Future Technologies for Integrated Electrical Load Leveling & Production & Use of Biomass

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Slides with "INL" logo kindly provided by

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IEEE-EPC Meeting

February 5, 2014

on

Nuclear-Renewable Energy System Integration & Optimization Using Dynamic Systems Models

www.inl.gov

Idaho National Laboratory

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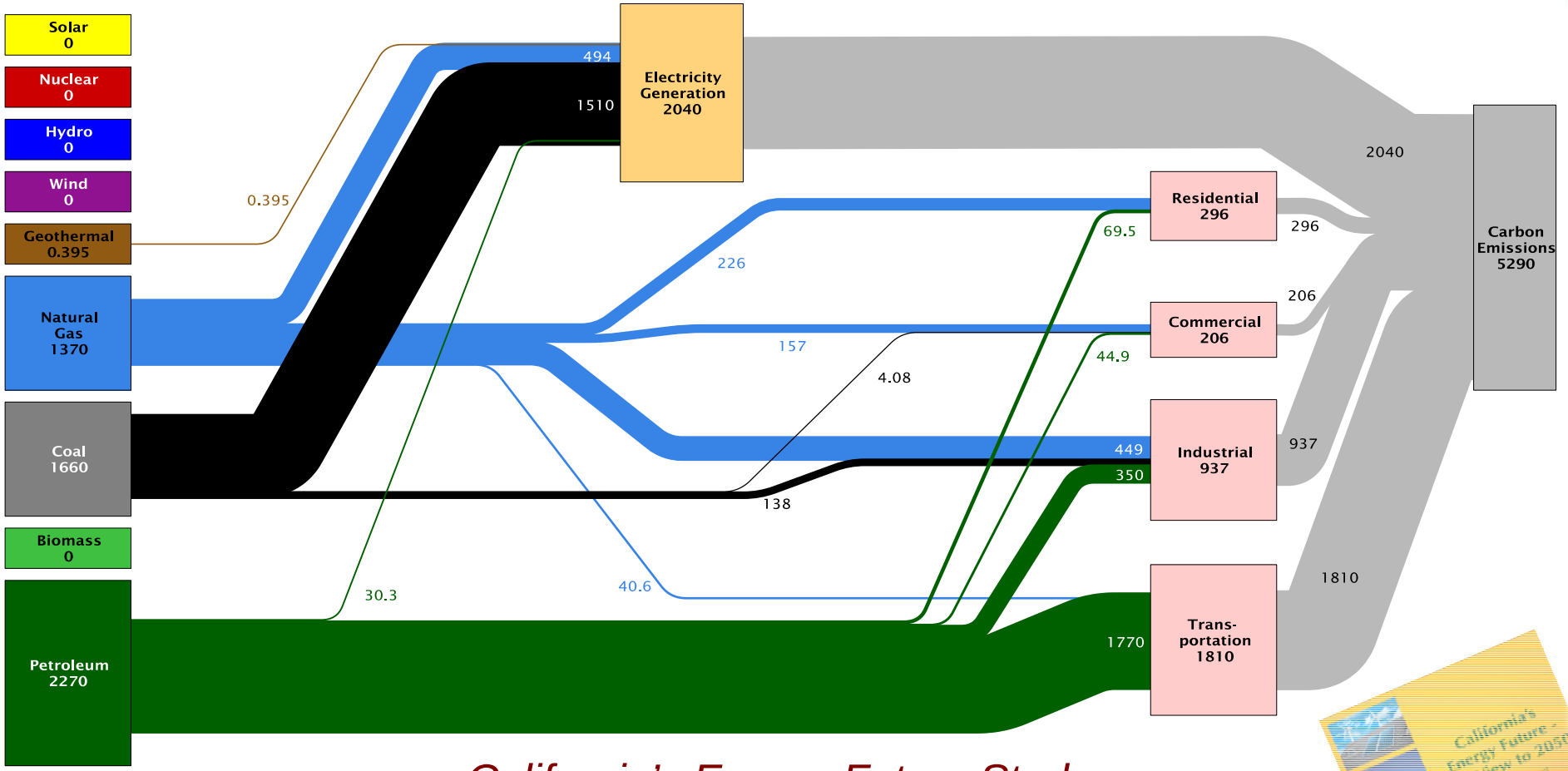
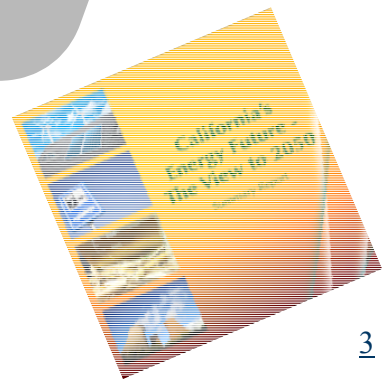
Lawrence Livermore National Laboratory

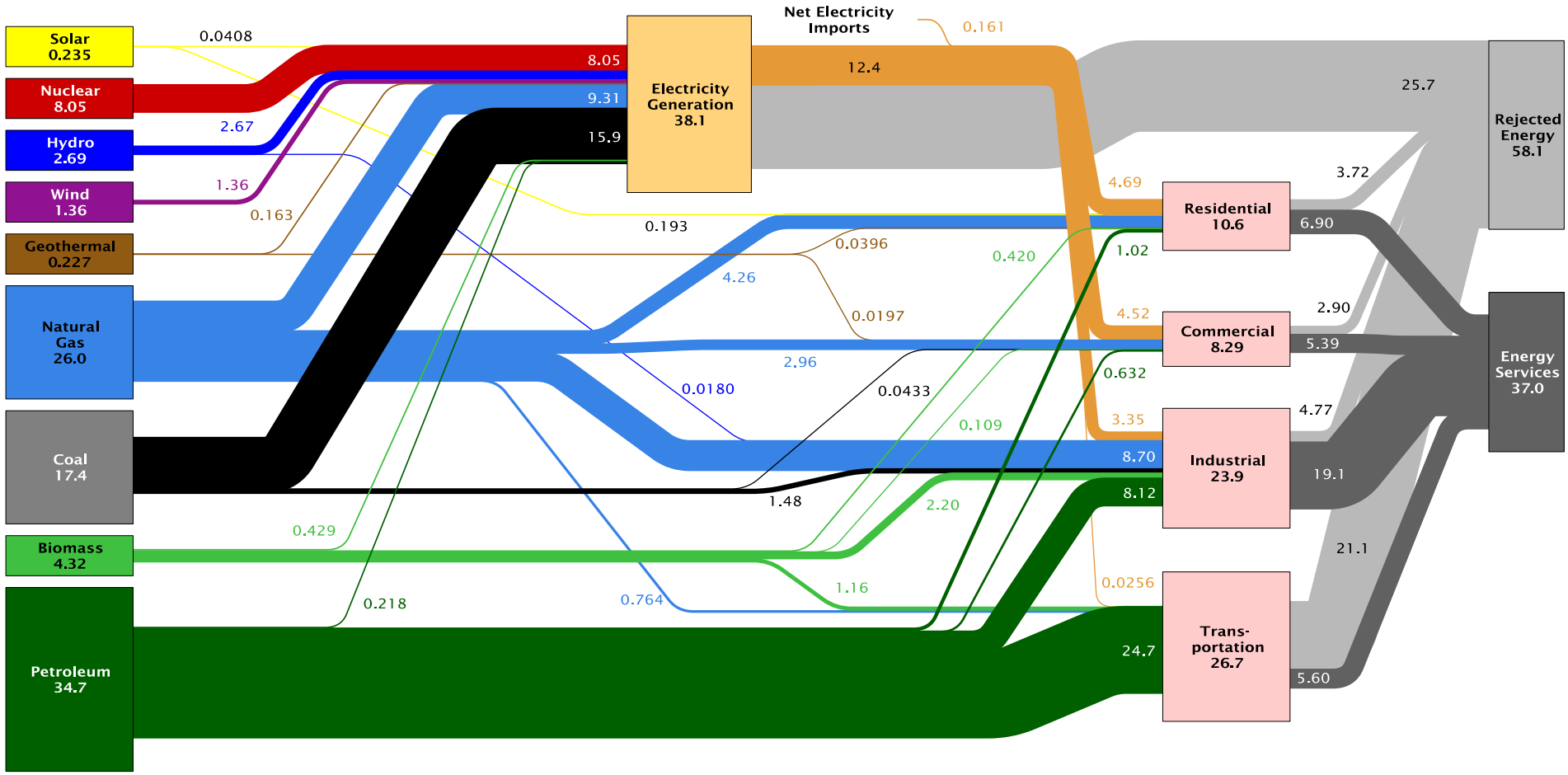
Estimated U.S. Energy-Related Carbon Dioxide Emissions in 2012: ~5,290 Million Metric Tons



California's Energy Future Study
Can't reduce CO_2 emissions to target with just renewables and natural gas.



Estimated U.S. Energy Use in 2012: ~95.1 Quads



The world and the U.S. are still powered by >80% fossil fuels.
Most of it is wasted.

Intuition says that:
Long-term trend is toward electric (from nuclear, hydro, wind, solar in current order of amount, but changing toward solar) and electric vehicles

- Electric engines avoid Carnot efficiency limitation
- Less wasted energy
- Less pollution and greenhouse gas (depending on how done)

If we start generating way more electricity with solar and wind:
How to match erratic generation to use:

- Use extra electric during low-load times to make fuels.
- But battery storage of excess electric avoids Carnot efficiency limitation in using fuels, so that will compete.
- Electrochemical fuel pdtn. (eg water splitting) also efficient
- Fuel cells have high theoretical efficiency too, but inefficiencies from over-potentials needed to get rates
- Make CO & liquid fuels from CO_2 w/ extra electric?
  $CO + H_2O \leftrightarrow CO_2 + H_2$ water-gas shift process
  CO_2 is also actual C source in methanol synthesis

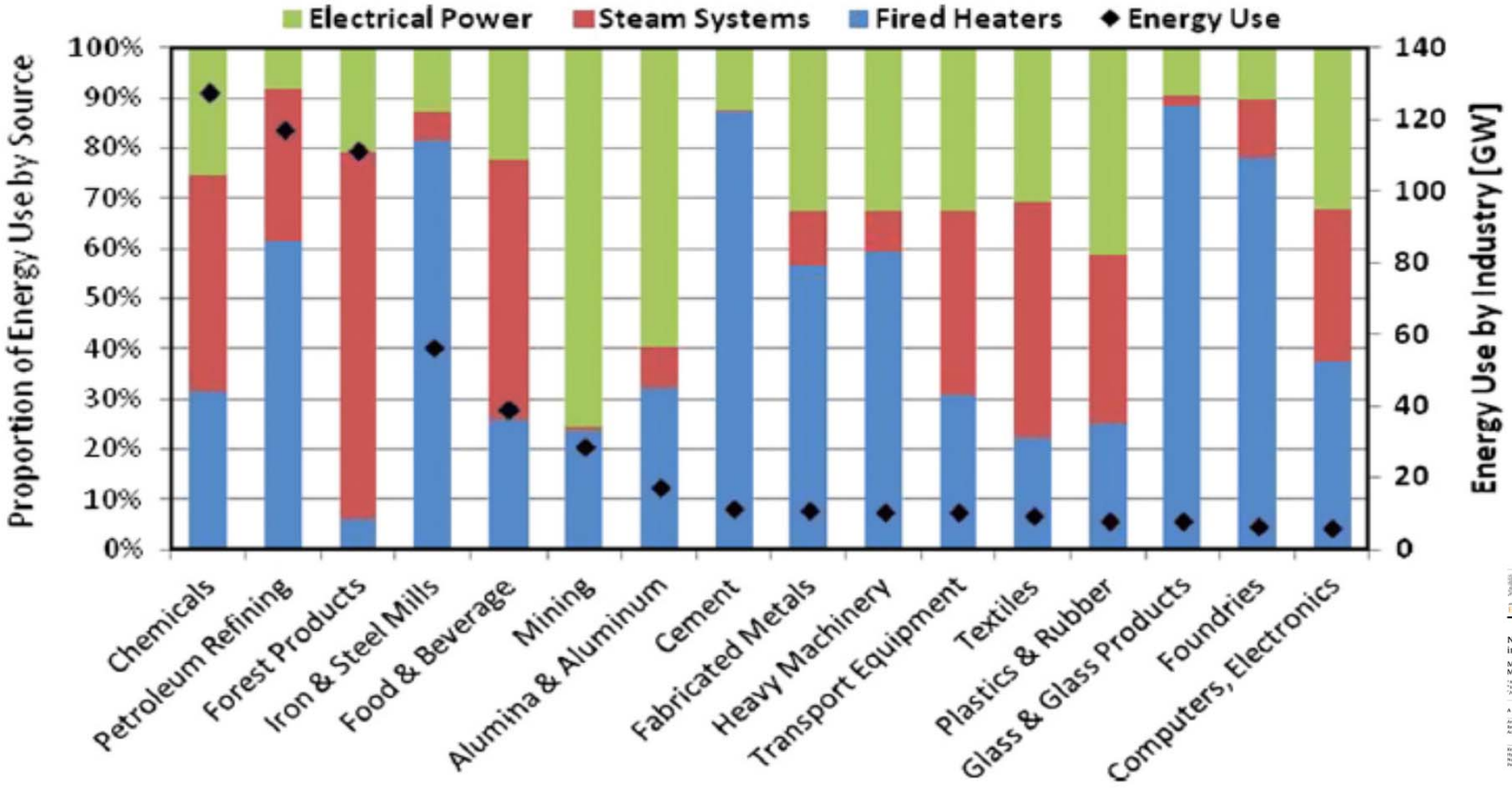
Production of Bulk Chemicals should also be considered for excess electricity use.

No Carnot efficiency loss on re-use of that energy.

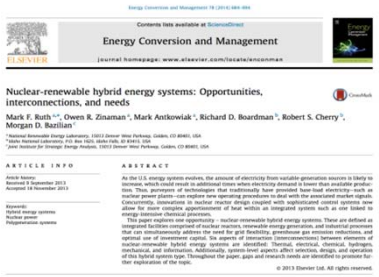
- Need new plant designs that cycle easily between max and min output

  (Same true if making fuels)
- Can’t avoid capital cost disadvantages

How can the manufacturing industry be changed?



Ruth, Boardman, et al. Energy Conversion Management, 2014


Energy Conversion and Management

Nuclear-renewable hybrid energy systems: Opportunities, interconnections, and needs

- Electrical loads are mostly constant.
- Can steam loads be produced by a thermal energy buffer?
- Can fired heaters be replaced with electromagnetic heating [or what?]
- Are there alternatives for hydrogen, chemicals, and fuels production?

Estimated U.S. Energy Use in 2012: ~95.1 Quads

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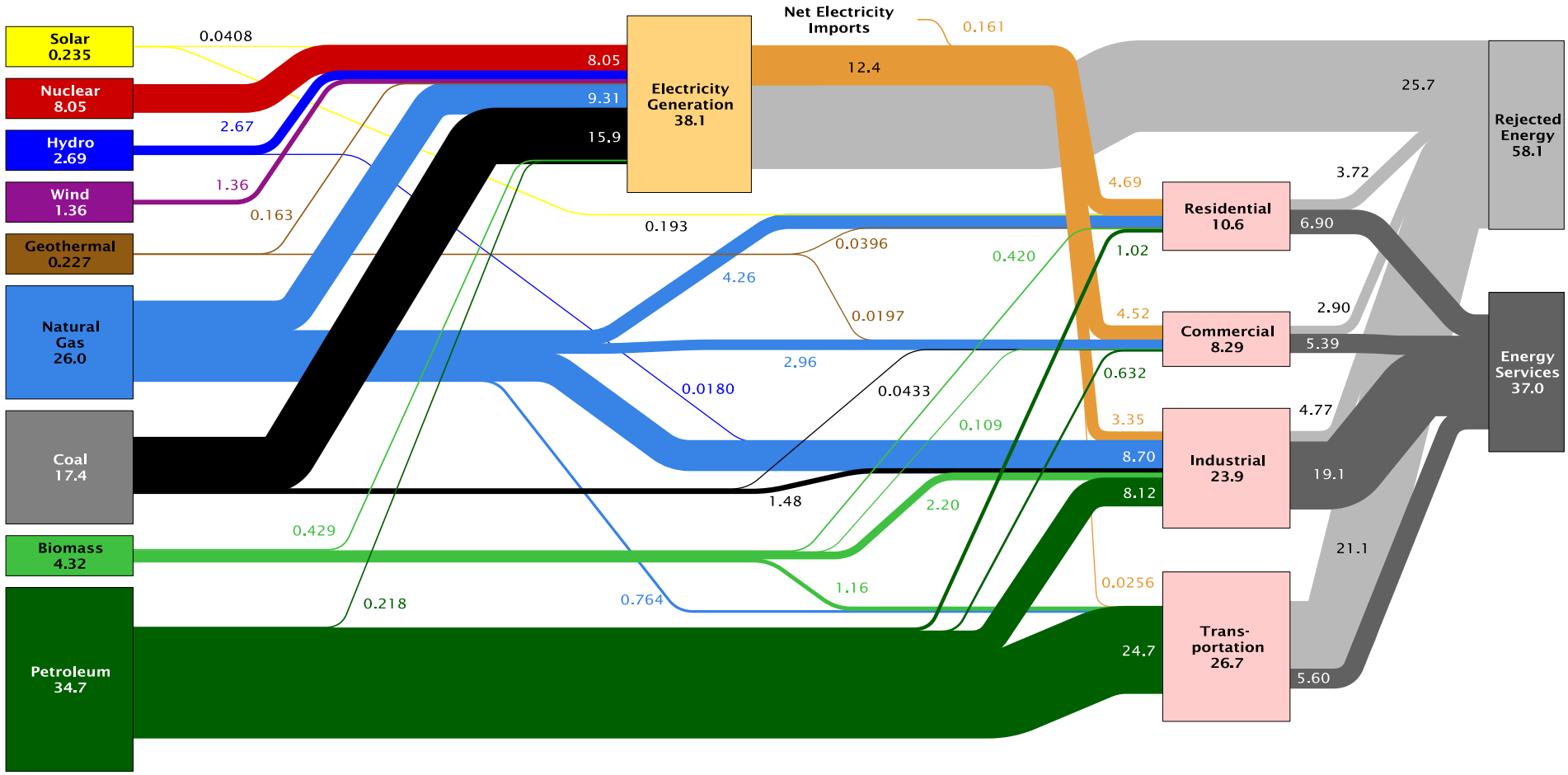
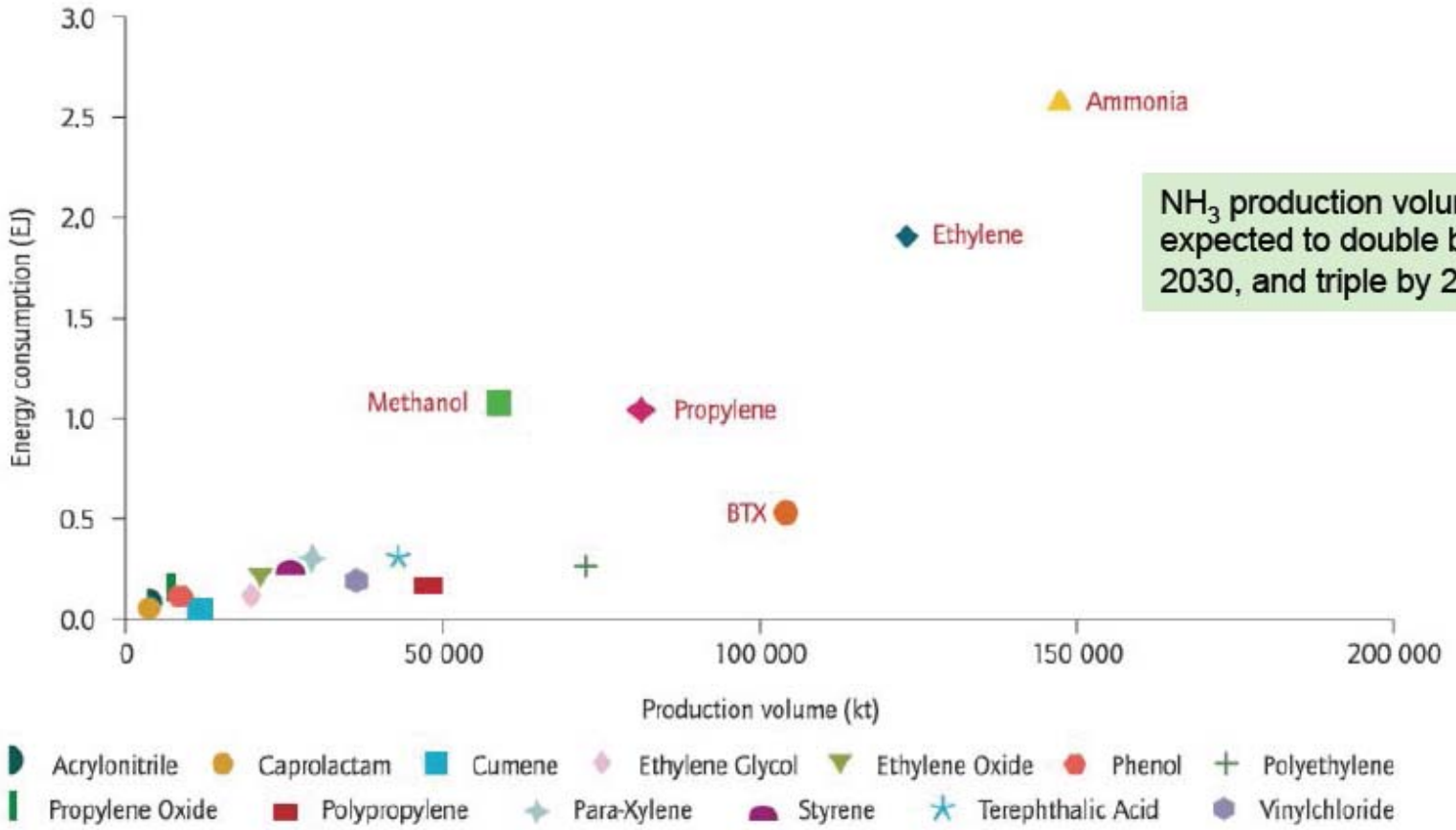


The world and the U.S. are still powered by >80% fossil fuels.
Most of it is wasted.

Figure 2: Global energy consumption versus production volumes of top 18 large-volume chemicals, 2010



NH_3 production volume is expected to double by 2030, and triple by 2050.

Note: Energy consumption for olefins in this figure represents that of the steam cracking process.
Source: DECHEMA

Technology Roadmap: Energy and GHG Reductions in the Chemical Industry via Catalytic Processes
International Energy Agency, 2013
http://www.iea.org/publications/freepublications/publication/Chemical_Roadmap_2013_Final_WEB.pdf

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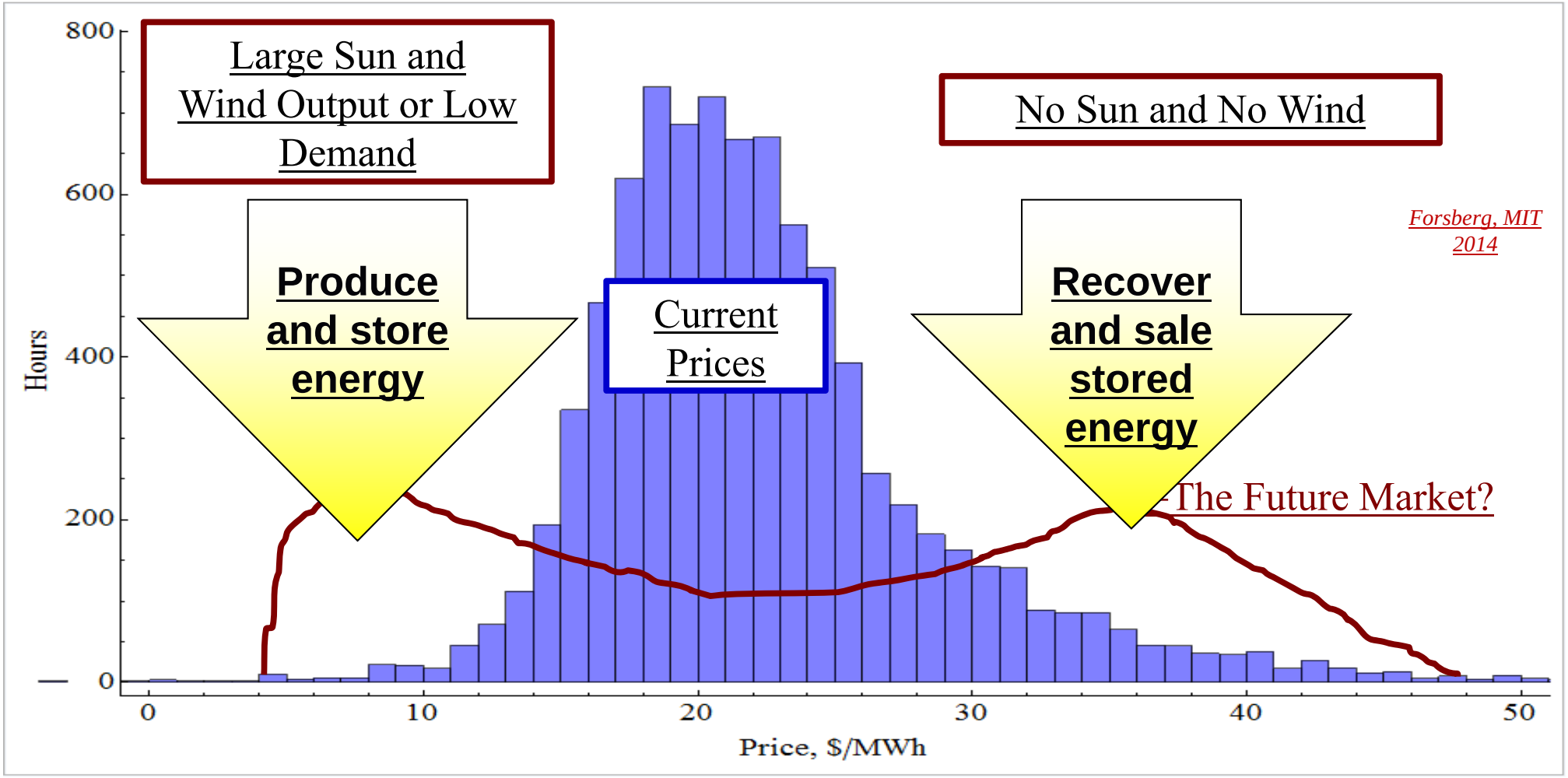
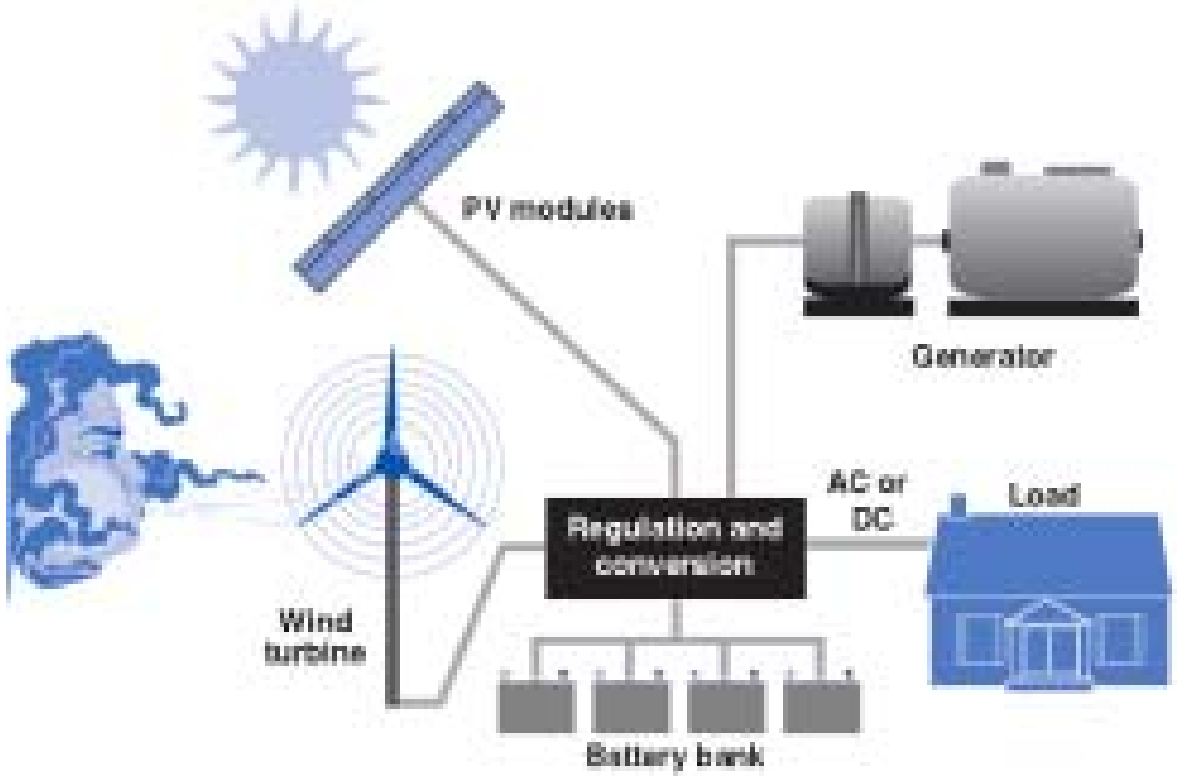
Hybrid systems energy storage viability depends on the electricity price curve



Distribution of electricity prices, by duration, at Houston, Texas hub of ERCOT, 2012

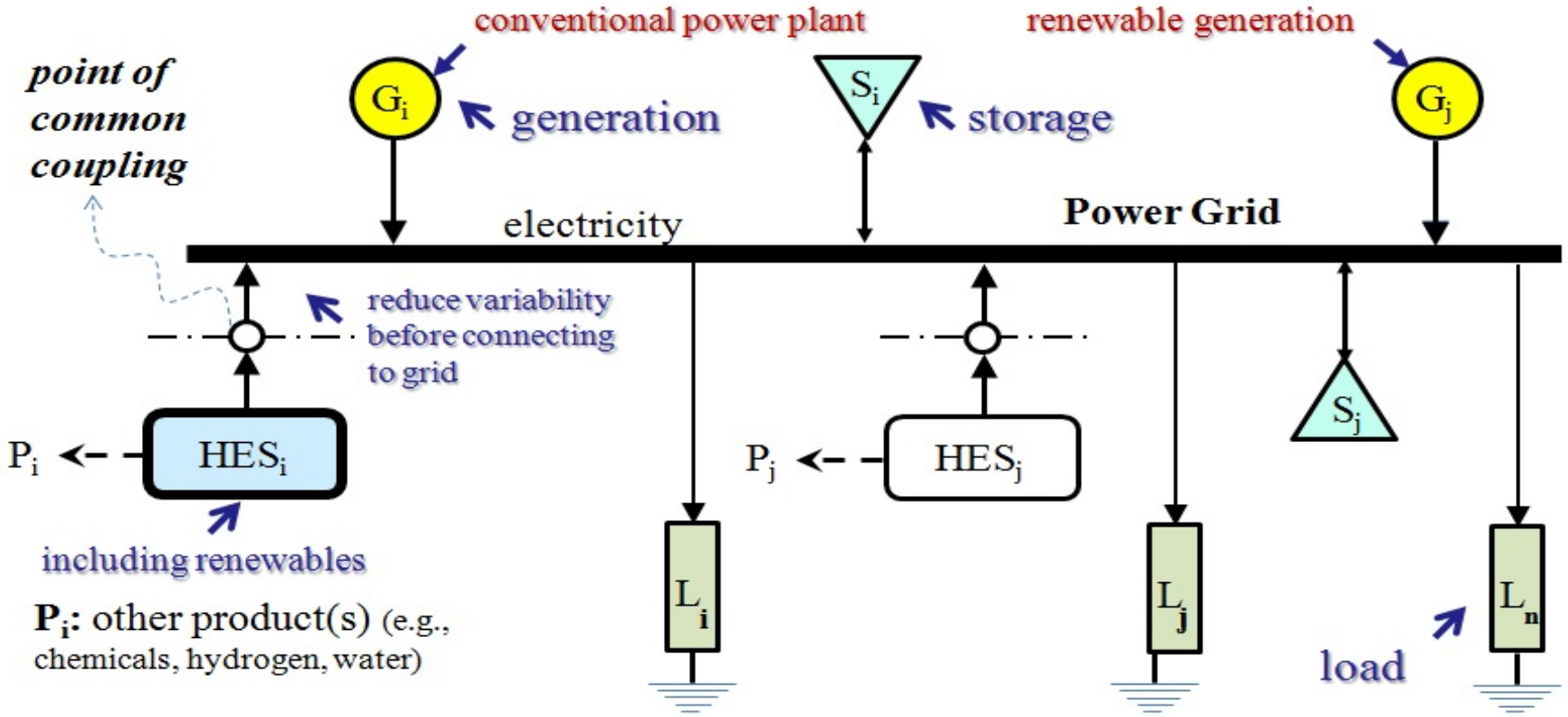
Hybrid Energy Systems- Simple Off-Grid Example



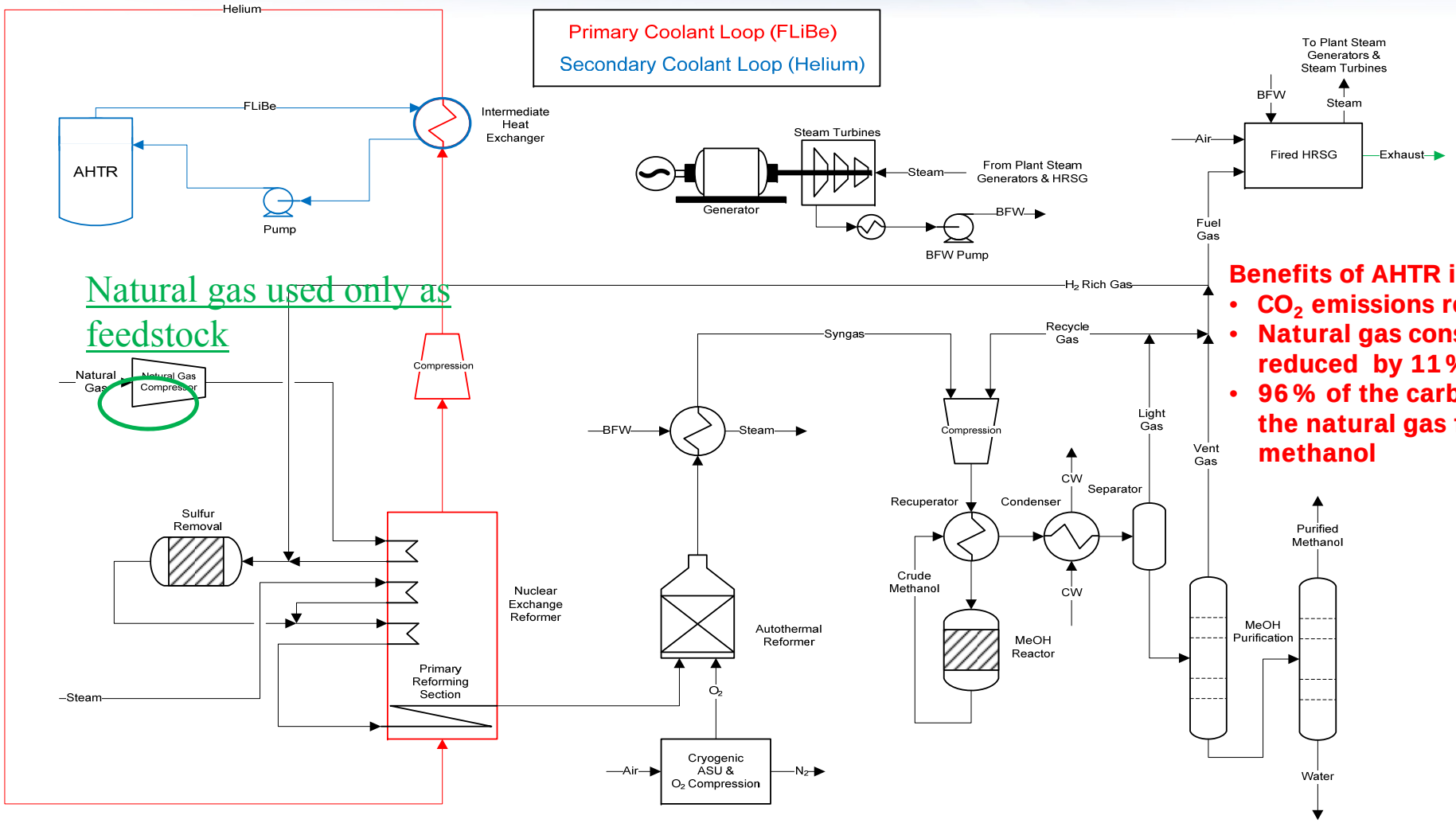
Hybrid energy systems (HES) = systems that combine multiple energy production systems—
such as nuclear, solar, wind, biofuels, coal and/or other fossil fuels – can make higher overall efficiency and level off electric load, esp. when combined with ‘smart grid’ technology.

WHY HYBRID

- ✓ Clean energy inputs for carbon reduction required across the TOTAL ENERGY SECTOR
- ✓ Renewable power generation and variable power demand create unprecedented load balancing challenges
- ✓ Many peaking units currently required to respond to generation shortages
- ✓ Baseload units may/will become intermediate-load following
- ✓ Storage required to smooth fast transient behavior (batteries, pumped hydro, compress. air, etc.)
- ✓ Thermal energy storage buffers and use by manufacturing industries

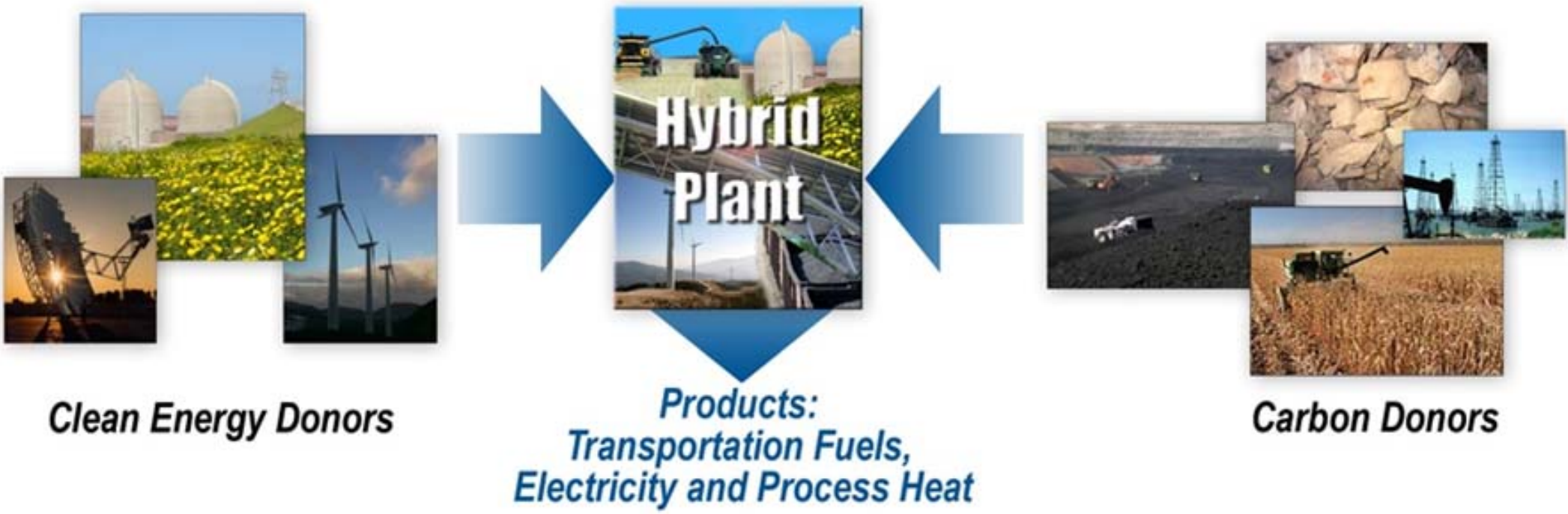


Methanol Production Process (with AHTR = Nuclear)



Benefits of AHTR integration:

- **CO_2 emissions reduced by 76 %**
- **Natural gas consumption reduced by 11 %**
- **96 % of the carbon contained in the natural gas feed goes to methanol**



Idaho Natl. Lab's OASIES Energy Modeling Systems

Optimized Analysis for Strategic Integrated Energy Systems

King's Comments:
World Economic Forum website at
http://www.weforum.org/content/**top-10-emerging-technologies-2013**

Energy-efficient water purification
Certain emerging technologies greatly increase the efficiency of desalination or purification of wastewater, potentially reducing energy consumption by 50% or more. Some techniques also allow water purification via renewable solar heating, removing the need for fossil fuels in the process.

Online Electric Vehicles
Electric vehicles have many advantages, but their heavy expensive batteries and short range often let them down. So now South Korea is pioneering online electric vehicles that are charged by wireless technology directly from the road they are driving on. Not only can the cars use a much smaller, cheaper battery, but the lower weight and greater efficiency means more than 80% of the electricity goes directly into driving the wheels.

King's Comments:
World Economic Forum website at
http://www.weforum.org/content/**top-10-emerging-technologies-2013**

cont.
Fourth-generation reactors and nuclear-waste recycling
Current nuclear power reactors use only 1% of the potential energy available in uranium, leaving the rest radioactively contaminated as nuclear "waste". Fourth generation reactors recycle spent fuel, which potentially extends uranium resources for centuries while dramatically reducing the volume and long-term toxicity of waste Such technologies are already being deployed in several countries and are offered by established nuclear engineering companies.

The vital ingredient

Chemical science and engineering for sustainable food
January 2009

RSC | Advancing the Chemical Sciences

IChemE

- Use of biomass for fuels challenges **food supply**
- Food needs increasing faster than population
- Fertilizer needs increasing way faster

NEEDS:

- Better chemical and biochemical methods to extract cellulose from lignocellulosic fuel crops.
- Methods for recycling carbon and nitrogen in soil in order to help maintain sustainable agriculture and reduce emissions of nitrous oxide, a potent greenhouse gas.

WATER:

- Improving chemical engineering technologies to conserve and reuse water, optimisation of water use, treatment of contaminated water, recycling water, desalinating water and harvesting water for irrigation.

SusChEM Workshop
Jan 17-19, 2012
Arlington, Virginia

SusChEM

Findings and opportunities from the 2012 NSF SusChEM workshop

Chair: Susannah Scott
Department of Chemistry & Biochemistry; Department of Chemical Engineering
University of California, Santa Barbara

Co-chair: Jim McGuffin-Cawley
Department of Materials Science and Engineering
Case Western Reserve University

Challenges for Conversion of Lignocellulosic Biomass to Fuels and Chemicals: Liquid-phase catalysis

Presentation to:
NSF Food Systems Committee

James A. Dumesic
Chemical & Biological Engineering
University of Wisconsin
Madison, WI 53706

See also his paper:
A roadmap for conversion of lignocellulosic biomass to chemicals and fuels, Curr*ent Opinion in Chemical Engineering* 2012, 1: 218–224

Can we use GVL as a solvent for biomass processing: hemicellulose?

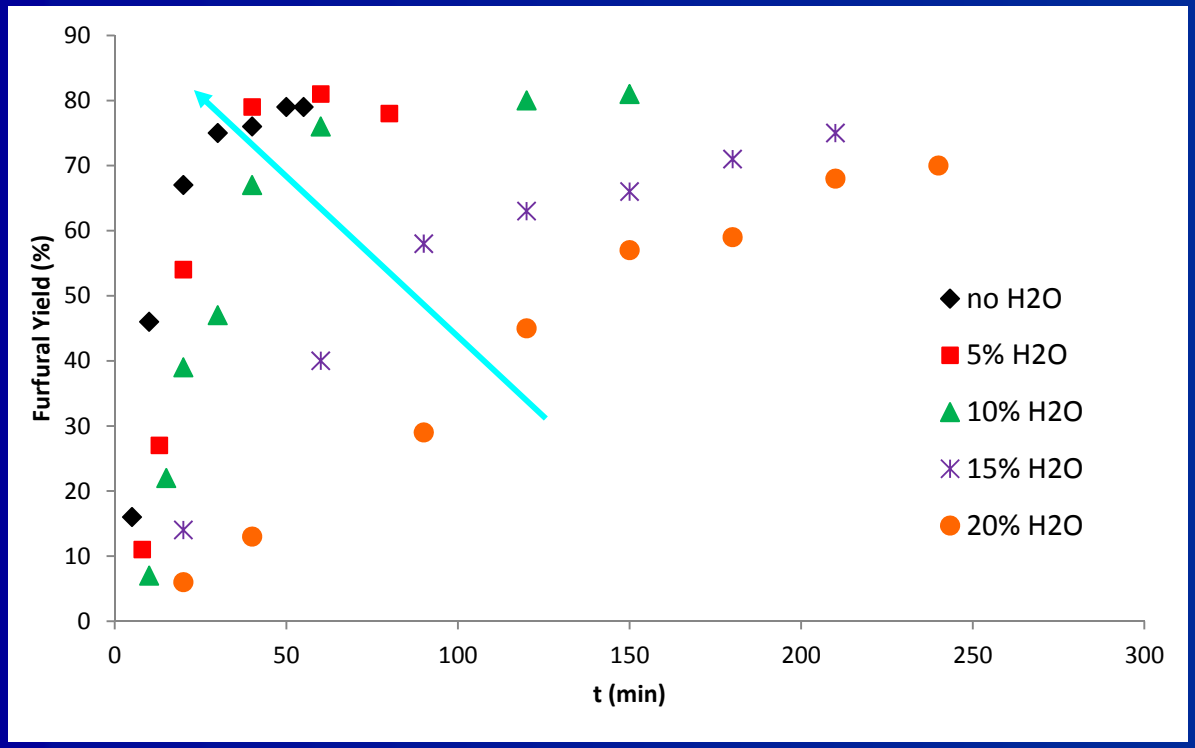
Conversion of hemicellulose into furfural using solid acid catalysts in GVL (gamma-valeroloactone)

Elif I. Gürbüz, Jean Marcel R. Gallo, David Martin Alonso, Stephanie G. Wettstein, Wee Y. Lim, and James A. Dumesic

Angew Chem Int Edition **52**, 1270 (2013).

Presence of water in the GVL solution

Feed: 2 wt% xylose, **T**=175°C **Catalyst:** H-mordenite



- As the water concentration is increased, the rate of furfural production decreases.
- Yields over 70% are achieved in all cases.
- Effect of water is particularly significant at water concentrations higher than 10 wt%.

Higher reactivity at lower concentrations of H_2O.

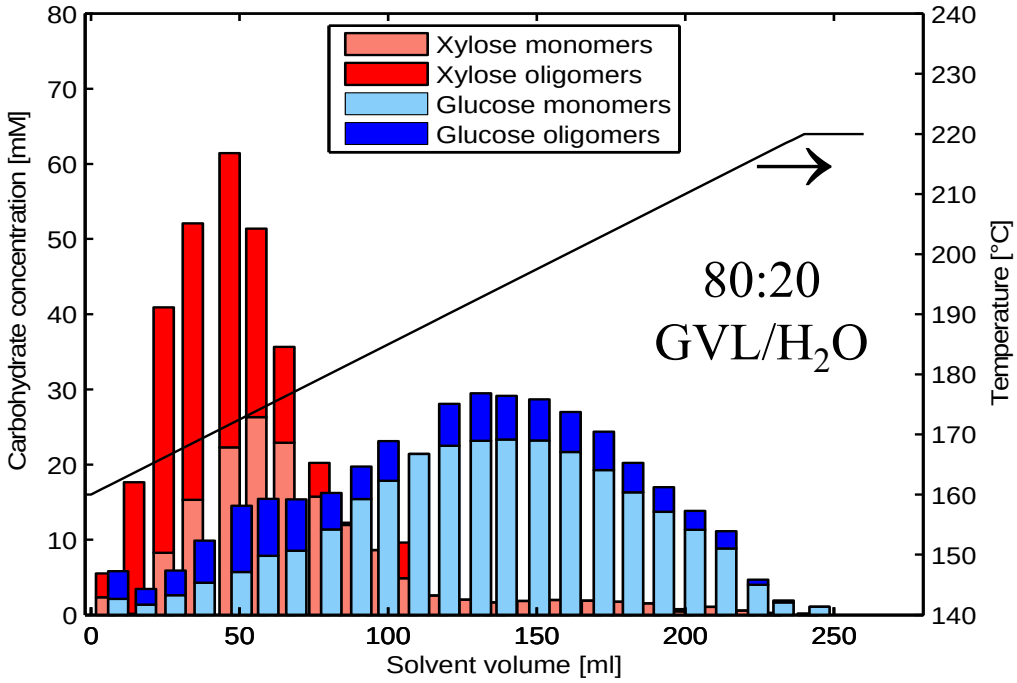
Can we use GVL as a solvent for conversion of hemi-cellulose and cellulose to xylose and glucose?

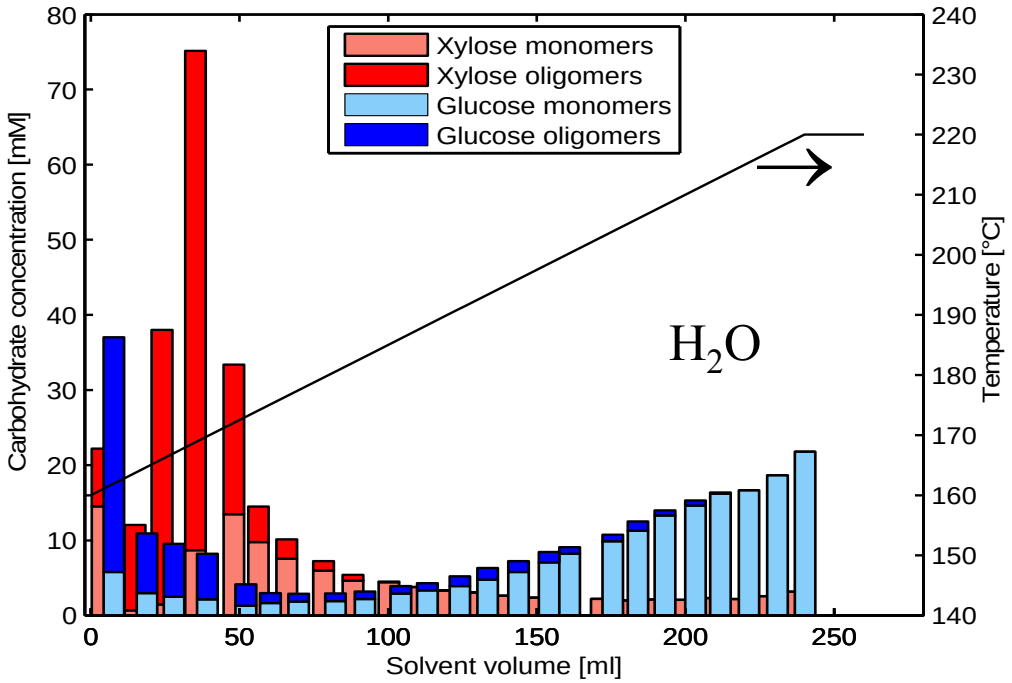
Non-enzymatic sugar production from biomass using biomass-derived γ-valerolactone

Accepted for publication in *Science*

Luterbacher, Rand, Martin Alonso, Han, Youngquist, Maravelias, Pfleger, and Dumesic

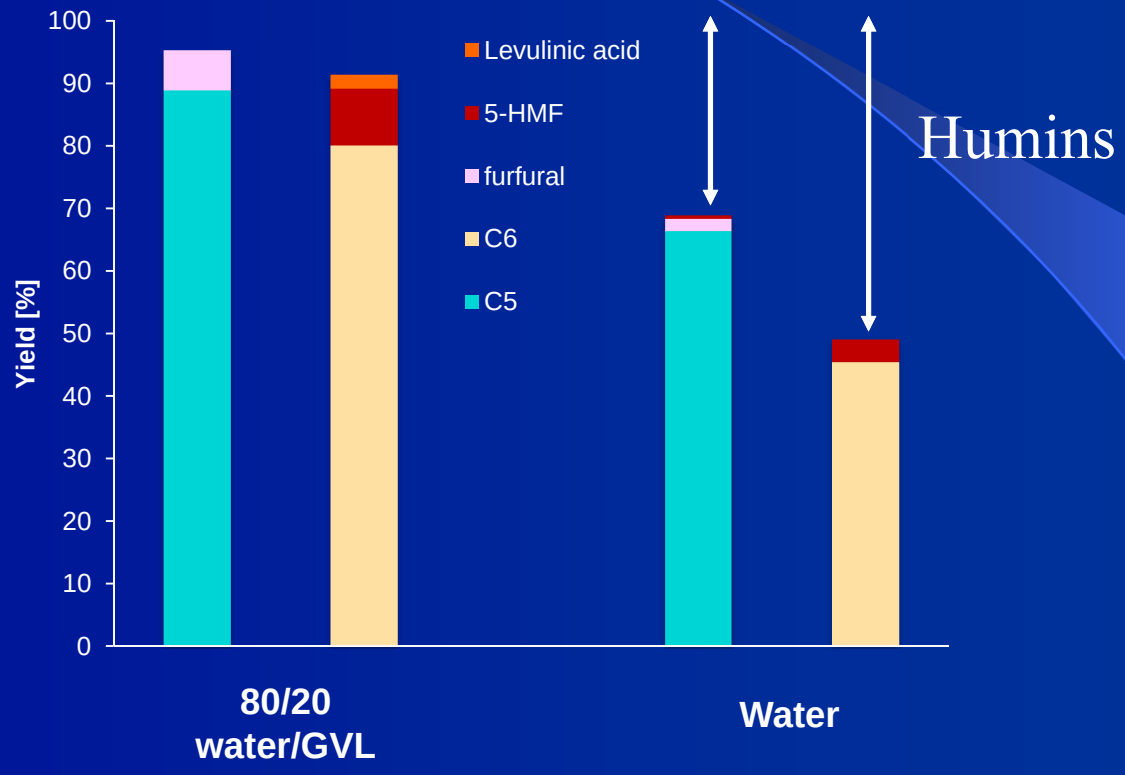
Sugar production





With **5 mM H_2SO_4**
= **10-100 times less** than typically used
for pretreatment!

Sugar Yields: Carbon Balances



The last 7 slides were from a presentation by James A. Dumesic to the NSF Food Systems Subcommittee

CONCLUSIONS / RECOMMENDATIONS

Electricity from solar, wind

- Need lots more storage
- Avoid Carnot Efficiency Limits
- Hybrid systems / Integration Essential

Biomass:

- Use only the non-edible parts of the plant
- Making chemicals is more promising than fuels

General:

Need govt. policy that rewards integrating new plants for energy efficiency