Opportunities and Challenges for an Ammonia Fuel Economy

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Topics

- Setting the Stage
- Ammonia Fuel
- Production/Consumption
- Issues
- Okay, what do we do next?

Relevant Quotes

- "If we don't succeed, we run the risk of failure."
- "[It's] time for the human race to enter the solar system.“
- “We are ready for any unforeseen event that may or not occur.”
- "It's wonderful to be here in the great state of Chicago."

- Dan Quayle

Relevant Quotes (cont.)

- "It isn't pollution that's harming the environment. It's the impurities in our air and water that are doing it.“
- “My friends, no matter how rough the road may be, we can and we will, never, never surrender to what is right.“
- "The future will be better tomorrow."

-Dan Quayle


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What We Know….(Drivers)

- Global warming
- Price of oil and gasoline
- CO2 in the atmosphere
- Methane in the atmosphere
- Natural gas is not going to get cheaper
- Ammonia can be made from coal or NG
- Ammonia can be made from water and air
- Ammonia burns cleanly in Fuel Cells and ICE
- Etc.

What We Don't Know…(Moderators)

- How 40 MT of hydrogen is going to be produced
- If fuel cells will ever be cost competitive
- Can NH3 be made safe for energy use
- What a hydrogen distribution system would look like
- If global warming can be stopped
- Can renewables be effectively harnessed
- The way out of this mess we find ourselves in….

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Anhydrous Ammonia

NH_3

- 75% H2 by volume
- 18% H2 by weight
- Zero Carbon

Benefits of Ammonia Fuel

- Clean
- Abundant
- High energy density
- Reasonably priced
- Stably priced (coal)
- Non-explosive and virtually non-flammable
- Easy to store/transport
- Readily made from renewables
- Easy to reform to hydrogen
- Can power ICE or FC
- Combustion produces potable water

Clean Power + "A Bonus"

Ammonia Plant

Ammonia Pipeline (250 psi rated)

- carbon steel
- shedule 80 PVC
- high pressure flexible tubing

$$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O + \text{energy}$$

- Inherently carbon free
- Can be operated NOx free

Energy and
Potable Water

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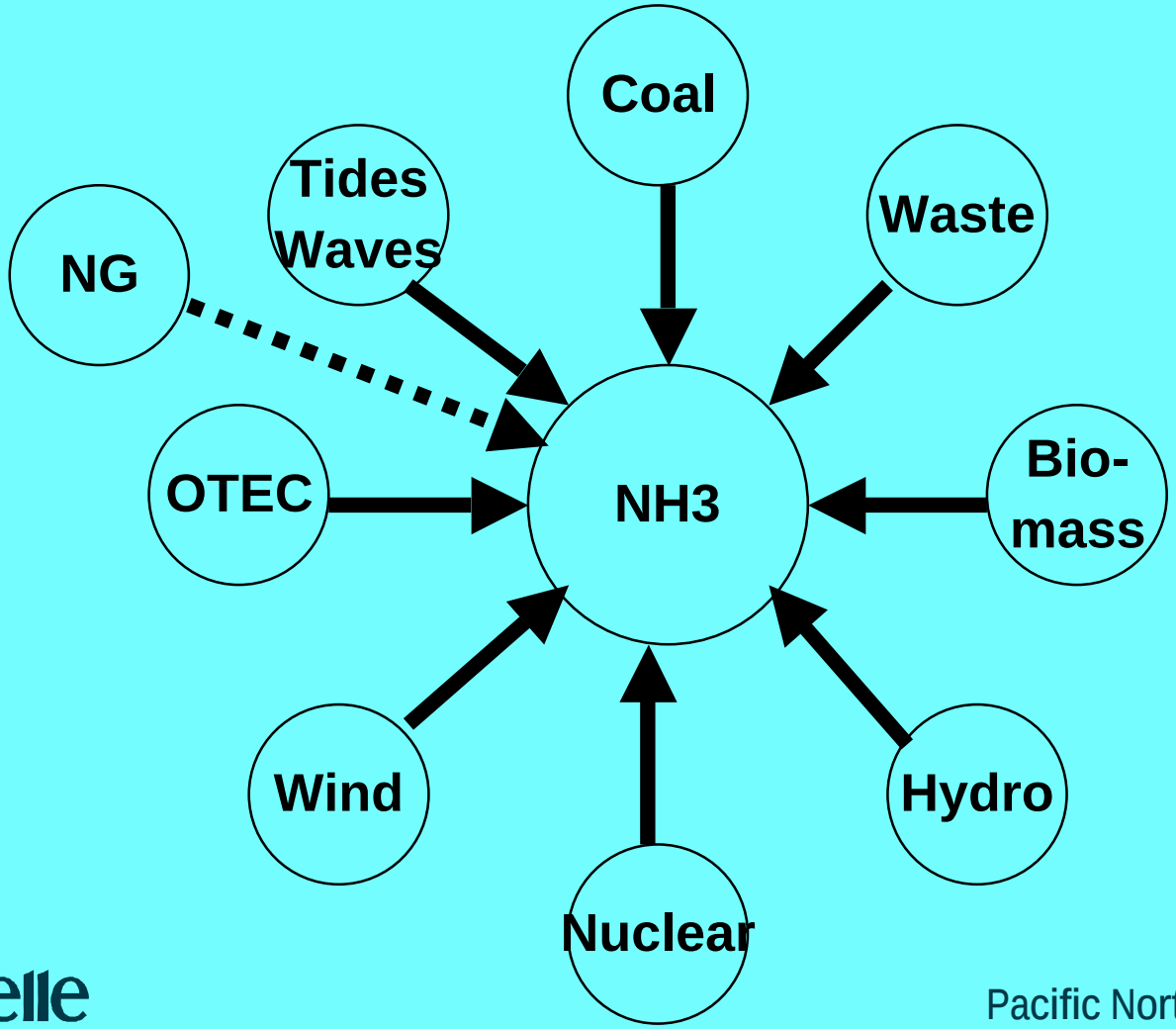
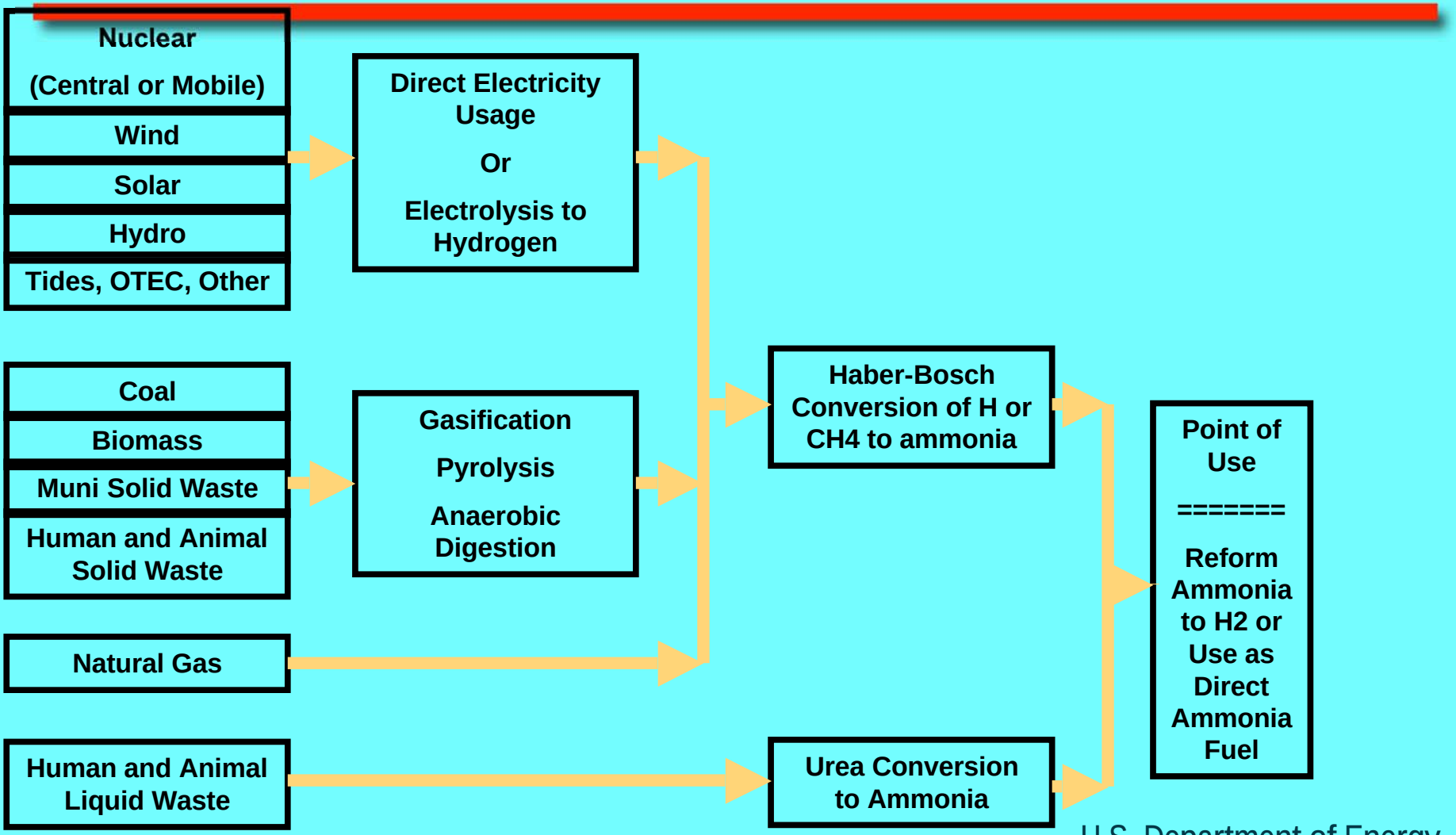
Ammonia Sources



Ammonia as a Direct Fuel or Hydrogen Carrier



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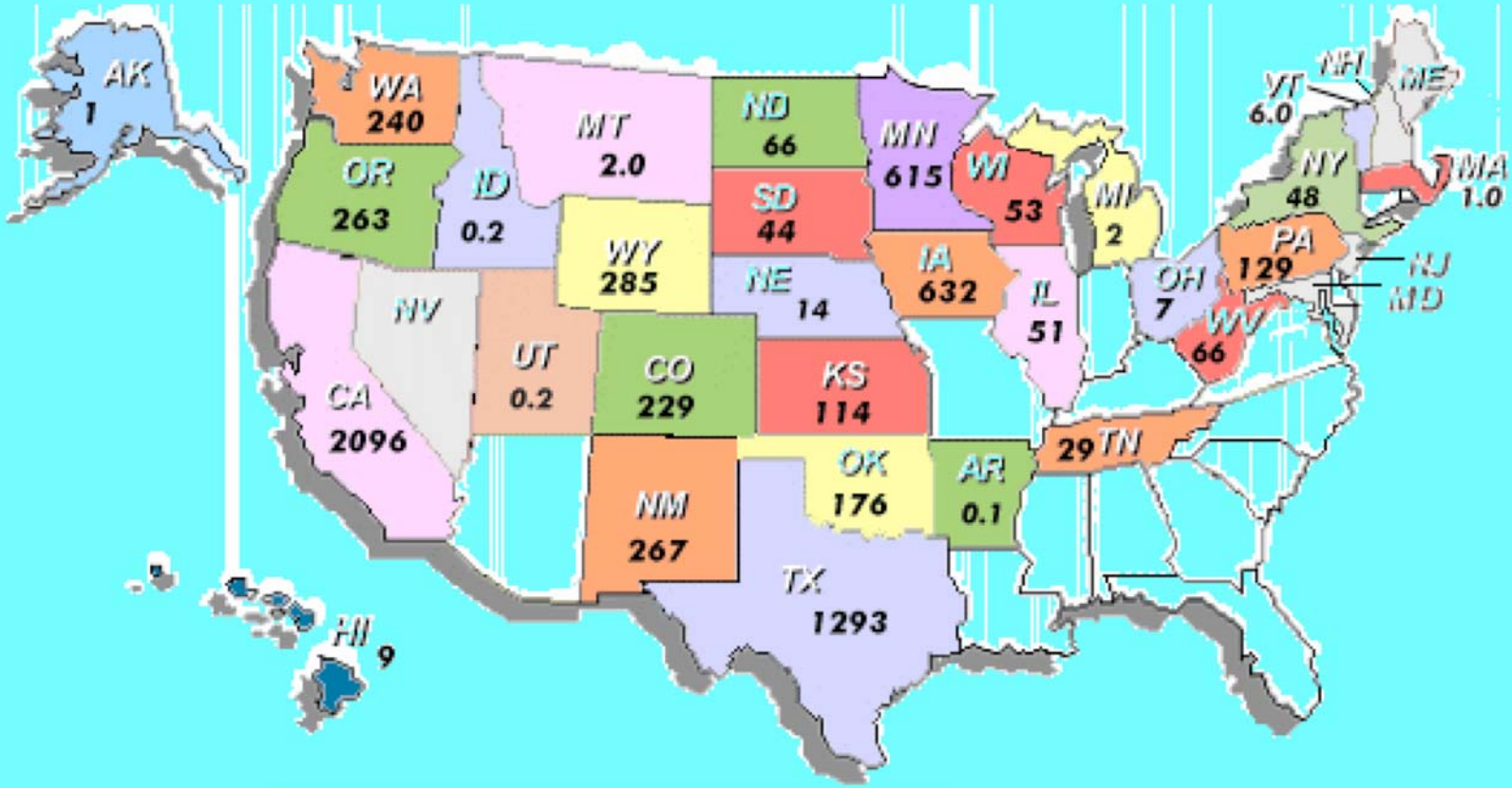
US Wind Projects—Jan 2005



Number indicates installed capacity

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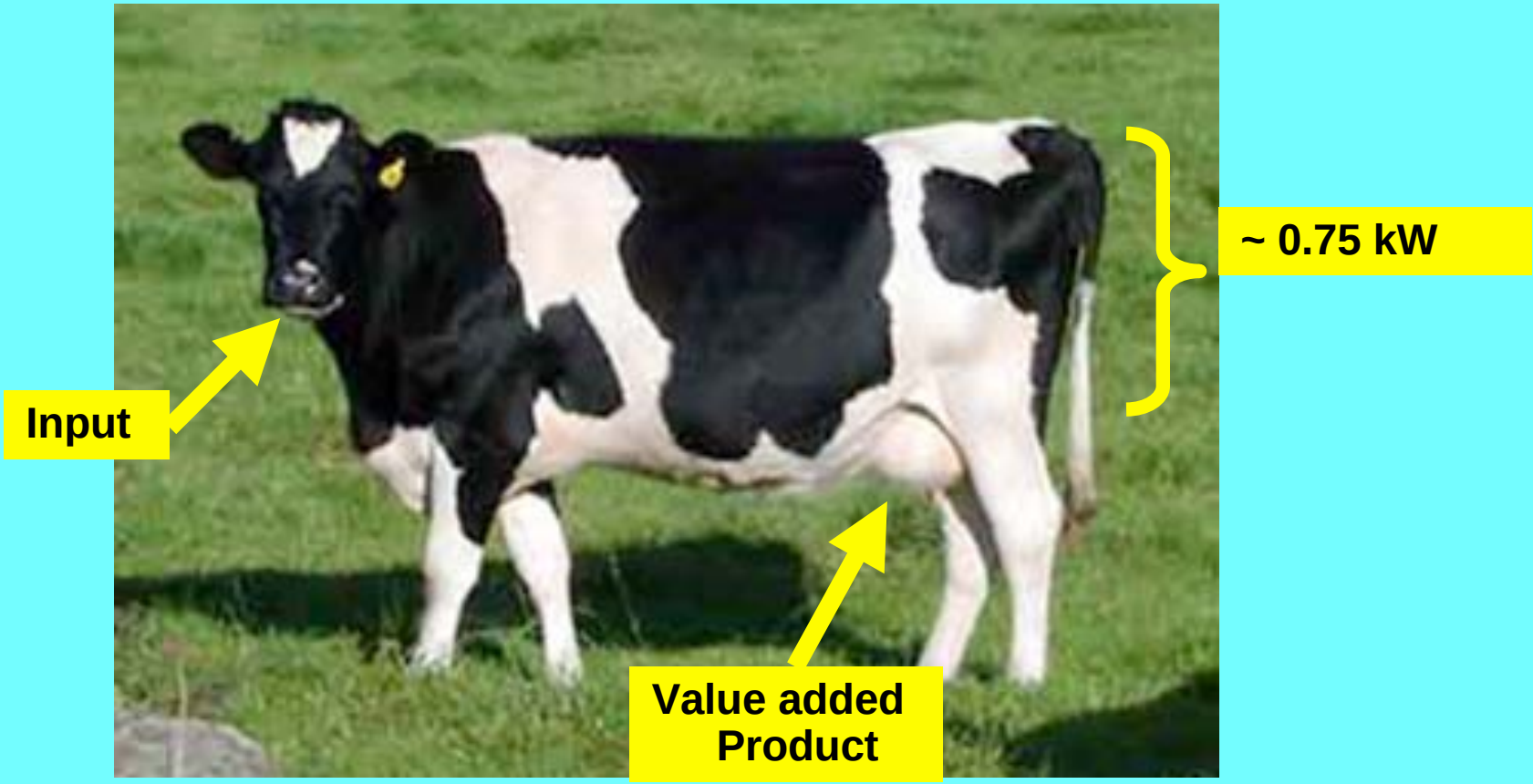
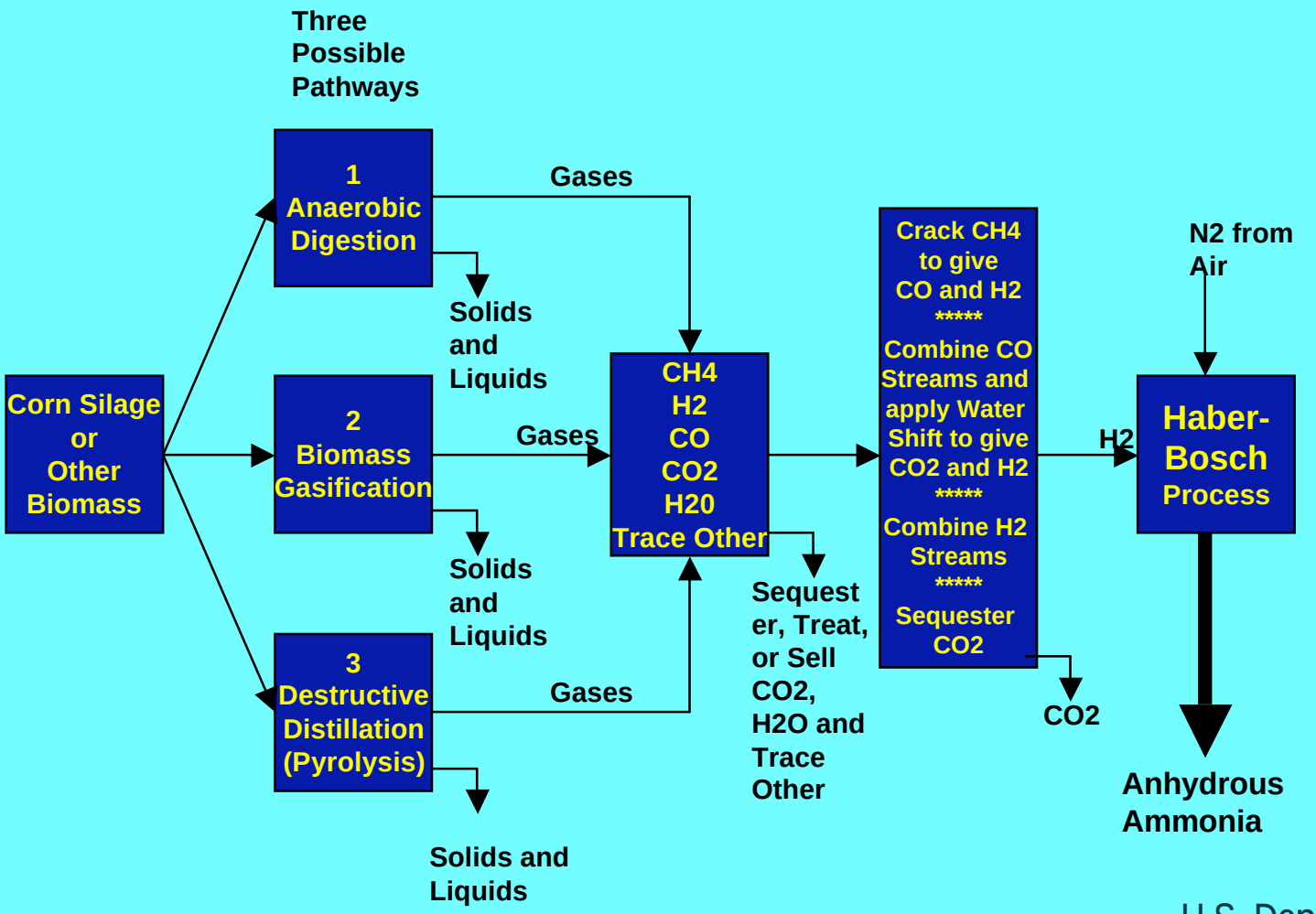
Wind & Hydro

Bovine Bioprocessor



Ammonia From Corn Silage or Other Biomass



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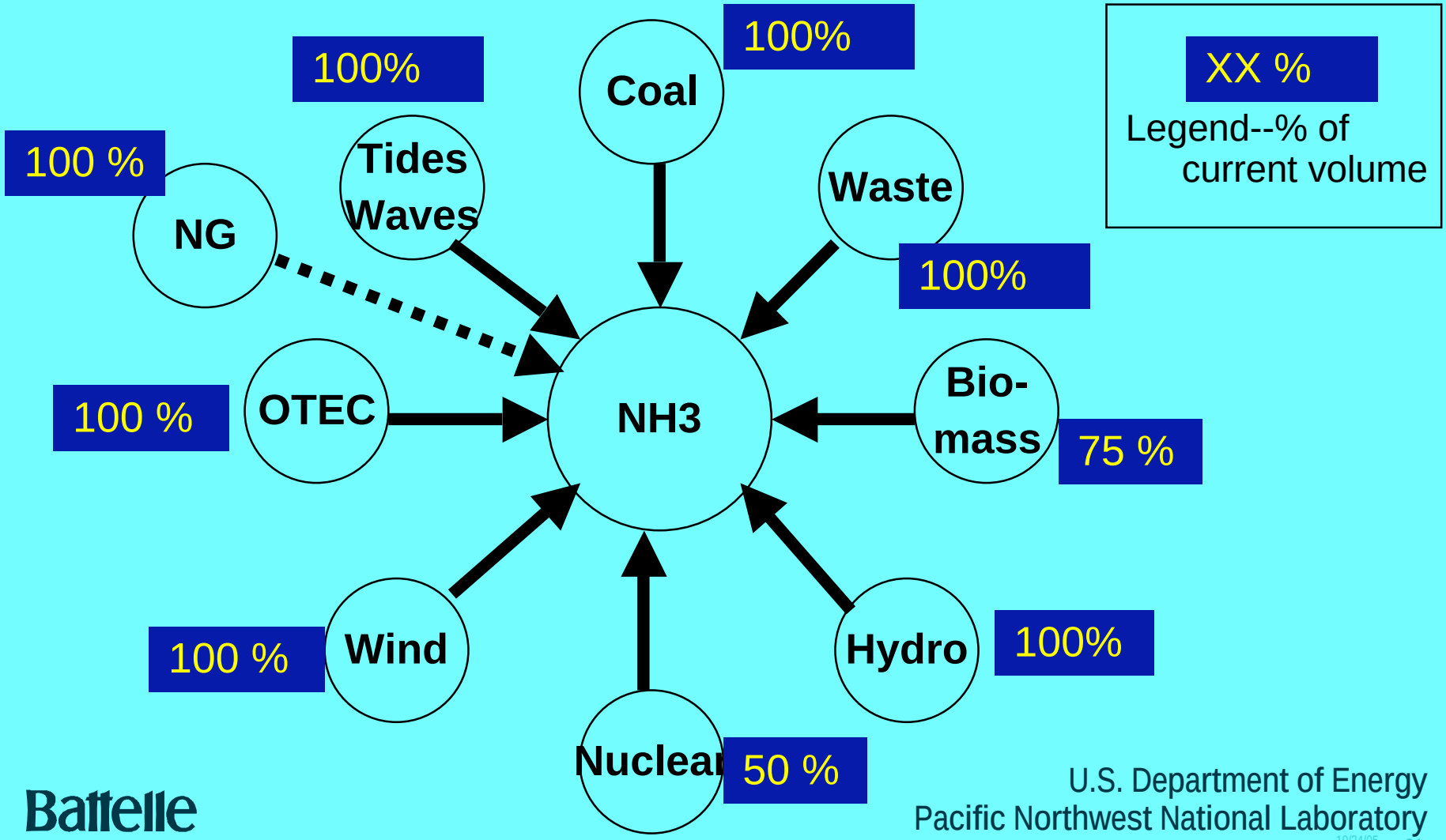
Scale of Things

- US gasoline use (2003)……..……5.9 Billion MWh
- US electric consumption (2003)…….. 3.7 Billion MWh
- Canadian electric consumption (2003)…….0.52 Billion MWh
- US hydropower production (2003)…….0.28 Billion MWh
- Untapped US hydropower……...0.26 Billion MWh
- Total California wind farms (2004)…….0.004 Billion MWh
- Current US ammonia production……..0.04 Billion MWh
- Biggest US Ammonia Complex……..0.01 Billion MWh
- Itaipu Hydro (12,600 MW)……..0.11 Billion MWh
- Super Inga Hydro (~40,000 MW)……..……0.35 Billion MWh
- 40 Mega Tons of hydrogen per year……1.3 Billion MWh
- Current US hydrogen production……0.05 Billion MWh

Ammonia Sources



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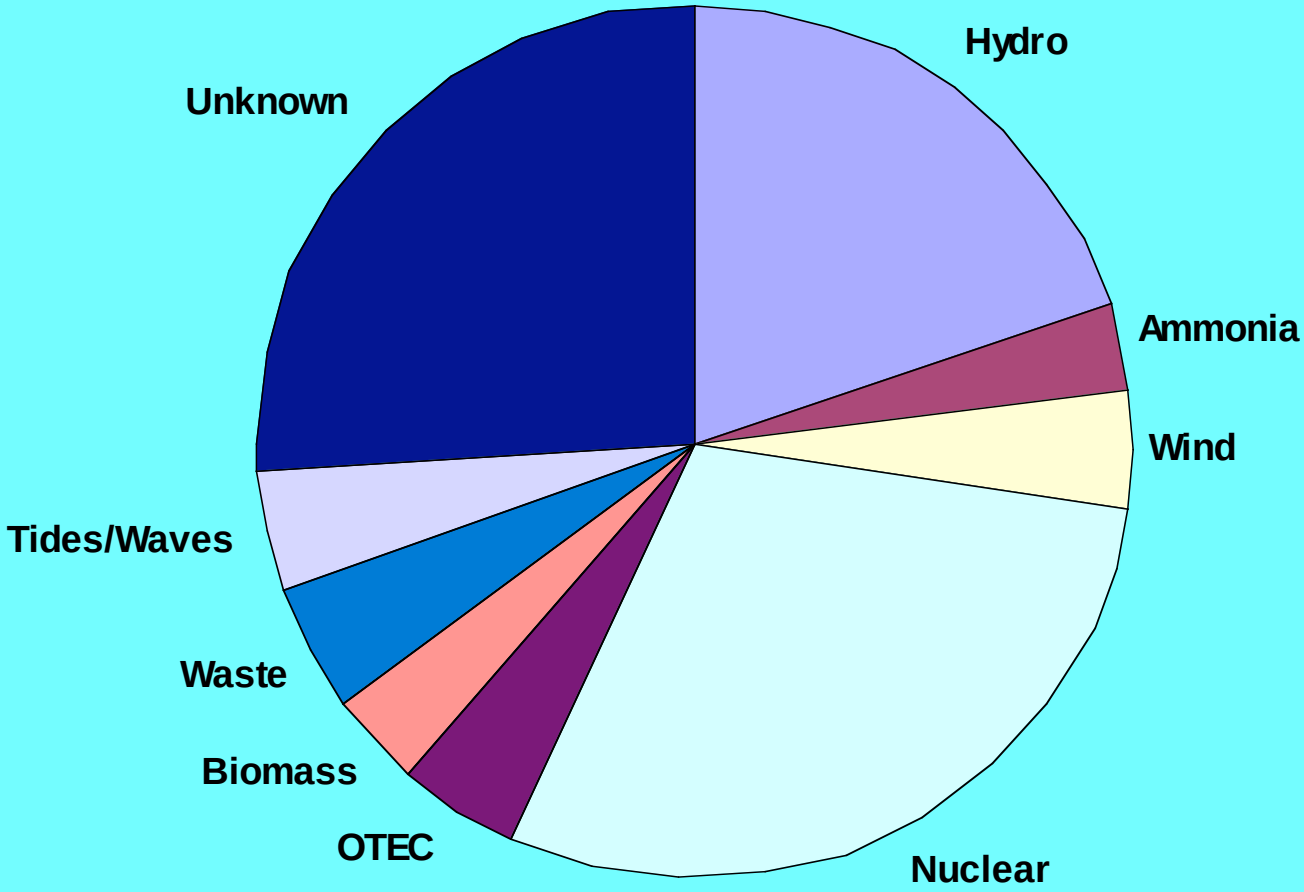
Energy For Hydrogen/Ammonia



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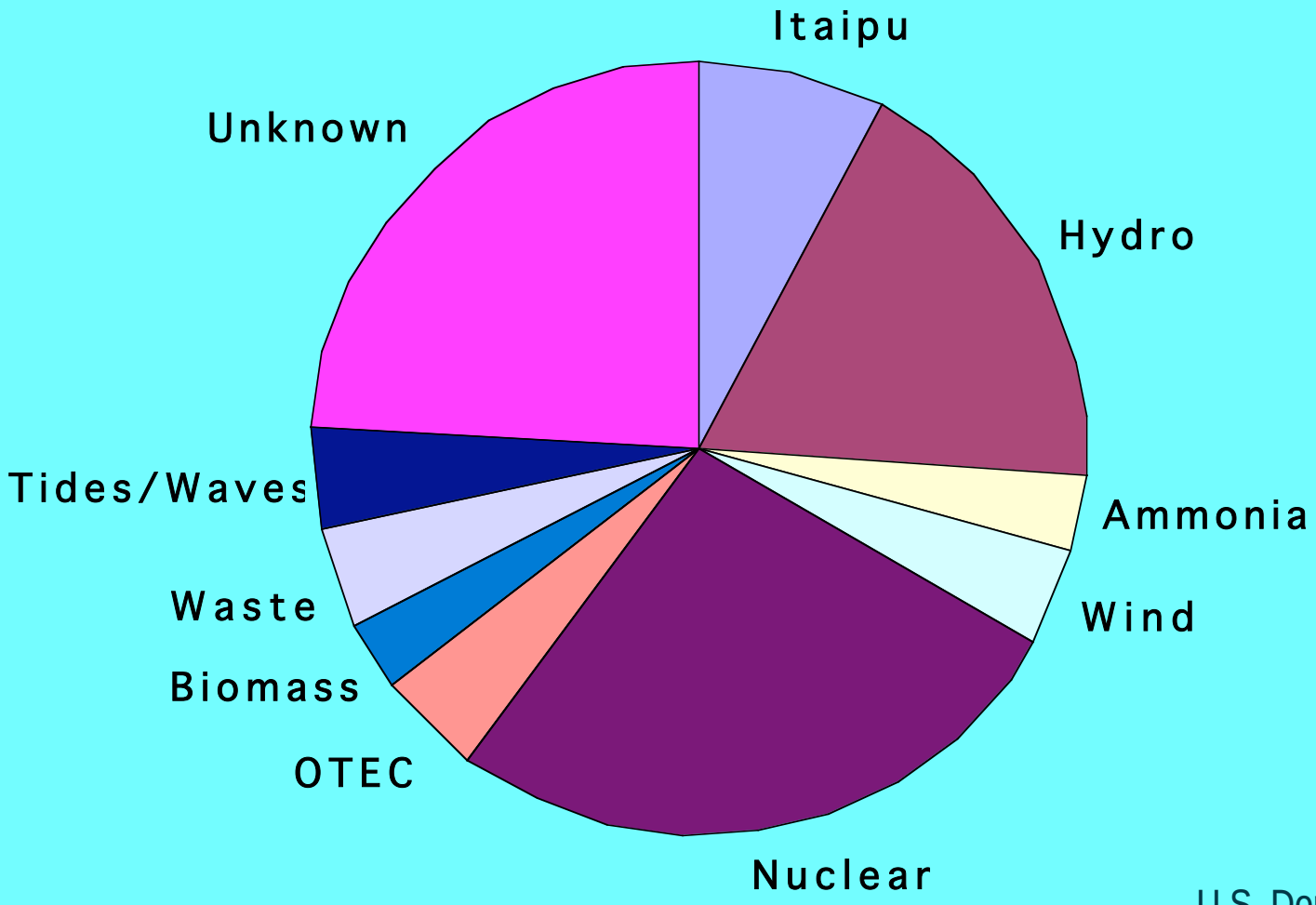
Let's Add A Mega Hydro Project



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Ammonia Toxicity—We Shall Overcome

Need

- Safe Storage
- Technology (e.g. filling connections)
- Chemistry, e.g.

$$HCO_3^- + NH_3 \rightarrow NH_4CO_3^- \ (pH \sim 7)$$

Bicarbonate solution nullifies ammonia

Ammonia alternates

- Urea ($CO(NH_2)_2$)

[urea] + [water] → [carbon dioxide] + 2 X [ammonia]

- Guanidine (CH_5N_3)

[guanidine] + [water] → [urea] + [ammonia]

- Ammonia “tablets” – $MgCl_2$-ammonia complex

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What We Need (to gain support for ammonia fuel)

- Public acceptance (not just midwest)
- Research
- More Efficient Electrolyzers
- Attention of auto makers
- Attention of ammonia producers
- Demo projects with proven efficient and safe operations

Development Priorities

Topic Area	Technical Obstacle	Addl Obstacles
Wind	Electrolyzers	NIMBY
Hydropower	Electrolyzers	Investment
Waste/Biomass	Separations Demonstrations	Economics
Coal	CO2 Sequestration	Market Uncertainty, Investment
Transport/Delivery	At Full Capacity	Red Tape, Investment
Safety	Technology Safe Experience	Public Acceptance
ICE	Demonstrations	Public Acceptance
Fuel Cells	Demonstrations	Public Acceptance
? Unexpected ?		

Upcoming Demonstrations

Production

- Wind-to-Ammonia pilot project

Usage

- Direct Ammonia ICE vehicle
- Direct Ammonia FC vehicle

Norsk Hydro Ammonia Vehicle

Ammonia fuelled car, Rjukan 1933

Source : "Worth a try"
Research and Development in Norsk Hydro through 90 years",
Oslo 1997 (page 125)

Upcoming Events

- NHA, March 2006, San Diego
- Hydro Expo, July 2006, Portland OR
- 3rd Annual Ammonia Fuel Conf, Oct 2006
  - St. Louis
  - Cincinnati
  - Salt Lake