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U.S. DEPARTMENT OF ENERGY

Decarbonizing Laboratories: Framework and Concepts

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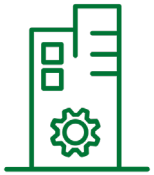
Decarbonizing Operational Energy Use



Energy Efficiency ***(Yes, it's still strategy #1)***

Beneficial Electrification

Clean Energy and Demand Flexibility

Metrics for Decarbonization

Greenhouse Gas Intensity
kg CO2e/sq.ft-yr

Site Energy Use Intensity
kBtu/sf-yr

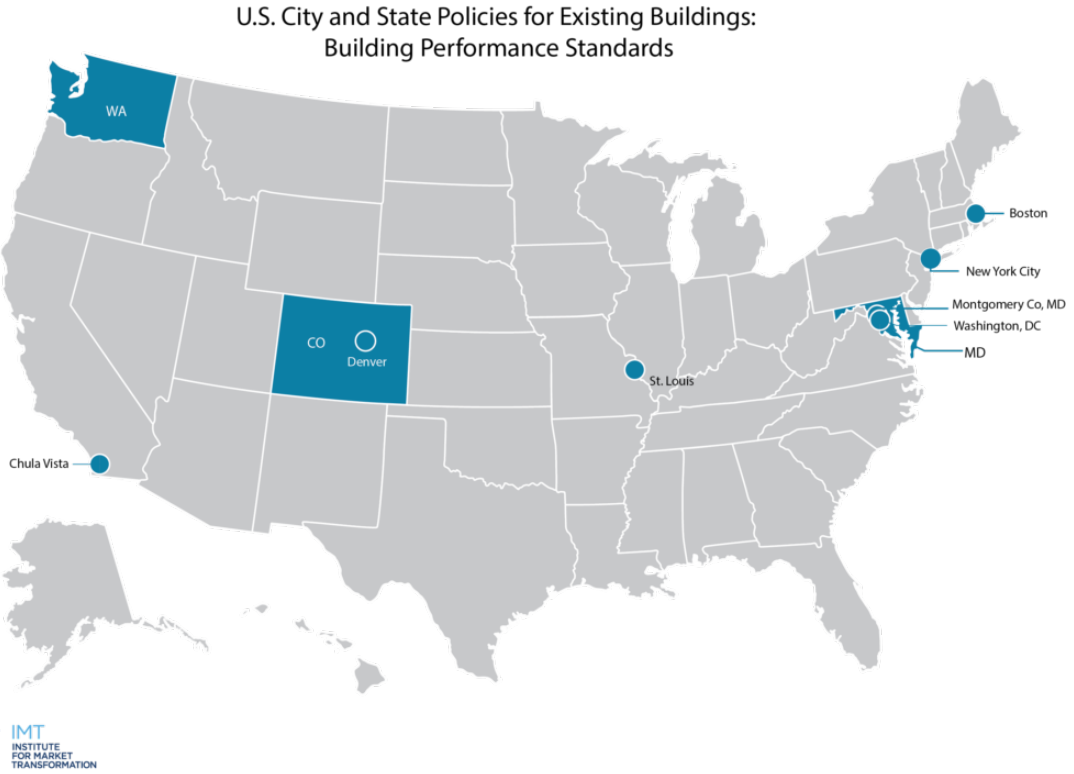
Direct ("Scope 1") Emissions Intensity
kg CO2e/sq.ft-yr

The Devil (and God?) is in the Details

- Grid emissions – city, state, region?
- Average vs. marginal emissions
- Hourly vs. annual emissions
- T&D losses – include?
- District systems
- How to account for RECs, PPAs

Get Ready for Existing Building Performance Standards

37 jurisdictions have committed to passing a BPS by Spring 2024



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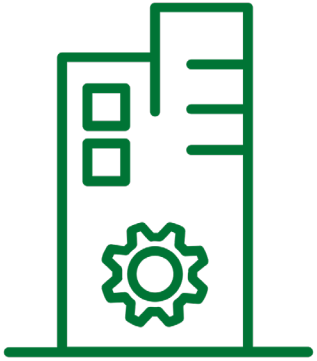

Energy Efficiency

Biology and Physical Laboratories – HVAC efficiency

Image source: isis.stfc.ac.uk

- Decouple space conditioning from ventilation, e.g. chilled beams, fan coils.
- Demand-controlled ventilation.
- Enthalpy wheel for general exhaust; Run-around for vivarium, fume hoods.
- Low pressure drop design.
- VAV exhaust discharge.
- Heat recovery from ULT freezer farms, process chillers, other lab equipment.

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Chemistry Laboratories – HVAC efficiency

Image source: labtesting.com

- All-air VAV with reheat in spaces with high make-up air rates and low internal loads.
- High-performance run-around heat recovery.
- Low pressure drop design.
- Filtered fume hoods for teaching labs and labs with consistent chemical types.
- (see Bio labs for other space types)

All lab types

Design and Planning

- Reduce demand via LVRA
- Smart lab planning – segregating office, cascading air, etc.

Envelope

- Performance per IECC 2021/ ASHRAE 90.1-2019.
- Minimize night heat loss/ perimeter heating needs
- Whole building airtightness: 0.25 cfm/sf@75pa or lower.

Lighting

- LED lighting with occupancy or vacancy sensors (motion and IR) and daylight-based dimming

Plug and Process

- Cooling via process water instead of heat rejection to room air.
- High efficiency ULT freezers
- BSCs with low power mode
- Plug load controls for non-lab spaces

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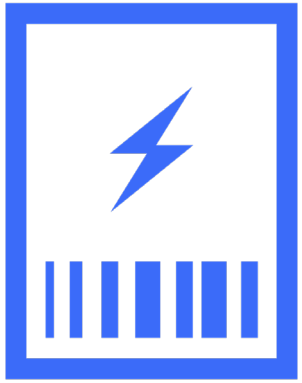

Beneficial Electrification

Space Heating: Site Considerations

	Tight high-density site (urban, zero lot-line)	Medium-density site	Low-density site (rural, campus)
Warm (zones 1-3)	Exhaust-source / Air-source	Air-source	Air-source / Ground-source hybrid
Cool (zones 4-5)	Exhaust-source / Air-source	Air-source / Ground-source hybrid	Air-source / Ground-source hybrid
Cold (zones 6+)	Air-source / Ground-source hybrid	Air-source / Ground-source hybrid	Ground-source

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Hybrid Solutions for Space Heating

	90% FF Reduction (fossil fuel for peak and back-up)	100% FF Reduction (fossil fuel for extreme conditions and back-up)
Warm (zones 1-3)	Exhaust-source / Air-source OR exhaust-source	Air-source OR exhaust-source + air-source OR exhaust-source + elec resist. OR air-source + electric resistance
Cool (zones 4-5)	Exhaust-source / Air-source OR ground-source OR exhaust-source	Exhaust-source + air-source OR exhaust-source + ground-source
Cold (zones 6+)	Exhaust-source OR ground-source	Exhaust-source + ground-source

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Space and Process Heating Considerations

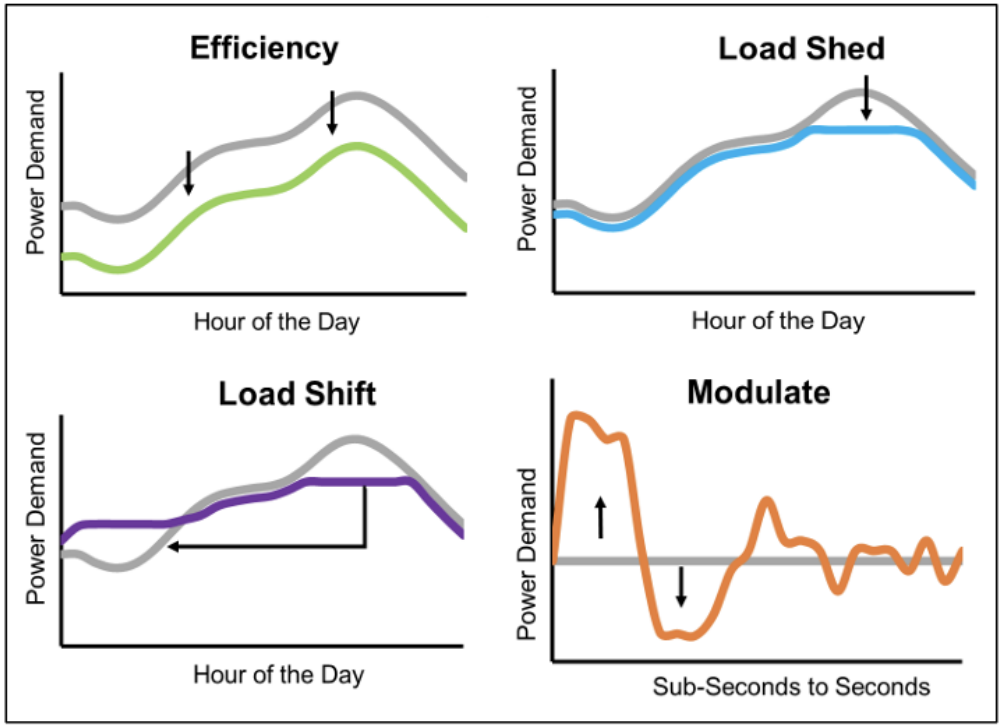
- New buildings can be designed to 130F water temperature or lower; Existing buildings may require higher.
- Existing process loads can be a significant driver of total demand, often rely on steam. High-lift heat pumps can provide first stage of heating. Steam heat pumps are an emerging technology.
- Avoid electric resistance boilers due to high demand on grid and costs.

- Roof space can be a challenge.

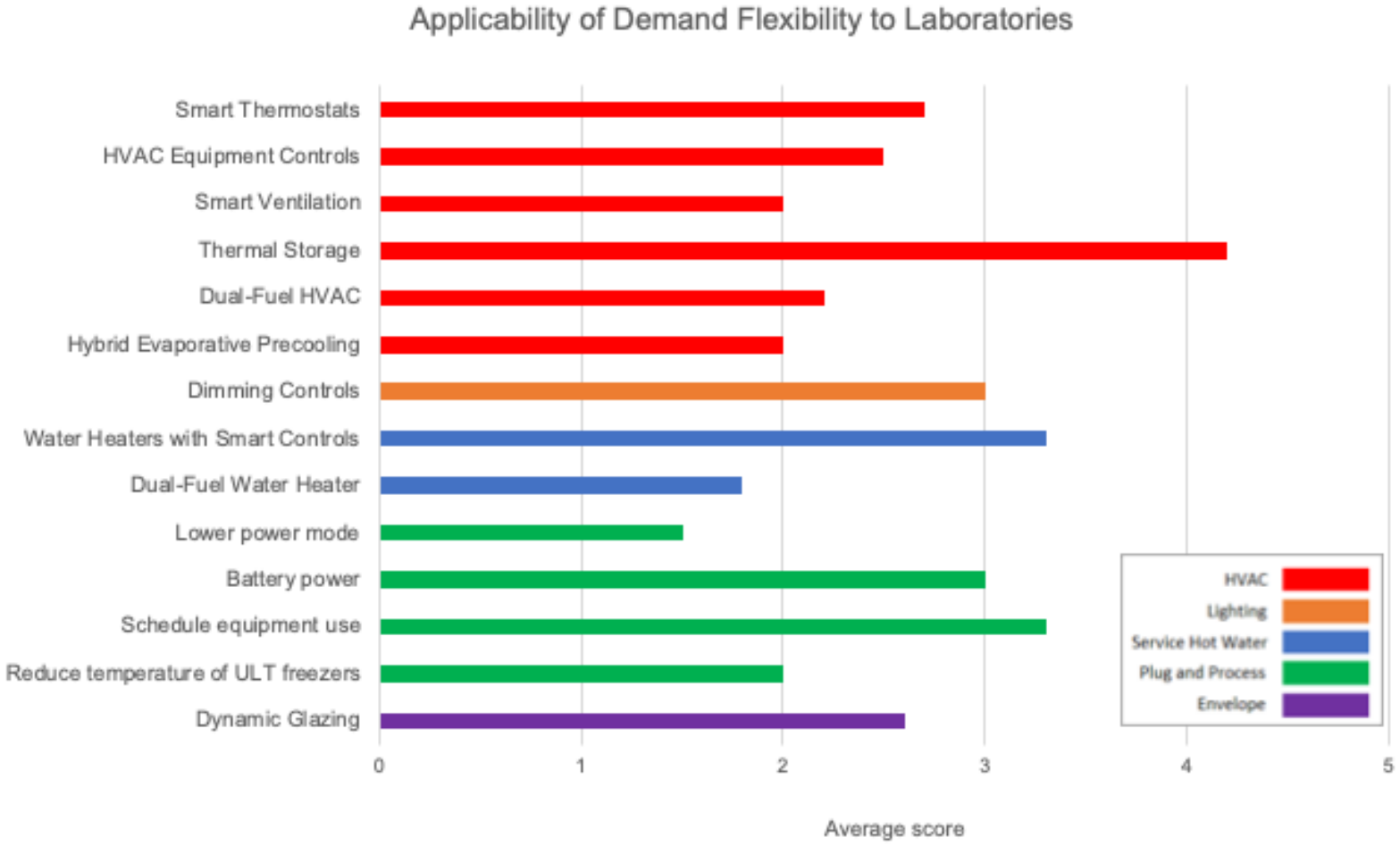
- Getting the last mile of electrification may not be worth the embodied carbon.

Demand Flexibility

When vs. *How Much* Energy



Source: "A National Roadmap for Grid-Interactive Efficient Buildings". U.S. Department of Energy.


Applicability of Demand Flexibility to Laboratories
Smart Thermostats
HVAC Equipment Controls
Smart Ventilation
Thermal Storage
Dual-Fuel HVAC
Hybrid Evaporative Precooling
Dimming Controls
Water Heaters with Smart Controls
Dual-Fuel Water Heater
Lower power mode
Battery power
Schedule equipment use
Reduce temperature of ULT freezers
Dynamic Glazing
0
1
2
3
4
5
Average score
HVAC
Lighting
Service Hot Water
Plug and Process
Envelope

Key Takeaways

- Efficiency first! It remains the foundation of decarbonization.
- Electrification options are highly context dependent on site type and climate. 100% electrification, high temperature loads can be especially challenging.
- Demand flexibility limited - but possible.

Bottom line: Decarbonization is not easy, but eminently possible and being done!

See: https://smartlabs.i2sl.org/decarbonization.html

Coming soon: I2SL Guide on Decarbonization

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Thank you

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