

The Joy of Stochastic Forecasting:

An Overview of the Stochastic Buildings Energy and Adoption Model

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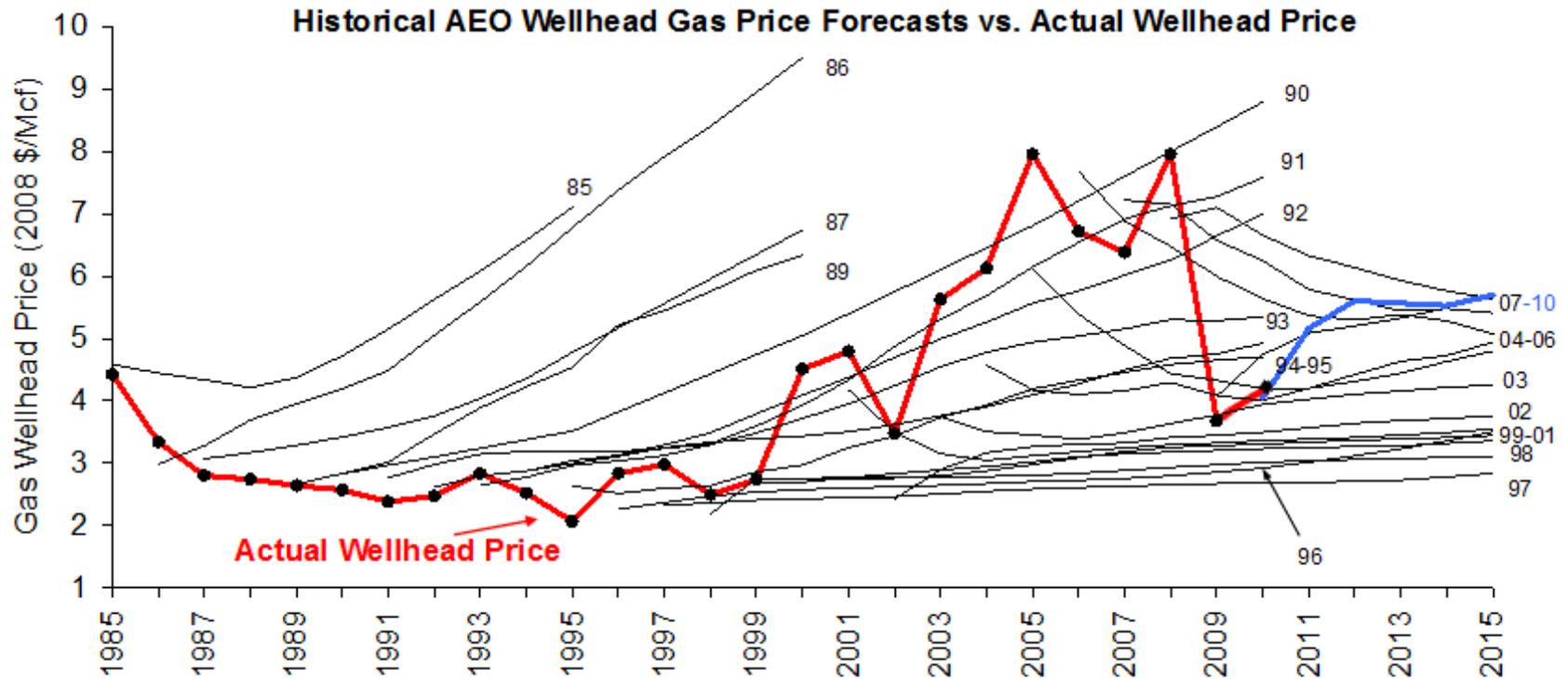




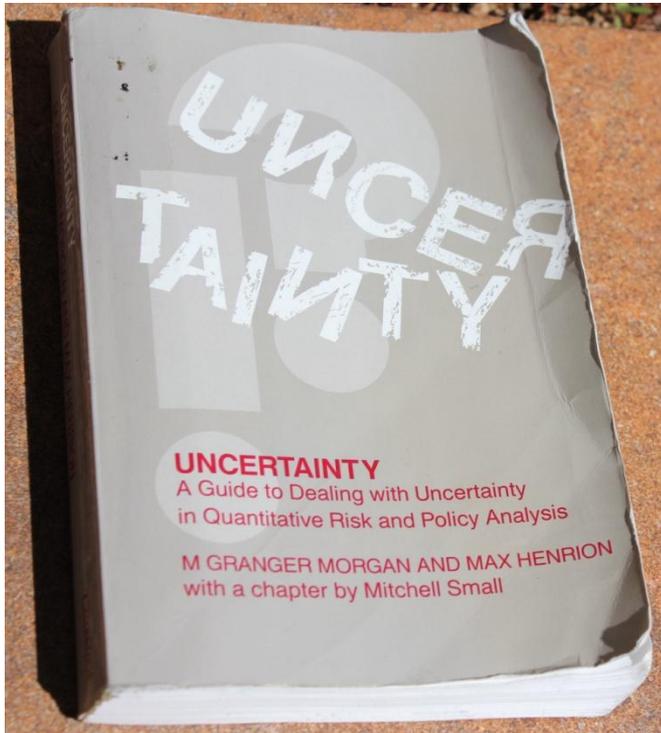
Understanding the value of well characterized uncertainty in energy forecasting



Value of Uncertainty



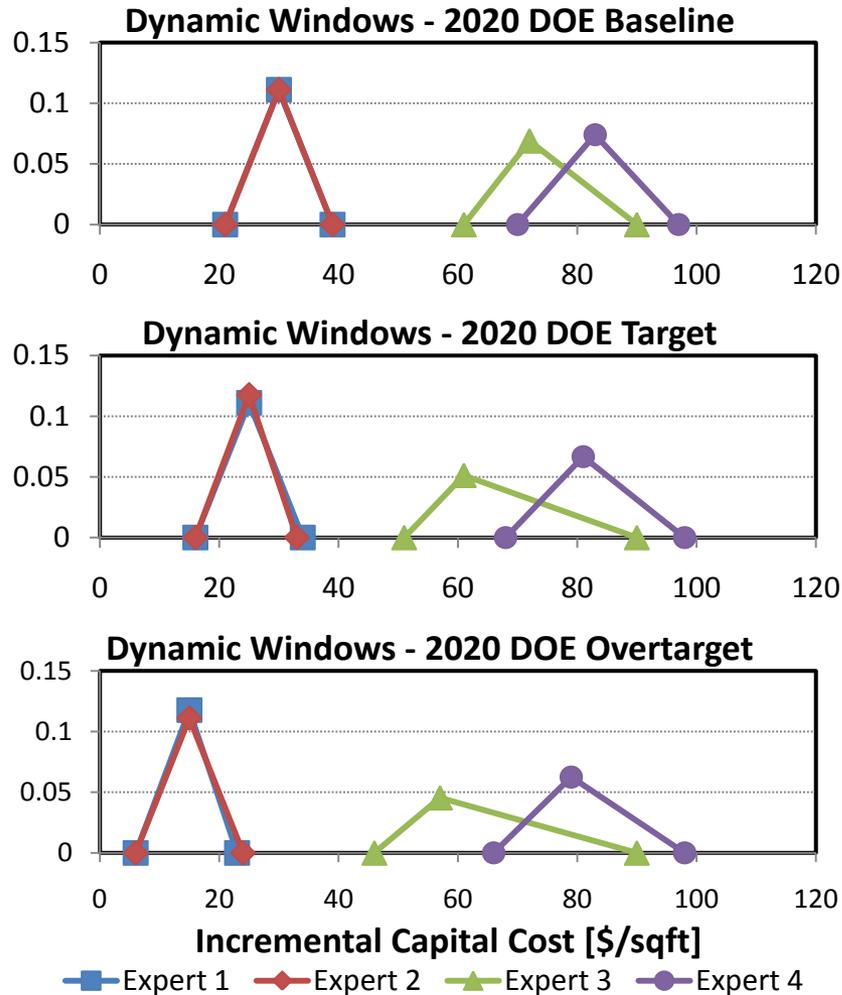
Morgan Henrion Method



- in classic 1990 book Morgan and Henrion discussed introduction of uncertainty into policy analysis
- they proposed the use of probability distributions collected from experts as the basis of Monte Carlo simulation
- Henrion advocates for open-source “systems” modeling
- use of system models enable radical forecasts
- they had an early version of the model that has become Analytica
- Sam Baldwin & Michael Leifman at DOE pushed for use of these methods and tools

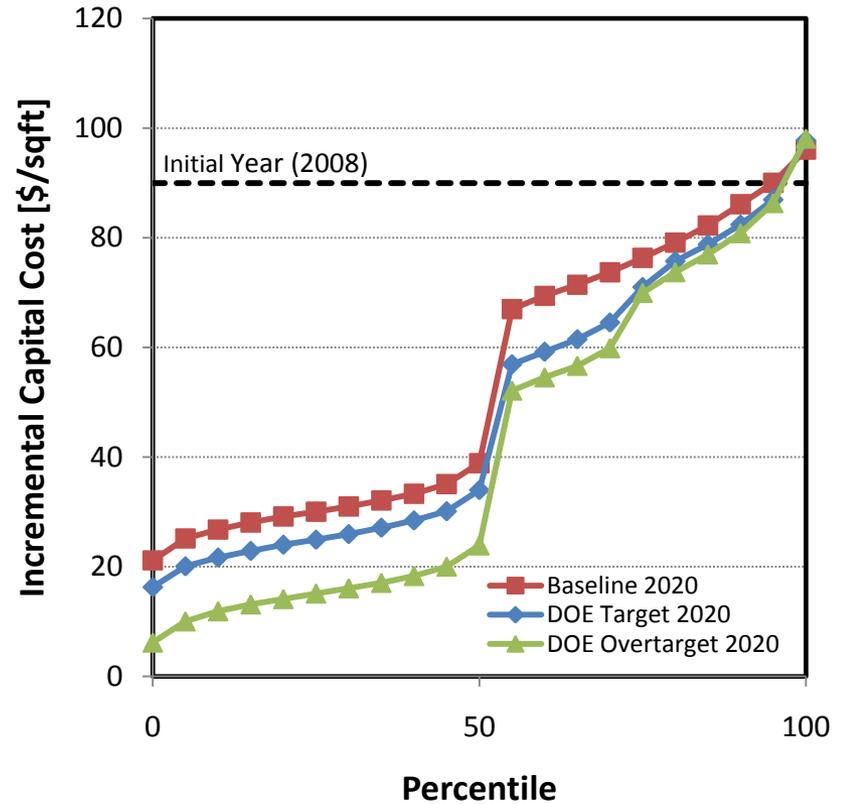
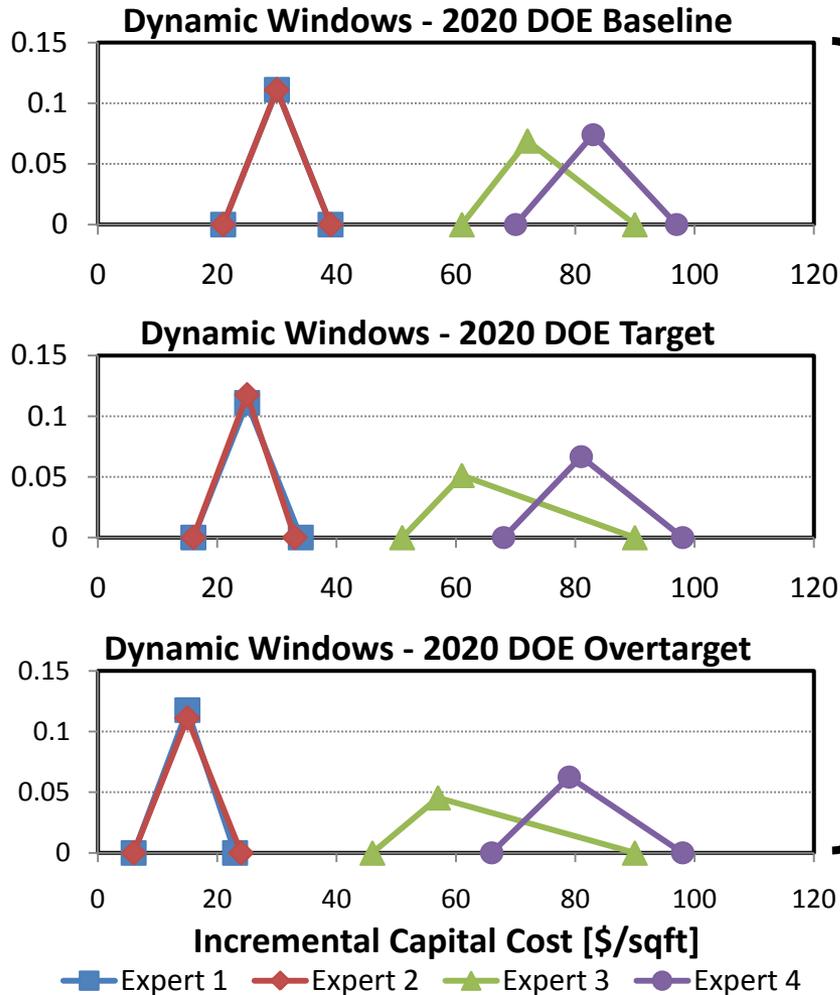


Sources of Stochastic Data



- Stochastic data obtained via process of expert elicitation
- Industry experts surveyed to predict technology performance
- Triangular distributions constructed for key parameters (cost, durability, efficacy, etc.)
- Performed for several specified years and funding scenarios

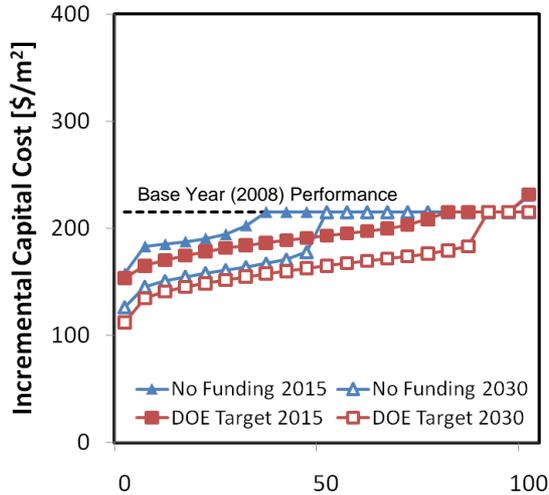
Sources of Stochastic Data



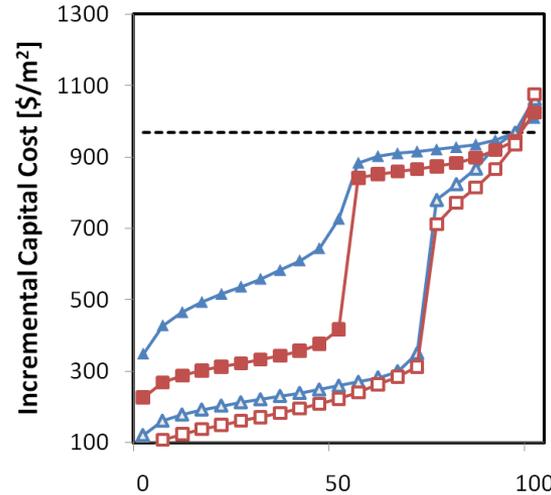
Characterization of Windows



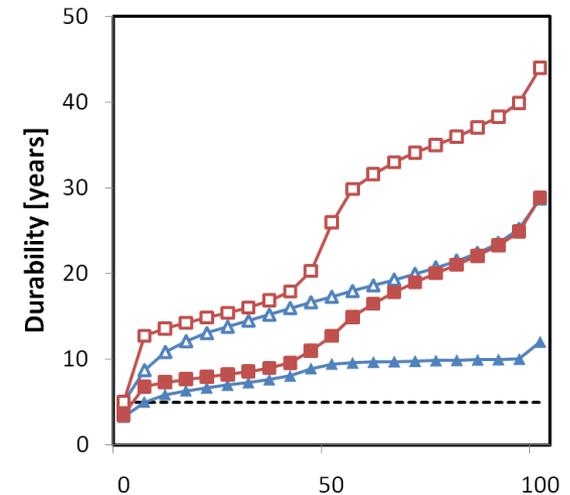
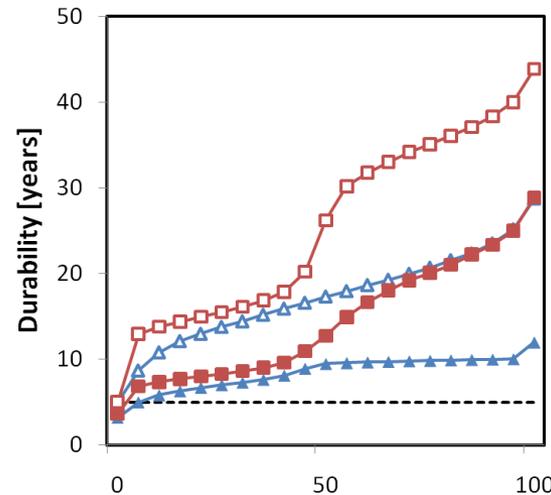
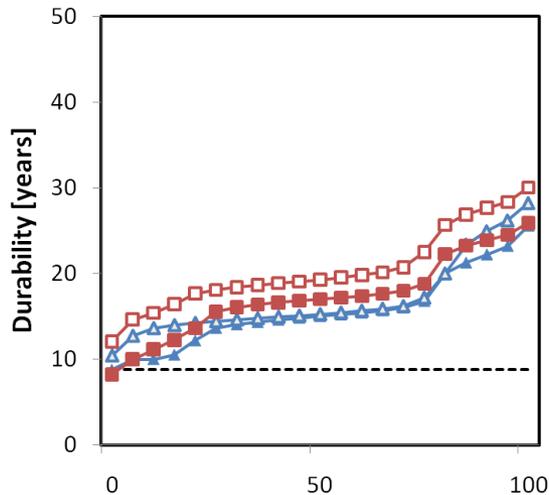
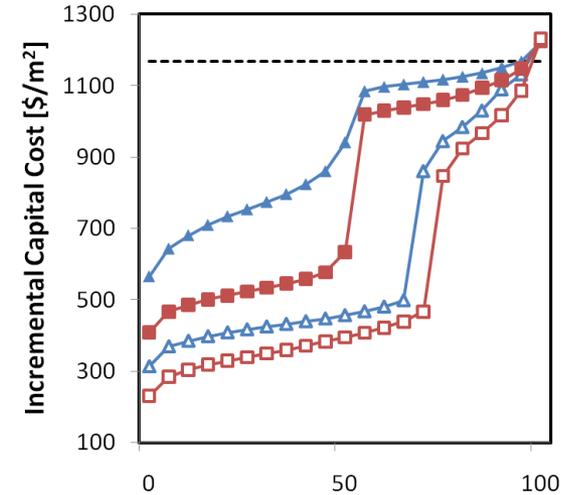
Highly Insulating



Dynamic



Combined



Percentile

Percentile

Percentile

What is SEDS?



Stochastic Energy Deployment System

- National forecast model for economy-wide energy use
- System based, not classic econometric model
- Multi-laboratory collaboration:
(NREL, LBNL, PNNL, ANL, Lumina)
- Buildings & Macroeconomics developed at LBNL
- Programmed in Analytica® to incorporate uncertainty
- Built to assess impact of US DOE research (GPRA)
- Assists in management and selection of research portfolio
- Open-source and executable on personal computer
- Forecasts aggressive CO₂ mitigation scenarios
- Disequilibrium model

What is SBEAM?



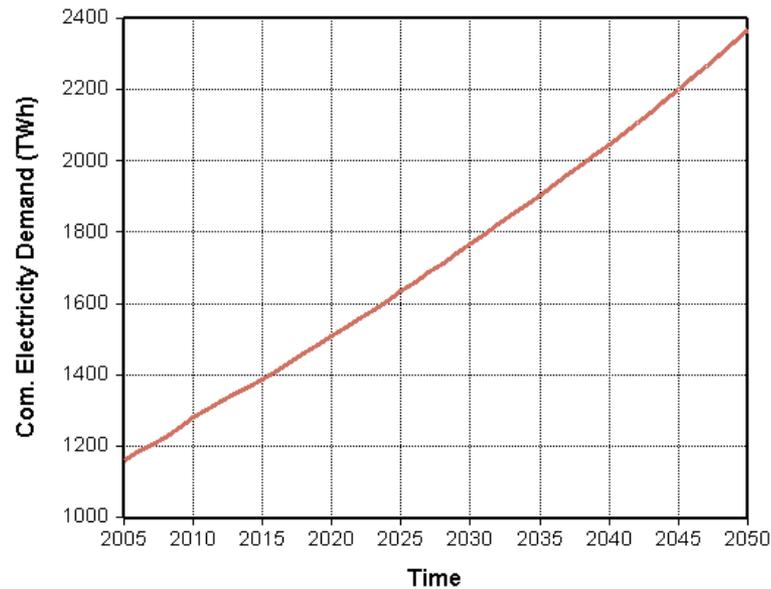
Stochastic Buildings Energy & Adoption Model

- Standalone SEDS module for entire US buildings sector (commercial & residential)
- Most comprehensive SEDS module
- Driven by demand for building services not energy (e.g. lumen-hours, HDD)
- Includes interaction between passive and active technologies
- Provides behavior & policy levers for analysis
- Includes regional & building type disaggregation
- Expert elicitations for PV, advanced windows & LEDs

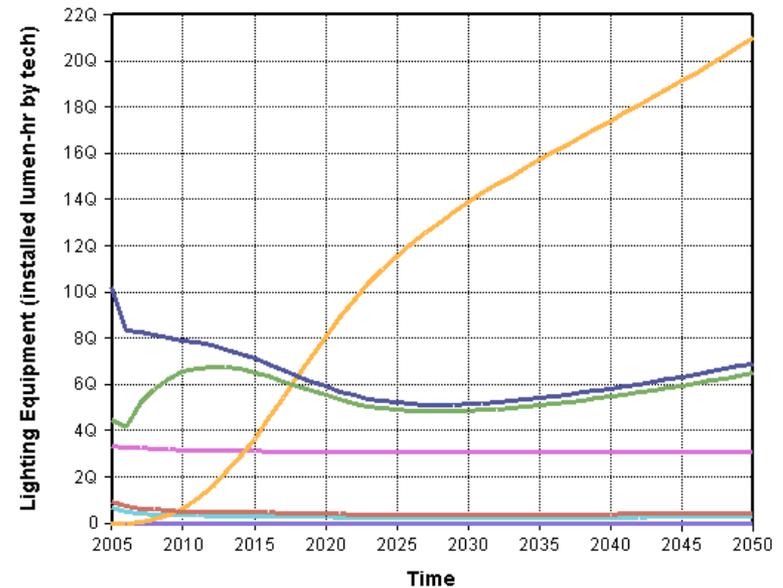
SBEAM Functionality



Commercial Electricity Demand Forecast



Commercial Lighting Equipment Marketshare



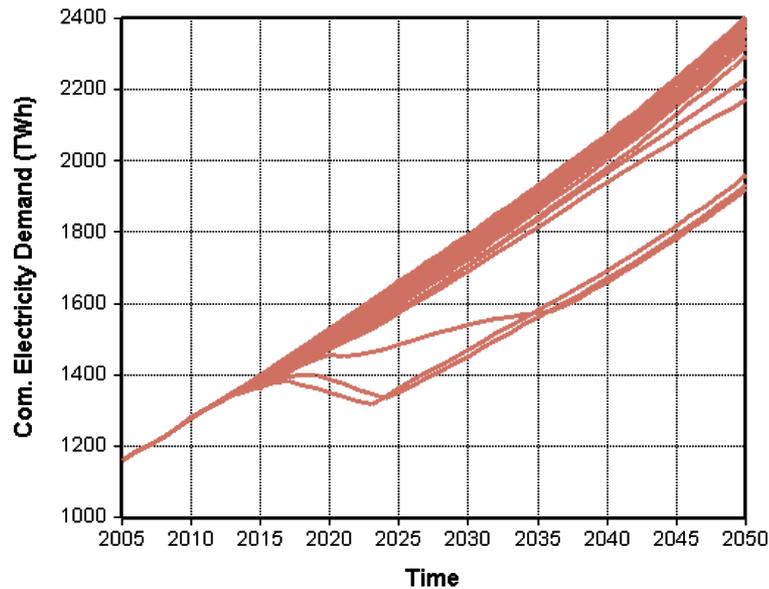
Lighting Technology Types

- com.incandescent
- com.flourescent
- com.cfl
- com.led (current soa)
- com.led (doe goal ssl)
- com.halogen
- com.HID

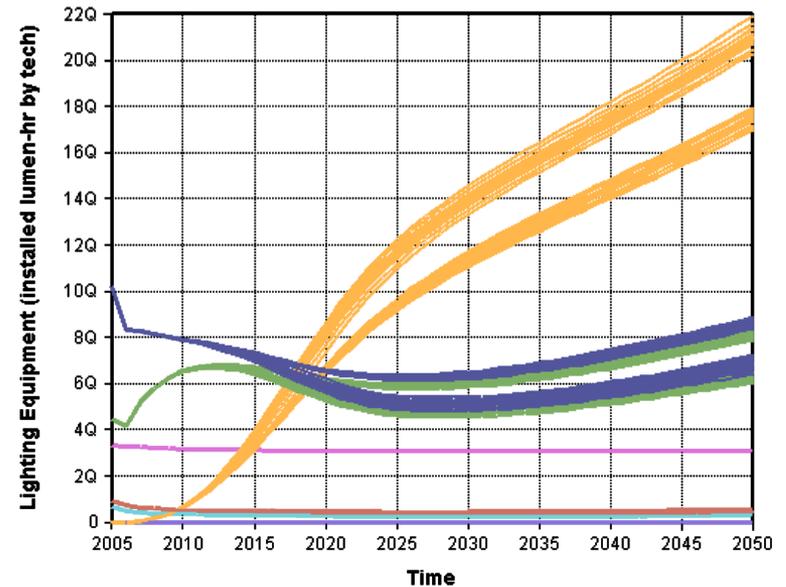
SBEAM Functionality



Commercial Electricity Demand Forecast



Commercial Lighting Equipment Marketshare



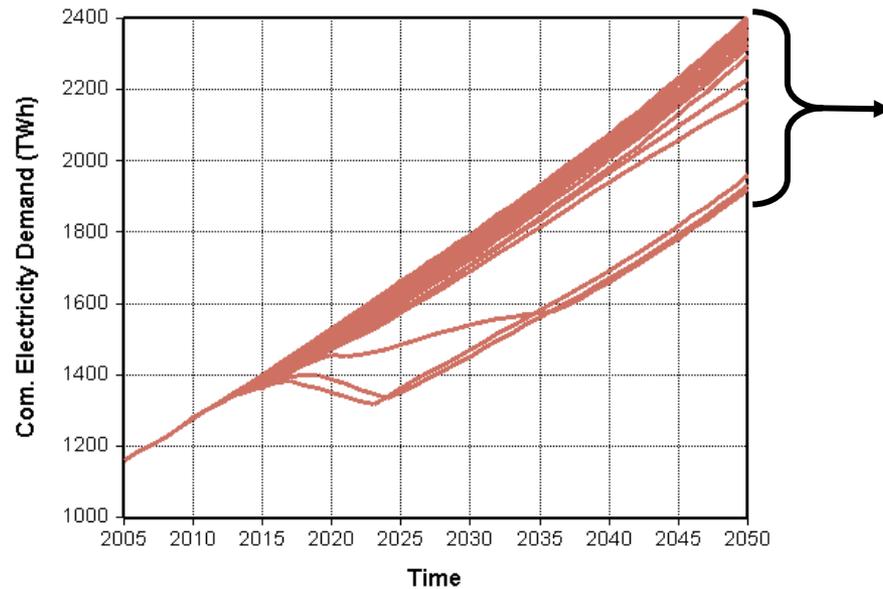
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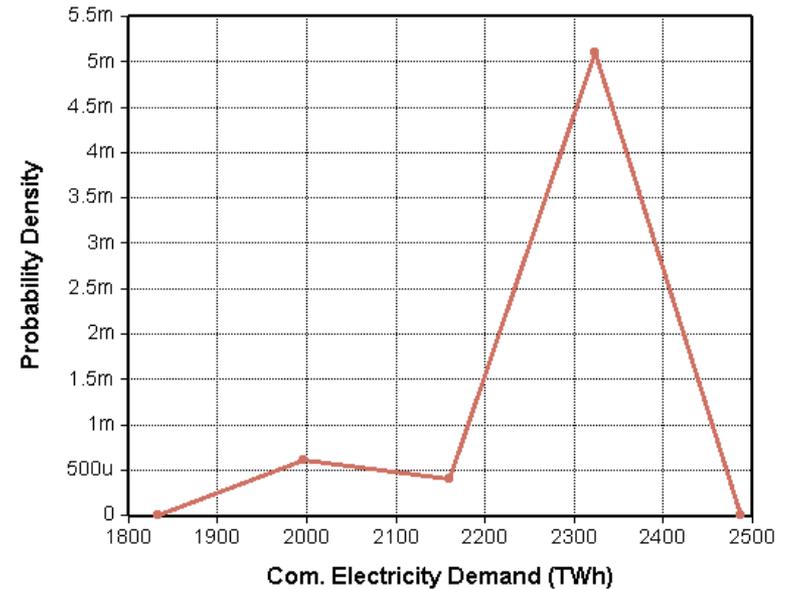
SBEAM Functionality



Commercial Electricity Demand Forecast



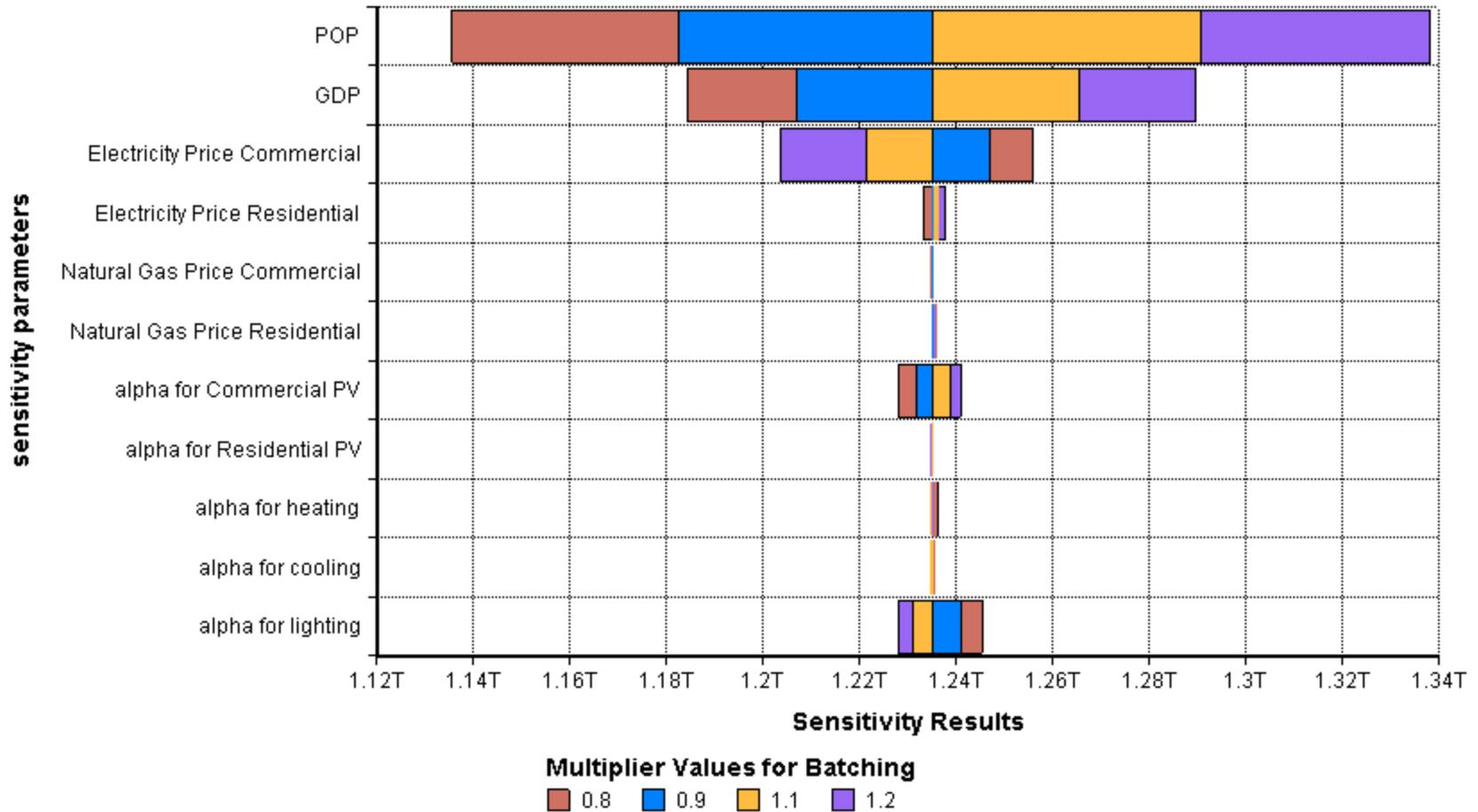
Distribution of Demand at 2050



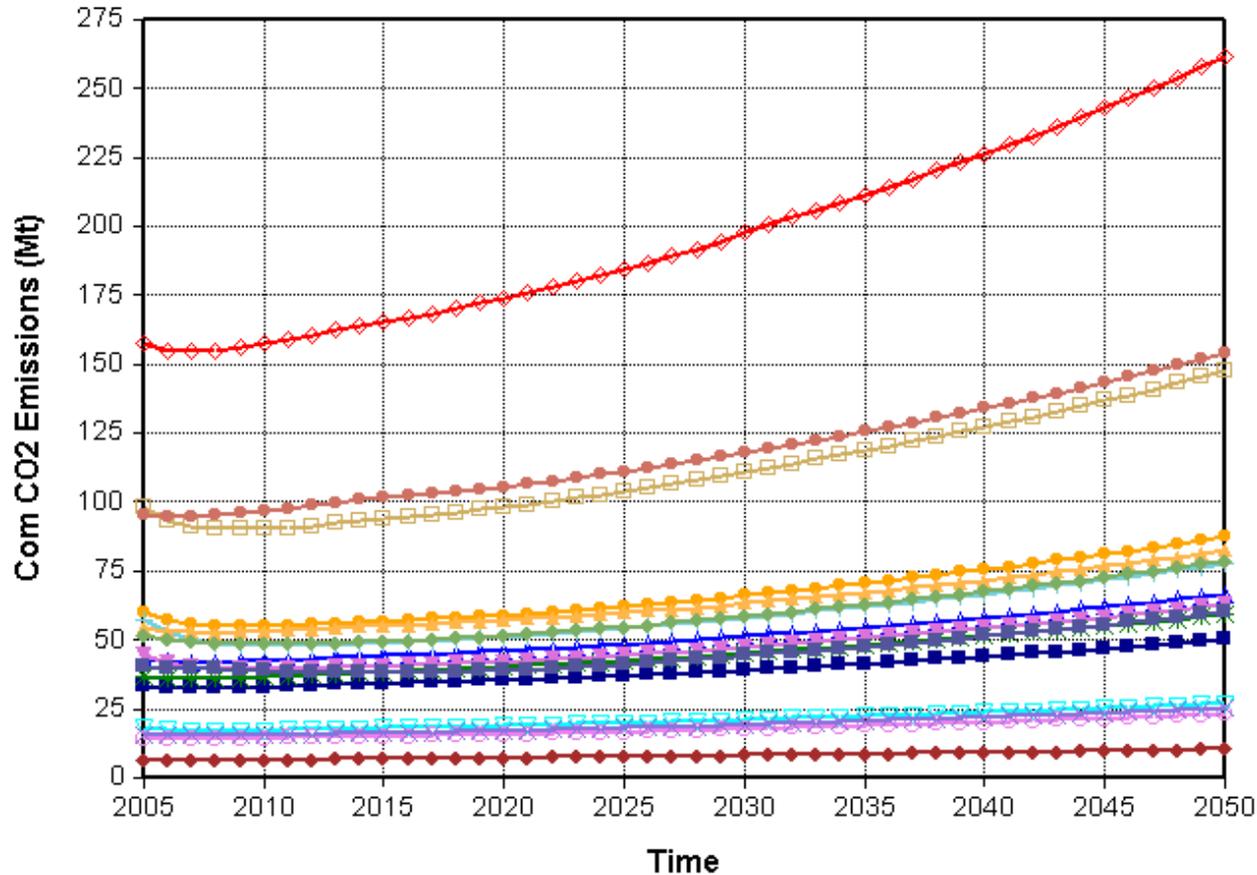
Sensitivity Analysis



CO₂ Emissions[kg] – Commercial at 2030



Building Types



Bc_bldg_types

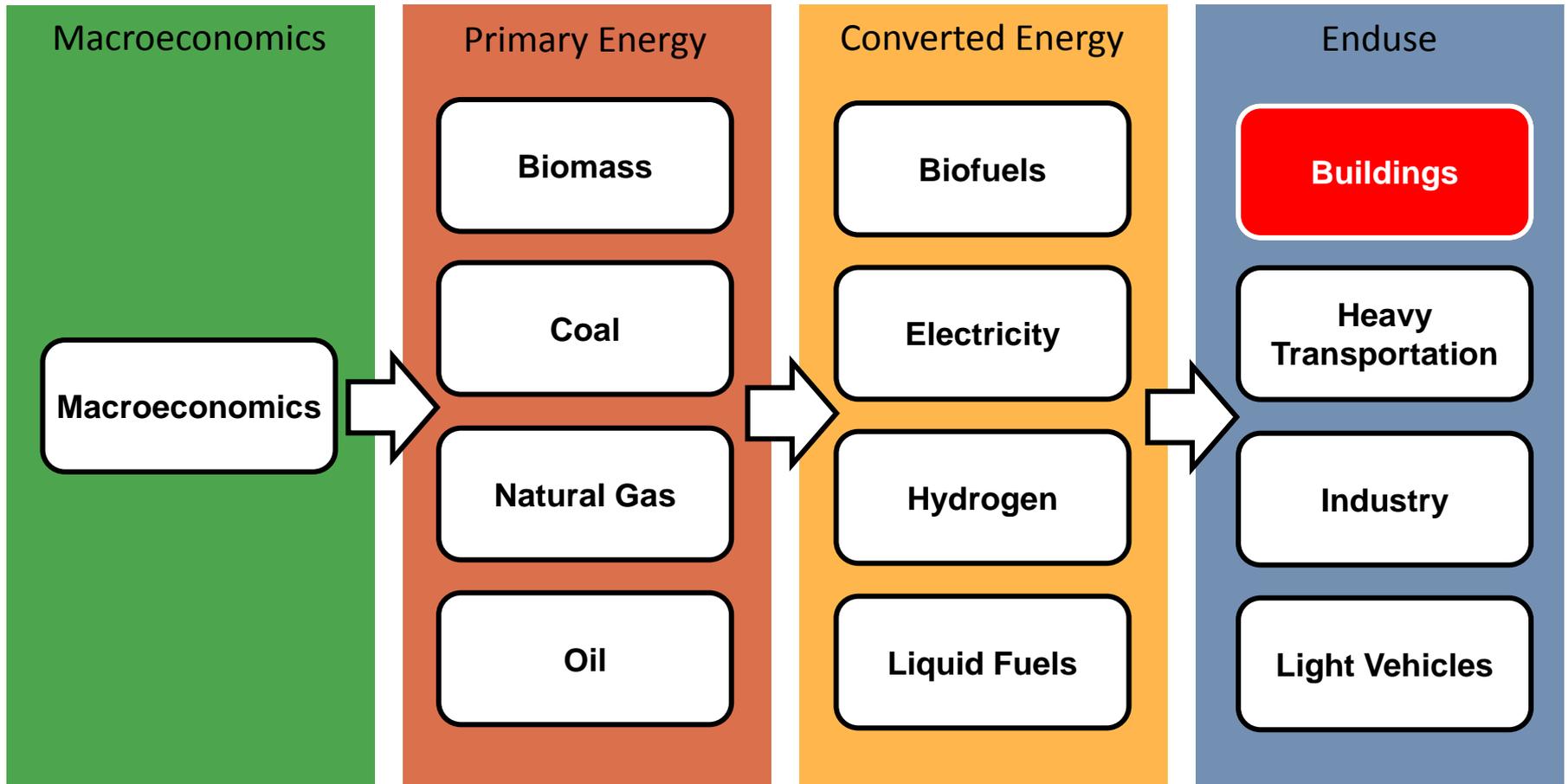
- education
- food sales
- food service
- inpatient health
- outpatient health
- lodging
- retail
- malls
- office
- public assembly
- public safety and order
- religious
- service
- warehouse
- other
- vacant

2

The particulars of the SBEAM



SEDS Scope



Data Flow Through SBEAM



Incoming Data

Outgoing Data

Macroeconomics

GDP

Population

Disposable Income

Natural Gas

Natural Gas Price

Liquid Fuels

Light Fuel Oil Price

Electricity

Electricity Price

Peak Electricity Demand

Base Electricity Demand

Buildings

Capital Investments

Macroeconomics

Natural Gas Demand

Natural Gas

Fuel Oil Demand

Liquid Fuels

Electricity Demand

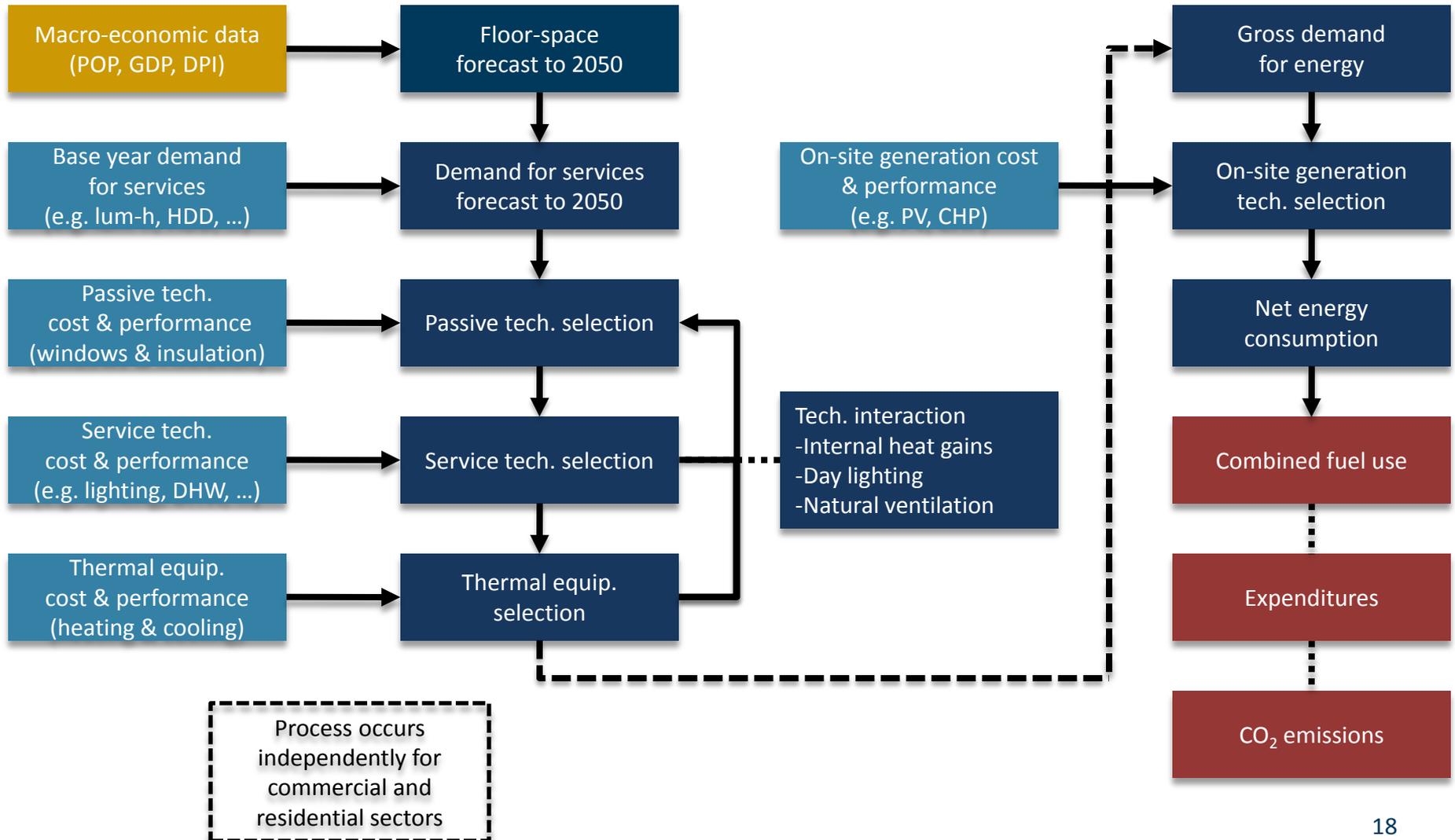
Electricity

CO₂ Emissions

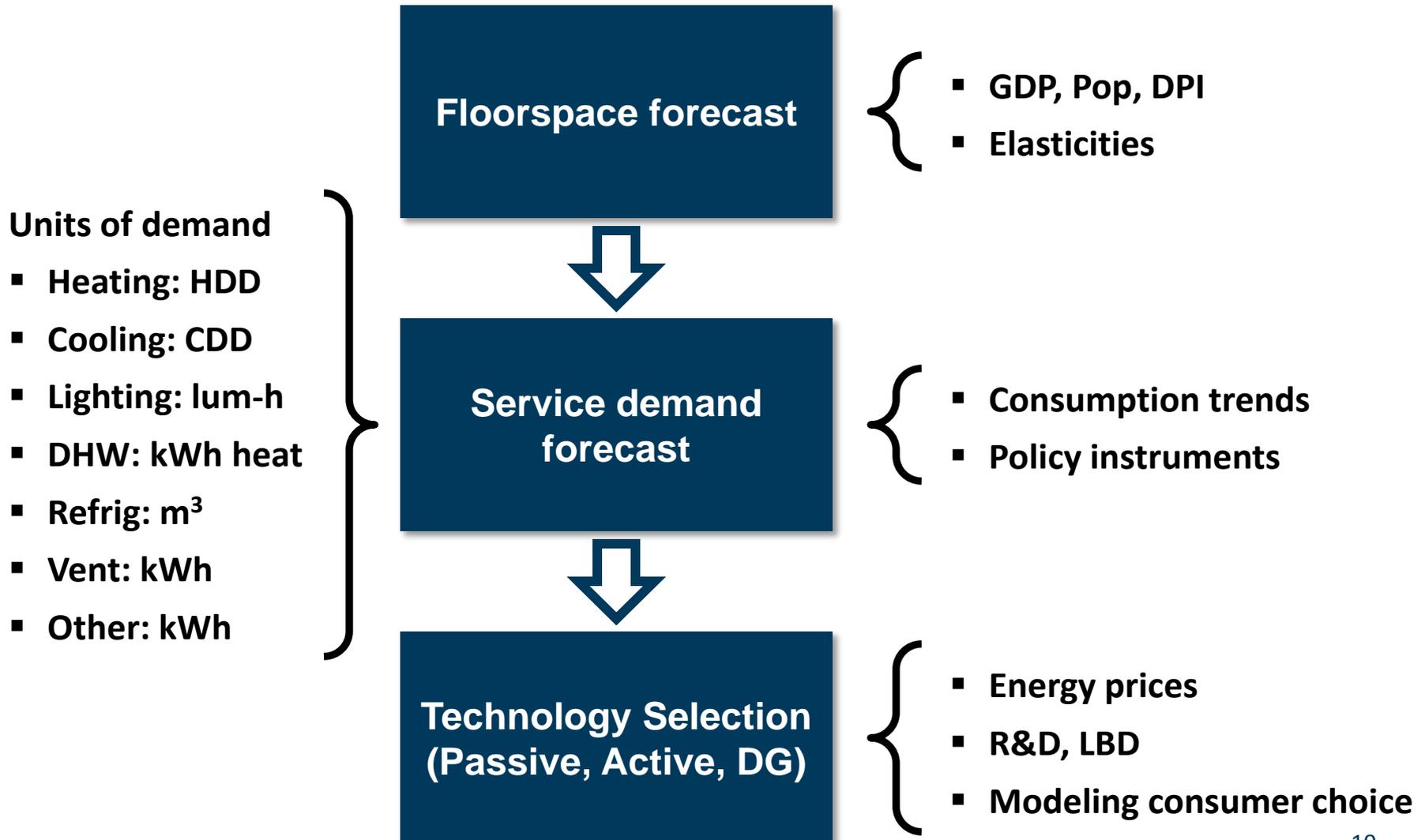
[t-1]

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SBEAM Structure



What matters in SBEAM?



How Is Choice Represented?



Logit Function

- Marketshare (MS_i)

$$MS_i = \frac{v_i}{\sum_i v_i}$$

- Utility (v_i)

$$v_i = e^{(-\alpha \cdot AC_i)}$$

Market share

Highest marketshare awarded to technology with the highest utility

Utility

Utility determined by annualized cost of technology and alpha factor

How Is Choice Represented?



Logit Function

- Marketshare (MS_i)

$$MS_i = \frac{v_i}{\sum_i v_i}$$

- Utility (v_i)

$$v_i = e^{(-\alpha \cdot MA_i)}$$

- Multi-attribute value (MA_i)

$$MA_i = LC_i - S_{h,i} - S_{c,i} - S_{l,i}$$

- Technology interaction

S_h - savings in heating

S_c - savings in cooling

S_l - savings in lighting

i : index over technologies

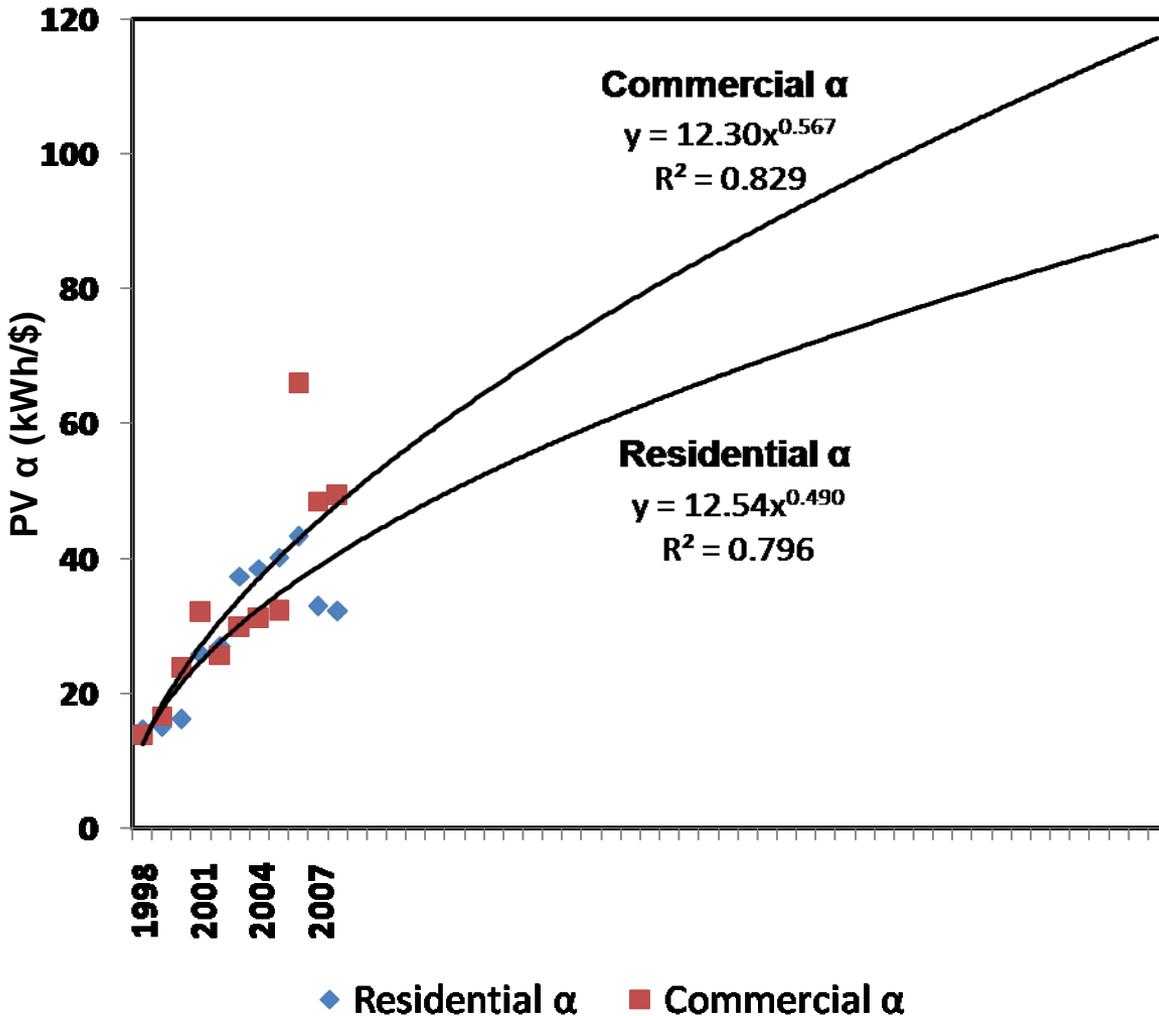
Multi-attribute

In the case of building shell, multi-attribute value includes savings from interaction with building services

α

Tunable parameter to represent consumer sensitivity to differences in price

Determining α



Example: On-site PV

Historical PV price and adoption levels



Historical effective α



Projection of α to 2050

Limitation:

10 year historic data to project 40 year forecast

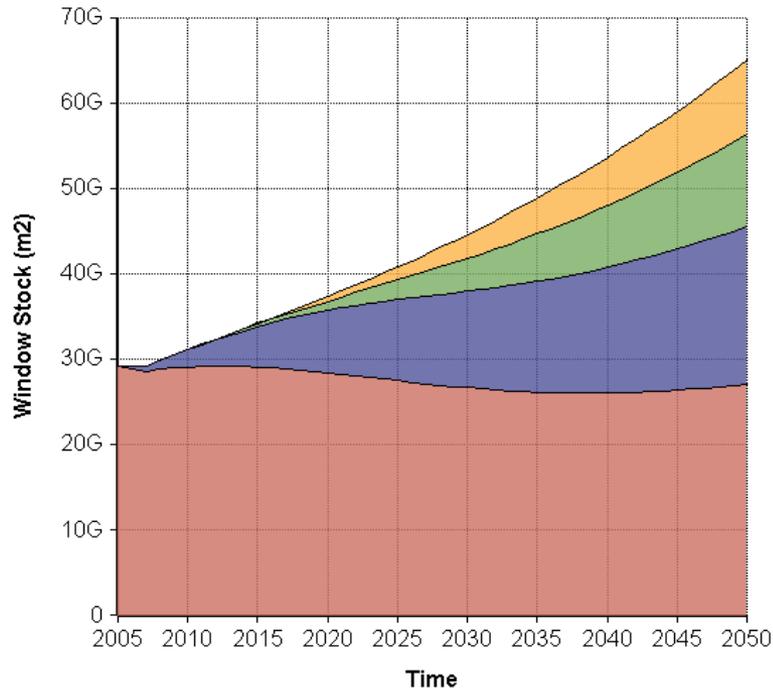
α Sensitivity



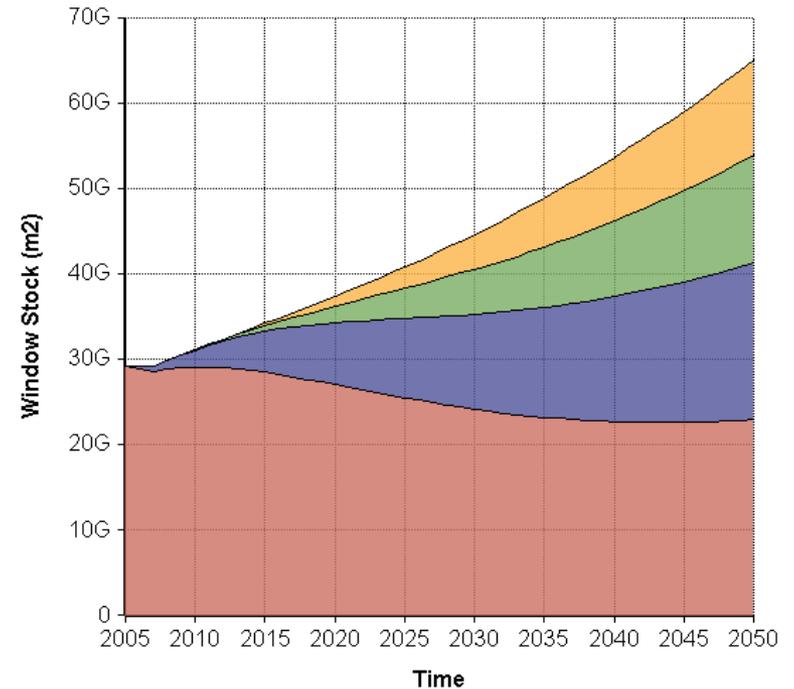
Total floorspace (com. & res.) served by window type

$\alpha \times 0.5$

Base Case (No DOE Funding)



Target DOE R&D Funding



Low Insulating Highly Insulating Dynamic Combined

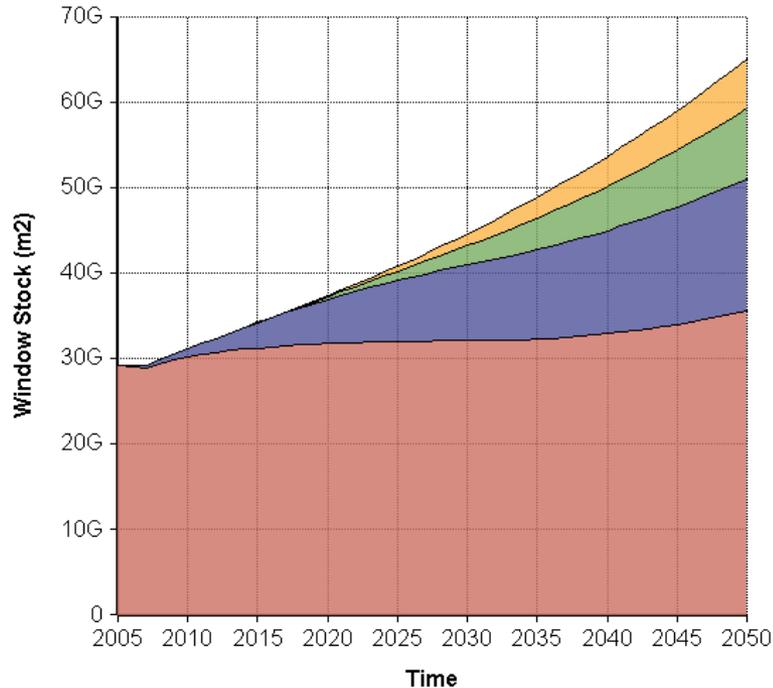
α Sensitivity



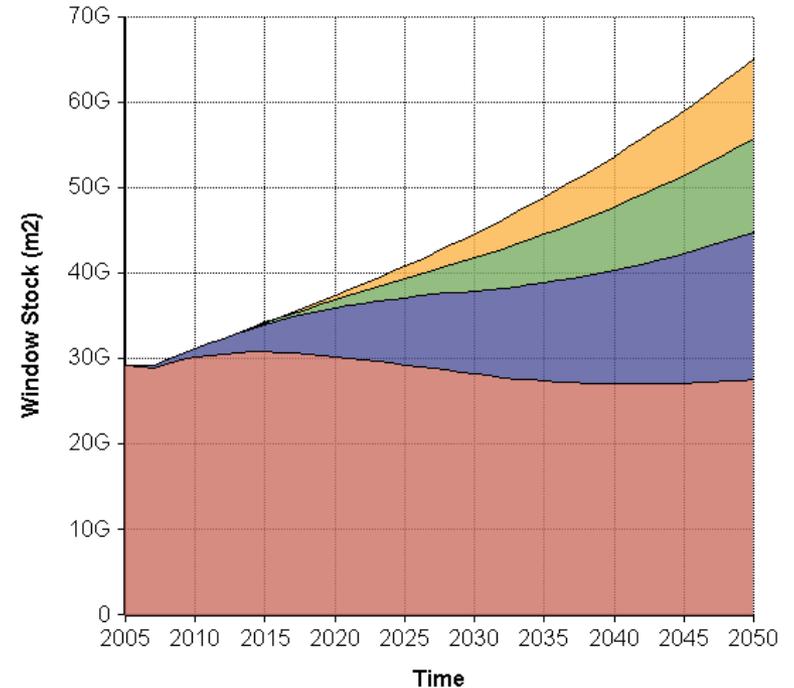
Total floorspace (com. & res.) served by window type

$\alpha \times 1$

Base Case (No DOE Funding)



Target DOE R&D Funding



Low Insulating Highly Insulating Dynamic Combined

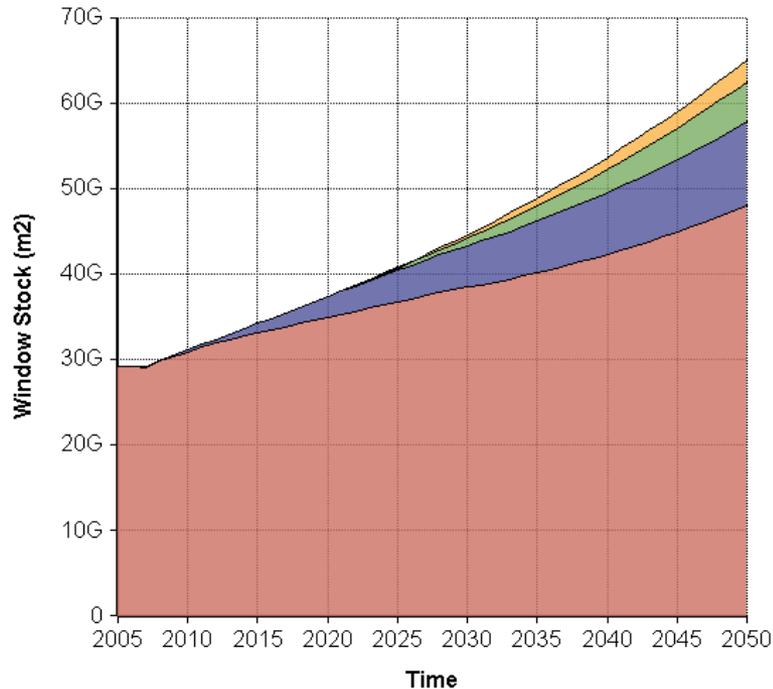
α Sensitivity



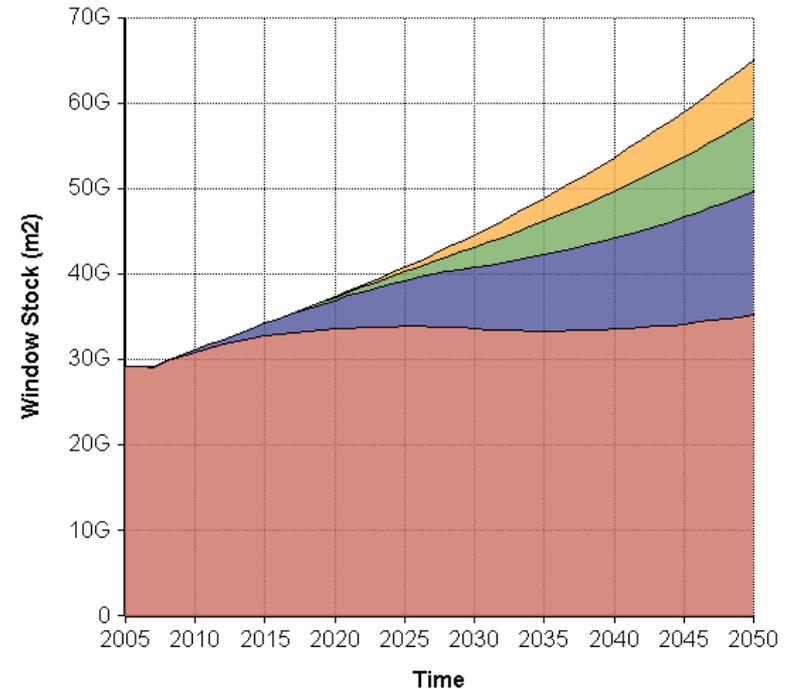
Total floorspace (com. & res.) served by window type

$\alpha \times 2$

Base Case (No DOE Funding)



Target DOE R&D Funding

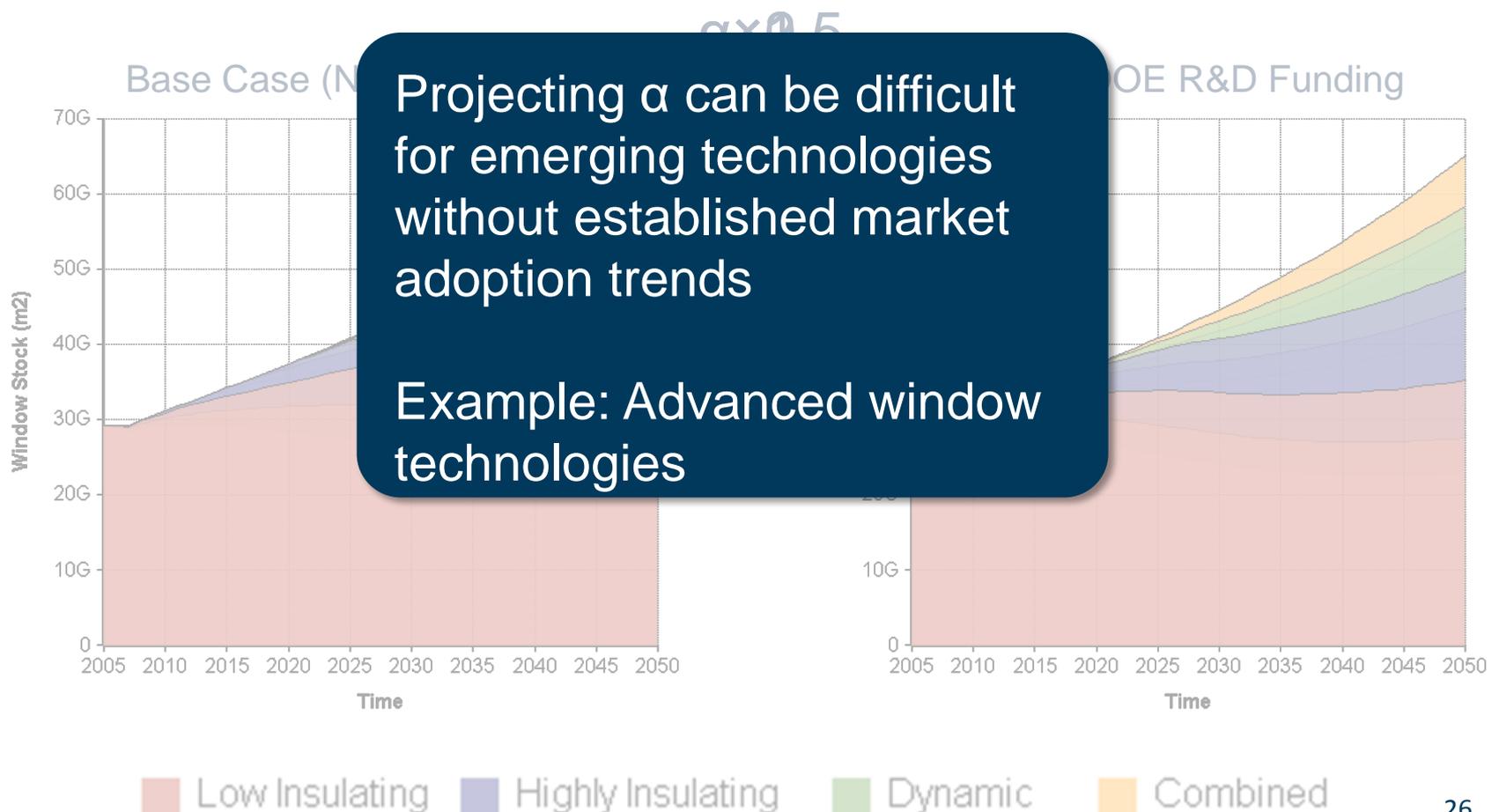


Low Insulating Highly Insulating Dynamic Combined

α Sensitivity



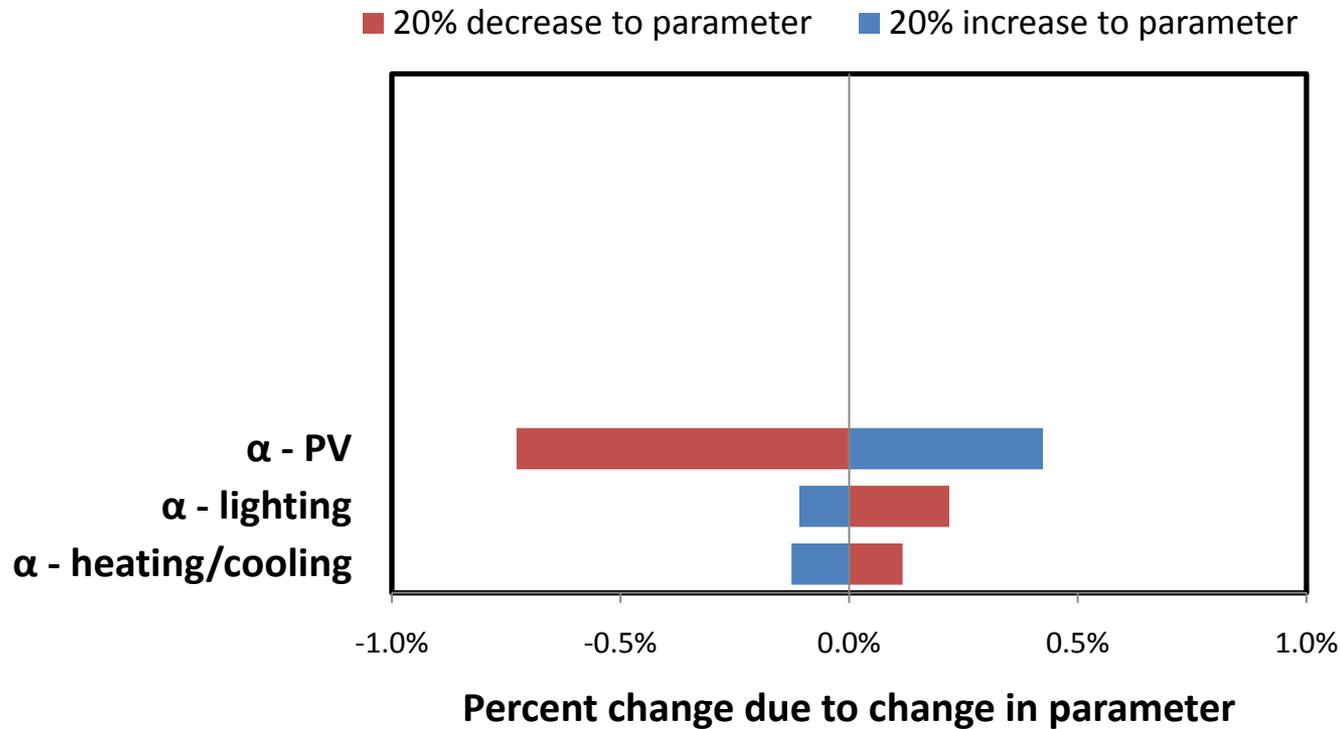
Total floorspace (com. & res.) served by window type



Relative Importance of α



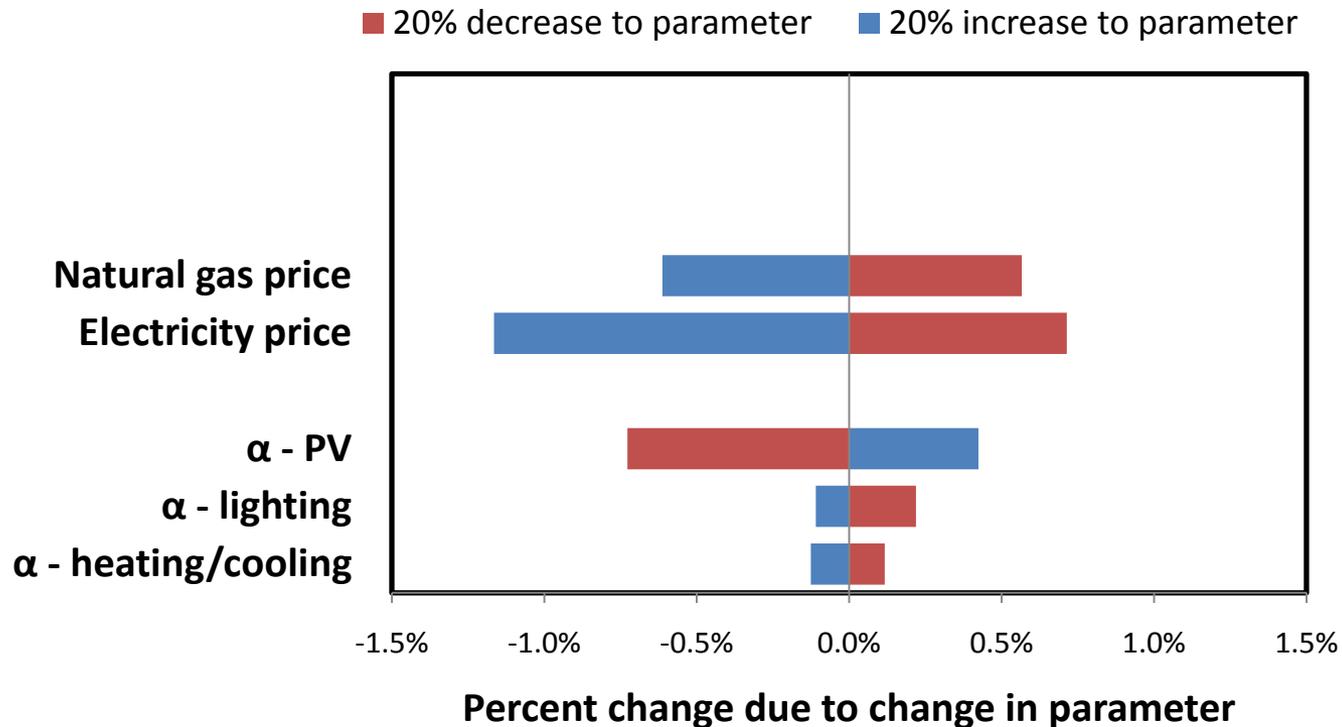
Total utility energy purchases (2030)



Relative Importance of α



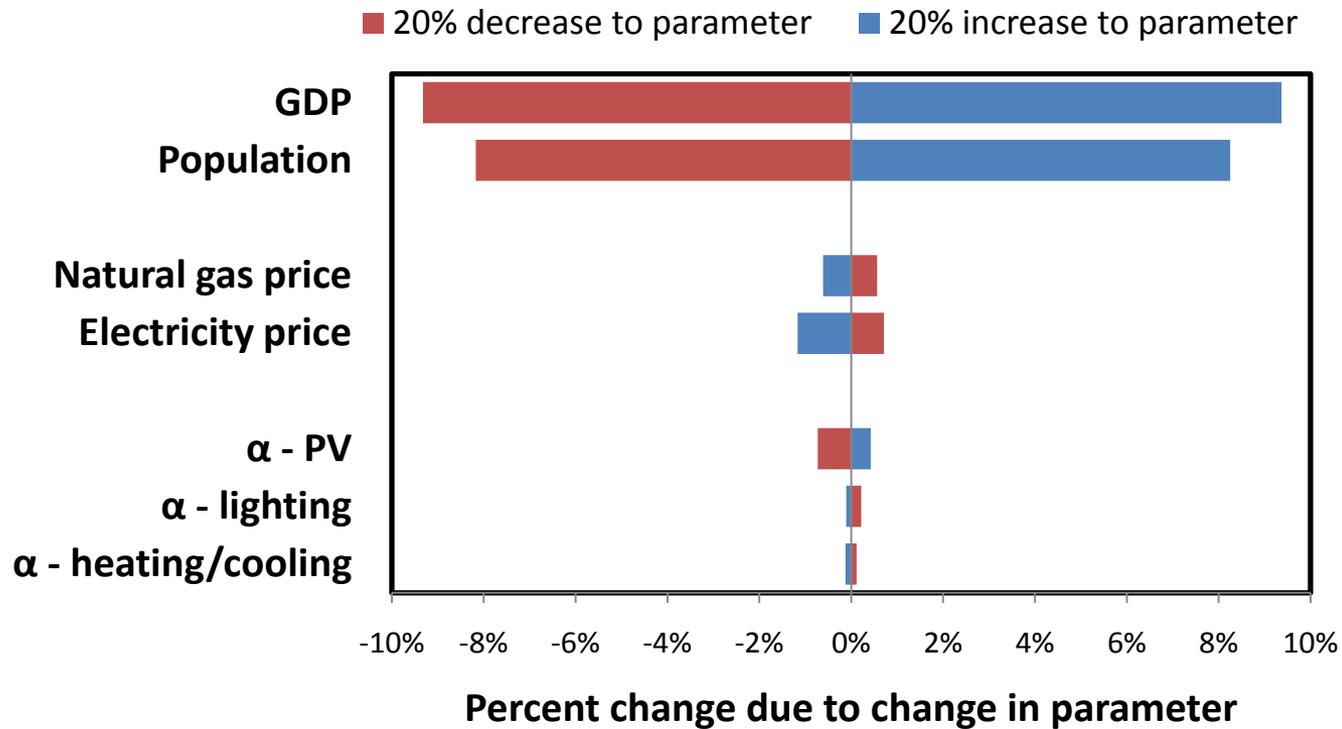
Total utility energy purchases (2030)



Relative Importance of α



Total utility energy purchases (2030)



Relative Importance of α



Total utility energy purchases (2030)

Energy demand scales with floorspace. Forecast of floorspace is driven by GDP and Population.

Elasticities are much more influential than consumer sensitivity to price in technology (α)

SBEAM provides the possibility to decouple economic growth and energy demand based on policy levers.

Popu
Natural gas
Electricity
 α - lig
 α - heating/co



Percent change due to change in parameter

3

Using SBEAM to conduct interesting analysis

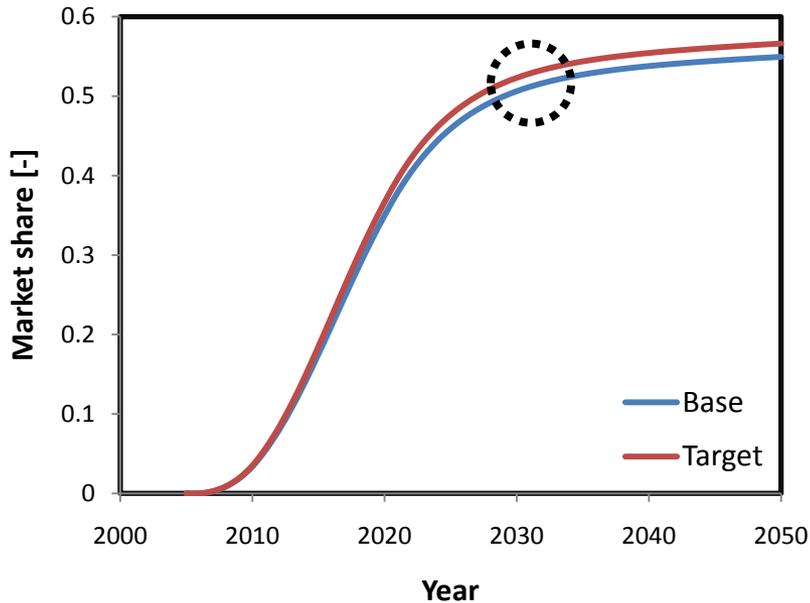


Evaluating R&D Scenarios

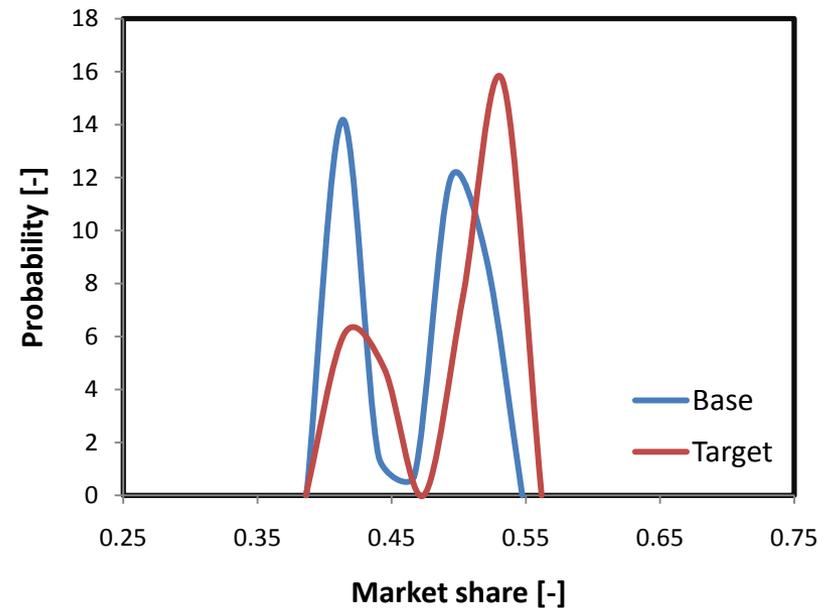


LED Lighting

Commercial LED Forecast



Likelihood of Com. LEDs in 2030

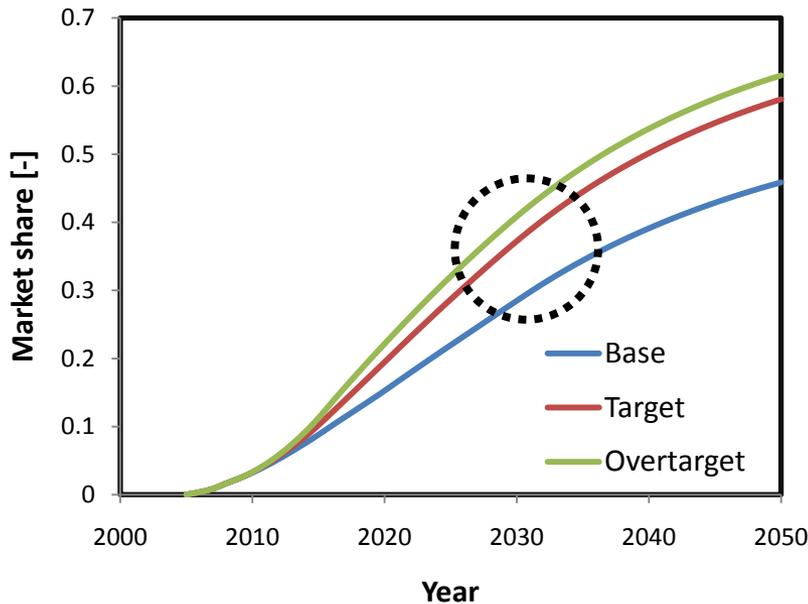


Evaluating R&D Scenarios

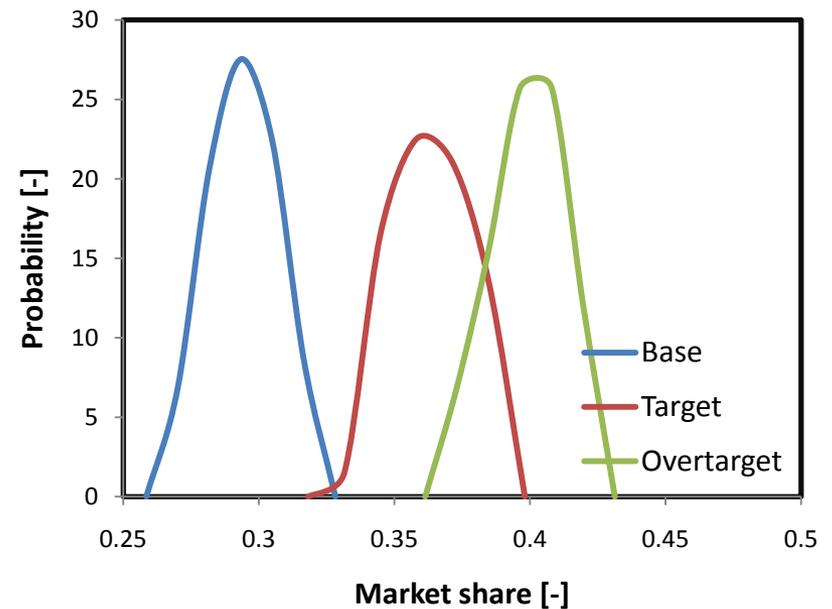


Advanced Windows

Total Adv. Windows Forecast



Likelihood of Adv. Windows in 2030

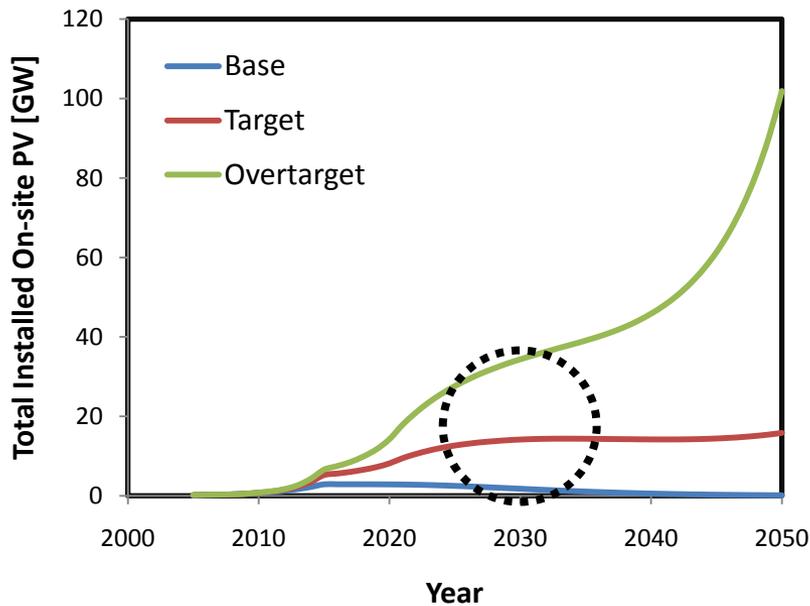


Evaluating R&D Scenarios

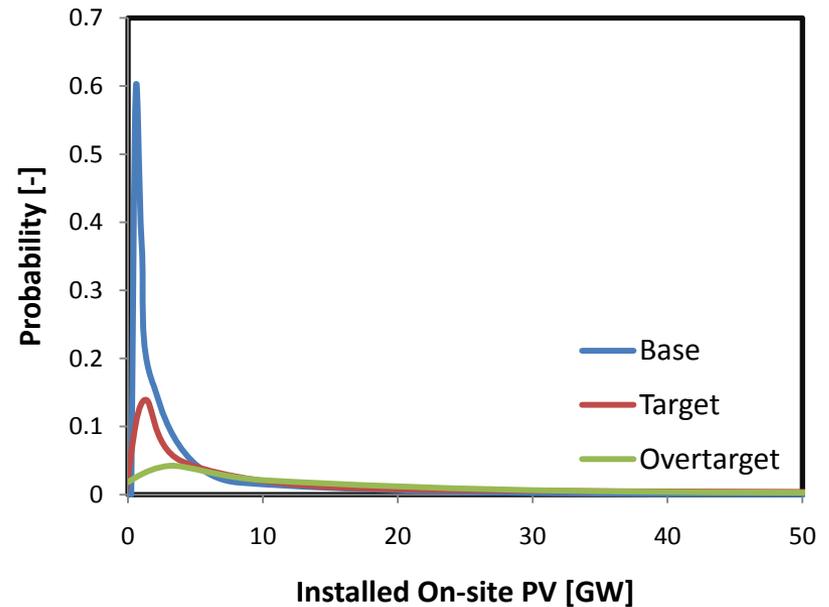


On-site PV

On-site PV Forecast



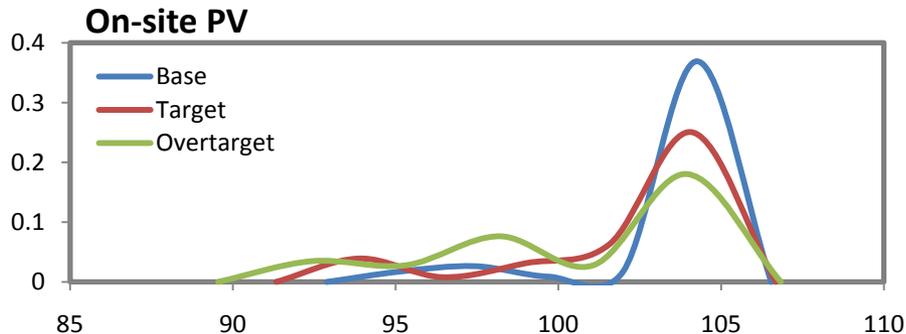
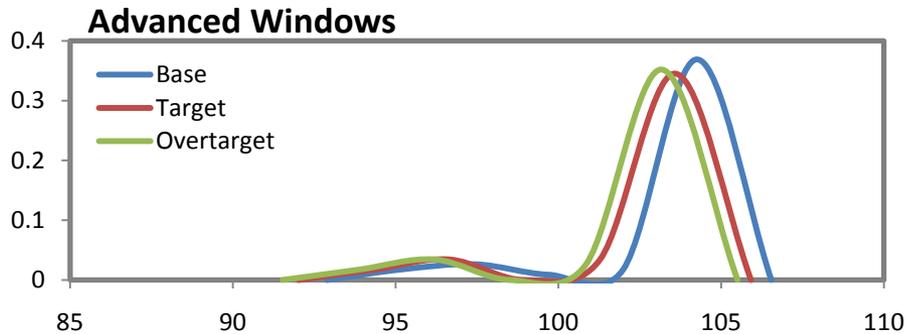
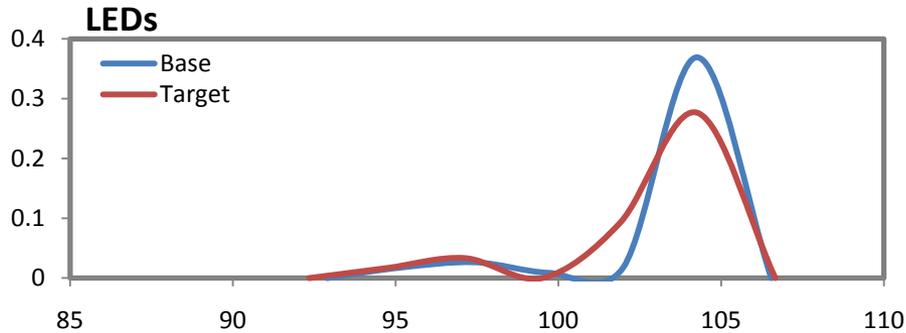
Likelihood of PV in 2030



Evaluating R&D Scenarios



Likely Cumulative Buildings Carbon Emissions 2005-2050



Gt CO₂

	[Gt]	μ	σ	savings
LEDs	B	103.45	2.24	--
	T	102.79	2.20	0.66
	O-T	--	--	--
Adv. Windows	B	103.45	2.24	--
	T	102.45	2.21	1.00
	O-T	101.95	2.20	1.50
PV	B	103.45	2.24	--
	T	102.16	2.99	1.29
	O-T	100.60	3.97	2.85

Conclusions



- What are the key values of SBEAM?
 - Uncertainty
 - Access
 - Flexibility
 - Collaboration
- Further development
 - Building Shell
 - Fuel Cells/CHP
 - Multi-service heat-pumps
- Other SEDS modules
 - Electricity
 - Transportation