Energy Technologies Area Lawrence Berkeley National Laboratory

BUENAS Methodology

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Bottom-up Energy Analysis System (BUENAS)

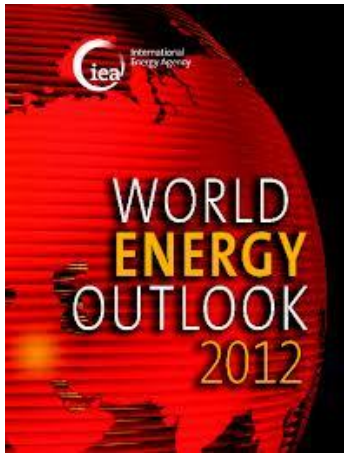
Engineering-based Bottom-up Model

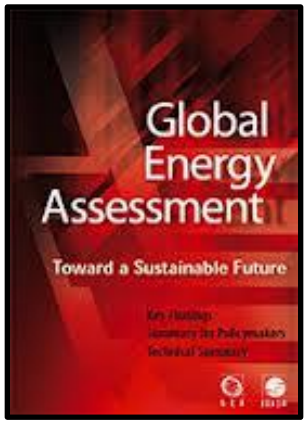
- Thorough representation of technology penetration
- Descriptions of technologic aspects of the energy system and how it can develop in the future
- Energy demand focused model
- Data intensive approach
  - Covers 15 building and industrial appliances and equipment ~200 equipment / country combinations
- Facilitates policy roadmapping – Many energy efficiency policies act at the end use level.

Sector	End Use Category	Appliance
Residential	Air Conditioning	Air Conditioner
		Central AC
	Cooking + Dishwashing	Cooking Products
	Fans	Fan
	Laundry	Clothes Dryers
		Washing Machine
	Lighting	Lighting
	Refrigerators & Freezers	Freezers
		Refrigerator
	Space Heating	Boiler
		Furnace
		Space Heating
	Standby	Standby
	Television	Television
	Water Heating	Water Heater
Commercial	Air Conditioning	Commercial AC
	Lighting	Lighting
	Refrigeration	Refrigeration
	Space Heating	Space Heating
Industry	Distribution Transformers	Distribution Transformers
	Motors	Motor

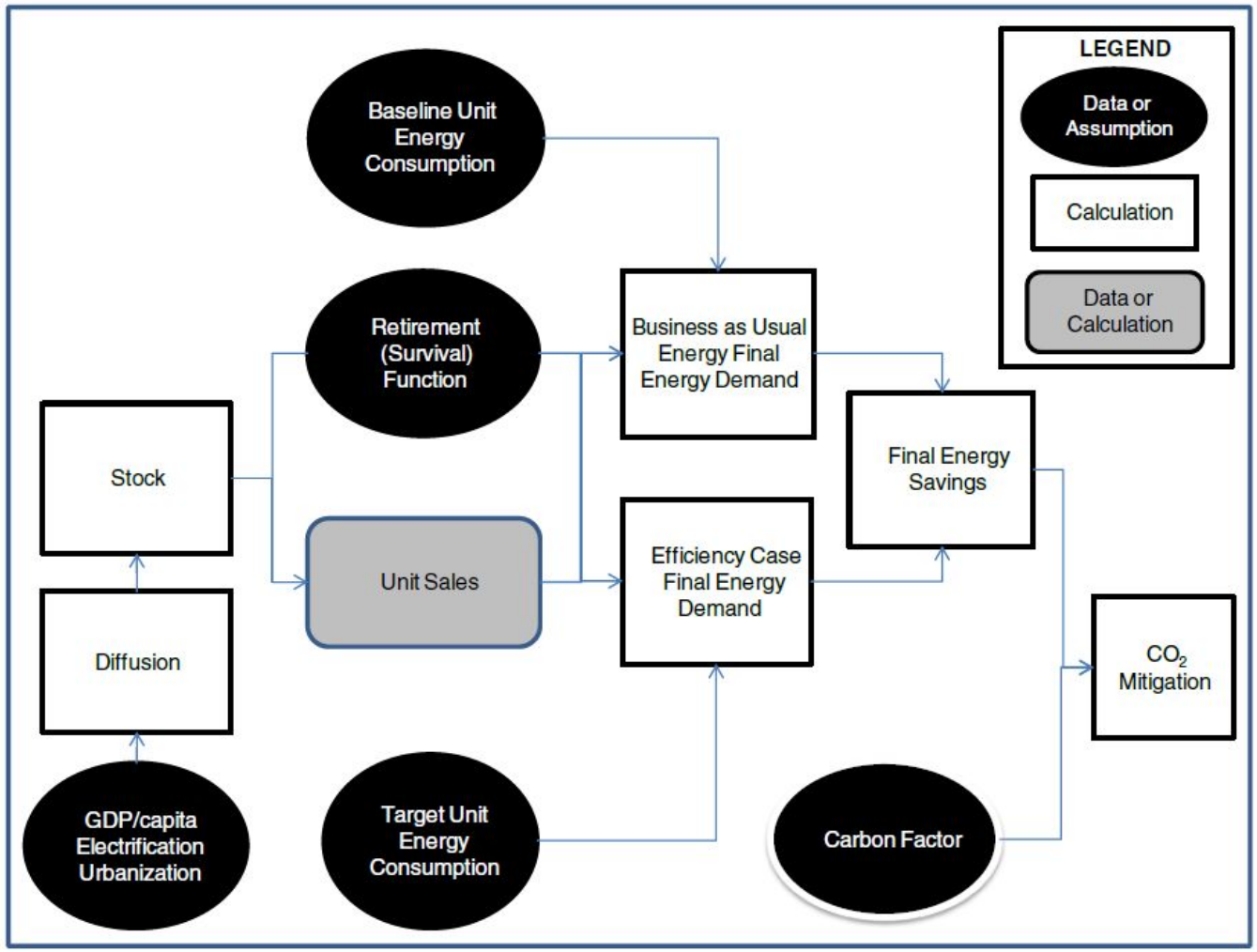
BUENAS Collaborations

- SEAD initiative
  - BUENAS is the analytical framework supporting activities of the Clean Energy Ministerial (CEM) Super Efficient Appliance Deployment (SEAD) Initiative
- Global Energy Assessment
  - BUENAS provided input of appliance energy demand forecast for global model coordinated by International Institute for Applied Systems Analysis (IIASA) in 2011Assessment, IPCC 5th Assessment
- International Energy Agency – World Energy Outlook
  - BUENAS provided percent energy savings results for WEO 2012 Efficient World Scenario





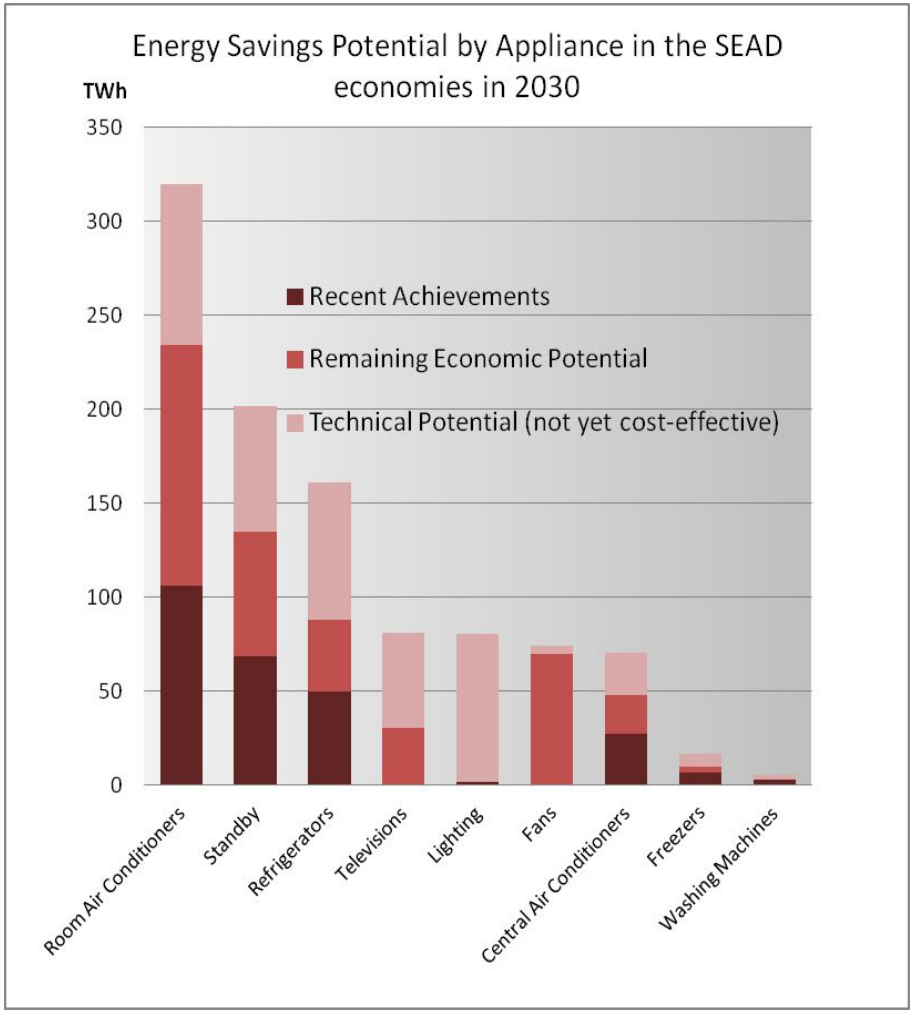
BUENAS Methodology



BUENAS Overview

Policy Scenarios

- Recent Achievements – calculates the impact of recently implemented MEPS and labels
- Cost-Effective Potential – Integrates BUENAS and Global Energy Efficiency Cost (GEEC) Database developed at LBNL to model *economic potential*
- Best-Available Technology – Most Aggressive scenario represents *technical potential*



Source: Letschert et al. 2013
Includes Australia, Brazil, Canada, China, EU, India, Indonesia, Japan, Korea, Mexico, Russia, South Africa, USA

Set Targets, Develop Policies and Establish Impact Assessment Frameworks for Lighting, Appliances and Equipment

METHODOLOGY

Residential Sector

- Technology Penetration – Equipment Ownership per Household
  - Modeled using external sales and stock forecasts when available
  - Modeled econometrically from Income, Urbanization, Electrification and climate variable when data is not available.
- Unit Energy Consumption – UEC per equipment
  - Varies according to performance and capacity (size)
  - Depends on hours of use
  - Business As Usual (BAU) represent the average UEC today
  - Scenarios created with the introduction of more efficient UEC
- Stock Accounting- MEPS Impacts
  - Sales determined by increase in households ownership rates and replacements.
  - Combined with marginal intensity to give stock energy.

Econometric Modeling for Appliance Ownership

- Ownership per HH of Ref, WM, AC, TV, Fans, and lighting bulbs

Logistic Function:

$$Diff_c = \frac{\alpha}{1 + \gamma \exp\left(\beta_{inc} I_c + \beta_{elec} E_c + \beta_{Spe} SPE_c\right)}$$

maximum diffusion

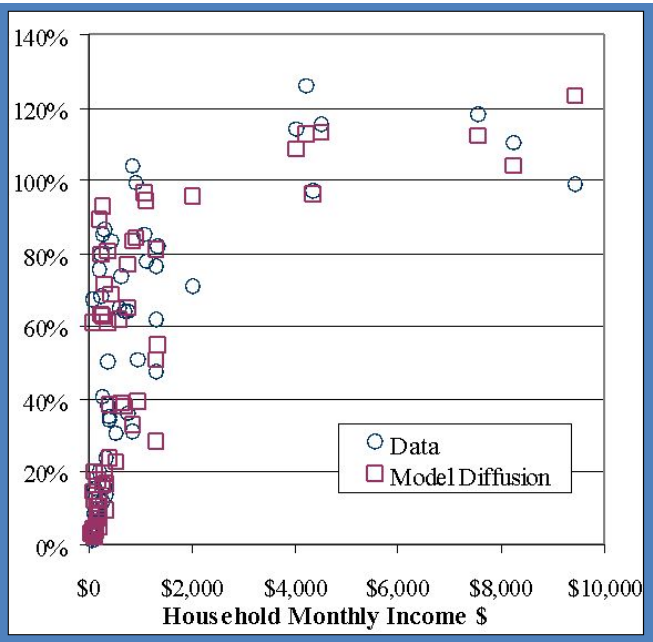
diffusion of the appliance for the country *c*

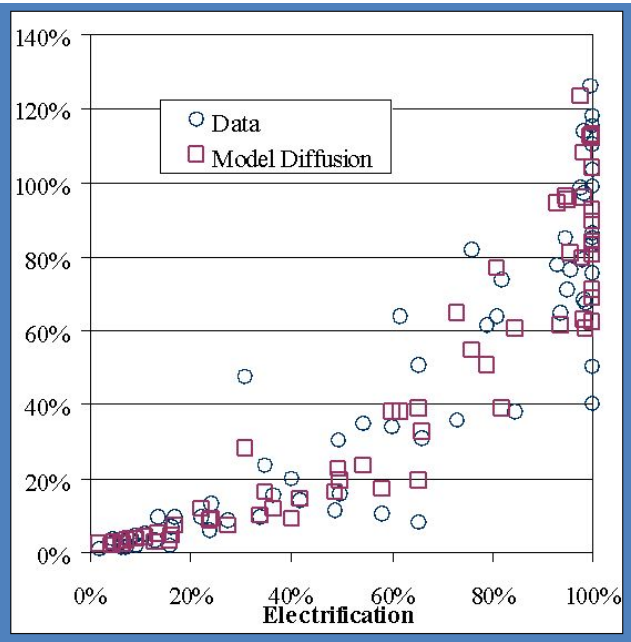
monthly household income

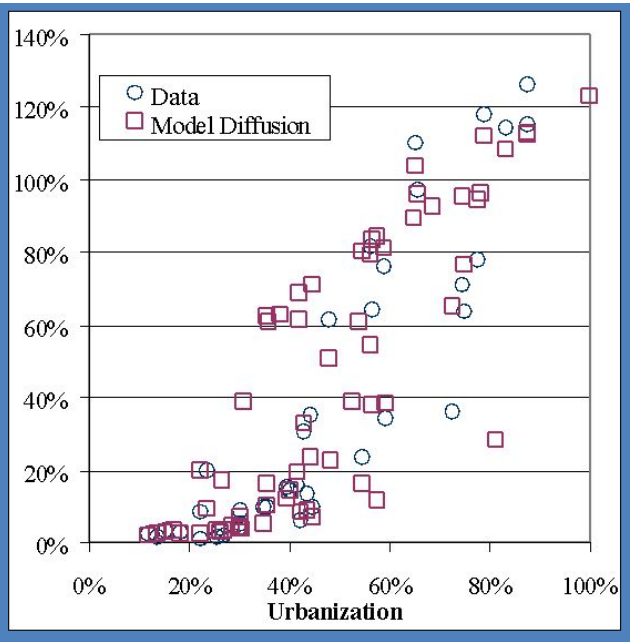
electrification rate

Appliance-specific variable

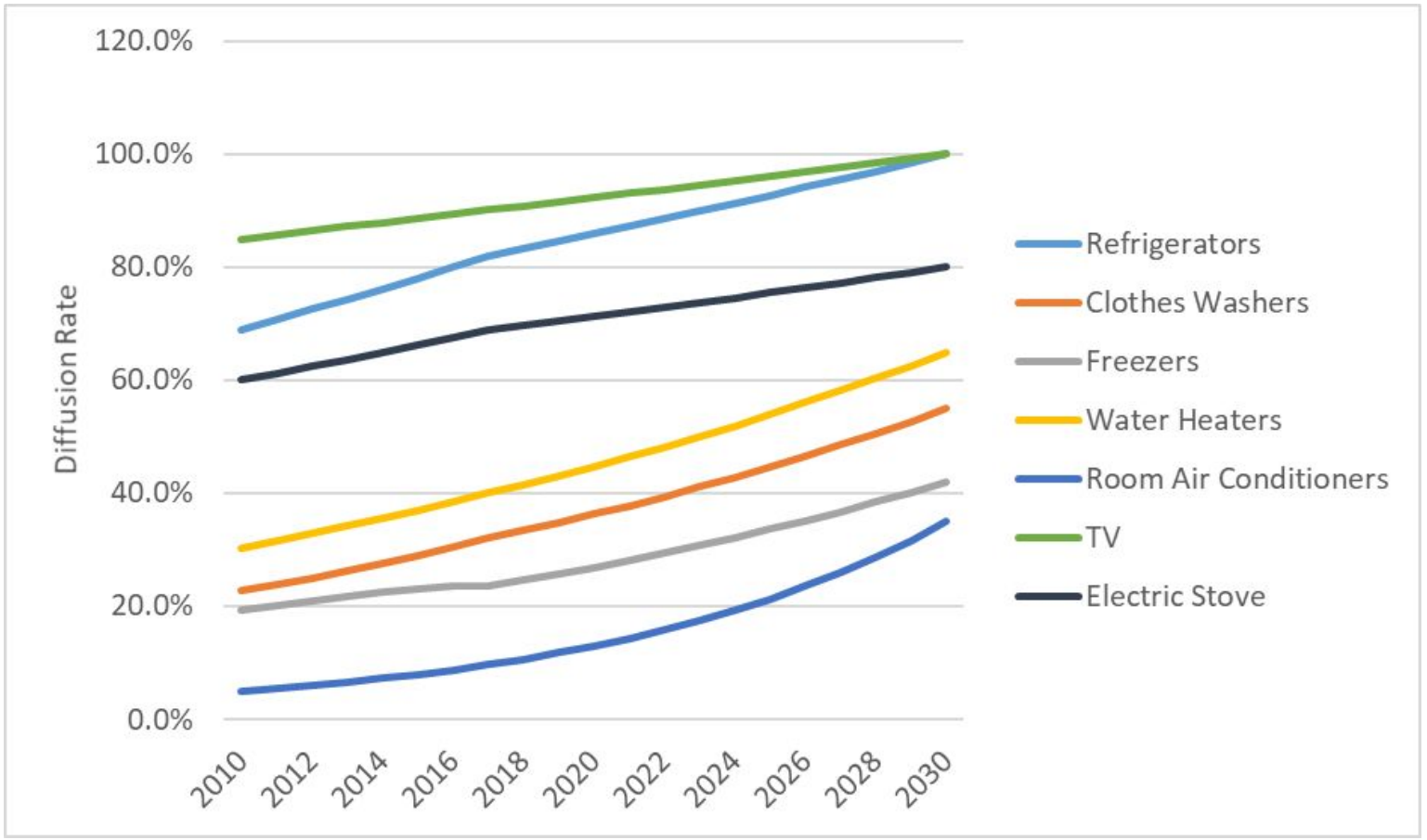
Refrigerator Model



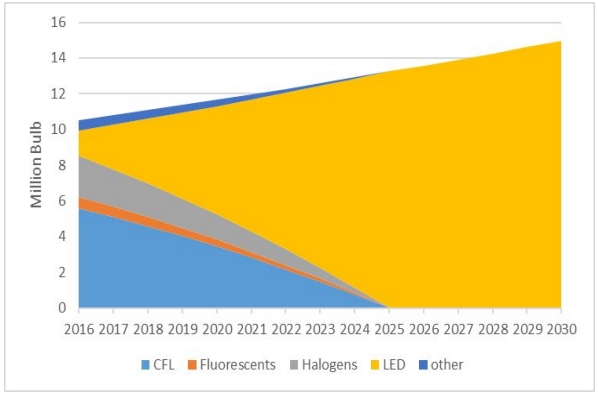


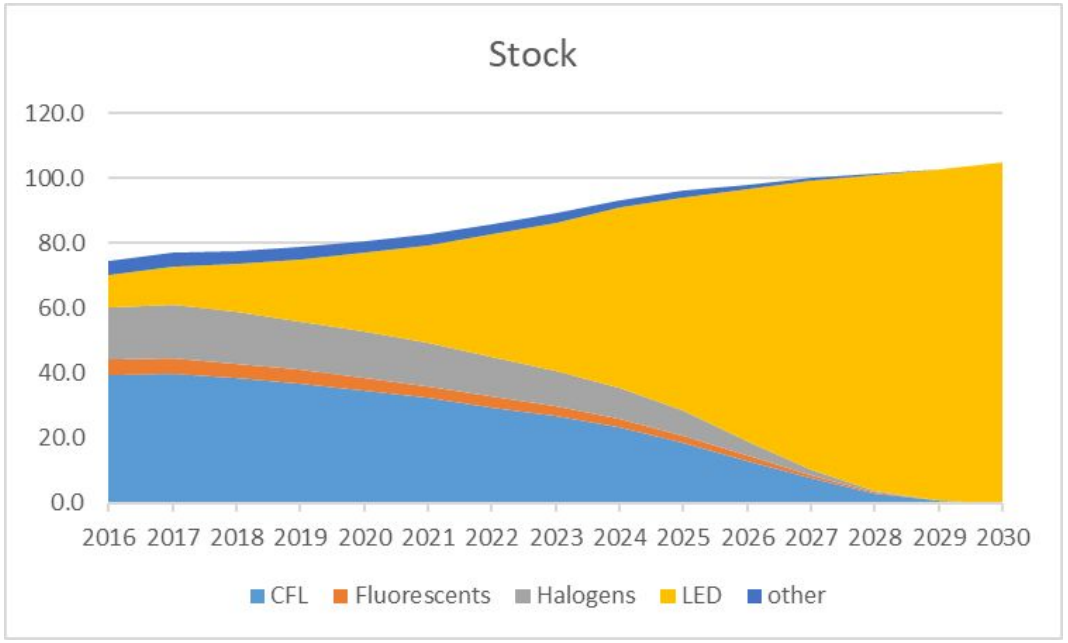


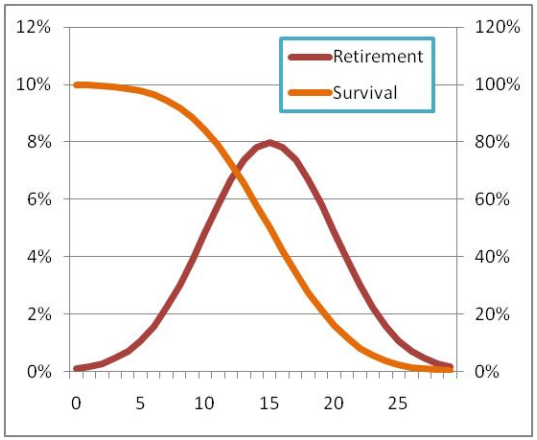
Activity Results for South Africa: Appliances



Stock Accounting Results for South Africa: Lighting







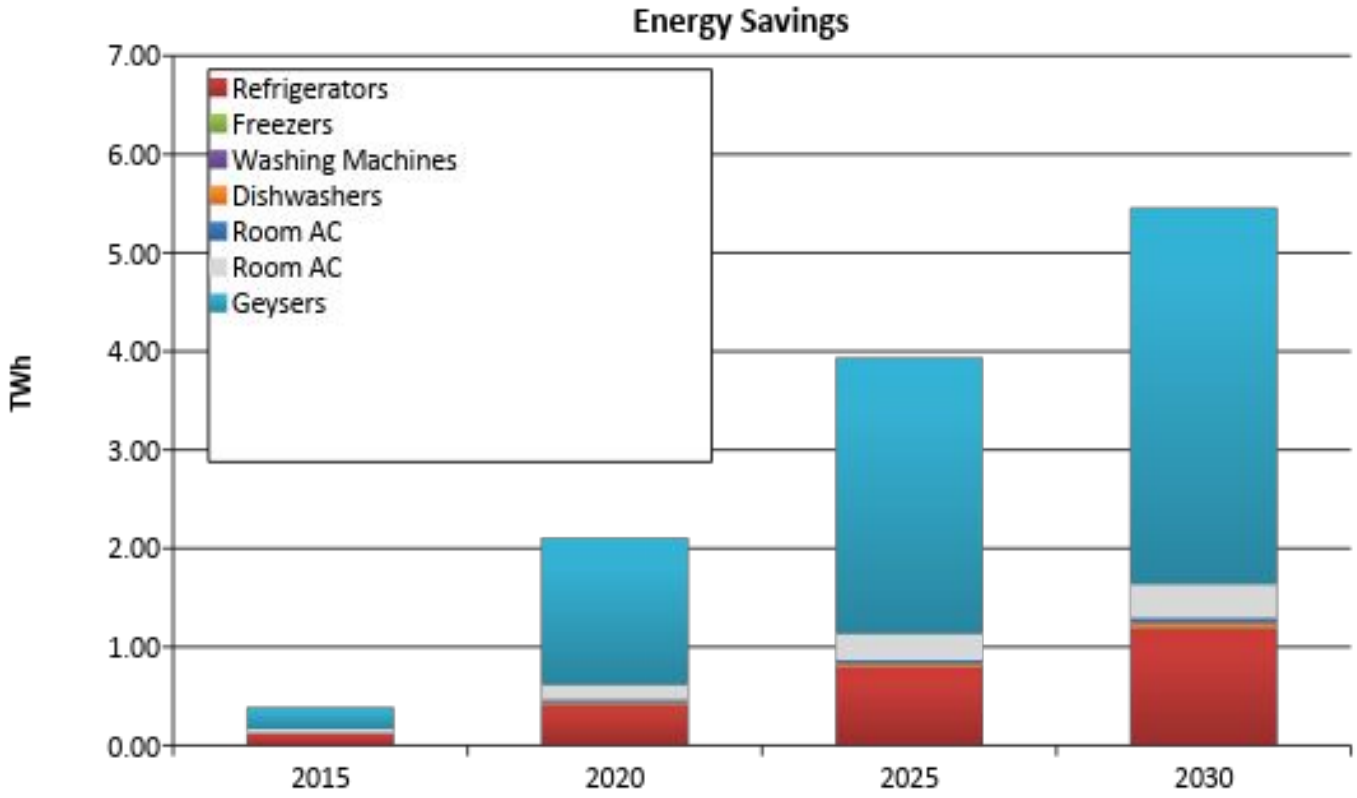
Relates Stock to Sales by a lifetime distribution function (historical and forecast)
Keeps track of number of units in the stock, distribution of age of the units in the stock

Projected lighting stock by technology in the residential sector (BAT assumptions)

Intensity Inputs for South Africa

Appliance	UEC (kWh)		
	2011 (FRIDGE)	2014 (Internet)	2015/6 (Post-MEPS)
Refrigerator	286.0	259.1	248.3
Refrigerator-Freezer	353.0	319.8	306.5
Freezers	406.0	507.6	423.1
Washing Machines	181.0	192.2	184.7
Dryers	294.0	274.3	274.3
Dishwashers	291.0	266.2	258.7
Oven	121.0	113.7	110.9
Split AC-Cooling Only	476.0	438.5	417.0
Split AC-Reversible	2241.0	2064.7	1963.4
Window AC-Cooling Only	476.0	482.9	478.3
Window AC-Reversible	2241.0	2273.5	2251.8
Geyser	810.1	810.1	457.5

Results for the Residential Sector

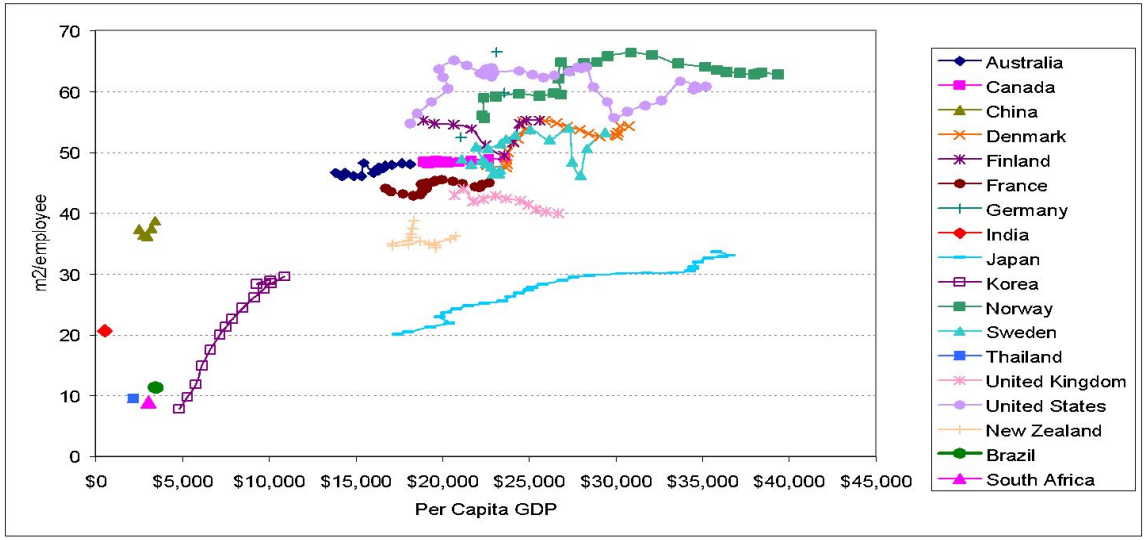


Commercial Sector

- Activity – Commercial Floor Area
  - Projection based on country income level
  - Modeled based on number of employees when data is not available
- Intensity – End Use Consumption per Floor Area
  - Varies according to penetration, efficiency and usage
  - Scenarios created by alternative efficiency forecast
  - Each end use reflects a mix of technologies
- Stock Accounting- Sales determined by increase in commercial floor area equipment penetration and replacements. Combined with marginal intensity to give stock energy.

Econometric Modeling for Service Sector

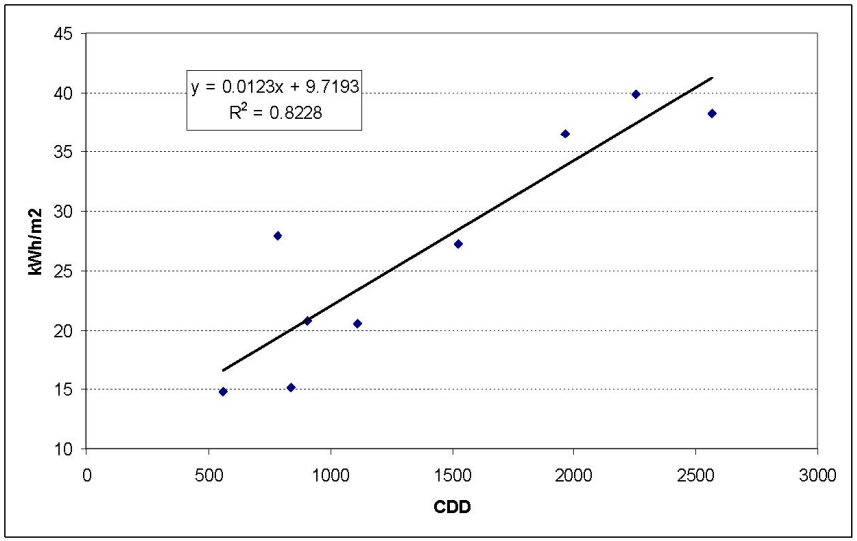
Activity

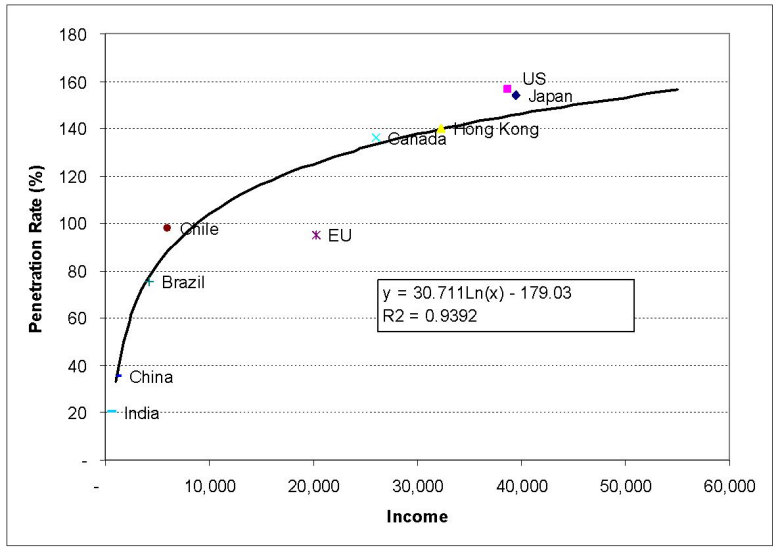


Surface/ employee (to then arrive at total floor area)

Intensity

Example for AC: (1) Maximum Demand as a function of Climate and (2) Penetration rate as a function of Income





Industry Sector

- Activity – Number of Motors
  - Modeled using external sales and stock data when available
  - Modeled econometrically from GDP value added and Industry Energy Intensity when data is not available
- Intensity – Annual Unit Energy Consumption per Motor
  - Varies according to capacity (size)
  - Depends on baseline efficiency in BAU.
  - Depends on load factor, hours of use
  - Scenarios created by alternative efficiency forecast.
- Stock Accounting- Sales determined by increase in motors stock and replacements. Combined with marginal intensity to give stock energy.

Set Targets, Develop Policies and Establish Impact Assessment Frameworks for Lighting, Appliances and Equipment

DATA NEEDS

Residential Sector Data Needs

For all variables: historical and forecast to 2040

Macroeconomic

- Population
- Household Size
- Urbanization %
- Electrification %
- GDP projections
- Cooling Degree Days

Appliance Specific

- Diffusion/ Stock
- Lifetime
- Technology market shares
- Product class market shares
- Average wattage
- Average efficiency
- Average hours of use
- Unit Energy Consumption
- Load Profile per end-use

Macro-economic and activity data
Services

For all variables: historical and forecast to 2040

Activity

- Commercial floor area (by building type)
- Number of employees
- Area per employee

End use Specific

- Equipment penetration in term of square meters (by commercial building type)
- Sales of products
- Technology market shares
- Energy Intensity
- Product class market shares
- Load Profile per end-use

Data Needs: Macroeconomic and activity data

Industry

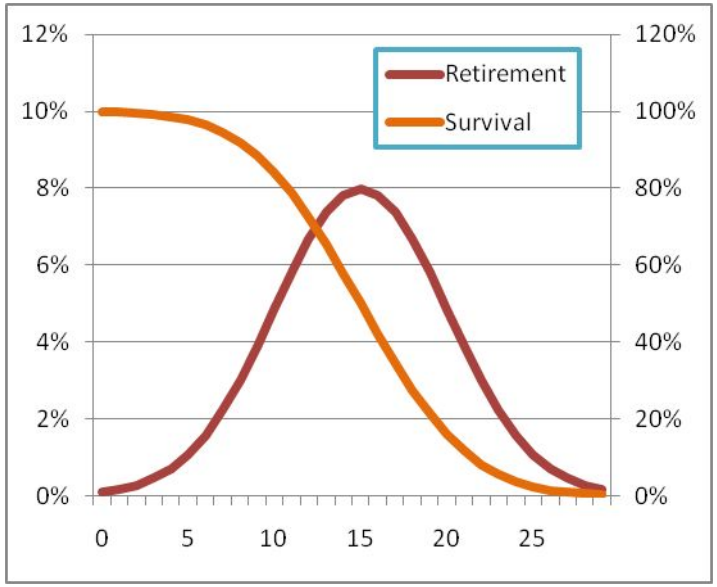
For all variables: historical and forecast to 2040

- GDP VA manufacturing sector
- Energy intensity in manufacturing sector
- % of motors consumption in industry
- Consumption by sub-sector

- Motors Stock
- Product class market shares
- Average Power
- Average Efficiency
- Average Load
- Average Hours of use
- Load Profile per end-use

Product Lifetimes

Product	Average Lifetime (years)
Incandescent Lamp	1
Fluorescent Ballast	15
CFL	5
Air Conditioner	12
Refrigerator	15
Standby	8
Television	10
Fan	8
Washing Machine	15
Rice Cooker	15



- All retired products are replaced
- Uses simplified version of normal distribution of lifetime

Additional Data Needs

Cost-Benefit Analysis

- Appliance/Equipment sales price data (Baseline, different efficiency levels)
- Electricity price (Marginal)
- Discount rates

METHODS FOR DATA COLLECTION

Possible Sources and Methodologies

Sales	• Trade associations • Market research companies • Customs data: National Import database: National Treasury Central Supplier Database (SARS) • Market assessment studies
Stocks	• Household Survey - Current household ownership of Equipment • Commercial Building Survey - number of employee per activity/building type • Industry surveys
Product class and Technology options	• Discussions with manufacturers or importers • Trade associations
Wattage rating Efficiency performance Products price	• Retail shops • Manufacturers or importers interviews
Hours of use	• Metering studies • Evaluation reports

New Data Sourcing Methods

International Database of Efficient Appliances (IDEA)

Thanks again!

EXTRA SLIDES

Residential Sector Decomposition Equation

$$E_{RB} = \sum_{m}^{OPTION} \left[\frac{P_m}{F_m} \times \left(\sum_{j} S_{j,m} \times UEC_{j,m} + E_m \sum_{i}^{OPTION} L_{i,m} \times Ca_{i,m} \times H_{i,m} \right) + P_m \times \sum_{k}^{OPTION} \left(CW_{m,k} + LK_{m,k} \right) \right]$$

where:

m = locale type (urban, rural)

P_m population in locale m

F_m = number of persons per household (family) in locale m

j = type of appliance or end-use device

$S_{j,m}$ = penetration of appliance or device j in percent appliance owned by household (values in excess of 100% would indicate more than one device per household on average)

UEC_j = energy intensity of appliance j in MJ or kilowatt-hours (kWh) per year

E_m = electrification rate in locale m

i = type of lighting bulb (incandescent, fluorescent, LED)

$L_{i,m}$ = number of lighting bulb of type i per household in locale m

$Ca_{i,m}$ = power of bulb of type i in locale m

$H_{i,m}$ = hours of use of bulb of type i in locale m

k = fuel type

$CW_{m,k}$ = cooking and water heating energy use of fuel k per capita per month in locale m in MJ/ca/month

$LK_{m,k}$ = Lighting energy use of fuel k per capita per month in locale m in MJ/ca/month