Novel Ways to Use Nuclear Energy for Transport: Biofuels and Shale Oil

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Transport Options for the Future Panel
American Nuclear Society Winter Meeting
4:00 PM; November 1, 2011
Washington D.C.

MIT Center for Advanced Nuclear Energy Systems

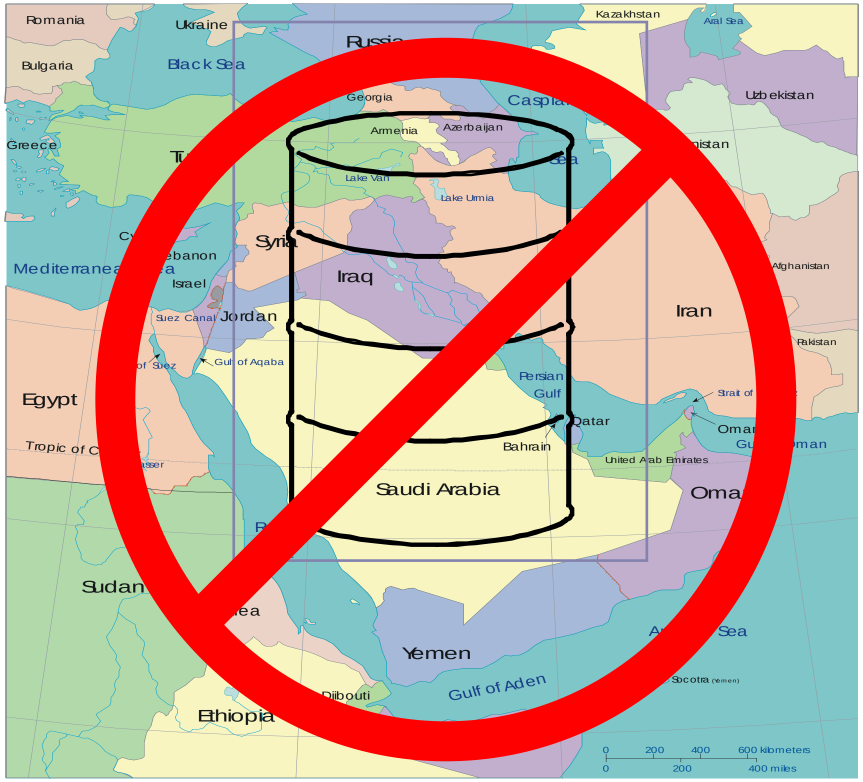
File: Nuclear Renewables
ANS 2011 Transport Panel

Outline

- The Energy Challenge
- Liquid Fuels
- Nuclear Biofuels
- Nuclear Shale Oil

Energy Futures May Be Determined By Two Sustainability Goals

No Imported Crude Oil



No Climate Change

Athabasca Glacier, Jasper National Park, Alberta, Canada
Photo provided by the National Snow and Ice
Data Center

2050 Goal: Reduce Greenhouse Gases by 80%

Liquid Fuels

Biofuels

Shale Oil

Three Inputs into Liquid Fuels

Carbon:
- Fossil fuel (CH_x)
- Biomass (CHOH)
- Atmosphere (CO_2)

Energy:
- Fossil fuel
- Biomass
- Nuclear

Hydrogen
- Fossil Fuel
- Biomass
- Water

Feedstock Conversion Process

Products:
- Ethanol
- Biofuels
- Diesel

Hydrogen Key Input for Lower Quality Feedstocks and Low CO_2
Biomass, Heavy oil, Oil Sands, Coal

We Will Not Run Out of Liquid Fuels

But the Less a Feedstock Resembles Gasoline, The More Energy it Takes in the Conversion Process

Liquid Fuel Feedstocks and Energy to Convert Feedstocks to Liquid Fuels

Chose Options Based On Availability and Energy Input

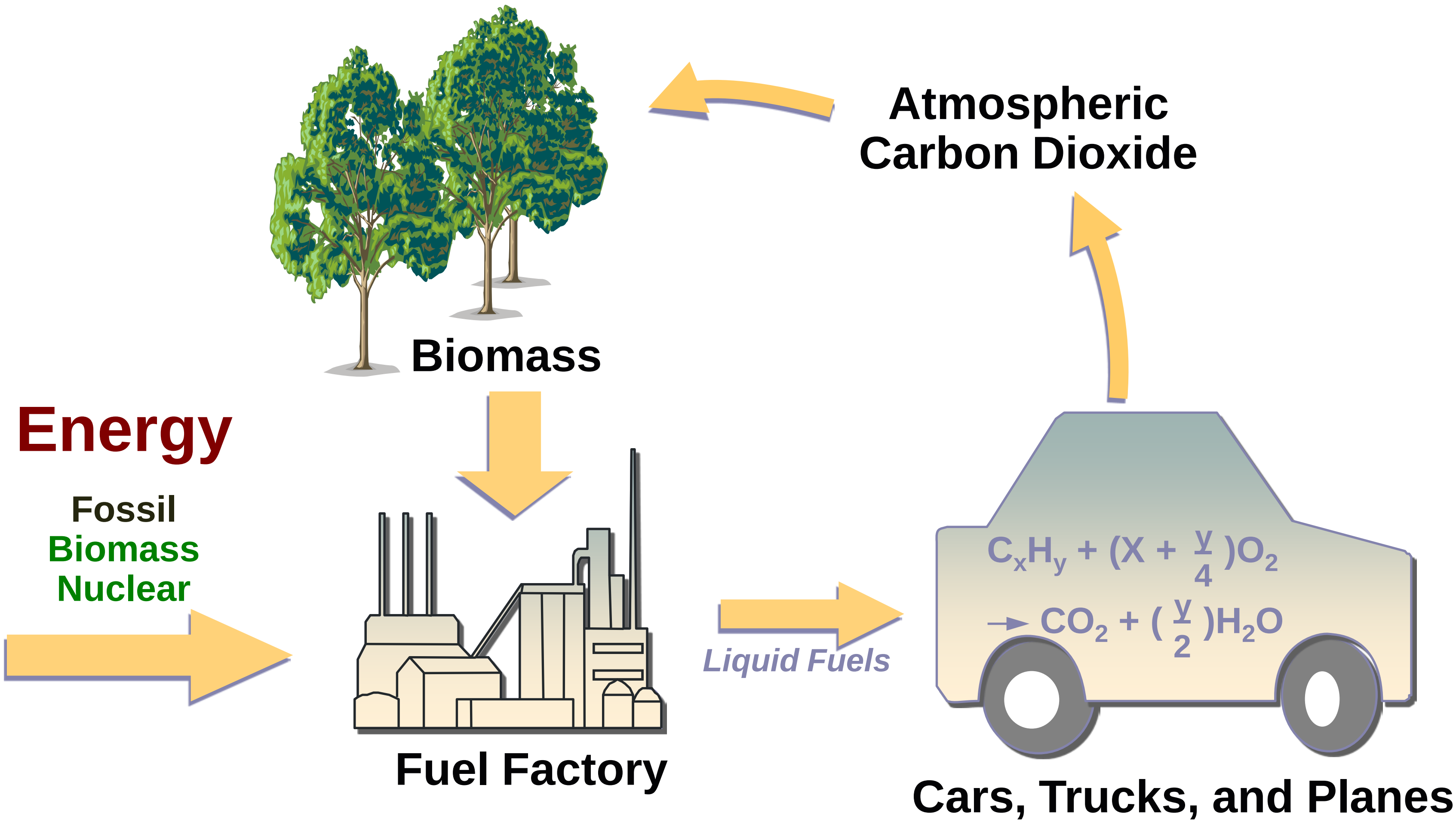
Feedstock	% World's Hydrocarbons	Heat Input As Fraction of Liquid Fuel Heating Value
Oil	2-3%	6-10%
Heavy Oil	5-7%	25-40%
Natural Gas	4-6%	~50%
Gas Hydrates	10-30%	
Oil Shales	**30-50%**	**>30%**
Coal/Lignite	20-30%	>100%
Biomass	**Annual**	**To 50%**

Observations on Resource Chart

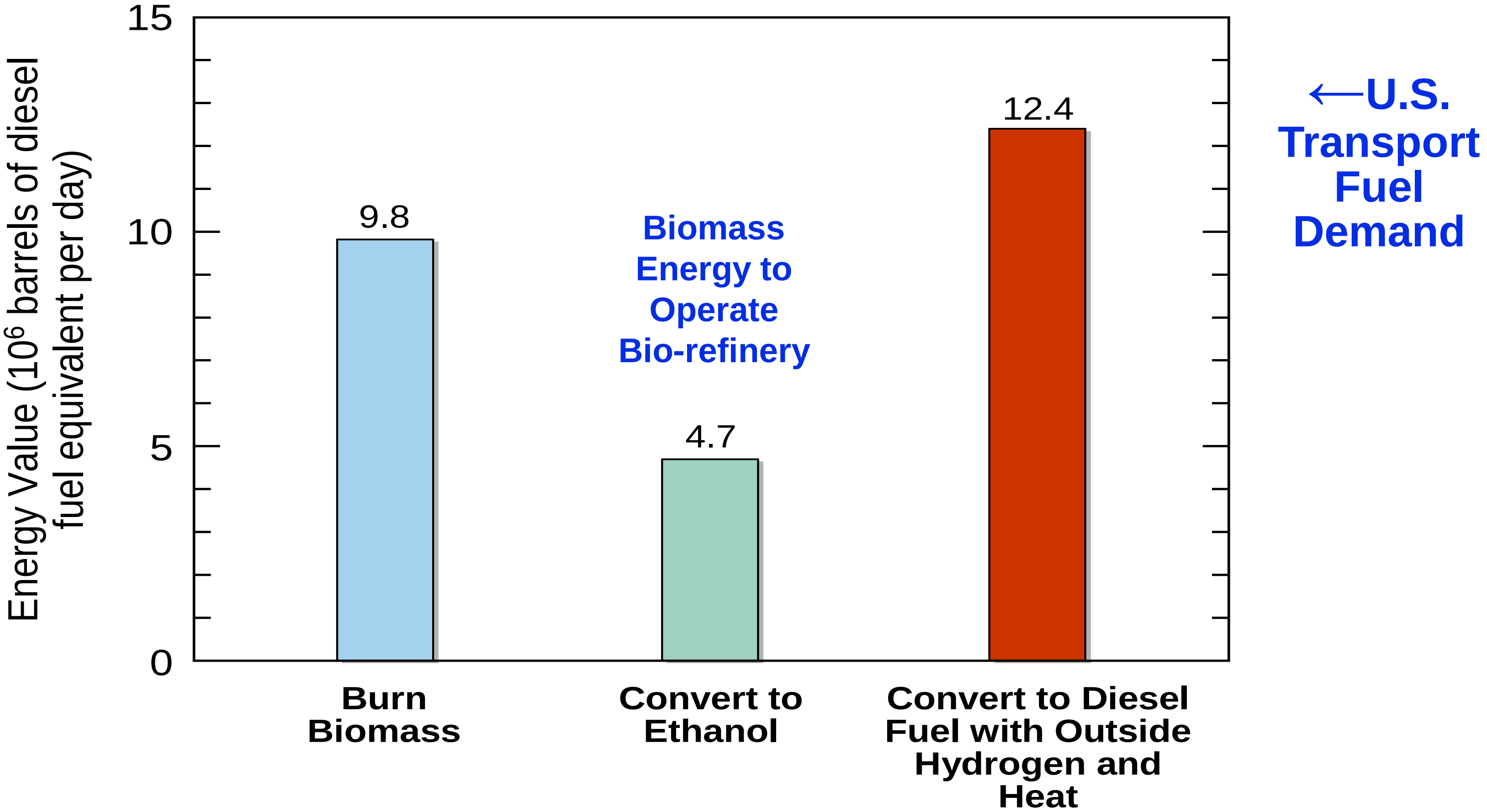
- Industrial world built on the least available fossil fuel—bad strategic policy
- Two interesting options for the United States
  - Shale oil: abundant, relatively low energy input to produce liquid fuels, and U.S. has the largest richest deposits in the world
  - Biomass: renewable, relatively low energy input to produce liquid fuels, and the U.S. has the largest and most efficient agricultural industry (soil, climate, technology) in the world
- Look into future nuclear biomass and nuclear shale oil options

Nuclear Biofuels

Biomass Fuels: A Potentially Low-Greenhouse-Gas Liquid-Fuel Option



U.S. Biomass Fuels Yield Depends On the Bio-Refinery Energy Source

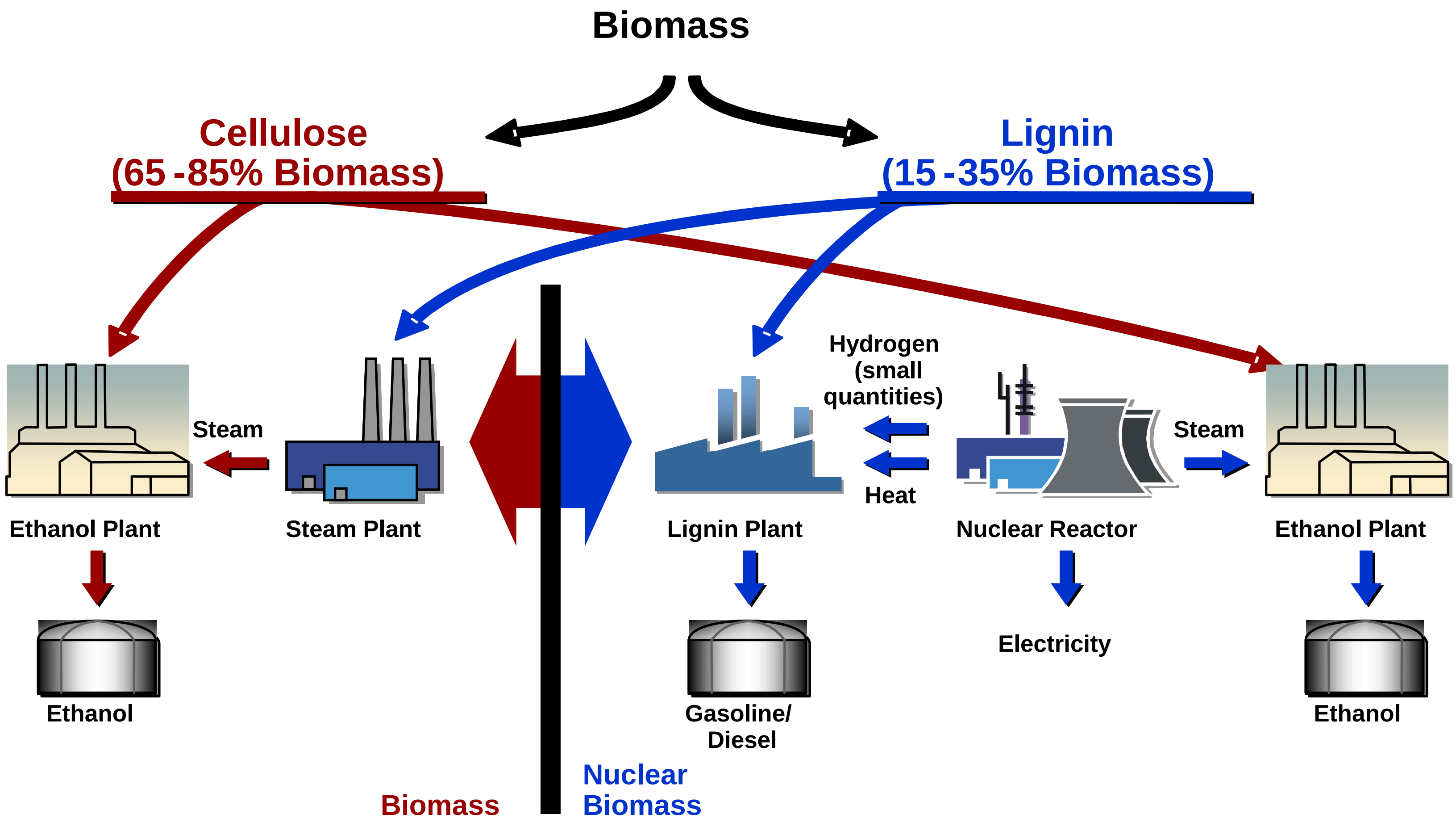


Without Impacting Food and Fiber Production

Future Cellulosic Liquid-Fuel Options

Biomass As Energy Source

Nuclear as Energy Source



50% Increase Liquid Fuel/Unit Biomass

Nuclear Energy Increases Liquid Fuels Per Ton of Biomass

Biomass As Feedstock and Boiler Fuel:

Useful But Not a Game Changer

Biomass Feedstock and Nuclear Energy

Replace Oil for Transport in United States

Nuclear Shale Oil

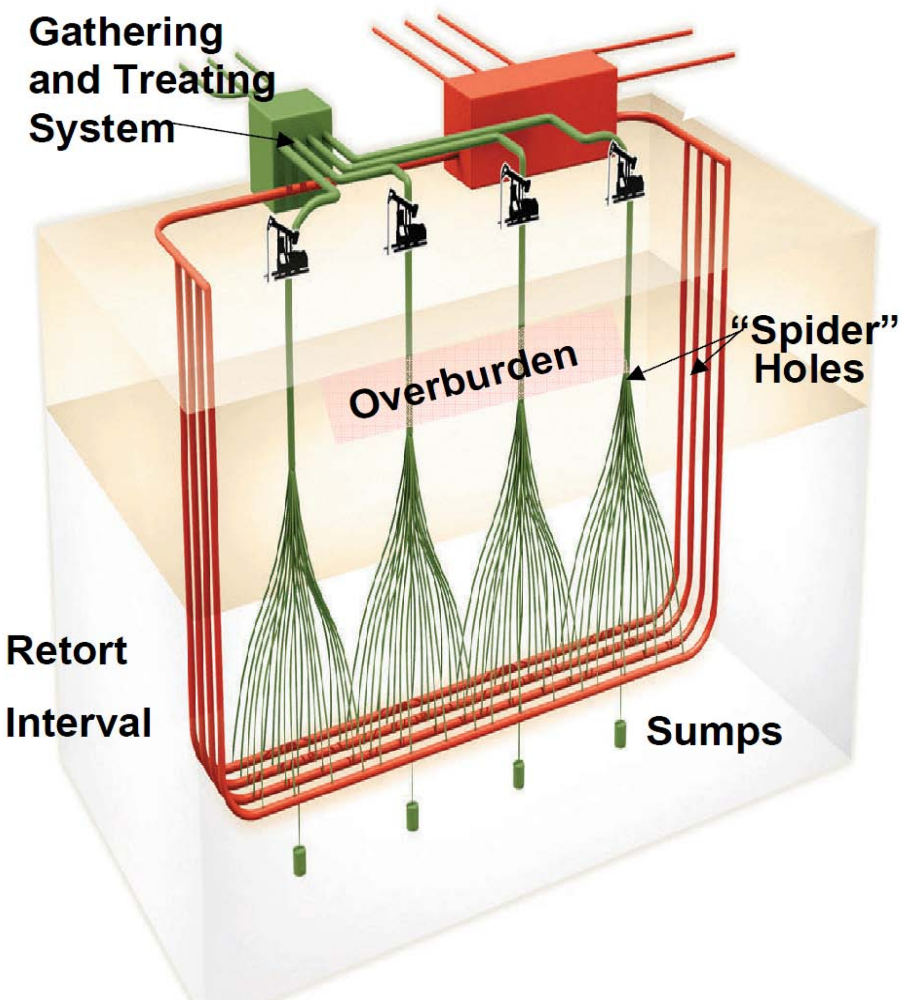
U.S. Oil Shale Could Replace Conventional Oil

- Green River recoverable reserves ~1.4 trillion barrels of oil
- Total world production of oil to date is 1.1 trillion barrels
- ~1 million barrels of oil per acre; Most concentrated fossil fuel on earth
- Pilot plants in operation

Conventional Shale Oil Production Implies Large Greenhouse Impacts

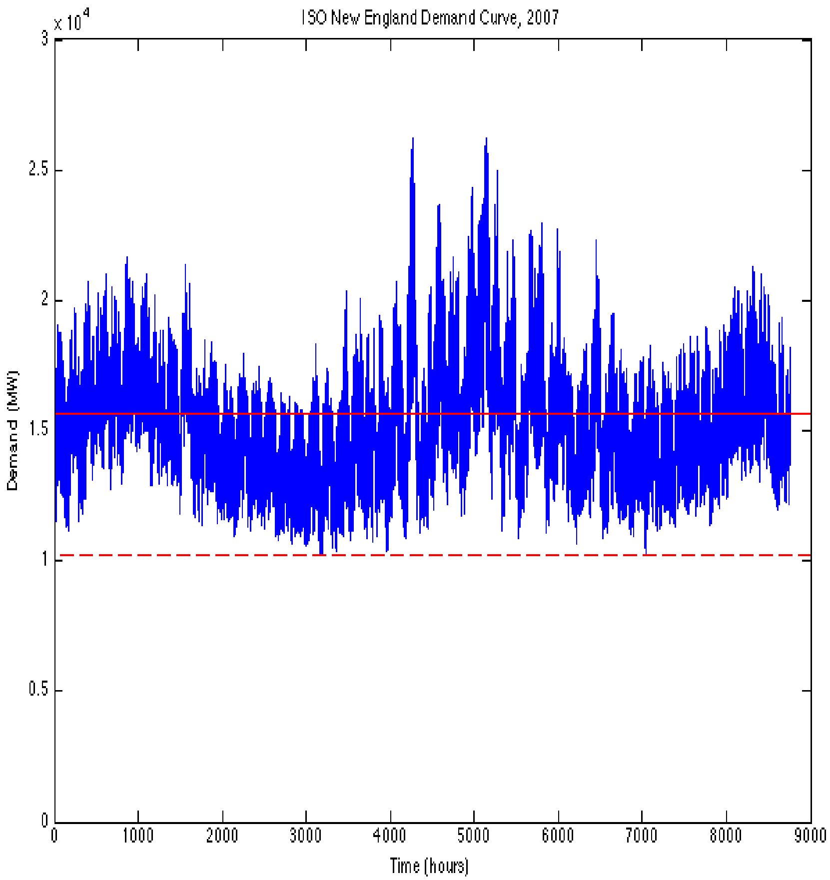
- Oil shale contains no oil but instead kerogen
- Heat kerogen underground to produce shale oil
- Current strategy—burn one third of oil and gas product to heat shale
- Large carbon dioxide release during production

Nuclear Shale Oil Option



- Nuclear heating of oil shale (~370 C plus ΔT) to decompose into shale oil and char
- Carbon residue left underground
- Low production carbon footprint with sequestration that works

Nuclear Shale Oil and Variable Electricity Production



- Shale heated over a period of months to years
- <u>Economic base-load nuclear plant</u> can heat shale at night and produce variable electricity as needed
- Replace variable load fossil power plants

Low Greenhouse Gas Emissions

Nuclear Shale Oil With Variable Electricity

- Replaces variable electricity from fossil plants
- Enables renewables with no-carbon (no gas turbine) backup from base-load nuclear
- Carbon credits from variable electricity lowers shale-oil carbon footprint to as low as half of gasoline from crude oil
- Lowest environmental impact fossil fuel

Nuclear Shale-Oil With Variable Electricity: the Cleanest Fossil Fuel?

- Example analysis: assumptions
  - 2-GWY nuclear: ½ variable electricity, ½ shale oil
  - 1-GWY nuclear heat yields 2 GWY shale oil
  - Nuclear and fossil electricity efficiencies identical
- Results
  - 1-GWY no-fossil fuel variable electricity
  - 2-GWY shale oil
  - CO_2 saved from nuclear variable electricity equal to not burning 1-GWY shale oil: Can be credited to shale oil

Net Greenhouse Gas Release per Liter Half That of Gasoline From Crude Oil

Conventional Shale Oil Production:

Large Greenhouse Impacts

Nuclear Shale Oil and

Variable Electricity

(1) Low Environmental Impact Fossil Liquid Fuel

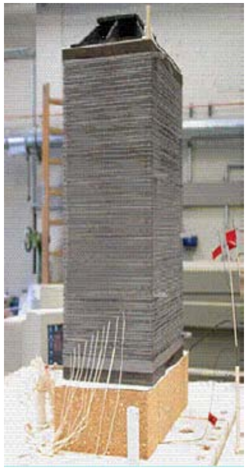
(2) Enable Large Scale Renewables with

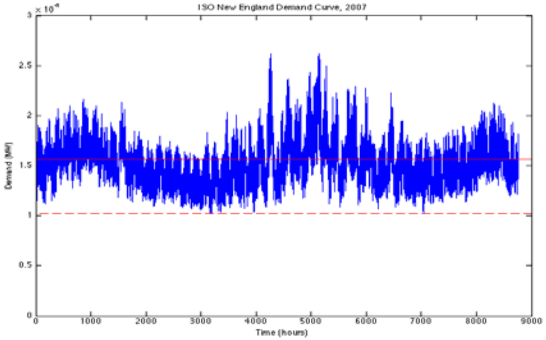
Low-Cost Low-Carbon Variable Electricity

Conclusions

- Liquid fuels central energy challenge to the U.S.
- Two areas where the U.S. has a natural advantage
  - Biomass—world's most productive agriculture
  - Shale oil—world's richest and largest deposits
- In both cases there is the potential for nuclear to be the enabling technology for a low-carbon liquid fuel future
- Many uncertainties remain
  - Technology
  - Economics
  - Institutional—probably the major challenge

Questions





Full Report

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Biography: Charles Forsberg

Dr. Charles Forsberg is the Executive Director of the Massachusetts Institute of Technology Nuclear Fuel Cycle Study, Director and principle investigator of the High-Temperature Salt-Cooled Reactor Project, and University Lead for Idaho National Laboratory Institute for Nuclear Energy and Science (INEST) Nuclear Hybrid Energy Systems program. Before joining MIT, he was a Corporate Fellow at Oak Ridge National Laboratory. He is a Fellow of the American Nuclear Society, a Fellow of the American Association for the Advancement of Science, and recipient of the 2005 Robert E. Wilson Award from the American Institute of Chemical Engineers for outstanding chemical engineering contributions to nuclear energy, including his work in hydrogen production and nuclear-renewable energy futures. He received the American Nuclear Society special award for innovative nuclear reactor design on salt-cooled reactors. Dr. Forsberg earned his bachelor's degree in chemical engineering from the University of Minnesota and his doctorate in Nuclear Engineering from MIT. He has been awarded 11 patents and has published over 200 papers.

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