Business Case for Energy Efficiency

United States, China and India

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Project Objectives

- Demonstrate for key countries that there are significant opportunities for energy efficiency improvement, at *net negative cost*, and therefore articulate a '*Business Case*' for efficiency.

- Emphasis on robust analysis, using bottom-up, technology based modeling.

- Possible efficiency scenarios:
  - Technical Potential
  - Economic Potential = ***Business Case***
  - Achievable Potential

Countries Covered

United States

- Highest per capita consumption
- Mature markets
- High Efficiency and well-developed policies

China

- Enormous Market.
- Rapid Accumulation of Consumer Goods
- Efficiency Programs in Place

India

- Largest Potential for Growth
- Relatively Low Baseline
- Emerging Programs.

Metrics

- Energy Savings – Direct (final) electricity and fuel savings (TWh) in 2030 from near term (2015) market shift.
- Greenhouse Gas Emissions Mitigation – Reduction in CO_2 (mt) emissions in 2030 from avoided electricity generation and fuel combustion.
- Reduction of Other Pollutants – Reduction in NO_x, SO_x and mercury emissions (mt) from avoided electricity generation.
- Financial Impacts – Net monetary savings ($billions) to consumers as a result of adoption of efficient products.
- Job Creation – Net increase in jobs as resulting from shift in consumer spending from energy to more job-intensive sectors of the economy (thousands of jobs).

What the report does and doesn't say

- *Does* indicate *where* cost-effective savings can be found – cost of conserved energy can be interpreted as a prioritization.

- *Does* say *how much* savings are there – robust metric gives the percent improvement and national level improvements available at net negative cost.

- *Doesn't* say *how* to capture savings – Section 1 discusses the history of efficiency programs, but doesn't evaluate their success. Conclusions are 'policy neutral' – many ways to get there.

Analysis Steps

1. List possible appliance groups to include.
2. Gather data on baselines, performance and cost of high-efficiency technologies
3. Determine maximum cost-effective efficiency from cost-benefit analysis
4. Forecast base case energy demand for each appliance through 2030
5. Forecast energy demand reduction through 2030 according to a market shift to identified efficiency level in 2015.
6. Calculate final energy savings through 2030
7. Calculate financial impacts from increased equipment costs and reduced energy bills
8. Calculate emissions using electricity carbon factors (EIA/IEA projections)
9. Calculate other impacts using coefficients.

Approach and Limitations

- Bottom-Up – Analyze appliances (freezer) and appliance groups (residential refrigeration) at highest level of detail possible – not aggregate end uses (HVAC) or sectors (residential)

- Cost-Driven – Include only those technologies for which data is available for equipment price and annual energy demand reduction for baseline and high-efficiency models.

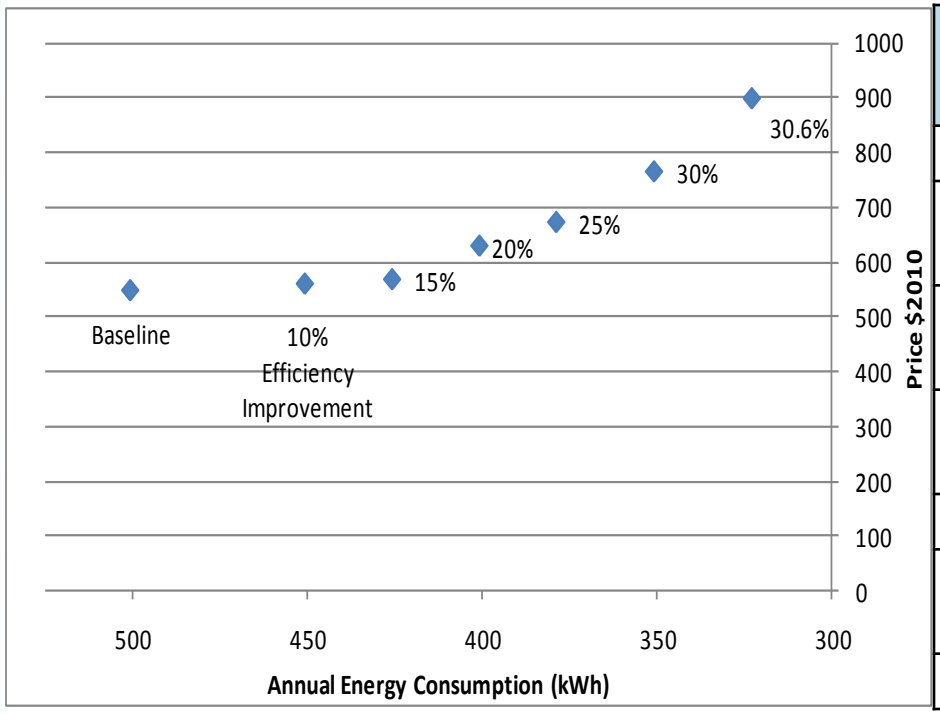
- Non-Speculative – Only include efficiency technologies not already required by standards to be implemented before 2015, but which are already deemed marketable, and use current market prices (conservative).

Trade-off between desire to be comprehensive and desire to be robust arises from data limitations.

Data Sources

- United States – Relied heavily on analyses performed as part of appliance standards rulemakings by U.S. Department of Energy.
- China – Retail price data, guided by China's labeling program.
- India – Retail data, literature, labeling program.

Cost-Efficiency Data – U.S. Example



Efficiency Level	Design Option
Baseline	See Table 5-A.2.1 of 1
10%	Increase Condenser Size by 100% & Increase Compressor EER from 5.55 to 6.1
15%	Increase Compressor EER from 6.1 to 6.26 & Use Brushless DC Condenser Fan Motor
20%	Increase Evaporator Size by 14% & Use Adaptive Defrost & Use Variable Speed Compressor
25%	12.2 sqft VIP in FZR Cabinet
30%	2.9 sqft VIP in FZR Door & 7.1 sqft VIP in FF Door & 6.7 sqft VIP in FF Cabinet
30.60%	1.9 sqft more VIP in FF Cabinet

Source: USDOE (2010a). Refrigerator, Refrigerator-Freezer and Freezers Rulemaking Technical Support Document. USDOE

Appendix of U.S. report contains data for ~60 product classes in 11 appliance groups

Identifying Cost-Effective Efficiency Targets

Cost-effectiveness described by Cost of Conserved Energy, the annualized investment in more expensive equipment needed to provide a unit of saved energy (kWh):

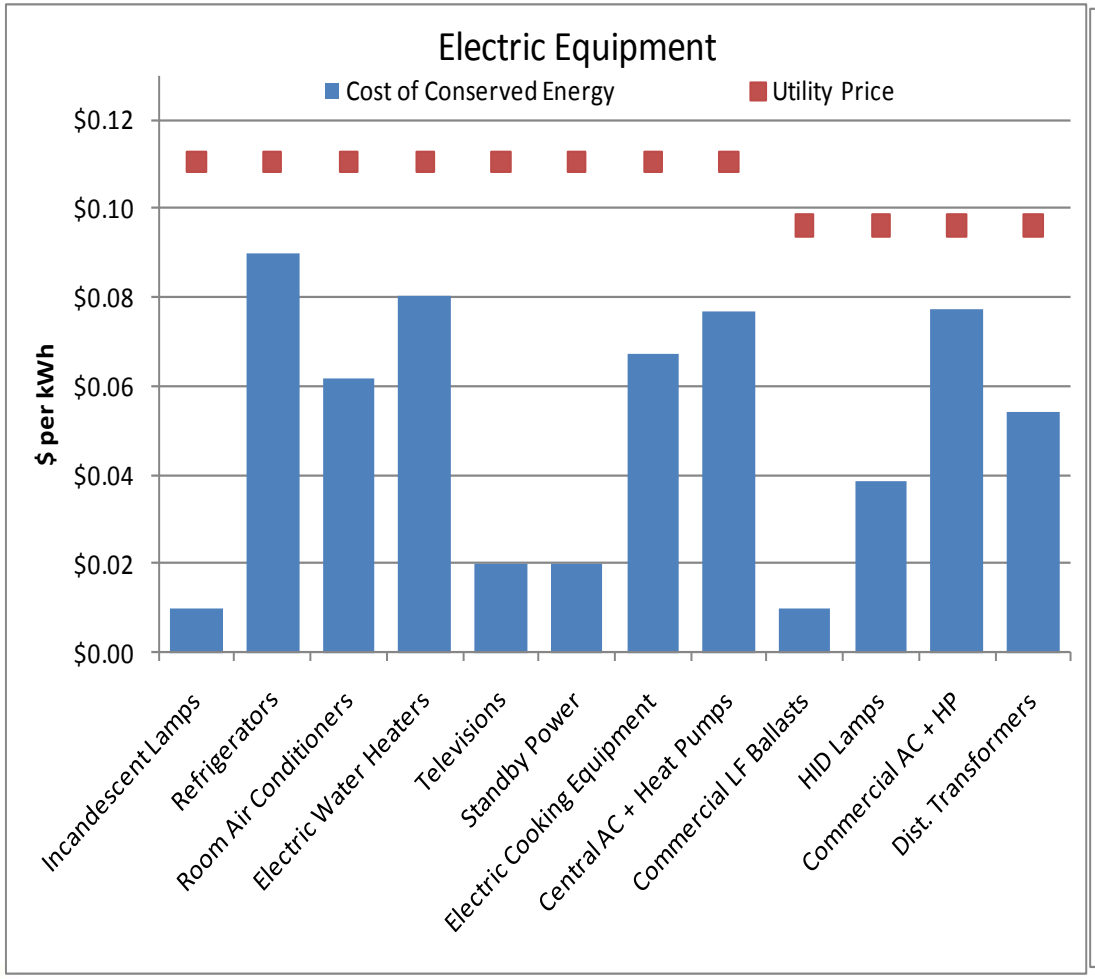
$$CCE = \frac{I \times q}{S}$$

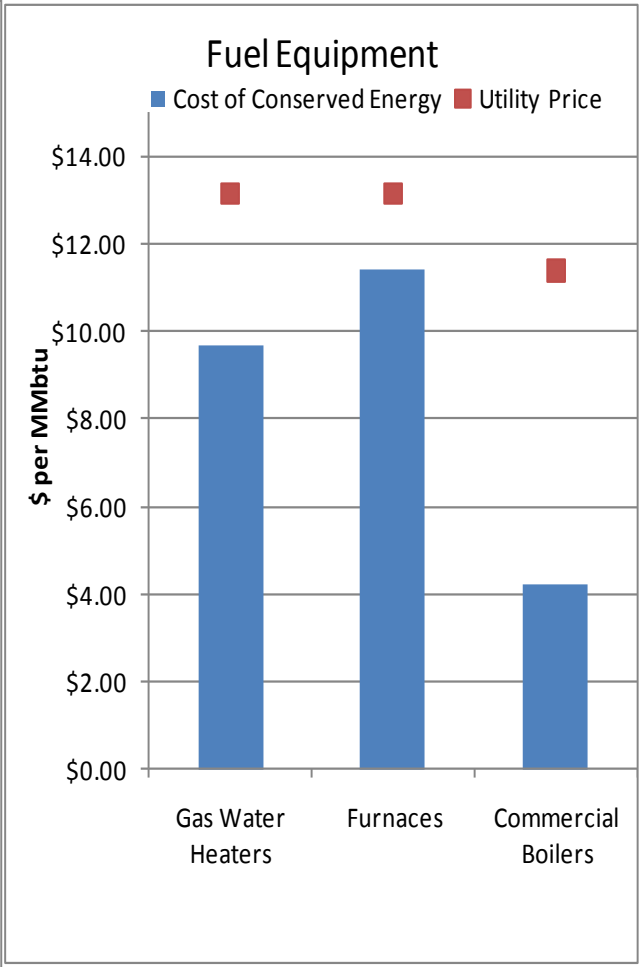
where I is the annualized capital cost, q is the capital recovery factor, and S is annual energy savings. The capital recovery factor q is given by:

$$q = \frac{d}{(1-(1-d)^{-n})}$$

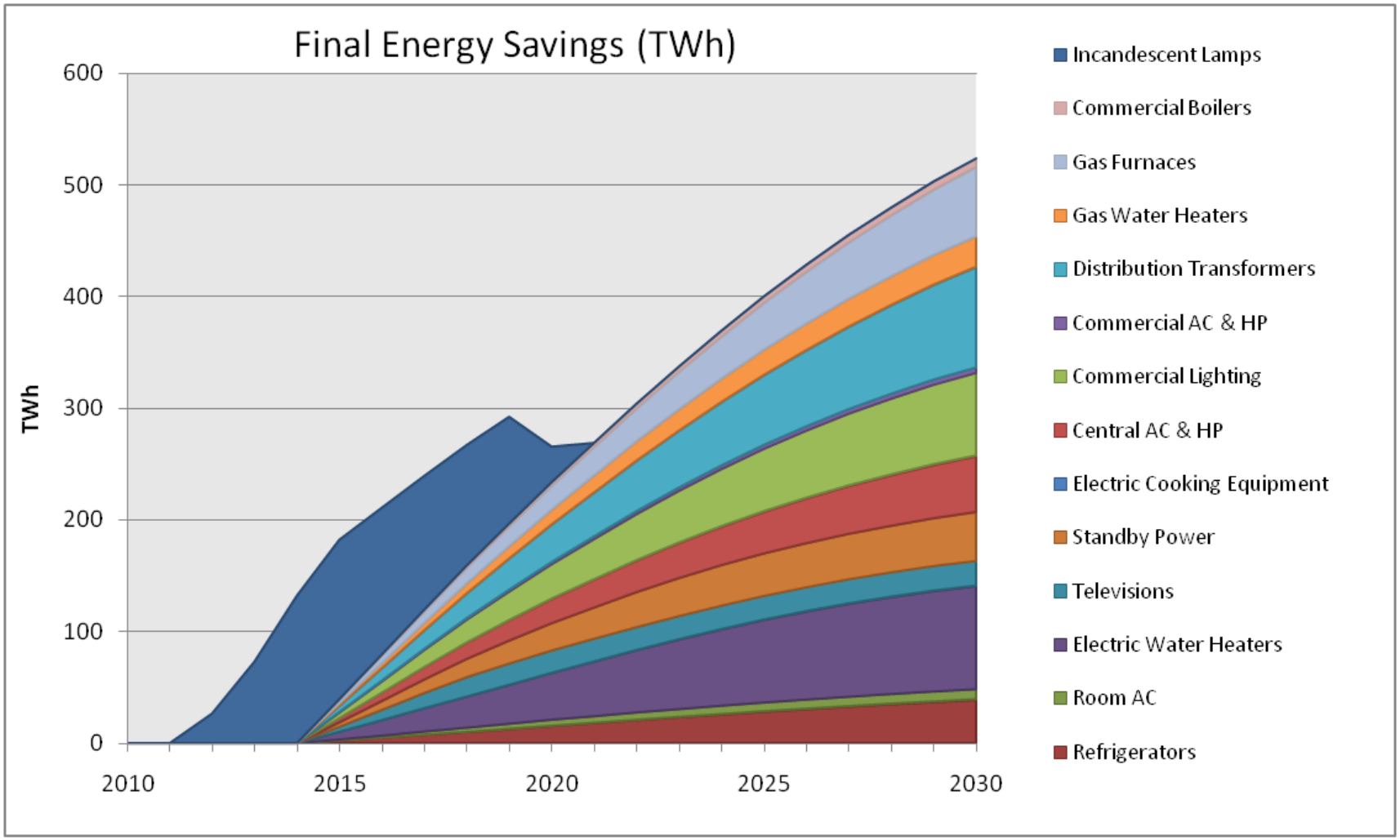
In this equation, d is the discount rate, and n is the lifetime of the equipment.

CCE Summary – U.S.





Final Energy Savings – United States



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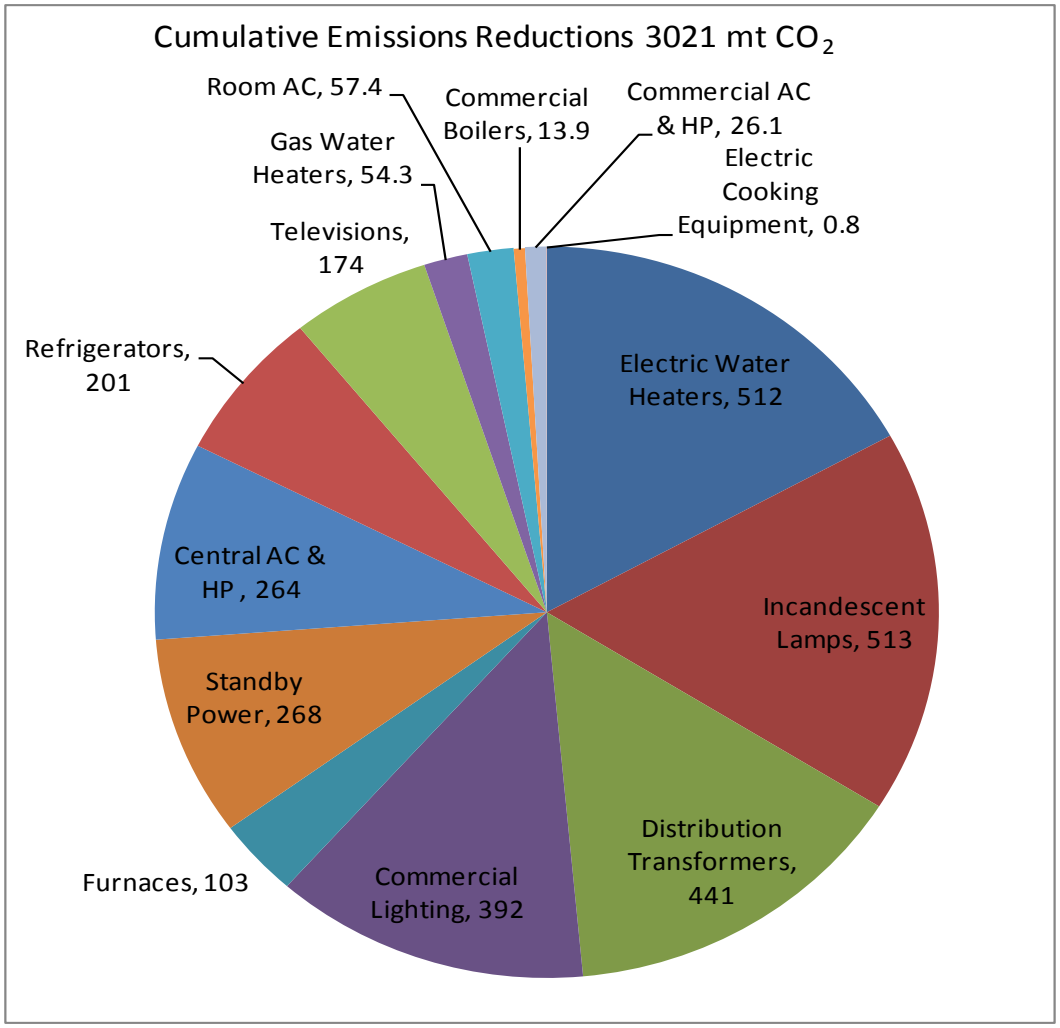
Emissions Contributions – U.S.



Financial Impacts – U.S.

Appliance Group	Cumulative Financial Impacts				
	Cost	Savings	Net	NPV @ 3% DR	NPV @ 7% DR
	$ Billions				
Incandescent Lamps	15.9	95.1	79.2	66.4	53.2
Commercial Lighting	9.4	67.9	58.4	37.9	22.1
Standby Power	9.3	51.2	41.9	27.5	16.3
Distribution Transformers	41.4	76.4	34.9	22.6	13.1
Televisions	6.0	33.1	27.1	18.4	11.3
Electric Water Heater	71.4	97.9	26.5	17.2	10.1
Central AC & HP	35.0	50.5	15.4	10.0	5.9
Refrigerators	31.3	38.4	7.1	4.6	2.7
Room AC	6.1	11.0	4.9	3.2	1.9
Gas Water Heaters	8.9	12.1	3.2	2.1	1.2
Furnaces	20.0	23.0	3.0	2.0	1.1
Commercial Boilers	1.0	2.7	1.7	1.1	0.6
Commercial AC & HP	3.5	4.5	1.0	0.7	0.4
Electric Cooking Equipment	0.1	0.1	0.1	0.04	0.02
Total	**259**	**564**	**304**	**214**	**140**

Summary – U.S.

Energy savings:

- 230 billion kWh of electricity and 0.14 EJ of natural gas per year in 2020
- 430 billion kWh of electricity and 0.35 EJ of natural gas per year in 2030
- A total of 4900 billion kWh of electricity and 3.1 EJ natural gas cumulatively through 2030

Cumulative greenhouse gas emissions mitigation:

- 3000 million metric tons of CO_2 through 2030
- 12 million metric tons of SO_2 through 2030
- 3.5 million metric tons of NO through 2030
- 62 metric tons of mercury through 2030

Financial impacts to consumers through 2030:

- Equipment investment of 260 billion dollars
- Energy bill savings of 560 billion dollars
- Net savings of 300 billion dollars

Job Creation

- Net creation of 85,000 to 200,000 jobs

China Efficiency-Cost Relationship for Room AC and Water Heaters

Class	Room AC								
	Residential AC (Cooling)			Residential HP (Cooling + Heating)			Commercial RAC		
Market share	30%			70%			100%		
Lifetime (years)	12			12			12		
Q	0.116			0.116			0.123		
Level	UEC (kWh)	Price ($)	CCE	UEC (kWh)	Price ($)	CCE	UEC (kWh)	Price ($)	CCE
Baseline (Level 3)	385	367		891	367		770	367	
High Efficiency (Level 1)	289	548	0.44	669	548	0.095	578	548	0.116
In-Class Target UEC	385			669			578		
Target End-Use UEC	584						578		
End-Use Baseline UEC	739						770		
Target End-Use CCE	0.095						0.116		

Class	Water Heaters					
	Waterheaters (Electric)			Waterheaters (Gas)		
Market share	100%			100%		
Lifetime (years)	15			15		
Q	0.100			0.100		
Level	UEC (kWh)	Price	CCE	UEC (GJ)	Price	CCE
Baseline	617	176		5.0	235	
1	370	367	0.077	4.1	470	28.362
2	185	441	0.061	1.5	441	5.915
Target End-Use UEC	185			1		
End-Use Baseline UEC	617			5		
Target End-Use CCE	0.061			5.92		

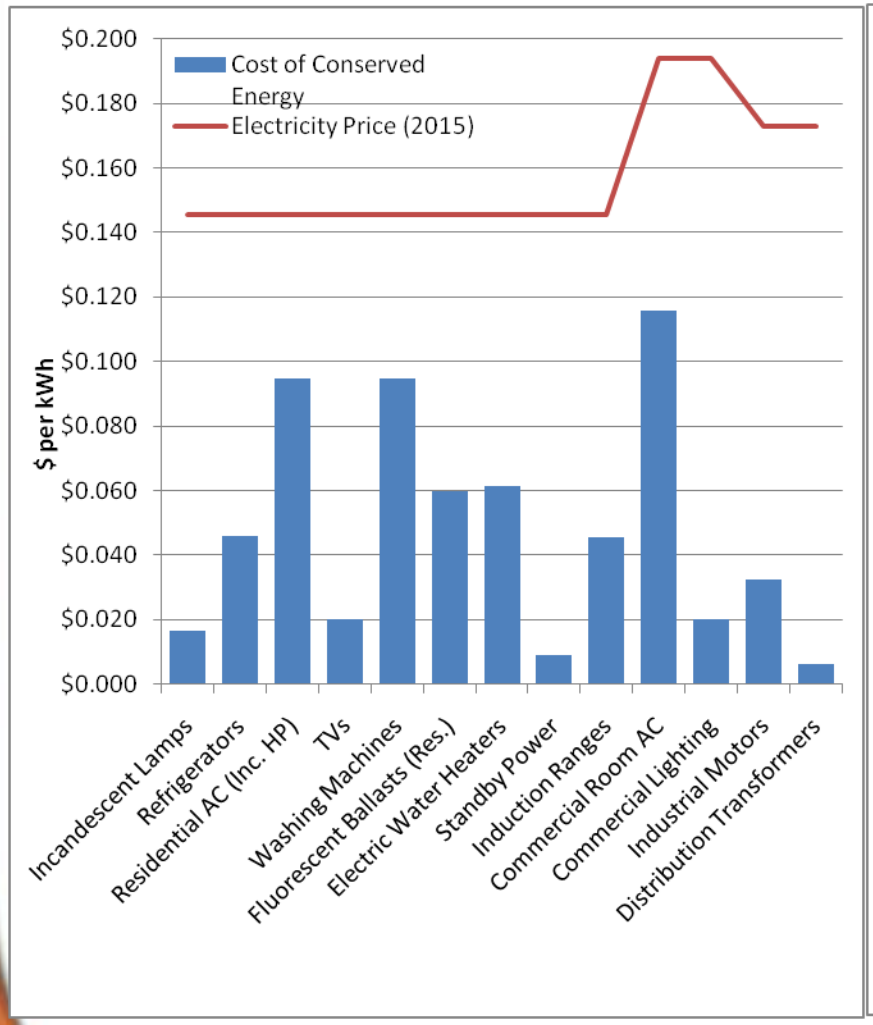
China Efficiency-Cost Relationship for Other Appliance Groups

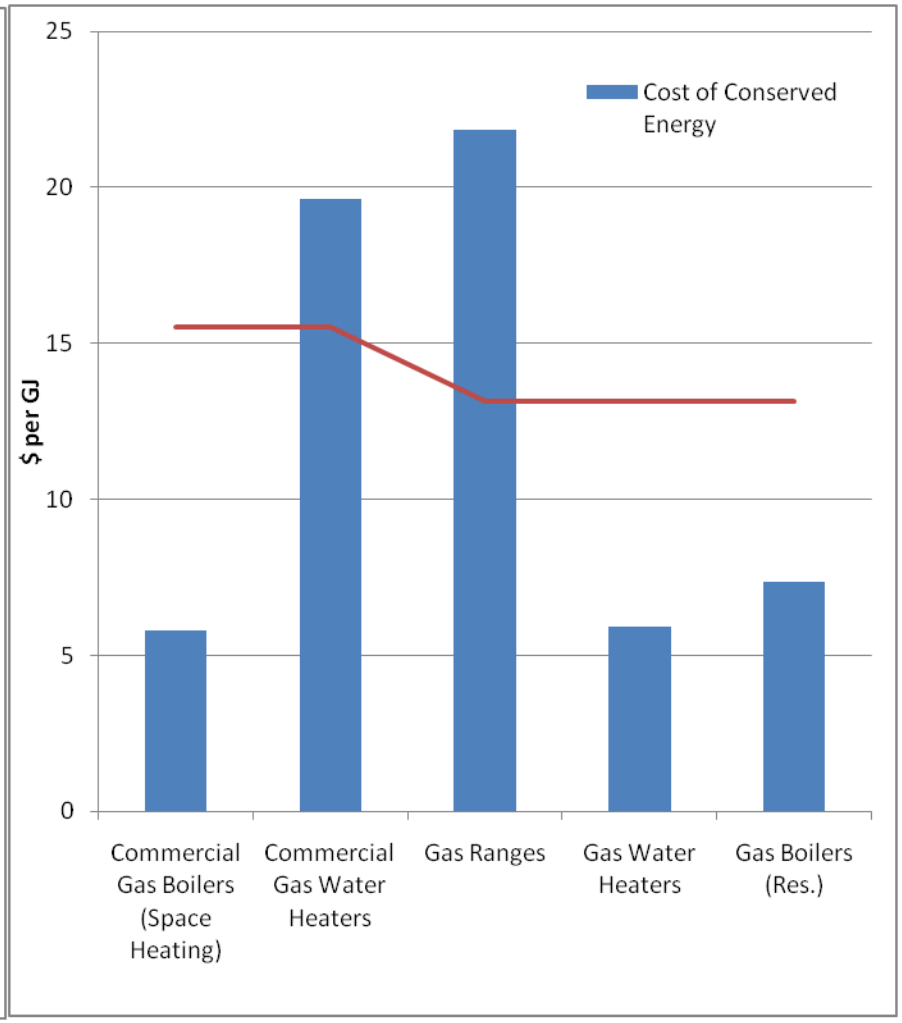
Equipment	Lifetime	Q	Baseline UEC	Target UEC	Baseline Price	Target Price	Target CCE
Electric Equipment	years	years	kWh	kWh	$	$	$/kWh
Refrigerator	15	0.100	548	292	323	441	0.046
Laundry (Washing Machine)	15	0.100	169	91.9	220	294	0.095
Cooking Products (Electric Induction Stoves)	15	0.100	437	398	34	51	0.045
Lamps (Incandescent)	5	0.235	50.4	12.6	1.47	4.11	0.016
End-Uses with more than one product class							
Fluorescent Lamp Ballast : Residential	15	0.100	56.4	49.0	0*	4.41	0.060
Fluorescent Lamp Ballast : Commercial	15	0.100	112.8	98.1	0*	4.41	0.030
Commercial Air Conditioning	12	0.123	48000	17576	13436	21850	0.427
Motors							
1 HP (90%)	10	0.146	1485	1397	61	91	0.050
10 HP (9%)	10	0.146	19800	18847	239	479	0.037
100 HP (.9%)	10	0.146	396000	387310	1683	4208	0.042
Liquid-Type Distribution Transformers							
30 kVA (6%)**	30	0.085	4503	3740	1174	2159	0.110
63 kVA (25%)**	30	0.085	7583	6395	1739	3232	0.107
100 kVA (44%)**	30	0.085	10950	9233	2264	4158	0.094
160 kVA (3%)**	30	0.085	15838	13430	3062	5622	0.091
200 kVA (14%)**	30	0.085	18781	15874	3665	6724	0.090
Fuel Equipment	years	years	GJ	GJ	$	$	$/GJ
Commercial Gas Boiler	20	0.091	181	2496	159	3935	5.79
Gas Boilers	17	0.092	14.7	734	13	881	7.37

*Assume no-cost for leaving magnetic ballasts installed, due to their long lifetime

** Losses only are shown for transformers

CCE Summary – China





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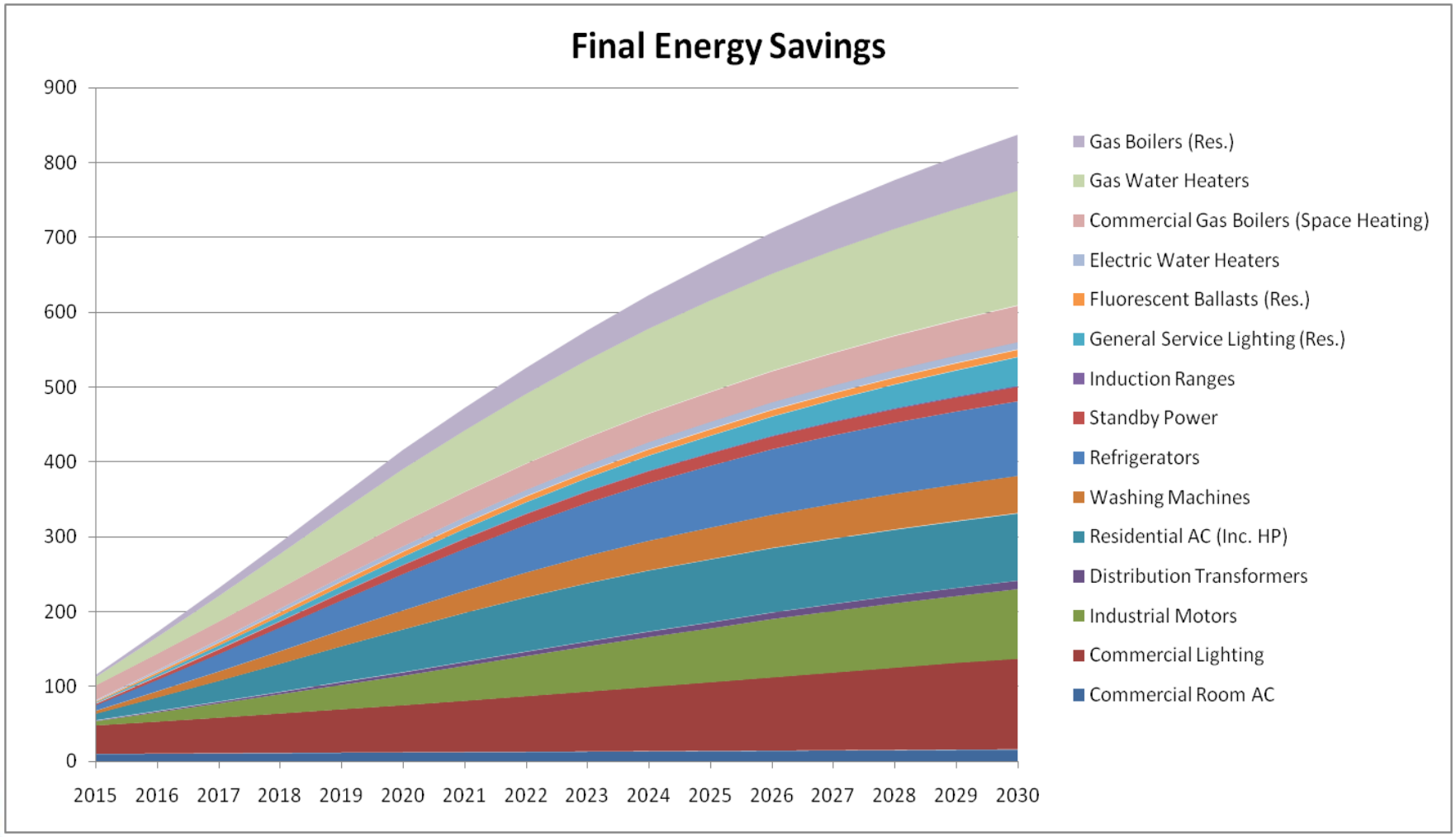
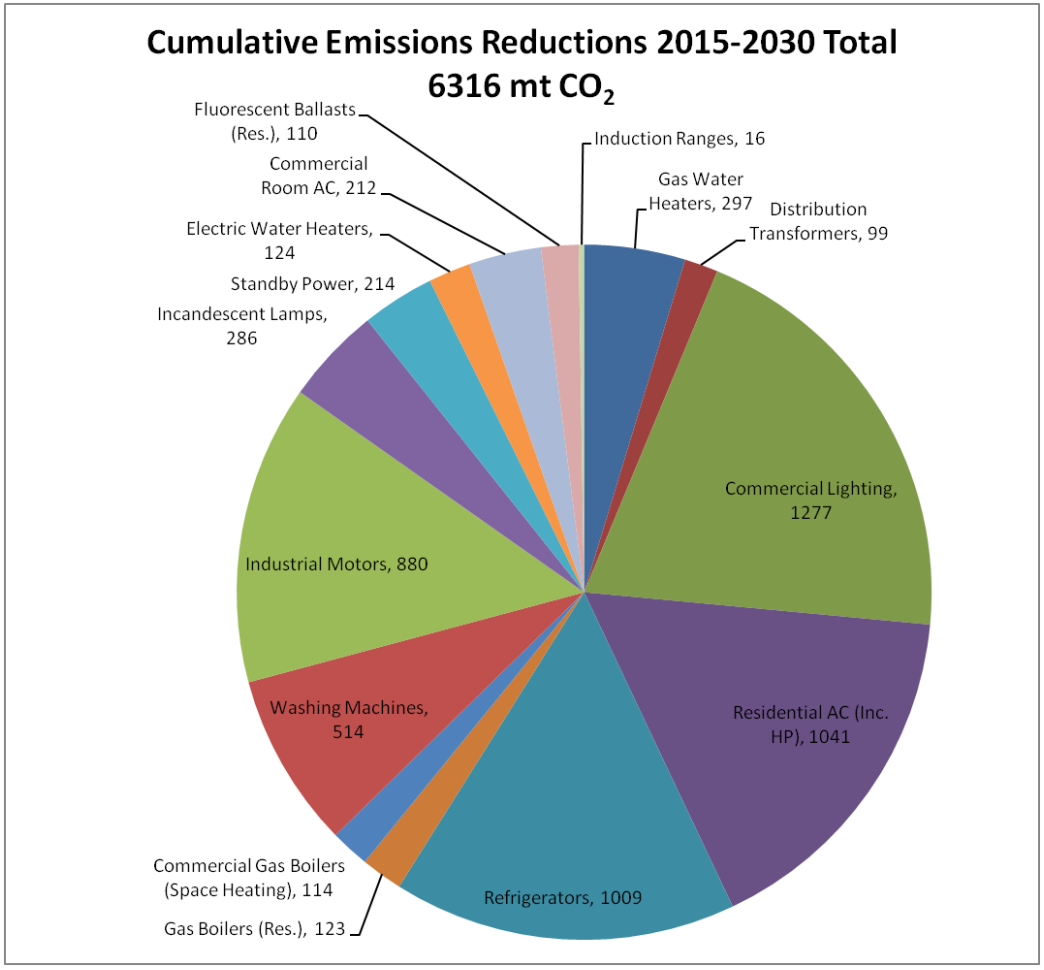
Final Energy Savings – China



Emissions Contributions – China



Financial Impacts – China

Appliance Group	Cumulative Financial Impacts				
	Cost	Savings	Net Savings	NPV @ 3% DR	NPV @ 7% DR
	Billions USD				
Commercial Lighting	25.0	242	**217**	145	88.0
Distribution Transformers	0.6	17	**16**	10	6.1
Refrigerators	45.6	144	**98.5**	64.3	37.8
Gas Water Heaters	31.3	70	**38.3**	24.9	14.6
Residential AC (Inc. HP)	96.5	148	**51.8**	34.2	20.4
Industrial Motors	28.2	149.4	**121.3**	78.6	45.9
Incandescent Lamps	4.6	41.0	**36.4**	23.2	13.2
Standby Power	1.9	30.5	**28.6**	18.9	11.3
Washing Machines	47.9	73.4	**25.5**	16.7	9.8
Commercial Gas Boilers (Space Heating)	11.8	31.7	**19.9**	13.4	8.3
Commercial Room AC	23.9	40.0	**16.1**	11.0	7.0
Electric Water Heaters	7.5	17.7	**10.3**	6.8	4.1
Gas Boilers (Res.)	16.1	28.7	**12.6**	8.1	4.7
Fluorescent Ballasts (Res.)	6.4	15.6	**9.2**	6.1	3.7
Induction Ranges	0.7	2.3	**1.6**	1.0	0.6
Total	**341**	**1034**	**693**	**455**	**271**

Summary – China

Energy savings:

- 420 billion kWh per year in 2020
- 840 billion kWh per year in 2030
- A total of 8,300 billion kWh cumulatively through 2030

Cumulative greenhouse gas emissions mitigation:

- 6300 million metric tons of CO_2 through 2030
- 21 million metric tons of SO_2 through 2030
- 27 million metric tons of NO through 2030
- 1400 metric tons of mercury through 2030

Financial impacts to consumers through 2030:

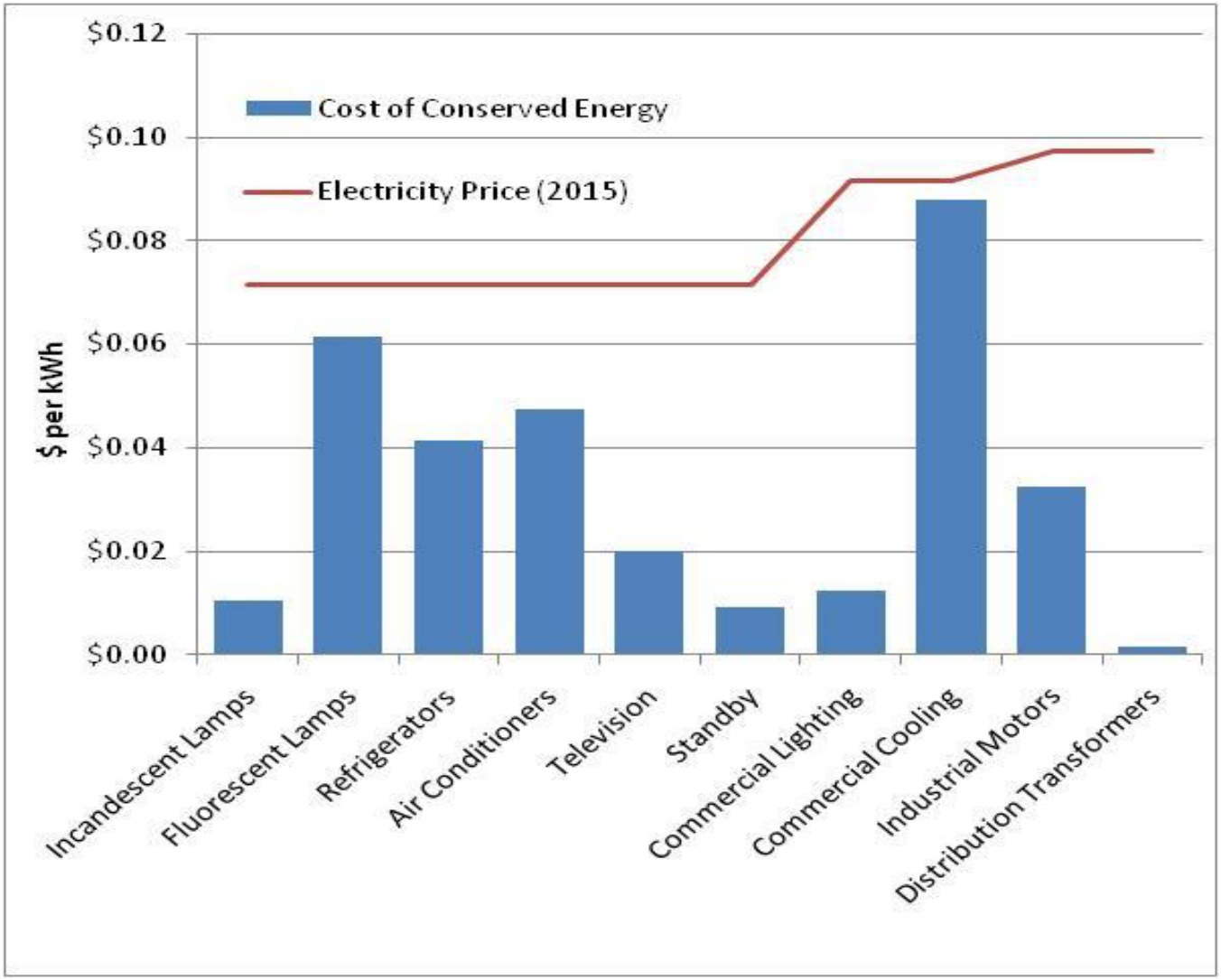
- Equipment investment of 340 billion dollars
- Energy bill savings of 1030 billion dollars
- Net savings of 690 billion dollars

* Estimates of job creation due to energy savings unavailable for China

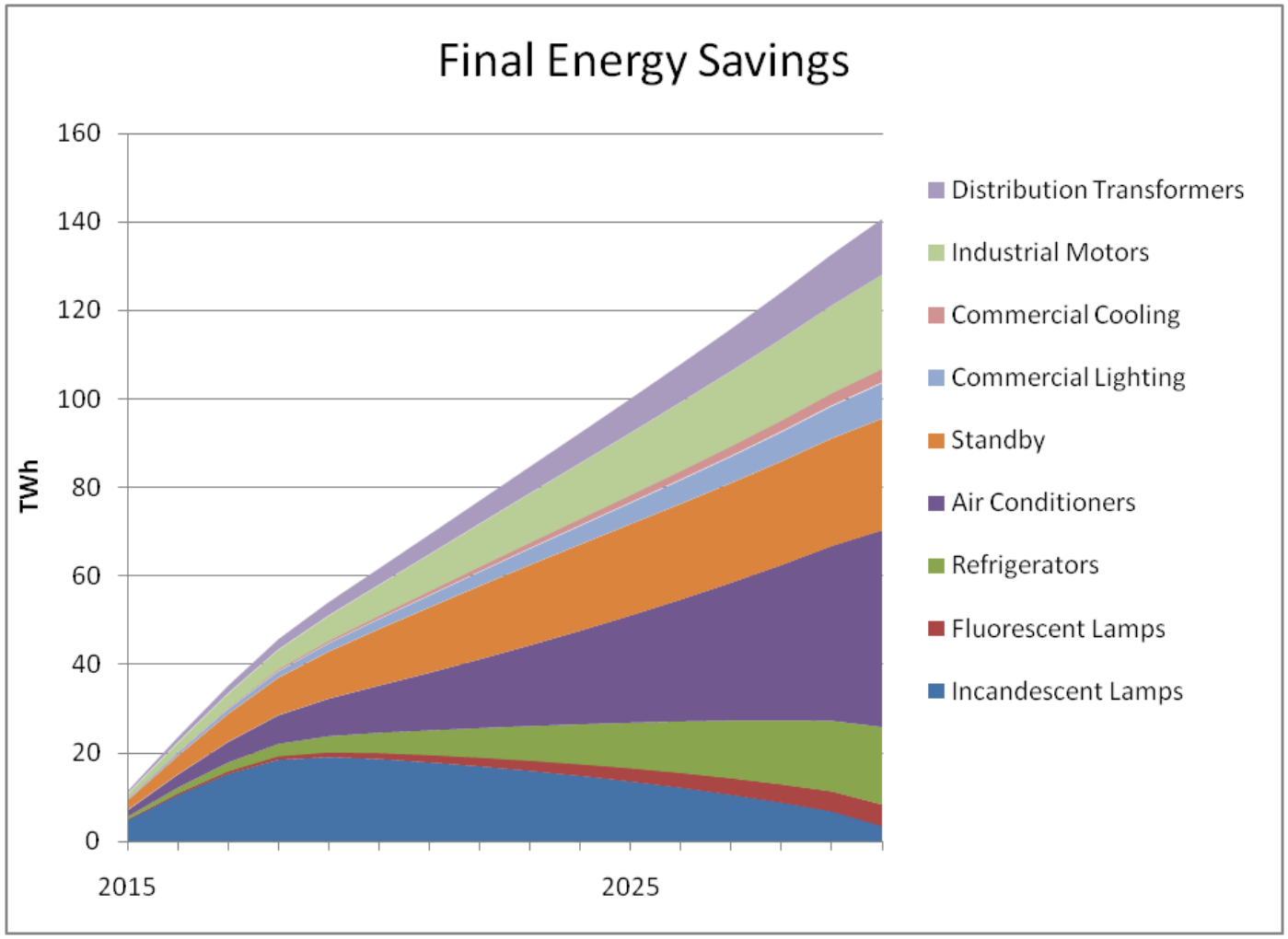
India Efficiency-Cost Relationship

Equipment	Lifetime	Q	Baseline UEC	Target UEC	Baseline Price	Target Price	Target CCE
Electric Equipment	years	years	kWh		$	$	$/kWh
Incandescent Lamps (Residential)	5*	0.264	88	21.9	0.29	4.11	0.011
Incandescent Lamps (Commercial)	5*	0.264	175	43.8	0.29	4.11	0.005
Fluorescent Lamps (Residential)	15	0.131	67	59.8	-	3.46**	0.062
Fluorescent Lamps (Commercial)	15	0.131	134	119.5	-	3.46**	0.031
Refrigerators (Direct Cool)	15	0.131	337	269	-	22**	0.042
Refrigerators (Frost Free)	15	0.131	675	432	-	43**	0.023
Air Conditioners (Residential)	15	0.131	2160	1812	-	97**	0.016
Commercial Cooling	15	0.131	-	1012**	-	547**	0.030
Motors							
10 HP (90%)	10	0.163	21700	21100	277	376	0.028
50 HP (9%)	10	0.163	108500	107000	1162	1444	0.033
100 HP (.9%)	10	0.163	216900	214800	2430	3394	0.076
Distribution Transformers							
25 kVA (6%)	22	0.114	1036	441	1036	441	0.065
60 kVA (25%)	22	0.114	1834	797	1834	797	0.051
100 kVA (44%)	22	0.114	2619	1068	2619	1068	0.037
160 kVA (3%)	22	0.114	3757	1653	3757	1653	0.016
200 kVA (14%)	22	0.114	4989	1880	4989	1880	0.030

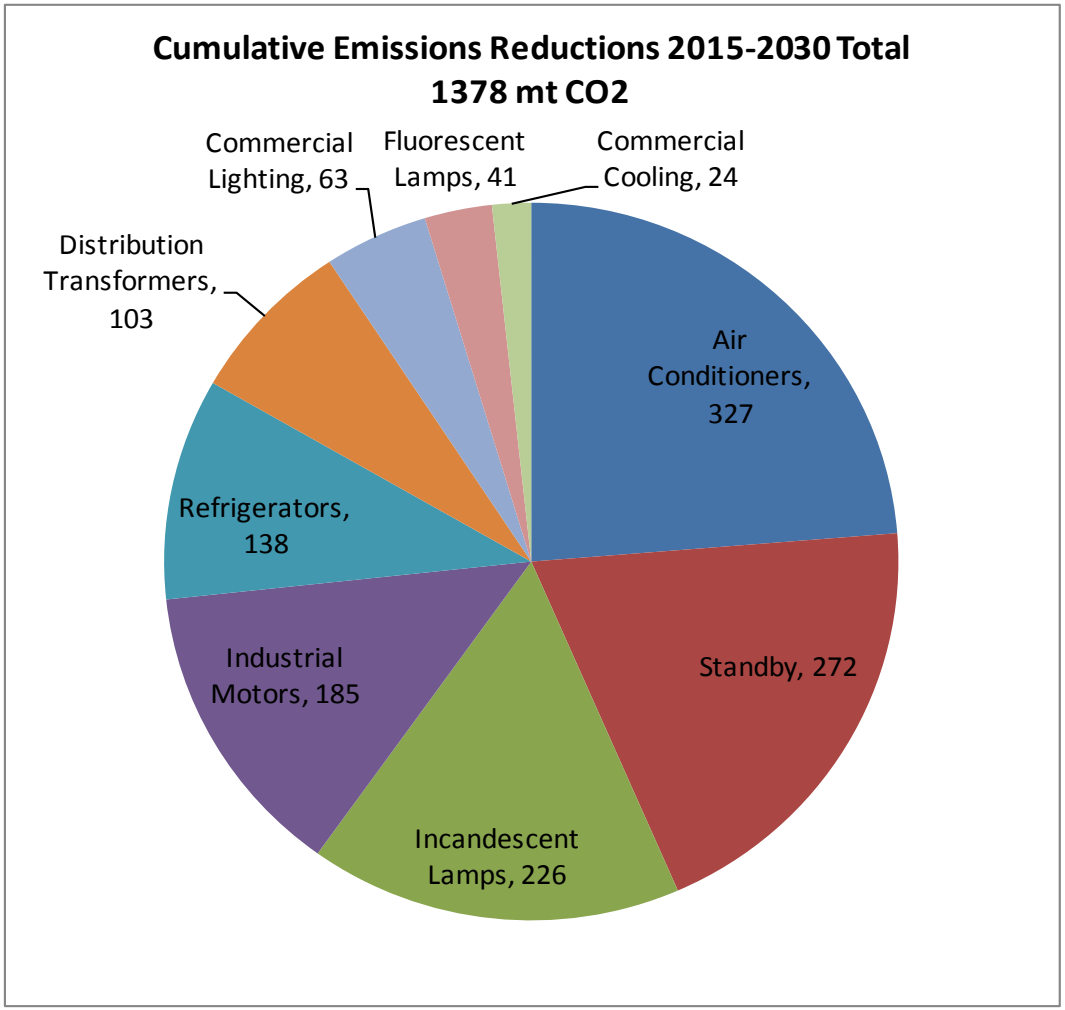
CCE Summary – India



Final Energy Savings – India



Emissions Contributions – India



Financial Impacts – India

Appliance Group	Cumulative Financial Impacts				
	Cost	Savings	Net Savings	NPV @ 3% DR	NPV @ 7% DR
	Billions USD				
Standby	2.3	18.0	15.7	8.5	5.0
Incandescent Lamps	2.2	14.8	12.6	8.9	5.9
Industrial Motors	5.6	16.7	11.1	0.4	0.2
Distribution Transformers	0.1	9.3	9.1	3.9	2.3
Air Conditioners	14.4	21.7	7.3	4.6	2.6
Commercial Lighting	0.7	5.4	4.6	2.3	1.3
Refrigerators	5.3	9.1	3.9	2.5	1.4
Fluorescent Lamps	2.3	2.7	0.4	0.2	0.1
Commercial Cooling	1.9	2.0	0.1	1.1	0.6
Total	**35**	**100**	**65**	**32**	**19**

Summary – India

Energy savings:

- 60 billion kWh of electricity per year in 2020
- 140 billion kWh of electricity per year in 2030
- A total of 130 billion kWh of electricity cumulatively through 2030

Cumulative greenhouse gas emissions mitigation:

- 1400 million metric tons of CO_2 through 2030

Financial impacts to consumers through 2030:

- Equipment investment of 35 billion dollars
- Energy bill savings of 100 billion dollars
- Net savings of 65 billion dollars

* Emissions factors for non-CO_2 pollutants unavailable for India

Take Home Messages

- United States – Despite aggressive programs and high efficiency (and expensive) equipment, significant cost-effective opportunities remain, due to technological learning. Therefore, policymakers should continue and accelerate efforts.
- China – Existing programs provide the framework for aggressive pursuit of cost-effective options to address already stated national goals.
- India – Initiated programs can target low-hanging fruit and high yield opportunities to lock in high-efficiency in a rapidly growing economy.
- **Cost effective energy savings can be found and realized through energy efficiency policies and programs in these countries, which contribute to significant economic and social benefits**
- **Should ASEAN countries identify and reap the similar energy efficiency opportunities?**

Thank You

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