Session C1: Designing for Decarbonization

Understanding the Scale and Impacts of Energy Efficiency Strategies on Laboratory Decarbonization

Session C1: Designing for Decarbonization

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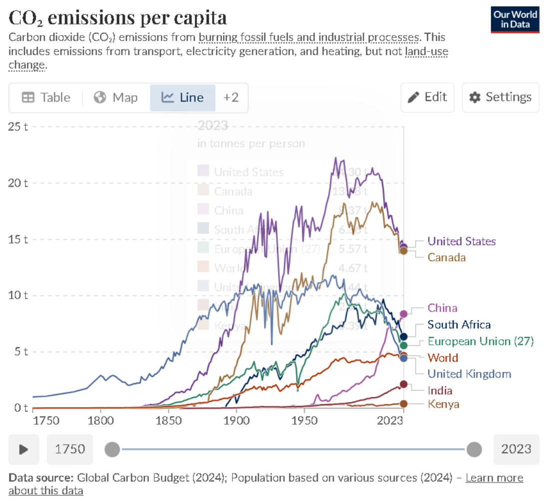
Scale

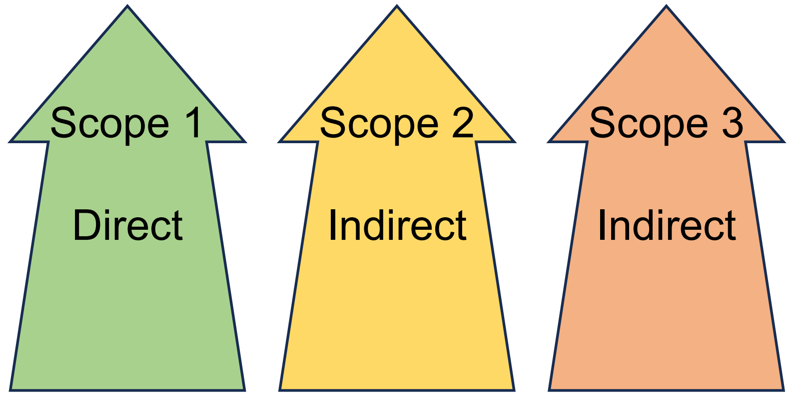


CO$_2$ emissions per capita

Carbon dioxide (CO$_2$) emissions from burning fossil fuels and industrial processes. This includes emissions from transport, electricity generation, and heating, but not land-use change.

Data source: Global Carbon Budget (2024); Population based on various sources (2024) – Learn more about this data

Sources

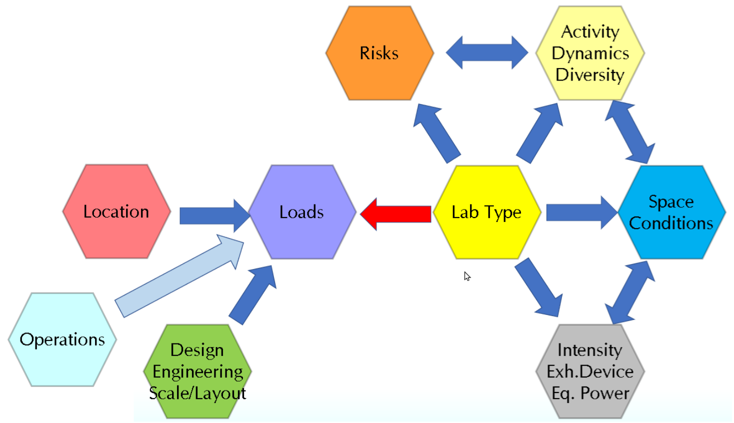


Scope 1
Direct

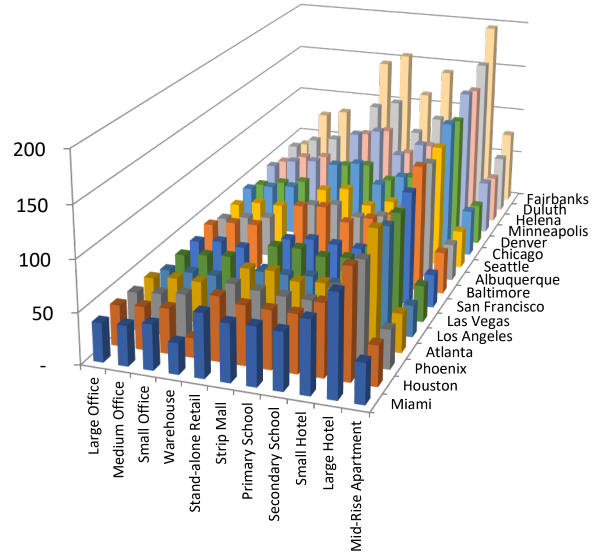
Scope 2
Indirect

Scope 3
Indirect

Drivers



Impacts



Learning Objectives

- Understand the Likely Quantitative Impact of Primary Design and Operations Decisions affecting Laboratory Energy Use.
- Understand the relative Impact of Energy Use on a Building's Carbon Footprint.
- Understand the Relative Significance of Design Decisions versus Building Operations on how they Impact Sustainability Goals.
- Learn how to Assess and Prioritize Design Decisions for maximum impact on Energy Use and Decarbonization.

Presentation Outline

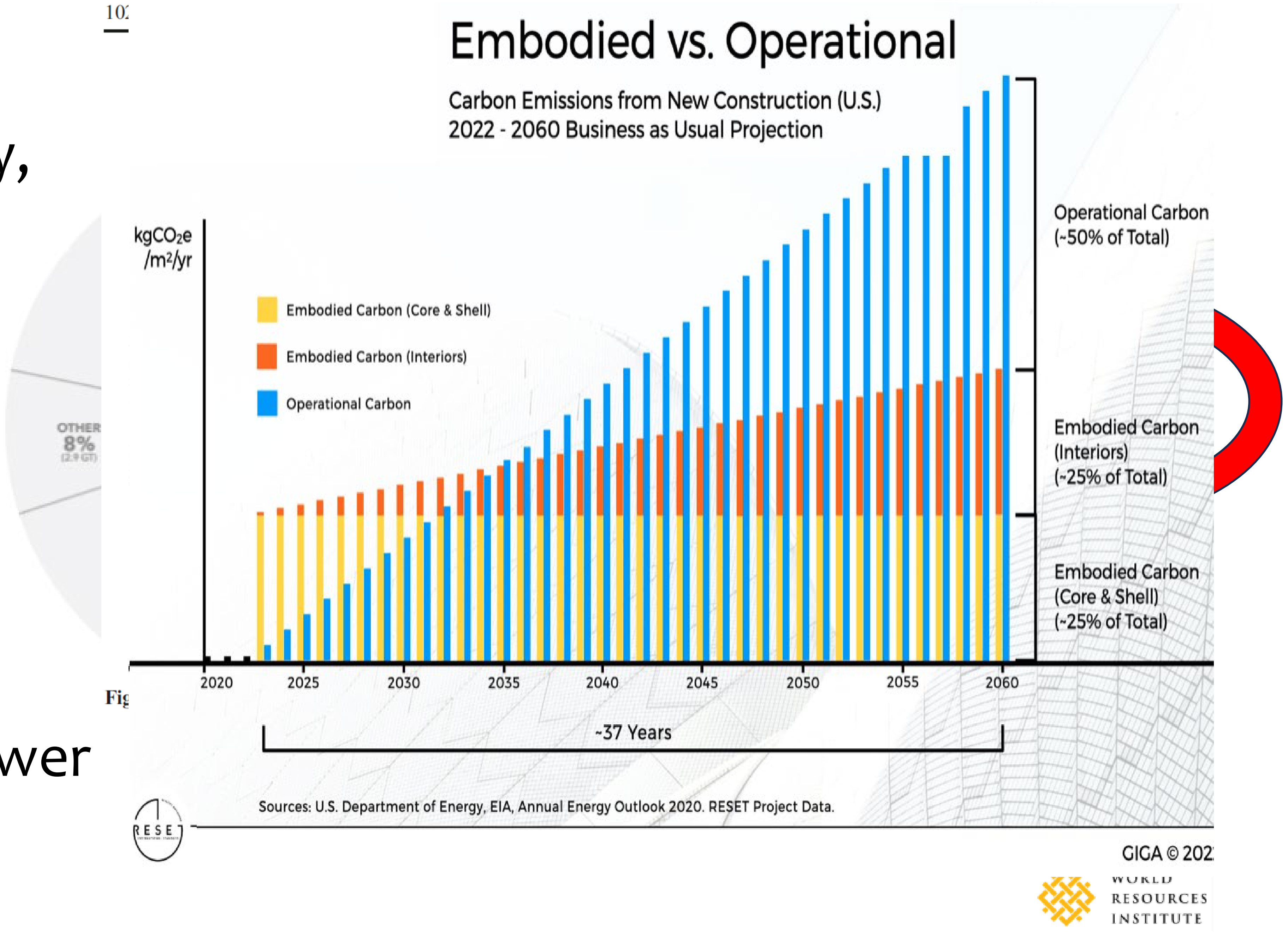
- Where does the Impact of Carbon on the Environment Come From … in Buildings?
- When does the Impact (“Footprint”) of Carbon Occur in Buildings?
- How does each Stage / Scope Affect the Overall Carbon Footprint?
- What is the Significance of Operations / Use on Carbon Footprint?
- How does the Type of Lab Influence Carbon Use and Options to Mitigate it?
- How does Location / Climate Influence Carbon Use and Options to Mitigate it?
- What Aspects of a Building Design & Use Influence Carbon Impact the Most?
- How do Energy Efficiency Strategies Impact the Carbon Footprint?

… finally …

- How might these “Expectations” … Change in the Future?

GHG and Carbon/Equivalent Emissions

- US leads the world in CO_2intensity
- Energy (75%) dominates, Agriculture, Industry, Waste & Land Use for GHG emissions
- Buildings Total Carbon Impact ➔ 42%
- Buildings Operational Carbon ➔ 65%
- Labs: Energy 2X - 10X Average building
- Labs: Higher Operational Carbon: 2X - 10X
- Reducing Energy & shifting Operational to lower Carbon will increase % Embodied Carbon
- By 2050, expect 50%-50% split



Sources: U.S. Department of Energy, EIA, Annual Energy Outlook 2020. RESET Project Data.

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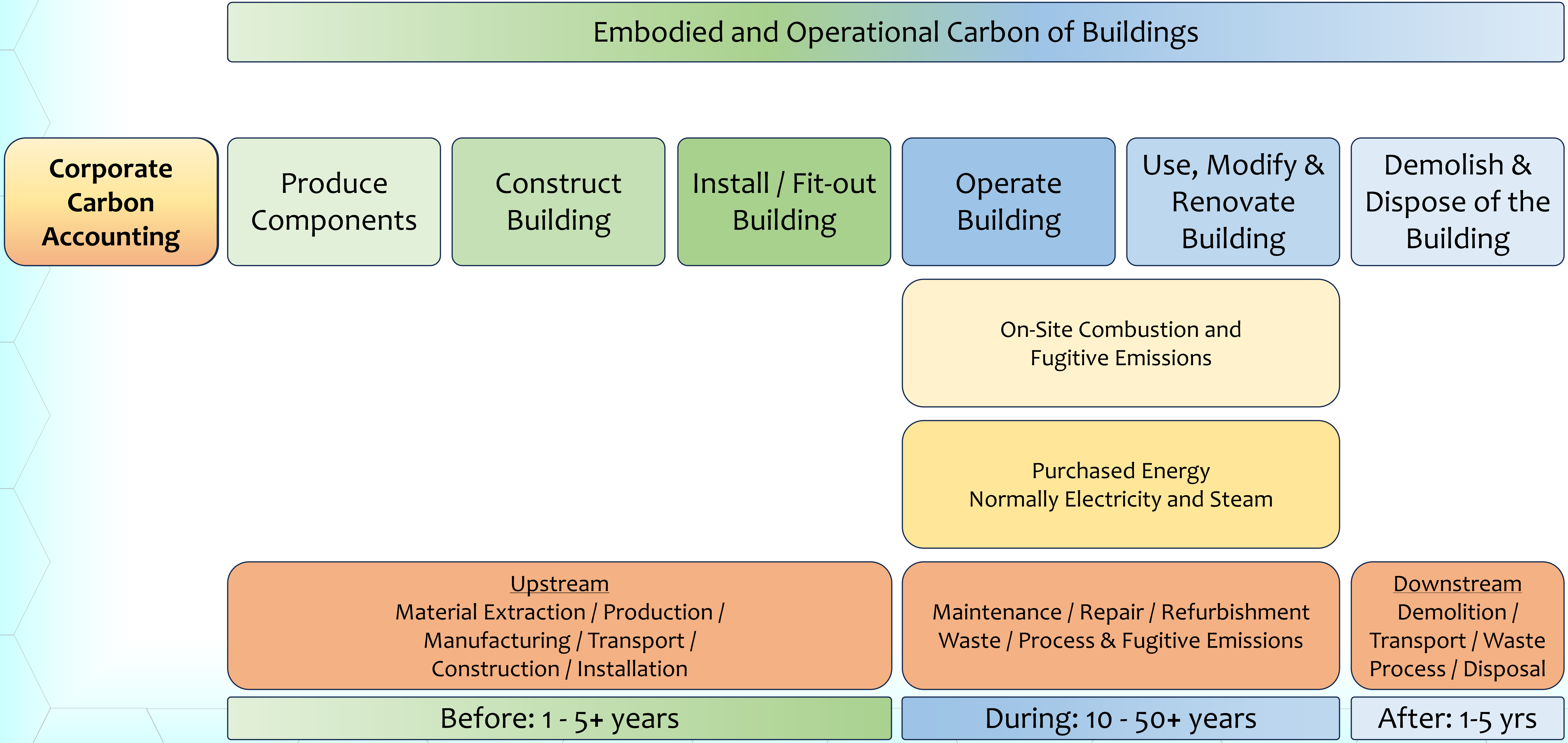
Where does the Impact of Carbon Come From … the Life Cycle of Buildings



Embodied and Operational Carbon of Buildings

Corporate Carbon Accounting

Produce Components

Construct Building

Install / Fit-out Building

Operate Building

Use, Modify & Renovate Building

Demolish & Dispose of the Building

On-Site Combustion and Fugitive Emissions

Purchased Energy
Normally Electricity and Steam

Upstream
Material Extraction / Production / Manufacturing / Transport / Construction / Installation

Maintenance / Repair / Refurbishment Waste / Process & Fugitive Emissions

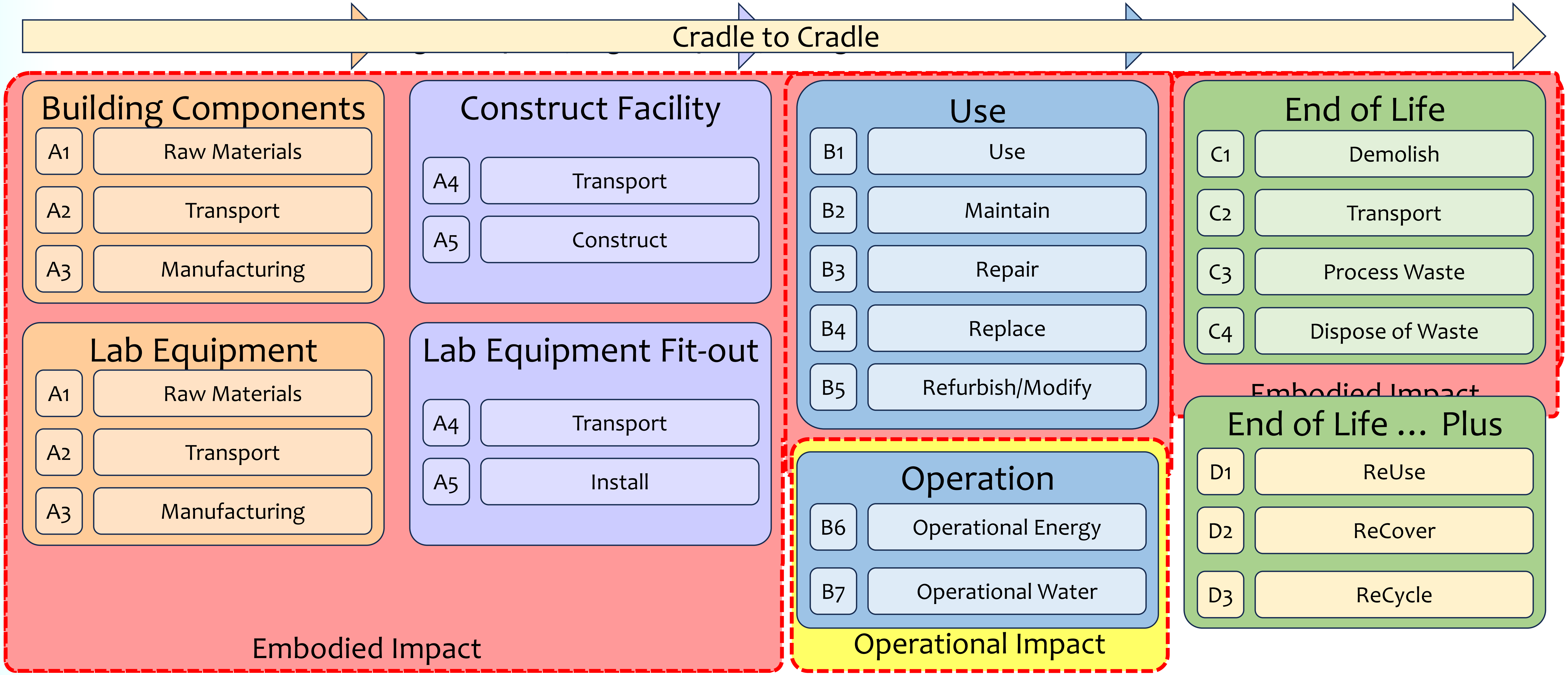
Downstream
Demolition / Transport / Waste Process / Disposal

Before: 1 - 5+ years

During: 10 - 50+ years

After: 1-5 yrs

Whole Life Cycle of Buildings



Cradle to Cradle

Building Components
A1 Raw Materials
A2 Transport
A3 Manufacturing

Lab Equipment
A1 Raw Materials
A2 Transport
A3 Manufacturing

Construct Facility
A4 Transport
A5 Construct

Lab Equipment Fit-out
A4 Transport
A5 Install

Embodied Impact

Use
B1 Use
B2 Maintain
B3 Repair
B4 Replace
B5 Refurbish/Modify

Operation
B6 Operational Energy
B7 Operational Water

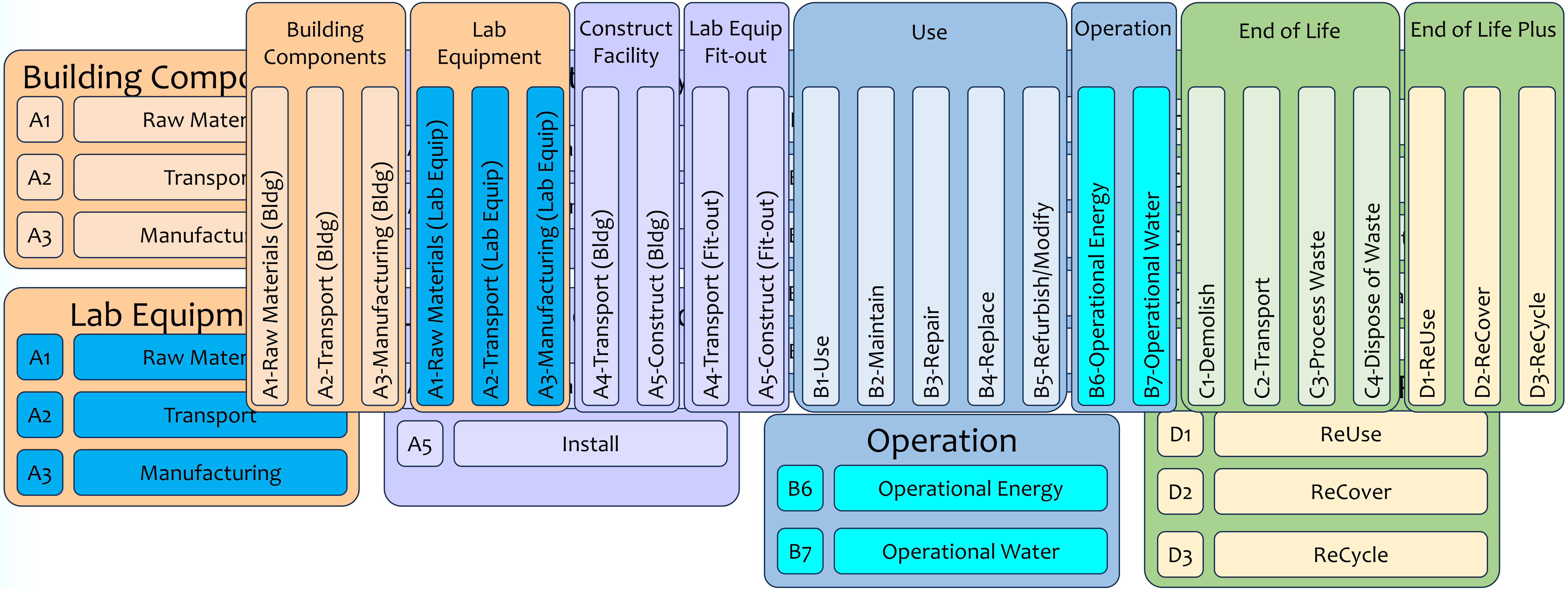
Operational Impact

End of Life
C1 Demolish
C2 Transport
C3 Process Waste
C4 Dispose of Waste

Embodied Impact

End of Life … Plus
D1 ReUse
D2 ReCover
D3 ReCycle

Whole Life Cycle of Buildings – Carbon & Costs



Building Components
A1-Raw Materials (Bldg)
A2-Transport (Bldg)
A3-Manufacturing (Bldg)

Lab Equipment
A1-Raw Materials (Lab Equip)
A2-Transport (Lab Equip)
A3-Manufacturing (Lab Equip)

Construct Facility
A4-Transport (Bldg)
A5-Construct (Bldg)

Lab Equip Fit-out
A4-Transport (Fit-out)
A5-Construct (Fit-out)

Use
B1-Use
B2-Maintain
B3-Repair
B4-Replace
B5-Refurbish/Modify

Operation
B6-Operational Energy
B7-Operational Water

End of Life
C1-Demolish
C2-Transport
C3-Process Waste
C4-Dispose of Waste

End of Life Plus
D1-ReUse
D2-ReCover
D3-ReCycle

Building Compo
A1 Raw Mater
A2 Transpor
A3 Manufactu

Lab Equipm
A1 Raw Mater
A2 Transport
A3 Manufacturing

A5 Install

Operation
B6 Operational Energy
B7 Operational Water

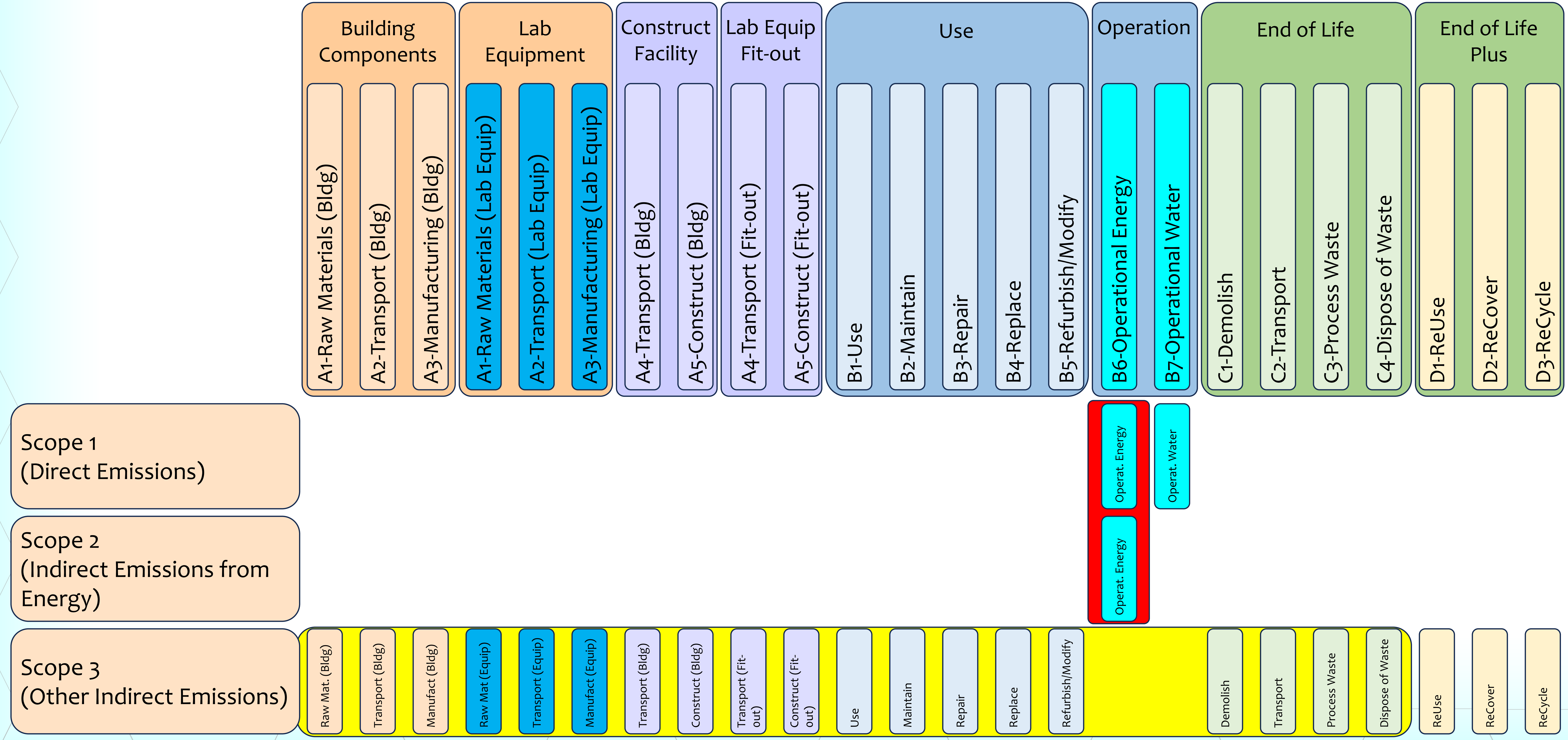
D1 ReUse
D2 ReCover
D3 ReCycle

Whole Life Cycle of Buildings – Carbon Impacts

	Building Components			Lab Equipment			Construct Facility		Lab Equip Fit-out	
	A1-Raw Materials (Bldg)	A2-Transport (Bldg)	A3-Manufacturing (Bldg)	A1-Raw Materials (Lab Equip)	A2-Transport (Lab Equip)	A3-Manufacturing (Lab Equip)	A4-Transport (Bldg)	A5-Construct (Bldg)	A4-Transport (Fit-out)	A5-Construct (Fit-out)
Scope 1 (Direct Emissions)	Raw Mat. (Bldg)	Transport (Bldg)	Manufact (Bldg)	Raw Mat (Equip)	Transport (Equip)	Manufact (Equip)	Transport (Bldg)	Construct (Bldg)	Transport (Fit-out)	Construct (Fit-out)
Scope 2 (Indirect Emissions from Energy)	Raw Mat. (Bldg)	Transport (Bldg)	Manufact (Bldg)	Raw Mat (Equip)	Transport (Equip)	Manufact (Equip)	Transport (Bldg)	Construct (Bldg)	Transport (Fit-out)	Construct (Fit-out)
Scope 3 (Other Indirect Emissions)	Raw Mat. (Bldg)	Transport (Bldg)	Manufact (Bldg)	Raw Mat (Equip)	Transport (Equip)	Manufact (Equip)	Transport (Bldg)	Construct (Bldg)	Transport (Fit-out)	Construct (Fit-out)

	Use					Operation		End of Life				End of Life Plus		
	B1-Use	B2-Maintain	B3-Repair	B4-Replace	B5-Refurbish/Modify	B6-Operational Energy	B7-Operational Water	C1-Demolish	C2-Transport	C3-Process Waste	C4-Dispose of Waste	D1-ReUse	D2-ReCover	D3-ReCycle
Scope 1 (Direct Emissions)	Use	Maintain	Repair	Replace	Refurbish/Modify	Operat. Energy	Operat. Water	Demolish	Transport	Process Waste	Dispose of Waste	ReUse	ReCover	ReCycle
Scope 2 (Indirect Emissions from Energy)	Use	Maintain	Repair	Replace	Refurbish/Modify	Operat. Energy	Operat. Water	Demolish	Transport	Process Waste	Dispose of Waste	ReUse	ReCover	ReCycle
Scope 3 (Other Indirect Emissions)	Use	Maintain	Repair	Replace	Refurbish/Modify	Operat. Energy	Operat. Water	Demolish	Transport	Process Waste	Dispose of Waste	ReUse	ReCover	ReCycle

Whole Life Cycle of Buildings – Carbon Impacts



Building Components
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- A3-Manufacturing (Bldg)

Lab Equipment
- A1-Raw Materials (Lab Equip)
- A2-Transport (Lab Equip)
- A3-Manufacturing (Lab Equip)

Construct Facility
- A4-Transport (Bldg)
- A5-Construct (Bldg)

Lab Equip Fit-out
- A4-Transport (Fit-out)
- A5-Construct (Fit-out)

Use
- B1-Use
- B2-Maintain
- B3-Repair
- B4-Replace
- B5-Refurbish/Modify

Operation
- B6-Operational Energy
- B7-Operational Water

End of Life
- C1-Demolish
- C2-Transport
- C3-Process Waste
- C4-Dispose of Waste

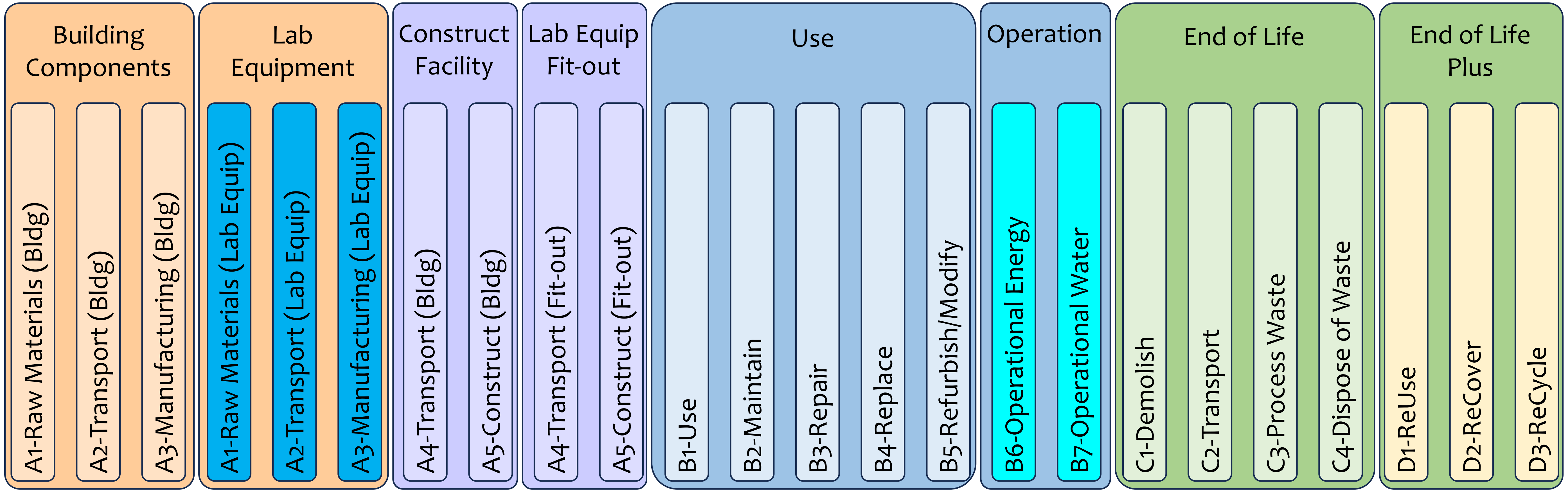
End of Life Plus
- D1-ReUse
- D2-ReCover
- D3-ReCycle

Scope 1
(Direct Emissions)

Scope 2
(Indirect Emissions from Energy)

Scope 3
(Other Indirect Emissions)

Scale of Carbon Impacts



Building Components
- A1-Raw Materials (Bldg)
- A2-Transport (Bldg)
- A3-Manufacturing (Bldg)

Lab Equipment
- A1-Raw Materials (Lab Equip)
- A2-Transport (Lab Equip)
- A3-Manufacturing (Lab Equip)

Construct Facility
- A4-Transport (Bldg)
- A5-Construct (Bldg)

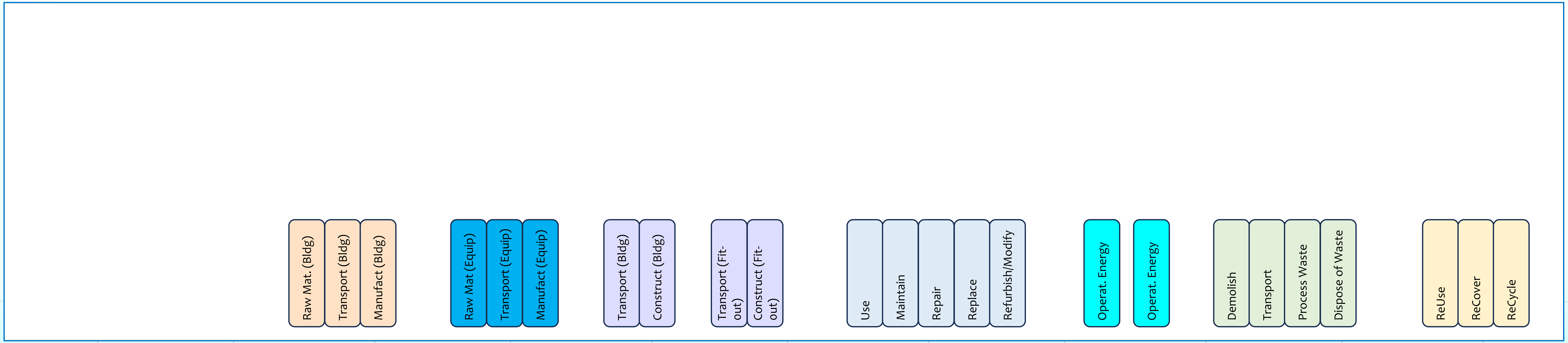
Lab Equip Fit-out
- A4-Transport (Fit-out)
- A5-Construct (Fit-out)

Use
- B1-Use
- B2-Maintain
- B3-Repair
- B4-Replace
- B5-Refurbish/Modify

Operation
- B6-Operational Energy
- B7-Operational Water

End of Life
- C1-Demolish
- C2-Transport
- C3-Process Waste
- C4-Dispose of Waste

End of Life Plus
- D1-ReUse
- D2-ReCover
- D3-ReCycle



Scale of Carbon Impacts

- Building Components
  - A1-Raw Materials (Bldg)
  - A2-Transport (Bldg)
  - A3-Manufacturing (Bldg)
- Lab Equipment
  - A1-Raw Materials (Lab Equip)
  - A2-Transport (Lab Equip)
  - A3-Manufacturing (Lab Equip)
- Construct Facility
  - A4-Transport (Bldg)
  - A5-Construct (Bldg)
- Lab Equip Fit-out
  - A4-Transport (Fit-out)
  - A5-Construct (Fit-out)
- Use
  - B1-Use
  - B2-Maintain
  - B3-Repair
  - B4-Replace
  - B5-Refurbish/Modify
- Operation
  - B6-Operational Energy
  - B7-Operational Water
- End of Life
  - C1-Demolish
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  - C3-Process Waste
  - C4-Dispose of Waste
- End of Life Plus
  - D1-ReUse
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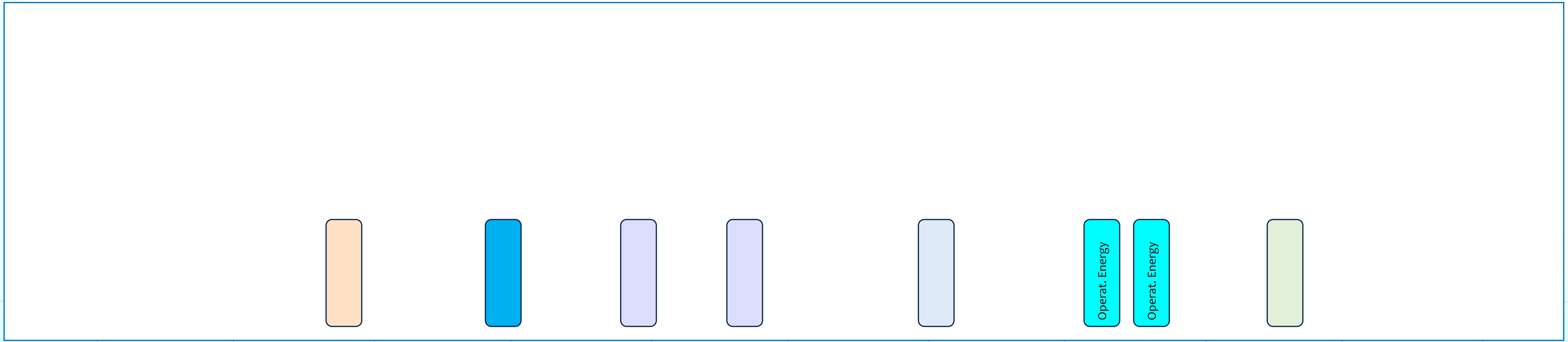
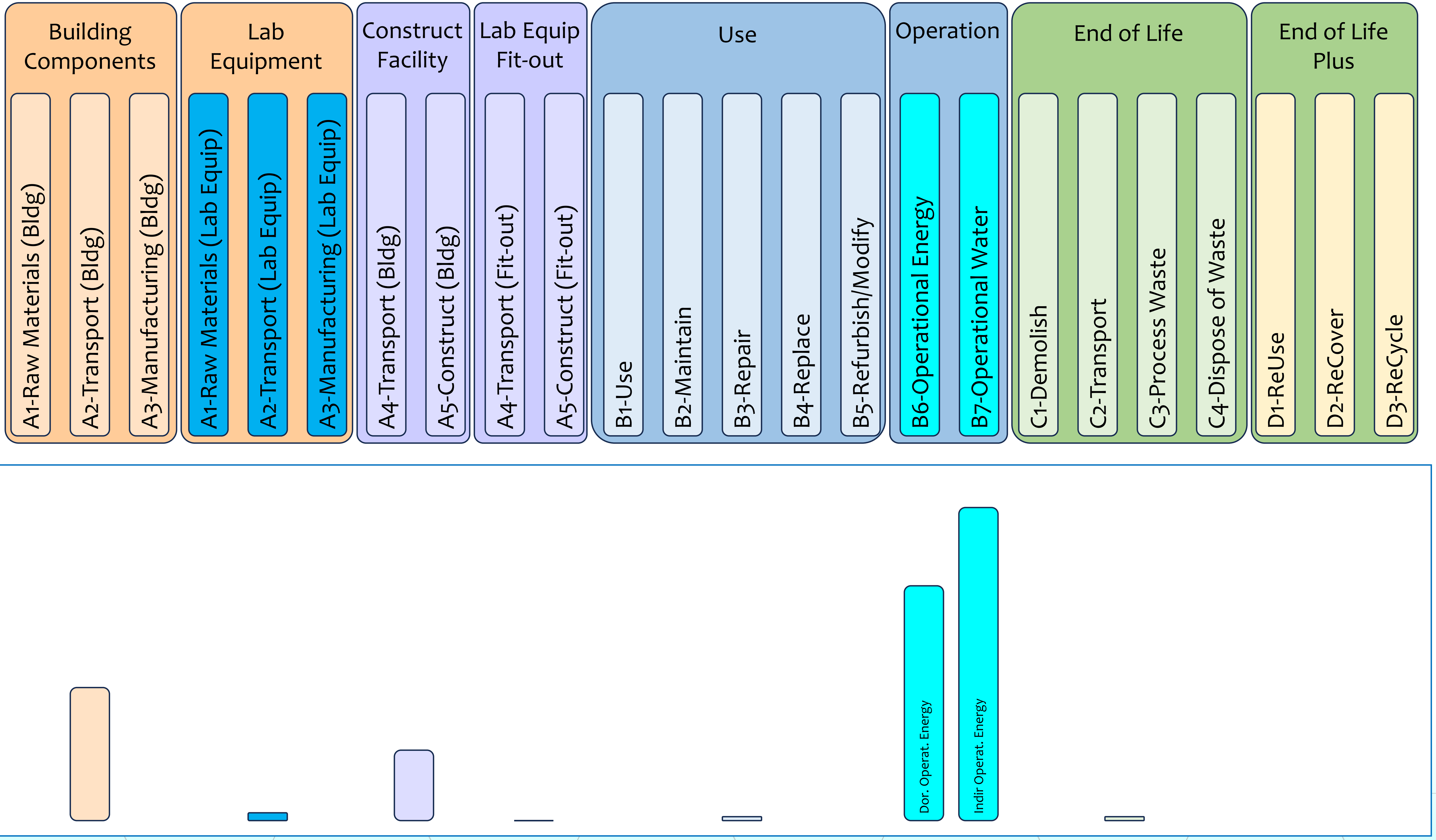
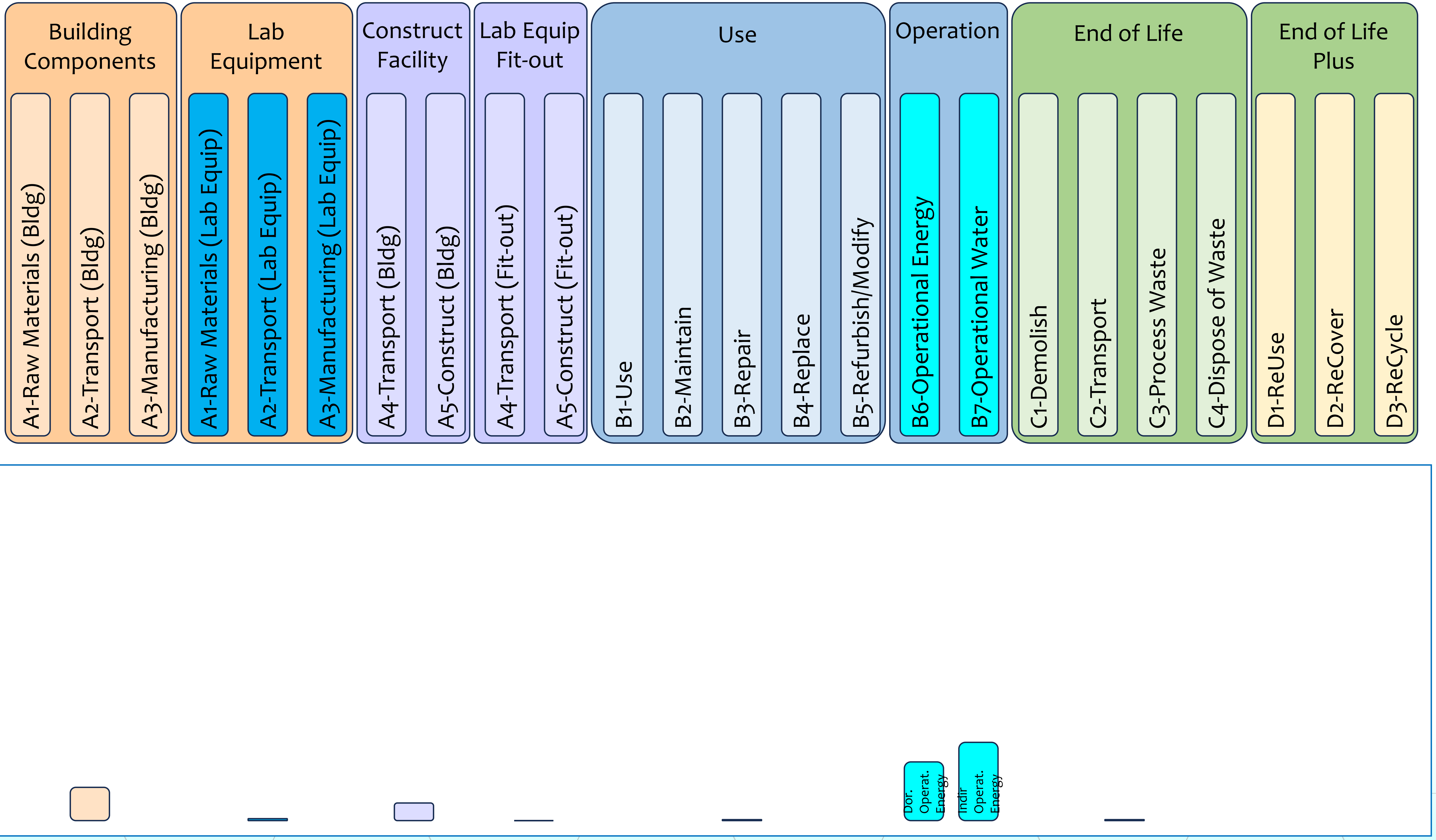


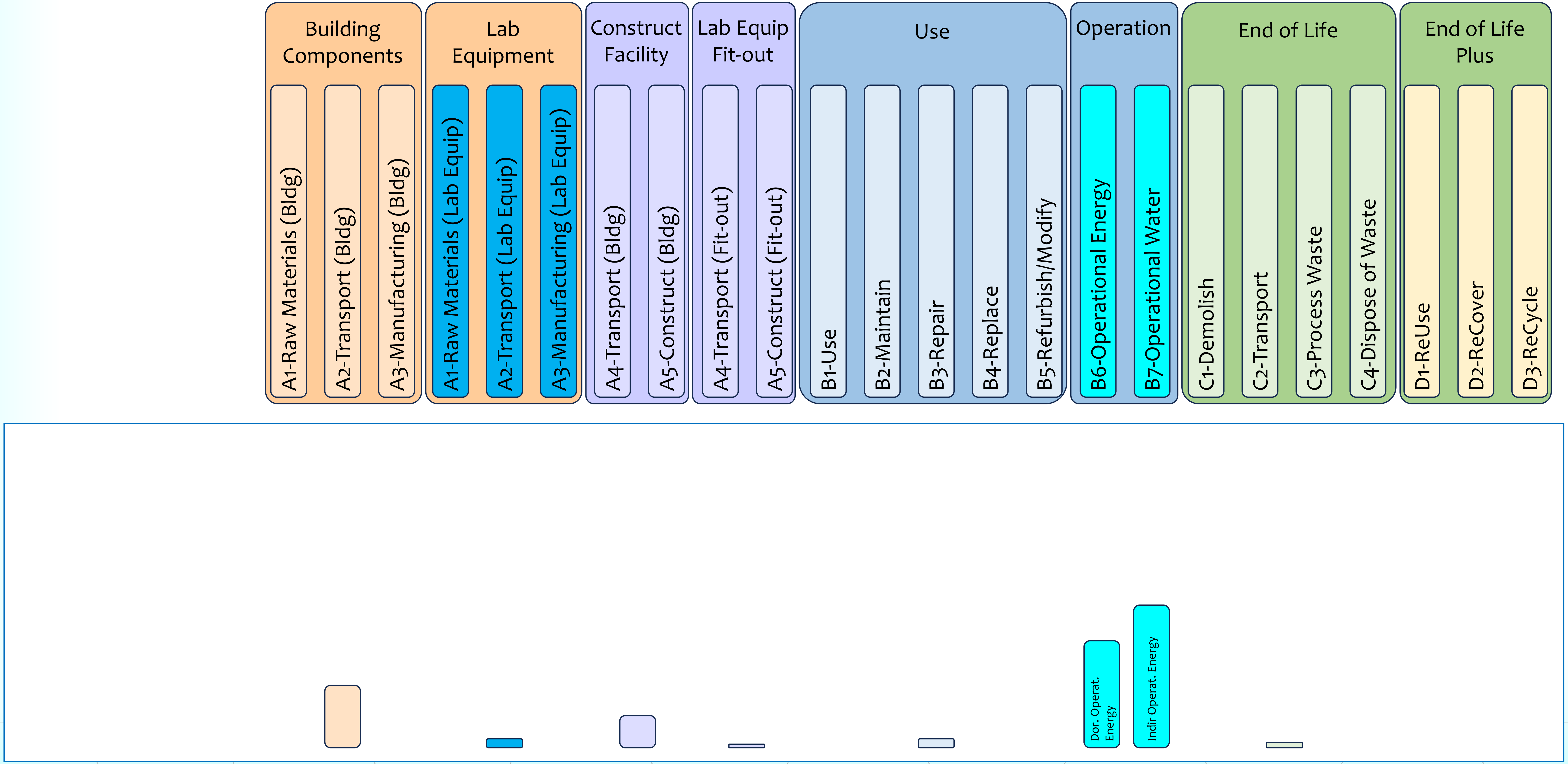
Scale of Carbon Impacts – Average Office Carbon Intensity



Scale of Carbon Impacts – Average Office Carbon Intensity



Scale of Carbon Impacts – Low Carbon Intensity Labs (Physics / Light Biology)



Building Components
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- A3-Manufacturing (Bldg)

Lab Equipment
- A1-Raw Materials (Lab Equip)
- A2-Transport (Lab Equip)
- A3-Manufacturing (Lab Equip)

Construct Facility
- A4-Transport (Bldg)
- A5-Construct (Bldg)

Lab Equip Fit-out
- A4-Transport (Fit-out)
- A5-Construct (Fit-out)

Use
- B1-Use
- B2-Maintain
- B3-Repair
- B4-Replace
- B5-Refurbish/Modify

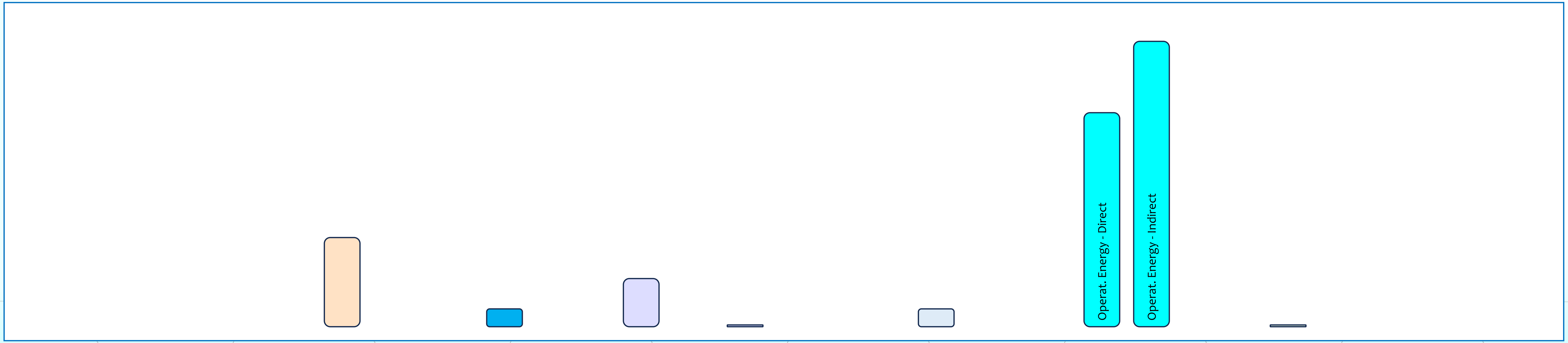
Operation
- B6-Operational Energy
- B7-Operational Water

End of Life
- C1-Demolish
- C2-Transport
- C3-Process Waste
- C4-Dispose of Waste

End of Life Plus
- D1-ReUse
- D2-ReCover
- D3-ReCycle

Scale of Carbon Impacts – Medium Carbon Intensity Labs (Biomedical)

- Building Components
  - A1-Raw Materials (Bldg)
  - A2-Transport (Bldg)
  - A3-Manufacturing (Bldg)
- Lab Equipment
  - A1-Raw Materials (Lab Equip)
  - A2-Transport (Lab Equip)
  - A3-Manufacturing (Lab Equip)
- Construct Facility
  - A4-Transport (Bldg)
  - A5-Construct (Bldg)
- Lab Equip Fit-out
  - A4-Transport (Fit-out)
  - A5-Construct (Fit-out)
- Use
  - B1-Use
  - B2-Maintain
  - B3-Repair
  - B4-Replace
  - B5-Refurbish/Modify
- Operation
  - B6-Operational Energy
  - B7-Operational Water
- End of Life
  - C1-Demolish
  - C2-Transport
  - C3-Process Waste
  - C4-Dispose of Waste
- End of Life Plus
  - D1-ReUse
  - D2-ReCover
  - D3-ReCycle



Carbon Intensity of Laboratories - Where Does Carbon Intensity Come From

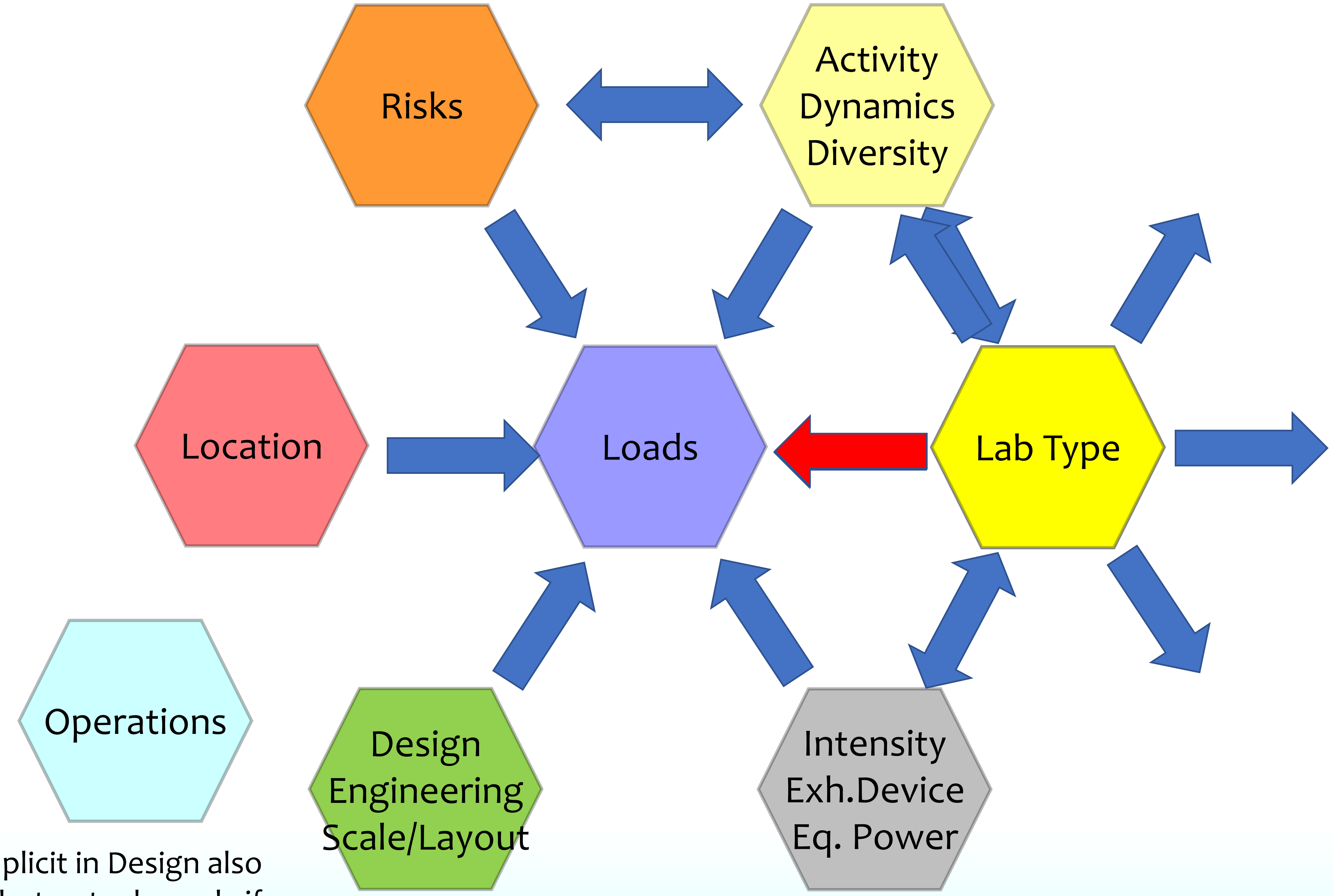
- Labs need Stable, Inert, Clean, Cleanable, Chemically Resistant and Adaptable materials
- Materials that meet these needs require more Extensive Mining, Processing, and Manufacturing to more critical specifications … More energy & effort to get them
- Critical Environmental Control of spaces, air quality and water quality
- Use of hazard materials requires Increased Levels Of Chemical Resistance, Contamination Control And Containment resulting in increased amounts of exhaust air, outside air make-up, barriers and chemically resistant material s that all add to the Carbon Intesnsity
- Many Lab Environments require More Extreme And More Critical Temperature And Humidity Control that increases aiflows and energy for conditioning
- Many Lab Environments Are Very Dynamic Over Time that often increases both the Controls challenges and the energy Efficiency challenges.
- What is the net Impact of these requirements? … **MORE CARBON INTENSE!**

Elements that affect How Building Design will Maintain Interior Environment

- Location and corresponding Climate and Elevation (altitude)
- Type/Function of the Lab & Intensity of Activity (Peak)
- Frequency of Activity (Time & Location)
- Duration of Activity
- Diversity of Activity (across both Rooms, Zones, Systems and the overall Building)
- What Response(s) are required to Maintain "Control" of the Indoor Environment
- How are the Response(s) affected by the Outdoor Environment
- What System Sizes, Types and Responses Best Maintain Control of the **Dynamics**

- All the above must be guided by … how the above factors **"Interact"**

What are the Primary Drivers of Energy? …more specifically what Drives Loads?


Risks

Activity
Dynamics
Diversity

Location

Loads

Lab Type

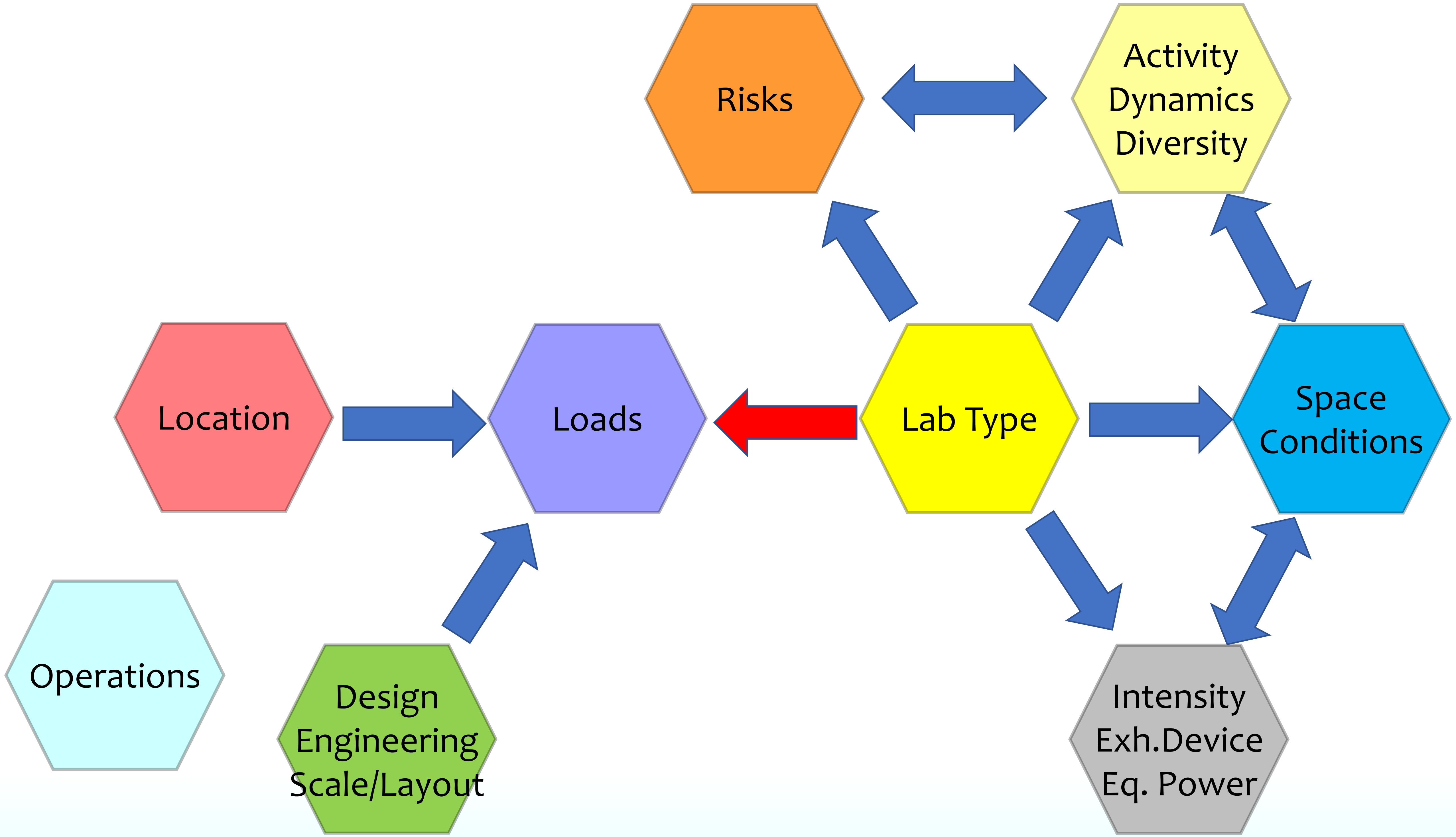
Operations

Design
Engineering
Scale/Layout

Intensity
Exh.Device
Eq. Power

Operations implicit in Design also affects Loads but not adversely if consistent with Design.

The Primary Drivers of Energy … Why and How? …



What Issues & Variables Most Impact Energy Use … Depends! … on What?

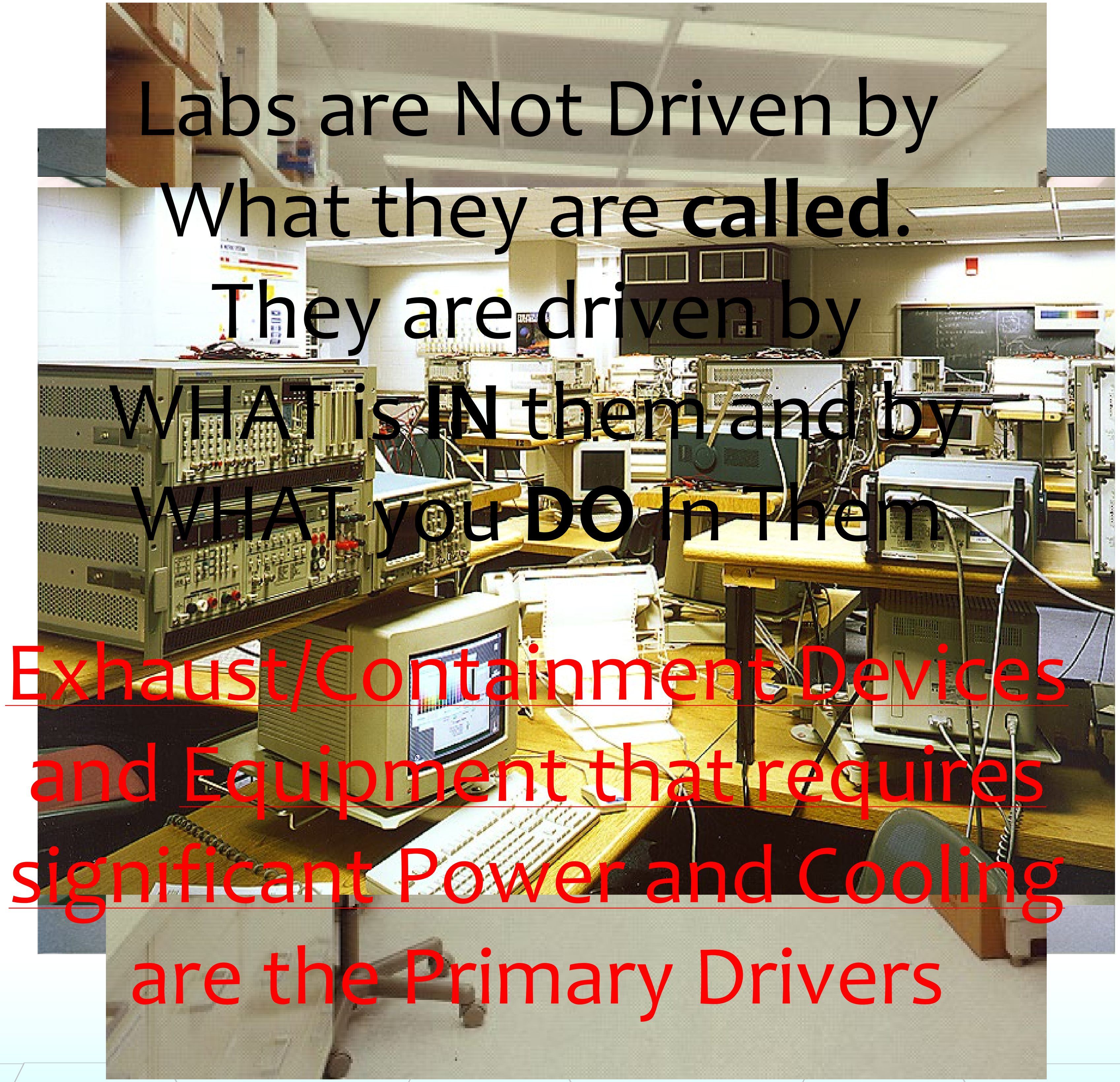
Issue
Location
Lab Type (Function)
Intensity
Arch. Design: Room Scale & Organization
Engineering Design
Operational Goals

What Issues & Variables Most Impact Energy Use … Depends! … on What?

Issue	Parameters	Options	Impacts	Scale of Impact
Location	High Cooling Loads High Humidification Loads High Heating Loads High Energy Use	Dot & Moist Hot & Dry Cold Hot and Moist		
Lab Type (Function)	Exhaust Device Driven Cooling Load Driven High Diversity	High Exhaust/Outside Air High Internal Equipment Heat		
Intensity				
Engineering Design				
Operational Goals				

Types of Labs (A to Z?) … How Much does Type make a difference?

Analytic, Animal, Agricultural, Anechoic, Aerospace, Automotive
Biology, Bioinformatics, Biotech, Biohazard, Biomedical, Botany
Chemistry, Containment, Clinical, Combinatorial, Cryogenics
Diagnostic, Discovery, Developmental, Disease
Electronics, Environmental, Energy, Ecology, Electrophysiology
Forensic, Food, FTIR (Fourier Transform Infrared Spectroscopy)
Genetics, Genomics, Gas Chromatography
Histology, HTS (High Throughput Screening), Hematology
Inorganic Chemistry, Infrared, Imaging , Immunoassay
Kinetics, Kinematics,
Laser, Lithography, Liquid Chromatography, Life Science
Materials, Microbiology, Meteorological, Microelectronics
Nanotechnology, Neurological, Necropsy
Organic Chemistry, Oceanographic, Oncology, Optical
Physics, Pharmaceutical, Petrochemical, Pathology, Proteomics
Quarantine, QC, Quantum Mechanics, Quartz
RadioChemical, Robotics, Recombinant DNA, Rheology
Semiconductor, Scale-up, Spectroscopy, Space, Standards
Toxicology, Teaching, Textile, Testing, Tissue Culture, Titration
Ultrasonic, UV
Vacuum, Vaccine, Viral, VOC
Wafer, Wet,
X-Ray Chromatography, Xenochemistry
Zoology

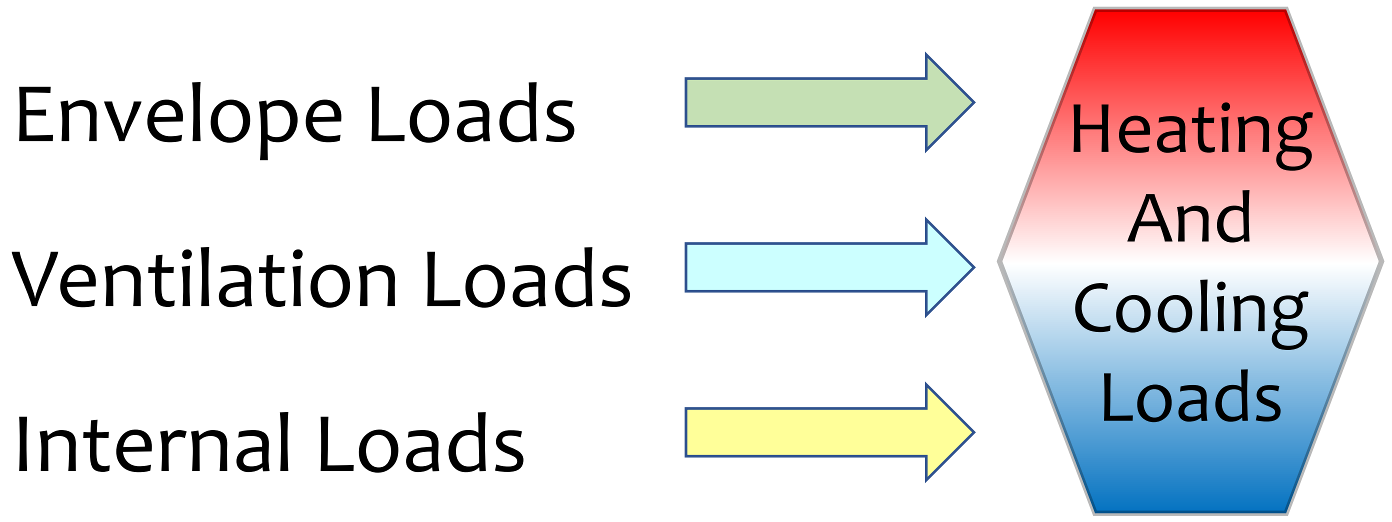


Labs are Not Driven by
What they are **called.**
They are driven by
WHAT is **IN** them and by
WHAT you **DO** In Them

Exhaust/Containment Devices
and Equipment that requires
significant Power and Cooling
are the Primary Drivers

Aspects of Laboratory Loads that Affect Energy Use and Carbon Intensity

- Usual Drivers of Loads, Airflows & Energy in Buildings:
  - Envelope Loads
  - Internal Loads
  - Ventilation Loads

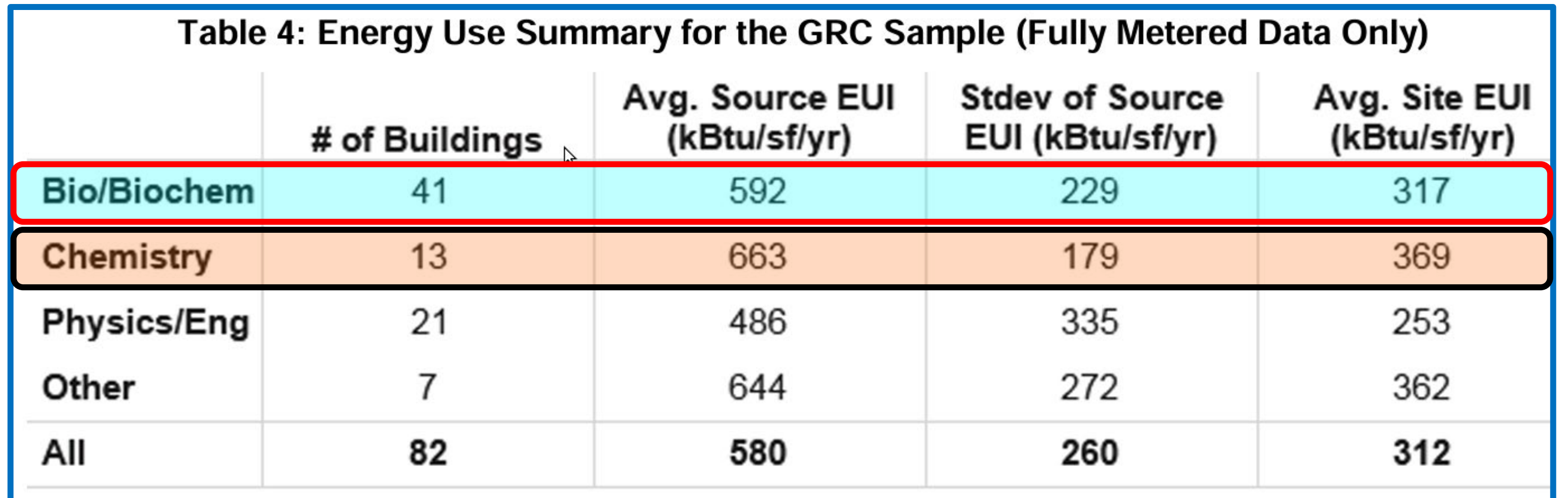


- Buildings with small Ventilation & Internal Loads are usually Envelope Driven …
- With Labs, Ventilation & Internal Loads Determine most Loads, Energy and Carbon Impact
- Which one Dominates will usually depend on upon two things:
  - **Type of Lab** … Whether it is Exhaust/Ventilation or Equipment Driven
  - Project Location/**Climate** … which Determines Scale of Heating/Cooling Loads from Ventilation
- Risk / Containment / Exhaust Air Make-up ➔ Ventilation / Outside Air Loads …
  - Buildings with large Exhaust Airflows are Ventilation Driven … Chemistry Labs …
  - Buildings with large Equipment loads are Internal Load Driven … Biology & Physics Labs …
- Labs with intermittent Loads (such as Teaching) have different Load & Occupancy Profiles

Lab Types – Differences, Similarities

- **Chemistry Labs**:
  - More & Larger Fume Hoods
  - More Chemicals/Risk
  - Less Equipment Loads (some within fume hoods)
  - Fewer Freezers & Refigerators
  - Lower Staffing Density (sometimes)
- **Biology/Biomedical Labs**:
  - Fewer & Smaller Fume Hoods
  - More BioSafety Cabinets
  - Less Chemicals (sometimes)
  - More Equipment Loads and Unstaffed use
  - More Freezers & Refrigerators
  - Higher Staffing Density
- EUIs can be similar because Ventilation and Equipment Loads tend to Offset each other
- Carbon Impacts are Different based on Energy Source

Table 4: Energy Use Summary for the GRC Sample (Fully Metered Data Only)



	# of Buildings	Avg. Source EUI (kBtu/sf/yr)	Stdev of Source EUI (kBtu/sf/yr)	Avg. Site EUI (kBtu/sf/yr)
Bio/Biochem	41	592	229	317
Chemistry	13	663	179	369
Physics/Eng	21	486	335	253
Other	7	644	272	362
All	**82**	**580**	**260**	**312**

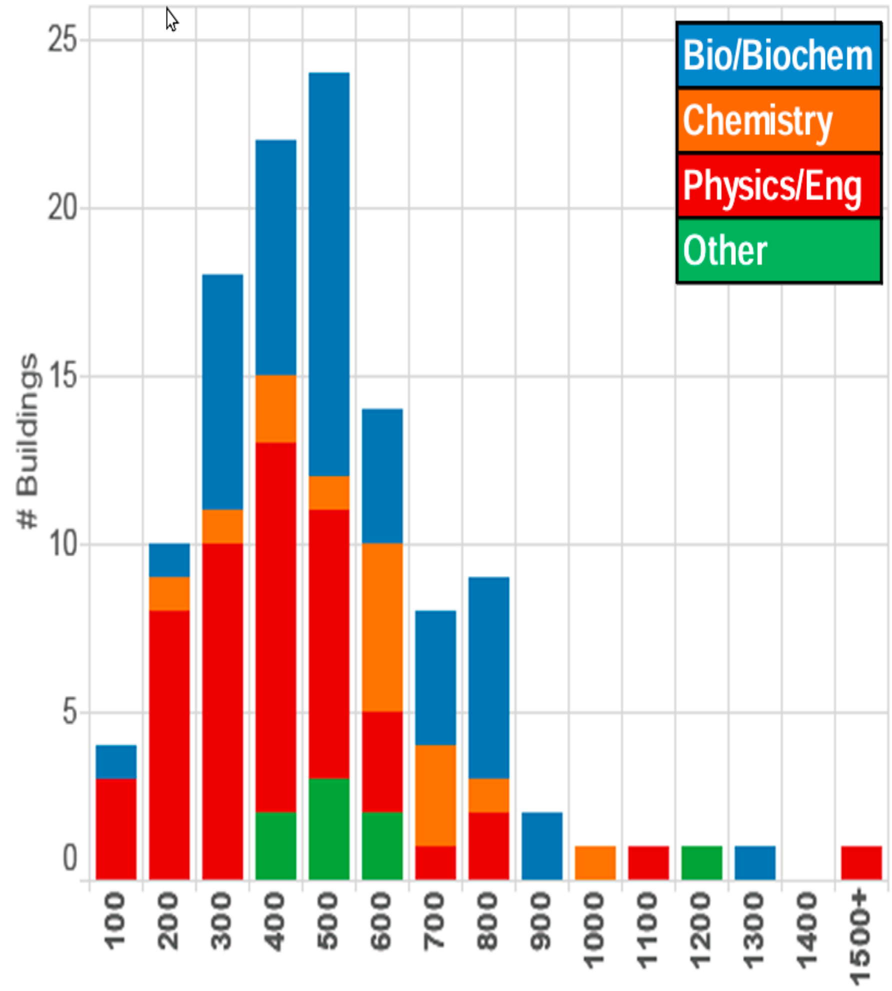
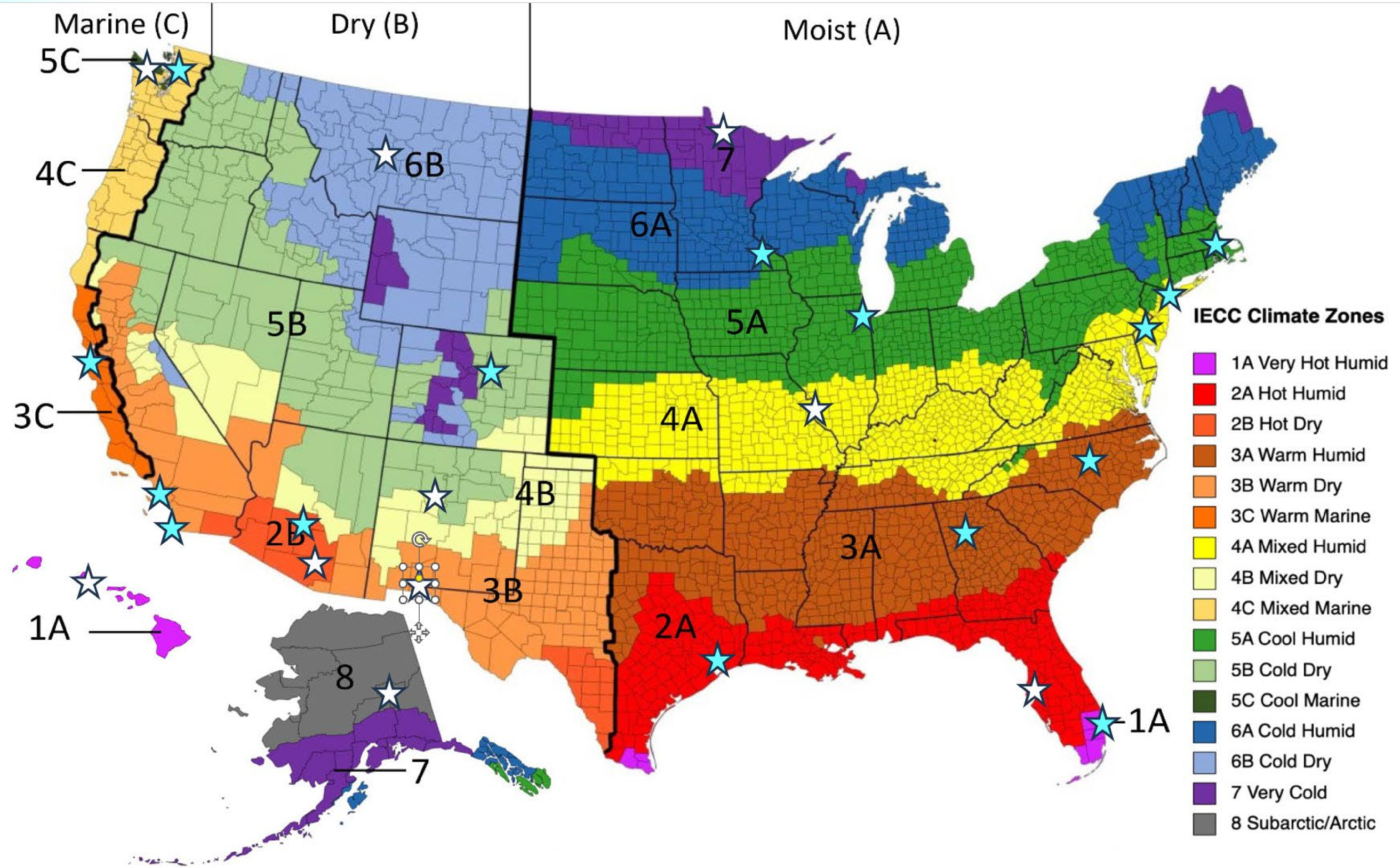
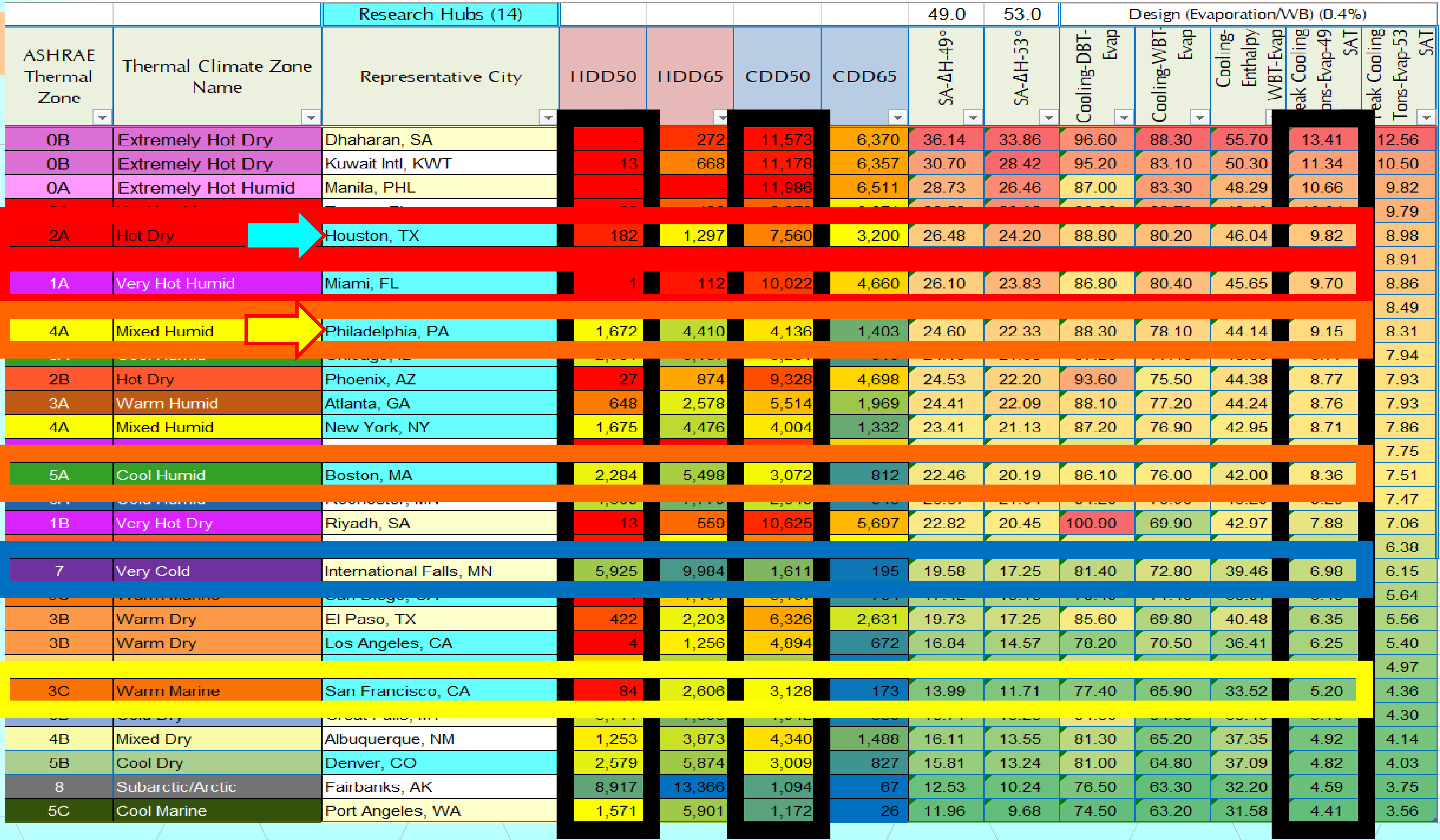


Figure 9: Source EUI Distribution (kBtu/sf/yr) for the GRC Sample (Fully Metered and Allocated)

ASHRAE / IECC Climate Zones/Cities … for Building Design & Energy Efficiency Goals

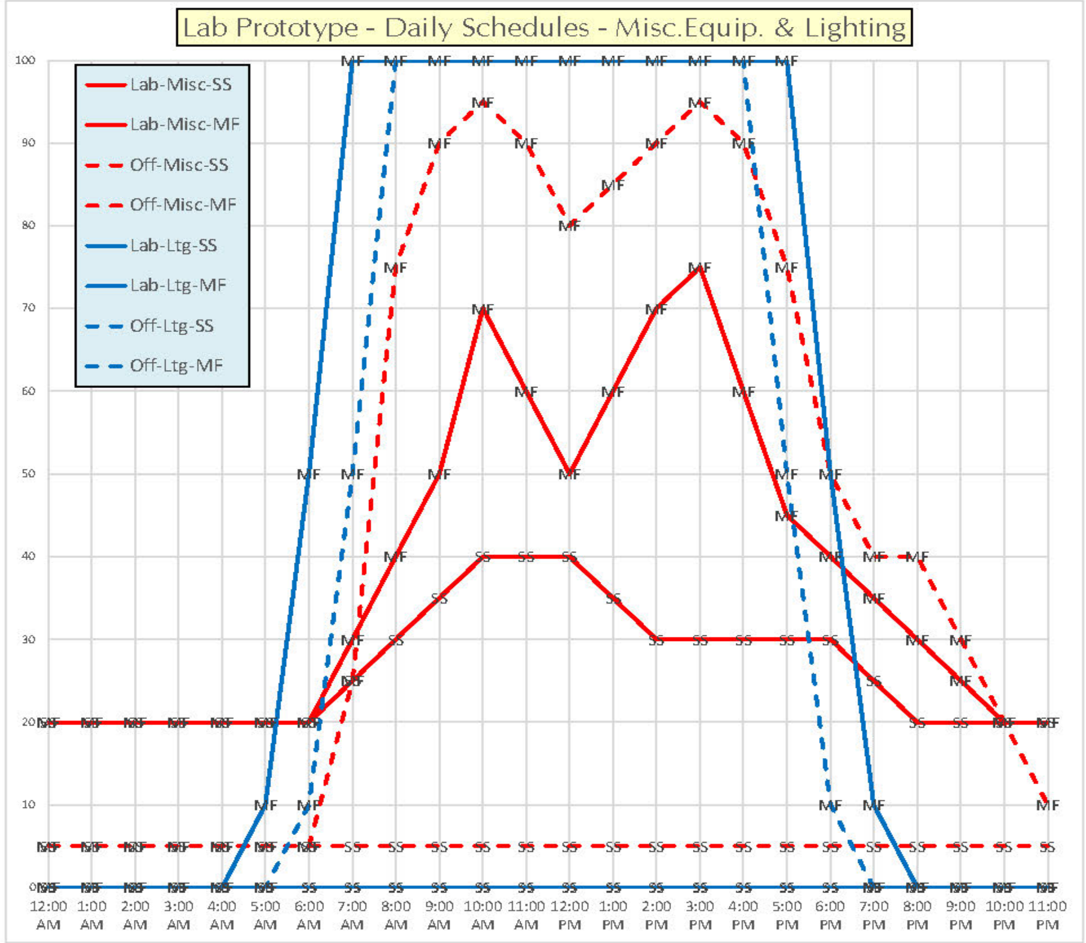




		Research Hubs (14)					49.0	53.0	Design (Evaporation/WB) (0.4%)				
ASHRAE Thermal Zone	Thermal Climate Zone Name	Representative City	HDD50	HDD65	CDD50	CDD65	SA-ΔH-49°	SA-ΔH-53°	Cooling-DBT-Evap	Cooling-WBT-Evap	Cooling-Enthalpy WBT-Evap	eak Cooling ons-Evap-49 SAT	eak Cooling Tons-Evap-53 SAT
0B	Extremely Hot Dry	Dhaharan, SA	-	272	11,573	6,370	36.14	33.86	96.60	88.30	55.70	13.41	12.56
0B	Extremely Hot Dry	Kuwait Intl, KWT	13	668	11,178	6,357	30.70	28.42	95.20	83.10	50.30	11.34	10.50
0A	Extremely Hot Humid	Manila, PHL	-	-	11,986	6,511	28.73	26.46	87.00	83.30	48.29	10.66	9.82
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	9.79
2A	Hot Dry	Houston, TX	182	1,297	7,560	3,200	26.48	24.20	88.80	80.20	46.04	9.82	8.98
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.91
1A	Very Hot Humid	Miami, FL	1	112	10,022	4,660	26.10	23.83	86.80	80.40	45.65	9.70	8.86
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.49
4A	Mixed Humid	Philadelphia, PA	1,672	4,410	4,136	1,403	24.60	22.33	88.30	78.10	44.14	9.15	8.31
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.94
2B	Hot Dry	Phoenix, AZ	27	874	9,328	4,698	24.53	22.20	93.60	75.50	44.38	8.77	7.93
3A	Warm Humid	Atlanta, GA	648	2,578	5,514	1,969	24.41	22.09	88.10	77.20	44.24	8.76	7.93
4A	Mixed Humid	New York, NY	1,675	4,476	4,004	1,332	23.41	21.13	87.20	76.90	42.95	8.71	7.86
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.75
5A	Cool Humid	Boston, MA	2,284	5,498	3,072	812	22.46	20.19	86.10	76.00	42.00	8.36	7.51
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.47
1B	Very Hot Dry	Riyadh, SA	13	559	10,625	5,697	22.82	20.45	100.90	69.90	42.97	7.88	7.06
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	6.38
7	Very Cold	International Falls, MN	5,925	9,984	1,611	195	19.58	17.25	81.40	72.80	39.46	6.98	6.15
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	5.64
3B	Warm Dry	El Paso, TX	422	2,203	6,326	2,631	19.73	17.25	85.60	69.80	40.48	6.35	5.56
3B	Warm Dry	Los Angeles, CA	4	1,256	4,894	672	16.84	14.57	78.20	70.50	36.41	6.25	5.40
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.97
3C	Warm Marine	San Francisco, CA	84	2,606	3,128	173	13.99	11.71	77.40	65.90	33.52	5.20	4.36
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.30
4B	Mixed Dry	Albuquerque, NM	1,253	3,873	4,340	1,488	16.11	13.55	81.30	65.20	37.35	4.92	4.14
5B	Cool Dry	Denver, CO	2,579	5,874	3,009	827	15.81	13.24	81.00	64.80	37.09	4.82	4.03
8	Subarctic/Arctic	Fairbanks, AK	8,917	13,366	1,094	67	12.53	10.24	76.50	63.30	32.20	4.59	3.75
5C	Cool Marine	Port Angeles, WA	1,571	5,901	1,172	26	11.96	9.68	74.50	63.20	31.58	4.41	3.56

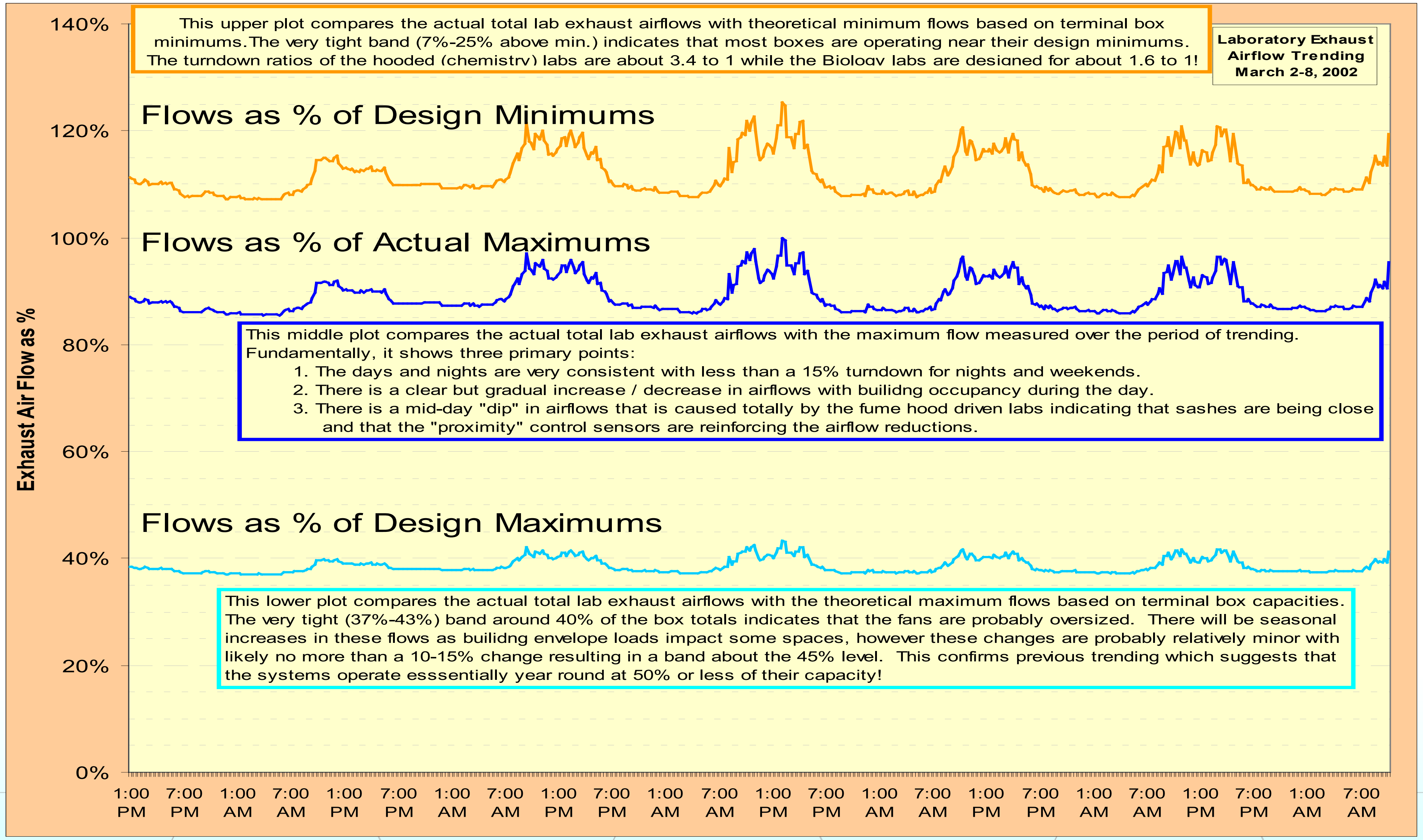
Dynamics of Occupancy, Internal Heat Gains, Ventilation, Equipment Usage

- Systems and Controls should Recognize the Dynamics of Typical Profiles
- Capturing Diversities Reduces both Peak Loads, Energy Use and Carbon Use
- Results in Smaller Equipment (Embodied Carbon) and Less Energy (Operational Carbon)
- Reduced Over-sizing Provides more Stable and Accurate Control
- Minimizes Total Carbon Footprint



Laboratory Exhaust Airflow Dynamics

- Whenever possible, controls should Modulate Room and Device Airflows to the Maximum extent possible
- Using Occupancy and Zone Presence Sensors to reduce both Exhaust Device Airflows and effective room Air Changes
- Safety and Containment should always be Maintained
- Variable Volume Systems Minimize Oversizing and Reduce Energy/Carbon



Laboratory Exhaust Airflow Trending March 2-8, 2002

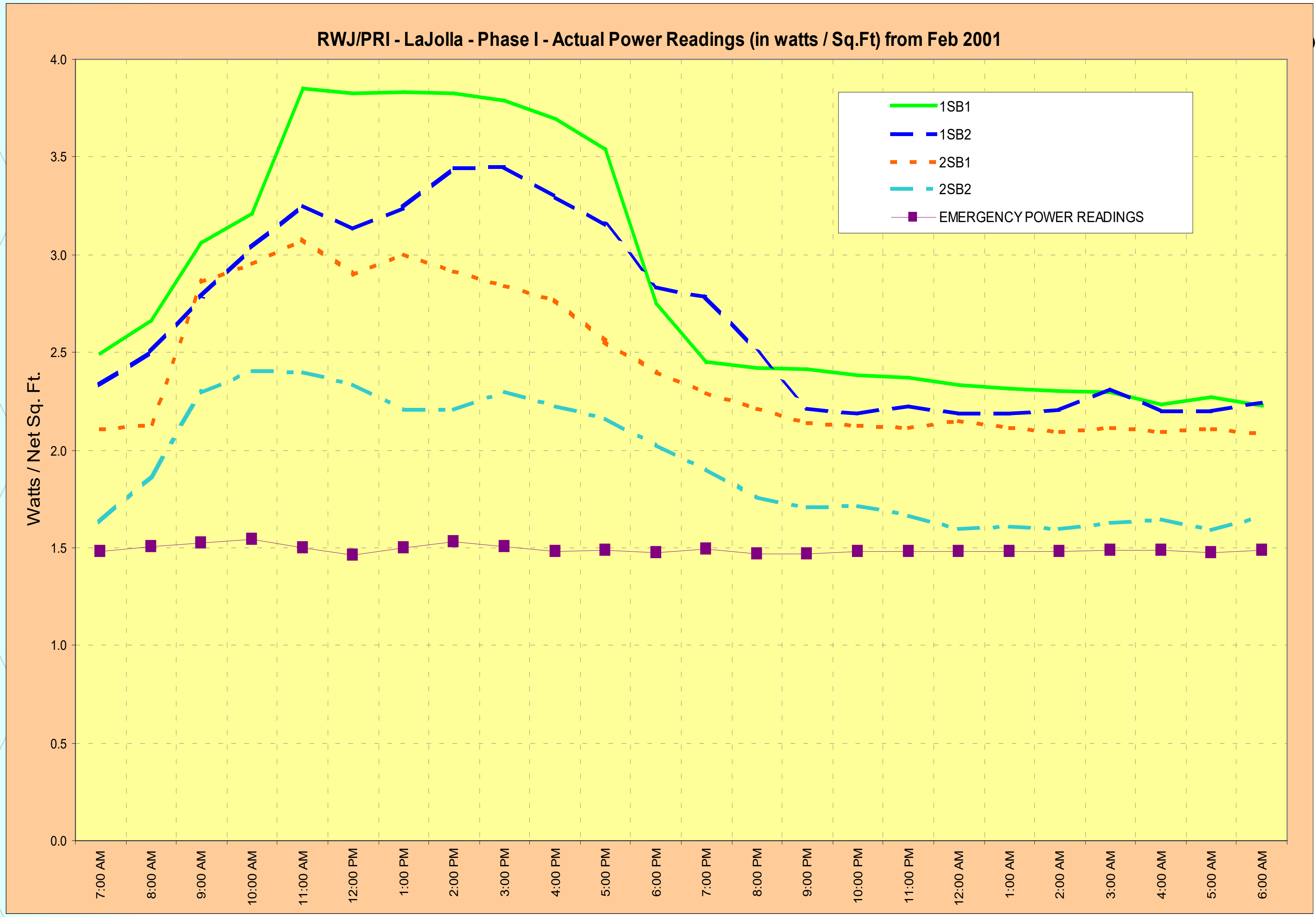
This upper plot compares the actual total lab exhaust airflows with theoretical minimum flows based on terminal box minimums.The very tight band (7%-25% above min.) indicates that most boxes are operating near their design minimums. The turndown ratios of the hooded (chemistry) labs are about 3.4 to 1 while the Biology labs are designed for about 1.6 to 1!

This middle plot compares the actual total lab exhaust airflows with the maximum flow measured over the period of trending. Fundamentally, it shows three primary points:

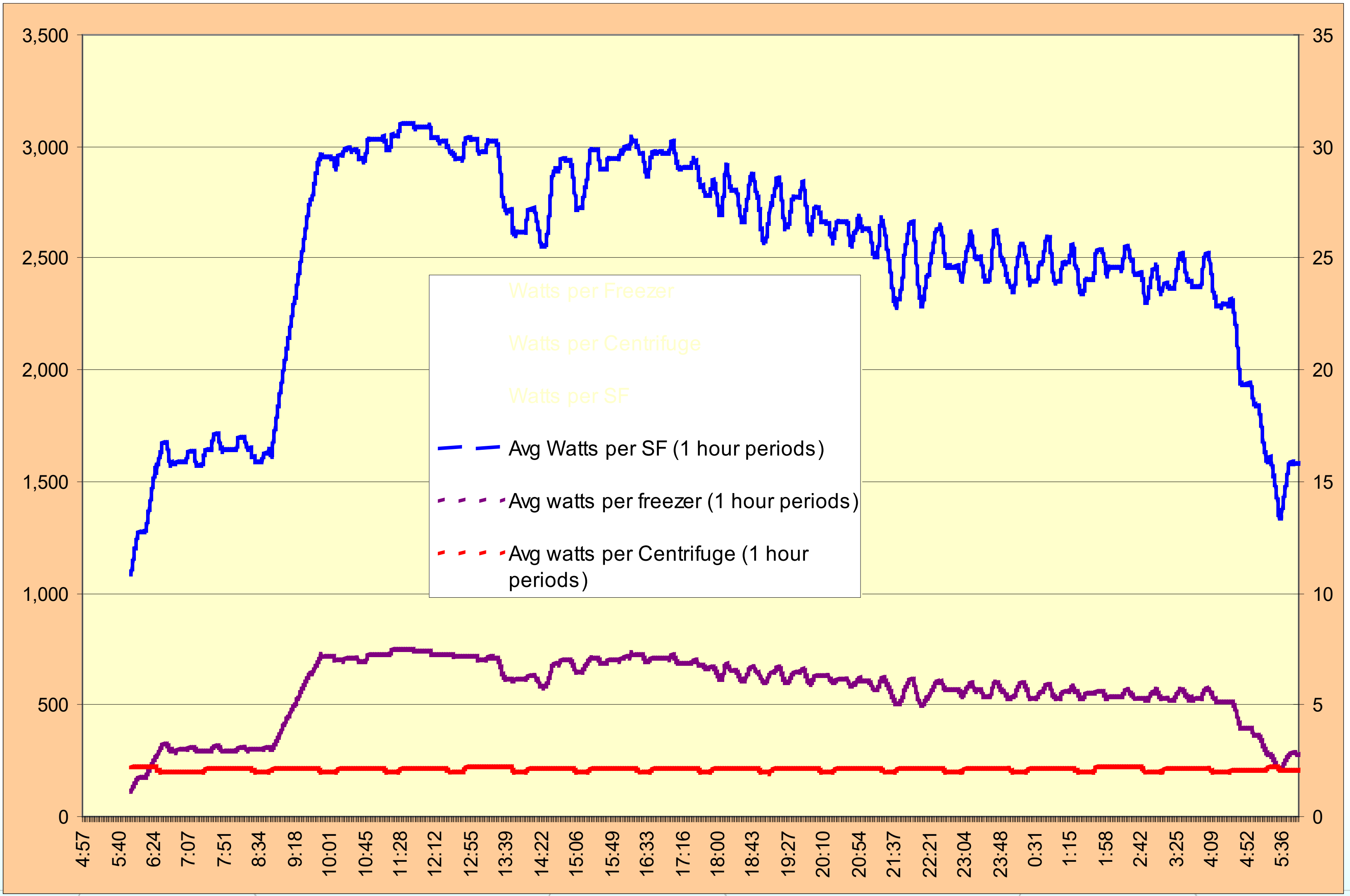
1. The days and nights are very consistent with less than a 15% turndown for nights and weekends.
2. There is a clear but gradual increase / decrease in airflows with builidng occupancy during the day.
3. There is a mid-day "dip" in airflows that is caused totally by the fume hood driven labs indicating that sashes are being close and that the "proximity" control sensors are reinforcing the airflow reductions.

This lower plot compares the actual total lab exhaust airflows with the theoretical maximum flows based on terminal box capacities. The very tight (37%-43%) band around 40% of the box totals indicates that the fans are probably oversized. There will be seasonal increases in these flows as builidng envelope loads impact some spaces, however these changes are probably relatively minor with likely no more than a 10-15% change resulting in a band about the 45% level. This confirms previous trending which suggests that the systems operate esssentially year round at 50% or less of their capacity!

Dynamics - Combination of Device Characteristics and Equipment Utilization

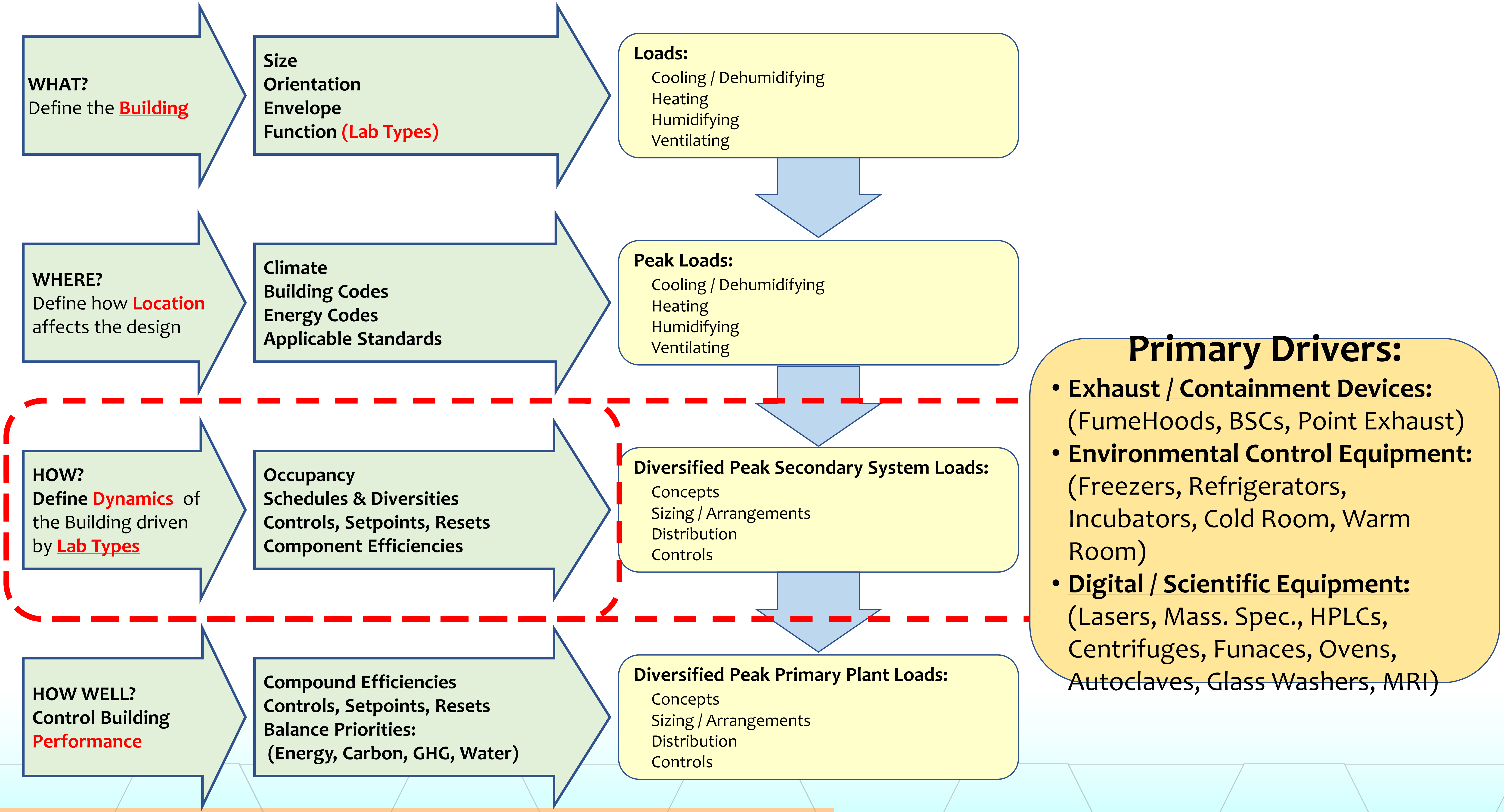


Power Requirements



Equipment Utilization

Mech/HVAC Engineering Systems ➔ Loads ➔ Performance ➔ Sizing, Selection, Distribution, Controls



WHAT?
Define the **Building**

Size
Orientation
Envelope
Function (Lab Types)

Loads:
Cooling / Dehumidifying
Heating
Humidifying
Ventilating

WHERE?
Define how **Location** affects the design

Climate
Building Codes
Energy Codes
Applicable Standards

Peak Loads:
Cooling / Dehumidifying
Heating
Humidifying
Ventilating

HOW?
Define Dynamics of the Building driven by **Lab Types**

Occupancy
Schedules & Diversities
Controls, Setpoints, Resets
Component Efficiencies

Diversified Peak Secondary System Loads:
Concepts
Sizing / Arrangements
Distribution
Controls

HOW WELL?
Control Building
Performance

Compound Efficiencies
Controls, Setpoints, Resets
Balance Priorities:
(Energy, Carbon, GHG, Water)

Diversified Peak Primary Plant Loads:
Concepts
Sizing / Arrangements
Distribution
Controls

Primary Drivers:

- **Exhaust / Containment Devices:** (FumeHoods, BSCs, Point Exhaust)
- **Environmental Control Equipment:** (Freezers, Refrigerators, Incubators, Cold Room, Warm Room)
- **Digital / Scientific Equipment:** (Lasers, Mass. Spec., HPLCs, Centrifuges, Funaces, Ovens, Autoclaves, Glass Washers, MRI)

Dynamic Ranges of Parameters in Typical Labs

- Fume Hood Face Velocities (normal)

Minimum	60-70 FPM
Typical	80-100 FPM
High	120 + FPM

- Fume Hood Face Velocities or Volumes (Minimum)

Minimum Velocity	60 FPM
Minimum Flows	~50% Full sash Area at 100 FPM

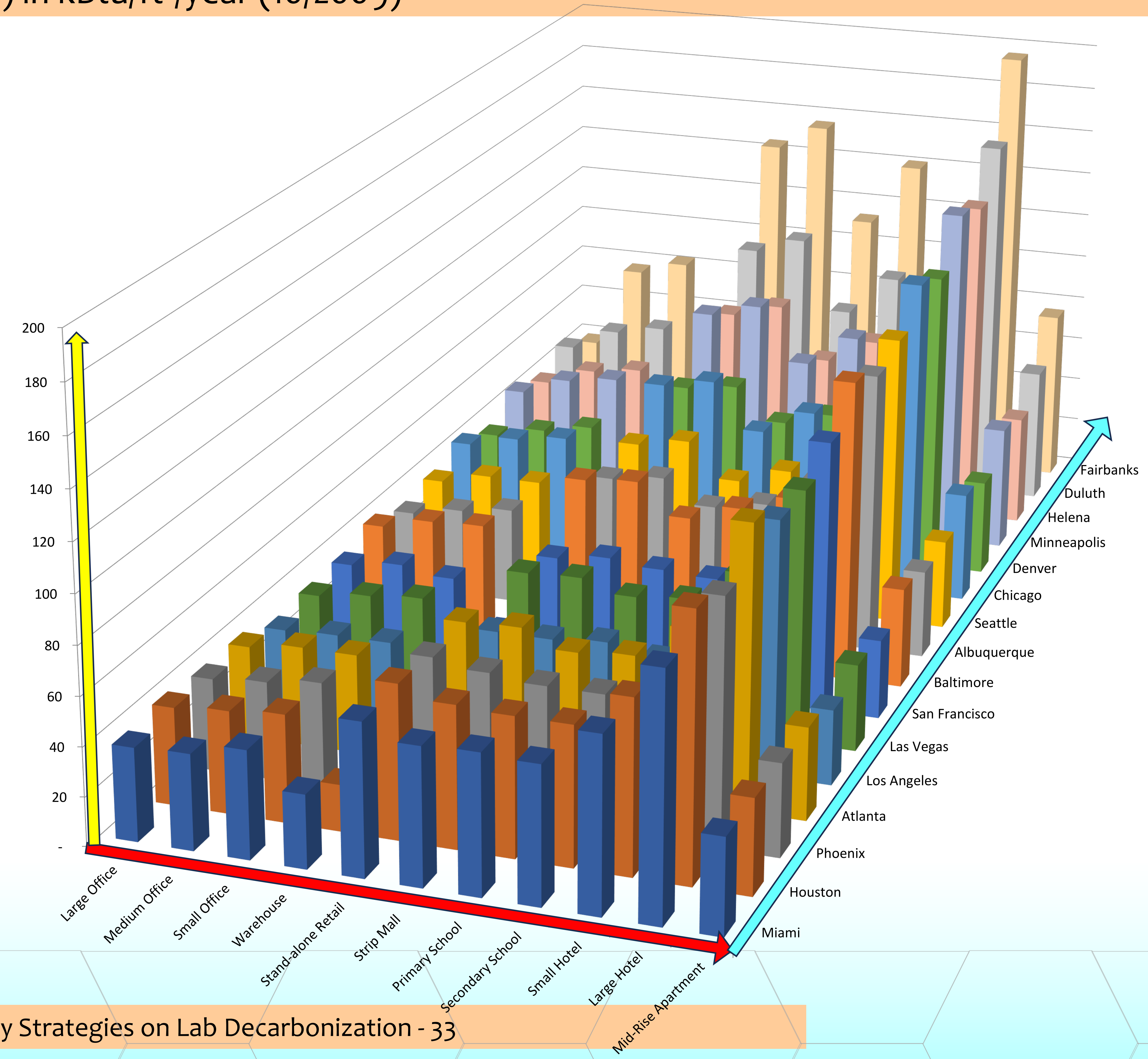
- Space Temperatures

Lab (with Lab coats)	70-72° F
Lab (without Lab coats)	74-76° F
Non-Lab occupied Space	72-76° F

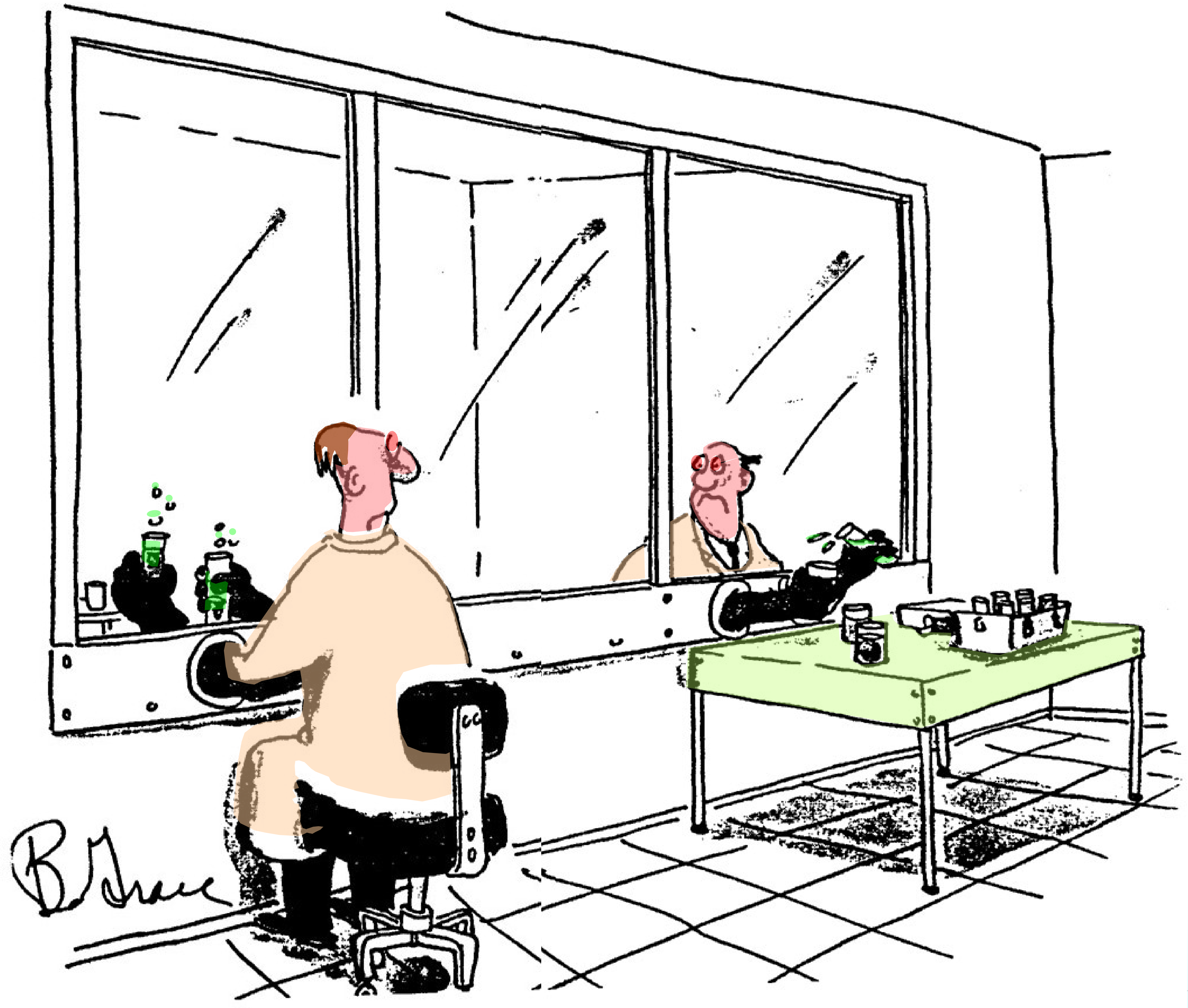
- Percentage of Outside Air

Maximum	100% supply
Minimum for non-dilution	25% supply

DOE Commercial Building Benchmarks - Prototypical Standard Building Models - New Construction Energy Use Intensities (EUIs) in kBtu/ft^2/year (10/2009)



… Perspective … is an Important Part of both Safety … and Good Engineering



Summary of Issues to Consider

- Impact of Building Useful Lifespan
- Changing Approaches To Repurposing Older Buildings
- Strategies to Provide Flexibility for Repurposing & Expansion
- Providing Resiliency without “Spare” Capacity
- Impact of Under- vs Over-sizing on Operational and Embodied Carbon
- Maximizing the Efficient Response to Dynamics
- Maximizing Use of Diversity
- Meeting Heating Loads without Fossil Fuels
- Exhaust Driven vs Load Driven Spaces
- Liquid vs Air-cooled Systems
- Using Ventilation Effectiveness for Contamination Control.
- Shared Use of Equipment both within and between Users
- Balancing Embodied vs Operational Carbon
- Decarbonization of Electrical Grid

Conservation Basics - for both Carbon and Energy

- Don’t do it./Don’t install it … Share equipment
- Do it only when necessary … Take better advantage of diversities to impact sizing as well as energy cost
- Do it more efficiently … Match equipment to circumstances
- Mirror the Building Dynamics as much as possible
- Know the loads and conditions … Avoid oversizing
- Do only as much as absolutely necessary … Apply different strategies for resilience rather than fully redundant equipment
- Follow the Straight Line Principal to Minimize losses

Observations & questions - how things may change

- Differences in Embodied versus Operational carbon
- Short vs long-term … One time vs multiple times … Embodied harder to quantify for payback … approaches conserve both types of carbon
- How to maximize Fume Hood Containment at lower Face Velocity
- How can technology options better address cooling needs without using outside air
- Can resiliency needs be met using less redundancy with more sophisticated controls
- What can be done to reduce the range of dynamics in labs?
- How will climate change impact carbon assumptions
- Heating versus cooling dominant.(fuel or electric driven.
- Efficiency improvements HVAC systems and renewable energy systems
- Measurement control improvements.

Observations & questions - how things may change (cont.)

- How politics/culture/codes affect decision-making
  - Renewable or fossil fuel dominant.
  - Short versus long-term attitudes
- How the grid affect decision-making?
  - Transition to electrification.
  - Increasing amount of renewable energy.
  - In increasing efficiency of renewable energy systems.
  - In increasing effectiveness of battery storage systems
- If buildings become zero energy in the next 25 years, as operational carbon is significantly reduced, How will the focus on embodied carbon change?
- How will the advent of more effective uses of AI change the nature of research using physical testing?
- How might Changes in the power of grid and electrification affect both our transportation systems and the organization of our society?

Questions?

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