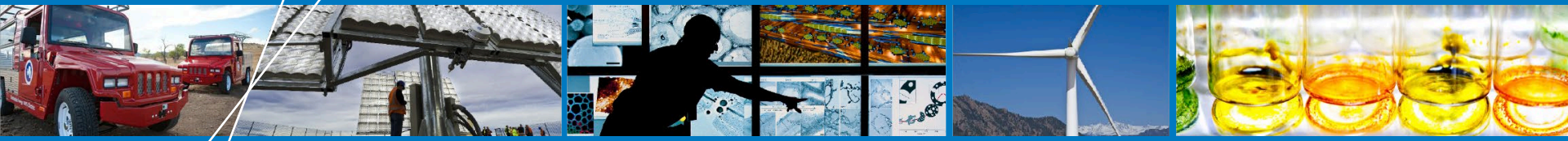
NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Industrial Scale Energy Systems Integration



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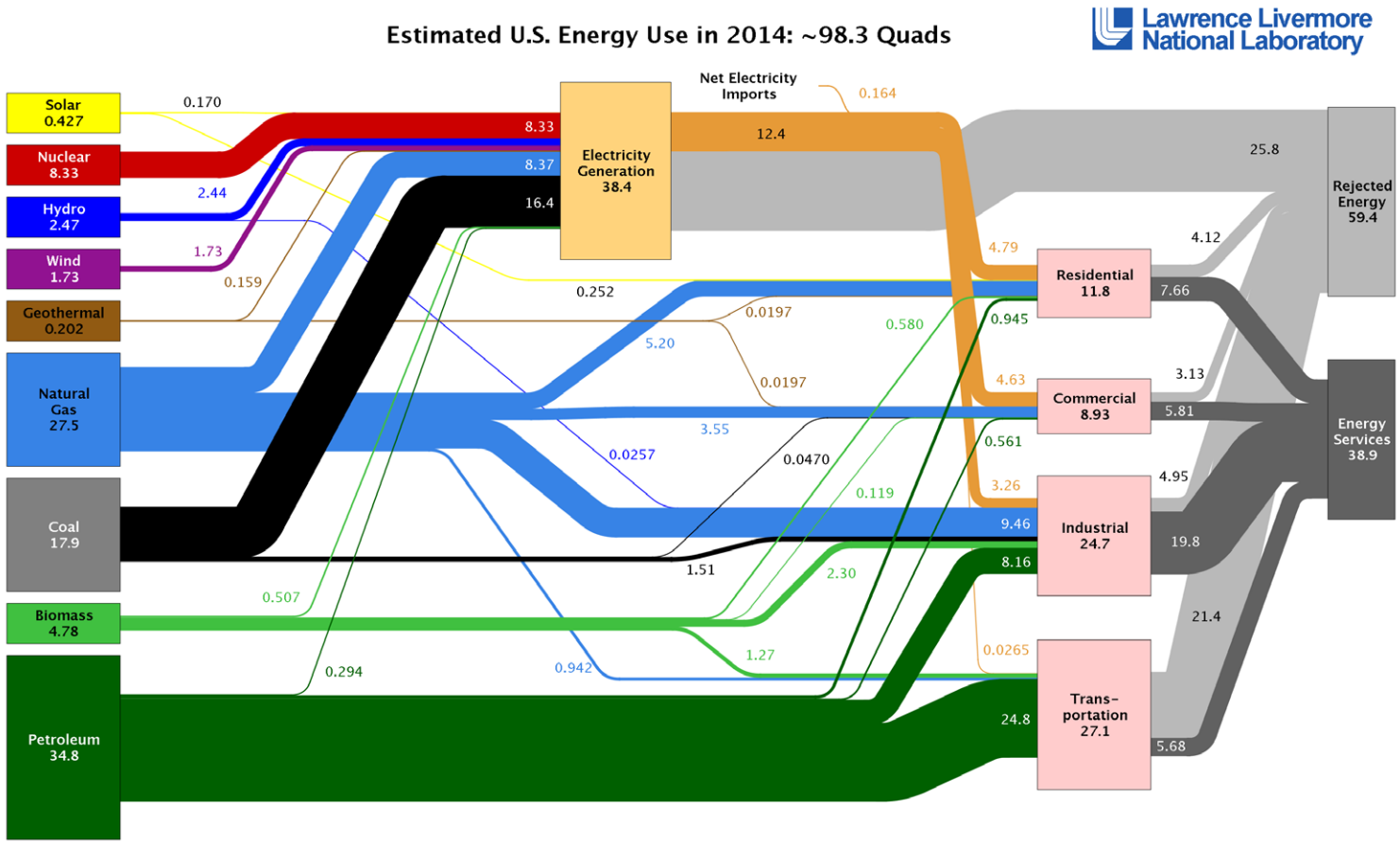
NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Outline

- **Industrial scale energy use**
- **Energy Systems Integration (ESI) opportunities in industry**
  - Combined heat and power
  - Trigeneration
  - Demand response
  - Integrated, hybrid energy systems

Energy Use in the Industrial Sector

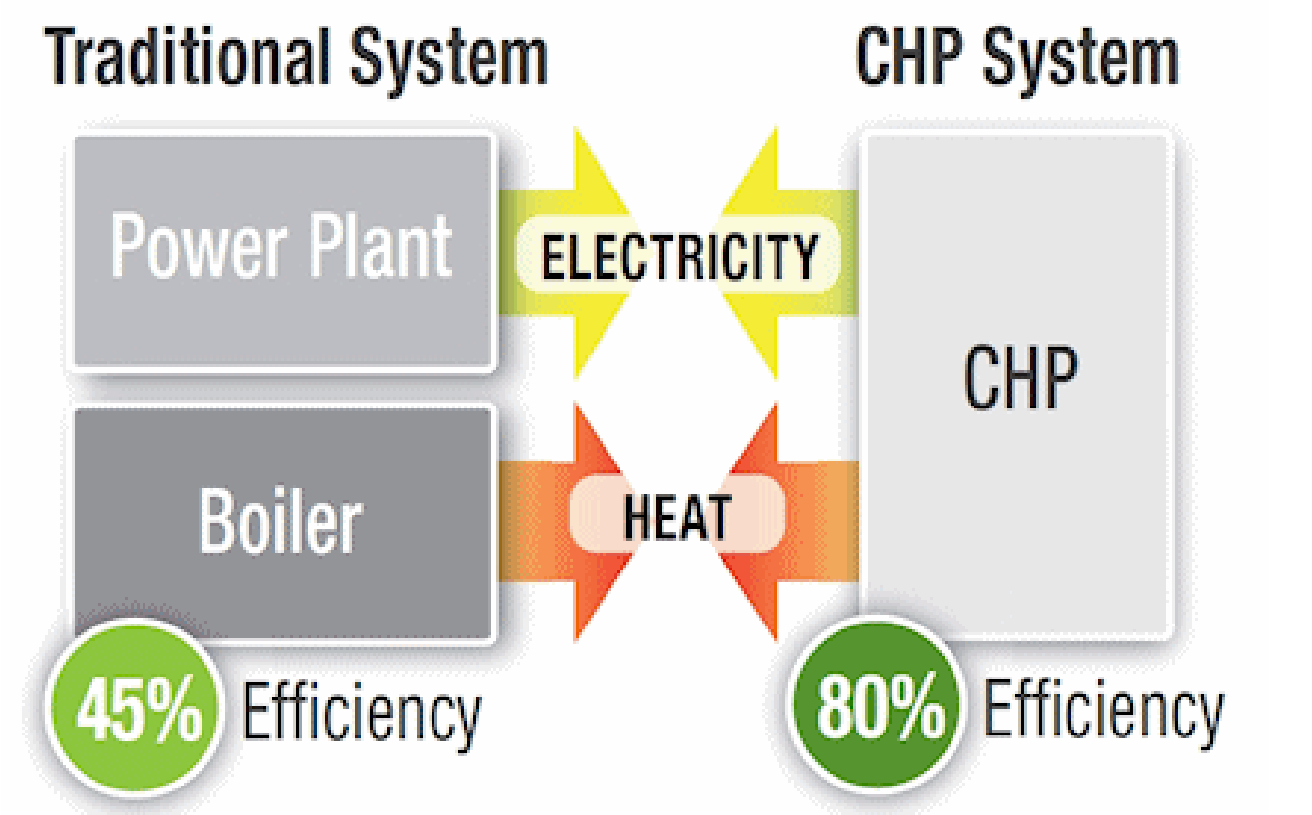


Source: LLNL 2015. Data is based on DOE/EIA-0035(2015-03), March, 2014. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." 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 65% for the residential and commercial sectors 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

- **25% of the total U.S. energy demand**
- **18% of carbon emissions**

Combined Heat and Power

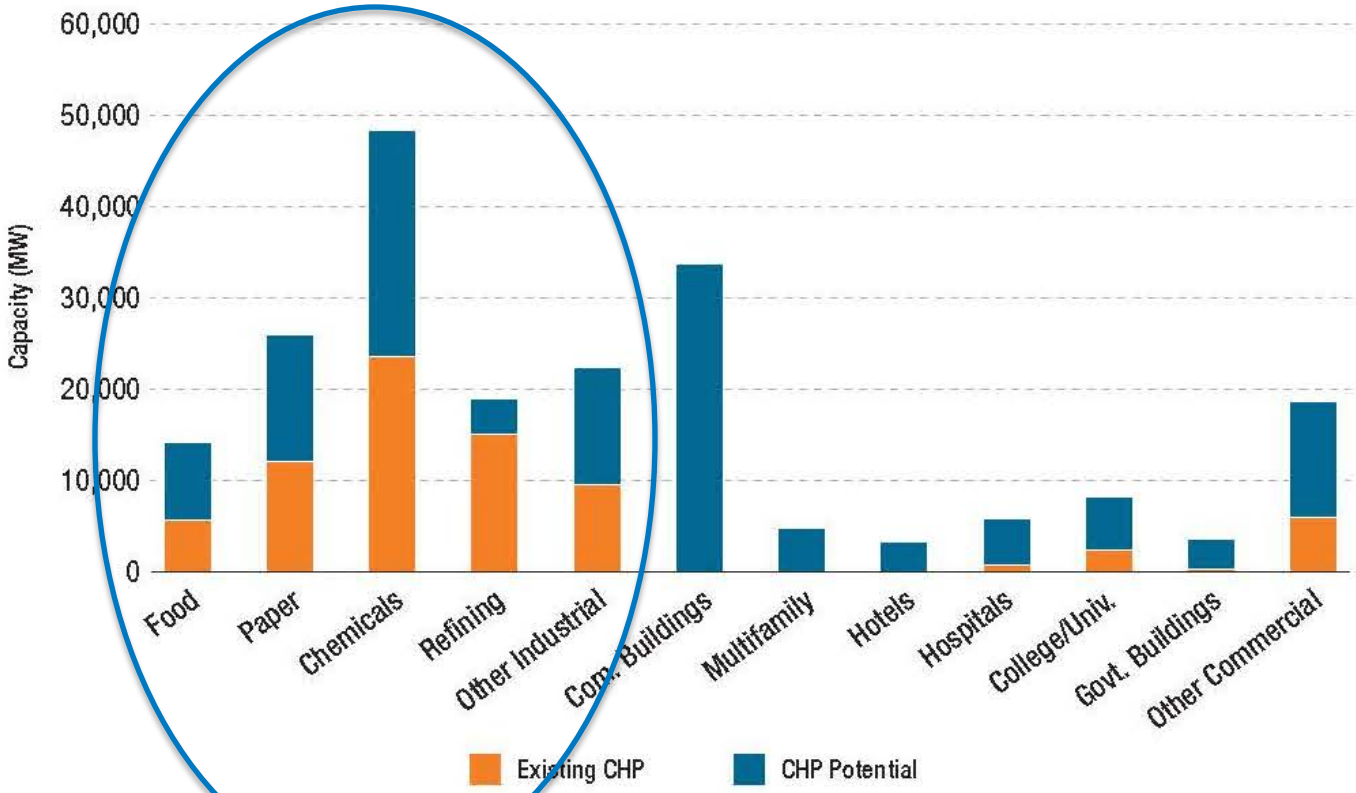
- U.S. CHP capacity in 2012: 71 GW
- Industry operates 87% of current CHP



Source: Combined Heat and Power: A Clean Energy Solution, DOE/EE-0779, August 2012

Economic Potential for Future CHP

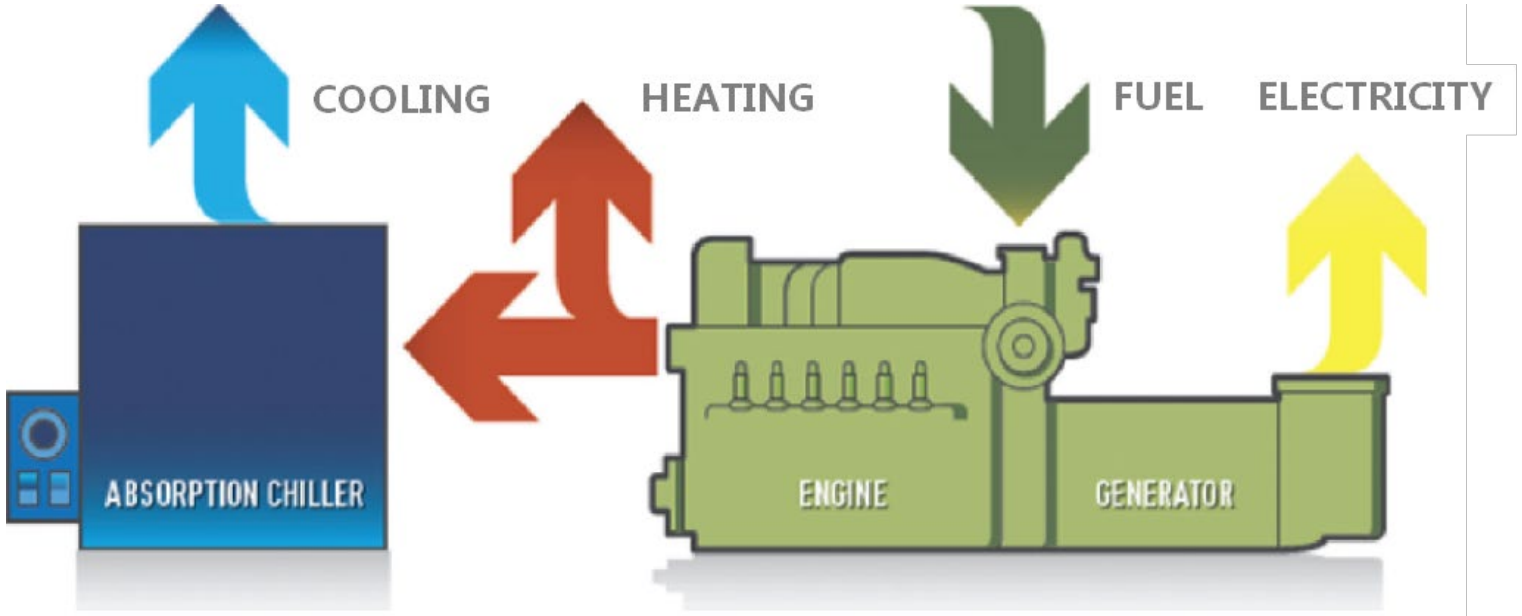
- **Industry could more than double CHP capacity to a capacity of 130GW**



Source: Combined Heat and Power: A Clean Energy Solution, DOE/EE-0779, August 2012

Trigeneration

- **Adding absorption chilling to CHP increases flexibility**
- **Industry requires more moderate temperature cooling than heating**



Source: http://www.esdmenergy.com/html/en/technologies/trigeneration.html

Demand Response by Industry

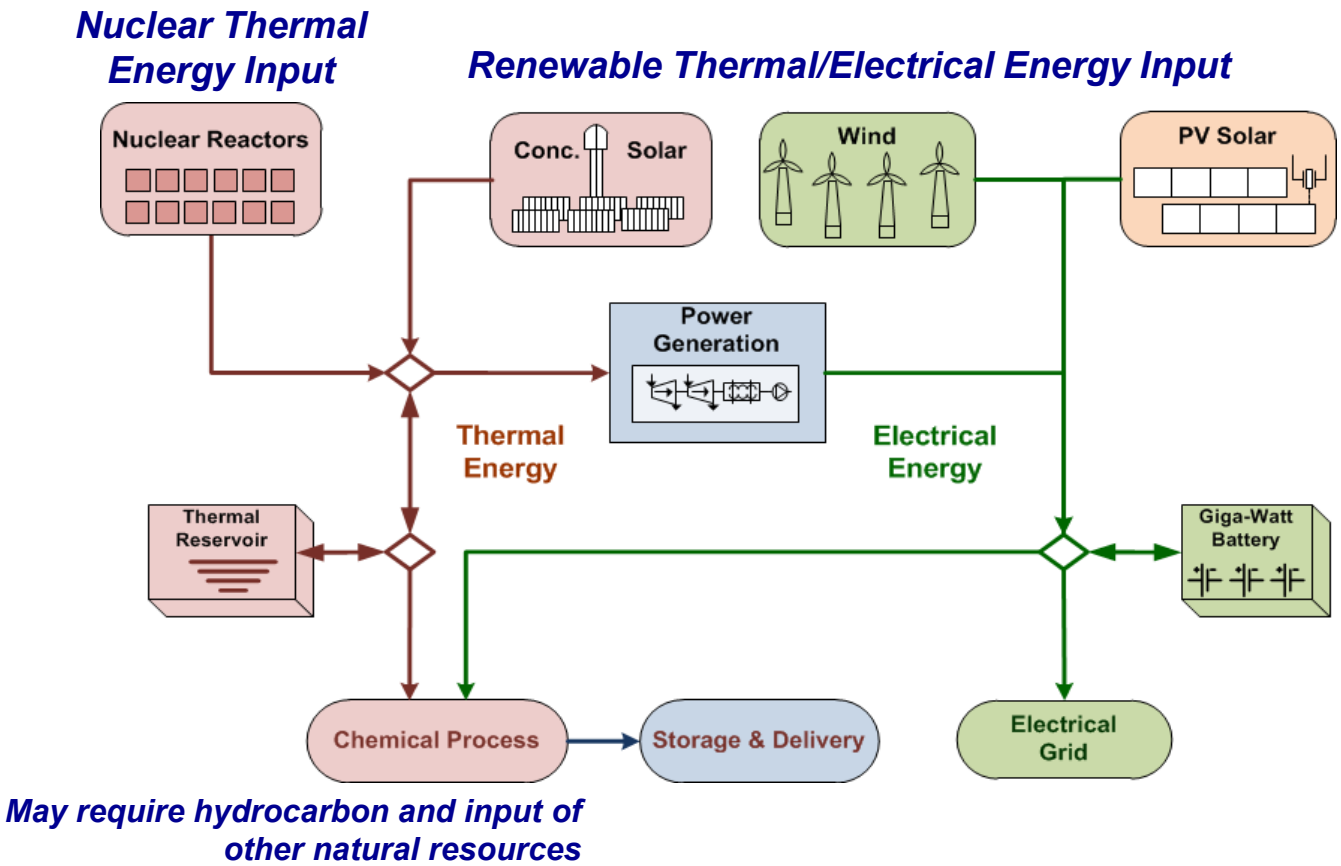
- **In 2012, industry provided 13 GW of demand response capacity – 47% of total available**

Table 3-2: Potential Peak Reduction (MW) from Retail Demand Response Programs by Region and Customer Class (2012)

NERC Region	Customer Class				
	Residential	Commercial	Industrial	Transportation	All Classes
AK	5	13	9	0	27
FRCC	1,762	1,097	447	0	3,306
HI	17	25	0	0	42
MRO	1,869	1,141	2,557	0	5,567
NPCC	84	421	88	14	606
RFC	1,520	815	3,502	0	5,836
SERC	1,399	1,170	3,475	2	6,046
SPP	172	391	760	0	1,323
TRE	88	333	59	0	480
WECC	1,684	1,056	2,365	165	5,269
All Regions	**8,600**	**6,462**	**13,261**	**180**	**28,503**

Source: FERC Staff Report "Assessment of Demand Response and Advanced Metering" December 2014

Integrated, Hybrid Energy Systems (HES)



- Dynamic co-optimization of power generation and industrial process
- Provides additional financial opportunities

Potential Benefits of Hybrid Energy Systems

Holistic optimization of capital assets and energy products

Additional revenue opportunities

Low-emission heat for industry

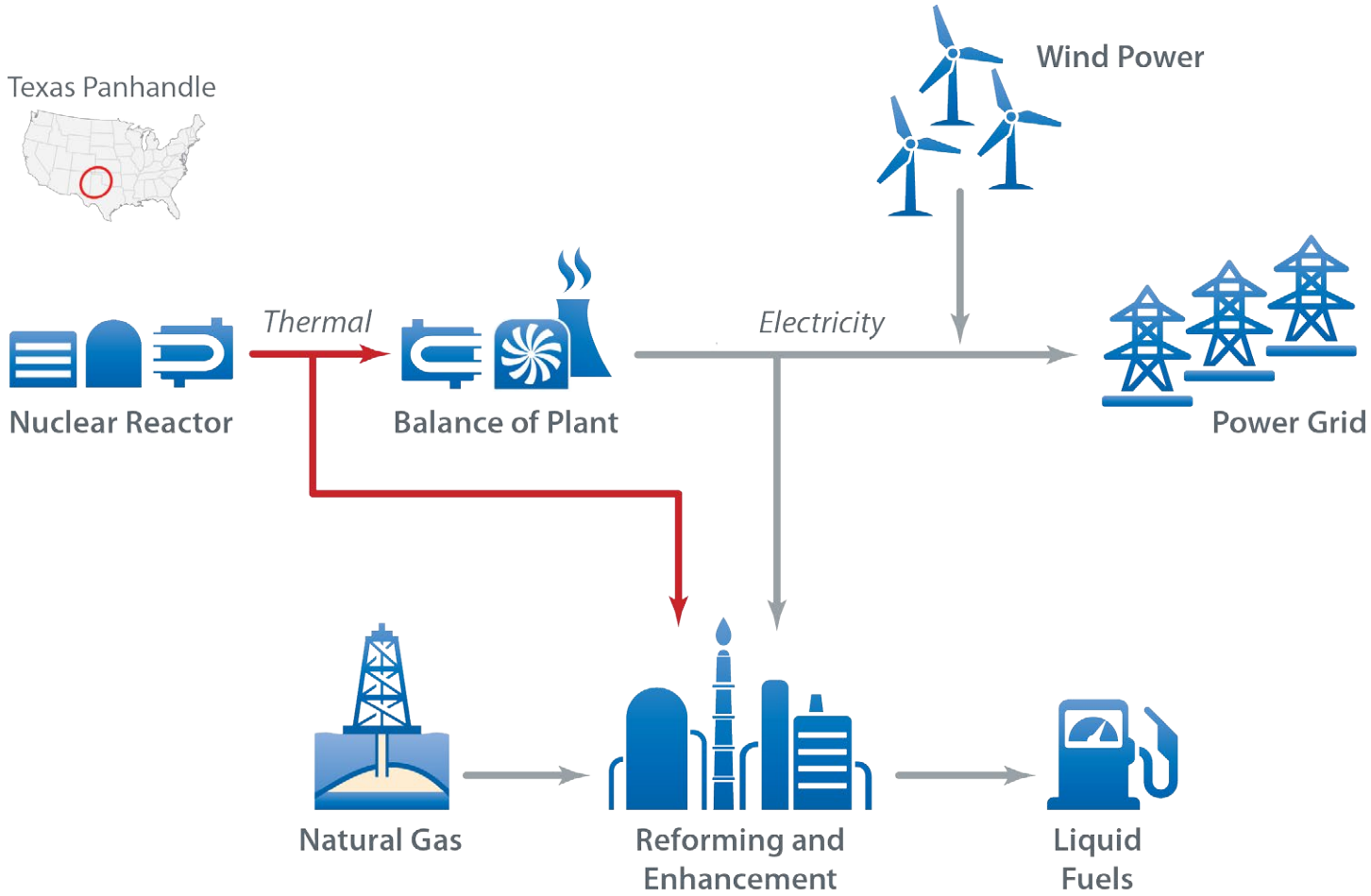
Commodity products

Grid capacity & flexibility

Grid inertia

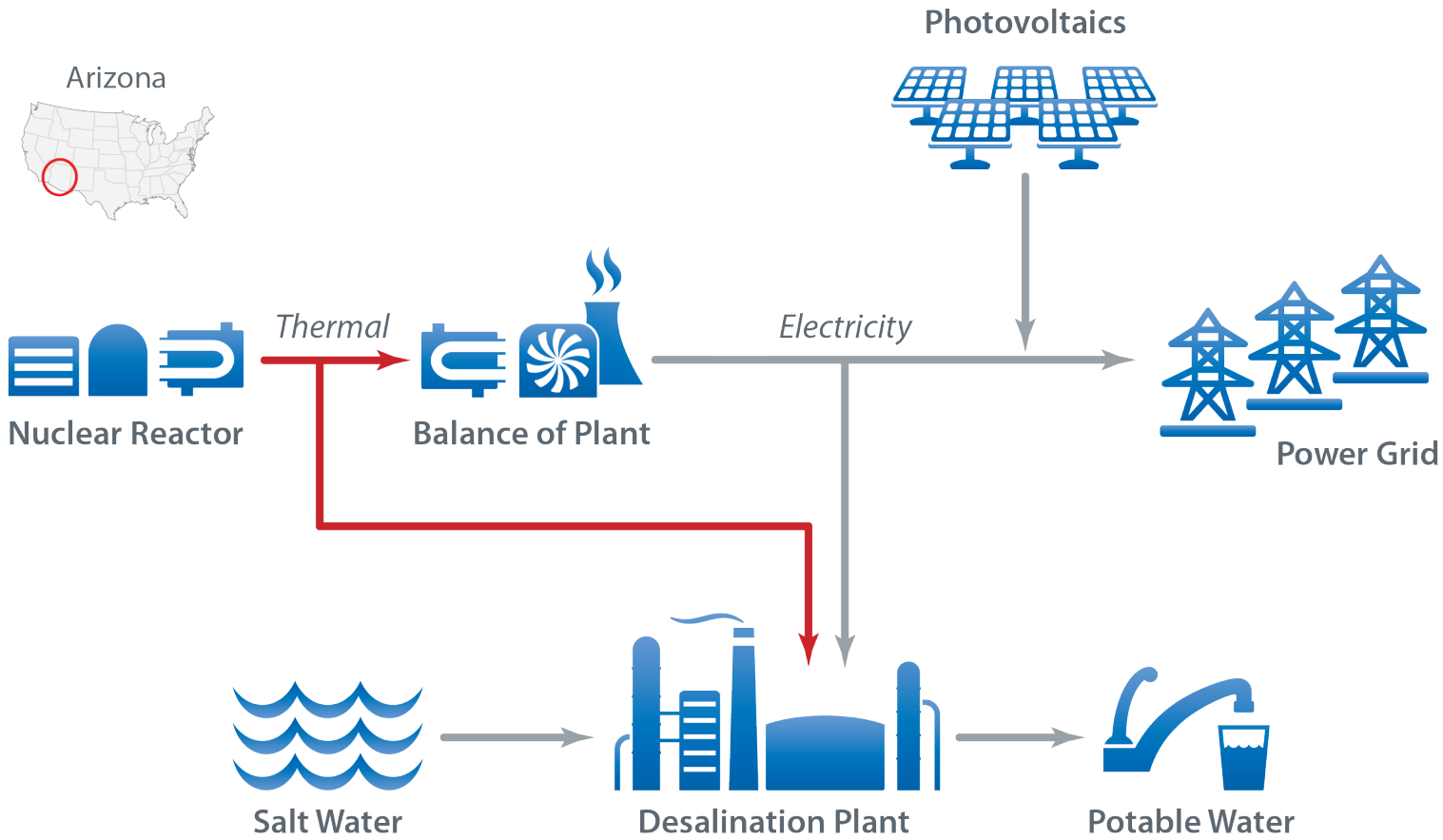
Dynamic, holistic optimization that produces highest-value products at each point in time

NE-RE HES Case Study: Gasoline Substitute



- **Thermal energy in the nuclear-renewable (NE-RE) HES is used to reform natural gas to a gasoline substitute**
- **Dynamic dispatch of thermal loads**

NE-RE HES Case Study: Desalination



- **Dynamic dispatch of both thermal and electrical energy**
- **Using both thermal and electrical energy potentially leads to new options**

Conclusions

- **Industry is 3rd largest sector for energy use and emissions in the U.S.**
- **Systems-level ESI considerations provide additional opportunities to increase income and reduce energy use and emissions**
- **Current options (CHP and demand response) should be extended (trigeneration) to realize more benefits**
- **Holistic optimization for hybrid energy systems can lead to new opportunities and markets for industrial ESI.**