CEE Motors & Motor Systems Breakout Session

Exploring Program Approaches to System-Level Savings

CEE Winter Program Meeting

January 25, 2012

11:00 – 12:30 pm PT

Session Objectives

- Review common efficiency measures in pumping, compressed air, and fan systems
- Identify measures to develop as scalable program approaches, including those that may be candidates for development as CEE initiatives, such as
  - Technologies for prescriptive programs
  - Program resources such as system checklists

Session Agenda

- Background and introductions
- *Assessing the Energy Efficiency Potential of Industrial Motor Systems*
  - Ali Hasanbeigi, Lawrence Berkeley National Laboratory
- Discussion
  - Identify scalable program approaches
- Summarize recommendations and next steps

CEE M&MS Initiative Resources

- *Motor Decisions Matter*℠ Campaign: www.motorsmatter.org
  - Support for repair-replace and ASD decisions and planning based on life cycle cost consideration
- CEE Motors List: www.cee1.org/ind/mot-sys/mtr-ms-main.php3
  - 1-200 hp general purpose motors that exceed EISA
- Motor and Drive Guidebook:

  www.cee1.org/ind/motrs/CEEMotorGuidebook.pdf
- 2012 Program Summary: www.ceeforum.org/content/2011-2012-cee-mms-program-summary
  - Prescriptive programs: motors, drives, other
  - Systems: pumps, fans, compressed air, retro-comm.
  - Education, training, technical, and financial resources

Summary of CEE Member Programs for Motor Systems*	
Description	**No. of Members**
Members with M&MS Program, any type	85
Custom programs	64
Adjustable Speed Drives (ASD)	53
Dedicated Pumping	18
Dedicated Fans	14
Dedicated Compressed Air	36

Examples of dedicated compressed air programs

- Leak Survey: $/hp for detection and repair
- Compressor: $/hp for 15-75 hp

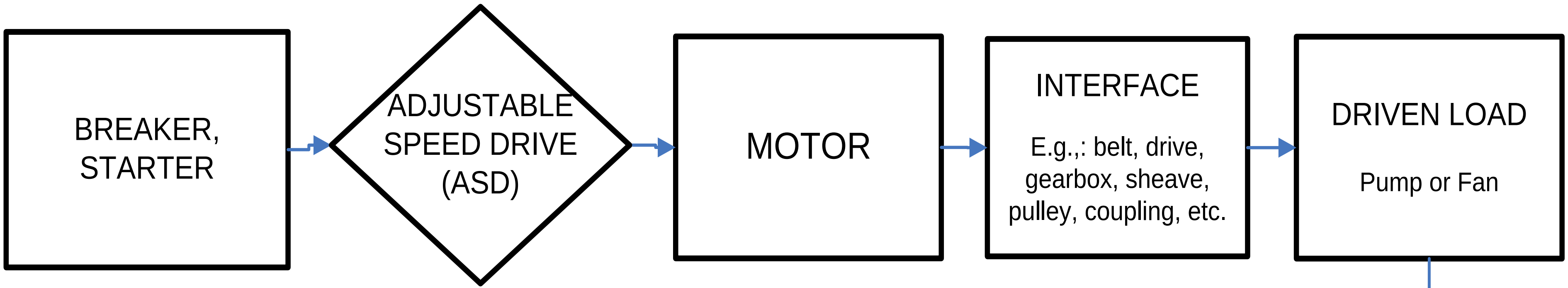
Examples of dedicated pumping programs

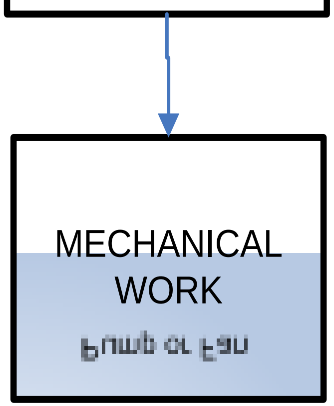
- High efficiency process pumps: $/hp for 1-20 hp
- Pump test program: efficiency tests for water applications

*Preliminary data based on 2009-2010 program summary; 2012 data not yet final

Preliminary System Framework

Motor System Definition



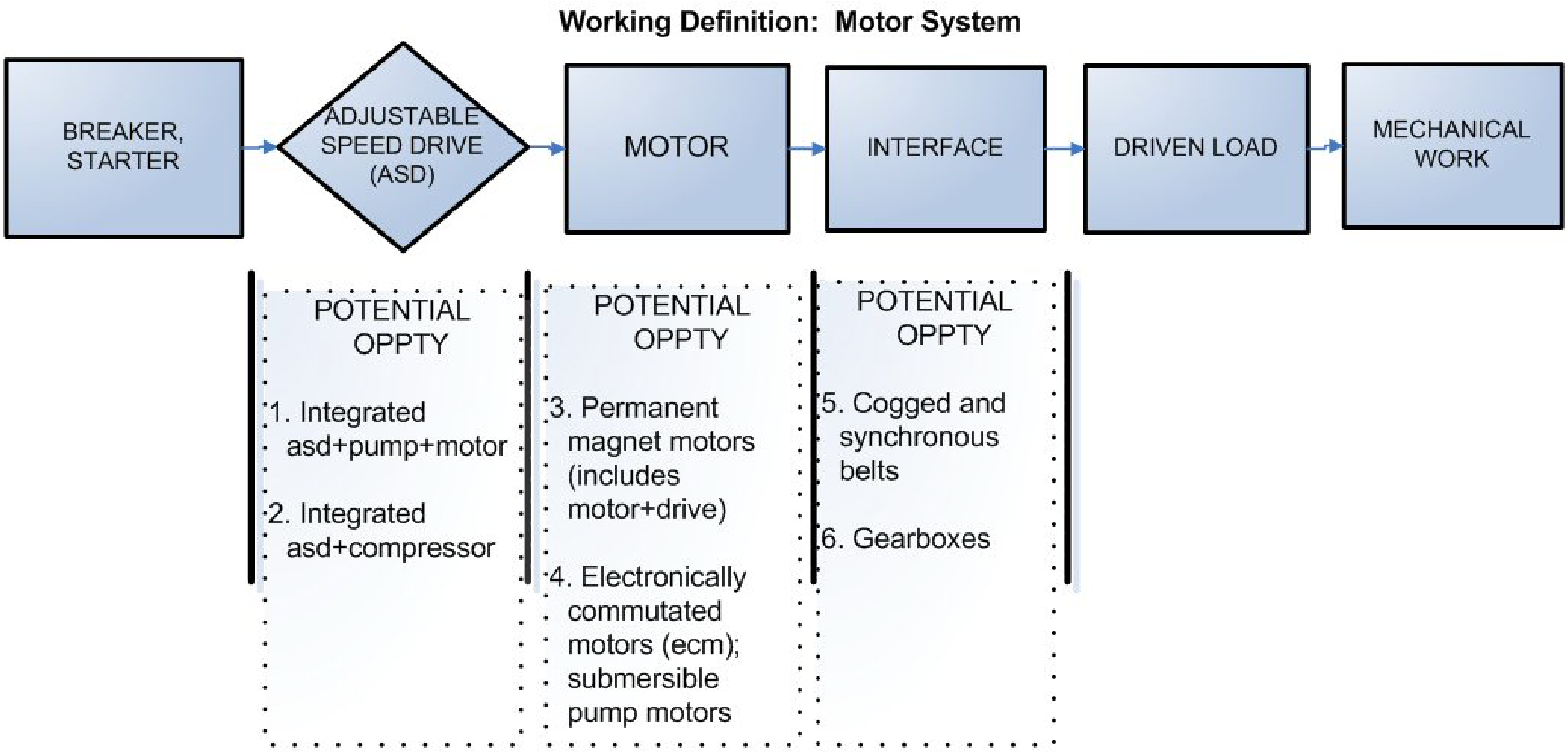


System-Level Approach Definition

Improve system-level efficiency with a payback of 18 mos. – 5 yr by assessing:

- Equipment size and selection relative to required work
- 2 or more components

Potential Opportunities for Prescriptive Approaches in Systems



Introductions - 1 minute or less

- Name, organization, your role

- High-level overview of your organization's approach to motor systems
  - Prescriptive programs
    - Motors, drives, fans, pumps, compressed air, etc.
  - Popular industrial motor system projects

Motor System Energy Efficiency Supply Curves:

Assessing the Energy Efficiency Potential of Industrial Motor Systems

Presenter:

Ali Hasanbeigi, Ph.D.

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Energy Analysis Department, EETD, LBNL

Research sponsored by:
United Nations Industrial Development Organization

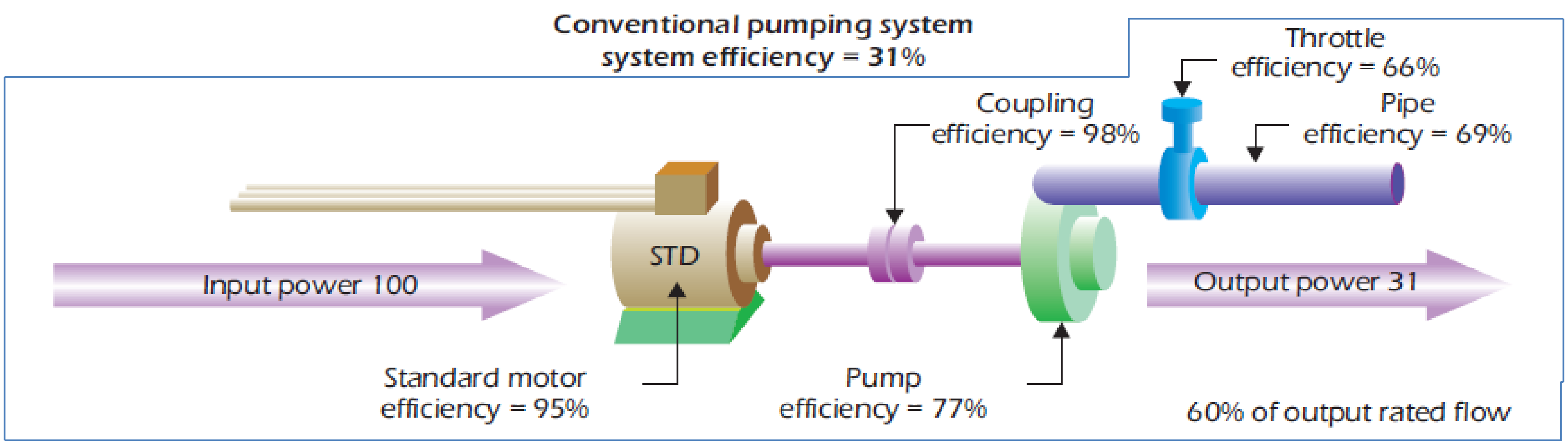
U.S. DEPARTMENT OF ENERGY

Outline:

- **Introduction**
- **Methodology** *(this section will be the main focus of this presentation)*
- **Results:** ***Motor systems efficiency supply curves***
- **Conclusion**

Introduction – Motor systems

1. Motor-driven equipment accounts for approximately 50% - 60% of manufacturing final electricity use.
2. Although data on motor system energy efficiency is limited in the aggregate, there is a well-documented body of best practices for improving the energy efficiency of these systems.
3. A transparent methodology is needed to assist policymakers in quantifying the saving potential.

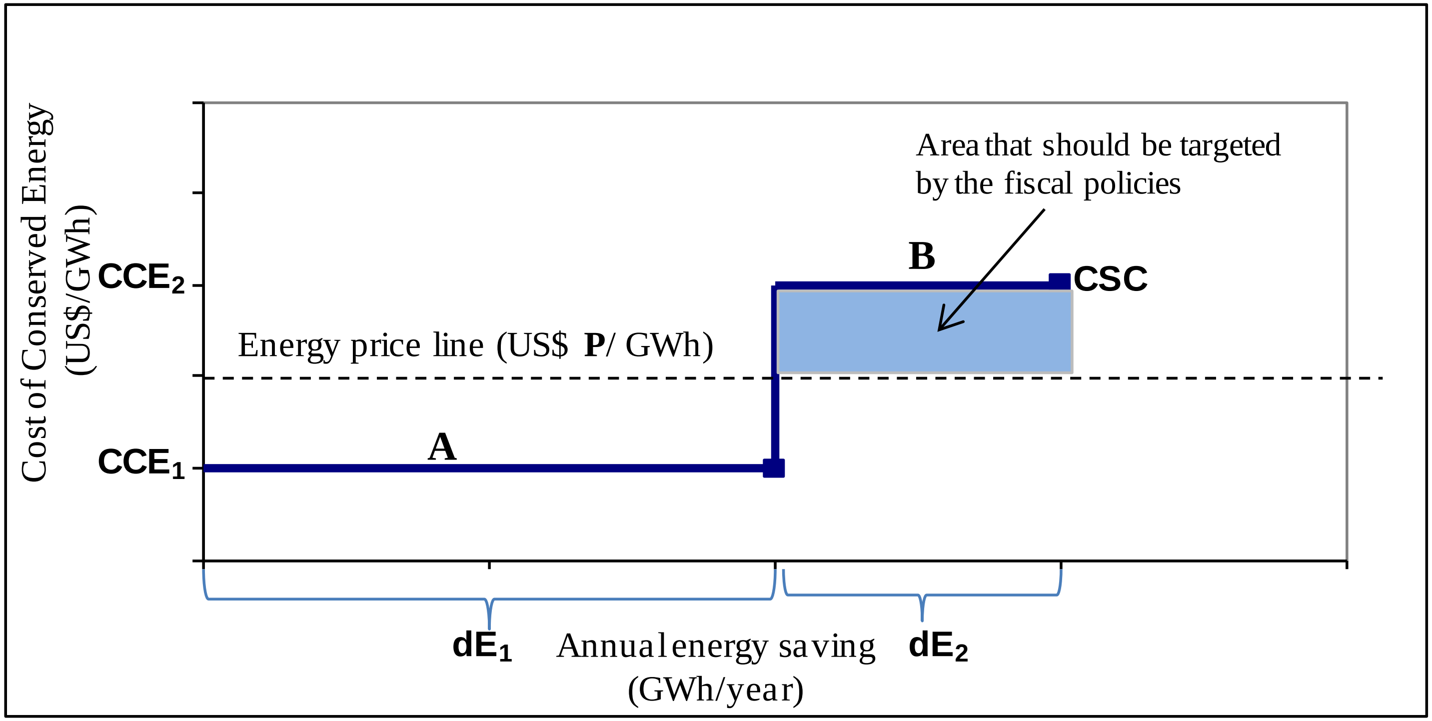


Conventional Pumping System Schematic (Almeida, et al., 2005)

Introduction - Conservation Supply Curve :

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

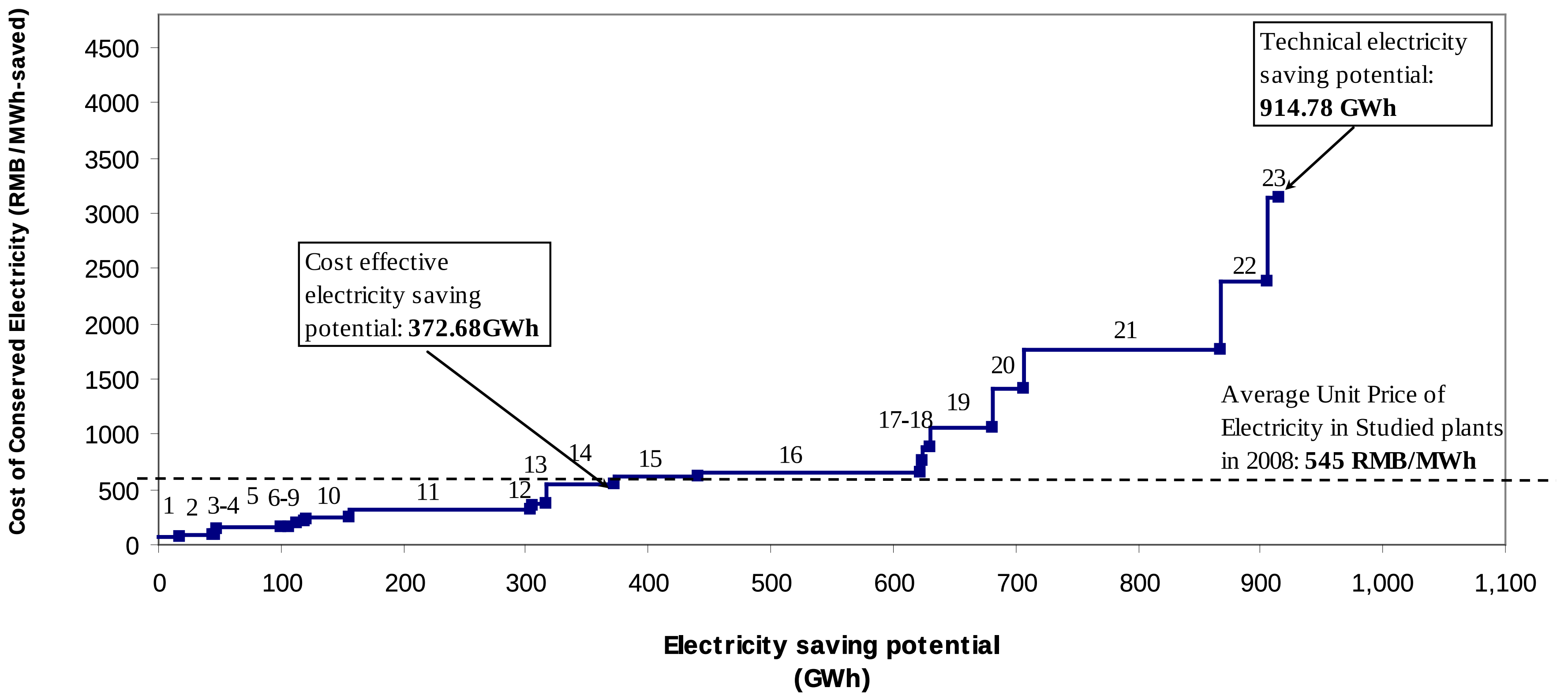
Cost of Conserved Energy (CCE) = (Annualized capital cost + Annual change in O&M costs) /Annual energy savings



Schematic view of a Conservation Supply Curve (CSC)

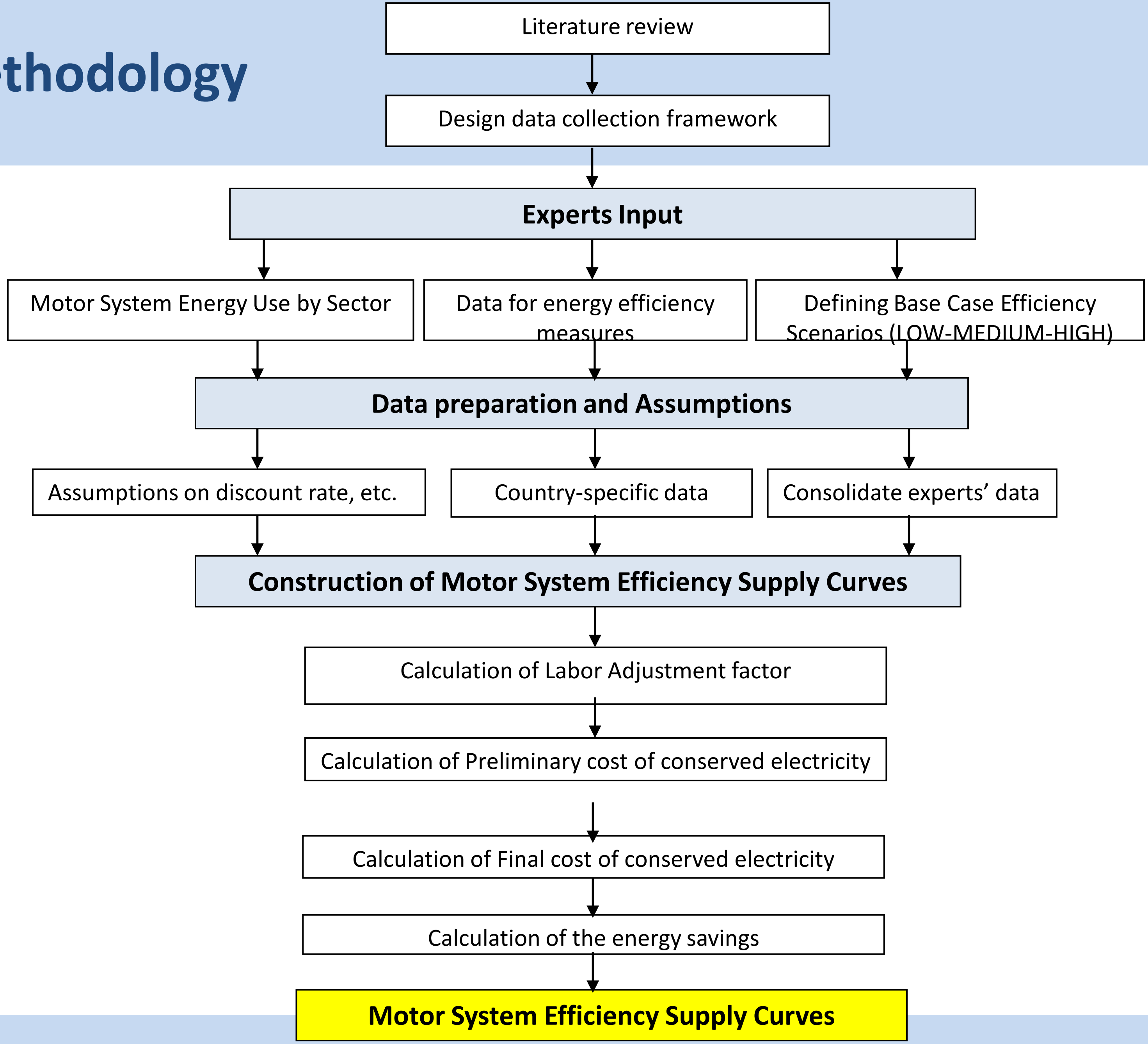
dE: Annual energy saving ; P: Energy price

Introduction - Conservation Supply Curve :



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

Methodology



Methodology

- **Target Countries :** United States, Canada, the European Union, Thailand, Vietnam, and Brazil.
- **Target motor systems:** pumping, compressed air, and fan systems
- **Designing the data collection framework**
- **Experts :**
  - Thirteen motor system experts from US, EU, China and Canada contributed to the analysis
  - At least four experts responded for each of the three systems analyzed
  - Delphi-type approach was used: Several cycles of input, analyses, and review by experts
- **Consolidate the expert inputs**
- **Country-specific data**: for the base year 2008 except for EU with 2007 as the base year.
- **Construction of motor system efficiency supply curves**
- **Sensitivity analysis** (for electricity price and discount rate)
- **Conclusion**

Methodology – comparison between conventional and new method

Conventional Conservation Supply Curve	Motor System Efficiency Supply Curve
1. Base year	1. Base year
2. Base case technology (inefficient tech.)	2. Base Case **System Efficiency (LOW-MED-HIGH)**
3. Current penetration rate of EE technology	3. Current Base Case **System Efficiency (LOW** or **MED** or **HIGH)**
4. Energy saving value given for EE measure compared to base case/inefficient technology (often a **single value**)	4. **System efficiency improvement by a measure as % over each of the LOW-MED-HIGH base case**
5. Capital cost of the technology (often a **single value**)	5. Capital cost of the measure **for each motor system size (5 size ranges -> 5 costs)**
6. **Often**, energy saving potential is calculated having EE measures implemented in <u>isolation</u> . Sometimes the "**additive effect**" is taken into account though.	6. **EE measures are treated in relation with each other (as a group)** by taking into account the so-called "**additive effect**".
7. **Single** Cost of Conserved Energy (CCE) is calculated directly for each measure and used in the CSC.	7. First, **Preliminary CCE** is calculated in which measures are treated in isolation. Then, **Final CCE** is calculated with "additive effect" included.

Methodology – step 1 & 2

Conventional Conservation Supply Curve	Motor System Efficiency Supply Curve
1. Base year	1. Base year
2. Base case technology (inefficient tech.)	2. Base Case **System Efficiency (LOW-MED-HIGH)**

Methodology – step 2

Defining three Base Case System Efficiency (LOW-MEDIUM-HIGH):

- A list of system energy efficiency practices representative of each of three base case system efficiency for each motor system type.
- Experts were asked to provide a **low** and **high** estimated range of the system energy efficiency (expressed as a %) for each base case.
- There was a **high degree of agreement** among experts for each system type regarding the range of system energy efficiency.
- The approach was to ***align the precision of the response to the available data***

Methodology - step 2

Characteristics of LOW-MEDIUM-HIGH Efficiency Base Case Scenarios for **Compressed Air** Systems

No.	LOW Efficiency Base Case Scenario
1	Few compressed air systems have ever been assessed for system energy efficiency
2	Maintenance is limited to what is required to support operations
3	Compressors are independently controlled; energy use of partly loaded compressor(s) not known
4	System pressure profile, supply/demand balance, and storage, not optimized
5	Leaks are greater than 35%, and there are no plans to fix them
6	There is widespread inappropriate use of compressed air
7	Motors of all sizes are routinely rewound multiple times instead of replaced
No.	**MEDIUM Efficiency Base Case Scenario**
1	~15% of compressed air systems have been assessed for system energy efficiency
2	Maintenance is a routine part of operations and includes some preventative actions
3	Compressor control is coordinated and a single trim compressor operates efficiently
4	Variable speed drives are proposed as a solution for flow control
5	Leaks are ≥ 20%, but < 35% and are fixed periodically
6	There is widespread inappropriate use of compressed air
7	Motors ≥ 37 kW are typically rewound multiple times, while smaller motors may be replaced
No.	**HIGH Efficiency Base Case Scenario**
1	~30% compressed air systems have been assessed for system energy efficiency
2	Both routine and predictive maintenance are commonly practiced
3	Compressor controls and storage are used to efficiently match supply to demand
4	System pressure profile from supply to end use has been optimized
5	Leaks < 20%; Leaks management is ongoing
6	Inappropriate end use of compressed air has been minimized
7	Most facilities have a written rewind/replace policy that prohibits rewinding smaller motors (typ <37 kW)

Methodology – step 3

Conventional Conservation Supply Curve	Motor System Efficiency Supply Curve
1. Base year	1. Base year
2. Base case technology (inefficient tech.)	2. Base Case **System Efficiency (LOW-MED-HIGH)**
3. Current penetration rate of EE technology	3. Current Base Case **System Efficiency (LOW** or **MED** or **HIGH)**

Methodology - step 3

Base case efficiencies assigned to each country for each motor system type.

Country	Pumping	Fan	Compressed air
US	MED	MED	MED
Canada	MED	MED	MED
EU	MED	MED	MED
Brazil	MED	LOW	LOW
Thailand	MED	LOW	LOW
Vietnam	LOW	LOW	LOW

Methodology – step 4 & 5

Conventional Conservation Supply Curve	Motor System Efficiency Supply Curve
1. Base year	1. Base year
2. Base case technology (inefficient tech.)	2. Base Case **System Efficiency (LOW-MED-HIGH)**
3. Current penetration rate of EE technology	3. Current Base Case **System Efficiency (LOW** or **MED** or **HIGH)**
4. Energy saving value compared to base case/inefficient technology (often a **single value**)	4. **System efficiency improvement by a measure as % over each of the LOW-MED-HIGH base case**
5. Capital cost of the technology (often a **single value**)	5. Capital cost of the measure **for each motor system size (5 size ranges -> 5 costs)**

Methodology - step 4 & 5

2. Determining the impact of energy efficiency measures and the cost of measures:

- A list of potential measures to improve system energy efficiency was developed for each system type .
- There are **10** measures for pumping systems, **16** measures for compressed air system and **10** measures for fan systems.
- Experts input:
  1. Estimate of **energy savings of each measure**, taken as an independent action, expressed as a % improvement over each of the LOW-MED-HIGH base cases.
  2. Estimate of **cost information** for each measure, disaggregated by six motor size ranges.
  3. **useful lifetime** of the measures

Methodology - step 4 & 5

Expert Input: Energy efficiency measures, % efficiency improvement and cost for **Pumping** systems

No.	Energy Efficiency Measure	Typical % Improvement in Energy Efficiency Over Current Pumping System Efficiency Practice			Expected Useful Life of Measure (Years)	Typical Capital Cost (US$)				
		% Improvement over LOW eff. base case	% Improvement over MED eff. base case	% Improvement over HIGH eff. base case		≤ 50 hp	>50 hp ≤ 100 hp	> 100 hp ≤ 200 hp	>200 hp ≤ 500 hp	>500 hp ≤ 1000 hp
1.1	**Upgrade System Maintenance**									
1.1.1	Fix Leaks, damaged seals, and packing	3.5%	2.5%	1.0%	5	$1,000	$1,500	$2,000	$2,500	$3,000
1.1.3	Remove scale from components such as heat exchangers and strainers	10.0%	5.0%	2.0%	4	$6,000	$6,000	$9,000	$12,000	$15,000
1.1.3	Remove sediment/scale buildup from piping	12.0%	7.0%	3.0%	4	$3,500	$3,500	$7,000	$10,500	$14,000
1.2	**Eliminate Unnecessary Uses**									
1.2.1	Use pressure switches to shut down unnecessary pumps	10.0%	5.0%	2.0%	10	$3,000	$3,000	$3,000	$3,000	*
1.2.2	Isolate flow paths to no-nessential or non-operating equipment	20.0%	10.0%	5.0%	15	$0	$0	$0	$0	$0
1.3	**Matching Pump System Supply to Demand**									
1.3.1	Trim or change impeller to match output to requirements	20.0%	15.0%	10.0%	8	$5,000	$10,000	$15,000	$20,000	$25,000
1.4	**Meet variable flow rate requirement w/o throttling or bypass****									
1.4.1	Install variable speed drive	25.0%	15.0%	10.0%	10	$4,000	$9,000	$18,000	$30,000	$65,000
1.5	**Replace pump with more energy efficient type**	25.0%	15.0%	5.0%	20	$15,000	$30,000	$40,000	$65,000	$115,500
1.6	**Replace motor with more energy efficient type**	5.0%	3.0%	1.0%	15	$2,200	$4,500	$8,000	$21,000	$37,500
1.7	**Initiate predictive maintenance program**	12.0%	9.0%	3.0%	5	$8000	$8,000	$10,000	$10,000	$12,000

Methodology - step 6 & 7

- The Cost of Conserved Energy can be calculated from:

Cost of Conserved Energy (CCE) =

(Annualized capital cost + Annual change in O&M costs) /Annual energy savings

- The annualized capital cost can be calculated from :

Annualized capital cost = Capital Cost*(d/ (1-(1+d)$^{-n}$)

d: discount rate (**10%**), n: lifetime of the energy efficiency measure.

Methodology – step 6

Conventional Conservation Supply Curve	Motor System Efficiency Supply Curve
1. Base year	1. Base year
2. Base case technology (inefficient tech.)	2. Base Case **System Efficiency (LOW-MED-HIGH)**
3. Current penetration rate of EE technology	3. Current Base Case **System Efficiency (LOW** or **MED** or **HIGH)**
4. Energy saving value compared to base case/inefficient technology (often a **single value**)	4. **System efficiency improvement by a measure as % over each of the LOW-MED-HIGH base case**
5. Capital cost of the technology (often a **single value**)	5. Capital cost of the measure **for each motor system size (5 size ranges -> 5 costs)**
6. **Often**, energy saving is calculated by EE measures treated individually and implemented in isolation , but sometimes the "**additive effect**" is taken into account.	6. **EE measures are treated in relation with each other (as a group)** by taking into account the so-called "**additive effect**".

Methodology – step 7

Conventional Conservation Supply Curve	Motor System Efficiency Supply Curve
1. Base year	1. Base year
2. Base case technology (inefficient tech.)	2. Base Case **System Efficiency (LOW-MED-HIGH)**
3. Current penetration rate of EE technology	3. Current Base Case **System Efficiency (LOW** or **MED** or **HIGH)**
4. Energy saving value compared to base case/inefficient technology (often a **single value**)	4. **System efficiency improvement by a measure as % over each of the LOW-MED-HIGH base case**
5. Capital cost of the technology (often a **single value**)	5. Capital cost of the measure **for each motor system size (5 size ranges -> 5 costs)**
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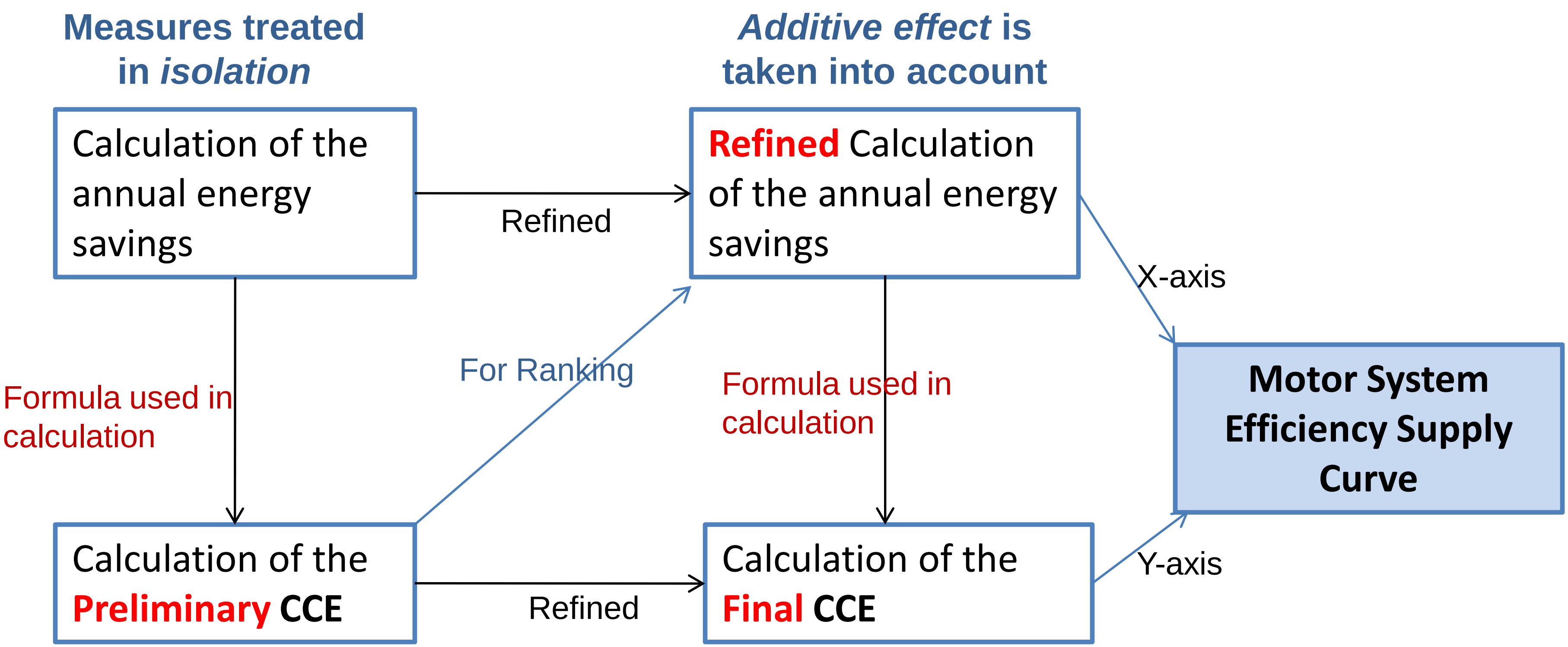
Methodology - step 6 & 7



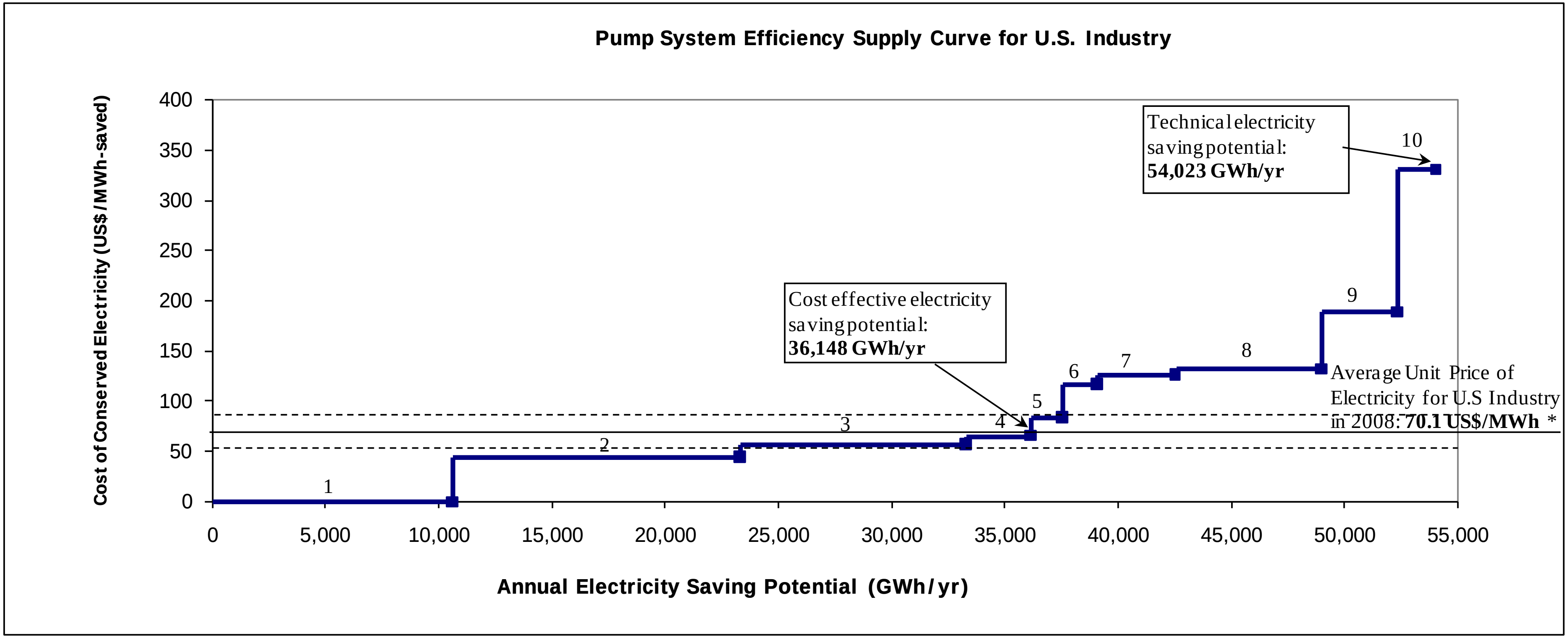
Schematic of the calculations for the development of Motor System Efficiency Supply Curves

Methodology - step 6 & 7

- The cost of conserved electricity (CCE) is calculated for each representative motor size (**5 CCE for 5 sizes**).
- Only one CCE value can be displayed on the Supply Curves.
- To consolidate the CCEs of all power ranges for each measure, the Motor System Energy Use (GWh/Yr) by Horsepower (for each type of system, i.e. pumping, fan, compressed air) was used to calculate the **weighted average CCE.**
- The **Labor Adjustment Factors** (LAF) was multiplied by the calculated weighted average CCE (both preliminary and final) in developing countries.

Results – Motor System Efficiency Supply Curves

Results - Pumping System Efficiency Supply Curves



U.S. Pumping System Efficiency Supply Curve

Results - Pumping System Efficiency Supply Curves

Cumulative annual electricity saving and CO2 emission reduction for the **Pumping** System efficiency measures in **U.S.** ranked by their Final CCE

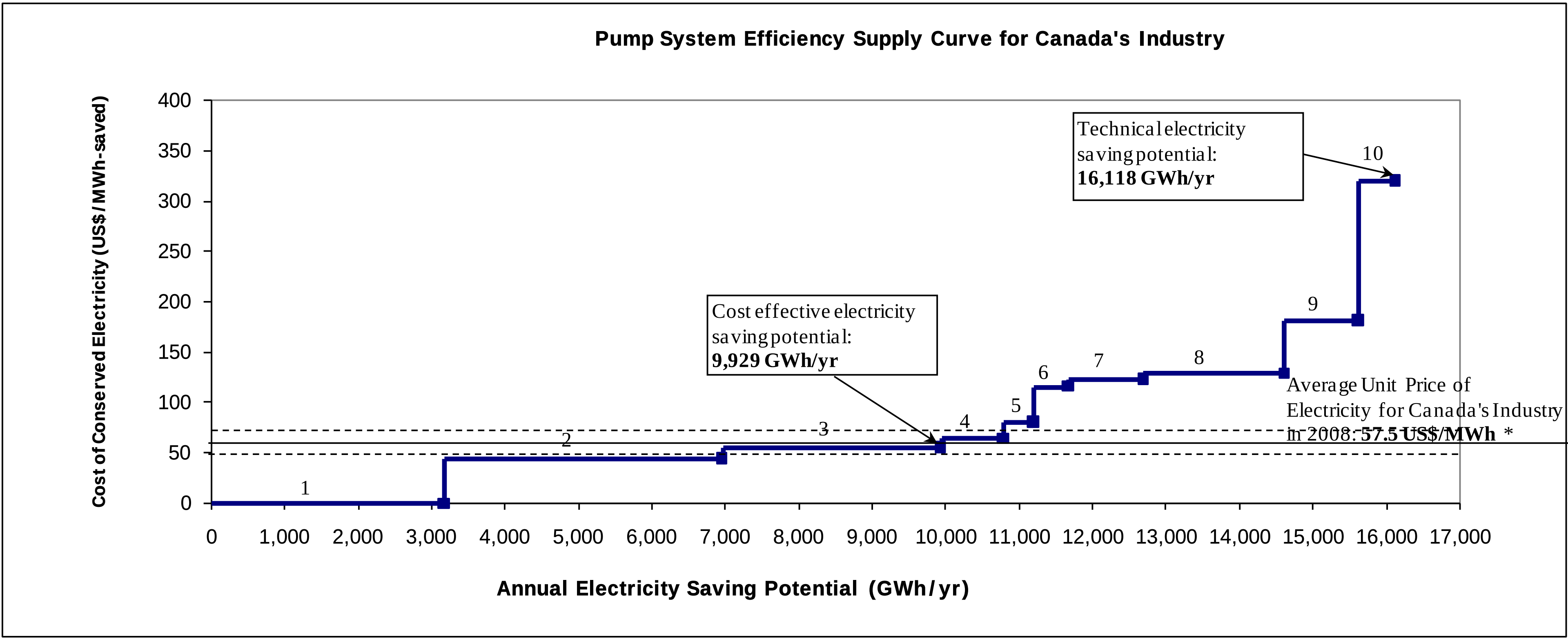
Rank	Energy Efficiency Measure	Cumulative Annual Electricity Saving Potential in Industry (GWh/yr)	Final CCE (US$/MWh-saved)	Cumulative Annual Primary Energy Saving Potential in Industry (TJ/yr)	Cumulative Annual CO_2 emission reduction Potential from Industry (kton CO_2 /yr)
1	Isolate flow paths to non-essential or non-operating equipment	10,589	0.0	116,265	6,382
2	Install variable speed drive	23,295	44.5	255,784	14,040
3	Trim or change impeller to match output to requirements	33,279	57.0	365,405	20,057
4	Use pressure switches to shut down unnecessary pumps	36,148	65.7	396,905	21,786
5	Fix Leaks, damaged seals, and packing	37,510	84.1	411,855	22,607
6	Replace motor with more energy efficient type	39,084	116.9	429,138	23,555
7	Remove sediment/scale buildup from piping	42,523	126.3	466,906	25,628
8	Replace pump with more energy efficient type	48,954	132.2	537,516	29,504
9	Initiate predictive maintenance program	52,302	189.0	574,280	31,522
10	Remove scale from components such as heat exchangers and strainers	54,023	330.9	593,171	32,559

Results - Pumping System Efficiency Supply Curves

Total annual cost-effective and technical energy saving and CO_2 emission reduction potential for the **U.S.** industrial **pumping** system in 2008

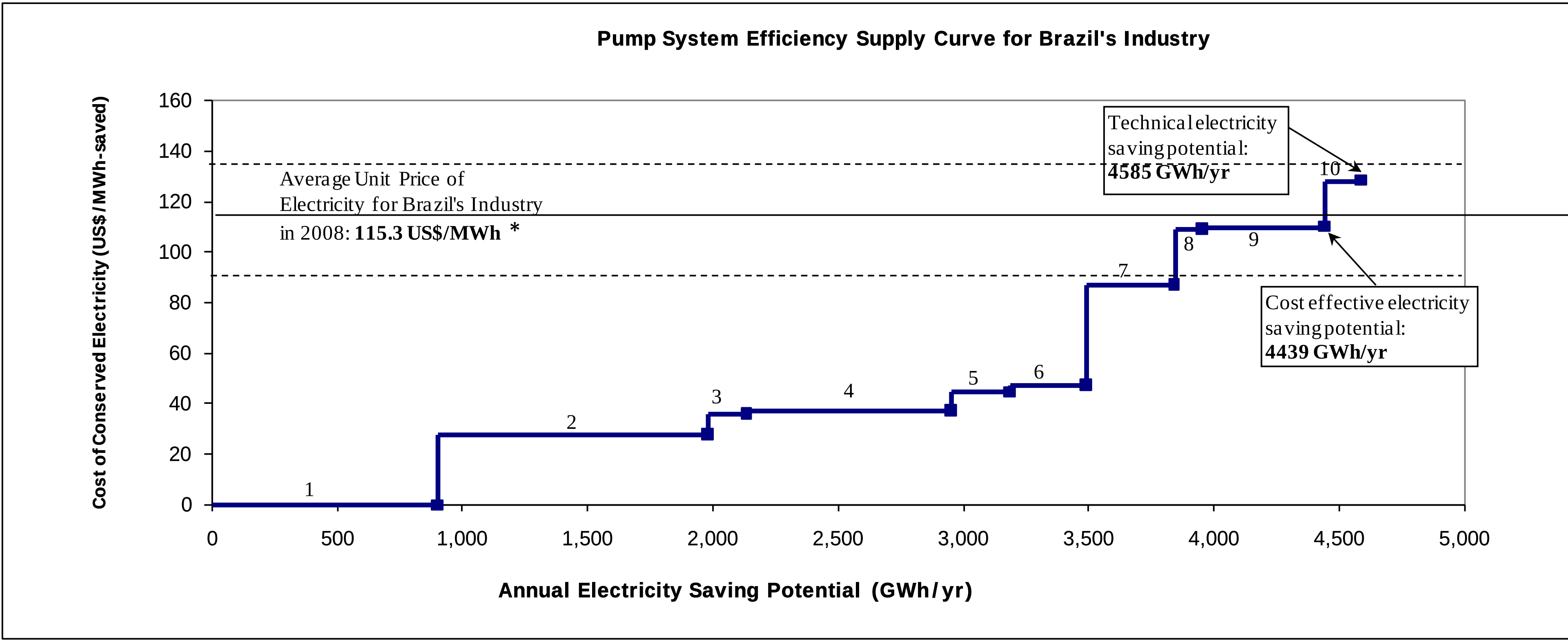
	Cost effective Potential	Technical Potential
Annual electricity saving potential for pumping system (GWh/yr)	36,148	54,023
Saving **from the total pumping system electricity use** in studied industries	**29%**	**43%**
Share of saving **from total electricity use in studied industries**	**4%**	**6%**
Annual primary energy saving potential for pumping system (TJ/yr)	396,905	593,171
Annual CO_2 emission reduction potential (kton CO_2 /yr)	21,786	32,559

Results - Pumping System Efficiency Supply Curves



Canada's Pumping System Efficiency Supply Curve

Results - Pumping System Efficiency Supply Curves



Brazil's Pumping System Efficiency Supply Curve

Results - Pumping System Efficiency Supply Curves

Total annual cost-effective and technical energy saving potential in the industrial **pumping** systems in studied countries

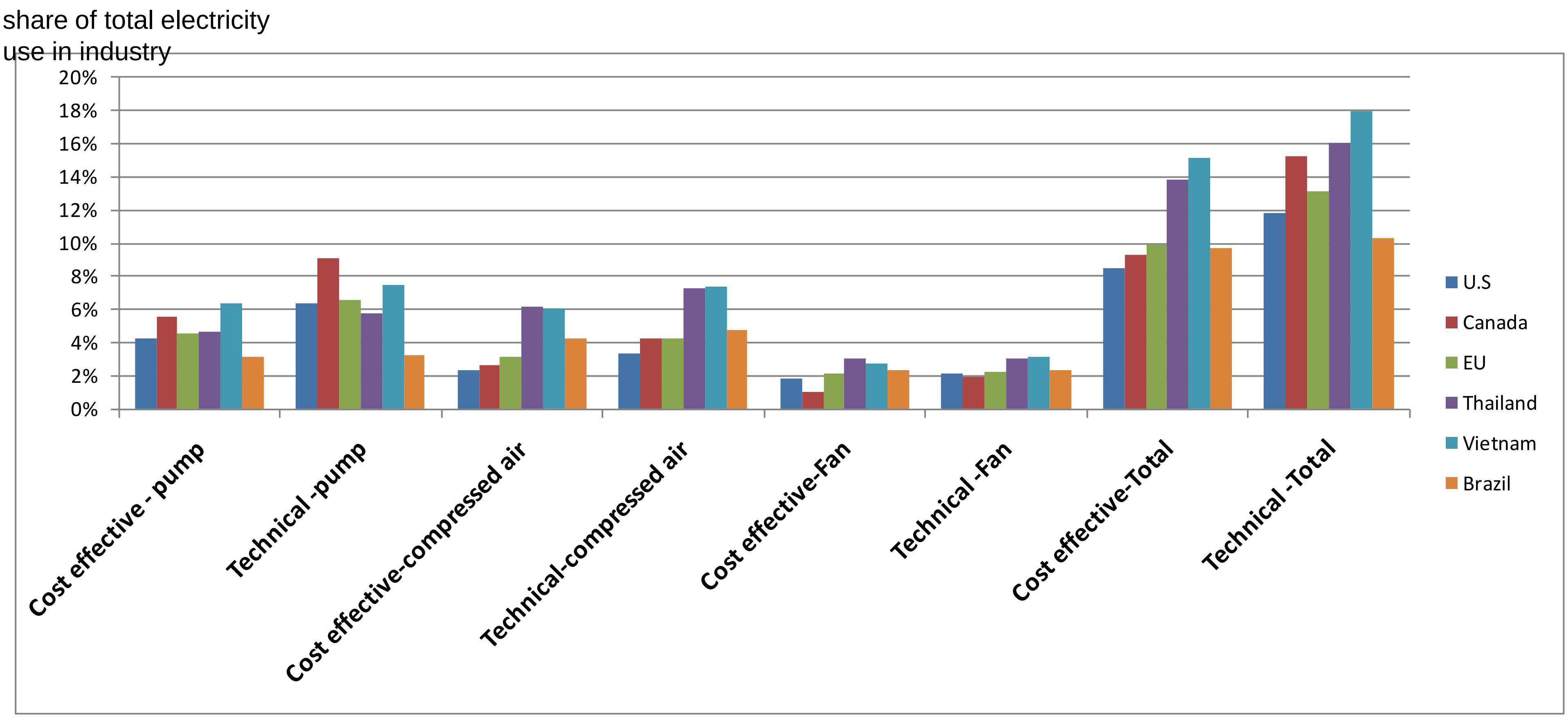
Country	Annual Electricity Saving Potential in Industrial Pumping System (100% penetration) (GWh/yr)		Share of saving from the total Pumping system energy use in studied industries in 2008 *	
	Cost effective	Technical	Cost effective	Technical
U.S	**36,148**	**54,023**	**29%**	**43%**
Canada	**9,929**	**16,118**	**27%**	**45%**
EU	26,921	38,773	30%	44%
Thailand	2,782	3,459	**36%**	45%
Vietnam	1,693	1,984	**49%**	**57%**
Brazil	4,439	4,585	**43%**	45%

Summary

Total annual cost-effective and technical energy saving potential in the industrial Motor systems in studied countries

	Sum of Annual Electricity Saving Potential in Industrial Pump, Compressed air, and Fan System (GWh/yr)		Share of total saving from Sum of electricity use in pump, compressed air, and fan systems in studied industries in 2008	
Country	**Cost effective**	**Technical**	**Cost effective**	**Technical**
U.S	71,914	100,877	25%	35%
Canada	16,461	27,002	25%	40%
EU	58,030	76,644	29%	39%
Thailand	8,343	9,659	**43%**	**49%**
Vietnam	4,026	4,787	**46%**	**54%**
Brazil	13,836	14,675	**42%**	**44%**

Summary



Energy savings by motor systems as a **share of total electricity use in industries studied in the base year**

Conclusions

- Many cost-effective opportunities for energy efficiency improvement in the motor systems in the six countries have been identified but frequently not adopted, leading to what is called an **"efficiency gap"**.
- Despite the **lack of empirical data**, there is a **strong need for quantifying the saving** potential in industrial motor systems **at national level-** <u>that's what we have tried to do</u>.
- The results of this study should be interpreted with caution keeping in mind the assumptions and the methodology used in the calculations such as:
  - **Experts judgment** used because of lack of empirical data
  - Because of the **lack of country-specific motor system data**, the U.S. industrial motor system data was used in several cases for all countries in this analysis
  - The implication of the **additive effect** is that measures on the supply curves should be implemented in order and the saving achieved by each measure depends on its rank on the supply curve.

Thank You!

For Further Information:

Find the full report on UNIDO website.

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