U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

Grid-Interactive Efficient Buildings Overview

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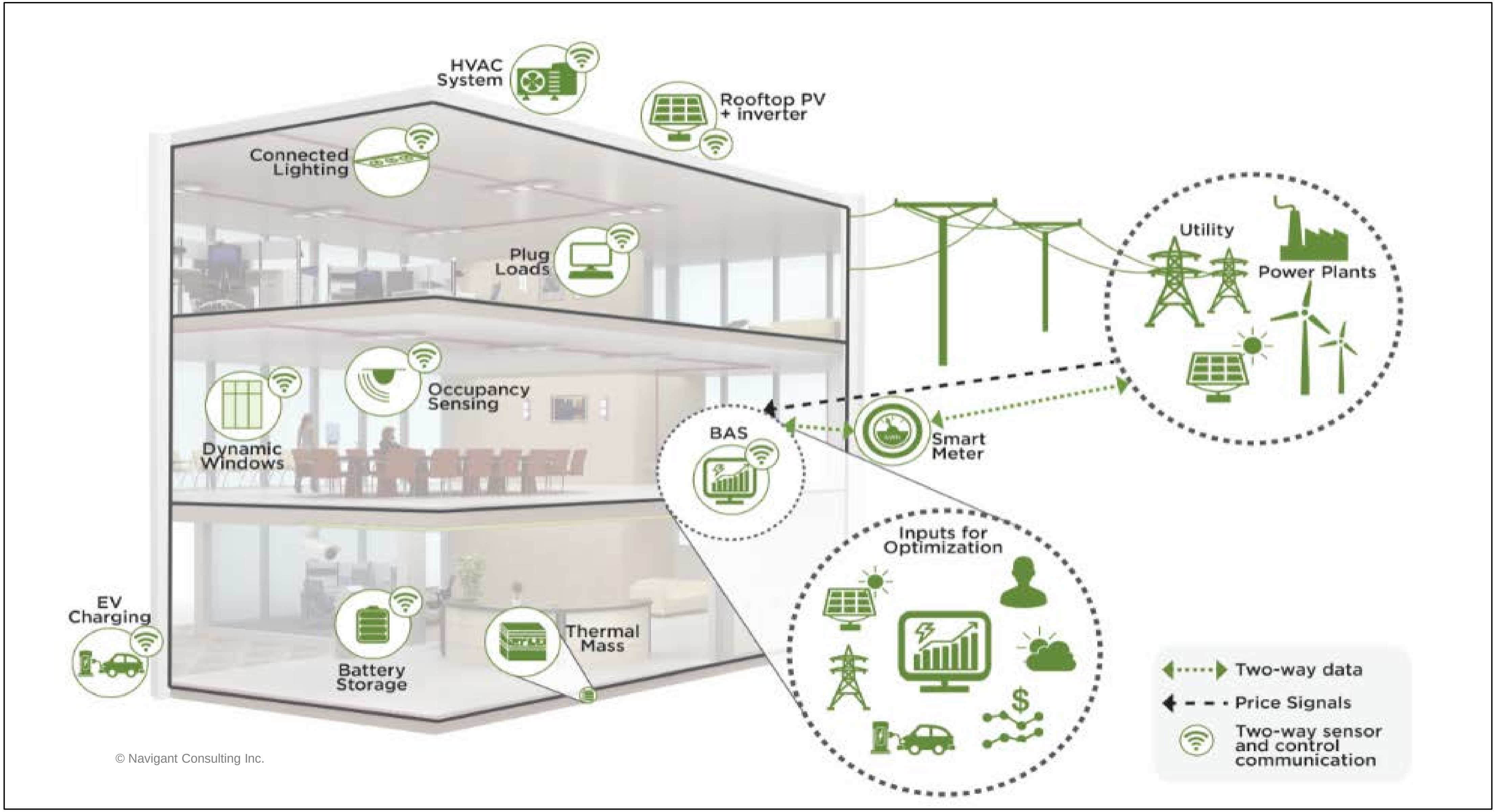
Grid-interactive Efficient Building



Key Characteristics of GEB

EFFICIENT

Persistent low energy use minimizes demand on grid resources and infrastructure

CONNECTED

Two-way communication with flexible technologies, the grid, and occupants

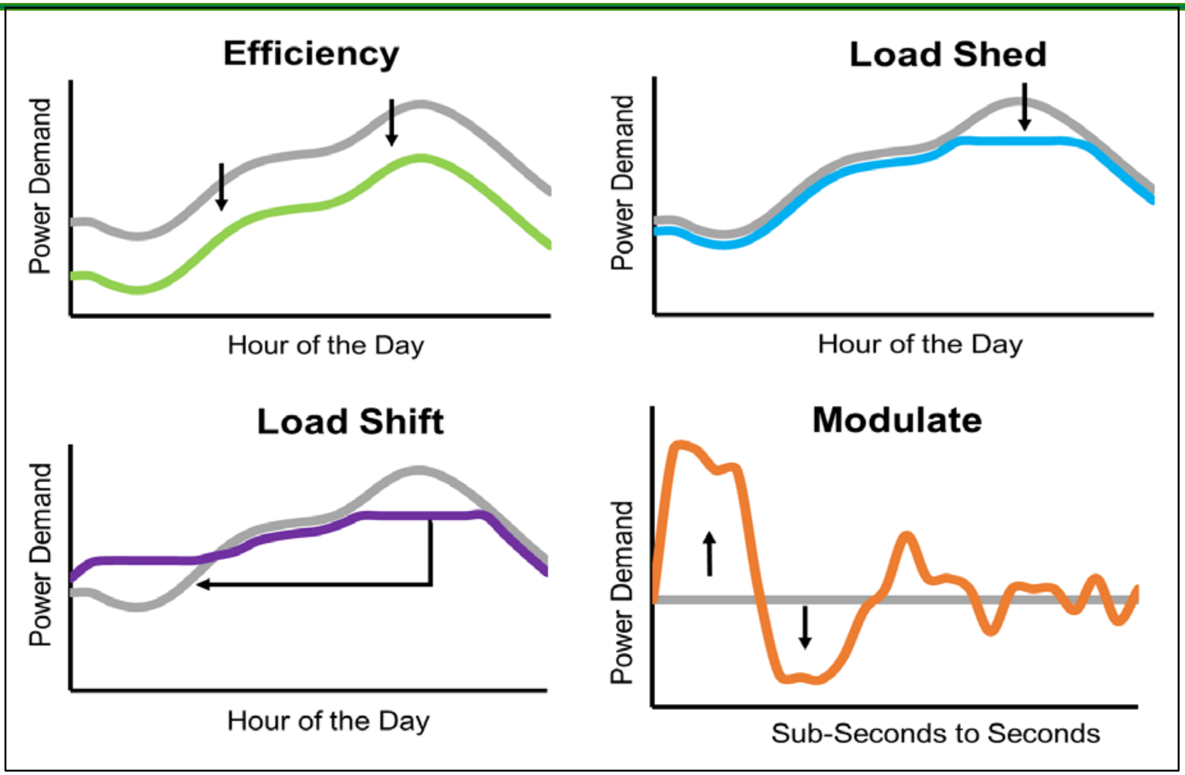
SMART

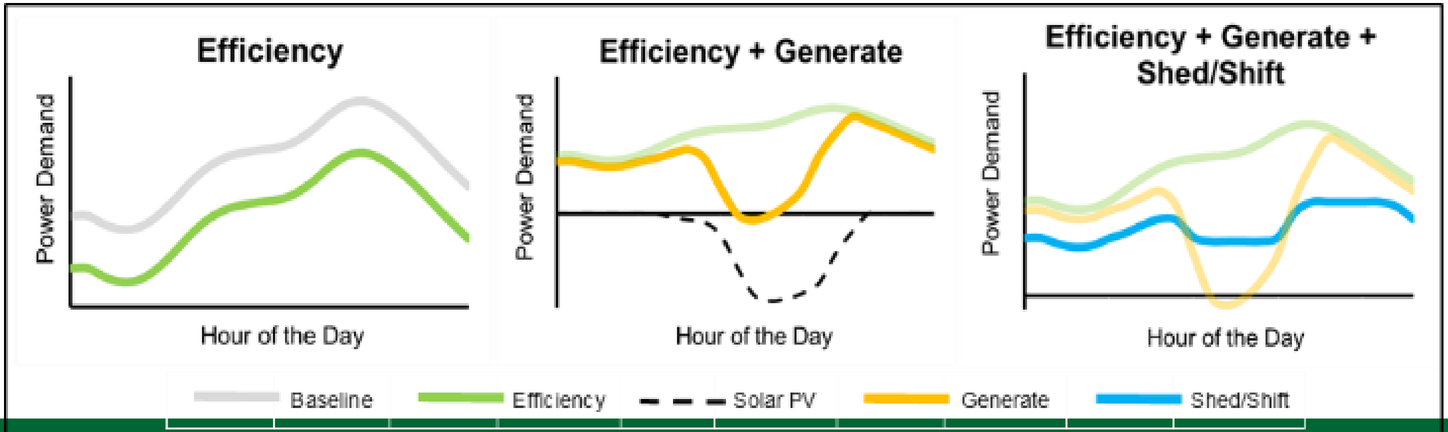
Analytics supported by sensors and controls co-optimize efficiency, flexibility, and occupant preferences

FLEXIBLE

Flexible loads and distributed generation/storage can be used to reduce, shift, or modulate energy use

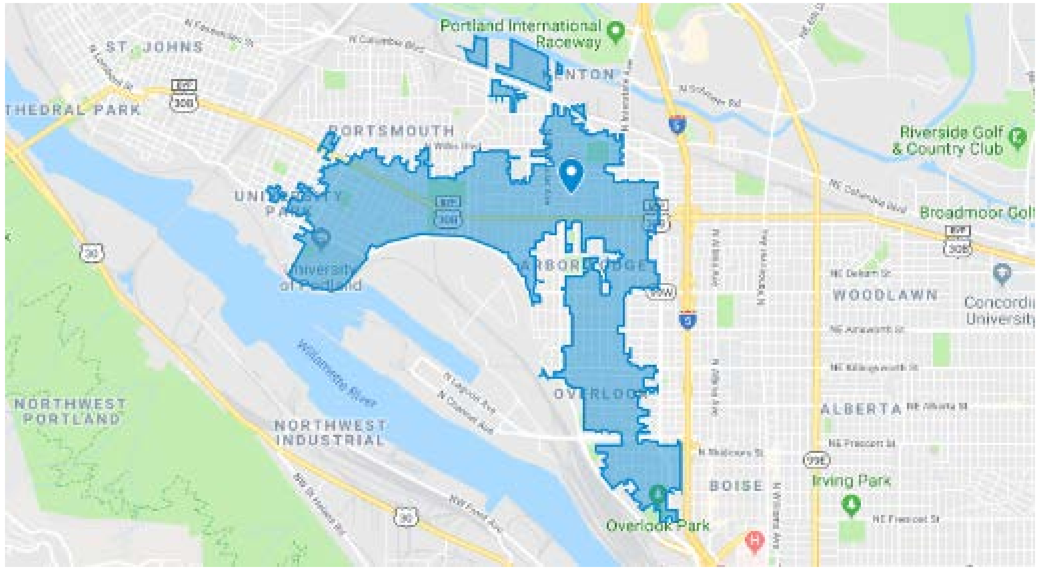
Demand Flexibility Provided by GEB





Example utility pilot: Portland General Electric Test Bed

- **Demand flexibility during summer/winter peak events**
- **Identify coordination opportunities for co-deployment of energy efficiency and demand response**
- **Residential customers**
  - T'stats, direct load control, heat pump water heaters, EV chargers, battery storage
  - Value propositions
  - Peak time rebate
- **Small and medium businesses**
  - Direct installation of smart thermostats
  - Plans to add EV charging and storage
  - Coordinating with Energy Trust of Oregon on efficiency and solar incentives
- **Focusing on neighborhoods served by 3 distribution substations**
- **Targeting 69 MW in summer and 77 MW in winter to fill a 2021 capacity gap identified in Integrated Resource Plan**



https://www.portlandgeneral.com/our-company/energy-strategy/smart-grid/smart-grid-test-bed
https://edocs.puc.state.or.us/efdocs/UAA/uaa173123.pdf
https://www.portlandgeneral.com/-/media/public/documents/rate-schedules/sched_013.pdf

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BTO’s grid-interactive efficient buildings portfolio

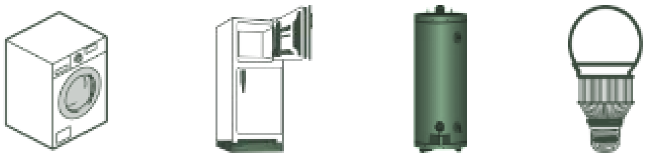
VALUATION

How do <u>*time & the interaction of flexibility options*</u> impact value?

Identify values to stakeholders, quantification of national value.

TECHNOLOGY OPTIONS

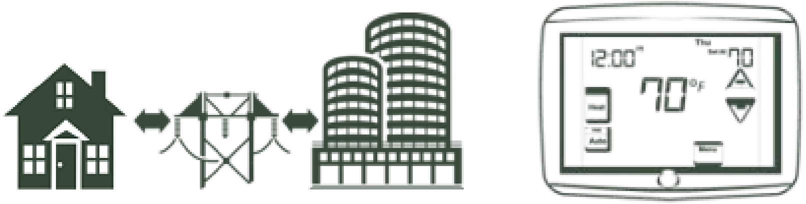
Which <u>end use technologies</u> provide solutions to specific grid needs?



Prioritize technologies / solutions based on grid services.

OPTIMIZATION

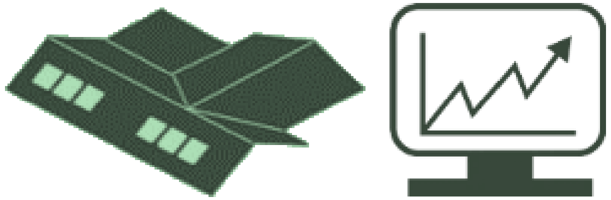
How to maintain or improve services while <u>optimizing for flexibility</u>?



Solutions that meet grid operator & building occupant needs.

VALIDATION

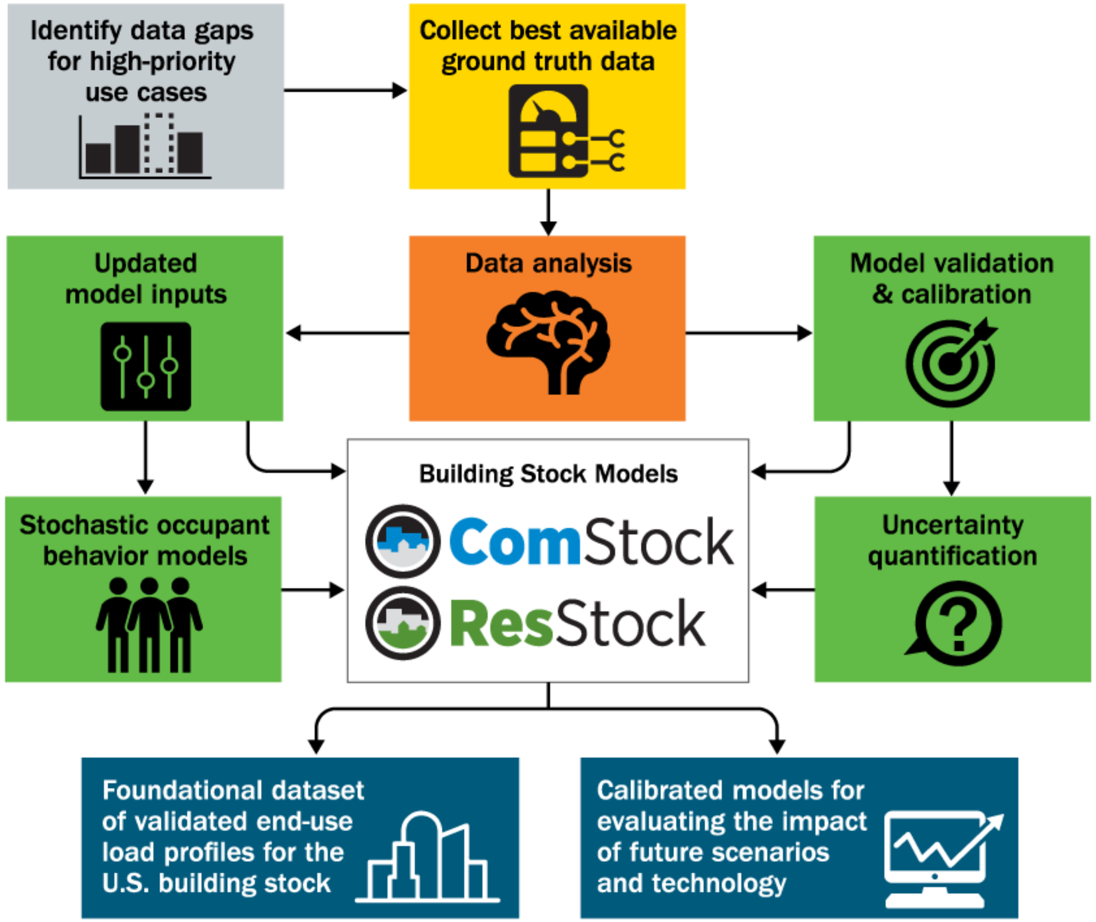
Do technologies <u>perform as predicted</u> and meet grid & occupant needs?



Verification of technologies / strategies, increasing confidence in the value of energy flexibility.

Valuation – Example Projects

Tools to Improve Valuation



Stakeholder Feedback on Value Proposition

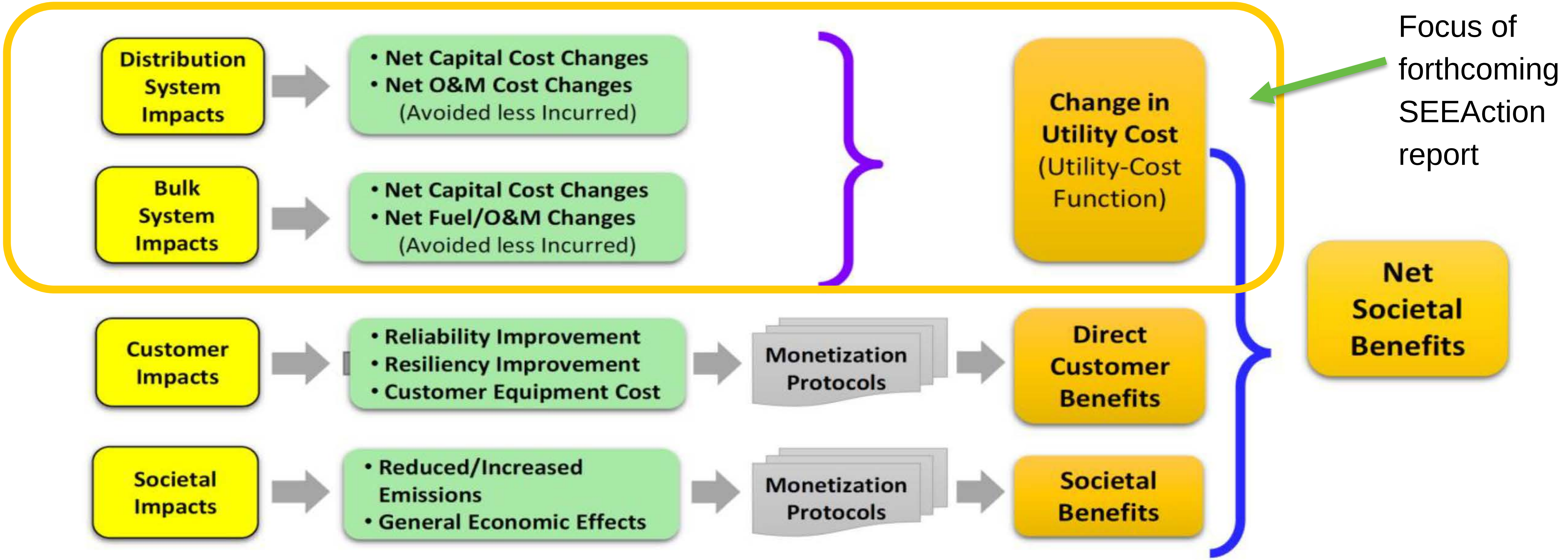
NASEO-NARUC Working Group

- Colorado
- Connecticut
- Florida
- Hawaii
- Massachusetts
- Michigan
- Minnesota
- New Jersey
- New York
- Oregon
- South Carolina
- Tennessee
- Virginia
- Wisconsin

Valuation – Example Projects

SEE Action GEB Series:

Focus on critical issues from state and local government perspective



Technology Characterization & Options

GEB Technical Report Series:

- Overview
- Heating, Ventilation, & Air Conditioning (HVAC); Water Heating; and Appliances
- Lighting & Electronics
- Building Envelope & Windows
- Sensors & Controls, Data Analytics, and Modeling

1 Establish Frameworks

- Defines grid-interactive efficient buildings and demand flexibility
- Establishes potential grid services and some basic requirements for buildings to provide needed flexibility

2 Assess Flexibility Potential

- Evaluate state-of-the-art and emerging building technologies that have the potential to provide grid services
- Considers implementation attributes

3 Discuss Research Opportunities

- Identify major research challenges of technologies with significant potential for grid benefits and opportunities for additional technology-specific research and development.

Key Findings -Technologies

- Efficient technologies with the ability to shed + shift present the greatest opportunity to provide grid services
    - HVAC, water heaters, dynamic envelope/windows, refrigeration, some appliances

- Although reports don't focus on passive envelope/window technologies they are also critical to consider for shifting potential

- Number of end uses that can provide fast grid services without impact on equipment life are limited

- Reports evaluated potential within end use, a needed next step is ranking across end uses

Key Findings-Operational Strategies

- **HVAC shedding and shifting is best aggregated at the building level**
  - Coordination of multiple devices, coupled with building thermal mass, and mechanisms and process that couple zones together make it likely that building-level approaches will outperform a device-level approach.
  - Greater optimization challenge given relationship with weather, occupant comfort, etc

- **Other end-uses providing shedding or shifting can be implemented at either the building level, device level or end-use level**

hallelujah

  - Limited physical interaction indicates that demand flexibility for different end uses can be implemented independently, without accounting for physical interactions with other end-uses.

- **End uses being used for modulation are best provisioned at the device level**
  - Given the time response requirements to provide these services, latency constraints point to the need to minimize the number of communication hops and coordination layers.

Case Study from GEB Technical Reports

Separate Sensible and Latent Load Space Conditioning

HVAC, Water Heating and Appliance R&D

- US DOE Buildings Technology Office's goal:
  - *reduce the average energy use per square foot of all U.S. buildings by 50%* from 2010 levels.

- Emerging Technologies Program's goal:
  - enable the development of cost-effective technologies capable of *reducing a building's energy use per square foot by 45% by 2030*, relative to 2010 high-efficiency technologies.

Two-pronged approach to accelerate the development of new technologies:

- Accelerate the development of near term technologies that have the potential to save significant amount of energy (including cost reduction activities, bending the cost curve)

- Accelerate the development of the next generation of technologies that have the potential of "leapfrogging" existing technologies by pursuing entirely new approaches (including crosscutting efforts)

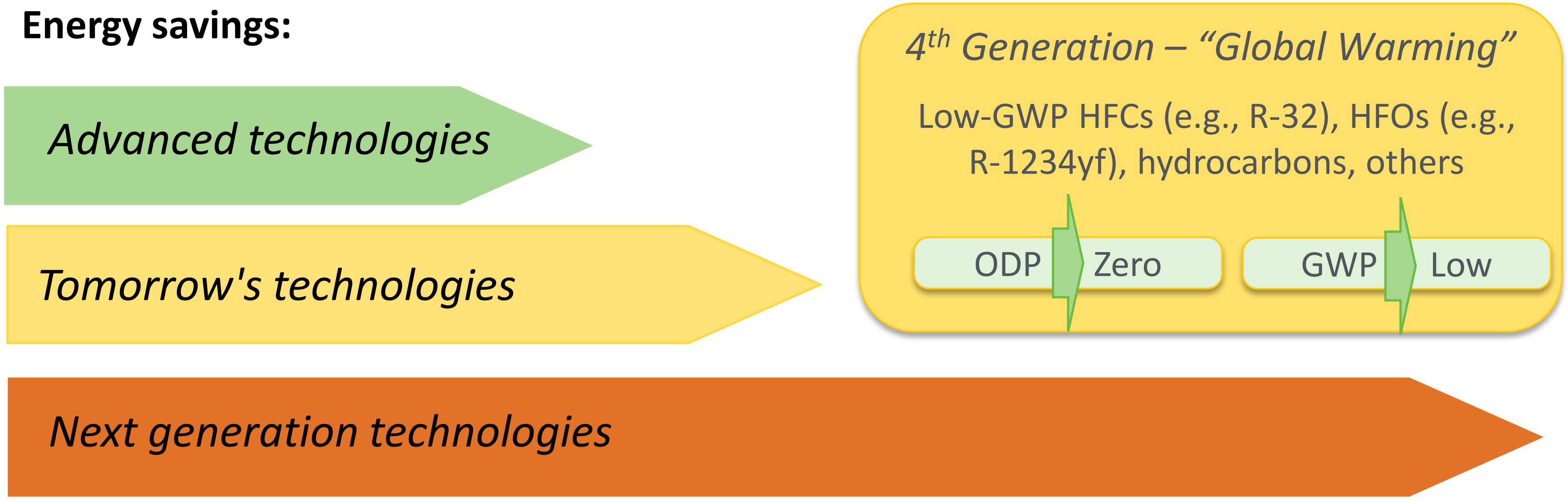
The goal is to develop technologies that save energy and reduce our environment burden while introducing them in the simplest application first, highest probability of success.

Efficiency first, innovation with a purpose

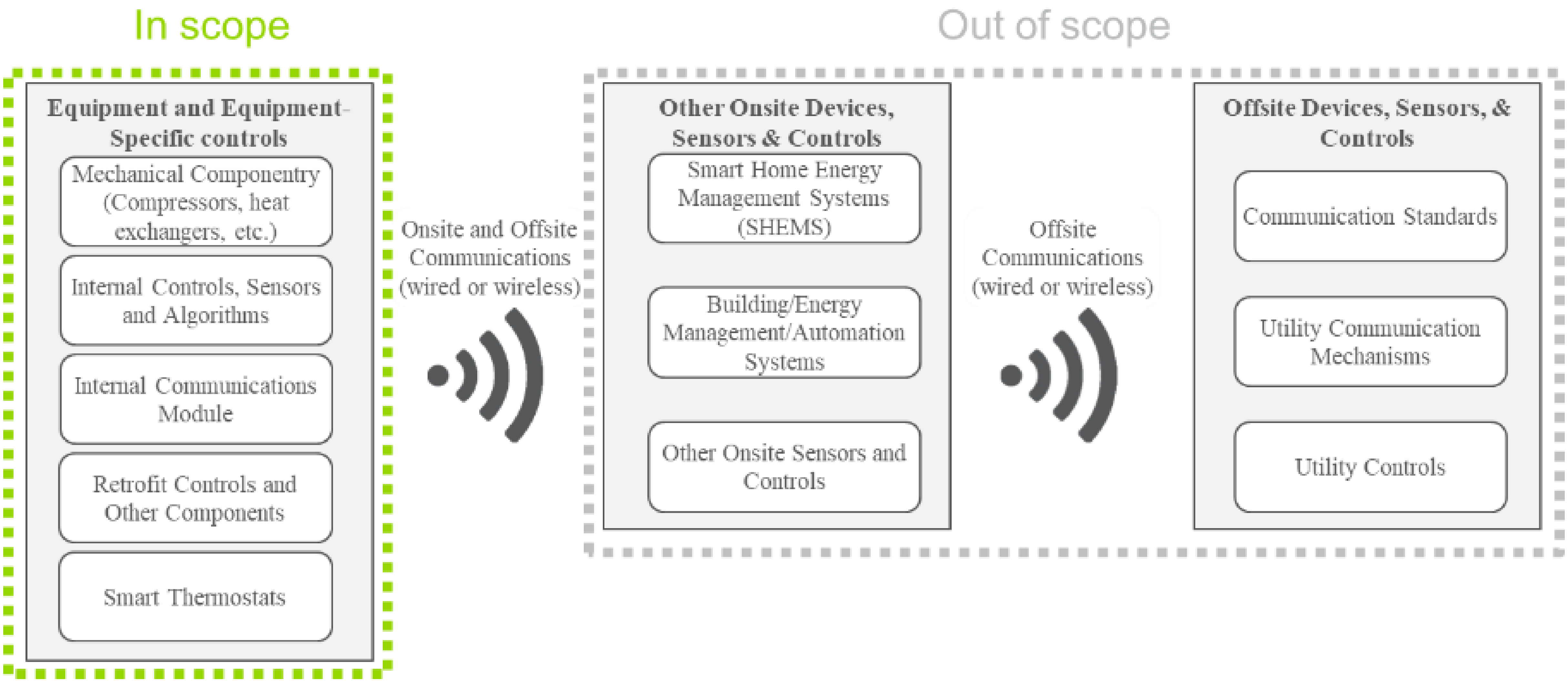
Develop the next-generation technologies that 'leapfrog' existing technologies and result in dramatically improved energy efficiency.

- **Short Term:** **Develop and evaluate low-GWP alternative refrigerants, including flammability characterization and hot climate performance**
- **Mid Term:** **Develop HVAC&R systems that can handle low-GWP refrigerants**
- **Long Term:** **Develop non-vapor compression (NIK) systems that use zero-GWP refrigerants**

Energy savings:



Focus on HVAC Equipment, not BAS/SHEMS



Summary Table- HVAC, Water Heating & Appliances

Category	High Potential	Medium Potential	Low Potential
HVAC	• Smart Thermostats • Separate Sensible and Latent Space Conditioning • Liquid Desiccant Thermal Energy Storage	• Advanced Controls for HVAC Equipment with Embedded Thermostats	• Hybrid Evaporative Cooling • Dual-Fuel HVAC
Water Heating	• Water Heaters with Smart, Connected Controls	• None	• Dual-Fuel Water Heaters
Appliances, Refrigeration, & Relevant MELs	• MELs: Water Heating	• Advanced Clothes Dryers • Advanced Dishwasher & Clothes Washer Controls • Connected Refrigerator & Freezer Advanced Controls • Advanced Controls for Commercial Refrigeration • MELs: Motors, water circulation, HVAC, refrigeration	• None
Natural Gas	• Building-Scale CHP • Water Heaters with Smart, Connected Controls	• Smart Thermostats • Modulating, Advanced Clothes Dryers	• Dual-Fuel HVAC • Dual-Fuel Water Heaters
Cross Cutting	• Thermal Energy Storage • Non-Vapor Compression Materials & Systems	• Modulating Capacity Vapor Compression	• None

Separating Sensible and Latent Loads Provide Efficiency & Flexibility

Conventional Air Conditioning Manages 2 Loads

1. Sensible Load (A to B): Temperature of the supply air reduced below the dew point

2. Latent Load (B to C): Moisture in the air condenses on the evaporator

3. Reheating (C to D) to Achieve Comfort

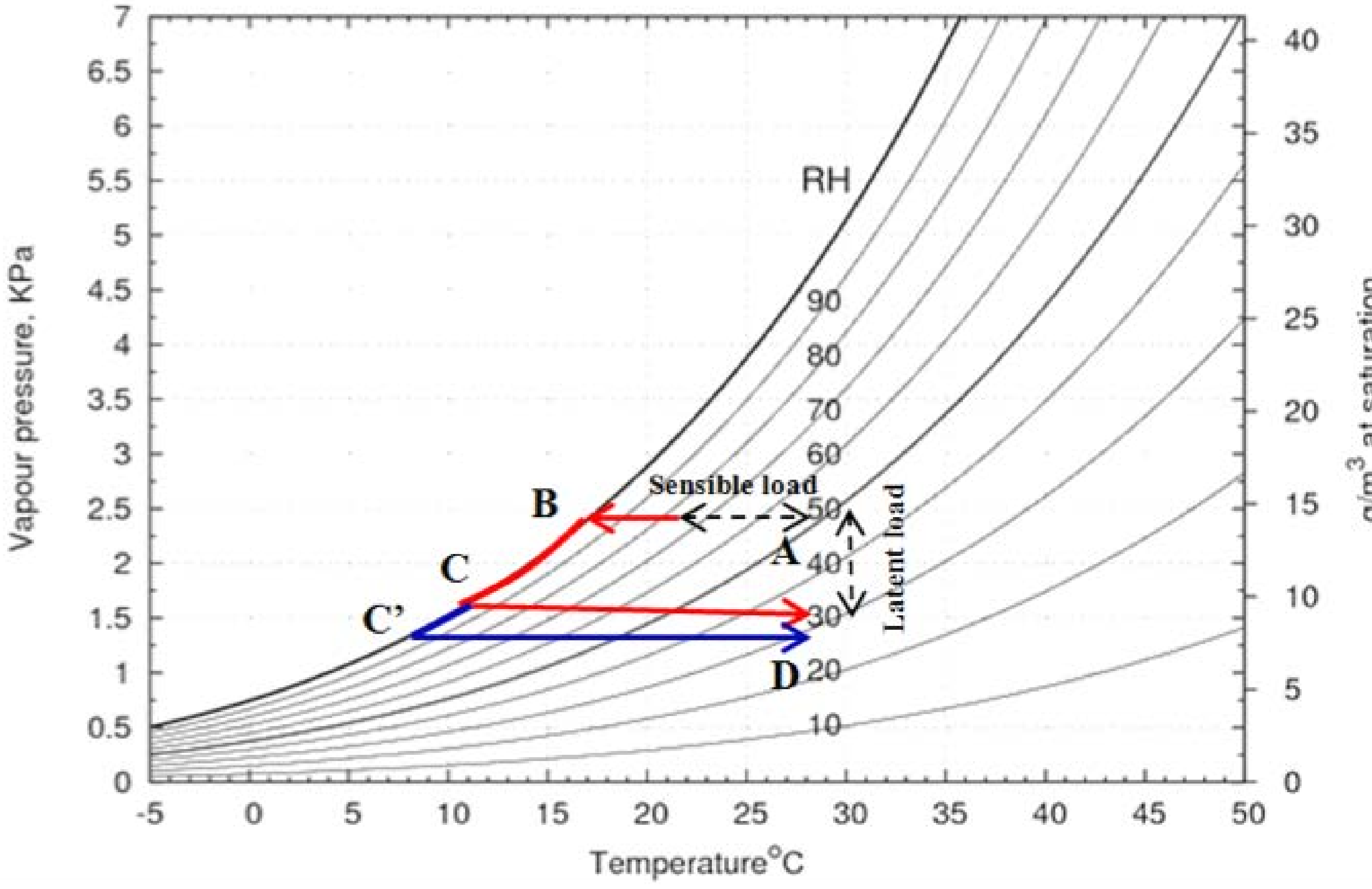


Figure 1. Operation of conventional air conditioning system.

HVAC Example: Separate Sensible and Latent Space Conditioning

Application:

- Residential and commercial space cooling systems.
- The latent cooling stage could be integrated into conventional HVAC equipment at the factory or installed as separate component in the field

Status:

- Commercially available for humid climates, particularly for commercial and industrial buildings.
- Researchers are exploring opportunities to incorporate desiccant wheels into conventional vapor-compression systems as well as a variety of non-vapor-compression (NVC) cooling cycles

Growth Potential:

- Further R&D is necessary to more closely integrate sensible and latent cooling stages and improve the operating efficiency, installed cost, and operational constraints such as size, weight, and maintenance that limit their adoption today.
- Today's products are largely installed to reduce operating cost and peak demand and may not be optimized to provide grid flexibility.

HVAC Example: Evaluation of Technology Characteristics

HVAC Technologies	Efficiency	Shed Load	Shift Load	Modulate Load	Overall Potential
Separate Sensible and Latent Space Conditioning	●	◐	◐	○	High

- Researchers project separate sensible and latent cooling system could provide energy savings of 30% and greater.[80] Solid or liquid desiccant systems using solar thermal or waste heat resources would offer additional energy savings; equipment downsizing is also possible
- Systems could shed load by reducing the sensible cooling stage and only operating the high efficiency latent cooling stage to maintain occupant comfort during peak events and allow for longer curtailment periods without causing discomfort.
- Some systems may offer load shifting by using thermal energy storage of liquid desiccants and other materials (see liquid desiccant thermal energy storage below)
- Separate sensible and latent cooling systems do not provide significant load modulation capabilities.

System Attributes

System Attribute	Definition
Reliability	The ability of the technology to consistently perform grid services as intended over the lifetime of the product.
Resilience	The ability of the technology to improve the resistance of the building to electric power outages and/or natural disasters (including earthquakes, hurricanes, tornadoes, and floods) by providing energy, services, occupant comfort, protection, and/or damage resistance.
System Readiness	The ability of the technology to interoperate with other technologies, networks, and systems while maintaining cybersecurity.
Usability	The ease of use of the technology to the customer including ease of installation, ease of operation, and ease of maintenance.
Manufacturability	The ability of the technology to be manufactured at a large scale; this includes the environmental sustainability of the raw materials, the manufacturing costs, and the final capital cost of the technology.
Human Health	The extent to which the technology contributes to a healthy and safe living environment for the building occupants.
Lifetime	The total average operational lifetime of the technology

SSLC System Attributes Example: Human Health

- **Improved air quality and indoor conditions: Premium HVAC technologies, which often includes those with grid-interactive functionality, provide superior comfort via precise control over temperature and humidity, resulting in:**
  - Better optimization of temperature and humidity to increase occupant comfort.
  - Avoided building maintenance associated with high indoor humidity (e.g. mold / mildew).
  - Improved ventilation and reduced contaminants.
  - For details, see https://www.nrel.gov/docs/fy14osti/60655.pdf.

Research Opportunities

All Connected Technologies	Interoperability	• Support the development and adoption of standardized semantic and syntactic specifications for connected devices and software systems
	Cybersecurity	• Support the adoption of secure system architectures and cyber-security best practices
	Cost	• Develop manufacturing processes that have low capital costs or can use existing manufacturing equipment with minimal investment • Develop materials and technologies compatible with scalable manufacturing methods that enable increasing production volumes
Separate Sensible and Latent Space Conditioning	Interoperability	• Support the development and adoption of standardized semantic and syntactic specifications for connected devices and software systems
	Complex installation and commissioning	• Develop packaged systems to reduce installation and commissioning complexity

Next Steps

- Current approach evaluated across end-use →

- Expand beyond EE targets to capture shed/shift→