Demand Flexibility for Laboratories

Technical Memo for FEMP Smart Labs Program

9-6-22

Paul Mathew, Lino Sanchez
Lawrence Berkeley National Laboratory

Introduction

Demand flexibility (DF) refers to the ability of buildings to reduce or shift their energy loads to mitigate demands on the grid. DF is a component of Demand Management and Grid-interactive Energy Buildings (GEBs). Alongside energy efficiency, DF is a key pillar of building decarbonization, especially with the increase in intermittent renewable generation on the electric grid. DOE released “A National Roadmap for Grid-Interactive Efficient Buildings” [1] as well as technical reports on DF technologies for HVAC [2], controls [3], lighting [4], and envelopes [5]. Figure 1 shows the four components of grid-interactive efficient buildings. For the purposes of this document, we define DF as comprising *load shed* and *load shift*.

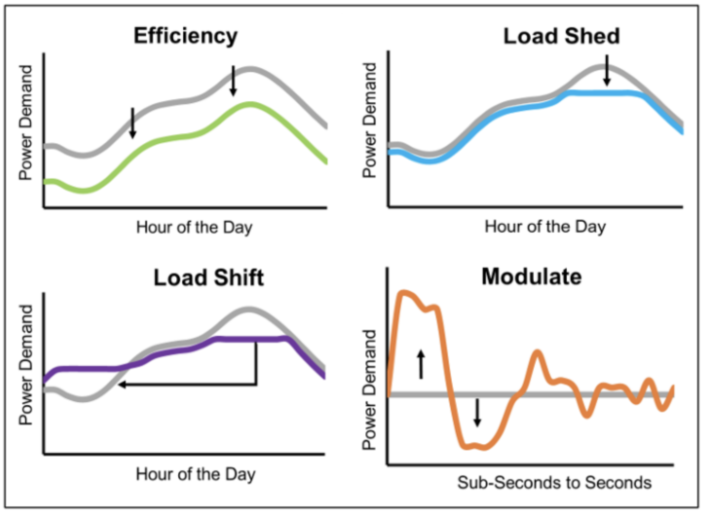

Figure 1. Components of grid-interactive efficient buildings [1]

There have been limited efforts to date on understanding the role of DF in laboratory buildings, which are highly specialized and have complex functional and safety requirements. Laboratory buildings are an important component of the federal building stock and FEMP tasked Berkeley Lab to explore the applicability of DF technologies and strategies to laboratories by interviewing relevant facilities staff at various federal agencies that have laboratory buildings.

Background: Demand Flexibility, GEB and EMIS

According to the *Federal Energy Management Information System (EMIS) Technical Resources Report [6]*, EMIS can help support agencies' demand management initiatives to reduce utility costs in two ways: utility-initiated and building-initiated reduction. Utility-initiated reduction occurs when the electric utility sends control signals or requests to the building to reduce demand. This can be accomplished through dedicated protocols, such as OpenADR, that communicate directly with the EMIS or directly to the BAS. Building-initiated reduction is when the facility operates equipment assets to deliberately achieve demand reductions and reduce utility costs. Because building-initiated demand management depends on integrated, organized, and accessible data to perform reliably, an EMIS can be a powerful tool for implementing these strategies [7,8,9].

GEBs are an emerging interest area for the Department of Energy and will continue to grow in significance for federal agencies [10]. Increasing peak electricity demand, infrastructure constraints, and an increasing share of variable renewable electricity generation are stressing the electrical grid. Flexible and dispatchable electricity loads, like those inherent to buildings, can be used to reduce grid stress. EMIS can interact with the utility grid, sending and receiving signals and initiating supervisory control over end use systems connected to the EMIS. GEB can manipulate energy assets, such as traditional power-consuming assets like lighting and HVAC, along with on-site resources like rooftop photovoltaics, EV charging, and battery storage. Depending on the availability of grid data (and associated revenue streams), GEBs can respond to grid needs while providing economic benefits to the agency. Additional benefits from pursuing a GEB strategy can include better system integration and control, increased resilience, and reduced utility costs. Beyond efficiency, advanced EMIS analytical solutions can play a significant role in load-changing functionalities (commonly referred to as shed, shift, and modulate) required for GEB in the following ways:

- Two-way communication of signals between buildings and the grid;
- Monitoring, predicting, and learning from building-level conditions (occupant needs and preferences) and outdoor conditions (weather and grid needs);
- Coordinating and executing complex control strategies that adapt based on changing conditions over multiple time scales;
- Estimating and verifying the energy and demand savings of different strategies and impacts from stochastic building conditions (e.g., occupancy behavior);
- Deciding among multiple strategies to optimize efficiency with flexibility and occupancy comfort [10].

Approach

We first conducted a literature review of the DOE GEB documentation, consisting of the afore-mentioned roadmap and technical reports. From these sources we compiled a list of potentially applicable DF technologies for laboratories. We did an initial screening and excluded technologies that were not relevant to laboratories, were still pre-commercial, or too ‘bleeding edge’ for broad application.

We reached out to laboratory operators and facilities personnel across 10 federal organizations to request an interview. These organizations included:

- Environmental Protection Agency (EPA)
- Food and Drug Administration (FDA)
- Lawrence Berkeley National Laboratory (LBNL)
- Los Alamos National Laboratory (LANL)
- National Aeronautics and Space Administration (NASA)
- National Institutes of Health (NIH)
- National Renewable Energy Laboratory (NREL)
- Pacific Northwest National Laboratory (PNNL)
- Sandia National Laboratories (SNL)
- U.S. Department of Agriculture (USDA)

We provided our compiled list of DF technologies in advance for prospective interviewees to review ahead of the interview and decide if other staff should be invited to the interview as well, based on specialized knowledge and experience. We conducted interviews with a total of six organizations - EPA, FDA, LBNL, LANL, NREL, SNL - and also received email feedback from USDA.

We asked interviewees to give us their assessment of each DF technology on the list and provide us with an “applicability” score for each technology based on how feasible it would be to implement at their facility, considering technical aspects as well as organizational buy-in from laboratory users and others. We asked them to ignore cost considerations for this exercise. Scores were given on a scale of 1 - 5, with 1 indicating low/not applicable and 5 indicating high applicability. The scores were then averaged across all six organizations. In addition, the interviewees also provided qualitative information on specific considerations and nuances for implementing these technologies.

Table 1. List of DF technologies and strategies considered for laboratories.

Category	DF technology/strategy for load shed or shift
HVAC	Smart thermostats to change temperature setpoints
	HVAC equipment controls e.g., raise chilled water supply temp.
	Smart ventilation for demand-based ventilation

	Thermal Storage
	Dual-fuel HVAC i.e., switch to non-electric fuel during peak event
	Increase hybrid evaporative pre-cooling
Lighting	Dimming controls to lower lighting power
Service hot water	Water heaters with smart connected controls
	Dual-fuel water heater i.e., switch to non-electric fuel during peak event
Plug and process	Apply lower power mode
	Switch to battery power
	Schedule equipment use
	Reduce temperature of ULT freezers
Envelope	Dynamic glazing to lower thermal loads from envelope

Findings

Figure 2 shows the average applicability score for each DF technology, color coded by category.

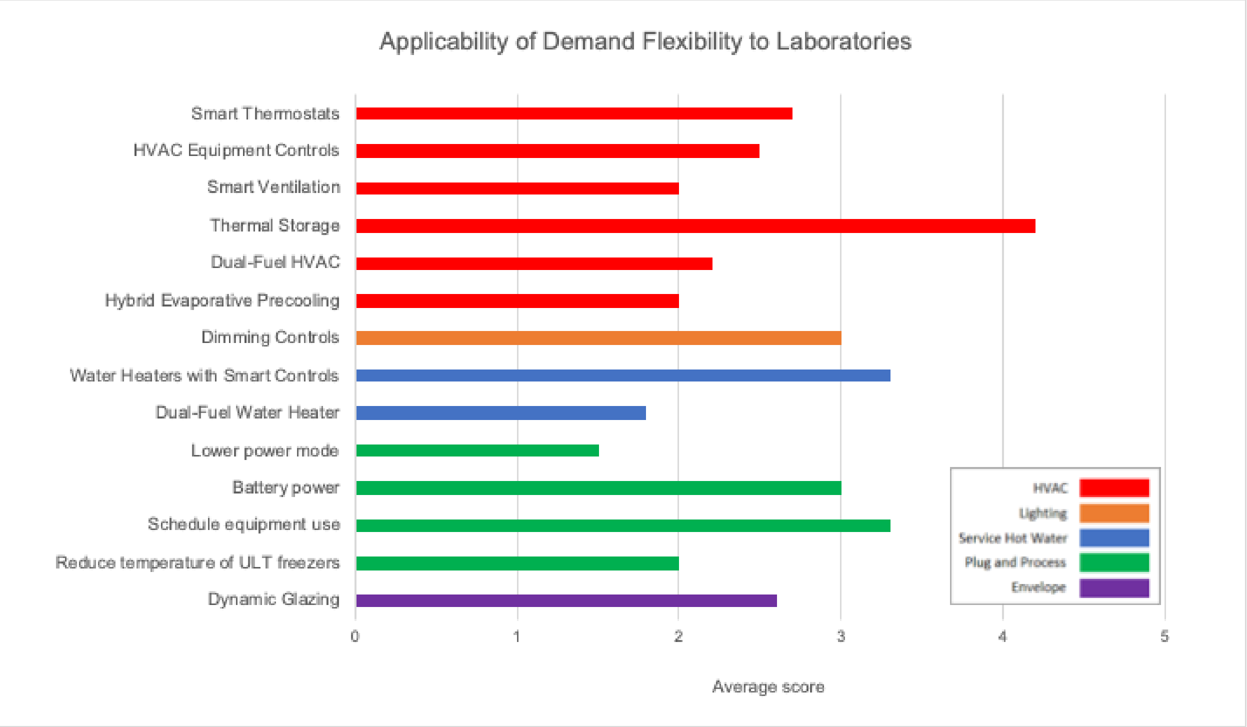

Figure 2. Average applicability scores for each DF technology

Based on our discussions with interviewees, below are key considerations by category:

HVAC

- In general, it is very difficult to get buy-in for modifying environmental conditions in laboratory spaces. It may be more feasible in non-lab spaces, provided doing so does not have any knock-on controls effects in the lab spaces. Furthermore, some labs require tighter temperature and humidity controls that preclude any demand flexibility.
- Thermal storage showed the most potential applicability and has already been implemented on some sites.
- With one exception all the respondents said that modifying ventilation requirements for demand flexibility was infeasible. One respondent remarked that it “hurts my head trying to think about how to do this!”
- In general, it appears that dual-fuel HVAC is not viable because it would seem overly redundant just to support demand flexibility.

Lighting

- Reducing light levels is generally feasible for non-laboratory spaces, such as office spaces, but not laboratory spaces.
- Scientists would generally be worried lighting changes would interfere with the laboratory environment and impact experiments, even if to a subtle degree.
- Some scientists might be amenable if lighting is reduced when laboratory spaces are not occupied, but overall this may be too complex to implement given scheduling variability.

Service hot water

- There was generally positive feedback towards smart and automated hot water systems to support grid flexibility since this would not directly affect service levels. However, even here there was considerable hesitation and perceived risk about applying this to laboratory process water loads.

Plug and process

- Batteries are seen as the most viable option for DF, but most of the interviewees noted the barriers to actually acquiring batteries at the scale needed to see significant impact. Most UPS systems only support a few minutes of power outage.
- Scheduling was seen as a good option to shift loads for equipment such as dishwashers that laboratory staff have explicitly confirmed will not be needed for experiments at given time periods.
- Forcing low-power modes would be a nuisance to scientists, with one respondent remarking scientists would likely just tell facilities staff “don't bother with us, just go away!" when asked to switch equipment to low-power mode.
- Temporarily lowering temperatures on ULT (ultra-low temperature) freezers was generally not seen as viable because even if technically feasible, it would be very difficult to get buy-in from the scientists.

Envelope

- Dynamic glazing was generally seen as a non-controversial option for reducing envelope loads, albeit still somewhat "exotic." It potentially has more impact in non-lab spaces, since laboratory spaces often by design are not positioned to receive much daylighting to begin with, and thus may not see much envelope load reduction through dynamic glazing.

Conclusion

Demand flexibility (DF) is a key facet of building decarbonization, especially as the electric grid decarbonizes with more intermittent renewable energy generation. There is an array of commercially available demand flexibility technologies, but there is limited information and experience on the applicability of these to laboratory buildings. We identified a list of DF technologies that could potentially be applied to laboratory buildings and interviewed six federal organizations to get an overall sense of the feasibility for implementing these technologies in their facilities.

The interview findings suggest that the feasibility of demand flexibility in laboratory buildings is mixed at best. While for the most part *technically feasible*, there are significant *implementation challenges*. The primary concern are the potential risks and disruption to the scientific mission and operations in the laboratory. Interviewees mentioned it would be very difficult to get buy-in from the scientific staff. Simply put, in the vast majority of cases scientists would not be willing to negatively impact their laboratory work just to reduce stress on the grid. Additionally, there is uncertainty about how changes in laboratory environmental conditions, e.g., temperature and light levels, may affect experiments. The interviewees indicated that scientists may be open to DF measures that do not directly impact their work e.g., use of battery or thermal storage systems. They may also be open to modest administrative measures such as operating some equipment at off-peak hours provided it does not affect their work and is not overly burdensome to administer, e.g., running glasswashers during off-peak hours. Interviewees indicated that DF measures such as reducing light levels or increasing thermostat set points may be more feasible in non-lab spaces such as offices and conference rooms. However, these impacts may be relatively small since most of the load in laboratory buildings is from the laboratory spaces and therefore may not be worth the organizational effort to implement.

In conclusion, based on these findings, it is warranted for FEMP to allow a federal laboratory building and/or a DOE National Laboratory laboratory building to participate in FEMP's Smart Facility Accelerator Program in the near future for more quantitative analysis of DF within these building types. It is also suggested that federal agencies consider DF-related energy conversation measures (ECMs) in third-party financed projects. Lastly, it is further suggested that the Smart Lab Toolkit be updated to include guidance on DF and GEB ECMs.

Acknowledgements

We would like to thank the following participants for engaging in our interviews and helping make this study possible:

- Dan Amon, EPA
- Suzanne Belmont, NREL
- John Elliott, LBNL
- Otto Van Geet, NREL
- Raphael Vitti, LBNL
- Genna Waldvogel, LANL
- Robin Jones, SNL
- Sandy Morgan, USDA

The authors also thank Jefferey Murrell and Jason Koman at FEMP for their guidance and feedback on this effort.

References

1. "A National Roadmap for Grid-Interactive Efficient Buildings". U.S. Department of Energy. Office of Energy Efficiency & Renewable Energy. Building Technologies Office. May 17, 2021.
2. Grid-interactive Efficient Buildings Technical Report Series. Heating, Ventilation, and Air Conditioning (HVAC); Water Heating; Appliances; and Refrigeration. U.S. Department of Energy. Office of Energy Efficiency & Renewable Energy. December 2019.
3. Grid-interactive Efficient Buildings Technical Report Series. Whole-Building Controls, Sensors, Modeling, and Analytics. U.S. Department of Energy. Office of Energy Efficiency & Renewable Energy. December 2019.
4. Grid-interactive Efficient Buildings Technical Report Series. Lighting and Electronics. U.S. Department of Energy. Office of Energy Efficiency & Renewable Energy. December 2019.
5. Grid-interactive Efficient Buildings Technical Report Series. Windows and Opaque Envelope. U.S. Department of Energy. Office of Energy Efficiency & Renewable Energy. December 2019.
6. Federal Energy Management Information System Technical Resources Report. U.S. Department of Energy. Office of Energy Efficiency & Renewable Energy. Building Technologies Office. May 17, 2021.
7. Granderson J., Lin G., and Piette M. A. 2013. Energy Information Systems: Technology Costs, Benefit, and Best Practice Uses. LBNL-6476E. Lawrence Berkeley National Laboratory, Berkeley, CA. Accessed March 1, 2016: http://eis.lbl.gov/pubs/lbnl-6476e.pdf
8. Cutler, Dylan, Stephen Frank, Michelle Slovinsky, Michael Sheppy, and Anya Petersen (2016). "Creating an Energy Intelligent Campus: Data Integration Challenges and Solutions at a Large Research Campus." ACEEE Summer Study on Energy Efficiency in Buildings. https://aceee.org/files/proceedings/2016/data/papers/12_1016.pdf. Accessed September 2022
9. Smart Energy Analytics Campaign. https://smart-energy-analytics.org/. Accessed September 2022
10. Neukomm, Monica, Valerie Nubb, and Robert Fares. Grid-Interactive Efficient Buildings: An Overview. Washington, D.C.: Office of Energy Efficiency and Renewable Energy. https://www.energy.gov/sites/prod/files/2019/04/f61/bto-geb_overview-4.15.19.pdf. Accessed September 2022