SolarSIM: A Dynamic Technology Diffusion Model Simulating Adoption of Distributed Solar Technologies

EUEC Energy and Environment Conference

Phoenix, AZ, February 3, 2009

Cory Welch (presenter) & Frank Stern
Summit Blue Consulting

SUMMIT BLUE
CONSULTING, LLC

Overview

SUMMIT BLUE
CONSULTING, LLC

- Model Overview
- Model Methodology
- Development of Input
- Key Output and Initial Insights

SolarSIM Overview

SUMMIT BLUE CONSULTING, LLC

- SolarSIM is a dynamic market simulation model that:
  - simulates *distributed* solar **PV**, **hot water**, **day-lighting** adoption;
  - calculates **8760 impacts** on energy and demand;
  - disaggregates adoption into key customer **segments**;
  - incorporates **diffusion theory** using a stock/flow framework;
  - includes **dynamic** technology prices, tax credits, & incentives;
  - is **transparent,** highly **flexible,** and **user friendly**;
  - has been applied to DG analyses for a APS (part of RW Beck study)

Overview

- Model Overview
- Model Methodology
- Development of Input
- Key Output and Initial Insights

Technologies / Segments

Technology	Residential Application	Commercial Application
Photovoltaic	✓	✓
Solar Hot Water	✓	
Solar Daylighting		✓

C&I Segments
Small Office
Small Retail
Large Grocery
Warehouse
School Gym
Education
Large Office
Large Retail
Industrial
Other

Existing applications have focused on these technologies and segments.

However, SolarSIM is easily modified to address additional technologies and/or different customer segments.

SolarSIM User Interface[1]

SUMMIT BLUE CONSULTING, LLC

Key Input

Model Details

Capital Costs

Cost Reduction Profile	(dmnl)	Edit Table
Initial System Cost	($/kW, or $/kWh)	Edit Table
System Size	(kW/sys, or kWh/sys)	Edit Table
Number of Systems ...	(sys/bldg, or sys/1Ksq.ft)	Edit Table

Diffusion Elements

Initial Building Stocks	(Bldgs, or 1000 Sq. Ft)	Edit Table
Building Stock Growth Rate	(dmnl/Year)	2.42%
Sensitivity to Payback	(dmnl)	0.3
Technology Applicability	(dmnl)	Edit Table
Initial Adopters	(Bldgs, or 1000 sq. ft)	Edit Table
Initial Advertising Effectiveness	(dmnl)	246.8u
Initial Word of Mouth (WOM)	(dmnl)	0.4205

Incentives & Credits

Max $ Credit per Bldg	($/bldg)	Edit Table
Initial Percent Tax Credit	(dmnl)	Edit Table
Phase-Out Multiplier	(dmnl)	Edit Table
Utility Incentive Rate	($/W, or $/(kWh-yr)/sys)	Edit Table
Utility Energy Incentive - Comm	($/kWh)	Edit Table

Electricity Prices

Baseline Electricity Price	($/kWh)	Edit Table
Electricity Price Growth Rate		Edit Table

Other

Impact per System	(kWh/y/sys, or kW/sys)	Edit Table
Inflation Rate	(dmnl/year)	2.5%
Market Share for Illustration	(dmnl)	Calc mid

Key Output

Impacts

Impact	(MW, or MWh/yr)	Calc mid
Commercial Impacts, Lumped	(MW, or MWh/yr)	Calc mid
Commercial Impacts	(MW, or MWh/yr)	Calc mid
Residential Impacts	(MW, or MWh/yr)	Calc mid
Hourly Load Impacts - Total	(MWh/yr)	Calc mid
Hourly Load Impacts - Res	(MWh/yr)	Calc mid
Hourly Load Impacts - Comm	(MWh/yr)	Calc mid

Incentives & Credits

Cumulative Incentives	($)	Calc mid
Annual Incentives & Credits	($/year)	Calc mid
Combined Credits, Incent		Calc mid

Adoption

Net System Cost	($/bldg, or $/1Ksq.ft.)	Result mid
Payback Period	(Years)	Result mid
Payback Period (w/o incentives)	(Years)	Calc mid
Fraction Willing to Adopt (WTA)	(dmnl)	Result mid
Adoption Fraction	(dmnl)	Calc mid
Adopters	(Bldgs, or 1000 sq. ft)	Result mid
Cumulative Building Installations	(Bldgs)	Result mid

1. Developed in Analytica® -- see www.lumina.com

SolarSIM User Interface

SUMMIT BLUE CONSULTING, LLC

Key Input

Model Details

Capital Costs

Cost Reduction Profile	(dmnl)	Edit Table
Initial System Cost	($/kW, or $/kWh)	Edit Table
System Size	(kW/sys, or kWh/sys)	Edit Table
Number of Systems ...	(sys/bldg, or sys/1Ksq.ft)	Edit Table

Diffusion Elements

Initial Building Stocks	(Bldgs, or 1000 Sq. Ft)	Edit Table
Building Stock Growth Rate	(dmnl/Year)	2.42%
Sensitivity to Payback	(dmnl)	0.3
Technology Applicability	(dmnl)	Edit Table
Initial Adopters	(Bldgs, or 1000 sq. ft)	Edit Table
Initial Advertising Effectiveness	(dmnl)	246.8u
Initial Word of Mouth (WOM)	(dmnl)	0.4205

Incenti
Max $ Cre
Initial Per
Phase-Ou
Utility Ince
Utility Ene
Electri
Baseline
Electricity
Other
Impact pe
Inflation R
Market Sh

Key Output

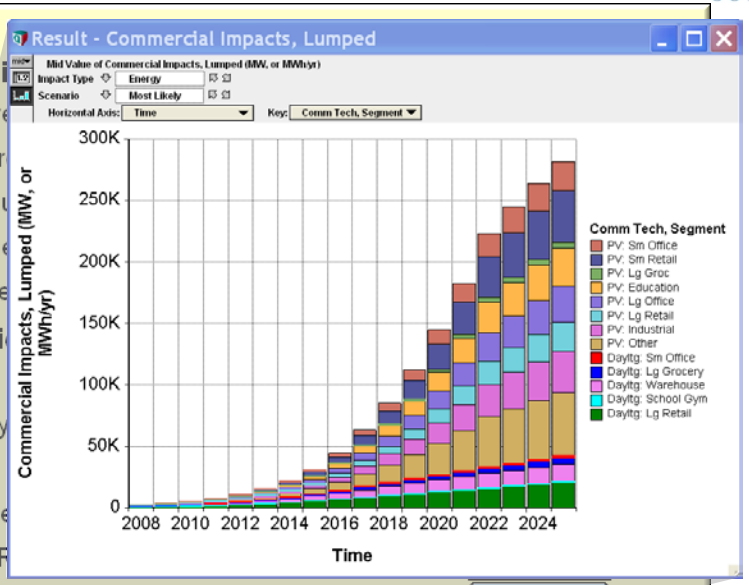
Impacts

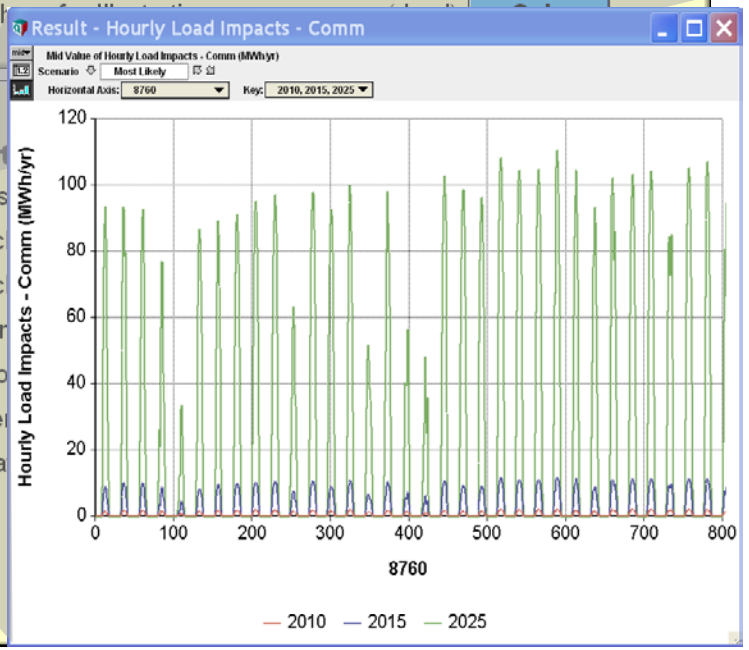
Impact	(MW, or MWh/yr)	Calc	mid
Commercial Impacts, Lumped	(MW, or MWh/yr)	Calc	mid
Commercial Impacts	(MW, or MWh/yr)	Calc	mid
Residential Impacts	(MW, or MWh/yr)	Calc	mid
Hourly Load Impacts - Total	(MWh/yr)	Calc	mid
Hourly Load Impacts - Res	(MWh/yr)	Calc	mid
Hourly Load Impacts - Comm	(MWh/yr)	Calc	mid

Incentives & Credits

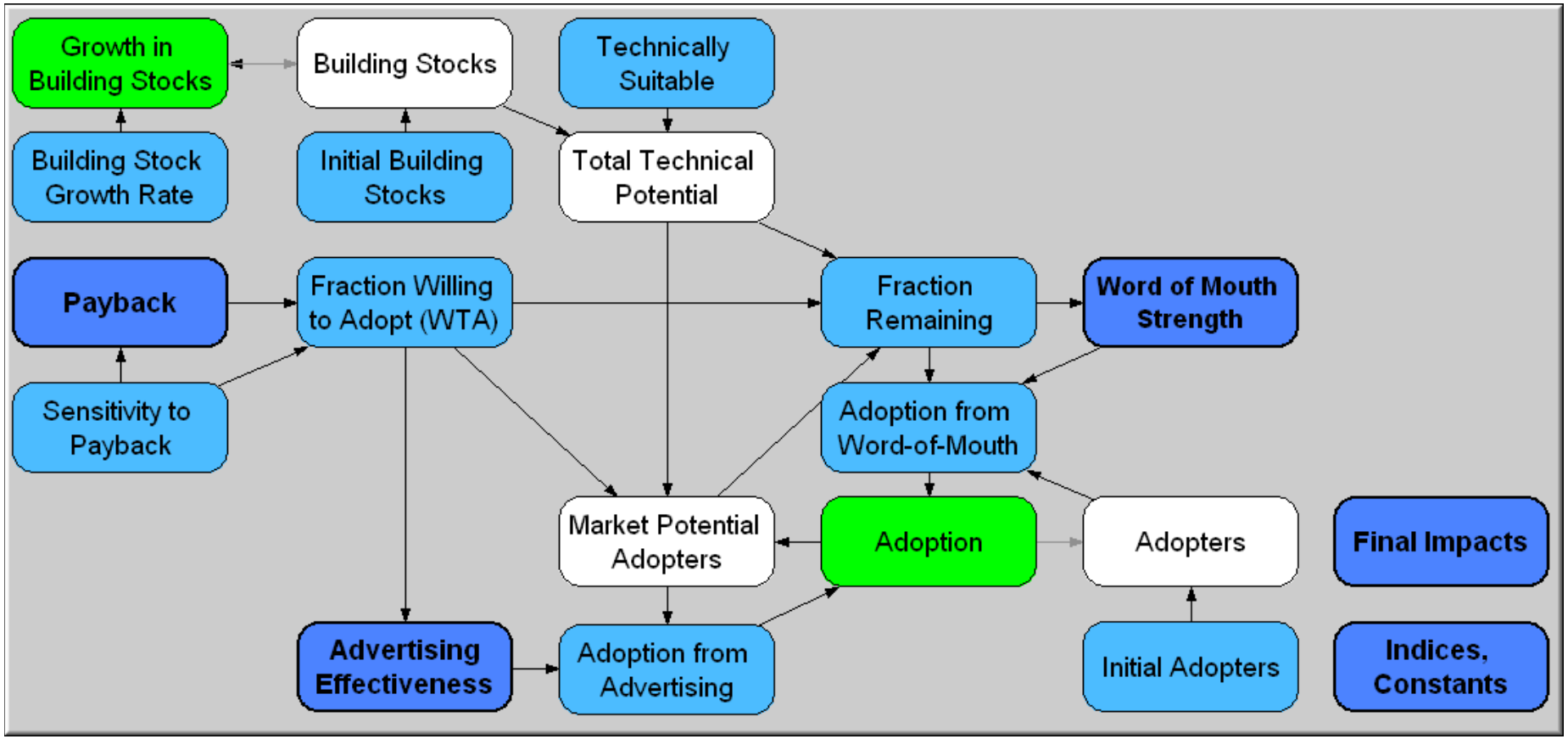
Cumulative Incentives	($)	Calc	mid
Annual Incentives & Credits	($/year)	Calc	mid
Combined Credits, Incent		Calc	mid

Adopt
Net Sys
Paybac
Paybac
Fraction
Adoptio
Adopter
Cumula





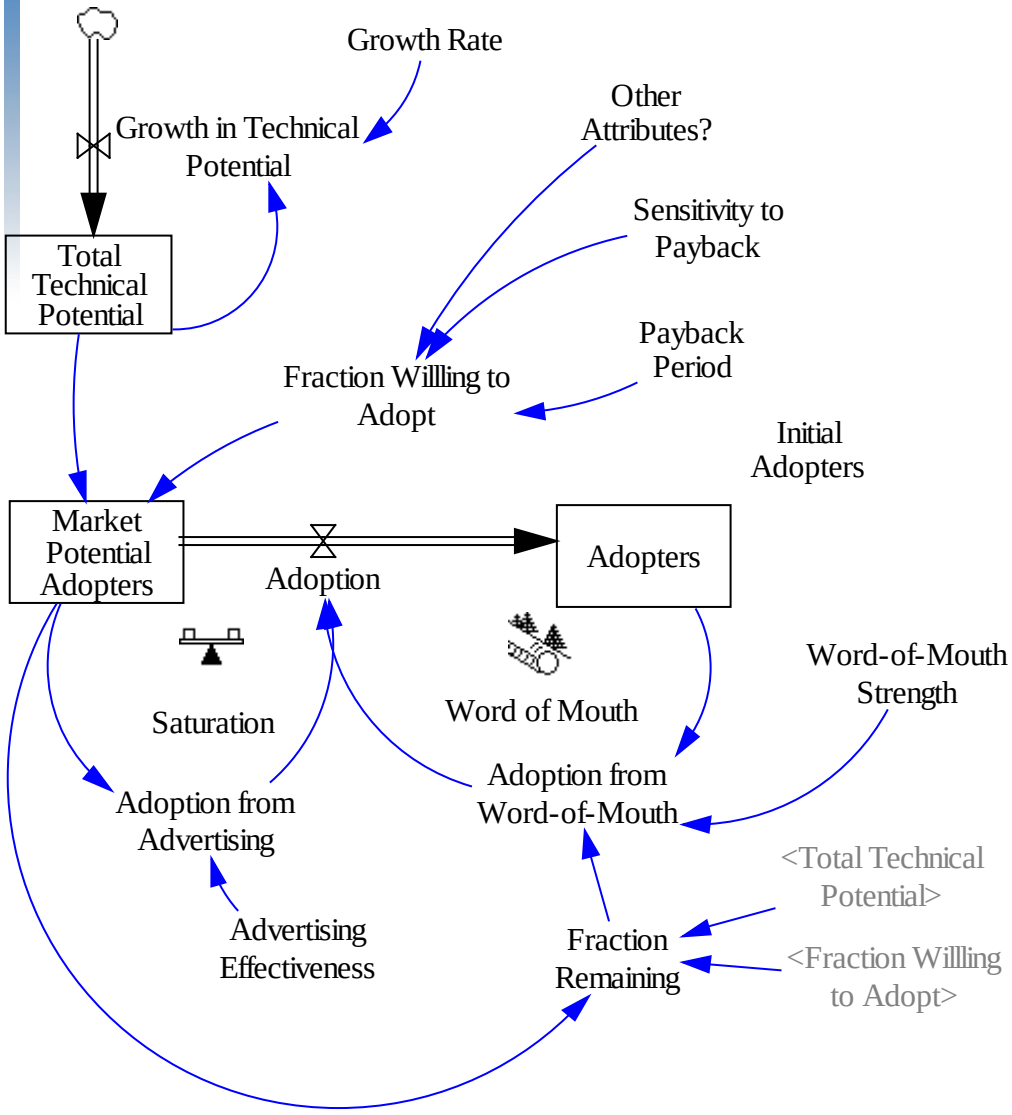
Technology Diffusion

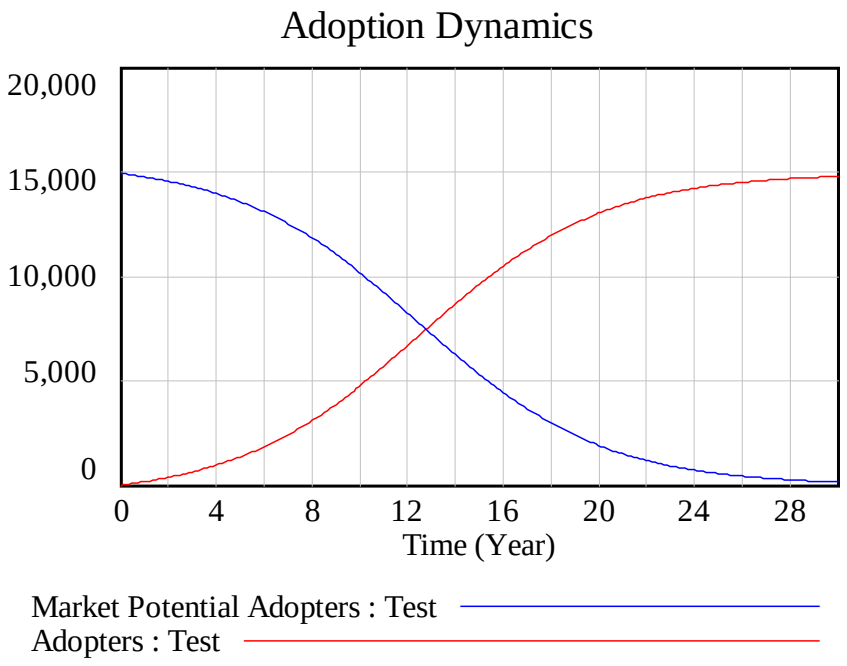


We developed an enhanced version of the Bass diffusion model[1], with diffusion parameters based on analysis of other PV adoption data (e.g., in Germany, CA, and NJ).

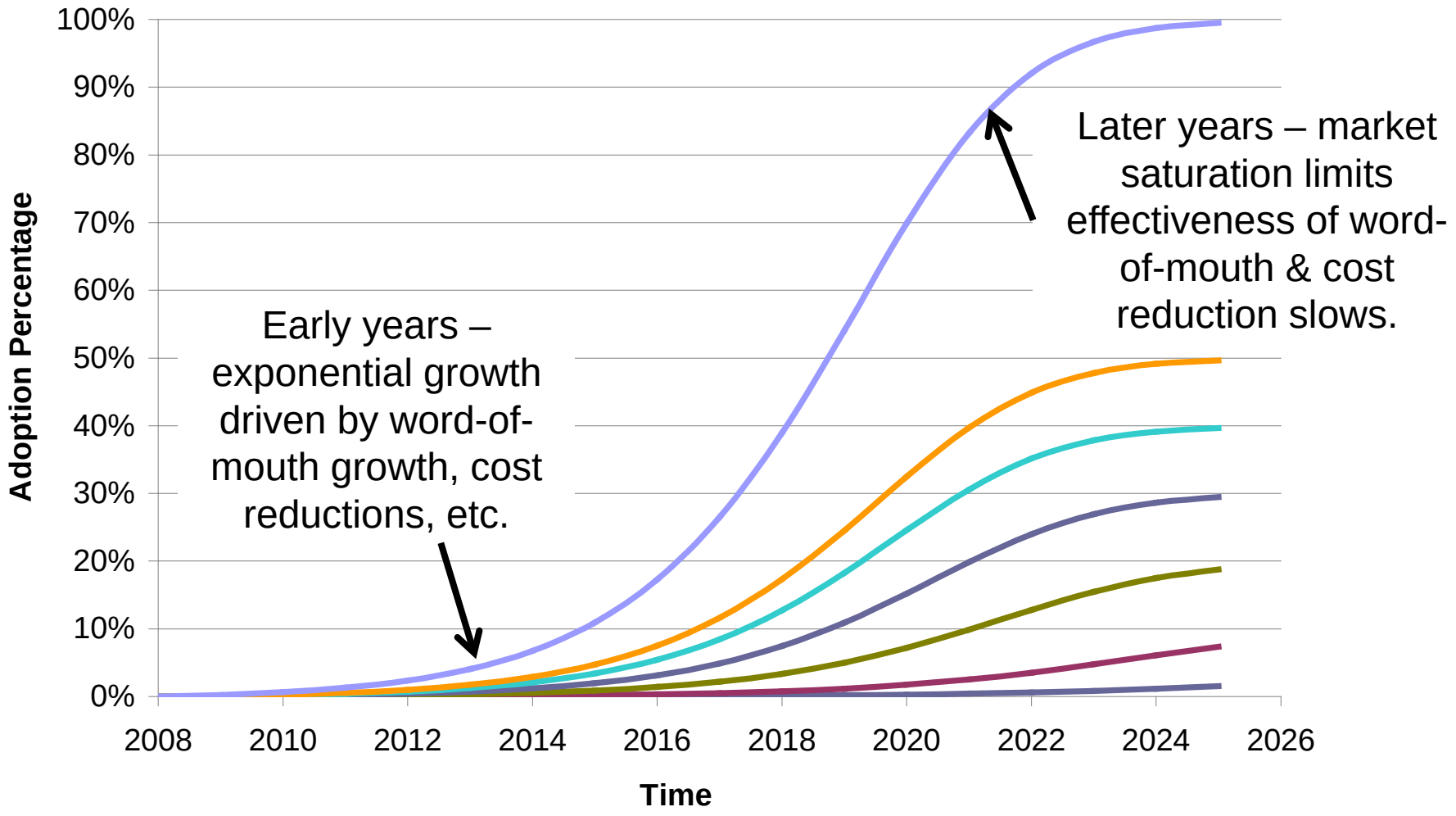
1. See Sterman, John D. *Business Dynamics: Systems Thinking and Modeling for a Complex World*. Irwin McGraw-Hill. 2000. p. 332.

Bass Diffusion Model





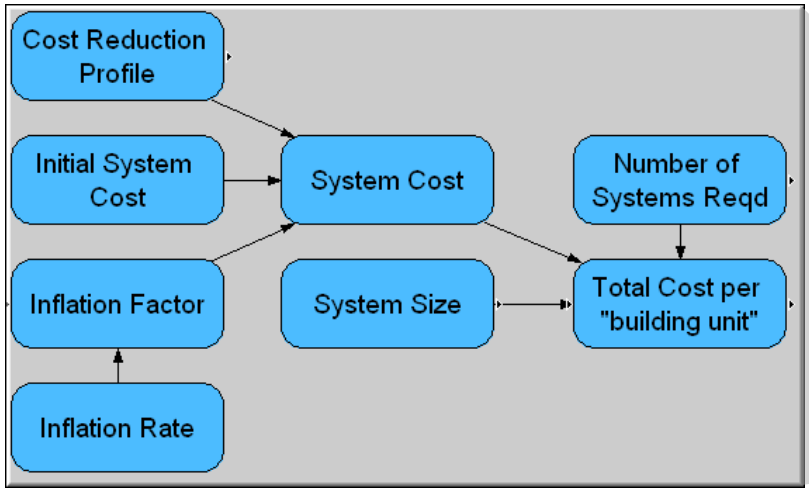
Example Diffusion Curves

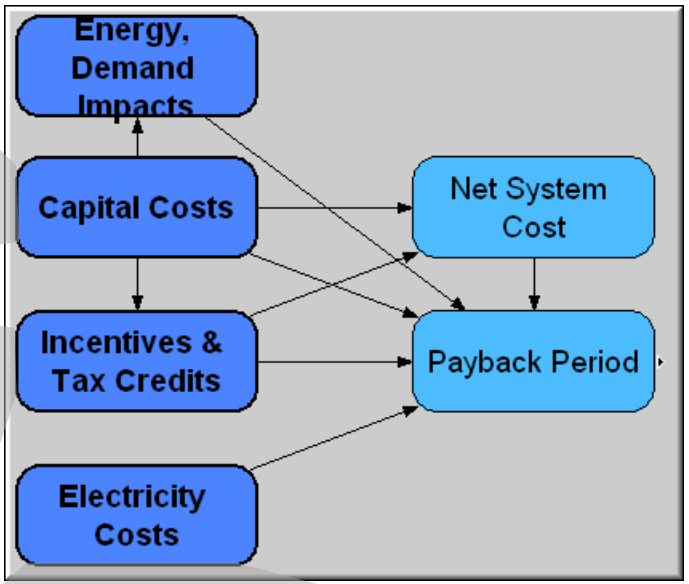


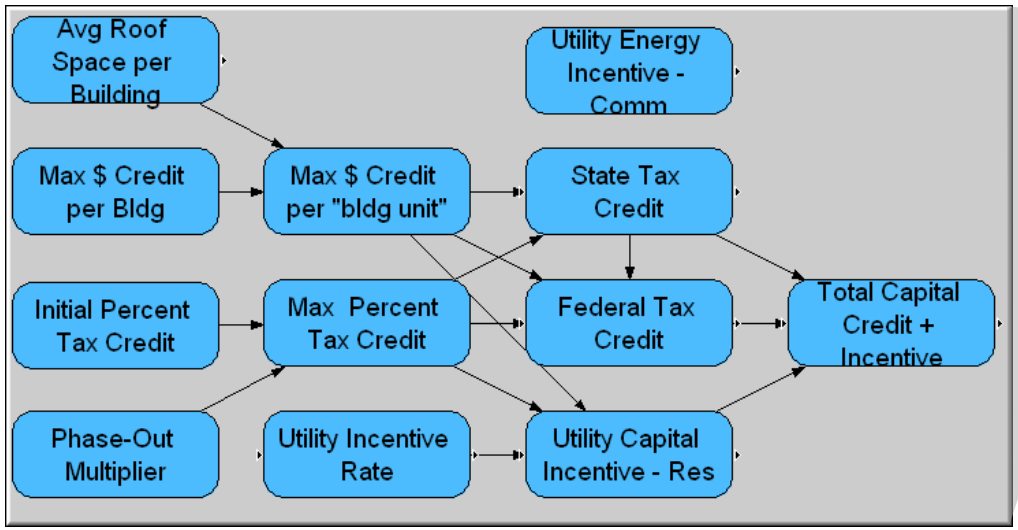
Curves illustrated here are simplified for illustration of various penetration profiles for different final adoption values. Simulated penetration curves will vary and are dependent on many factors, including prices/incentives over time, initial values, etc..

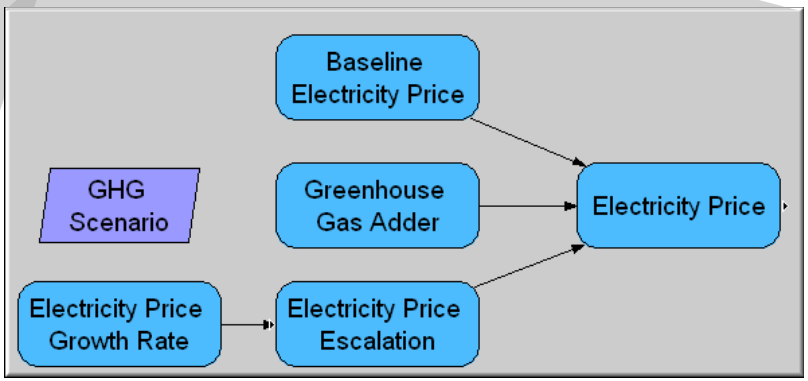
Payback Calculations

SUMMIT BLUE CONSULTING, LLC









Overview

- Model Overview
- Model Methodology
- Development of Input
- Key Output and Initial Insights

Key Model Input

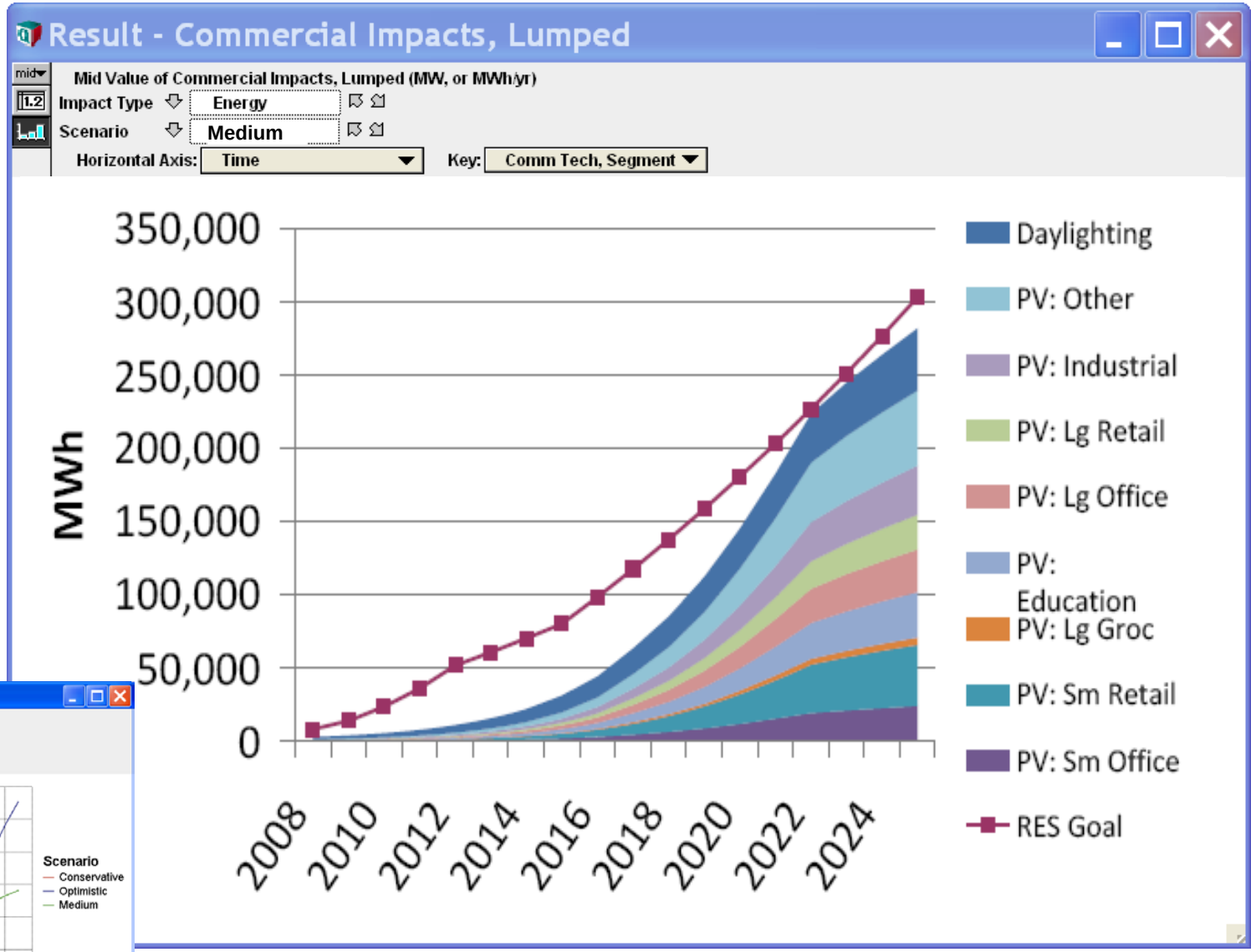
SUMMIT BLUE CONSULTING, LLC

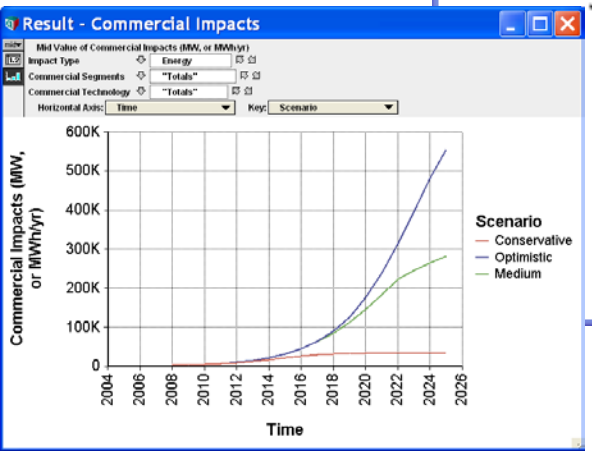
- Customer Characterization
  - Utility customer data, census data, CBECS, utility baseline & end-use studies
- Energy & Demand Impacts
  - Solar Hot Water: EnergyPlus (DOE)
  - Solar PV: Solar Advisor Model (SAM -- NREL)
  - Daylighting: eQuest (enhanced version of DOE-2)
- Technology Costs & Incentive
  - DOE forecasts (PV) and various industry data.
- Diffusion Parameters
  - Germany, New Jersey & CA diffusion data

Overview

- Model Overview
- Model Methodology
- Development of Input
- Key Output and Initial Insights

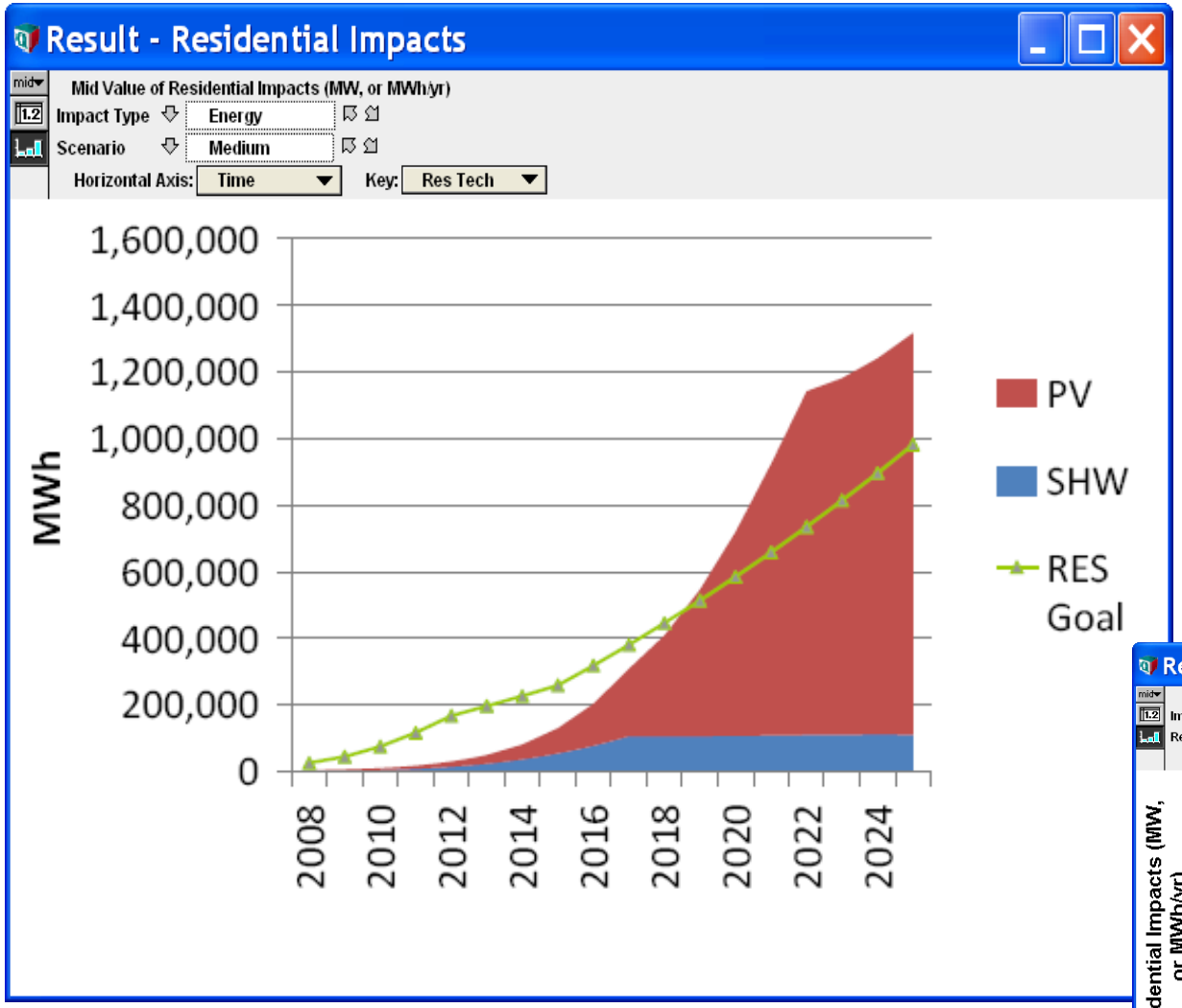
Example[1] Output – C&I Energy

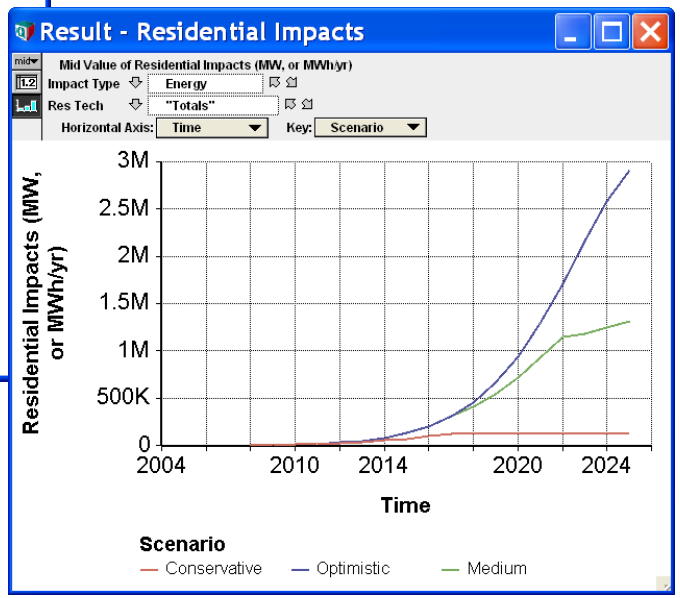




1. For illustration only

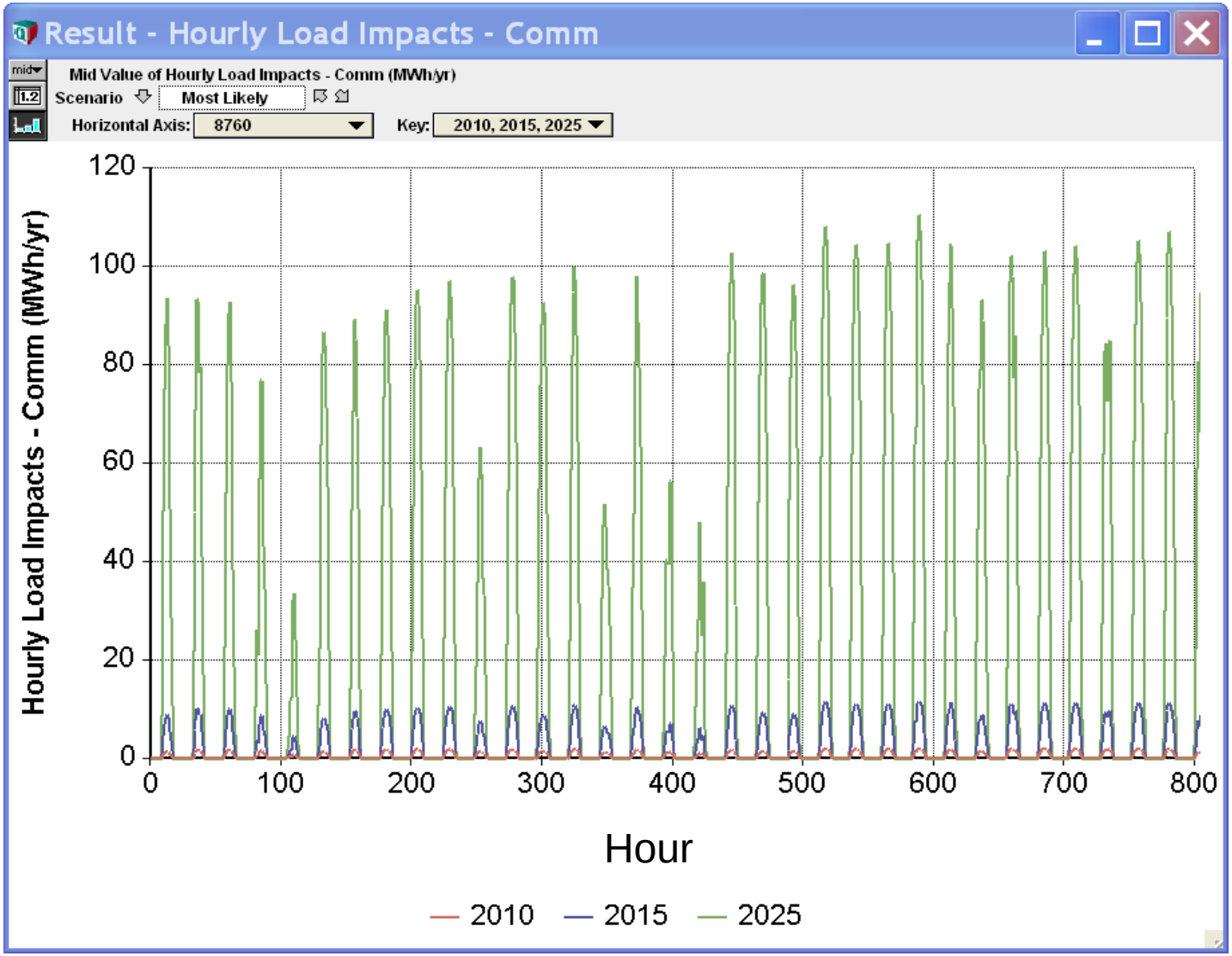
Example[1] Output – Res. Energy





1. For illustration only

Example[1] Output – 8760 Impacts



1. For illustration only

Initial Insights

- Diffusion highly sensitive to assumptions regarding:
  - price reduction assumptions
  - tax credits & utility incentives
  - assumptions regarding consumer willingness to pay
- Continued cost reduction, credits, incentives necessary
  - renewable energy standard targets may be difficult to reach in conservative scenarios
- Technology is initially slow to diffuse – word-of-mouth awareness accelerates adoption later
  - incentives/credits removed too early can stall adoption
  - Renewable energy standard targets tend to be more linear and difficult to achieve in early years
- Enhanced understanding of consumer decision-making and sensitivities could narrow adoption uncertainty

?’s

Contact Information

Cory Welch, Frank Stern

Summit Blue Consulting

cwelch@summitblue.com

fstern@summitblue.com

720-564-1130