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Advancing Industrial Sustainability Through Energy Efficiency Improvements in Motors and Motor-driven Systems

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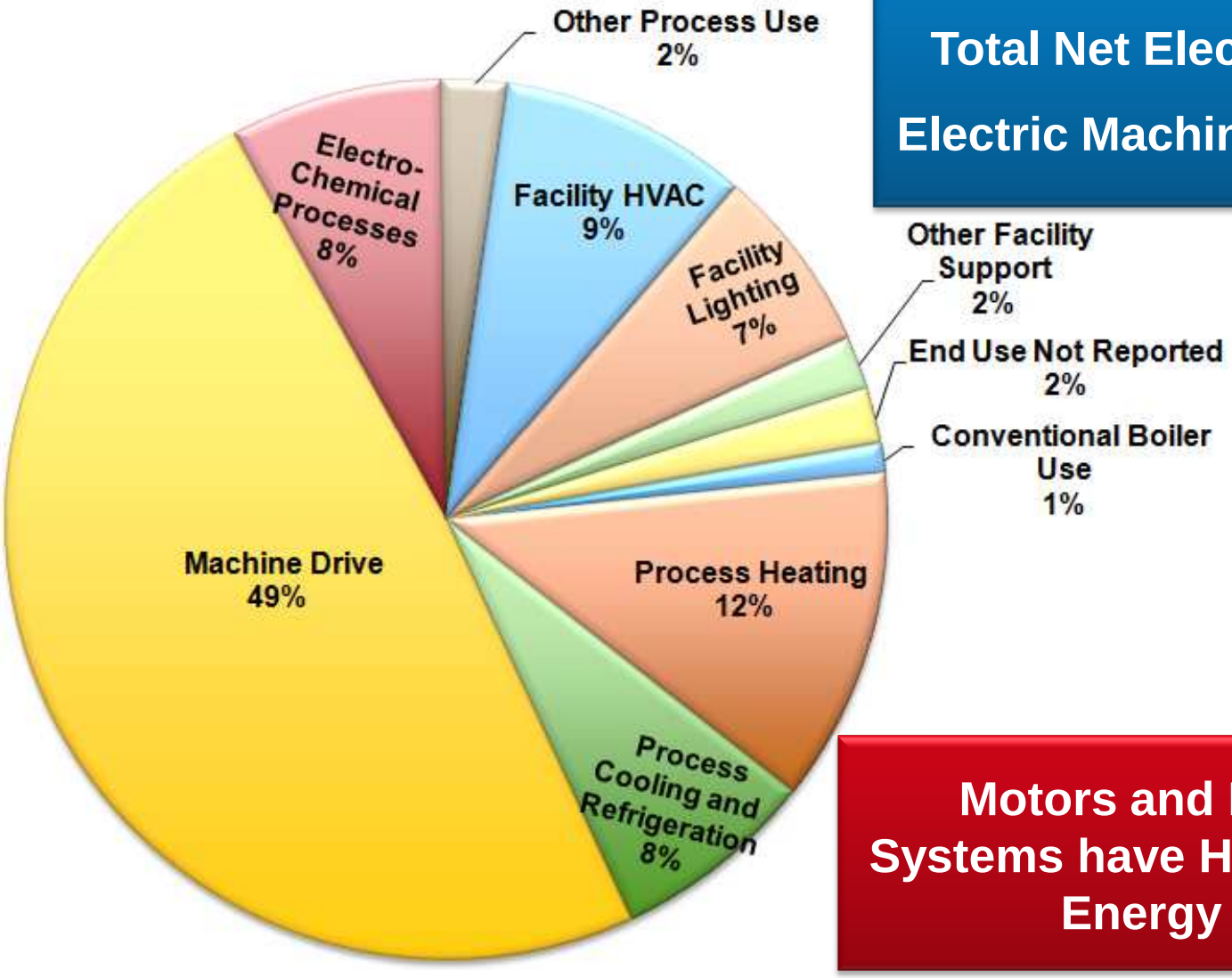
Outline

- Motors and Motor-driven System – Energy Use
- Industry Challenges
- Establishing a Motor Inventory
- Development of Motor Stock Turnover Model
- Applications of the Model
- Summary

Industrial Net Electricity Consumption



Total Net Electricity = 714 TWh

Electric Machine Drive = 347 TWh

Motors and Motor-driven Systems have Huge Potential for Energy Savings

Source: http://www.eia.gov/consumption/manufacturing/data/2010/pdf/Table5_1.pdf accessed on March 01, 2013

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Impact of Motor Legislations World-wide

[1]EPAct 1992 covered only general purpose motors in the 1-200 HP range
[2]European CEMEP was a voluntary standard with three efficiency classes EFF1-3; now replaced by IEC 60034-30
[3]EISA 2007 standards mandatory for new motors from December 2010. Expands standards to all general purpose motors upto 500HP as well as Type II motors
[4]IEC60034-30 mandates all motors in EU to meet IE3 by January 1, 2015
[5]Small motors are defined as 2-digit frames not part of EISA 2007. Standard will be mandatorily enforced from 2015
[6]EISA placeholder for IE4 and NEMA push to increase ASD penteration to increase energy savings

Government Legislations Push Motors to their Maximum Efficiency

What are the Industry Challenges ?

- Induction Motors are STILL the most common type of motors used in all sectors
- New motors (Permanent Magnet motors, BLDC etc) don't have high penetration
- Why?
- Reasons:
  1. Lack of Simple Energy Savings Potential Calculation Tools – DOE Motormaster+ is a good starting point but complex
  2. Lack of tools to quantify Deemed Energy Savings – market penetration and scenario analysis
  3. Reduced level of awareness – proper selection of a drive and motor – right sizing vs. over sizing - system level solutions

EPRI Motor Stock Turnover Model

1. Establish Market Size for Motors and Drives (M&D)
2. Development the Motor Stock Turnover Model
3. Validation of the Model
4. Deemed Energy Savings Calculations – Application of the Model

Industrial Motor Population & Applications

Motor Horsepower	28 Chem	26 Paper	33 Metals	29 Petrol.	20 Food	Other	*All SICs Percent*	*All SICs Number*
1–5	42.4%	52.2%	55.0%	32.0%	65.8%	63.9%	*58.8%*	*7,306,080*
6–20	30.0%	22.3%	26.1%	38.6%	22.6%	25.6%	*26.4%*	*3,288,035*
21–50	14.5%	13.0%	10.7%	18.9%	6.2%	7.2%	*9.1%*	*1,129,527*
51–100	5.9%	6.3%	3.5%	6.2%	2.4%	1.9%	*2.9%*	*363,940*
101–200	4.1%	3.1%	2.1%	2.8%	1.8%	1.2%	*1.8%*	*220,908*
201–500	2.2%	2.0%	1.7%	1.0%	0.9%	0.2%	*0.7%*	*86,836*
501–1000	0.6%	0.9%	0.7%	0.3%	0.4%	0.0%	*0.2%*	*28,047*
1000+	0.4%	0.3%	0.3%	0.2%	0.0%	0.0%	*0.1%*	*10,958*
All Sizes	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	*100.0%*	*12,434,330*

Major Industrial Applications of Motors & Drives

Pumps	**Material Handling**	**Material Processing**
Fans	**Compressed Air**	**Refrigeration**

Total Installed Base (Industrial) = 12 Million Motors

Source: United States Industrial Motor Systems Market Opportunities Assessment. U.S. DOE Motor Challenge. December 1998

NAICS = North American Industry Classification System | **SIC**: Standard Industrial Classification

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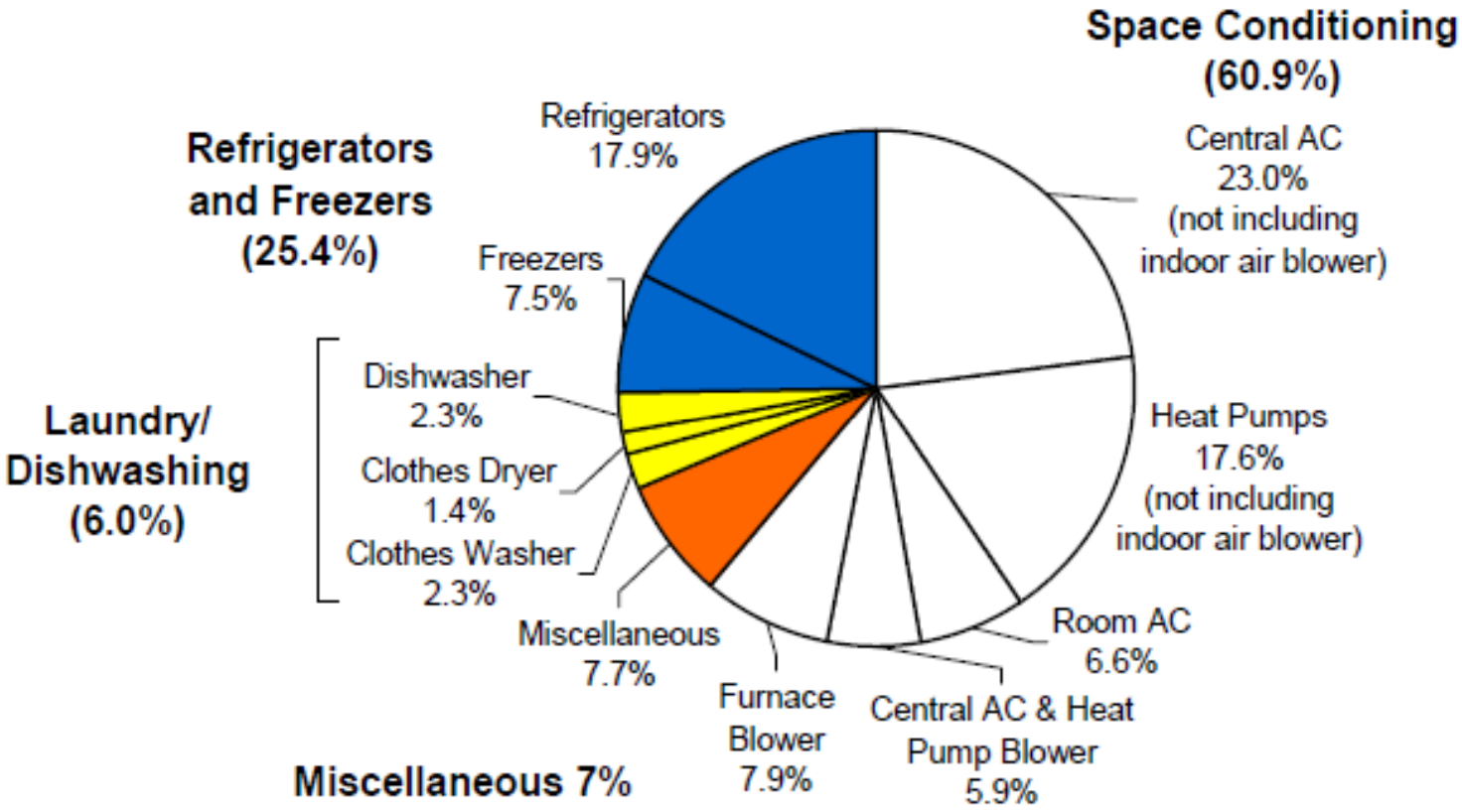
Residential Motor Population & Applications



Total Installed Base (Residential)= 864 Million Motors

Majority of them are Fractional hp Motors

Source: Opportunities for Energy Savings in the Residential and Commercial Sectors with High-Efficiency Electric Motors, U.S.DoE, December 1999

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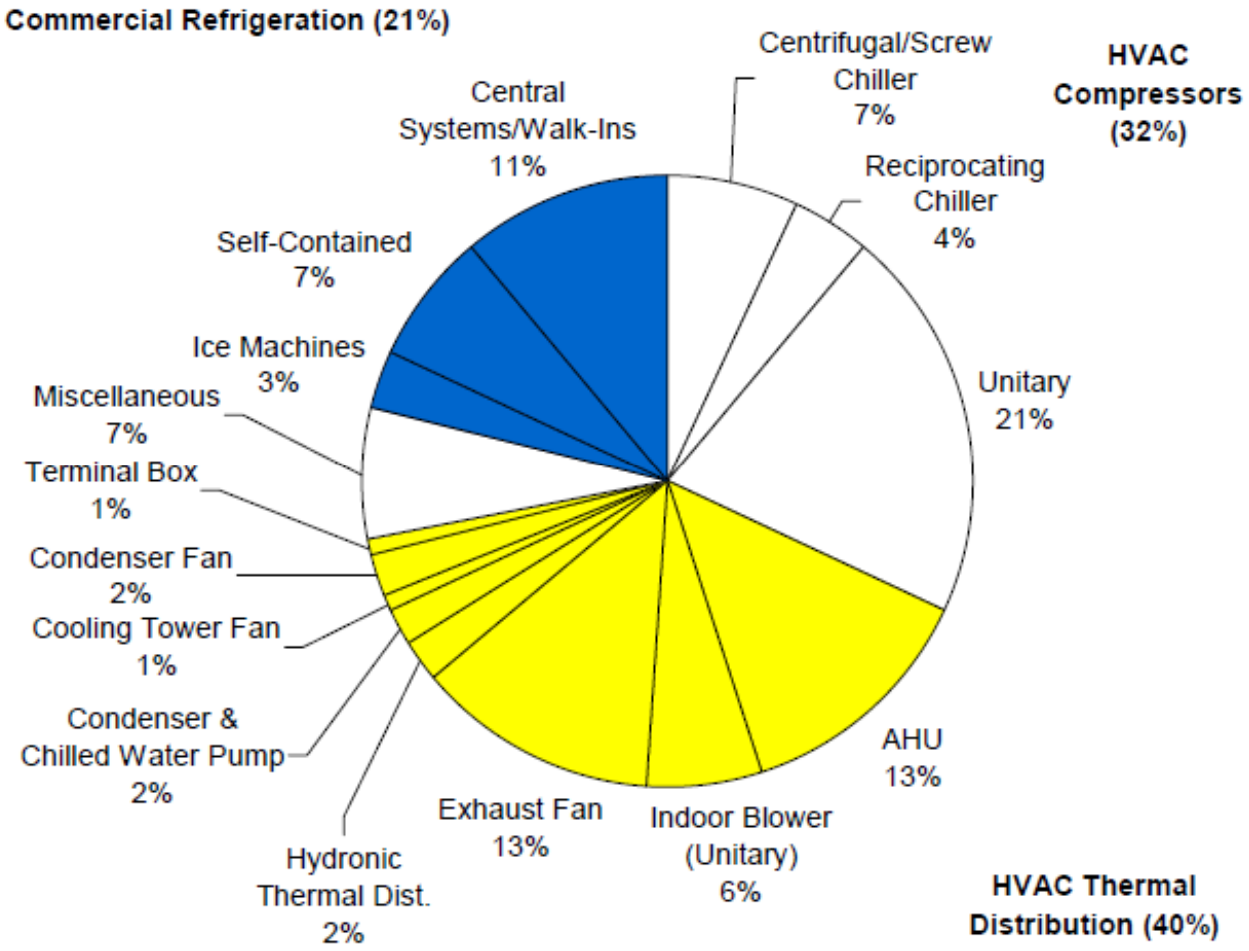
Commercial Motor Population & Applications



Total Installed Base (Commercial)= 123 Million Motors

Source: Opportunities for Energy Savings in the Residential and Commercial Sectors with High-Efficiency Electric Motors, U.S.DoE, December 1999

Total Motor Population Residential, Commercial and Industrial Sectors

Disribution of Motor Population by Sector							
Year:1994							
Industrial Sector			Commercial Sector			Residential Sector	
Distribution of Motor Population by Horsepower (hp)							
Motor Horsepower	Motor Population in all SICs (millions of units)		Motor Horsepower	Motor Population in all applications (millions of units)		Motor Horsepower	Motor Population in all applications (millions of units)
1–5	7.31		< 1/10	22.90		< 1/10	220.00
6–20	3.29		1/10- 1/4	24.10		1/10- 1/4	262.50
21–50	1.13		1/4 -1/2	39.10		1/4 -1/2	159.50
51–100	0.36		1/2 -1.0	2.55		1/2 -1.0	144.00
101–200	0.22		1 - 2	15.50		1 - 2	31.00
201–500	0.09		2 - 5	11.70		2 - 5	47.00
501–1000	0.03		5 - 10	1.90			
1000 plus	0.01		10-25	4.60			
			25-50	0.32			
			50-100	0.12			
			100-250	0.02			
			250-500	0.09			
Total: All Sizes	**12.43**		**Total: All Sizes**	**122.90**		**Total: All Sizes**	**864.00**

Total Installed Capacity of Motors in Various Sectors - Summary

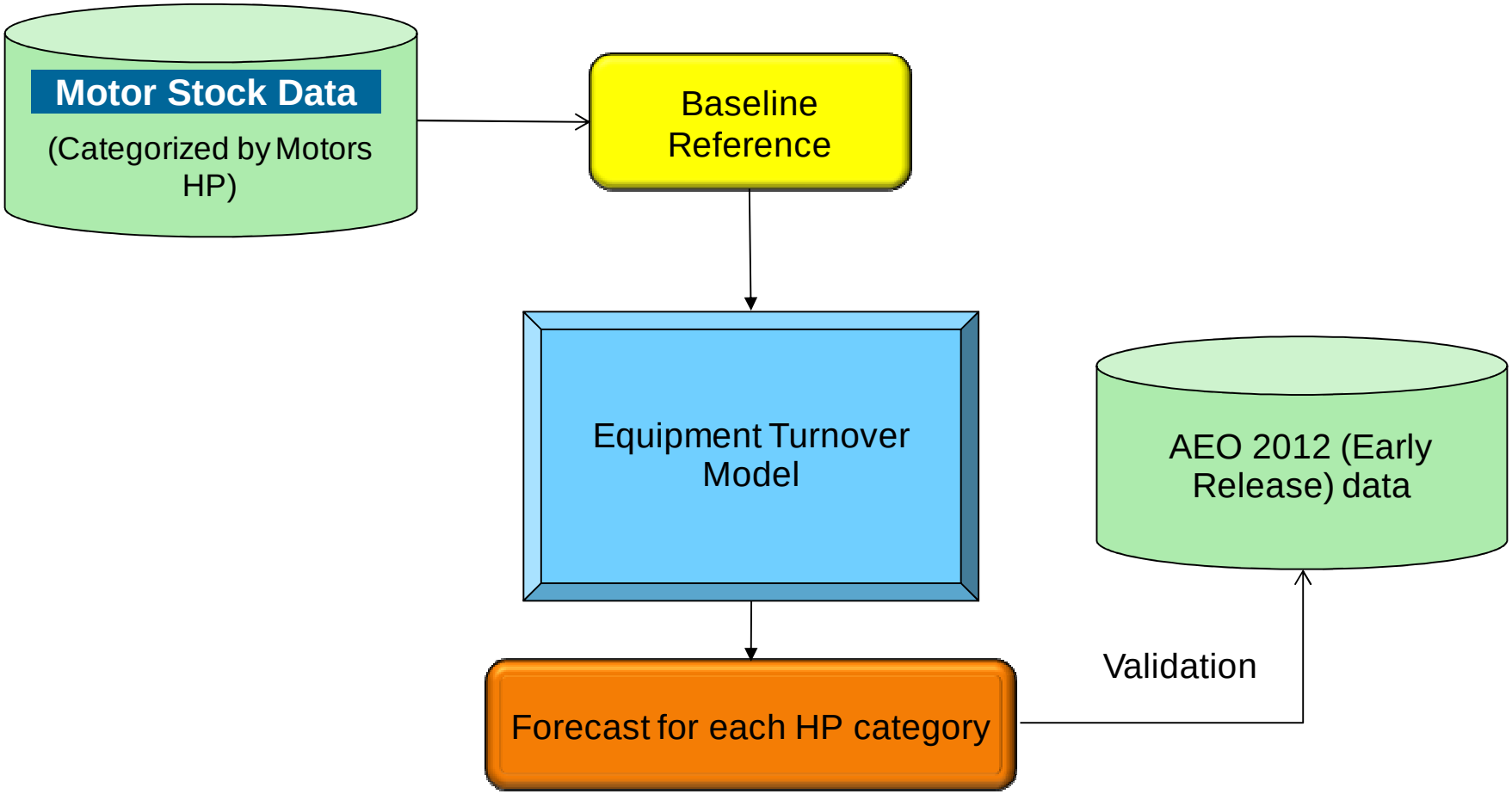
- Residential Sector: 864 million motors
- Commercial Sector: 123 million motors
- Industrial Sector: 12 million motors

- Total motor population = **~ 1 Billion** (does not account for transportation and agriculture sector)
  - Total Fractional hp Motors = ~875 million
  - Total Integral hp Motors = 125 million

Data Source: DOE MECS 1994 survey, Residential and Commercial Motor report by DOE, 1995

Development of Motor Stock Turnover Model

General Methodology



Assumptions/ Challenges

- 0% repair for Residential and Commercial motor applications
- Stock data available only from 1994
- Unavailability of Shipment / Sales data – required granularity missing – eg: units sold in various hp range
- Validation based on certain industry-wide accepted assumptions:
  - E.g. Industrial motor electricity usage is 50-60% of total industrial electricity usage
- No definitive way to correlate motor electricity use in residential and commercial sectors
- Sales data of residential appliances used for residential motor sales because motors are integrated in the white-good appliances

Assumptions/ Challenges (Contd…)

Industrial Data

- Stock data available in 1994 and shipment data from 2001-03
- Sales data (2001,2002,2003) has great linear fit (R2>.96-1)
  - Assumption: Sales data is extrapolated back to 1994.
  - (Sales has an increasing in these years although the rate of increase slows in latter half)
  - Zero sales in converted to constant
- Repair rate - available data from EASA (Electrical Apparatus Service Association)

Modeling

- Categorized into age bins (for UEC and quantity)
  - **>20 years**
  - **10-19 years**
  - **5-9 years**
  - **2-4 years**
  - **New**

- UEC stands for Unit Energy Consumption

Stock Turnover for each HP Category

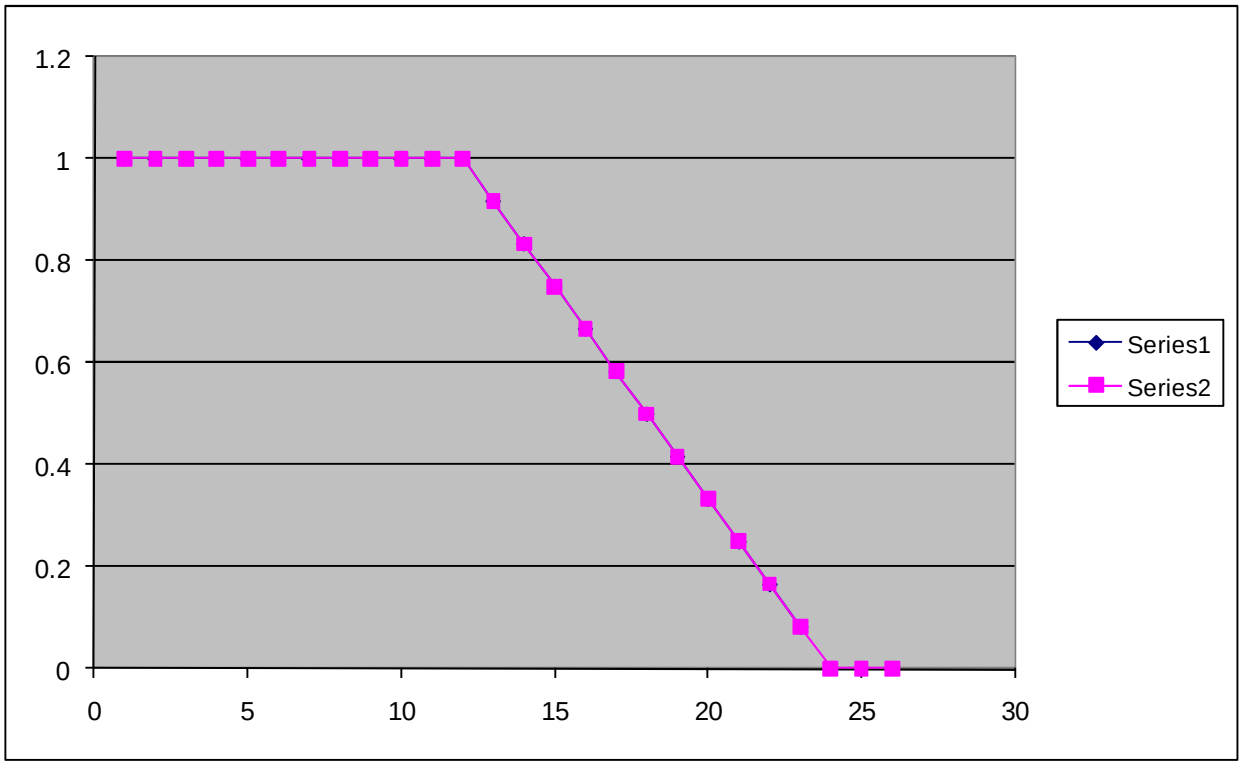
- First year: Motor Stock divided according to age bin in reference

	UECs (kWh)					Age Distribution (%)				
End Use Sheet Labels	>20	10-19	5-9	2-4	New	>20	10-19	5-9	2-4	New
HP1_5	3806	3806	3806	3806	3806	5.00%	25.00%	40.00%	25.00%	5.00%
HP6_20	18285	18285	18285	18285	18285	5.00%	25.00%	40.00%	25.00%	5.00%
HP21_50	64727	64727	64727	64727	64727	5.00%	25.00%	40.00%	25.00%	5.00%
HP51_100	200374	200374	200374	200374	200374	5.00%	25.00%	40.00%	25.00%	5.00%
HP101_200	376170	376170	376170	376170	376170	5.00%	25.00%	40.00%	25.00%	5.00%
HP201_500	1045868	1045868	1045868	1045868	1045868	5.00%	25.00%	40.00%	25.00%	5.00%
HP501_1000	2753877	2753877	2753877	2753877	2753877	5.00%	25.00%	40.00%	25.00%	5.00%
HP1000Plus	8241194	8241194	8241194	8241194	8241194	5.00%	25.00%	40.00%	25.00%	5.00%

- Stocks: combination of Starting stock+ Sales (extrapolated)
- Repaired Stocks: % of Total stock

Retirement Function

- X-axis represents – age of motor in years
- Y-axis represents – survival ratio
- Lifetime of motor = 25 years (assumption)



Validation of the Model

	Slope	Intercept	R^2
HP1_5	22000	-4.4E+07	0.987829
HP6_20	19000	-3.8E+07	0.988654
HP21_50	9000	-1.8E+07	0.997949
HP51_100	4000	-7993333	0.960769
HP101_200	1000	-1995000	1
HP201_500	1000	-2000000	1
HP501_1000	0	0	0
HP1000Plus	0	0	0

Curve Fitting Parameters

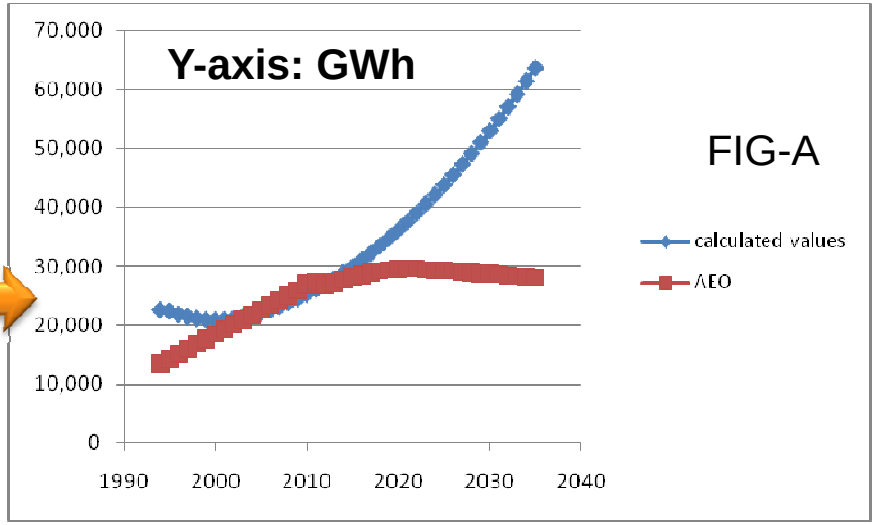


FIG-A

- Using the available data for industrial sector, a non-linear model to predict energy as well as stock was developed
- Validation against existing AEO data suggests increasing error (Fig-A)
  - AEO reduces energy usage based on assumption that better technology are used in future
- Adjusted the model to align with AEO
  - Less than **5%** error margin (Fig-B)

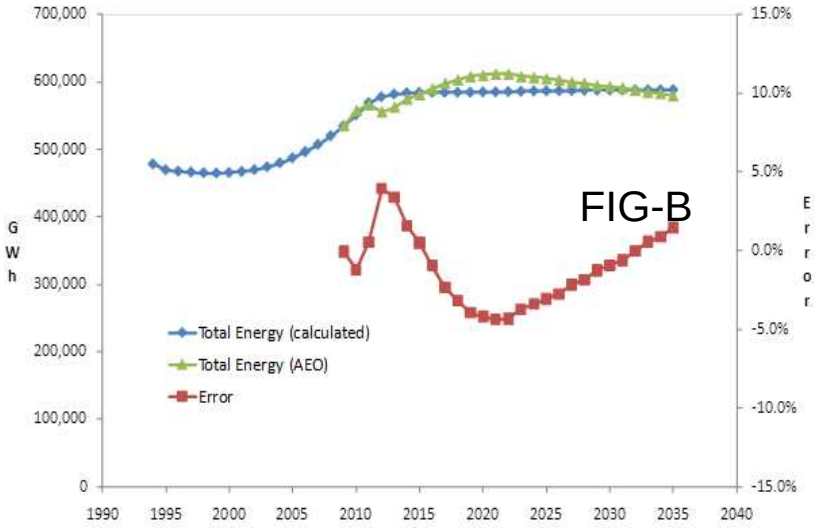
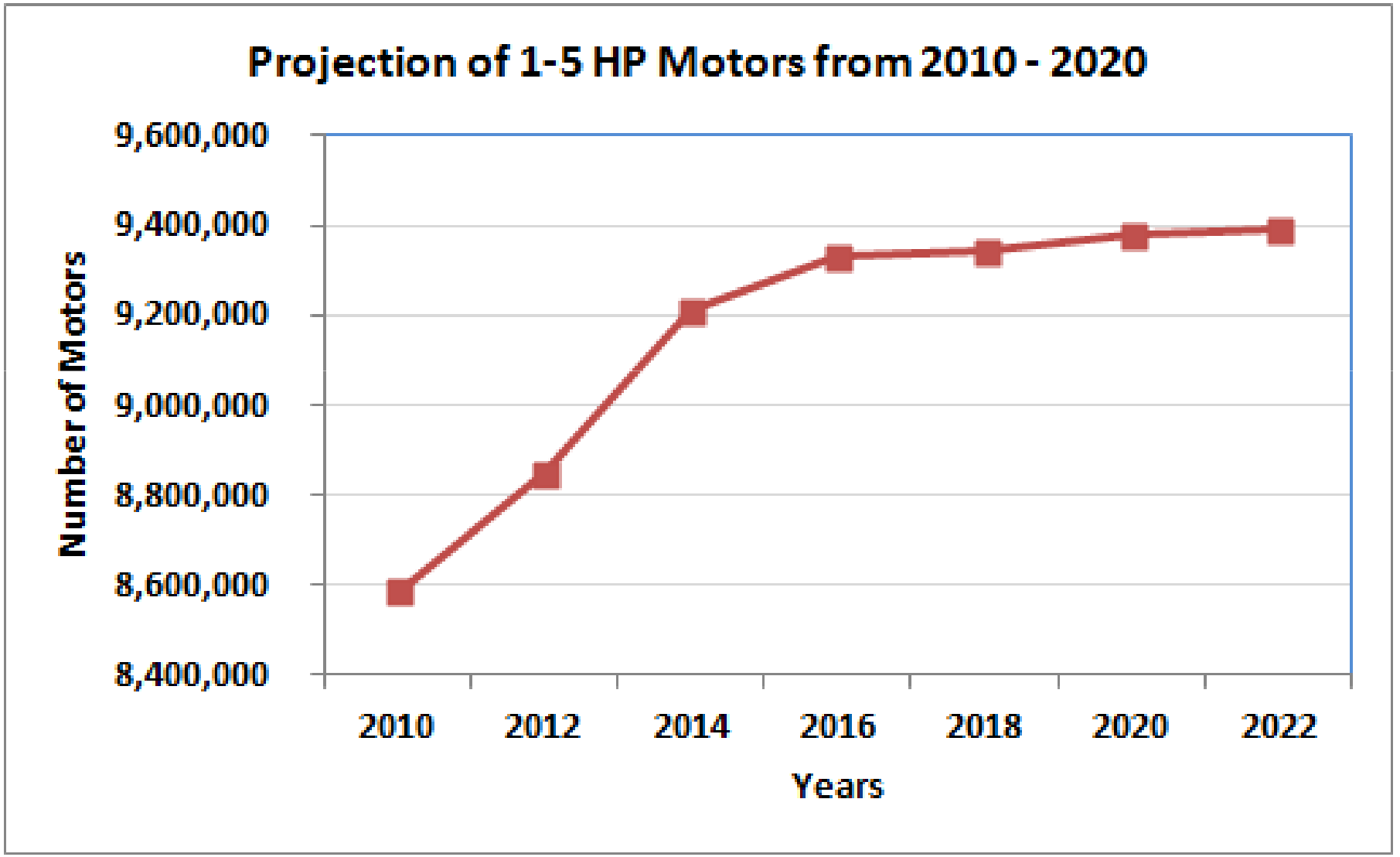


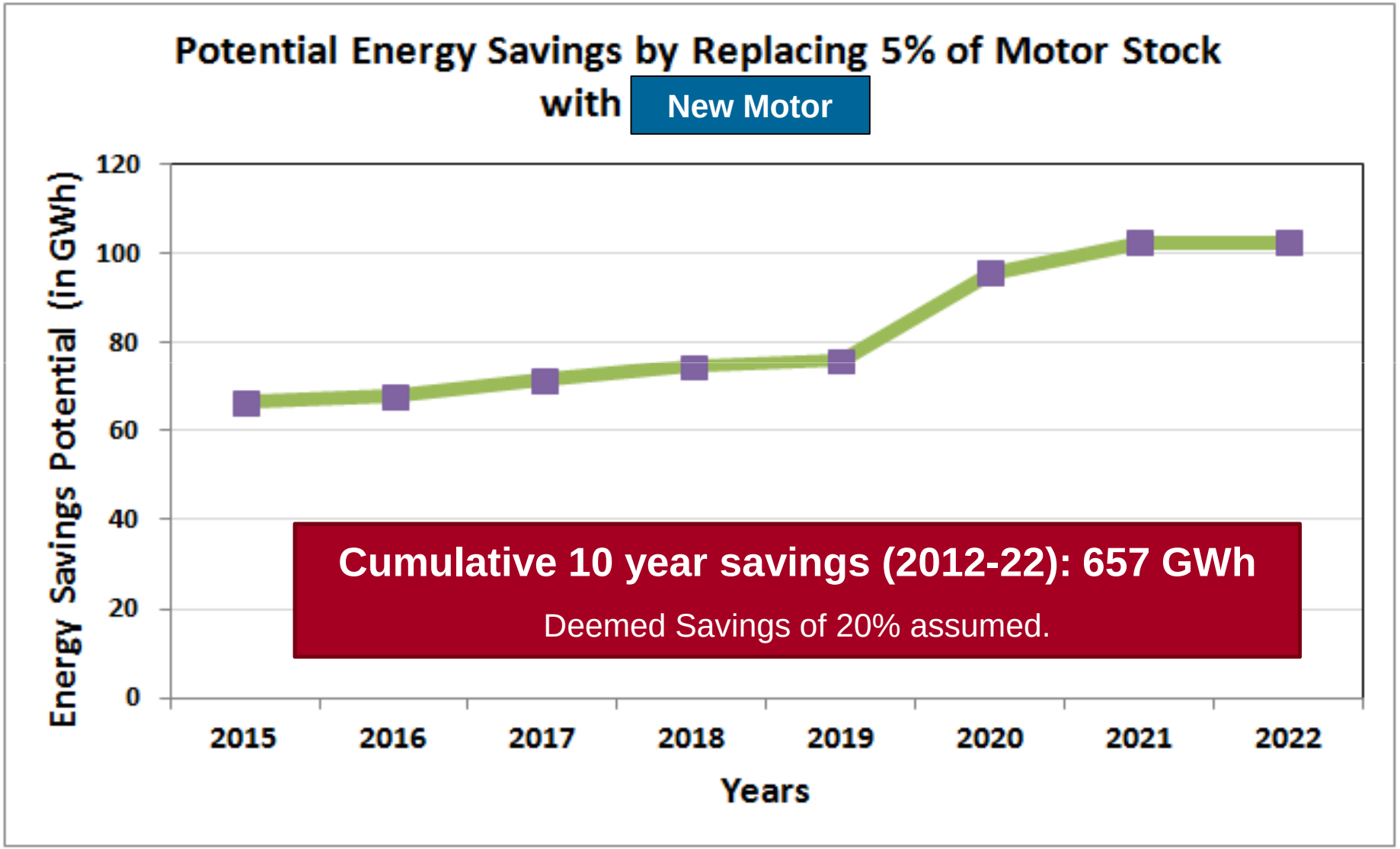
FIG-B

AEO – Annual Energy Outlook

Model Output – Market Projections



Model Output: Deemed Savings Projections for a New Motor



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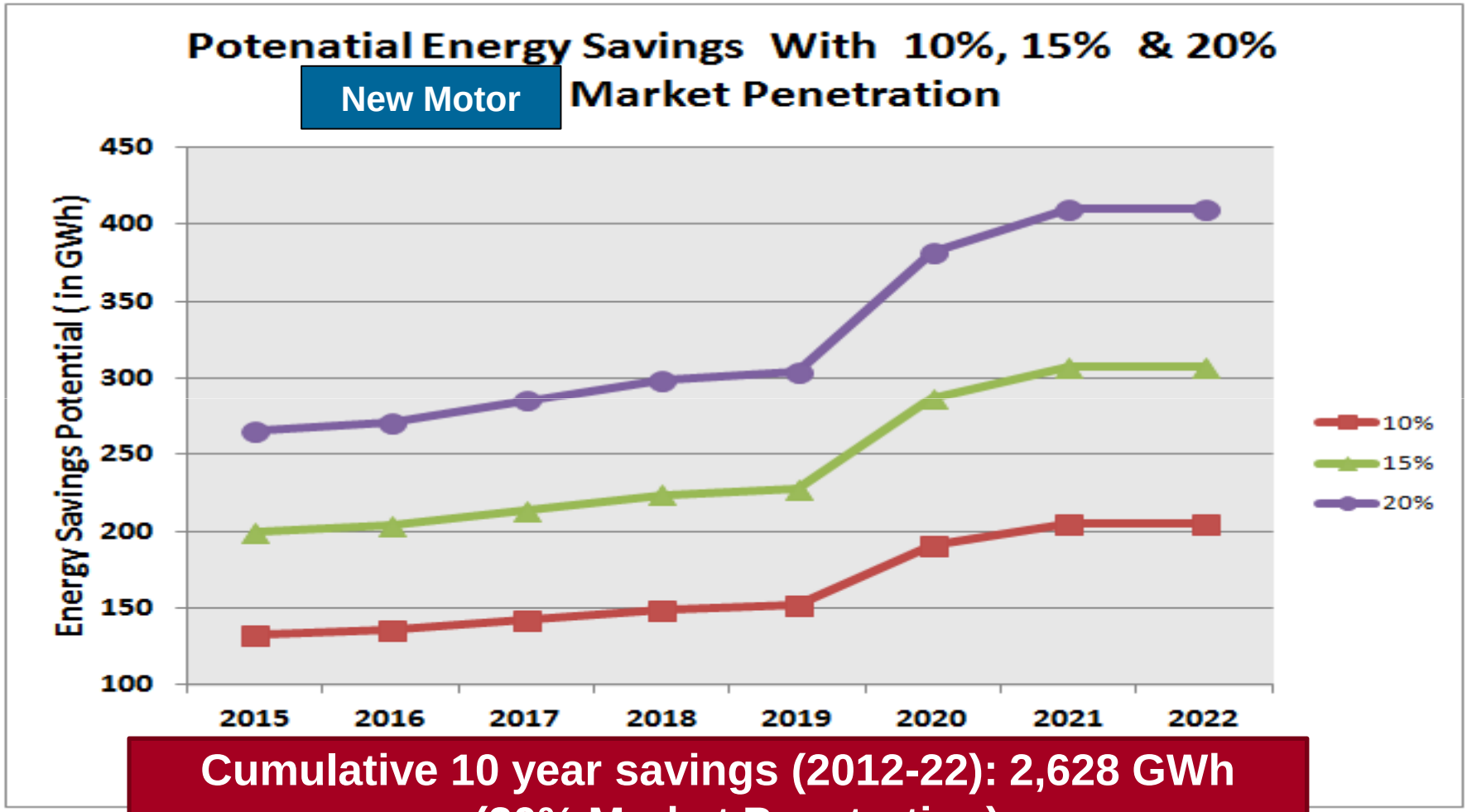
Model Output: Scenario Analysis



Cumulative 10 year savings (2012-22): 2,628 GWh (20% Market Penetration)

Deemed Savings of 20% assumed.

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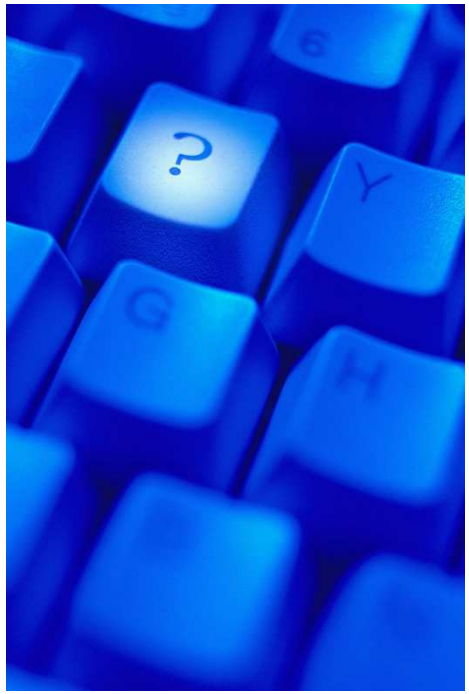
Residential and Commercial Sector

- Similar approach was pursued for the residential and commercial sectors.
- Different applications were organized by HP, and average UEC was calculated.
- 0% repair of motor was assumed in case of residential and commercial.
- Currently data for validation is being scouted – no availability of energy related data for validation of model

Summary

- Motor stock data – gathered from DOE and other sources
- Motor stock turnover model– comprehensive one stop place for all motor data related to Residential, Commercial and Industrial - available – can be extrapolated to 2030 and beyond
  - Industrial sector – data verified and validated against AEO
  - Residential and Commercial – Not validated but data can be tweaked if we get better sales or energy data
- Applications – Matrix of applications that match new motor characteristics:
  - available for residential, commercial and industrial
  - Energy savings potential can be calculated
  - Model put to use for a new motor type (R&D)
  - Model can be customized for an Industrial Facility

Questions



Contact Information:

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Thank You for Your Attention!!

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