Benefits Analysis of Irvine Smart Grid Projects

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U.S.-China Climate Change Working Group - Smart Grid

- A joint U.S.-China research effort and dialogue on climate change
- Launched by Secretary Kerry and State Councilor Yang in 2013 as a three-year program (2014-2016)
- Two sub-groups: Advanced Technology & Benefits
- Benefits Subgroup picked 2+ smart grid demonstrations on each side for benefits analysis (BA)
- U.S. ones are
    1. Irvine Smart Grid Demonstration Project (ISGD) & U.C. Irvine campus (UCI),
    2. The Philadelphia Navy Yard (TNY)
- China ones are
    1. Sino-Singapore Tianjin Eco-city (TEC)
    2. Shenzhen Bay Technology and Ecology City (B-TEC)
- Benefits subgroup outcomes: Foundation for common approaches to benefits analysis to provide transferable methods and results to accelerate dissemination and deployment of smart grid technology

Outline

- Benefits Analysis Method
- Project Descriptions
  - Irvine Smart Grid Demonstration (ISGD)
  - U.C. Irvine Campus
- Results
- Key Limitations of SGCT

- Benefits Analysis

EPRI-DOE Method & SGCT Tool

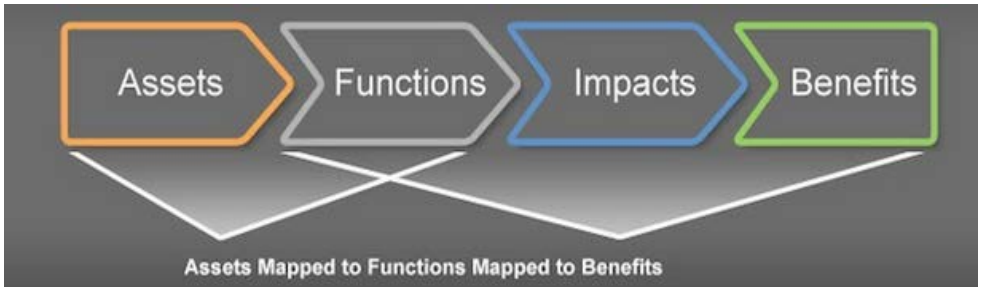
EPRI-DOE Benefits Analysis Method

In order to develop a standard framework that can be applied by anyone interested in assessing the benefits of smart grid projects,

1. *U.S. Department of Energy (DOE),*
2. *Electric Power Research Institute (EPRI),*

jointly develop a methodology to systematically estimate the benefits of smart grid projects.

Benefits are derived from the types of assets (i.e., components, technologies) deployed in a smart grid project and the types of functions they enable.

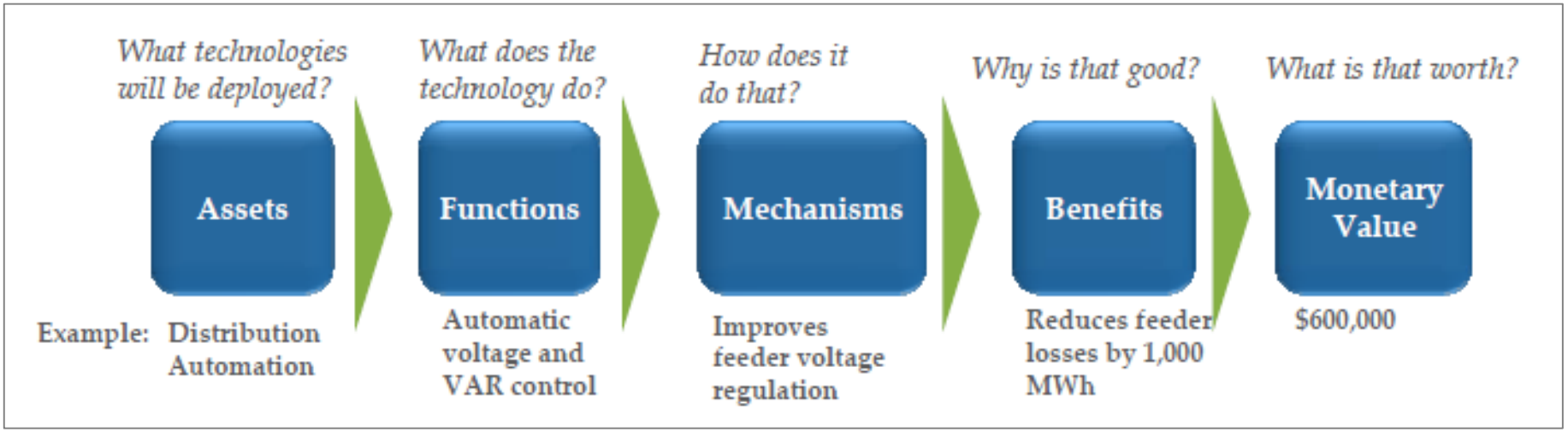


Source: https://www.smartgrid.gov/recovery_act/program_impacts/analytical_approach

Smart Grid Computational Tool (SGCT)

SGCT is developed based on EPRI-DOE method. Benefits categories included in SGCT:

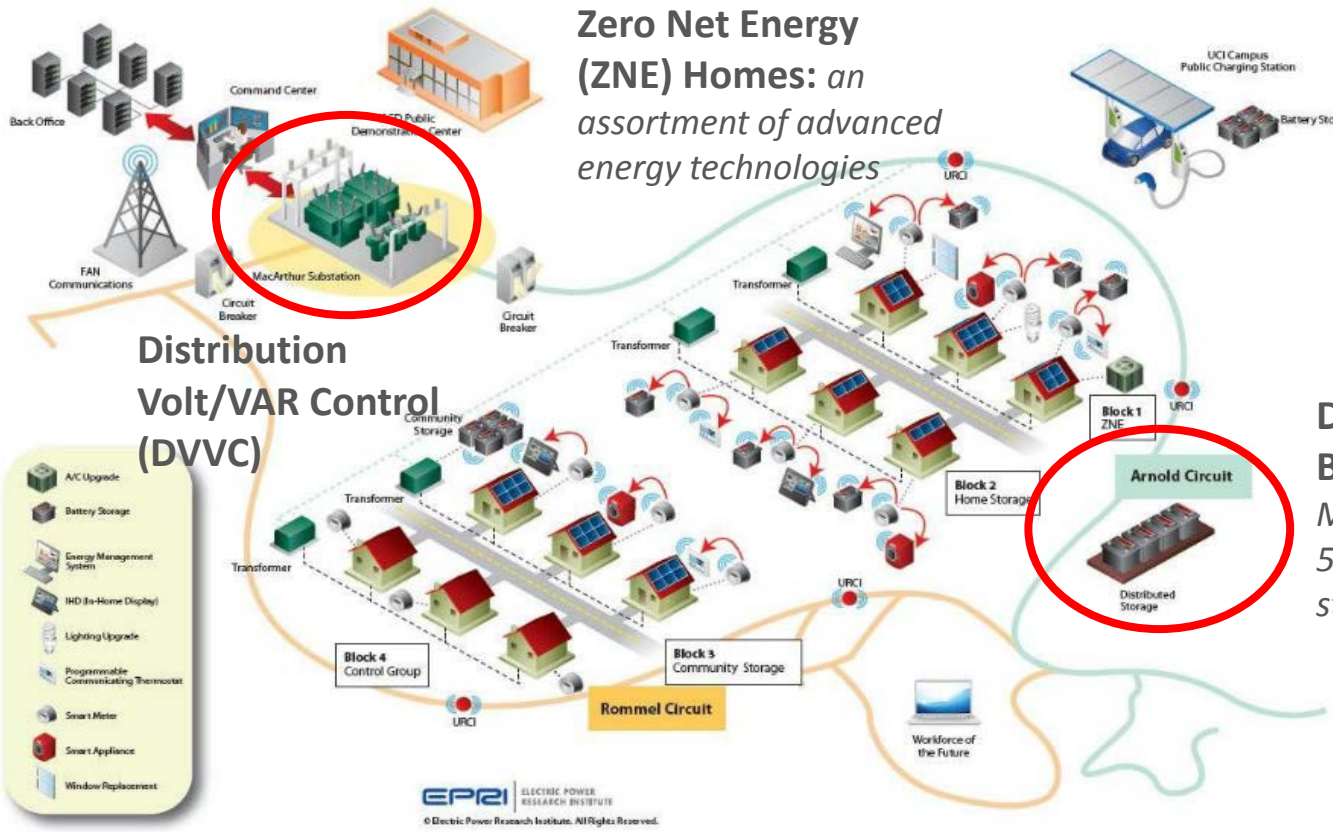
1. *Economic:* reduced costs, or increased production at the same cost
2. *Reliability and power quality:* reduction in interruptions and power quality events
3. *Environmental:* reduced greenhouse gas emissions and other pollution
4. *Security and safety:* improved energy security, increased cybersecurity, and reductions in injuries, loss of life, and property damage



- # Project Descriptions

ISGD & U.C. Irvine Campus

Irvine Smart Grid Demonstration Project (ISGD)



Zero Net Energy (ZNE) Homes: *an assortment of advanced energy technologies*

Distribution Volt/VAR Control (DVVC)

Distribution Level Battery (DBESS): *2 MW of real power and 500 kWh of energy storage*

Southern California Edison (SCE) operated the ISGD project, and many of the project components were located on or near UCI.

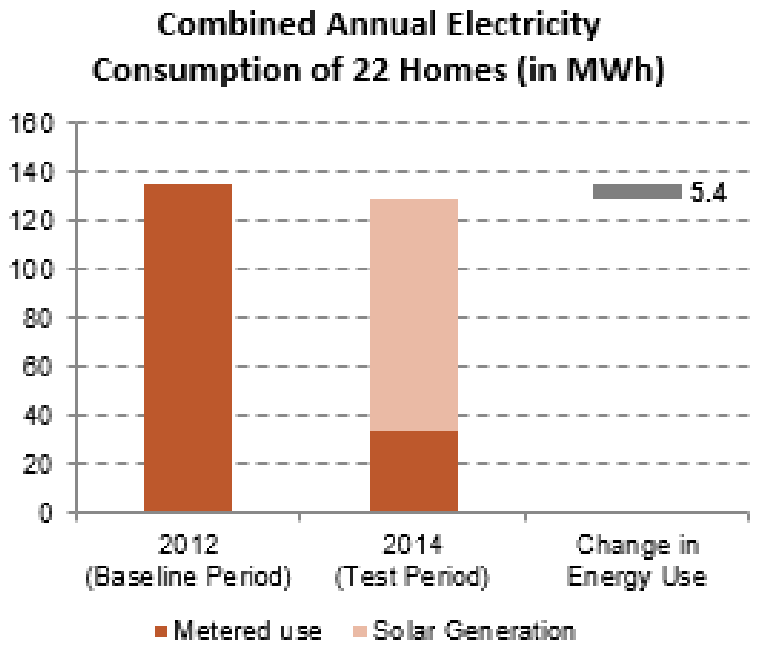
ISGD - ZNE

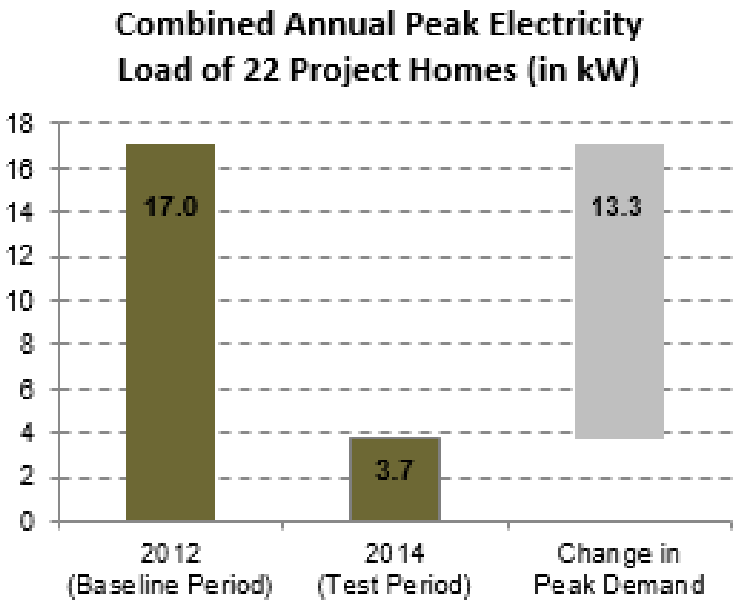
- Multiple technologies deployed to improve customers' net energy consumption, usage patterns and grid performance:
  1. Devices capable of demand response:

     smart refrigerators, clothes washers, dishwashers, electric vehicle charging stations, programmable communicating thermostats, home energy management systems, and in-home displays
  2. Energy efficiency upgrades:

     heat pumps, all LED lighting upgrades, insulation, solar hot water heaters, low flow shower heads, and smart power strips and load timers
  3. Residential energy storage units
  4. Community energy storage device
  5. Solar PV arrays

ISGD - ZNE Energy and Peak Savings





NOTE: Note that the significant amount of energy savings in the houses are in natural gas, not electricity, which is not shown here. The substitution of heat pump heating in the Sub-project 1 tends to increase electricity consumption, as do the addition of electric vehicles, while PV and other measures reduce it. Here, only the electricity balance is reported, so whether these homes met the ZNE standard is not answered.

ISGD - DBESS & DVVC

- Distribution Level Battery (DBESS)

  2 MW / 500 kWh energy storage device used to help:

  - Prevent the distribution circuit load from exceeding a set limit
  - Reduce peak load on the circuit

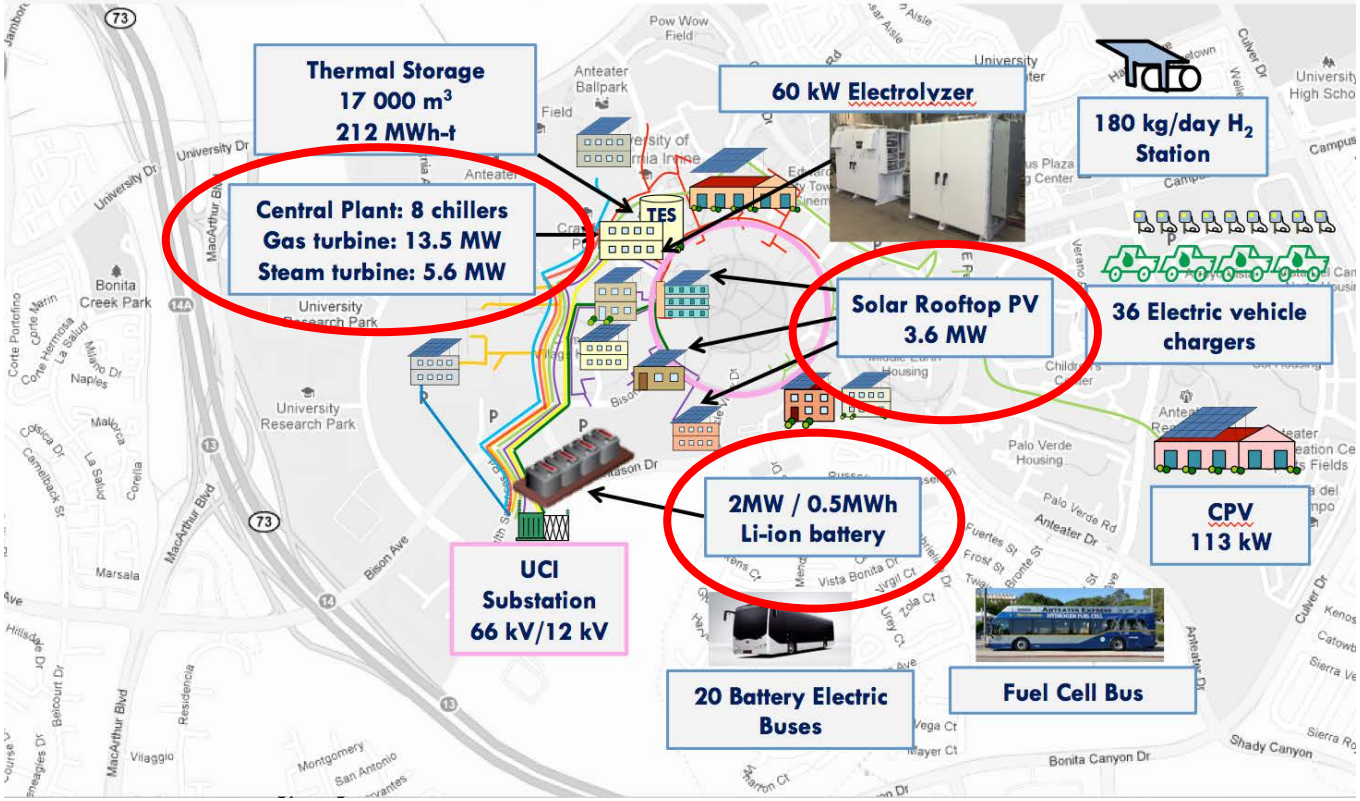
- Distribution Volt/VAR Control (DVVC)

  Volt/VAR control to help:

  - Reduce voltage on the distribution feeder and provide VAR support to the transmission system
  - Reduce peak load and electricity consumption of customers serviced from Mac Arthur substation (7 circuits / ~8,300 customers)

Field experiments showed 2.6 % energy savings from DVVC on the seven circuits, served from MacArthur substation.

U.C. Irvine, Campus



+ **Microgrid Controller (MgC)** (complete by 2017)

- Net zero carbon goal by 2025, while providing increased reliability and reduced operating costs.

U.C. Irvine - CHP & Solar PV

- 19 MW CHP Plant (currently installed)

  a 13.5 MW gas turbine, a heat recovery steam generator (HRSG), a duct burner, and a 5.5 MW steam turbine

  - HRSG supplies 99 % of the heating loads on the campus through the district heating system. Additional steam is used to drive the steam turbine.
  - The gas turbine and steam turbine supply about 96 % of the electrical needs on the campus

- 3.6 MW Solar PV (currently installed)

  893 kW installed on the rooftops of 12 buildings and an additional 2.6 MW installed on three parking structures

  - 3.5 % of the electricity used on the campus

NOTE: Low penetration is largely a result of the minimum turndown of the gas turbine to remain in emissions compliance and the inability of the UCI microgrid to export to the utility.

U.C. Irvine - MgC & Solar PV

- MgC (to be installed Fall 2016)

  will enable

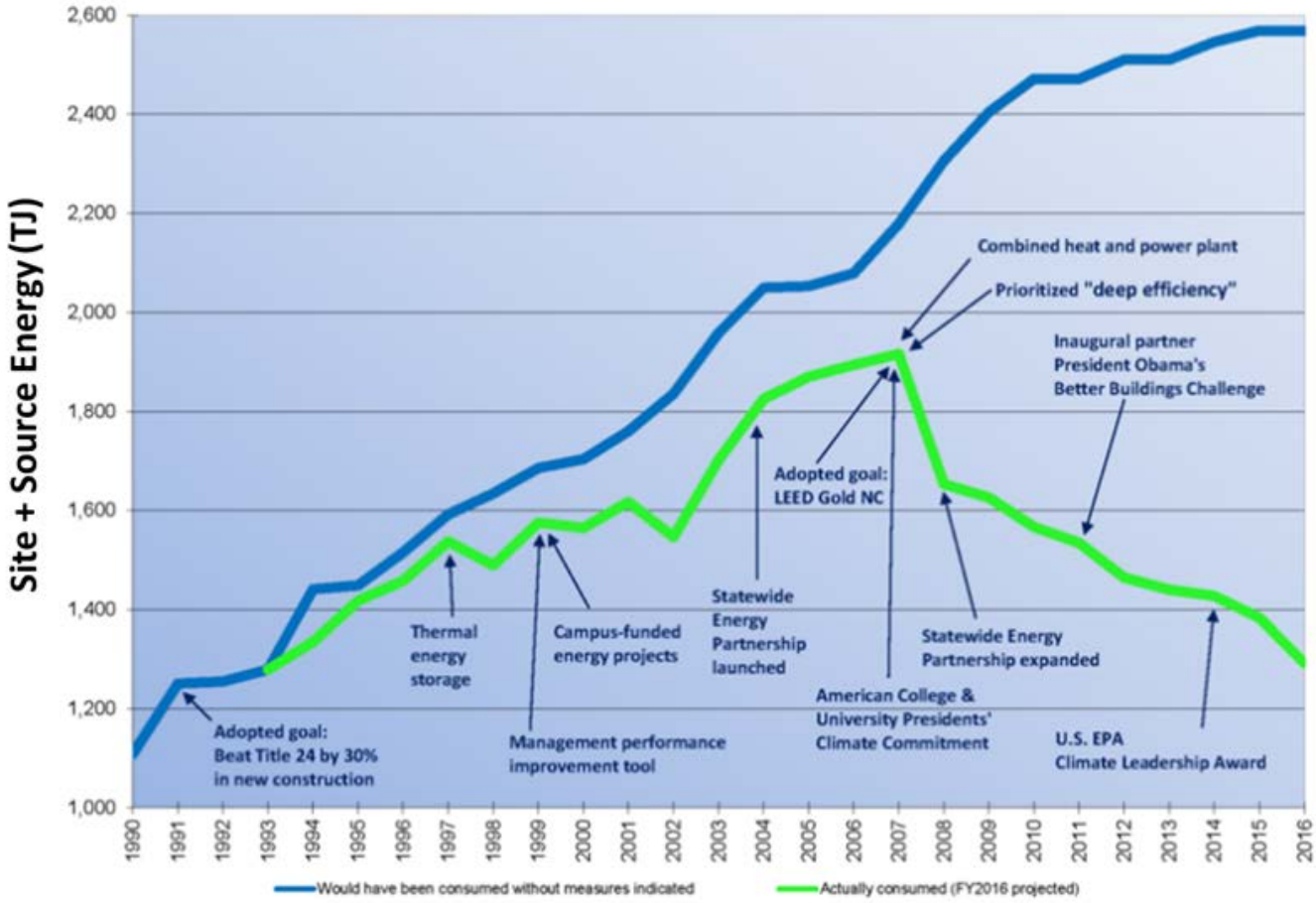
  - islanding from the utility system
  - efficient, reliable, and resilient operation with reduced emissions
  - existing and future ancillary services

- 2 MW Battery (currently installed)

  recently installed 2 MW-0.5 MWh lithium-ion iron phosphate battery consists of battery, auxiliary equipments, and 12 kV interconnection skids used to help:

  - reduce electricity import from the utility
  - as a balancing resource during islanding

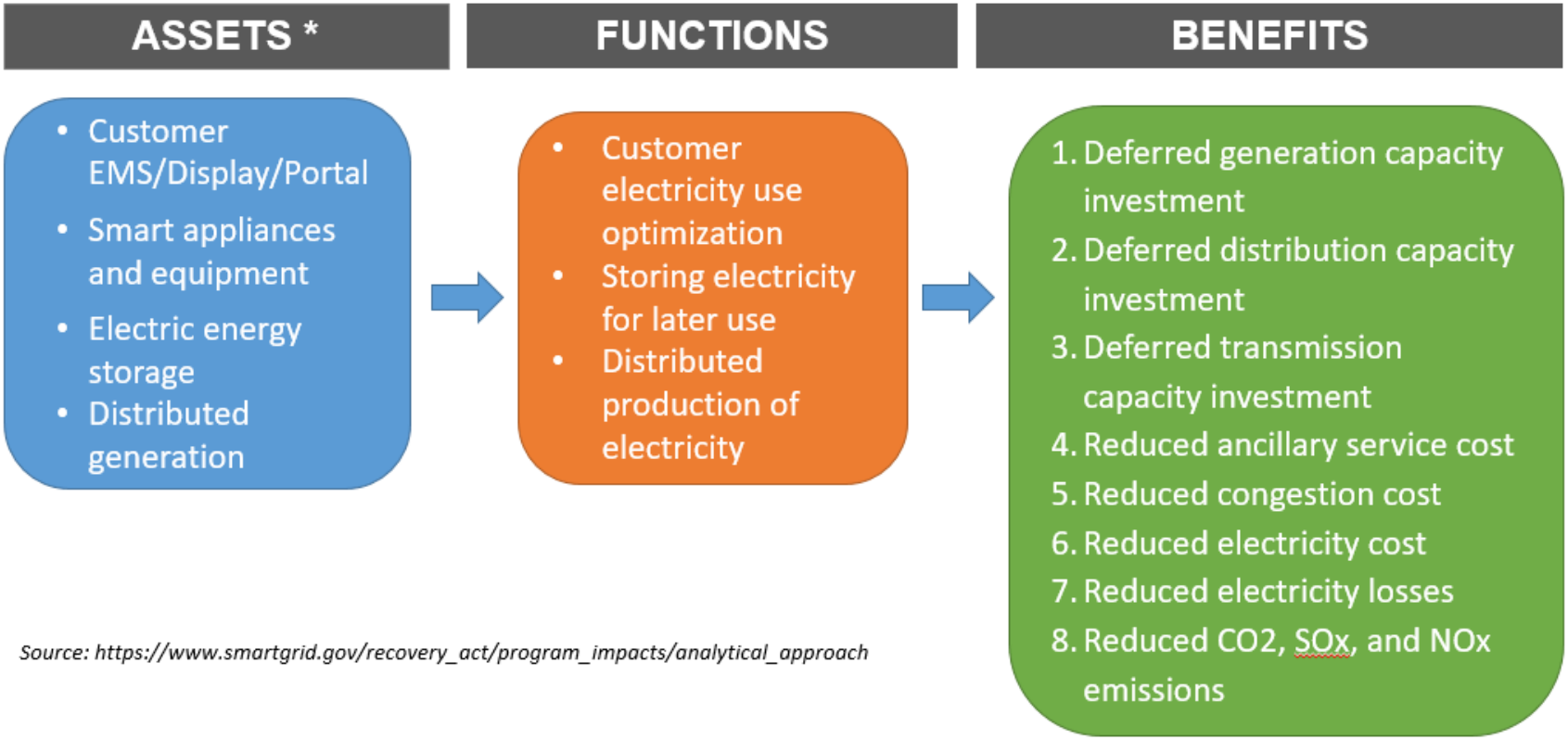
U.C. Irvine energy use reduction history



Benefits Analysis Results

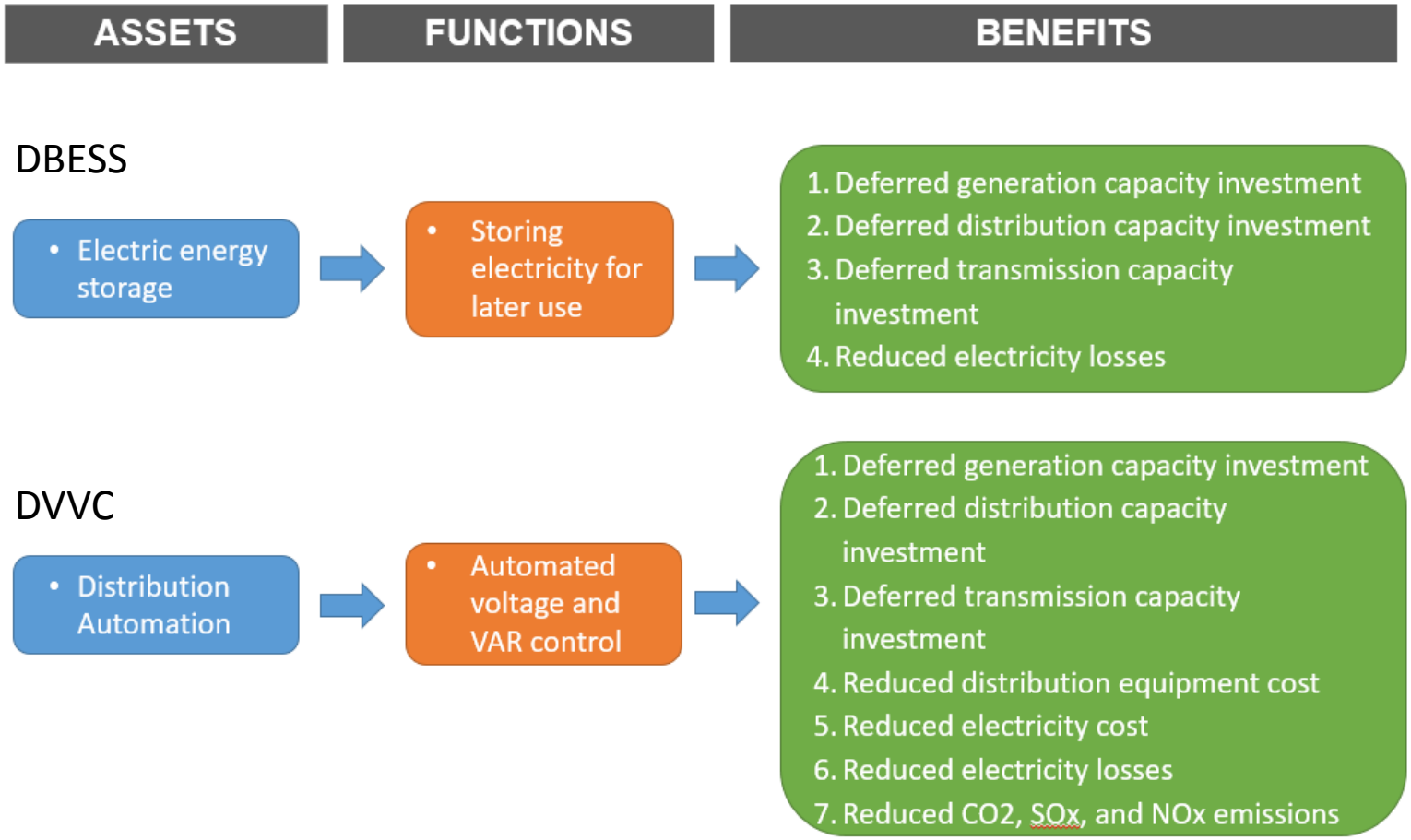
ISGD & U.C. Irvine Campus

ISGD - ZNE
SGCT Set up



Source: https://www.smartgrid.gov/recovery_act/program_impacts/analytical_approach

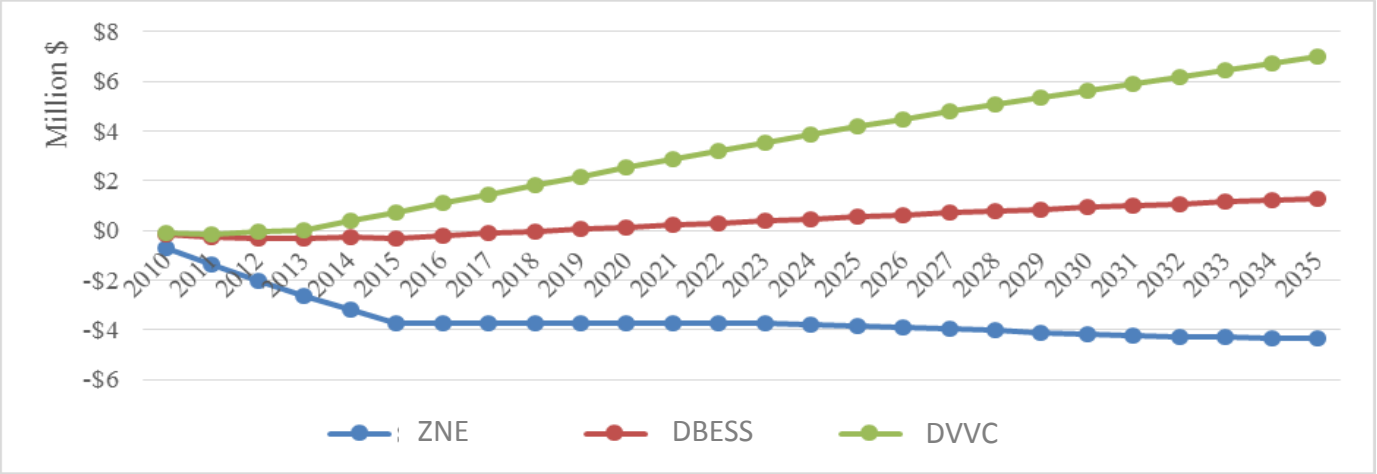
ISGD - DBESS & DVVC SGCT Set up



ISGD - BA Results

	ZNE	DBESS	DVVC
NPV (of annual cost)	$(4.64M)	$(0.85M)	$(0.59M)
NPV (of annual benefit)	$0.30M	$2.14M	$7.58M
NPV (of annual net benefit)	$(4.34M)	$1.30M	$6.99M
B/C Ratio	0.1	2.5	12.9

Cumulative net present benefits of each Sub-project



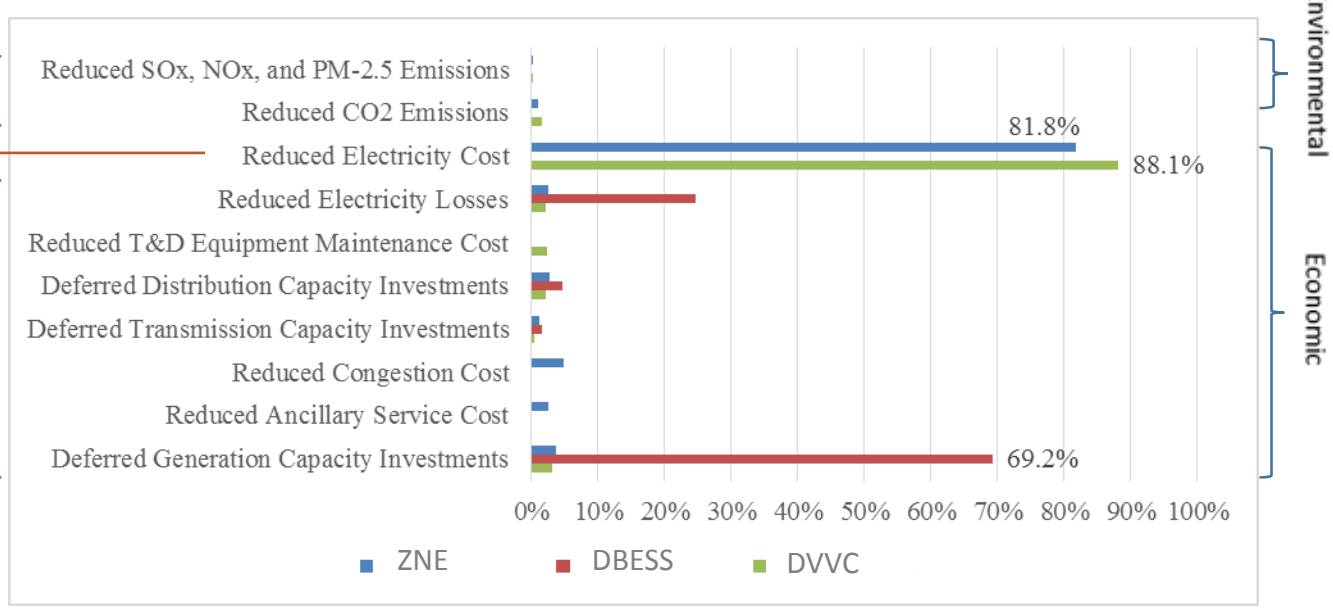
ISGD - Distribution of Benefits

ISGD stakeholder groups for benefits

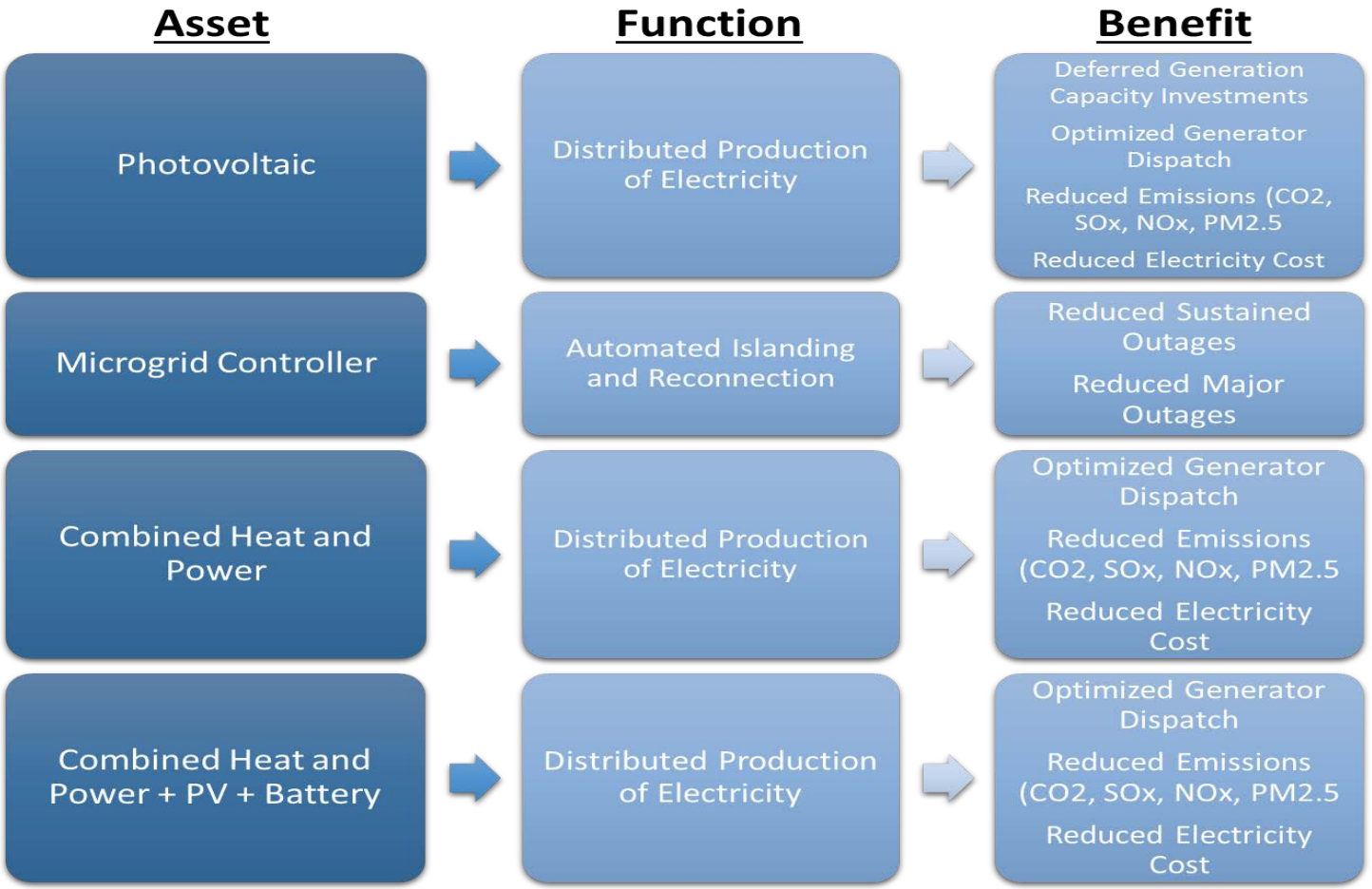
Society benefits

Customer benefits

Utility benefits



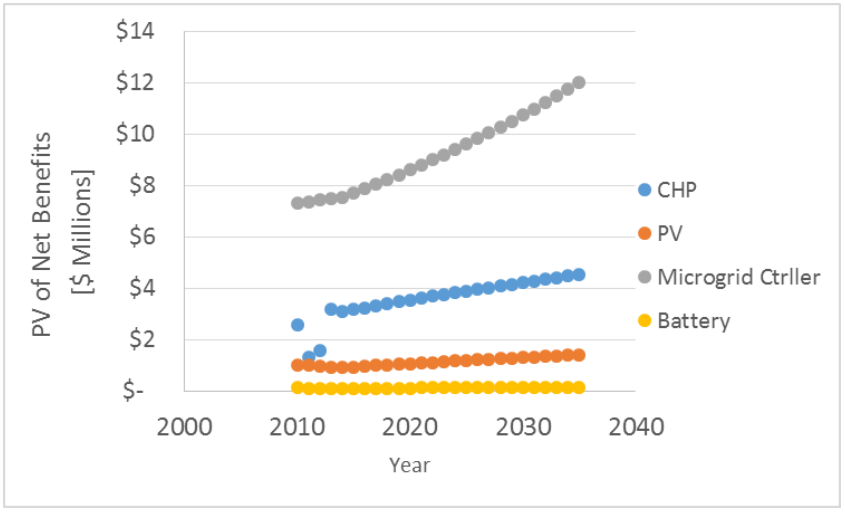
U.C. Irvine - SGCT Set up



U.C. Irvine - BA Results

	CHP	PV	Microgrid Controller	Battery
NPV (of annual cost)	$ (1.22M)	$ (0.55M)	$ (0.05M)	$ (0.02M)
NPV (of annual benefit)	$ 4.95M	$ 1.73M	$ 9.68M	$ 0.14M
NPV (of annual net benefit)	$ 3.72M	$ 1.18M	$ 9.64M	$ 0.12M
B/C Ratio	4.0	3.2	212	6.8

Cumulative net present benefits of each Sub-project



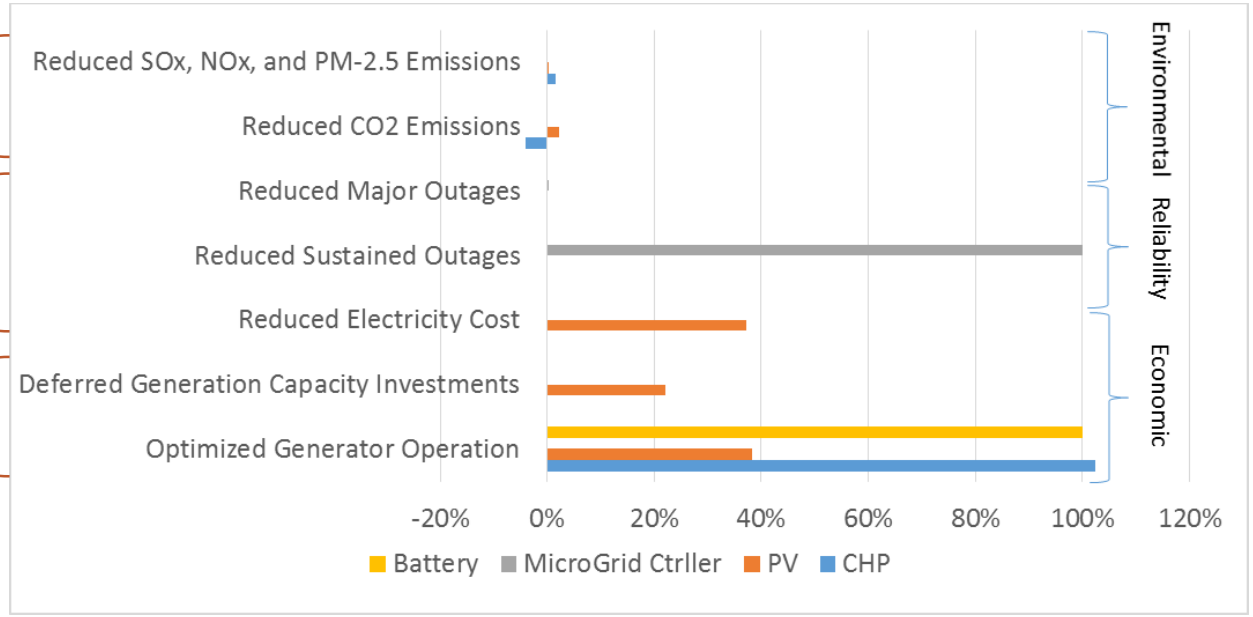
U.C. Irvine - Distribution of Benefits

U.C. Irvine stakeholder groups for benefits

Society benefits

Customer benefits

Utility benefits



Key Limitations of SGCT

- Some technologies do not necessarily map to all their benefits
  - e.g., DVVC function to energy cost benefit (addressed in analysis shown here by manual adjustments)
- Some benefits also missing
  - e.g., Battery storage asset to reliability benefit
- SGCT cannot be edited
- Tariff representation is simple (constant)
- Treatment of uncertainty and variation over time are limited
- Nothing on scaling up of projects is provided

Thank you

ISGD - ZNE Retrofits

- Three blocks of single family detached homes with different characteristics:
  1. Zero Net Energy (ZNE) block (9 homes)
     a. Demand response devices
     b. Energy efficiency upgrades
     c. Residential energy storage units (4 kW)
     d. Solar PV arrays (~3.9 kW)
  2. Residential Energy Storage (RESU) block (6 homes)
     a. Demand response devices
     b. Residential energy storage units (4 kW)
     c. Solar PV arrays (3.2-3.6 kW)
  3. Community Energy Storage (CES) block (7 homes)
     a. Demand response devices
     b. Community energy storage unit (25 kW)
     c. Solar PV arrays (3.2-3.6 kW)

General Assumptions - ISGD

- Distribution and transmission losses: 4.8% and 2.7%,
- The value of T&D capacity is based on projected total cost to add capacity system wide over a 5-10 year horizon, although actual benefits, will depend on the location of peak reductions,
- Societal discount rate: 5% / inflation factor: 2.4% / load growth: 1.6%,
- Value of CO2, NOx, and SOx: $12/tCO2, $3000/tNOx, $250/tSOx,
- Analysis period: 25 year.

NOTE: The analysis and results reported here should be regarded as preliminary and intended to be illustrative for the purpose of demonstrating and assessing the SGCT.