The Manufacturer Economics and National Benefits of Cooling Efficiency for Air Conditioners in Brazil

Virginie Letschert

International Energy Studies Group
Lawrence Berkeley National Laboratory

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Lawrence Berkeley National Laboratory

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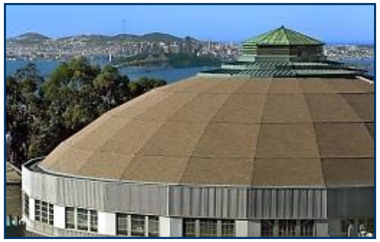
- More than two decades of work internationally on clean energy and climate policy, appliances, buildings, transport, industry, air quality.

- Significant focus on energy efficiency, including technical Support to US DOE Appliance Standards Rulemakings.

- Technical Support to Clean Energy Ministerial (CEM) Advanced Cooling (AC) Challenge, Superefficient Equipment and Appliance Deployment (SEAD) Initiative and US –India Space Cooling Collaboration.



- Technical support for revision of India’s 2016 AC standard, EESL bulk procurement program for ACs and Kigali Amendment negotiations.
- Technical support for market transformation programs for efficient ACs in various countries including China, Brazil, Mexico, Egypt, Indonesia and U4E “model regulations”.

Background

- The Kigali Amendment to the Montreal Protocol, which entered into effect in January 2019, aims to phase down HFCs as a way to mitigate climate change. LBNL research has shown that transitioning to low-GWP refrigerants and higher AC energy efficiency in concert could double the impact of the Kigali Amendment (Shah et al., 2015).
- Brazil could benefit from this opportunity, not only because it is one of the largest AC markets, but also because it has great potential to improve AC energy efficiency.
- The Kigali Cooling Efficiency Program (K-CEP) is implementing a project aimed at establishing state-of-the-art energy-efficiency policies in Brazil's AC sector and encouraging the transition to low-GWP refrigerants.
- This presentation provides a set of impact analyses, which are being used to support Brazilian policy actions.
- The analyses focus on revised AC minimum energy performance standards (MEPS) that could be implemented in conjunction with projects promoting the transition to low-GWP refrigerants.
- The results could also be used to inform the design of complementary programs—such as bulk procurement, rebate programs, and buyers' clubs—targeting high-efficiency ACs

Analysis Highlights

- The goal of the analysis is to demonstrate that a revision of the Brazilian AC MEPS is technically feasible and economically justifiable
- Large local manufacturer base (90% of the market) benefiting from government tax incentives and strong manufacturers associations
- The market already sees over 30% of inverter ACs. In order to support this market transformation, the analysis considers **a seasonal efficiency metric** to take into account the benefits of inverters
- Our analysis shows large benefits for all stakeholders:
- Very short **(2 year) Payback** Period for consumers from increased AC efficiency
- At the national level, these savings represent up to **27 Billion R$** (NPV)
- Also avoiding up to:
  - **4.5 GW** demand in the power sector by 2035
  - **60 Mt** CO_2 emissions (cumulative 2021-2035)
  - **16 TWh** electricity savings annually by 2035
- **Manufacturers will see a benefit** from switching to inverter technology

Policy and Analytical framework

- INMETRO Categorical label is in place since 2006, with 3 revisions since then. Top category A is roughly equivalent to 2010 Chinese MEPS (3.23 EER). Procel SEAL is based on Label A as well.
- MEPS has been revised 3 times since 2007. MEPS is set a level B (3.02 EER) since 2018
- Scope: Mini - split ACs up to 60,000 Btu/hr (17.58 kW)
- Representative cooling capacity: 1 RT (3.5kW)
- Energy Efficiency Metric: While the current MEPS and Labeling program is based on ISO 5151 and does not consider variable-speed operation, we developed a seasonal energy-efficiency metric to support revision of the label based on ISO 16358
- Efficiency Levels: from Current MEPS (Label B converted into CSPF) to Best Available Technologies
- Timeframe: MEPS in 2021, forecast impacts to 2035

Energy Use Analysis

ISO CSPF and Energy Use for 1-RT (3.5-kW) ACs by Efficiency Level

Efficiency Level (EL)	Comparable EER	Seasonal Efficiency in CSPF[a]		Unit Energy Consumption (UEC)[b]			
				Residential		Commercial	
		Fixed-speed unit	Variable-speed unit	Fixed-speed unit	Variable-speed unit	Fixed-speed unit	Variable-speed unit
	W/W	W/W	W/W	kWh/year	kWh/year	kWh/year	kWh/year
INMETRO Label B	3.02	3.21	4.31	498	371	627	467
INMETRO Label A	3.23	3.43	4.61	466	347	586	437
Intermediate Level #1	3.44	3.65	5.14	439	314	552	395
Intermediate Level #2	3.50	3.72	5.34	431	302	542	380
Intermediate Level #3	3.98	4.23	6.83	368	234	464	294
Highest Level	4.80	NA[c]	8.65	NA	184	NA	231

[a] We estimated CSPF for each case based on the performance data and ISO CSPF in accordance with ISO 16358, for two 1-RT fixed-speed models and three 1-RT variable-speed models.

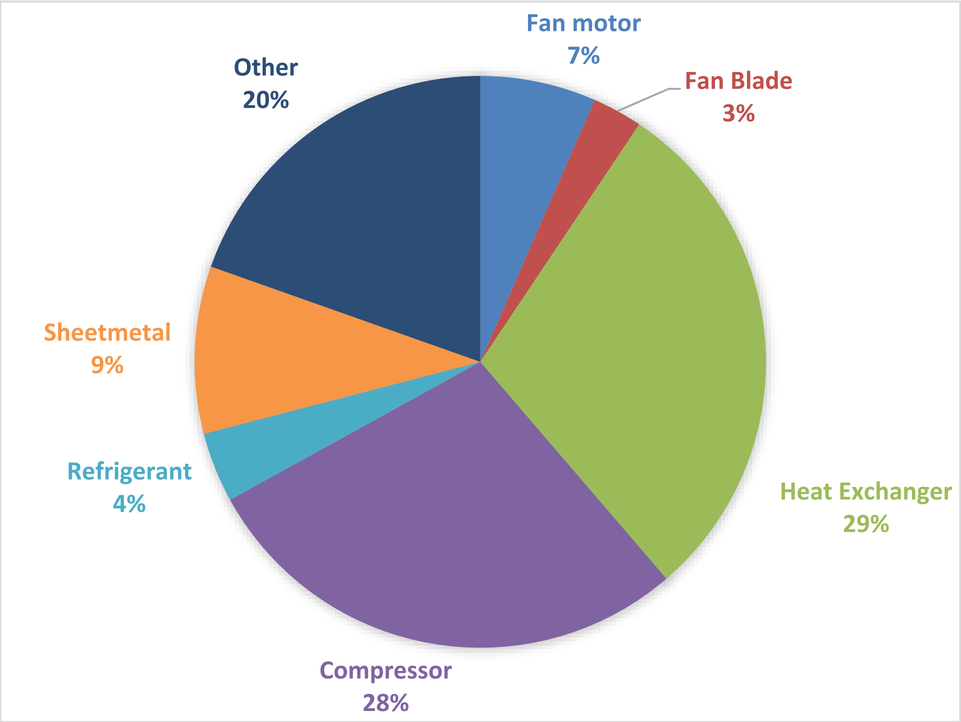
[b] We adjusted UECs based on ACs being used 3.1 hours per day in the residential sector and 3.9 hours in the commercial sector (Mitsidi Projetos, 2018), from UEC results in accordance with the ISO 16538 method based on 1,817 hours per year (about 5 hours per day).

[c] There are no commercially available fixed-speed units that achieve EER 4.5 or above.

Engineering Analysis

Purpose: Establishes the relationship between the retail prices and the efficiency of ACs.

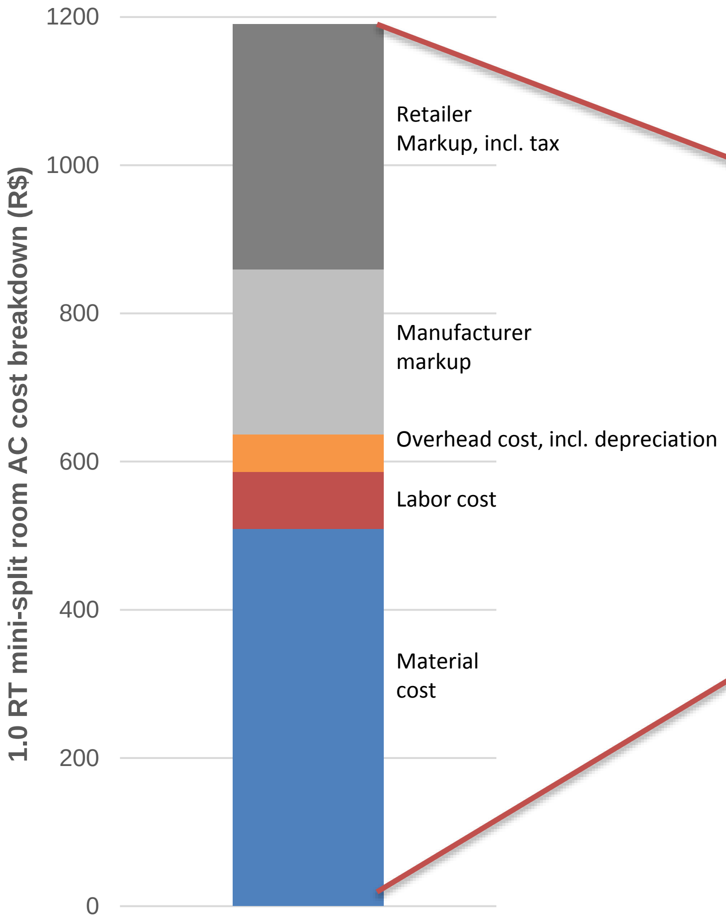
Baseline Costs: 1 RT mini-split Room ACs in Brazil (INMETRO Label B)



Total manufacturing cost = 648 R$

Note: *In this analysis, we account for the Brazilian regulation on "processo produtivo básico" or PPB, which mandates 30% minimum local manufactured content for FSD AC compressors as well as a 3% mandatory investment in research and development for producing variable-speed ACs*

Baseline AC retail price/cost break-down



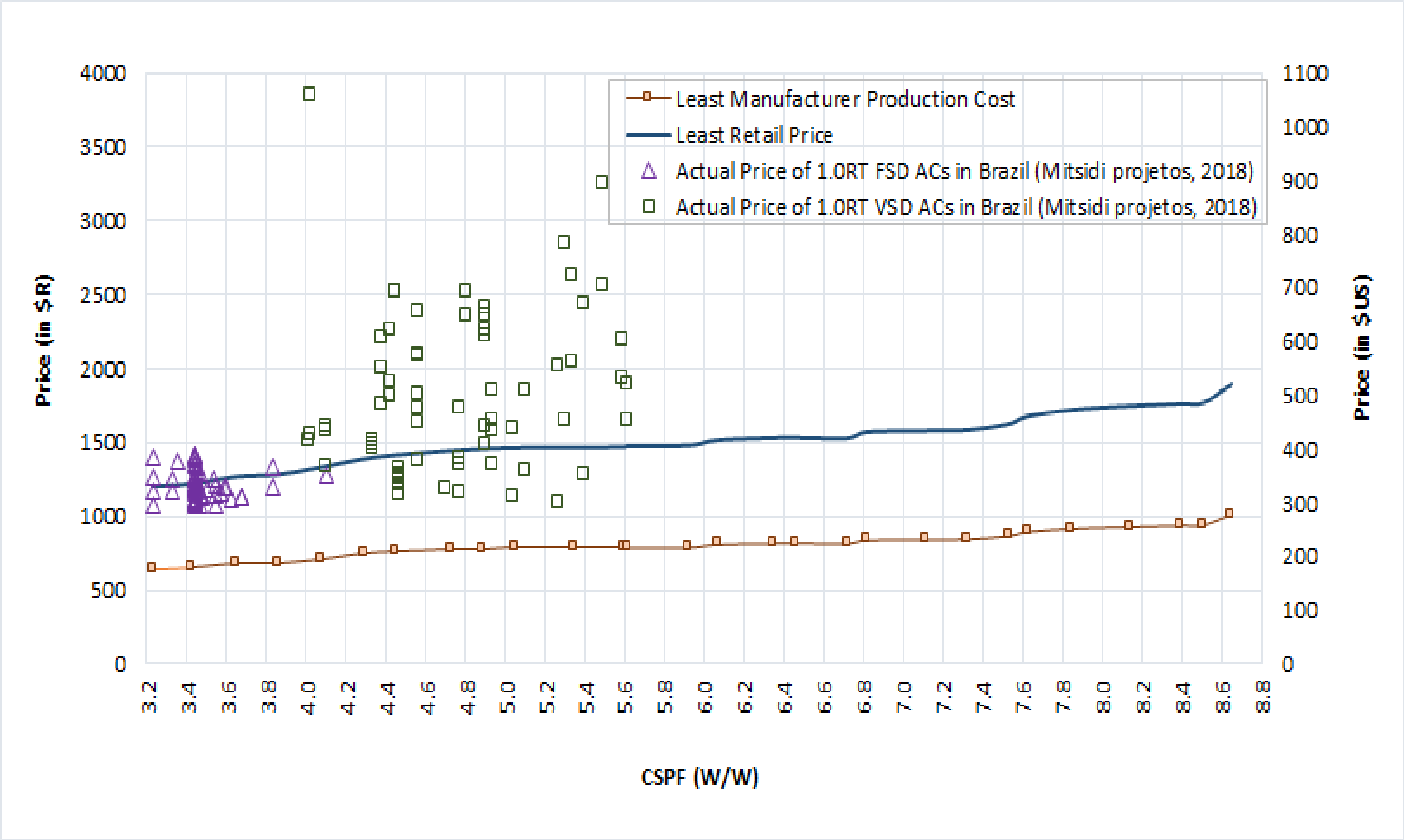
	Cost (R$)	Share (%)
Material cost	509	53%
Labor	76	
Depreciation and overhead	51	
Manufacturer markup	223	47%
Retailer markup	331	
TOTAL	1191	

Options to further improve efficiency of room ACs

	Component	Mfg Cost (BRL)	Incremental Mfg Cost (BRL)	Retail Price Increase from Base Case (BRL)	Energy Savings from Baseline
Baseline Compressor	2.8 EER Compressor	178			
Compressor 1	3.0 EER Compressor	186	8	14	5.5%
Compressor 2	3.2 EER Compressor	211	33	62	10.5%
Compressor 3	3.4 EER Compressor	240	62	115	15.0%
Compressor 4	3.6 EER Compressor	330	152	284	20.0%
Inv AC	Alternating Current Compressor with variable speed drive	265	87	163	23.5%
Inv DC	Direct Current Compressor variable speed drive +compressor	337	159	298	25.5%
All DC	Variable speed drives for fans and compressor	402	224	418	29.0%
Baseline Heat Exchanger (HE)	-	190			
HE 1	UA of both HEs increased by 20%	217	27	50	7.5%
HE 2	UA of both HEs increased by 40%	293	103	192	13.5%
HE 3	UA of both HEs increased by 60%	365	175	327	18.0%
HE 4	UA of both HEs increased by 80%	389	199	372	21.0%
HE 5	UA of both HEs increased by 100%	499	309	577	24.0%
Baseline Valve	-	0			
TXV	Thermostatic Expansion Valve	11	11	21	5.0%
EXV	Electronic Expansion Valve	19	19	35	9.0%

Note: *Manufacturing cost estimates listed, except compressor, are LBNL's current best estimates for a 1.0 RT mini-split room AC in Brazil. Compressor cost is based on Brazilian data.*

Cost-curve model:
1 RT mini-split Room ACs in Brazil



Note 1: *Manufacturing cost estimates listed, except compressor, are LBNL's current best estimates for a 1.0 RT mini-split room AC in Brazil.*
Note 2: *In the **Reference scenario**, we assume **30%** of the compressors in Brazil is from local manufacturers.*
Note 3: *All designs with VSD consider the 3% R&D investment mandated by Law*

Consumer Impact Analysis

Efficiency Level (EL)	Market-Weighted CSPF	Average Purchase Price	UEC	Average Electricity Bill	Average Life-Cycle Cost	Life-Cycle Cost Savings	Payback Period
	W/W	R$	kWh/year	R$	R$	R$	years
BAU	3.60	$1,258	469	$309	$3,411		
MEPS at CSPF = 3.43	3.64	$1,261	463	$306	$3,388	$23	0.7
MEPS at CSPF = 3.65	3.77	$1,289	447	$295	$3,342	$69	2.1
MEPS at CSPF = 5.34	5.36	$1,474	313	$206	$2,910	$501	2.1
MEPS at CSPF = 6.83	6.84	$1,578	243	$160	$2,692	$719	2.1
MEPS at CSPF = 8.65	8.65	$1,897	191	$126	$2,773	$637	3.5

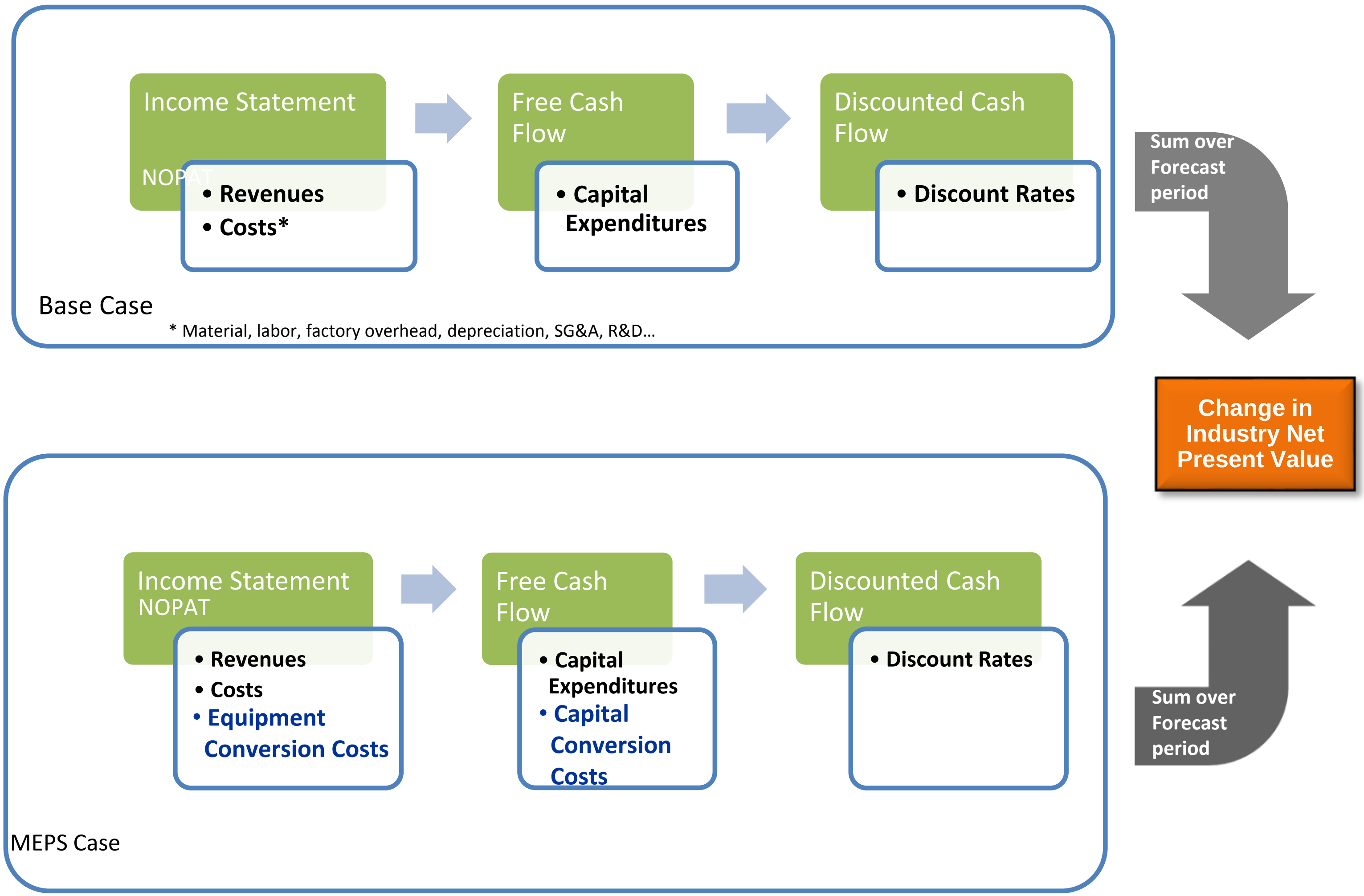
Life-cycle cost and payback-period calculations use an electricity rate of R$0.66/kWh, which is a weighted average between residential and commercial customers (ANEEL, 2018a; ANEEL, 2018b; Mitsidi Projetos, 2018). The life-cycle cost calculation uses a 10.5% discount rate and assumes a lifetime of 10 years based on stakeholder feedback.

Manufacturer Impact Analysis

Purpose:

- Evaluates the costs and benefits of transitioning to higher EE levels from the manufacturer perspective
- Determines what are the investments required to meet higher efficiency levels in terms of capital and equipment costs.
- Determines what are the impacts on manufacturer revenues.
- Determines what is the impact on manufacturers cash flow and net present value for the industry.

Manufacturer impacts analysis - Methodology



Equipment conversion costs represent the one-time investments in R&D, testing, certification, and marketing

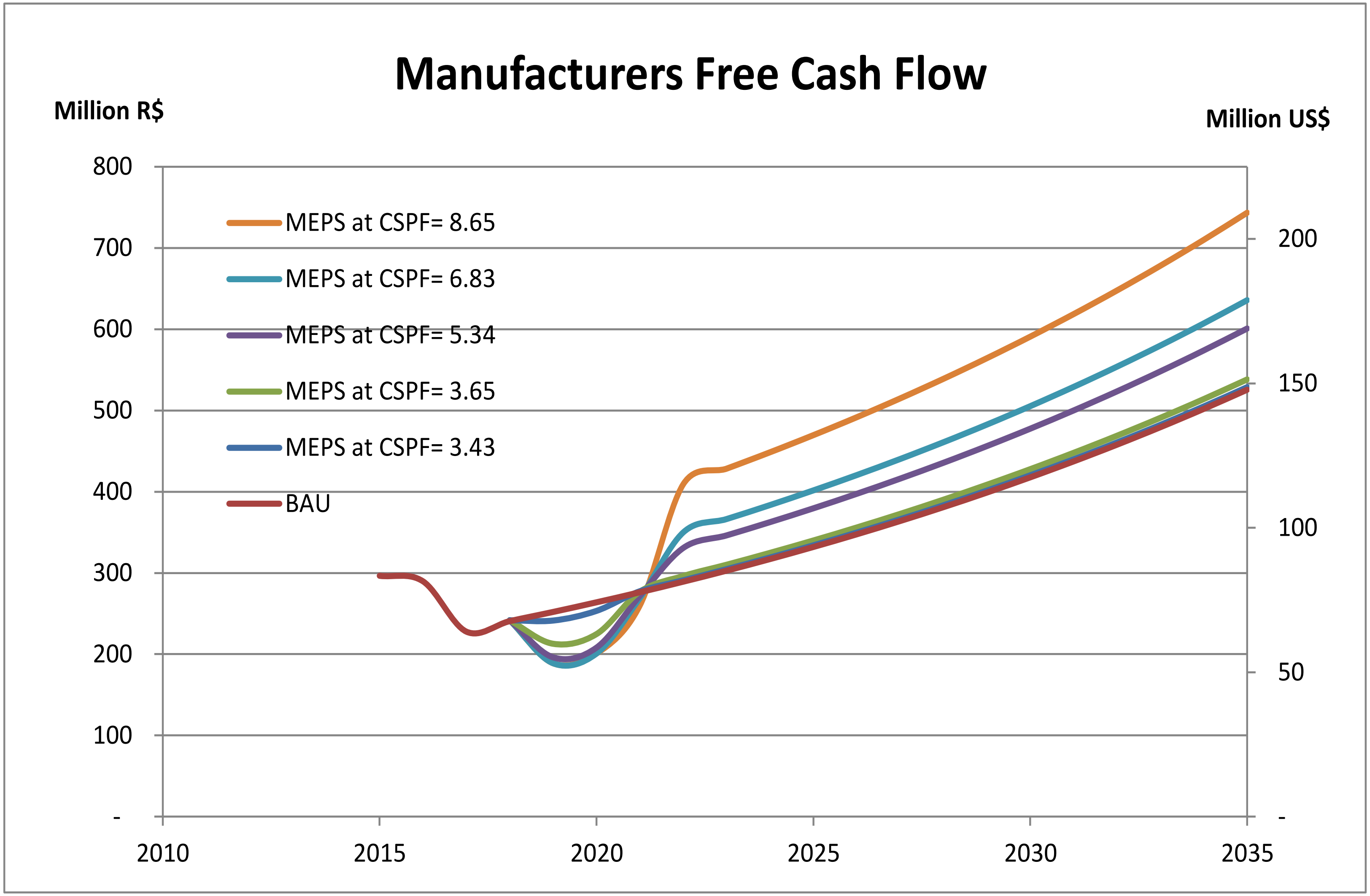
Capital conversion costs represent the one-time investments in PPE process resulting from MEPS

Source: based on the U.S. Department of Energy Appliance Standards Government Regulatory Impact Model (GRIM)

Summary of Inputs

Inputs	Description	Value	Source
Tax Rate	Corporate effective income tax paid (percentage of earning before taxes)	8.5%	tradingeconomics.com
Discount Rate	Weighted average cost of capital	10%	waccexpert.com
Working Capital	Current assets less current liabilities (percentage of revenues)	10%	USDOE (2016)
SG&A	Selling, general, and administrative expenses (percentage of revenues)	14%	USDOE (2016)
Research and Development	Research and development expenses (percentage of revenues)	1% 3% for VSDs	Stakeholder feedback
Capital Expenditures	Cash expenditure to acquire or improve capital assets (percentage of revenues)	2%	USDOE (2016)
Depreciation	Amortization of fixed assets (percentage of revenues)	2%	USDOE (2016)
Equipment Conversion Costs	One-time investments in research and development, testing, certification, and marketing	Constant at all ELs, scales with production capacity	LBNL estimates
Capital Conversion Costs	One-time investments in plant, property, and equipment process resulting from the MEPS		LBNL estimates
Stranded Assets	Assets replaced before the end of their useful lives as a direct result of the MEPS		LBNL estimates

Manufacturer Cash Flow



Industry Net Present Value

	MEPS at CSPF = 3.43	MEPS at CSPF = 3.65	MEPS at CSPF = 5.34	MEPS at CSPF = 6.83	MEPS at CSPF = 8.65
Product Conversion Cost (million R$)	7.7	26.6	43.7	45.7	45.7
Capital Conversion Cost (million R$)	16.3	56.2	73.9	86.6	86.6
Total Investment Required (million R$)	24.1	82.8	117.6	132.4	132.4
Change in INPV (million R$)	-18.3	-26.6	245.3	400.3	921.8

Note: Capital and Equipment Conversion Costs are LBNL current best estimates (being refined with manufacturers). They will need to be formally submitted by manufacturers in order to be eligible for financing programs

National impacts

At the national level, the technical potential for ACs (i.e., at MEPS of 8.65 CSPF) translates into the following benefits:

- Cumulative (2021–2035) consumer benefits of **R$27 billion** (based on future sales, AC prices, and operating cost savings, with a 6.5% discount rate)
- **16 TWh** in electricity savings annually by 2035, 132 TWh cumulative savings (2021–2035)
- **4.5 GW** of avoided demand in the power sector by 2035 (representing approximately R$30 billion)
- **60 million metric tons of avoided CO_2 emissions** (cumulative 2021–2035), considering a marginal carbon factor of 0.356 kg/kWh (MCTIC, 2018)

Overall, we find a cost/benefit ratio of 1:400 between each amount of money invested in industry (R$132 million) and national benefits in terms of avoided generation capacity and electricity savings (R$57 billion).

Conclusions and Policy recommendations

- A shift to inverter technology provides the maximum benefits to users, energy sector and manufacturers (win-win-win)
- Since the analysis was done, a revision of the efficiency metric is underway. This will allow:
  - Consumers to identify higher efficiency ACs that provide the maximum benefit
  - Encourage manufacturers to introduce more efficient ACs on the market
- Beside the MEPS, other programs can help move the market progressively:
  - Revision of the INMETRO label (underway)
  - Revision of the Procel label (end of 2019)
  - Bulk procurement, buyers club to drive down costs and encourage adoption of efficient technology by consumers
  - Grants and financing programs for manufacturers could be designed to encourage the required investments and unlock the benefits to consumers, the Brazilian energy sector, and the local AC manufacturing sector.

Thank you!

Contact: Vletschert@lbl.gov

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