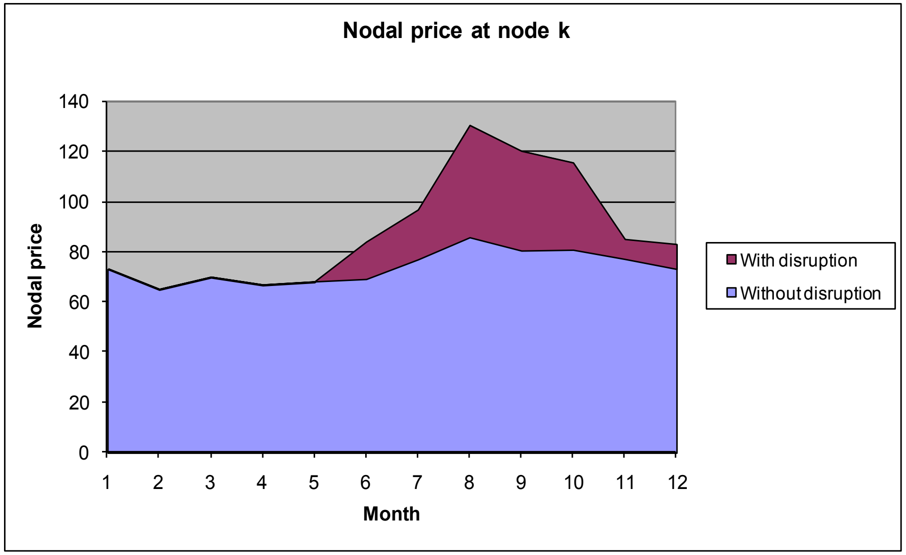
Resilience metric: op-cost increase to events

Resilience: Ability to minimize & recover from event consequences.

Concept: Consider events and consequences exhibiting measureable changes with design variation.

Perspective: 40yr, national multisector model.



Extreme Events:

Six month loss of rail access to Powder River Basin coal;
One year interruption of 90% of Middle East oil;
Permanent loss of U.S. nuclear supply;
Six month interruption of Canadian gas supply;
One year loss of U.S. hydro resources due to extreme drought;
Sustained flooding in the Midwest that destroys crops, reducing the availability of biofuels, and interrupts key corridors of east-west railroad system.

Consequences: Increase in 1-year operational costs.

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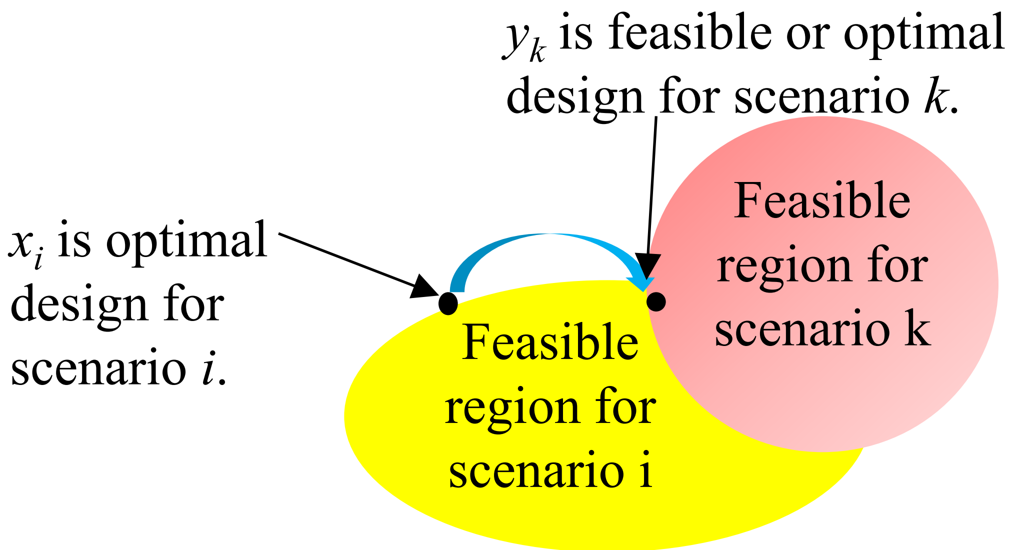
Flexibility metric: adaptation cost

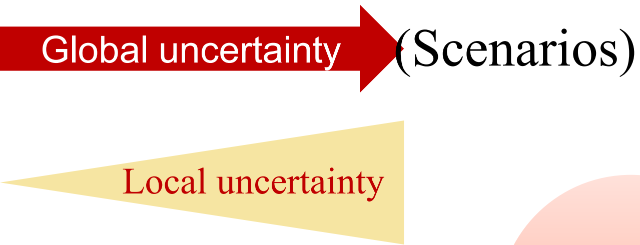


The <u>adaptation cost</u> of x_i if scenario k happens is the minimum cost to move x_i to a feasible or optimal design y_k in scenario k. It measures the cost of a wrong decision: we planned for scenario i but scenario k happened.

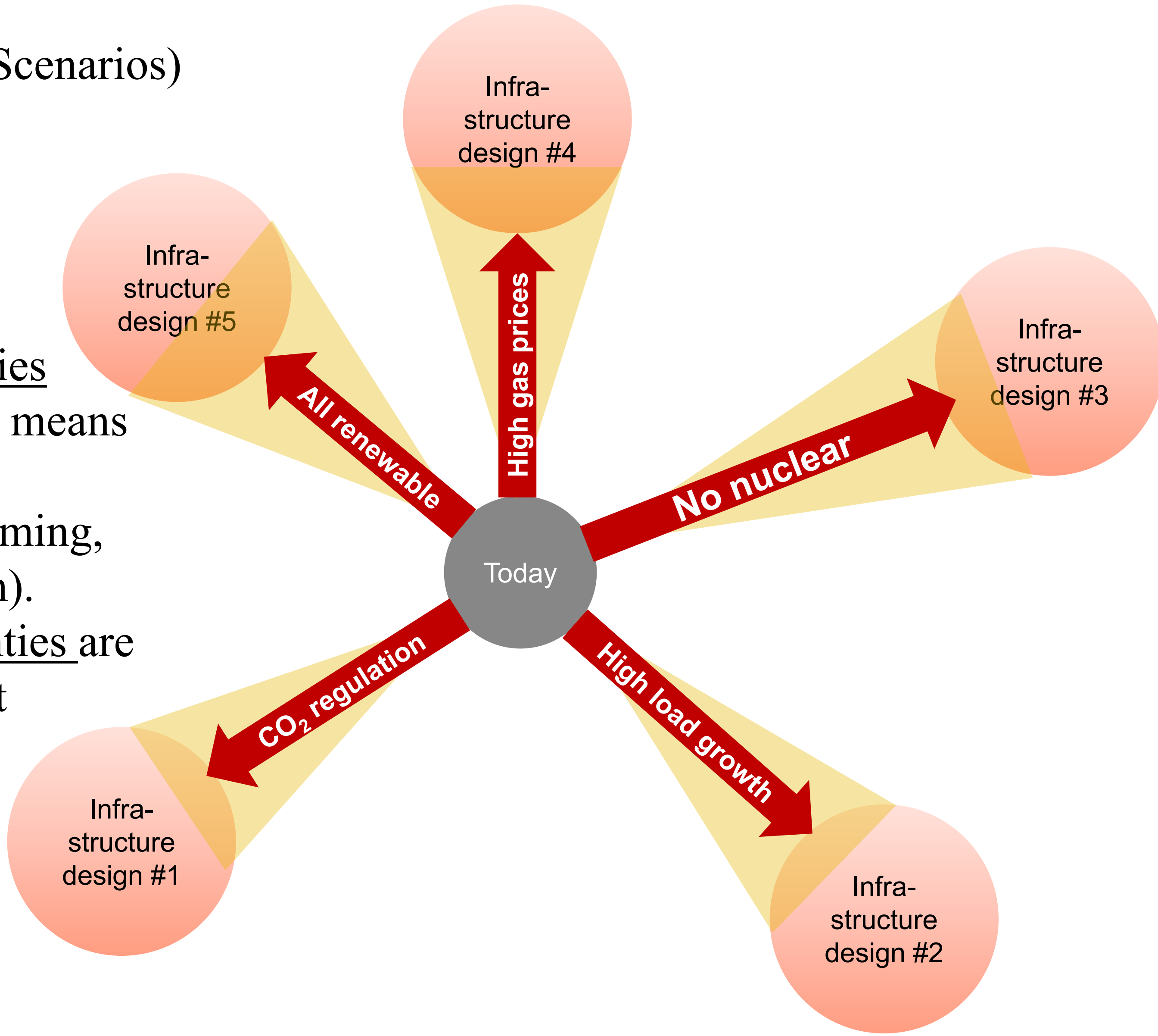
The most flexible plan is the x_i that minimizes the sum of all adaptation costs over all scenarios, i.e.,

$$\text{Find } x_i \text{ such that } \sum_{\text{Scenarios } k \neq i} AdaptationCost(x_i \text{ to } y_k) \quad \text{is minimum.}$$

Handling Uncertainty



1. Local uncertainties handled by various means (e.g., Monte Carlo, stochastic programming, robust optimization).
2. Global uncertainties are explored as distinct scenarios.



Public Education and Policy

*2006 survey:

What is the impact of nuclear power plants on CO_2 emissions?

80% got it wrong

**2008 survey:

Which costs more today: electricity from wind turbines or electricity from coal-fired plants?

82% got it wrong

#2009 survey (women):

67% identify coal power plants as a big cause or somewhat of a cause of global warming, 54% think the same about nuclear energy;
43% don't know that coal is the largest source of US electricity.

##2003, 2007 survey:

For both survey years, "People see alternative fuels (hydro, solar, wind) as cheap and conventional fuels as expensive."

*T. Curry, et al., "A survey of public attitudes towards climate change and climate change mitigation technologies in the United States: Analyses of 2006 Results," Publication LFEE 2007-01-WP, MIT Laboratory for Energy and the Environment.
#M. D;Estries, "Survey: Women fail on energy knowledge," July 3, 2009, report on a survey commissioned by Women Impacting Public Policy and Women's Council on Energy and the Environment.
**H. Klick and E. Smith, "Public understanding of and support for wind power in the United States,"Renewable Energy, Vol. 35, July 2010, pp. 1585-1591.
S. Ansolabehere, "Public attitudes toward America's energy options," MIT-NES-TR-008, June 2007.

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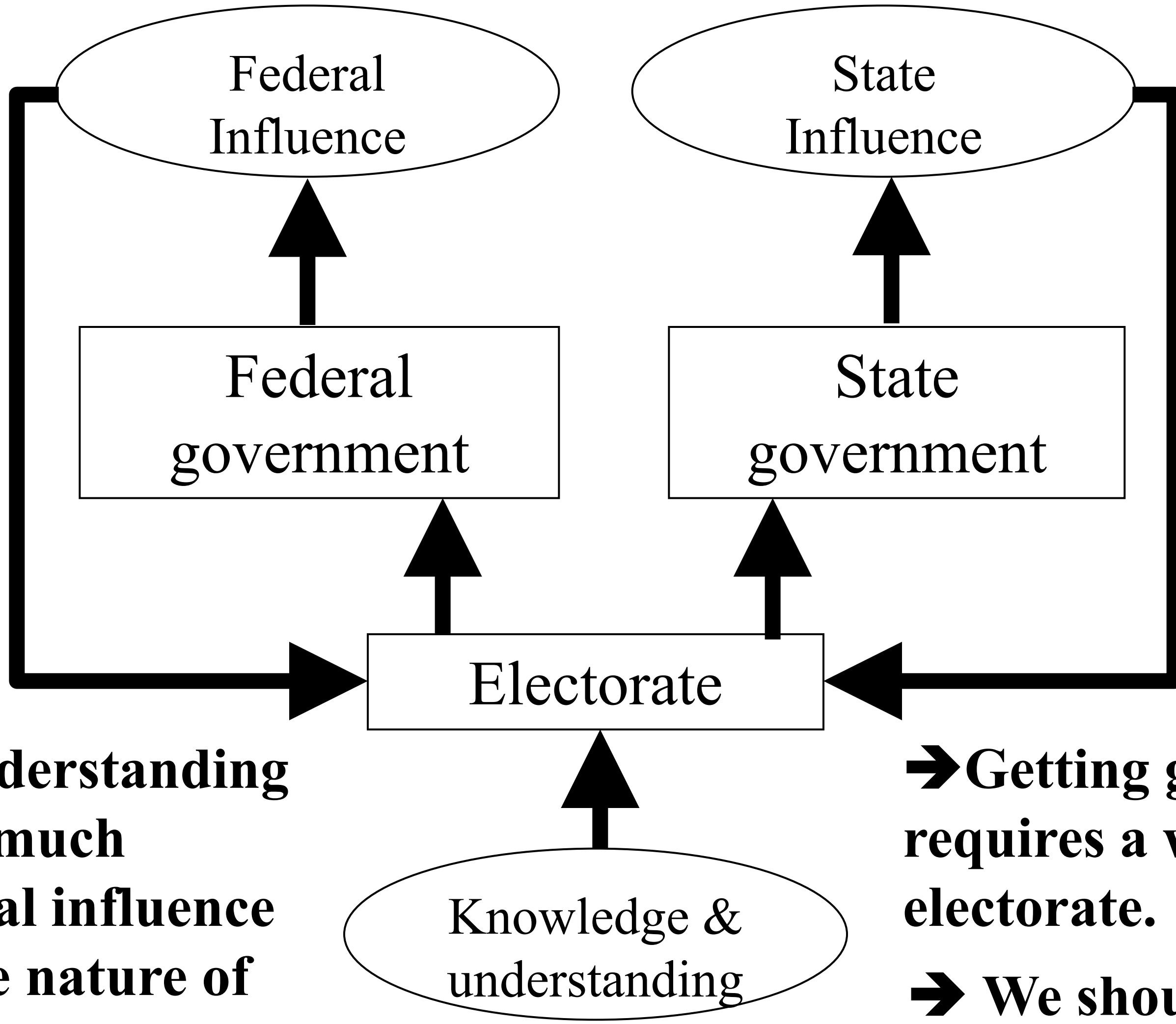
Public Education and Policy



➔**Public understanding affects how much governmental influence occurs & the nature of that influence.**

➔**Getting good policy requires a well-informed electorate.**

➔ **We should help electorate see the impact on their lives of each infrastructure design.**

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Concluding comment

There is need to centrally ***design***, at the national level, interdependent infrastructure systems. This need is driven by two attributes of these infrastructure systems:

- A well-recognized but still true attribute: Economies of scale motivate centralized designs to avoid inefficient infrastructure investment;
- What is relatively new: Infrastructure lives for 50 years or more, and climate impacts take decades to turn;
  ➔free markets are today too short-term to adequately respond to these issues, and the consequences of getting it wrong are potentially severe.

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