Future Electricity Supply

Some Key Factors

Metso User's Group Meeting
July 15, 2013

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Key Factors

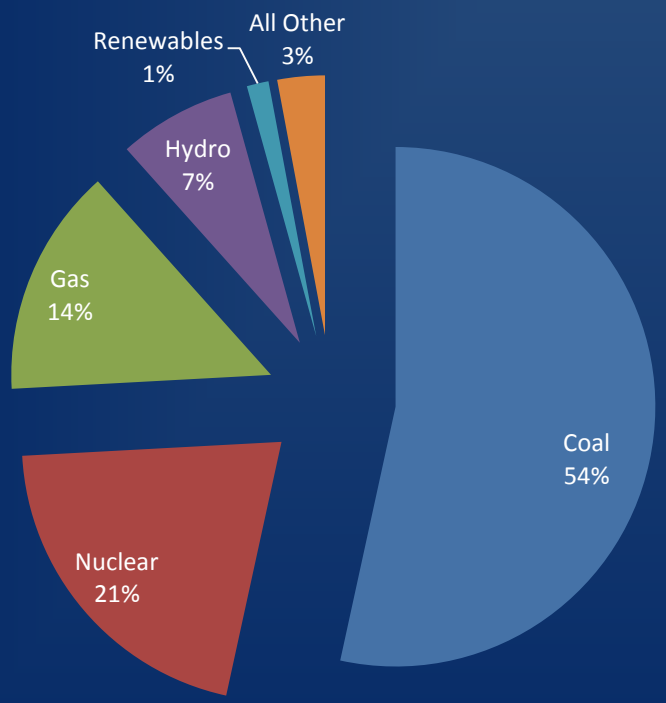
- Natural gas
- Renewables
- Subsidies
- Carbon pricing
- Other low-carbon technology elements

Key Points

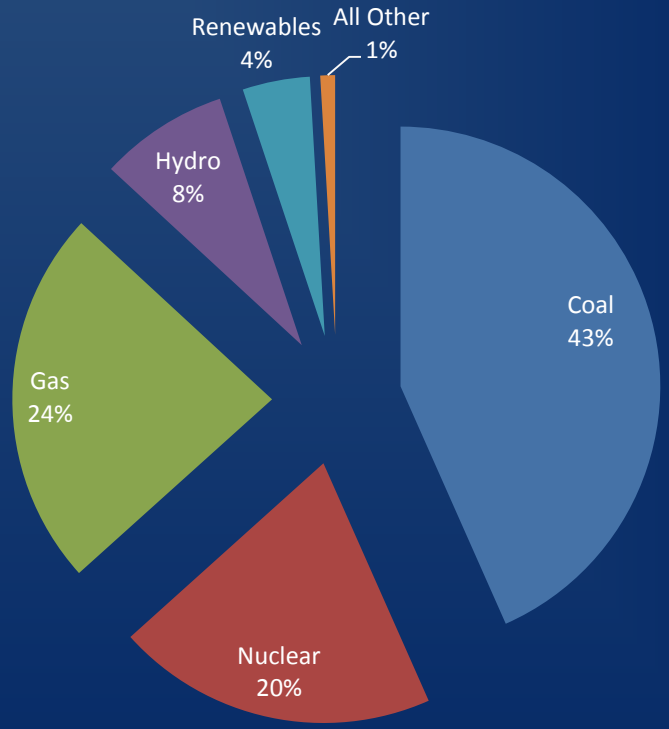
- Natural gas as a “bridge” to low carbon future
- Subsidies required for renewables R&D, RD&D
- Financing subsidies
  - carbon policy revenues
  - national tax revenues
  - local feed-in-tariffs
- Other low-carbon elements necessary
  - Scalability of renewables
  - Intermittency of renewables

United States Electricity Generation Mix

Generation Mix 2000
(% of 3,637,529 GWh total)



Generation Mix 2011
(% of 3,955,065 GWh total)

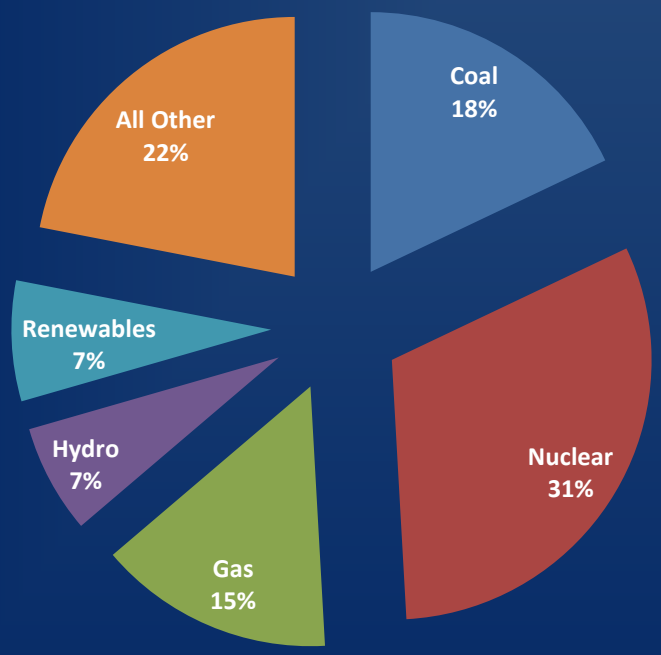


Renewables: Wind is about 3%; biomass is about 1%

Source: Energy Information Administration accessed at
http://www.eia.gov/totalenergy/data/annual/showtext.cfm?t=ptb0802b

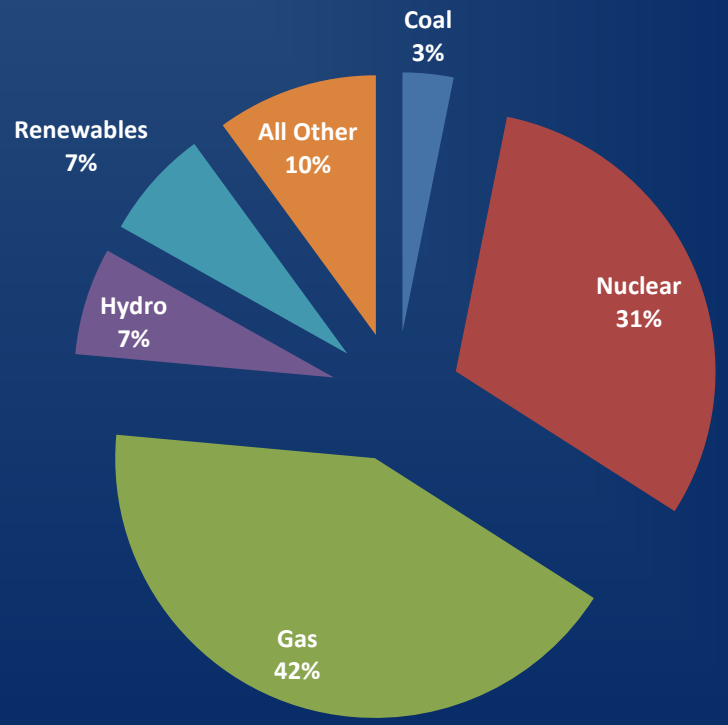
New England Electricity Generation Mix

Generation Mix 2000
(% of 110,198 GWh total)



Renewables: Mostly biomass

Generation Mix 2012
(% of 116,942 GWh total)



Renewables: Wind is about 1%; biomass is about 5%

Source: ISO New England accessed at http://www.iso-ne.com/nwsiss/grid_mkts/enrgy_srcs/

Market Forces

- **Natural gas is gaining generation share due to low prices**
  - Resource driven: shale gas
  - Technology driven: hydraulic fracturing (“fracking”)
- **Trend is market driven**
- **Gains would be reinforced with carbon pricing**
  - Gas generation emits about ½ the CO2 of coal
- **Gas typically sets price in restructured New England market**
  - Competitive market facilitates shift to gas generation

Electricity and Natural Gas Costs

Figure 4-5 shows the average annual all-in wholesale electricity cost ($/MWh) and natural gas prices for 2010 through 2012.

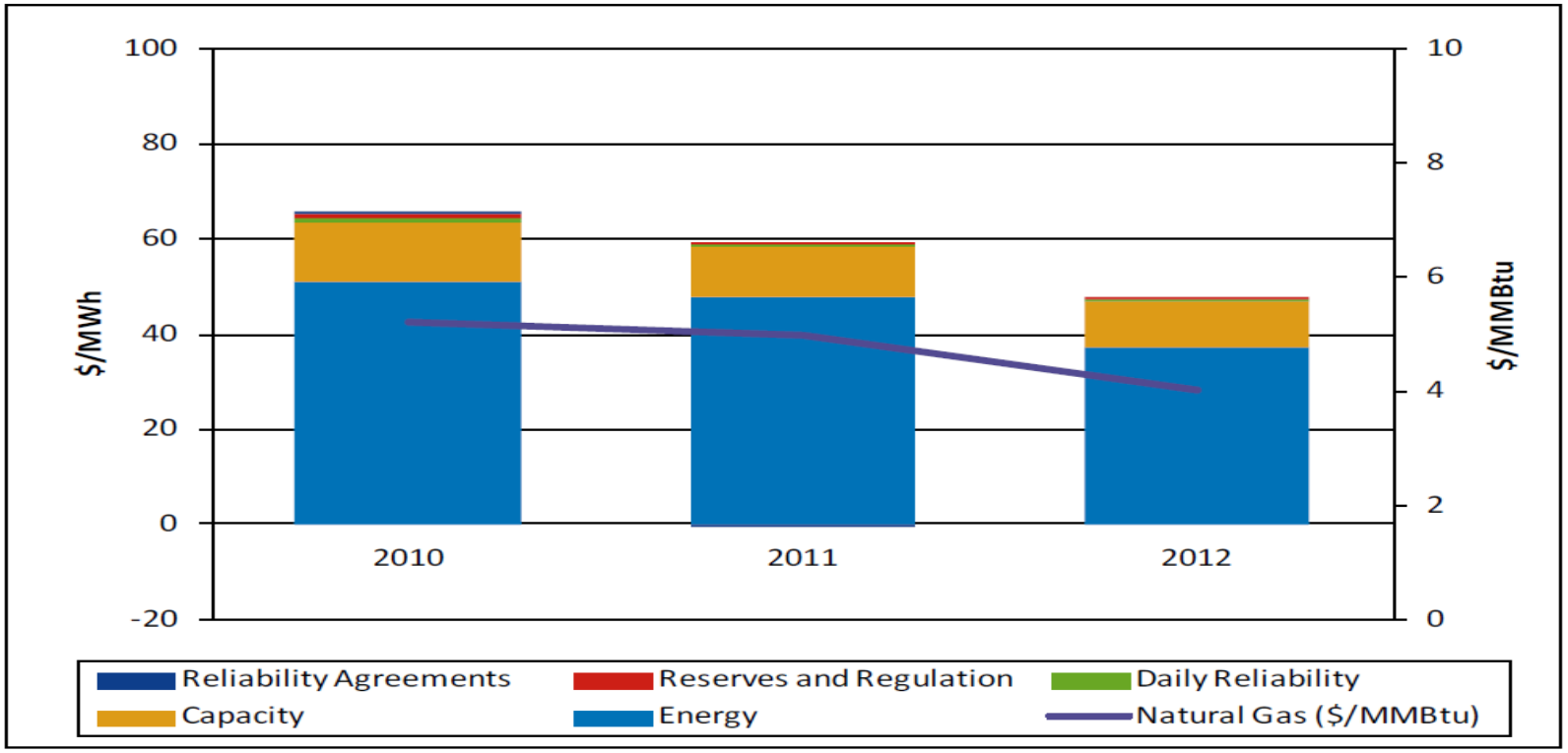
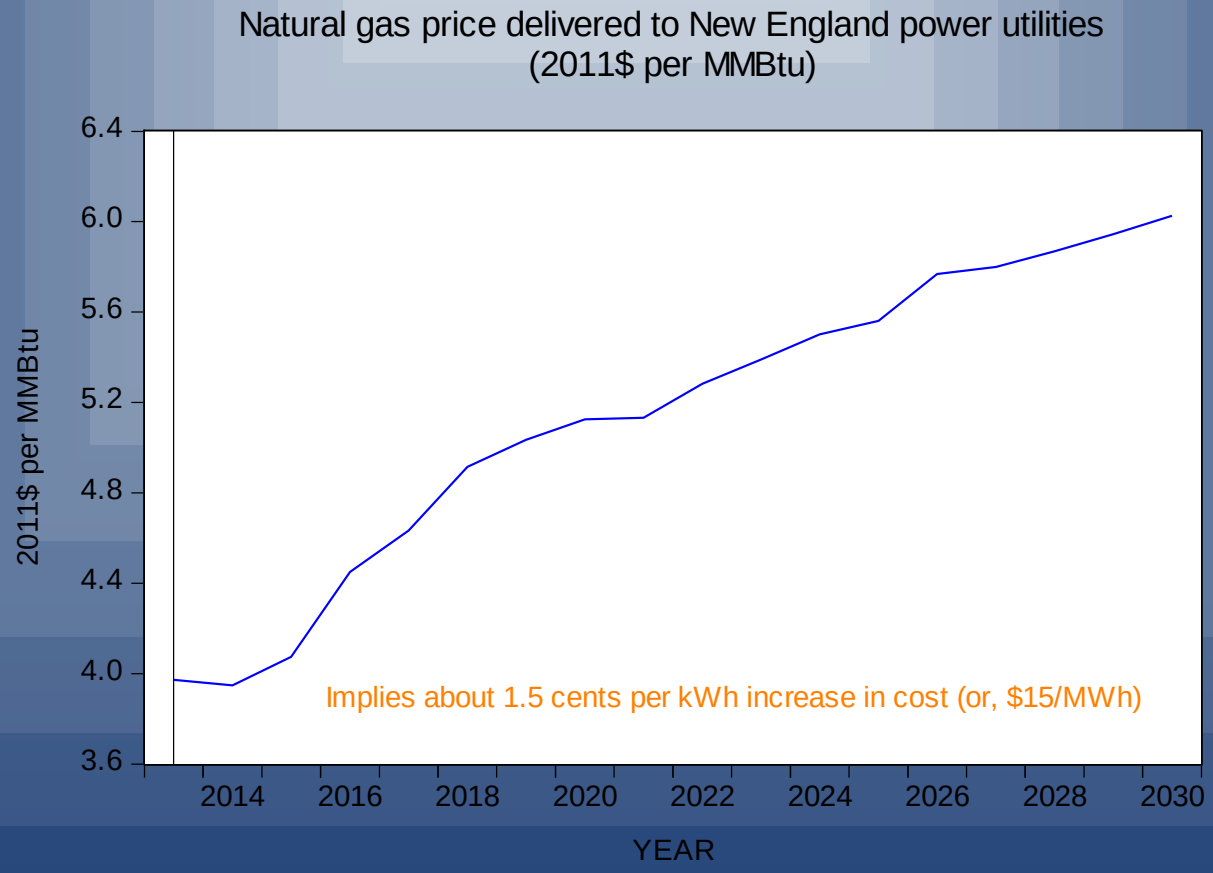


Figure 4-5: All-in cost, 2010 to 2012 ($/MWh).

Notes: The daily reliability and Reliability Agreement costs are allocated systemwide to enable a systemwide rate to be calculated. These costs actually are allocated to the load zone in which they occur. MMBtu stands for *millions of British thermal units*, a measure of the amount of heat energy in natural gas.

Source: Natural gas price information provided by the Intercontinental Exchange, Inc. (ICE), http://www.theice.com.

Baseline Gas Price Scenario



Source: Energy Information Administration, Annual Energy Outlook 2013

Gas Price Scenario Upside Risks

- Hydraulic fracturing damage/environmental costs
  - IEA estimate: 7% cost increase to cover
    (IEA, *Golden Rules for a Golden Age of Gas*, 2012)

- U.S. exports of LNG
  - Recent studies that show modest price impacts
    - Range of impacts: 2% to 11%
      - http://www.brookings.edu/research/testimony/2013/03/19-liquefied-natural-gas-ebinger

- Pipeline capacity in New England
  - Investment required
  - Recent legislative action in Maine to facilitate more capacity

Pipeline Capacity

Figure 2-8 shows the monthly price of natural gas for December 2009 to February 2013. Prices are highest in the winter periods, providing evidence that pipeline capacity gets more difficult to obtain as temperatures drop and the demand for natural gas increases. The natural gas price increase shown in the figure for winter 2012/2013 also provides evidence that the gas infrastructure is almost completely utilized.

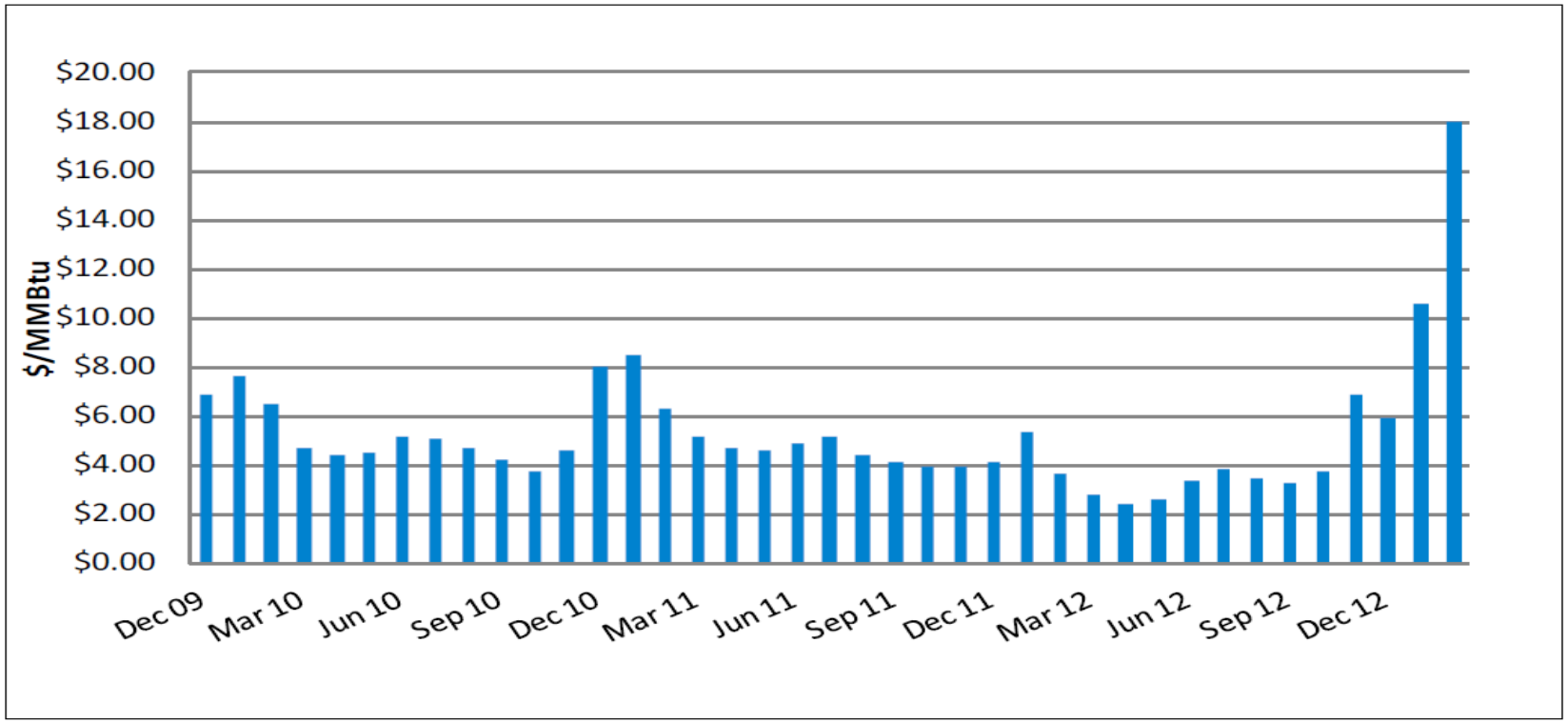


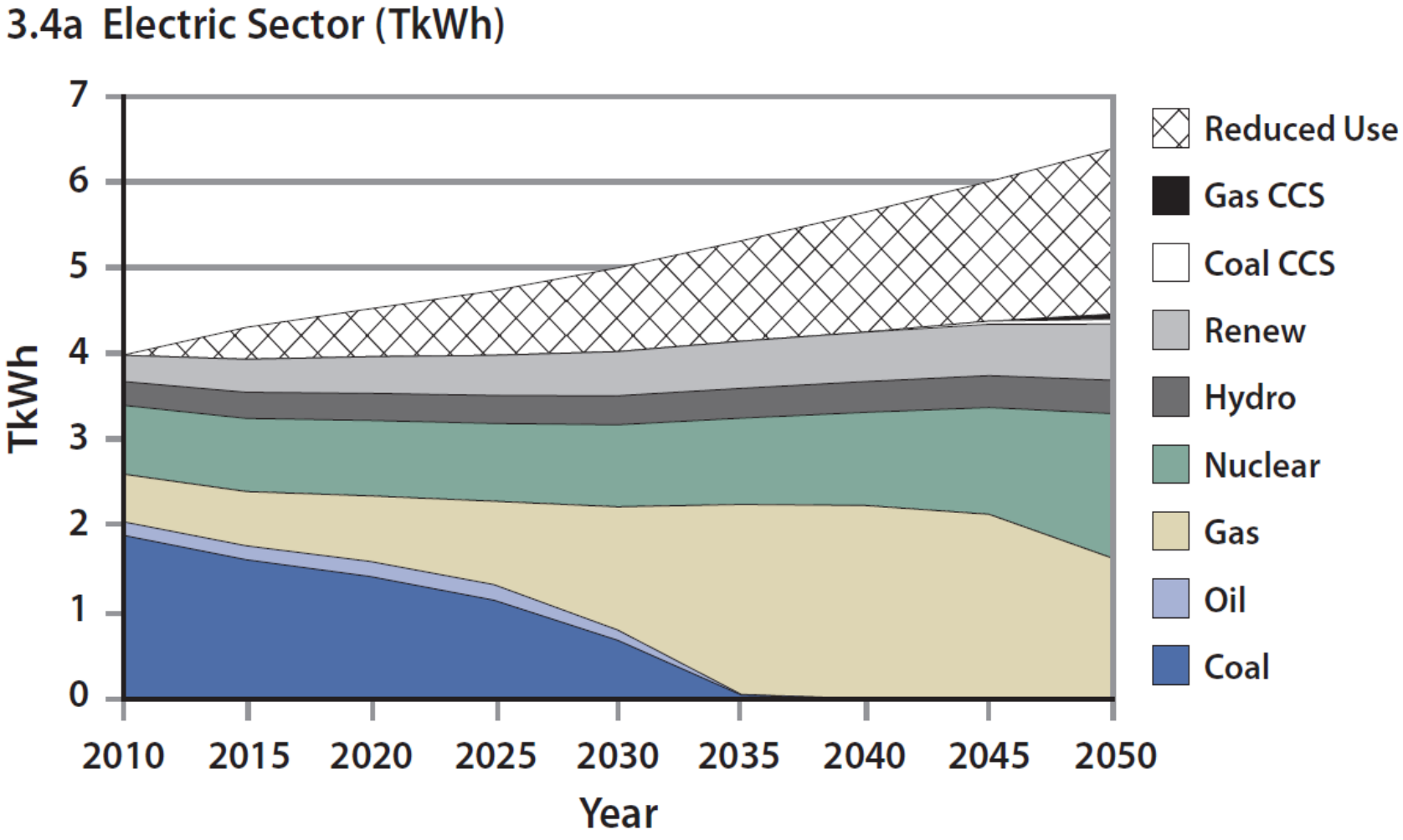
Figure 2-8: Monthly natural gas prices, December 2009 to February 2013.

Natural Gas Plays Role as "Bridge"

- Relatively low cost supply over long term
- Energy security benefits
  - North American supplies
  - LNG exports have marginal price impact
- Environmental benefits
  - About ½ carbon emissions of coal
  - Limited cost to mitigate fracking damages

Natural Gas as a Bridge

Figure 3.4 Energy Mix under a Price-Based Climate Policy, Mean Natural Gas Resources

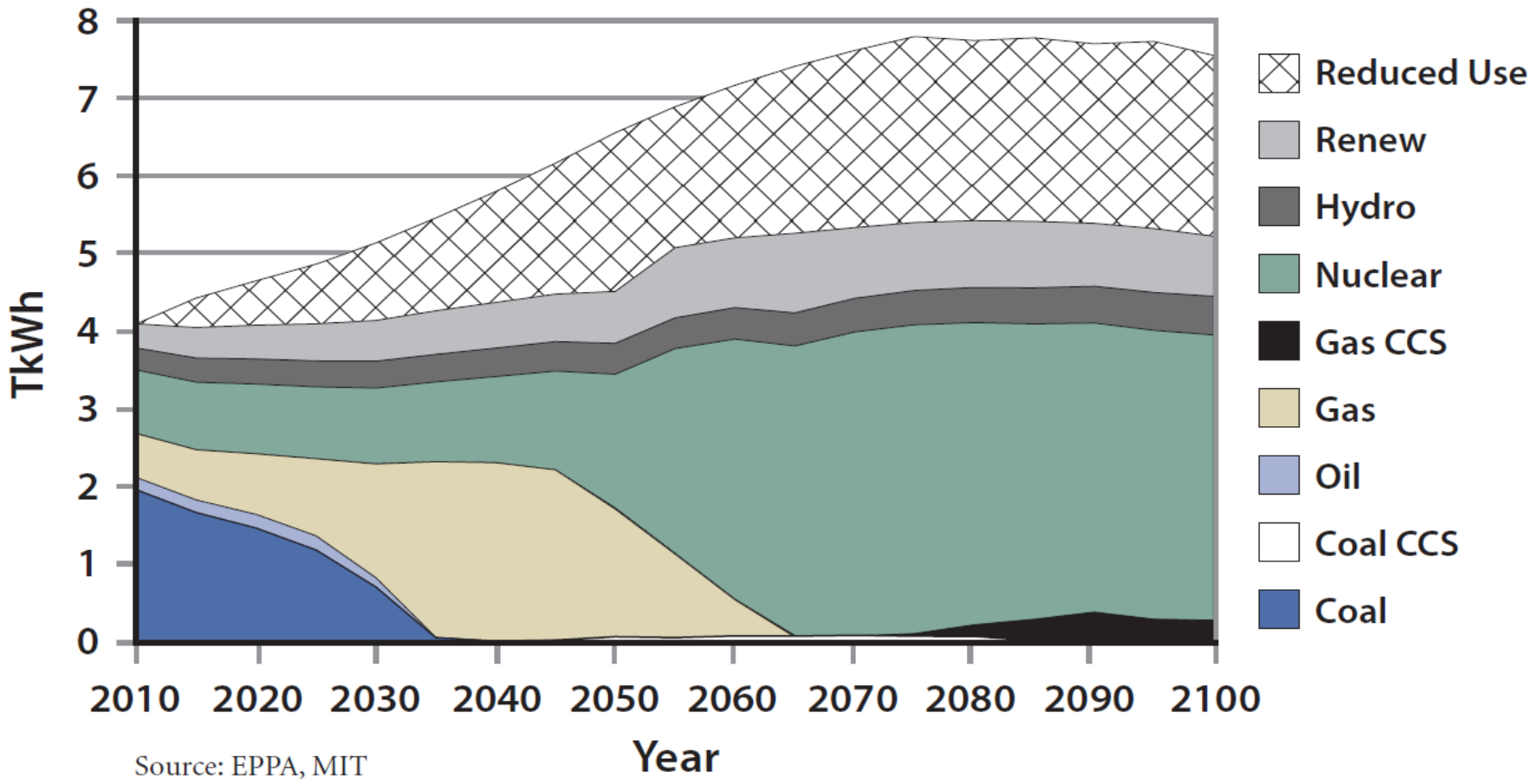


Source: M.I.T., *The Future of Natural Gas* (2011)

Where Does the Bridge Land?

- In a more "nuclear" low carbon future

Figure 3.12 Energy Mix in Electric Generation under a Price-Based Climate Policy, Mean Natural Gas Resources and Regional Natural Gas Markets (TkWh)



Source: M.I.T., *The Future of Natural Gas* (2011)

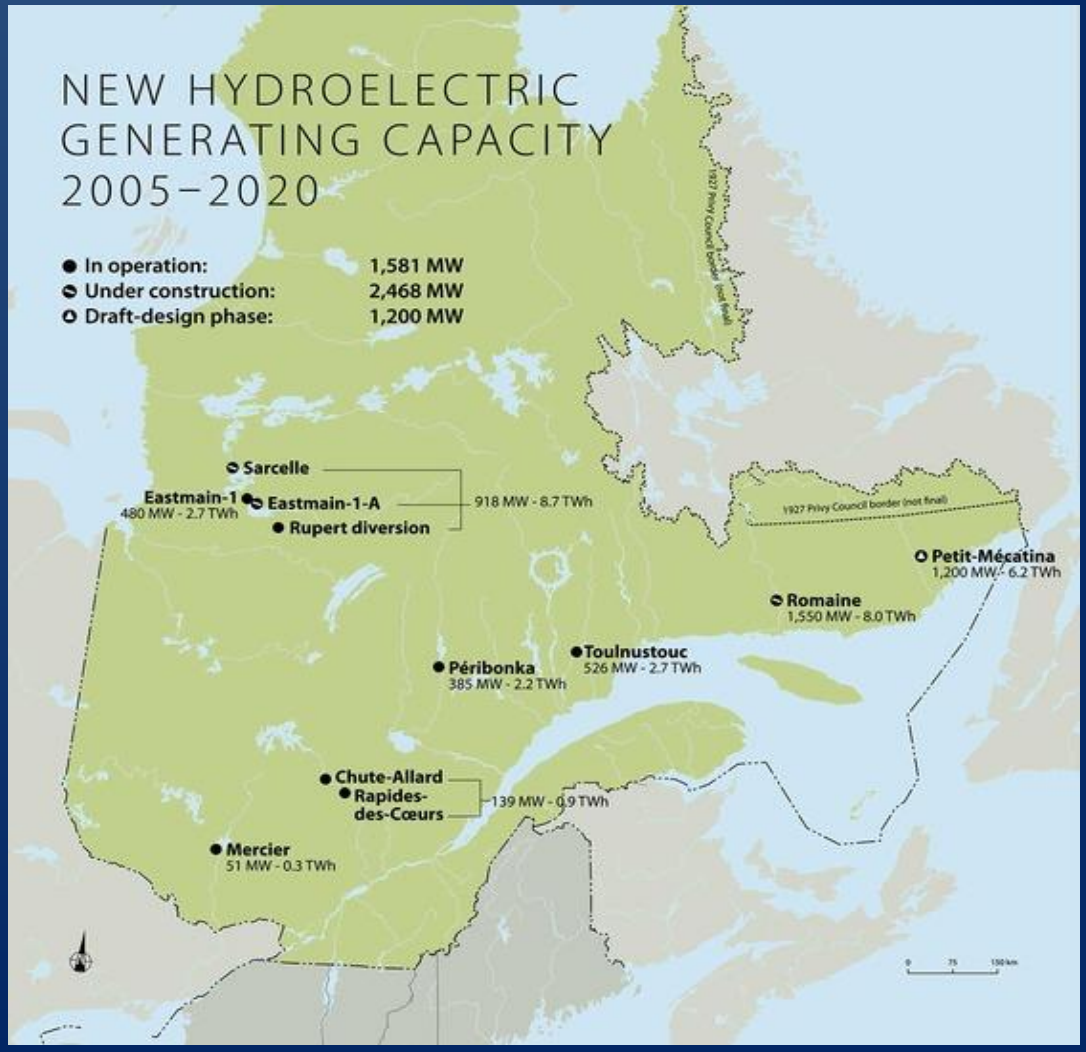
Where Does the Bridge Land?

- In a more "renewables" low carbon future
  - **Wind power** in New England
    - Studies support up to 20% - 25% penetration
      - DOE, NREL, *Eastern Wind Integration and Transmission Study* (January 2010)
      - ISO New England, *New England Wind Integration Study* (November 2010)
  - **Bio-mass** is constrained by value in competing uses
    - Report of the (Maine) Governor's Wood-to-Energy Task Force (September 2008) accessed at

http://www.maine.gov/doc/initiatives/wood_to_energy/documents/WoodtoEnergyTaskForceReport.pdf

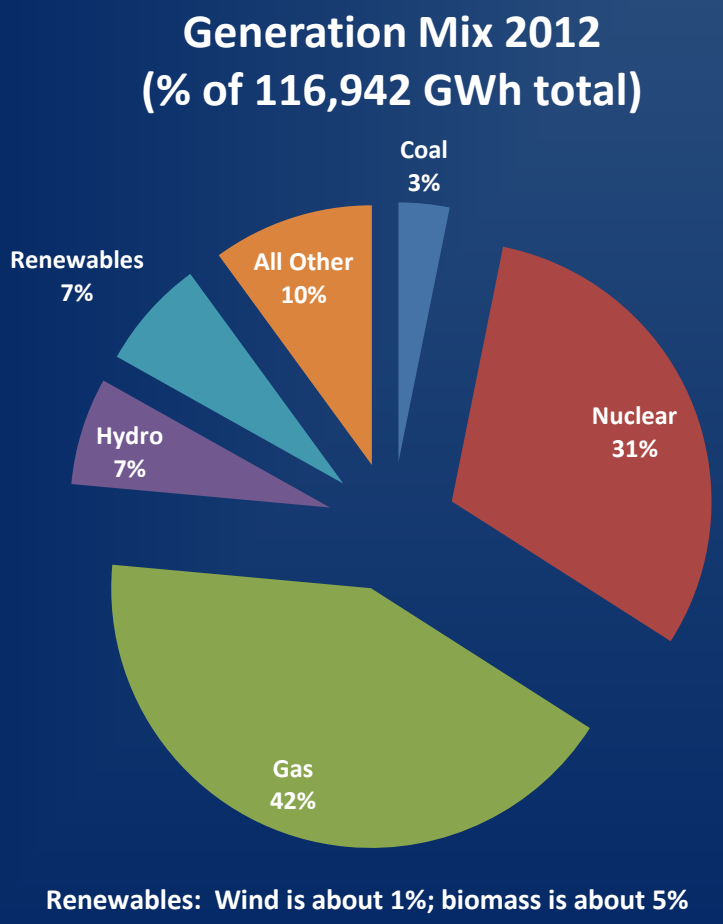
Where Does the Bridge Land?

- In a more "renewables" low carbon future
  - **Hydro power**



Source: Hydro-Québec accessed at http://hydroforthefuture.com/projets/9/developing-quebec-s-hydropower-potential

New England Electricity Generation Mix

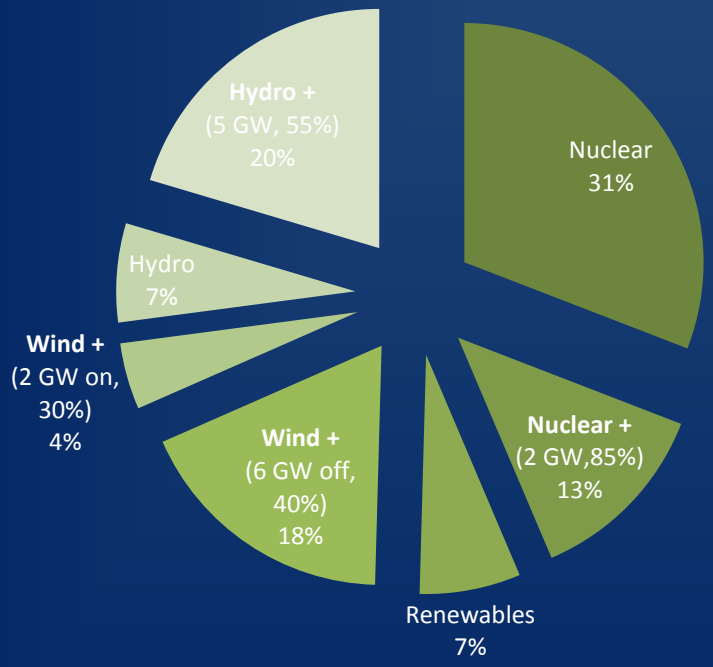


- **Future Generation Mix Post Natural Gas Bridge ?**
  - Reduced use
    - (higher price)
  - Wind and biomass
  - Hydro
  - Nuclear

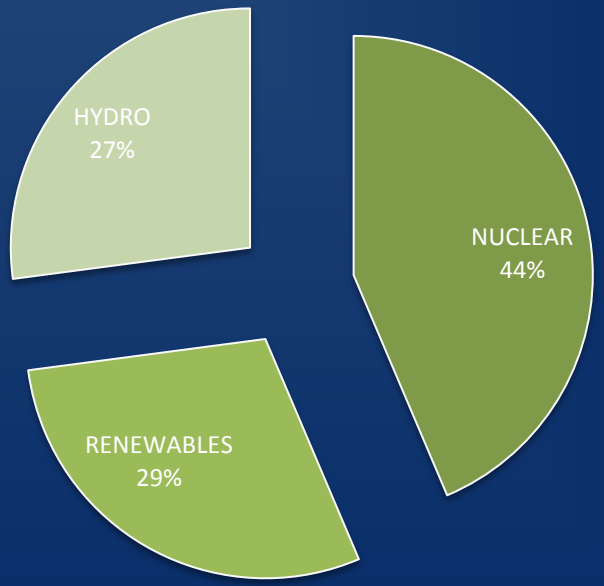
Source: ISO New England accessed at http://www.iso-ne.com/nwsiss/grid_mkts/enrgy_srcs/

A Future Low Carbon Generation Mix
Post Natural Gas Bridge

Future Scenario: New England Low Carbon Generation Mix ?



Future Scenario: New England Low Carbon Generation Mix ?



Note: Assume that reduced use flattens trend as it does approximately in M.I.T. study graph.
So total = about 117,000 GWh. [Approximate 10% difference between generation and demand (NEL) is ignored.]

Source: Author

Some Concluding Thoughts

- Natural gas is an economical bridge to a low carbon generation future
  - Relatively low cost alternative
  - Relatively secure
  - Less carbon intensive than coal or oil
  - Flexible in managing intermittency of renewables (storage ultimate solution?)

- Supply prices likely in range of 5 – 10 cents/kWh with carbon price (constant dollars)

Some Concluding Thoughts

- Where the bridge lands depends on
  - Outcome of RD&D on renewables (including storage technology)
  - Attitudes towards nuclear power and its costs
    - Progress on waste disposal issue key?
    - Japanese and German reaction to Fukushima meltdown
  - Attitudes towards hydro power (and more transmission lines)

- Low carbon generation future without nuclear & hydro is challenging
  - Scalability
  - Intermittency

Some Concluding Thoughts

- Many renewables are not competitive with natural gas generation
  - Even assuming carbon pricing at levels often discussed in the U.S.
  - Onshore wind offers the best matchup currently
    - Learning curve effects over several decades have lowered costs
- Learning curve effects are likely to push down costs of other renewables
  - Offshore wind
    - Various proposals in New England currently range $0.20 - $0.30/kWh
    - R&D and RD&D efforts required to lower these costs
      - A competitive target with carbon pricing
        - Target discussed in Maine : 10 cents/kWh
        - When achieved? Early 2020s **or** late 2020s

Some Concluding Thoughts

- Funding subsidies required to achieve learning and cost reductions
  - To date in New England
    - Local feed-in-tariffs (PUC mandated above market payments)
    - Federal tax subsidies (30% ITC/50% expensing, MACRS 5-year property)
    - Federal production tax credit
  - In future
    - Recycling **federal** carbon charge revenues?
    - Continued federal tax subsidies?
    - New federal feed-in-tariff?
  - RD&D learning lowers costs benefitting
    - Consumers of electricity
    - Renewables firms through enhanced global competitiveness
  - National versus local subsidy funding mechanism?
    - Tapered over time to reflect reduction of costs through RD&D

Some Concluding Thoughts

- Cost range with **mature** renewables, nuclear, and hydro: 10 to 15 cents per kWh?
- Electricity prices in a future low-carbon generation mix system are likely to be **higher**
- Higher prices are economically correct if they reflect all costs
  - Including what the National Academy of Sciences refers to as “hidden costs of energy”
    - E.g., climate and health costs of carbon
    - http://www.nap.edu/openbook.php?record_id=12794
- Higher prices lead to reduced use (demand effect)
  - Higher efficiency may not result in reduced use (rebound effect)

Some Concluding Thoughts

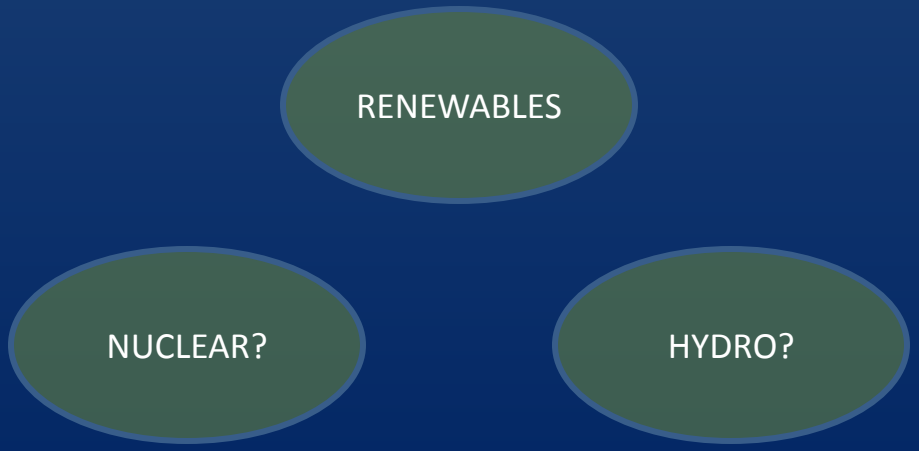
Bridge Period

- Expansion of natural gas
- Renewables RD&D
- Subsidies for RD&D
- Carbon pricing policy

Some Concluding Thoughts

Post-Bridge Period

Phase out of natural gas
Renewables phased in
Subsidies ended
Carbon pricing policy
Reduced Use



Thank You!

Questions

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