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U.S. DEPARTMENT OF ENERGY

Energy Efficiency Improvements Potential in the U.S. Petroleum Refining Industry

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Outline

- U.S. Refinery Sector
- Methodology
- Results – Energy conservation supply curve
- Concluding remarks

U.S. Refinery Sector Background

In 2013, 144 U.S. Refineries:

- *Processed nearly 16 million barrels of oil per day†*
  equal to 21% of world total ‡
- *Consumed over 3,000 PJ †*
  12% of U.S. total Industrial Energy Consumption†
- *Produced $436 billion USD of refined product†*
  7% of U.S. total Industrial Economic Output †

† U.S. DOE, Energy Information Administration – Annual Energy Outlook 2014
‡ U.S. DOE, Energy Information Administration – International Energy Outlook 2014

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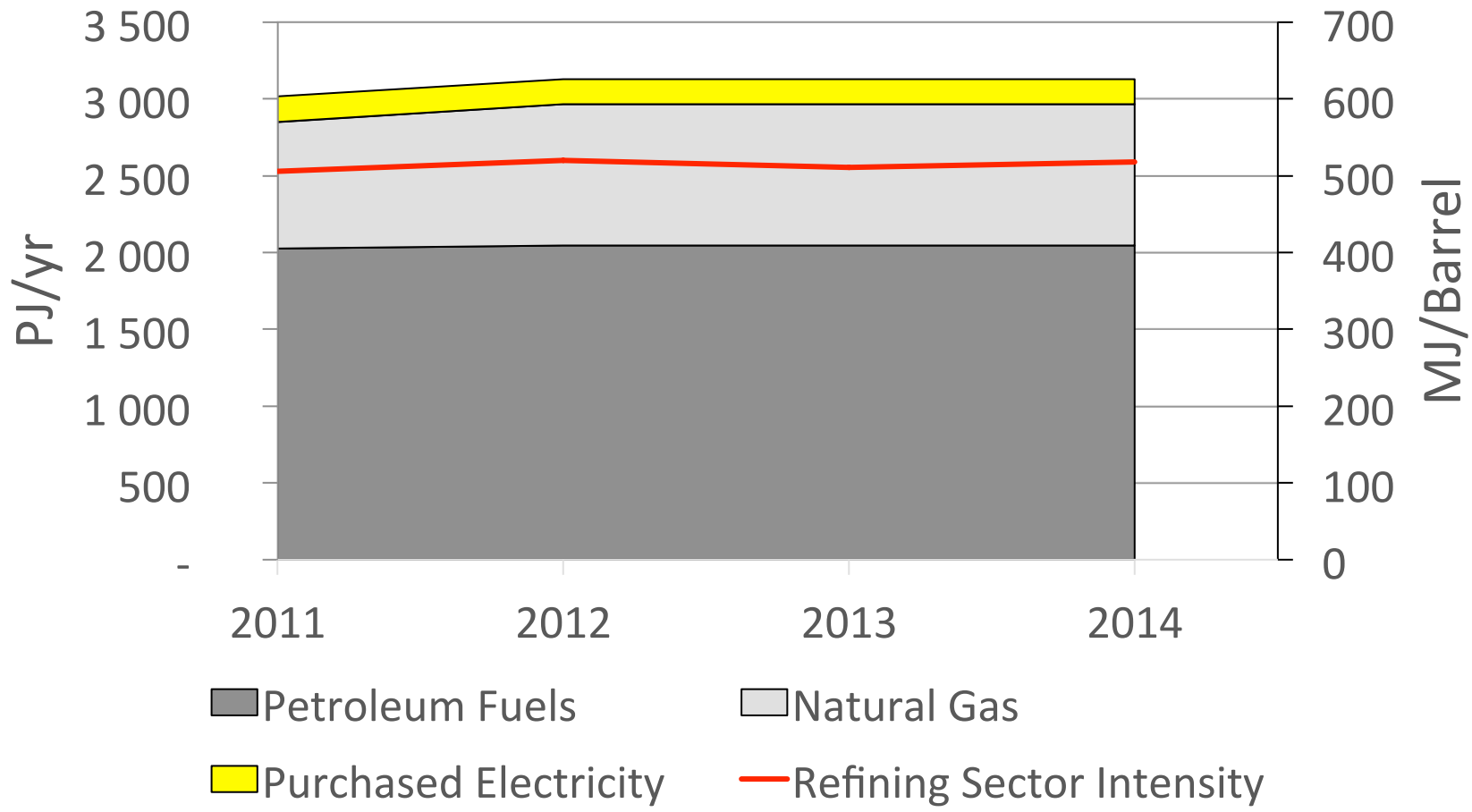
U.S. Refinery Sector Energy Consumption and Intensity†



† U.S. DOE, Energy Information Administration – Annual Energy Outlook 2014
* 2014 value is an estimate

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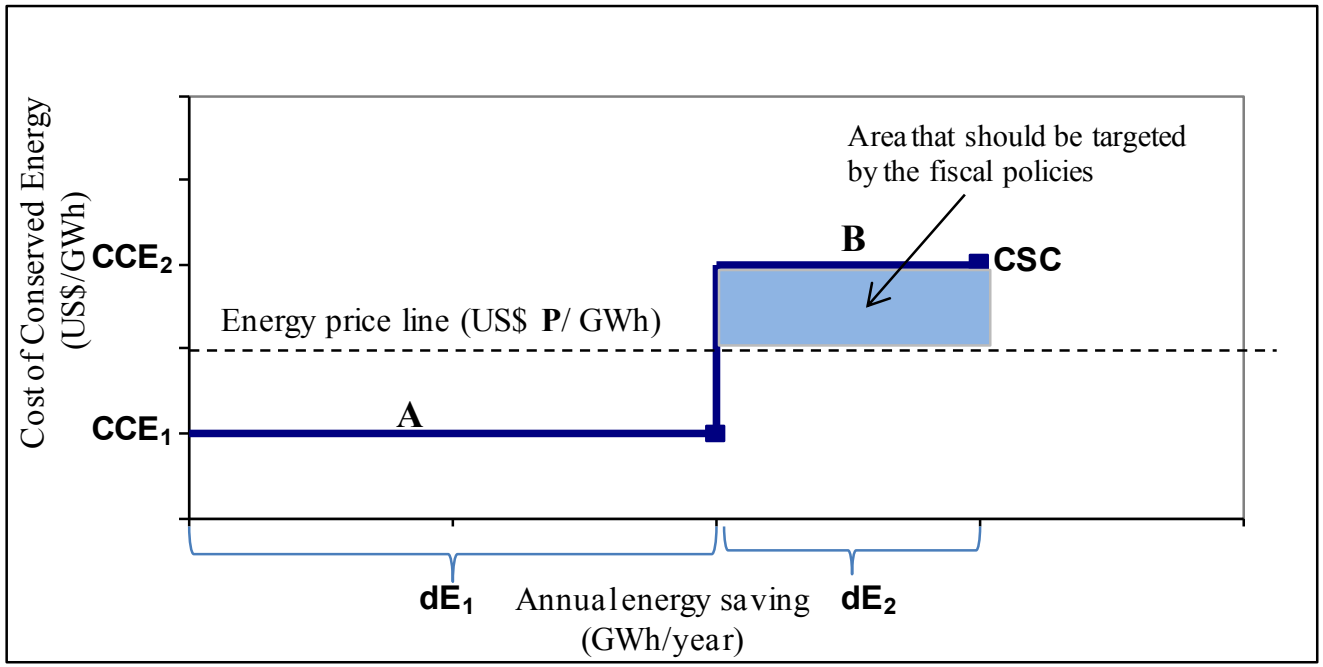
Introduction of Energy Conservation Supply Curve

- The **Energy Conservation Supply Curve** is an analytical tool that shows the energy saving potential as a function of the marginal Cost of Conserved Energy.

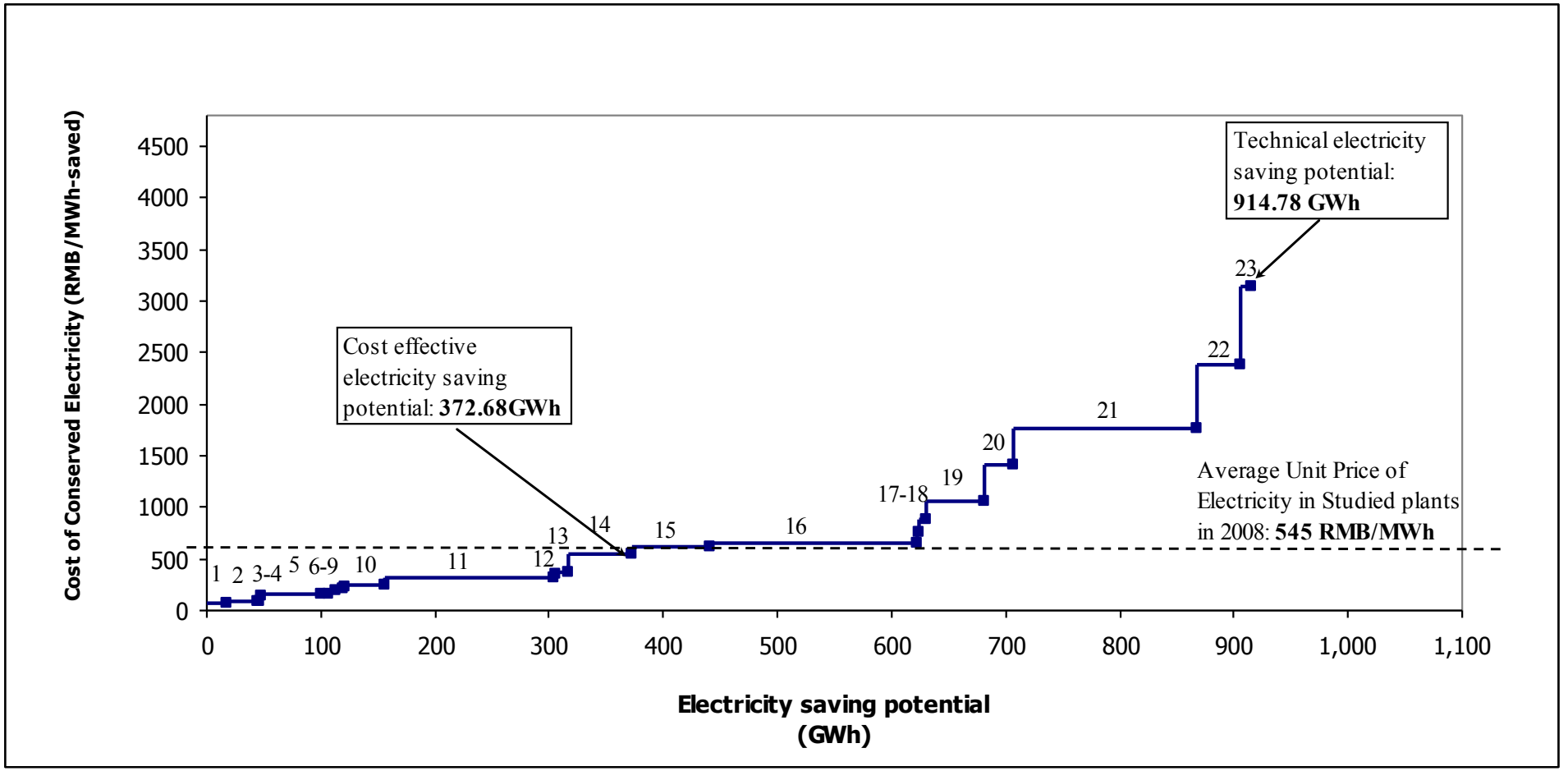
$$\text{Cost of Conserved Energy (CCE)} = \frac{\text{(Annualized capital cost + Annual change in O\&M costs)}}{\text{Annual energy savings}}$$



Schematic view of a Energy Conservation Supply Curve

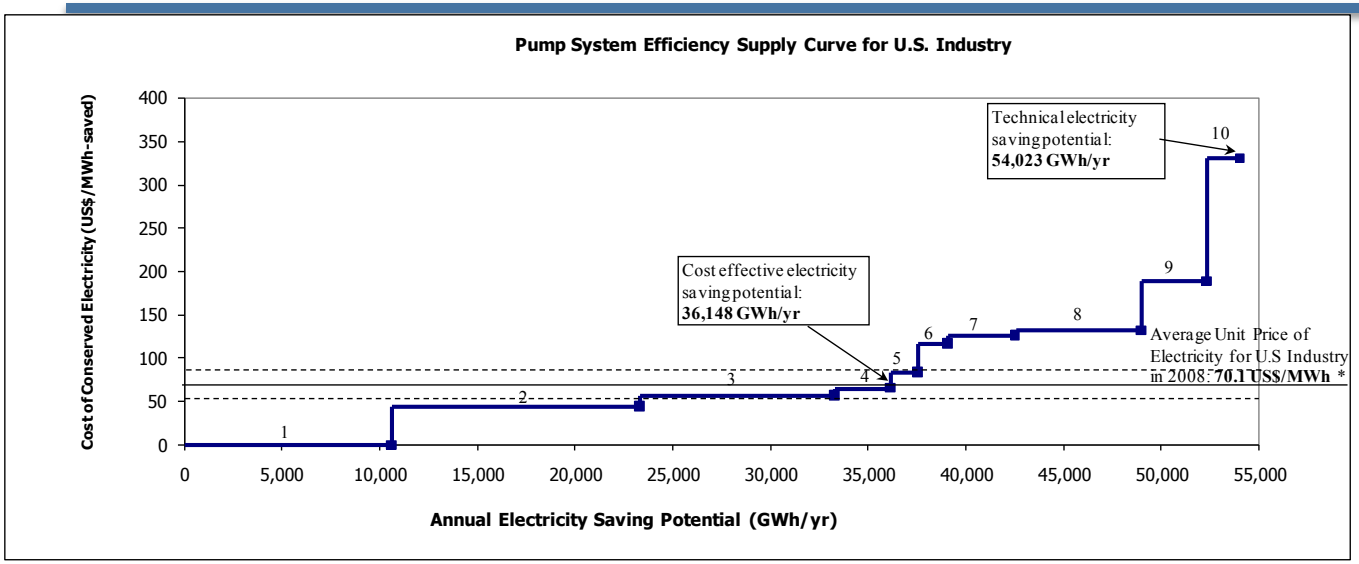
dE: Annual energy saving ; P: Energy price

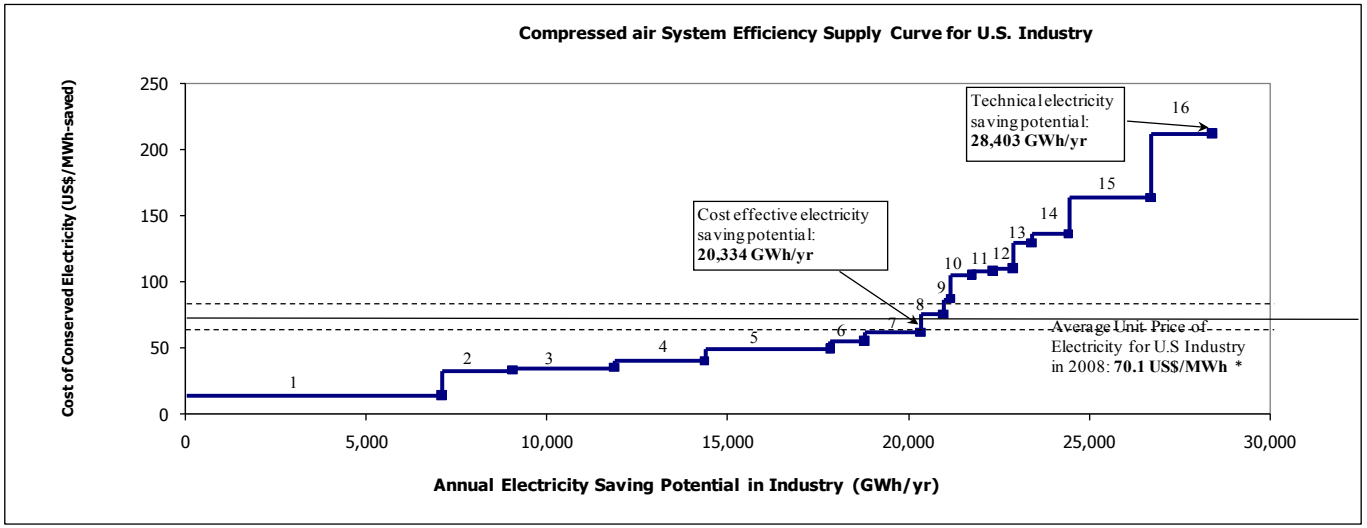
Example of an Industry-Specific Energy Conservation Supply Curve



Electricity Conservation Supply Curve for 16 Studied Cement Plants in Shandong Province, China
(LBNL study)

Example of a System-Specific Energy Conservation Supply Curve





Motor Systems Efficiency Supply Curves

UNIDO UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

UN-Energy

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Objectives and Novelty

- The objective of this study was to estimate the energy saving potential and its associated cost in the U.S. Petroleum Refining Sector.
  - Using a technology-level bottom-up model
  - At the process unit level
  - Capturing the highly integrated nature of petroleum processing units

- The novelties of this are:
  - The first detailed technology and process level estimate of energy saving potential in the U.S. Petroleum Refining Sector
  - The first energy conservation supply curve model for the U.S. refining sector
  - Accounting for the inter-dependence between efficiency measures

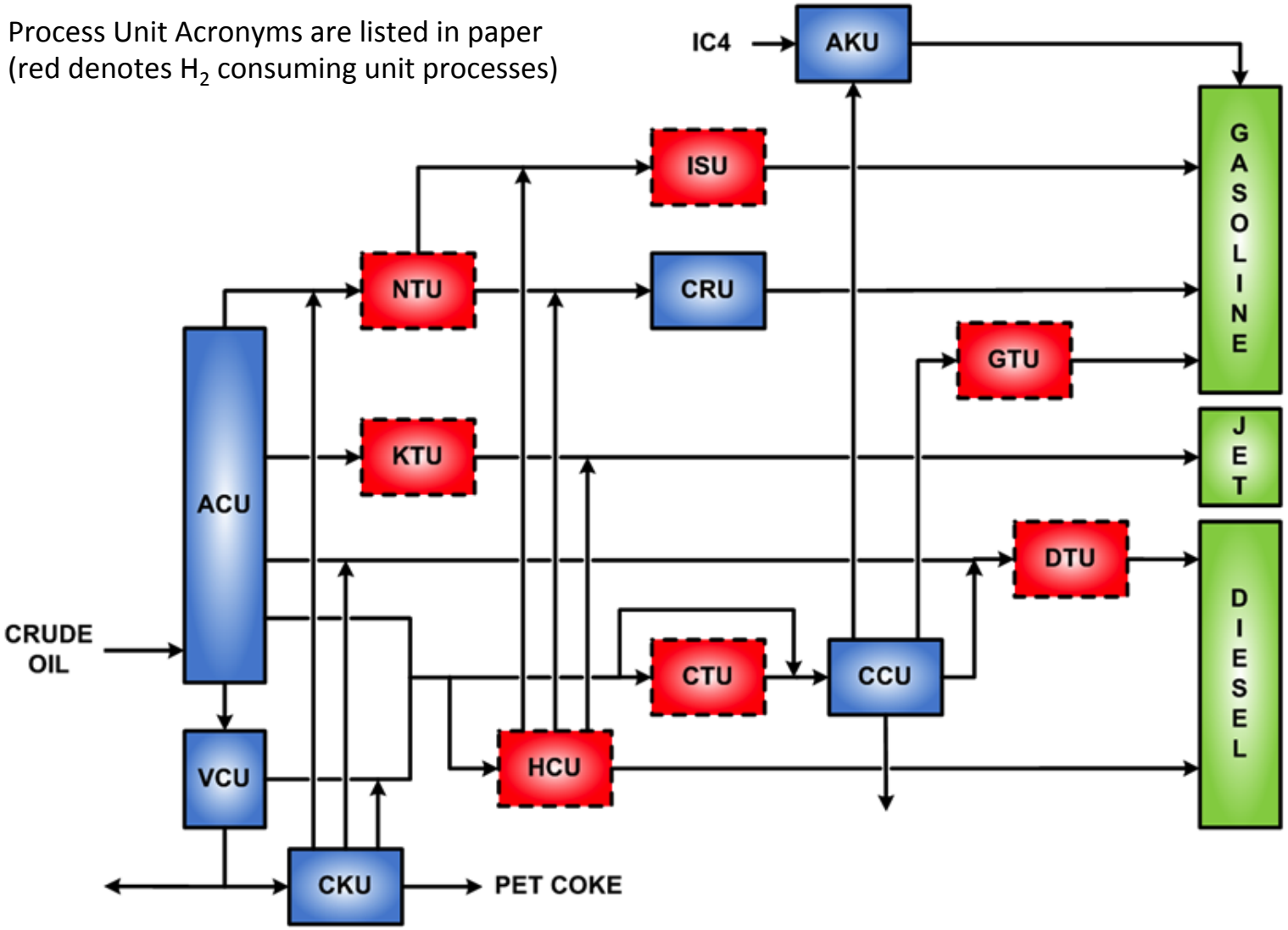
Modeling U.S. Petroleum Refineries

- No two U.S. refineries are alike:
  - Age
  - location/markets/crude assays/products
  - Size and process unit configurations
  - …and detailed energy consumption is proprietary

- Detailed information on the performance of individual petroleum refineries is generally not available at the process level
- Twelve core processes that dominate energy consumption within the U.S. refinery industry are modeled in a notional generic refinery
- The model developed is carbon and energy balanced

A notional model for a generic U.S. refinery:
Overall Process Block Flow Diagram - 12 processes

Process Unit Acronyms are listed in paper
(red denotes H_2 consuming unit processes)



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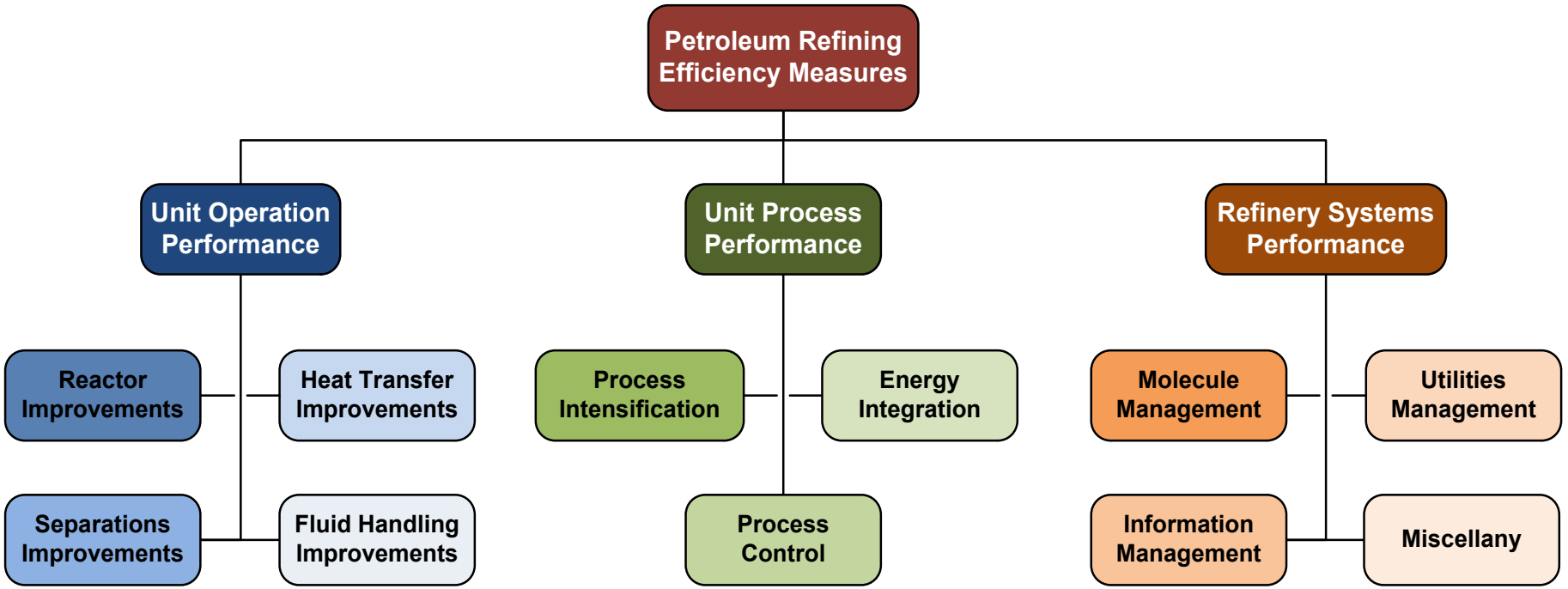
Efficiency Improvement Hierarchy



- The total number of energy efficiency measures: **330**

Note: some measures were similar across different process units

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Estimated Energy Consumption for the U.S. Petroleum Refining Model in 2010

Process	Throughput	Fuel (PJ)		Electricity (GWh, Final)	
	Million bbl/ year	ISBL	OSBL	ISBL	OSBL
CDU	5,540	399	638	4,048	1,769
CKU	725	107	26	2,246	868
CTU	1,081	48	392	143	2,076
CCU	725	-335	42	2,305	2,081
HCU	474	92	471	61	2,251
DTU	1,033	51	243	150	1,225
KTU	575	29	53	401	376
NTU	1,213	103	100	176	423
CRU	992	313	119	979	1,507
ISU	147	6	28	21	9
GTU	419	34	136	60	423
AKU	170	0	35	4	500
Total Modeled Energy Consumption in 2010		848	2,283	10,596	13,507

ISBL: “inside the battery limits” = Direct energy use

OSBL: “Outside the battery limits” = Indirect energy use, e.g. utilities such as steam

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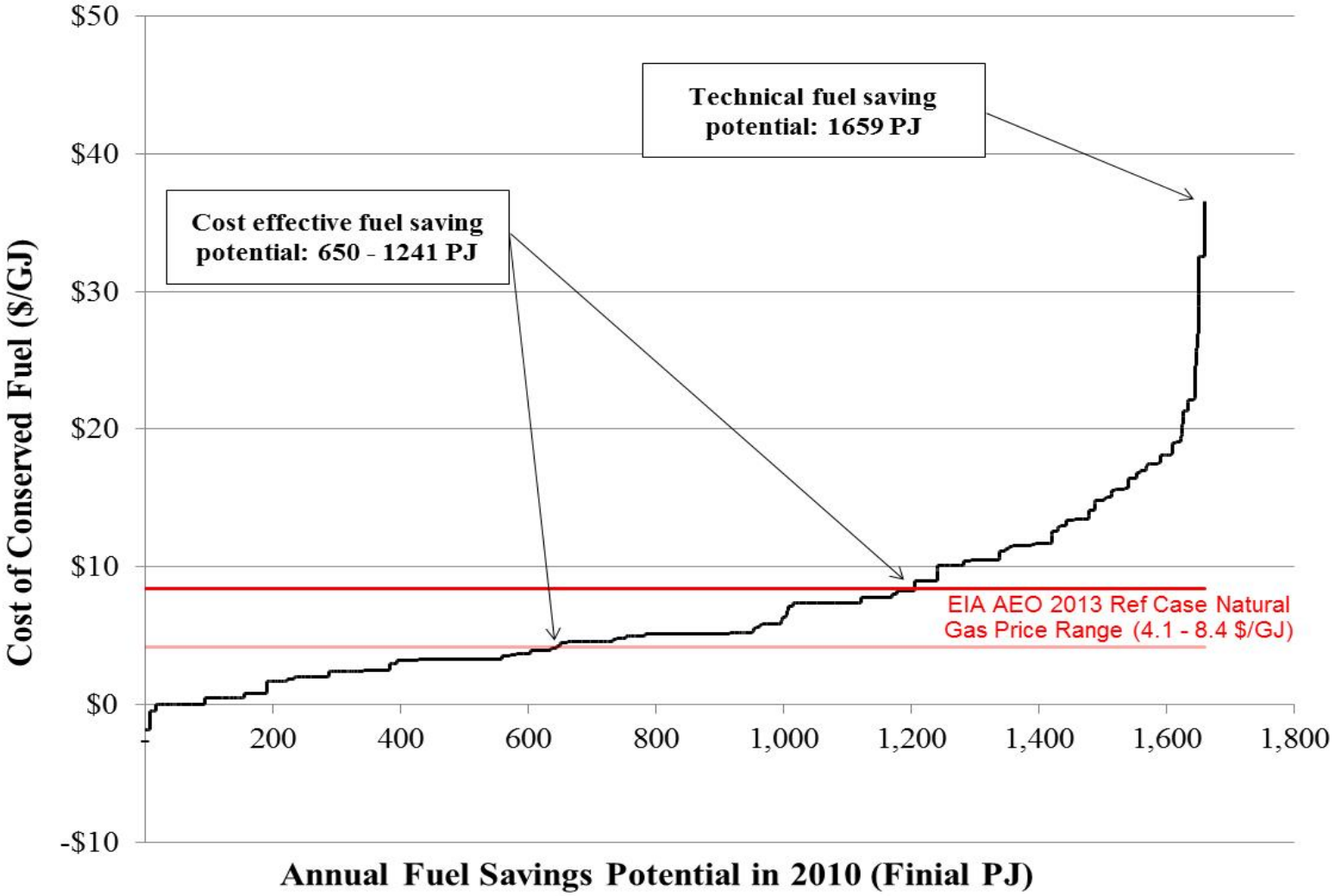
Aggregate Energy Conservation Supply Curve of the U.S. Refining Industry



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Top largest energy saving measures

Energy Savings Measures	Processing Unit	Fuel Savings (PJ/yr)	Cost of Conserved Energy (€/GJ)
Install HRSG Post Regenerator	CCU	132	$5.14
Install Overhead Vacuum Pump	CDU	129	$3.31
Install Furnace Air Pre-Heat	CDU	49	$7.74
Install Overhead Chillers	CDU	44	$10.47
Revamp Heat Integration (low-cost)	CDU	40	$2.45
Improve catalysts to reduce H2 consumption	HCU	36	$7.39
Add Recycle & ST Ejector	CDU	36	$0.76
Install New Internals	ACU	34	$9.00
Reduce Coking of Tube Surfaces	CDU	34	$3.19
Efficient Burners/Control X Air	CDU	32	$3.90
Install Furnace Air Pre-Heat	CRU	30	$11.54

Energy Efficiency & Associated CO_2 Emissions Reduction Potential Estimates

	Fuel Savings (PJ/yr)	Electricity Savings (GWh/yr)	CO_2 Emissions Reductions (Million t CO2/ yr)
Cost Effective with lower energy price	556	651	32
Cost Effective with higher energy price	1205	411	36
Total technical potential	1653	2255	94
Share of technical potential from 2010 energy use	53 %	9 %	

Conclusion

- Series of energy conservation supply curves were developed for each of the twelve primary refining technologies that make-up a composite representation of the U.S. industry
- Significant energy saving potential exist with a large cost-effective potential
- Detailed operational data on individual refineries is confidential and not available => a number of simplifying assumptions were made in order to model the entire sector as a single notional refinery
- Despite the lack of data, policy makers and other interested parties want to know what's the magnitude/range of energy saving potential and cost. That's what we have tried to do.

Thank You!

Questions and Comments?

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