RMI Innovation Center

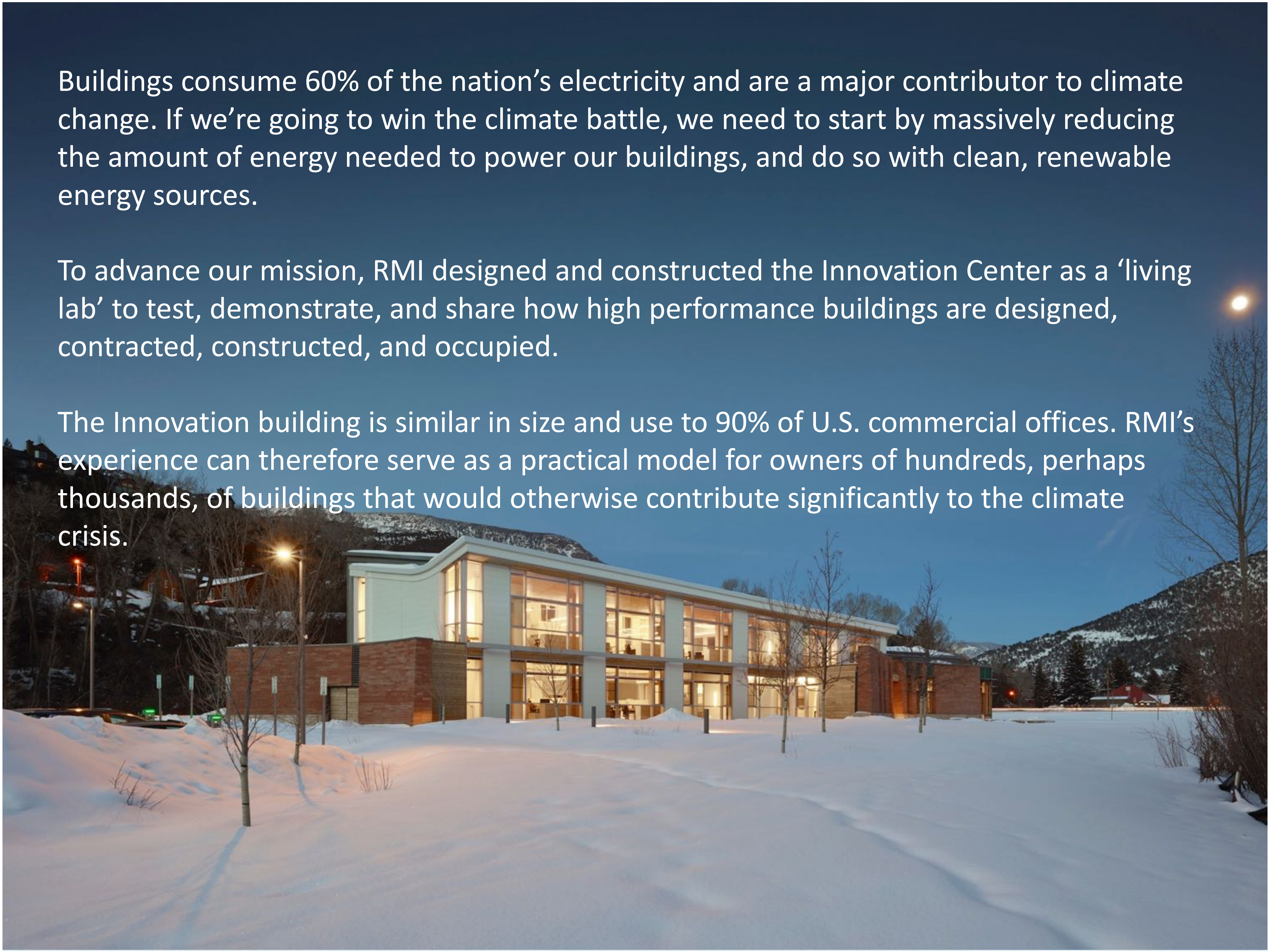
Year 1 Insights, Results, and Lessons Learned
Current as of February , 2017

ROCKY MOUNTAIN INSTITUTE

Buildings consume 60% of the nation's electricity and are a major contributor to climate change. If we're going to win the climate battle, we need to start by massively reducing the amount of energy needed to power our buildings, and do so with clean, renewable energy sources.

To advance our mission, RMI designed and constructed the Innovation Center as a 'living lab' to test, demonstrate, and share how high performance buildings are designed, contracted, constructed, and occupied.

The Innovation building is similar in size and use to 90% of U.S. commercial offices. RMI's experience can therefore serve as a practical model for owners of hundreds, perhaps thousands, of buildings that would otherwise contribute significantly to the climate crisis.




If every commercial building in the US increased its energy efficiency to this level we would save enough energy in 1 month to power New York City for a year.

Innovation Center Highlights

Achieves **net-positive energy** (only 200 buildings are NZE as of 2016)

The **highest performing** building in the **coldest climate zone** in the US even before PV

74% more efficient than the average office building in its climate

LEED Platinum certified, Passive House Certified, PHIUS+ Source Net Zero Project and meets Architecture 2030 goals

No cooling system and a small, distributed heating system with equivalent capacity of 1 mid sized home

Used emerging **Integrated Project Delivery (IPD)** contracting method

Building Overview

Type: Commercial office building.

Use: Headquarters of Rocky Mountain Institute, accommodating 50 staff and 80+ in convening center

Location: Basalt, Colorado

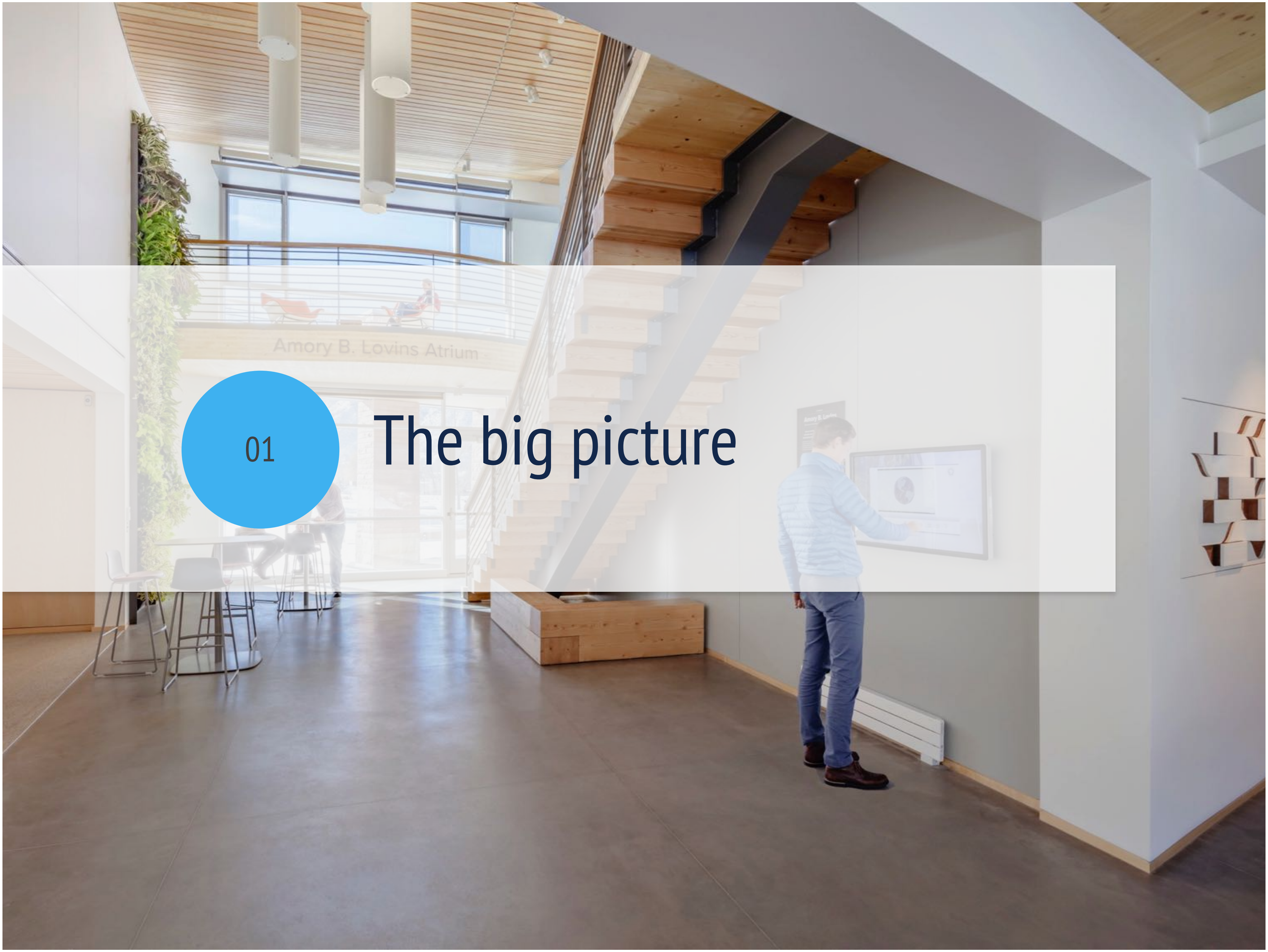
Size: 15,610 sq. Ft

Completed: Dec, 2015

Overview

1. The big picture
2. Results from the first year of occupancy
3. Passive design for zero net carbon
4. Thermal comfort, occupant engagement
5. Energy generation, storage, and grid interface
6. Contracting methodology
7. Water use and biophilia
8. Cost, value and payback
9. Appendix

Lessons learned are provided in each section



01 The big picture

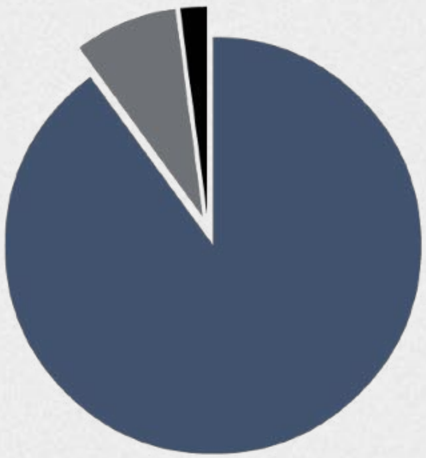
The big picture

The most significant contributions delivered by the Innovation Center go beyond just providing an office building but a model to drive change in the building and energy industry

1. PUSHES THE BOUNDARY OF PASSIVE DESIGN TO ADVANCE THE INDUSTRY
2. MODELS AN INNOVATIVE APPROACH TO THERMAL COMFORT
3. IS PRODUCTIVE FOR OCCUPANTS, AND THE ELECTRICITY GRID
4. DEMONSTRATES A RESILIENT, 100-YEAR BUILDING
5. LIVES UP TO EXPECTATIONS – WALKS THE TALK

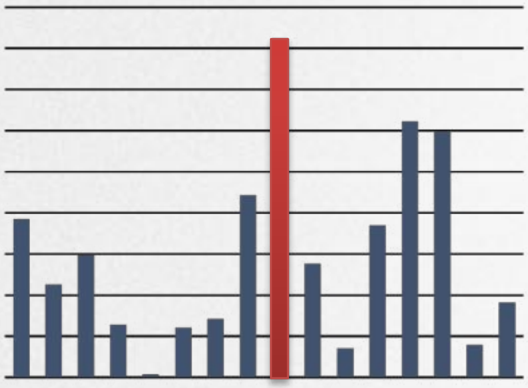
This building serves as a model

The Innovation Center is right in the 'sweet spot' to move the market



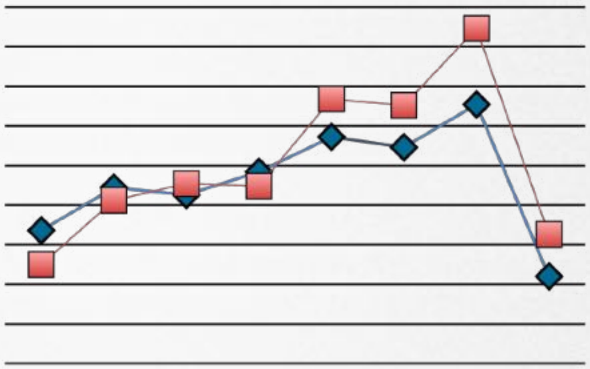
90%

OF COMMERCIAL BUILDINGS ARE UNDER **25,000 SF**



OFFICES

ARE THE BIGGEST USE OF COMMERCIAL BUILDINGS UNDER **25,000 SF**



HALF

OF COMMERCIAL BUILDINGS UNDER **25,000 SF** ARE OWNER OCCUPIED

Source: CBECS 2003 and 2012

Bringing zero to scale

RMI's Pathways to Zero Initiative builds on the lessons learned from the Innovation Center (and other successes) to drive the adoption of superefficient and net zero energy or zero net carbon buildings in both new and existing buildings and at the portfolio and district level

1. There is a urgent need to **cut CO_2 emissions** to reduce the impact of climate change.
2. Buildings are the **largest single source** of CO_2 emissions, accounting for nearly half of global CO_2 emissions.
3. This change must make significant strides **before 2030.**
4. The industry needs transformative models to design, build and operate buildings.
5. To have the necessary impact, ZNC needs to **scale** from individual buildings to portfolios, cities and districts.
6. Transformative business models, that provide **first cost and lifecycle cost wins** will drive both new and existing buildings.
7. The industry needs mechanisms for onsite and distributed renewable energy.

RMI is working on the Almono redevelopment, a 180-acre site that will become the largest net-zero development in the world, with a strong business model to support it.

Global recognition to maximize influence

Since the building opened, the Innovation Center has been recognized through:

- Over **20 articles and blogs** published (including Architecture Magazine, ASHRAE's High Performance Building Magazine, Building Green, USGBC, Fast Company, Green Tech Media and Virgin.com)
- **3 books** will publish case studies (including Green Studio Handbook)
- Over **30 presentations** at influential industry events (including Greenbuild 2015, ILFI Net Positive Conference, Getting to Zero Forum, Rocky Mountain Green, PassiveHouse Annual Conference)
- Weekly **tours** given to **thousands of individuals from 7 countries**.
- Design teams using lessons learned, industry interest in the Impact Studio, visitors interested in implementing aspects of the IC into their orgs

Noteworthy awards and certifications:

- PassiveHouse Institute '**Best Overall Project of 2016**' and 'Best Office/Institutional Project of 2016'
- The Innovation Center's architectural firm, ZGF Architects, was selected by Architect Magazine as the "Top Firm Overall and in Sustainability" for their innovation beyond green rating systems with the Innovation Center.
- Honorable Mention in Fast Company's 2016 Design Innovation Award
- ILFI **Living Building Petal Certification** and **Zero Energy Certification.**
- **LEED Platinum Certification**
- **Passivehouse Certified and PHIUS Source Net Zero Certified**

Top lessons learned

The biggest take-always from our design, construction and operation

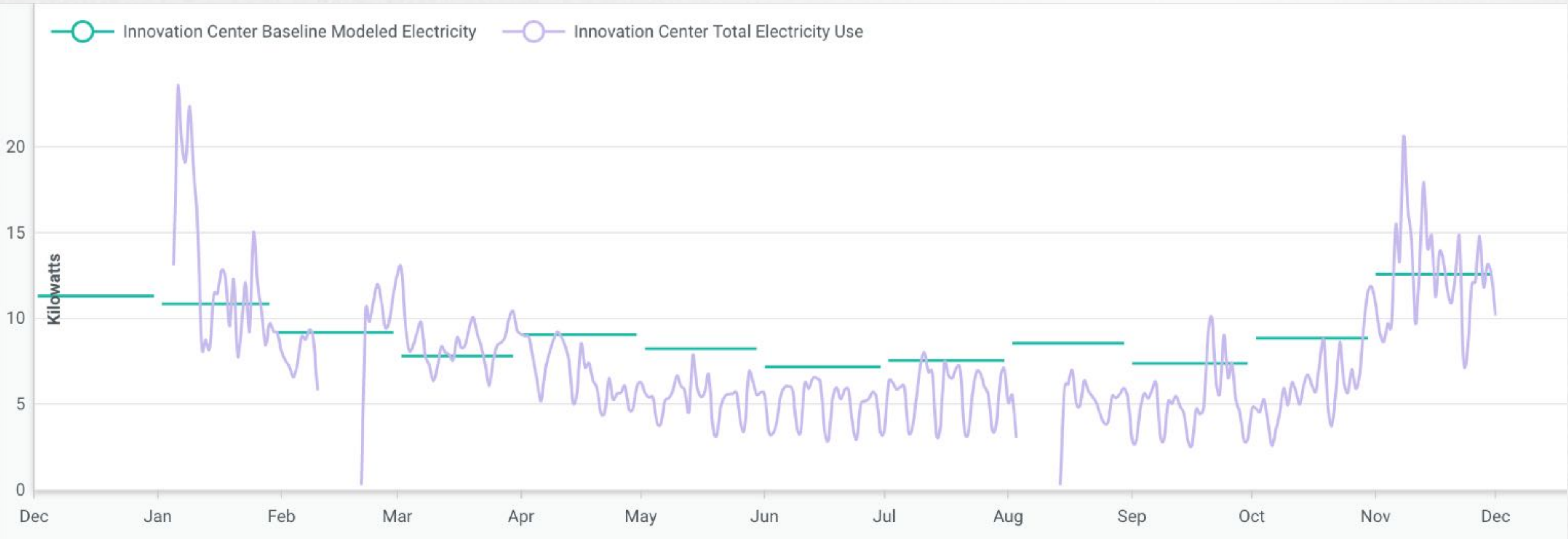
1. WHOLE SYSTEMS APPROACH MAKES NZE COST EFFECETIVE
2. COMMISSIONING AND MONITORING IS ABSOLOUTELY CRITICAL
3. OCCUPANT ENGAGEMENT AND EDUCATION IS REQUIRED TO MEET NET ZERO ENERGY GOALS
4. IPD IS USEFUL TO HELP MANAGE COST, CONTRACTS, AND RISK
5. MAJOR MARKET GAPS IN METERING AND CONTROLS, OPERATING TO NZE

02

Results from the first year of occupancy

Energy performance: better than expected

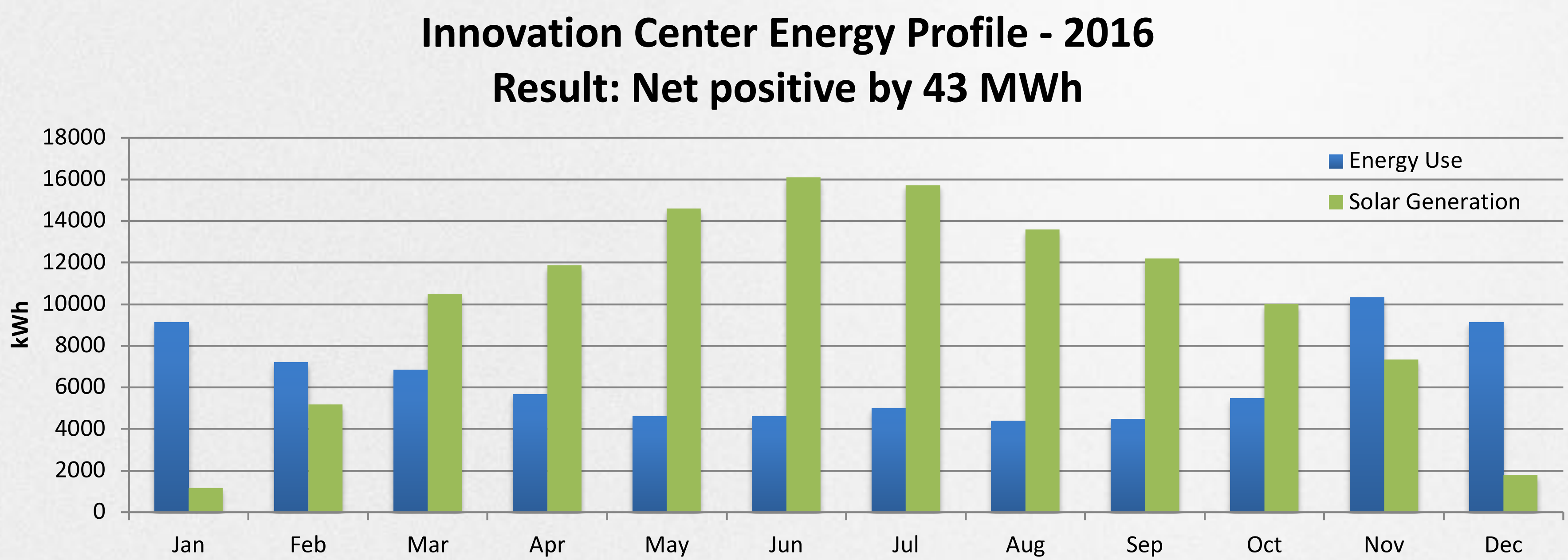
- EUI is trending at 15.9 kbtu/sqft/yr, lower than our modeled use (17.2 kbtu/sqft/yr)
- Operating at net positive energy



Energy use vs. energy generation

Balancing winter and summer energy production and needs

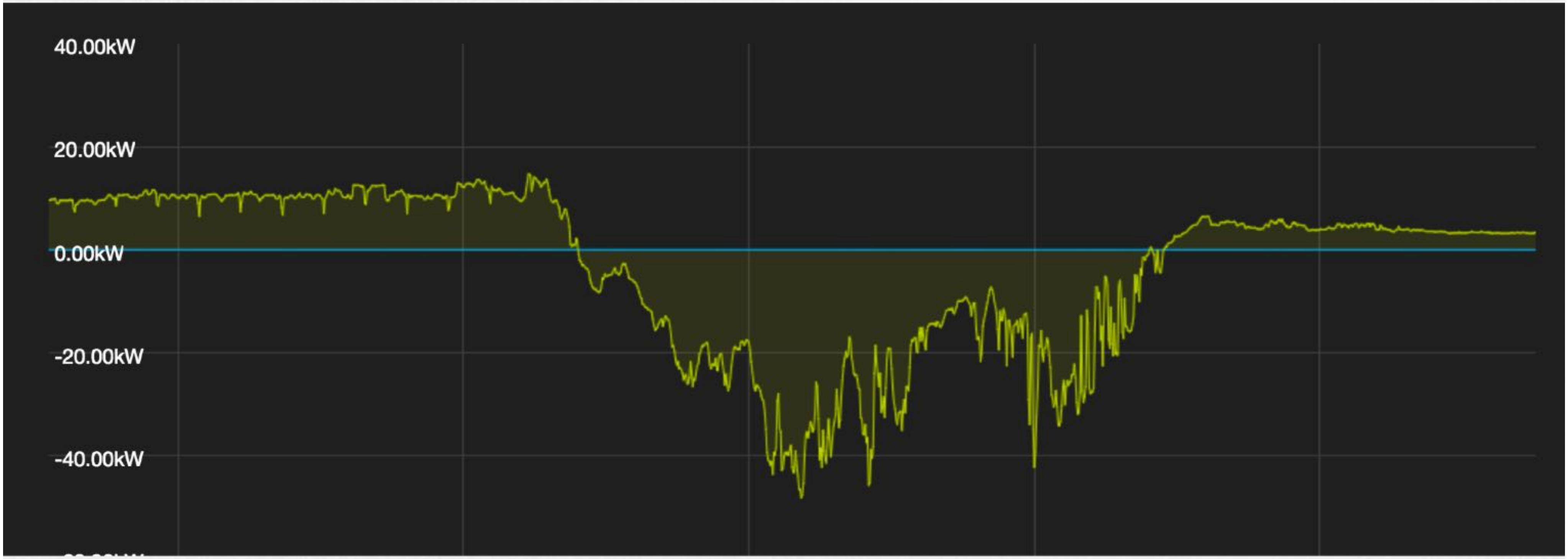
- As expected, summer energy generation from the rooftop PV is ~3x our energy use
- This excess energy use is necessary since winter energy generation is lower, and winter energy use is higher



Battery performance

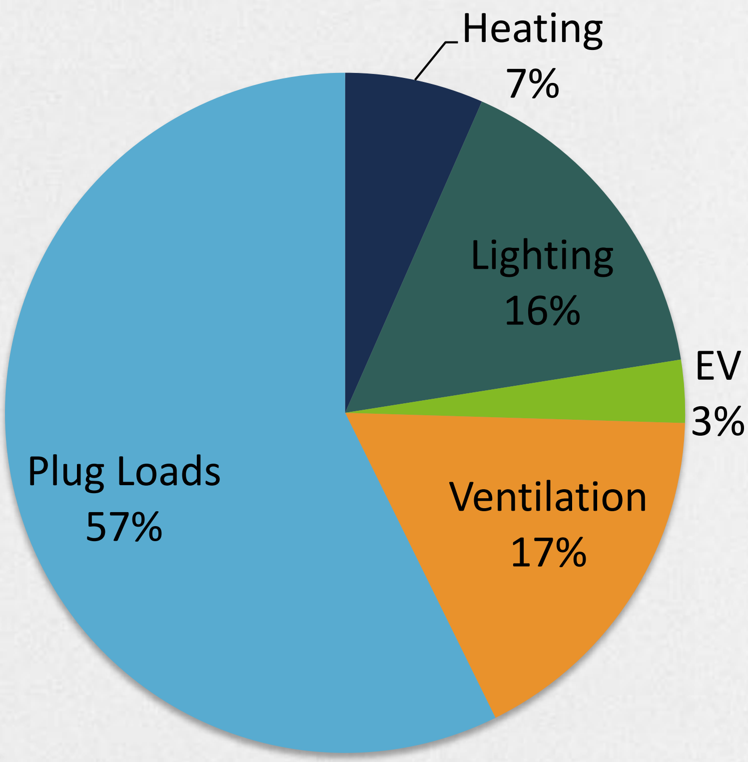
- Tailoring our energy use and holding demand well below 50 kW
- Most of the time below 10 kW

This chart shows a typical day, where our load peaks at night. We have not had to use the battery for demand charge management because our load does not get near 50kw. The battery therefore provides a buffer for future increases in loads.

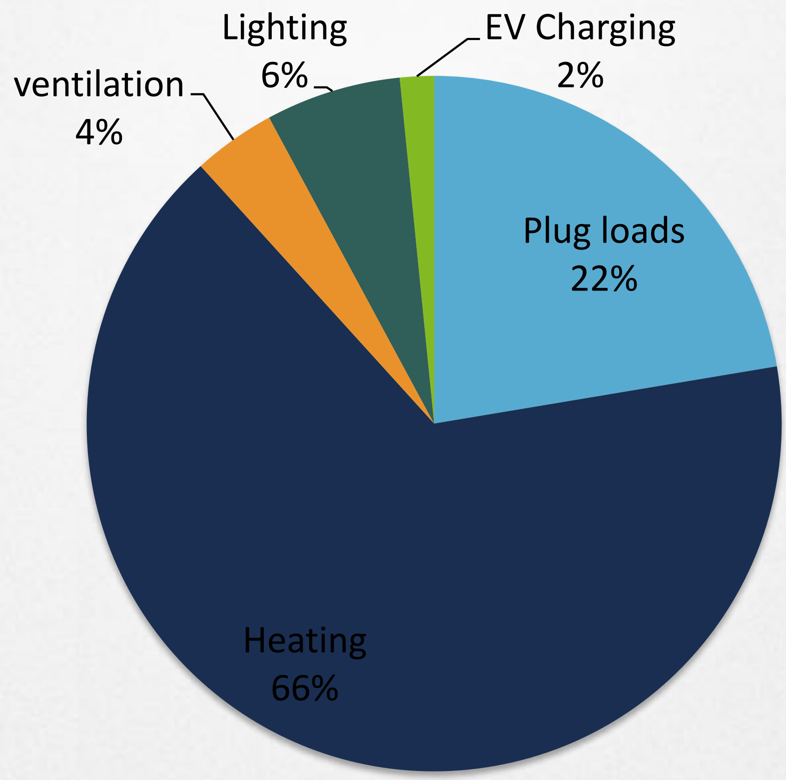


Energy end-use breakdown

June, 2016 (kWh)

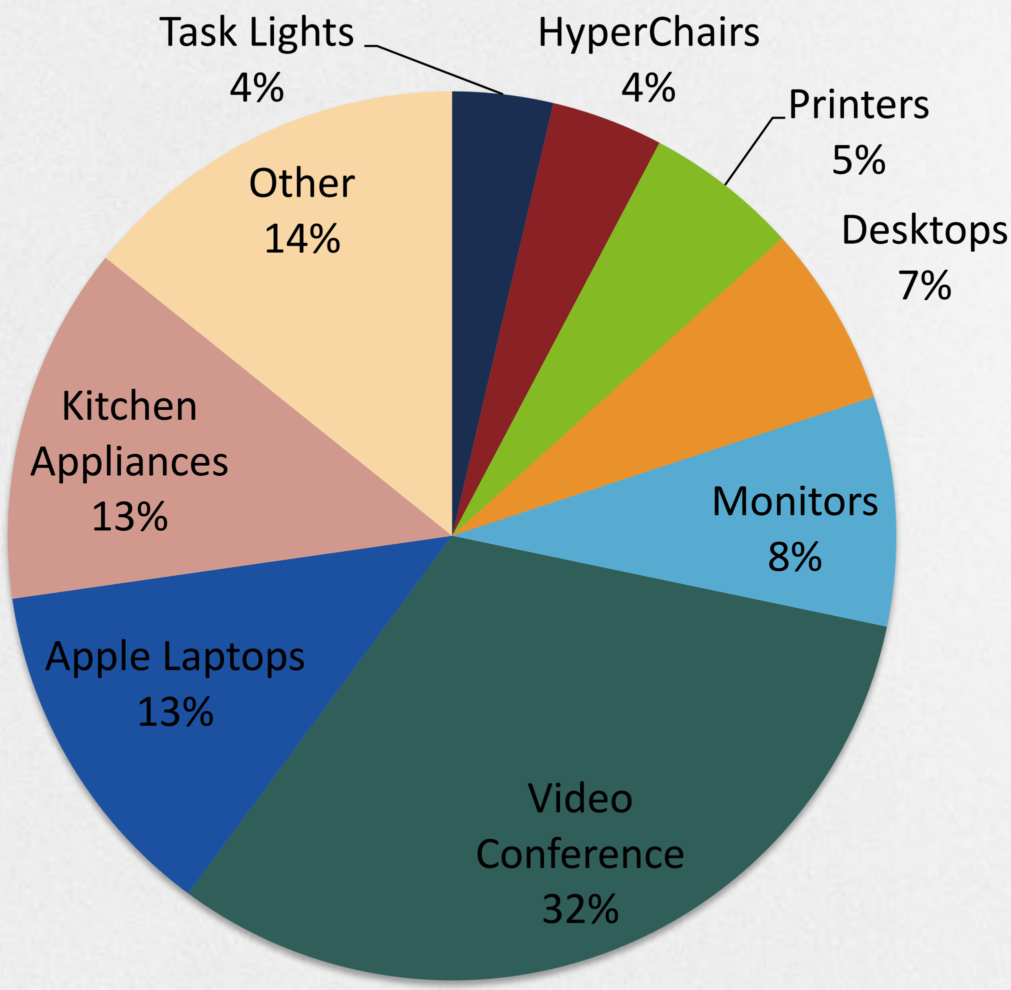


January, 2017 (kWh)



- Summer: Plug loads drive consumption
- Winter: Heating drives consumption
- EV is small due to one car charging offline during this time

Breakdown of plug loads

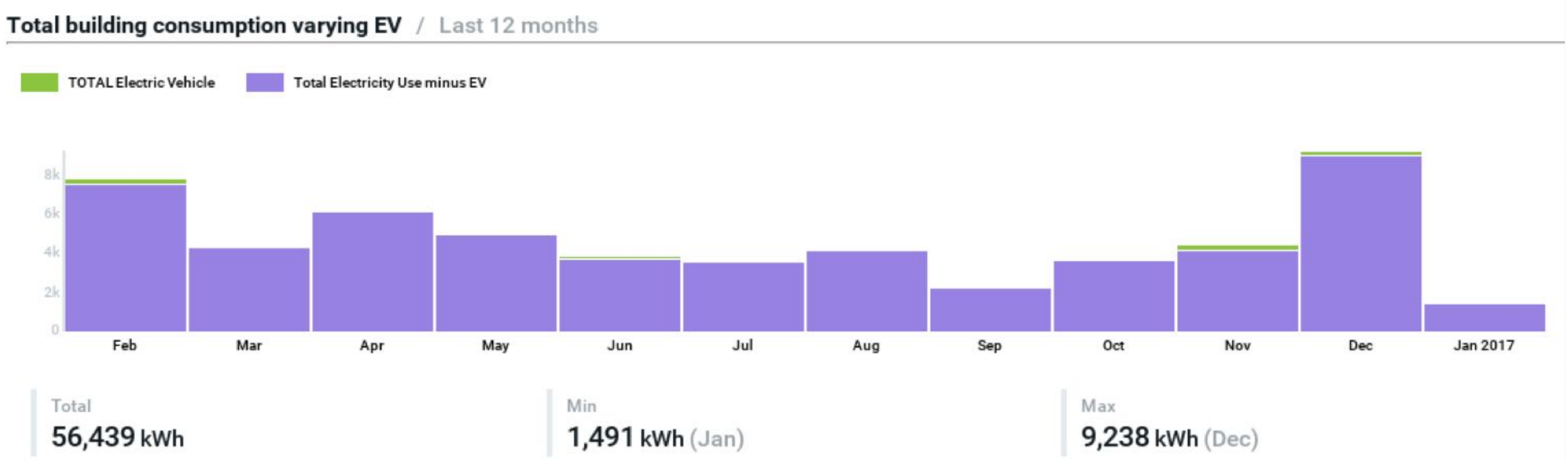


June 2016 (kWh)

- Video Conference biggest load, even with automatic shutdowns in evening
- Generally 20 laptops on site and only 3 desktops. Laptops significantly more efficient.
- Kitchen appliances include induction stove, fridge and espresso machine. RMI culture cooks more with stove/oven than standard office.

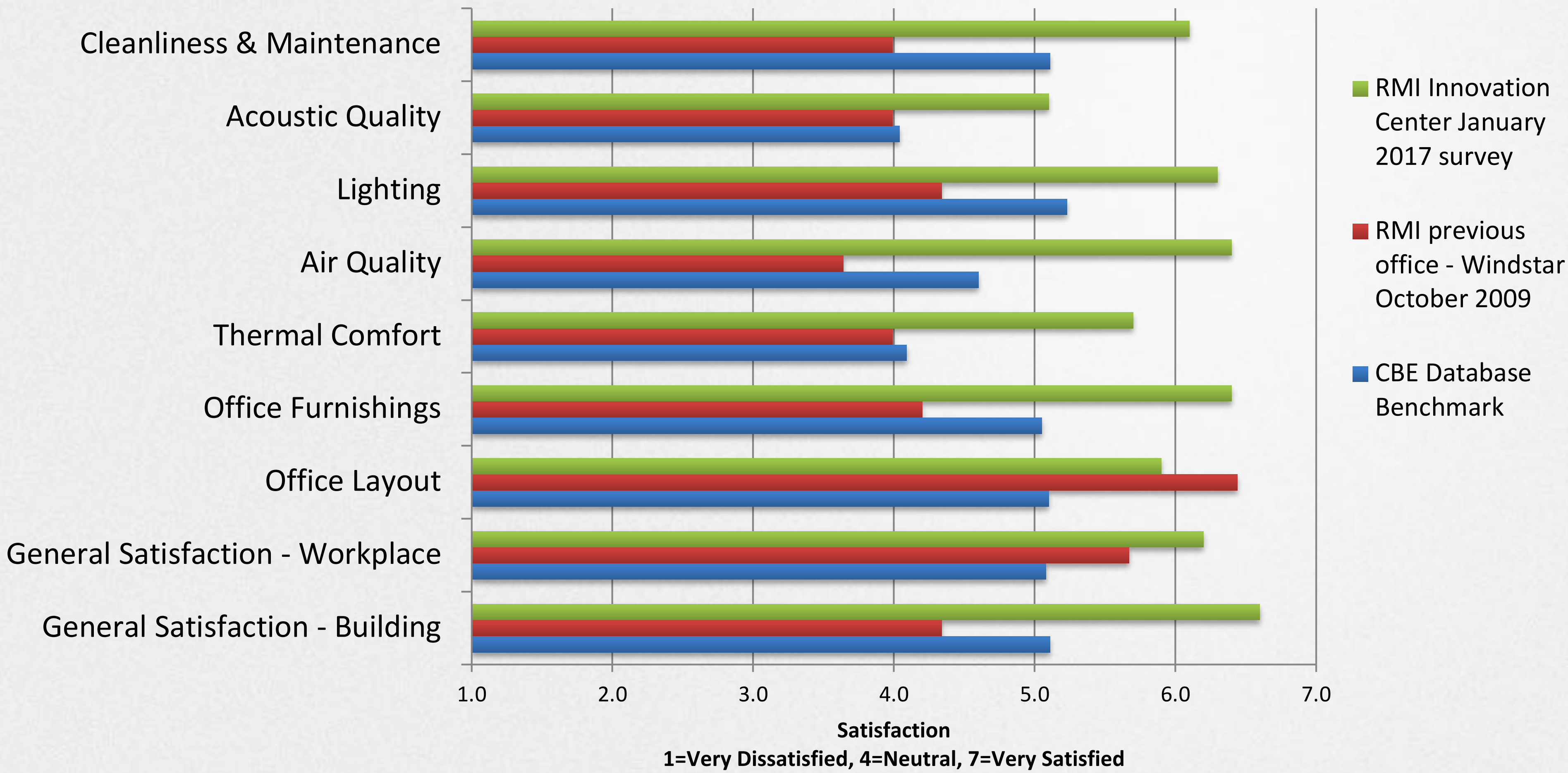
Total energy consumption

- Weekend temperature setbacks working, could still be lower
- Electric Vehicles are (currently) a minor load



Occupant satisfaction survey results

RMI's occupants are more satisfied across all categories than a baseline building. They are also 39% more satisfied than they were in our previous office



Productivity and overall satisfaction

Key findings from year one occupant survey: Very positive results that support our cost analysis.

- **74%** occupants feel the building increases productivity
- **78%** of employees tend to spend more time at the office because they like the space in which they work
- **83%** of employees agreed the Innovation Center assists them in articulating the RMI brand
- **88%** 'Very Satisfied, 'Satisfied' or 'Somewhat Satisfied' with space temperature
- **46%** feel their thermal comfort 'Significantly Enhances', 'Enhances' or 'Somewhat Enhances' their ability to get their job done.
- **100%** staff are 'Very Satisfied or 'Satisfied' with the daylighting and electric lighting
- **37%** felt the lighting quality 'Significantly Enhanced' their ability to get their job done

Occupant survey lessons learned

Additional feedback on productivity, comfort, lighting, and layout

- May require some adjustment to open office (personal calls/conversations, distracting)
- Acoustics is the biggest challenge
- Building trended on the cooler side. Biggest problems identified during prolonged periods of overcast
- Glare was a bit more distributed, but only 8% were ‘Somewhat Dissatisfied’. The issues being ‘glare from windows’ and ‘daylight reflecting on computer screen’

03

Passive design for NZE

Passive performance

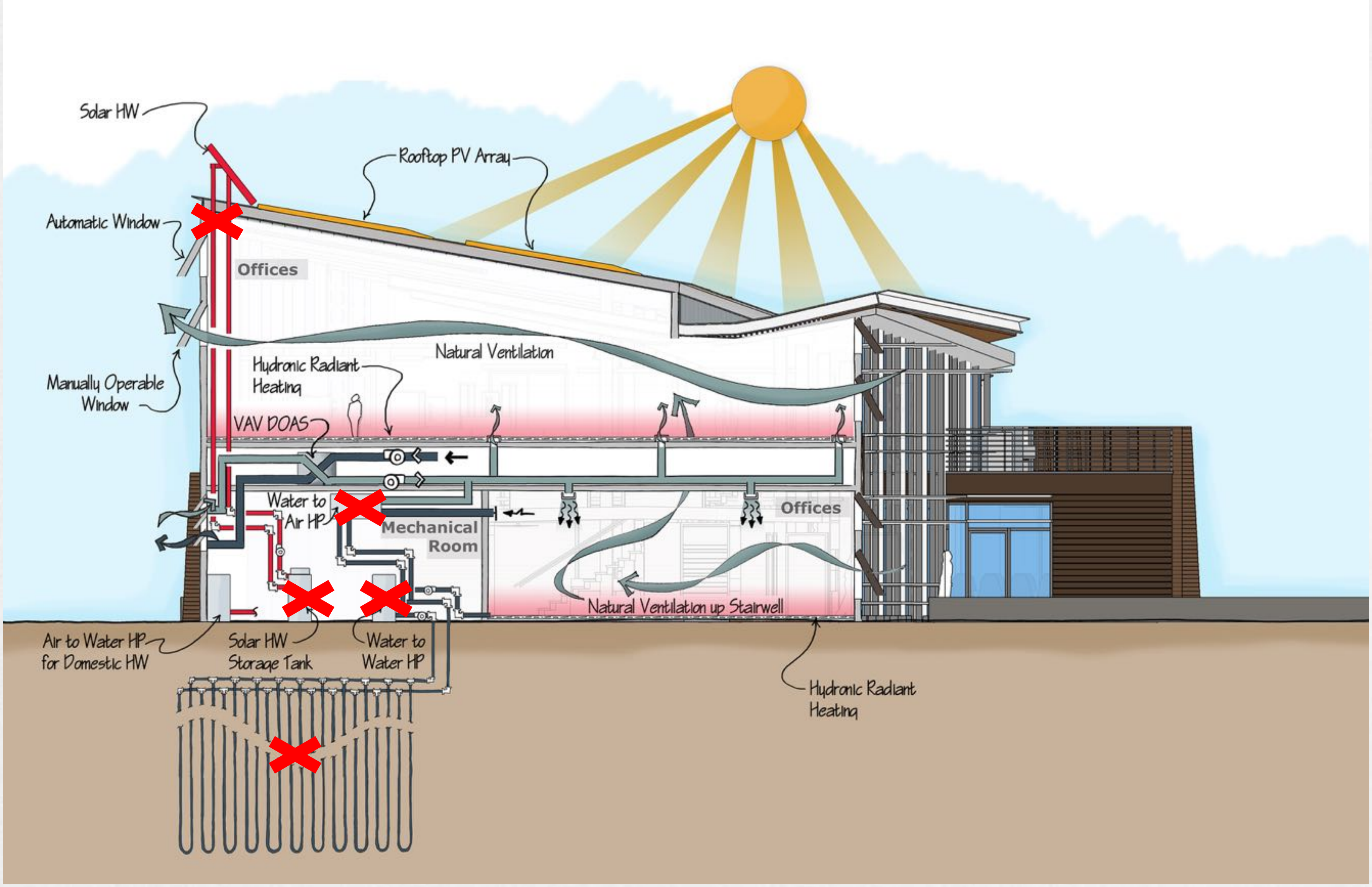
The Innovation Center is one of **the top 20 most energy-efficient buidlings in the country.** It uses **74% LESS energy per square foot** than the average building in the same climate.

This level of performance is achieved thanks to passive, integrative design. We started by considering what occupants need from the building—a comfortable, pleasing, and productive space. Then we found many methods to fulfill that need most efficiently, while emitting far less carbon.

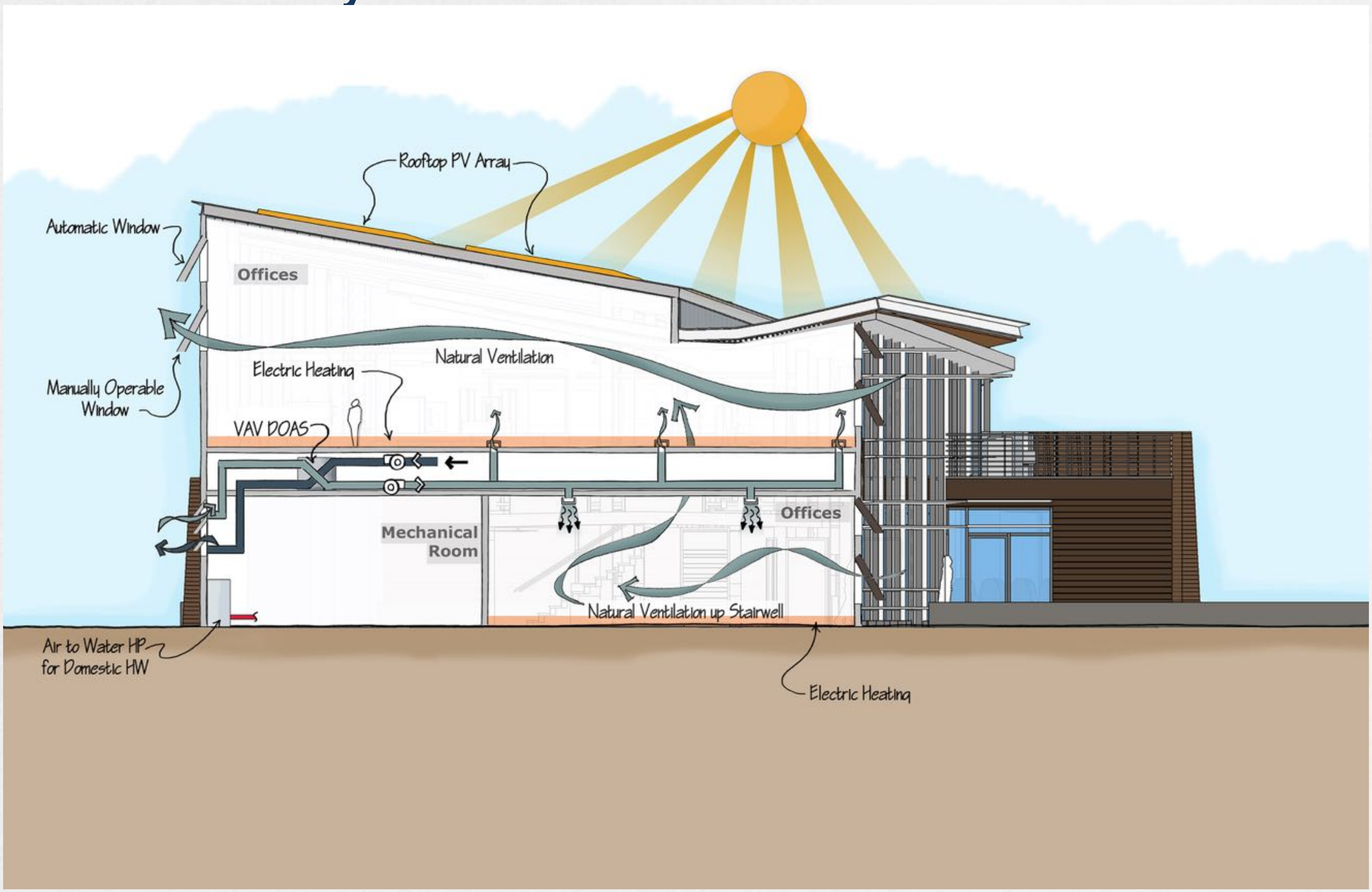
THE RESULT: A state-of-the art building with an EUI of 15.9 kbtu/sf

Maximizing our energy efficiency dramatically reduces our carbon footprint.

Basecase design...

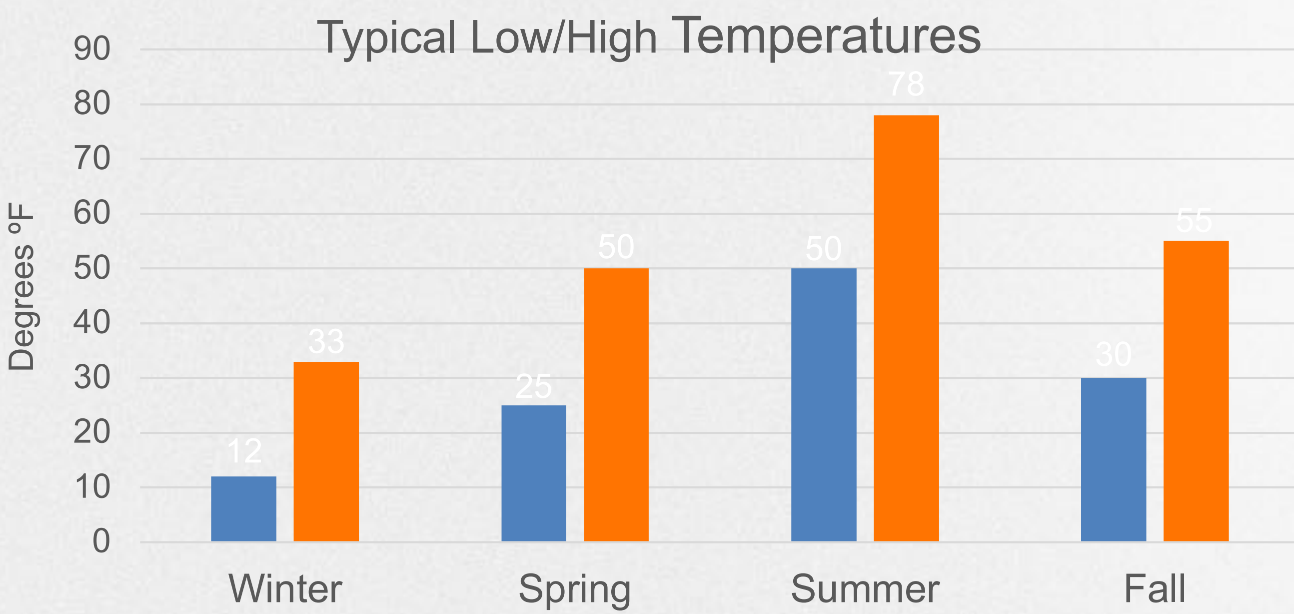


The final system…



Climate in Basalt, Colorado

Generally warm in summer, very cold in winter, low humidity, with high daily temperature swings in shoulder months.



	Winter	Spring	Summer	Fall
Low	12	25	50	30
High	33	50	78	55
Δ	21	25	28	25

Max Daily Temperature Swing (°F)

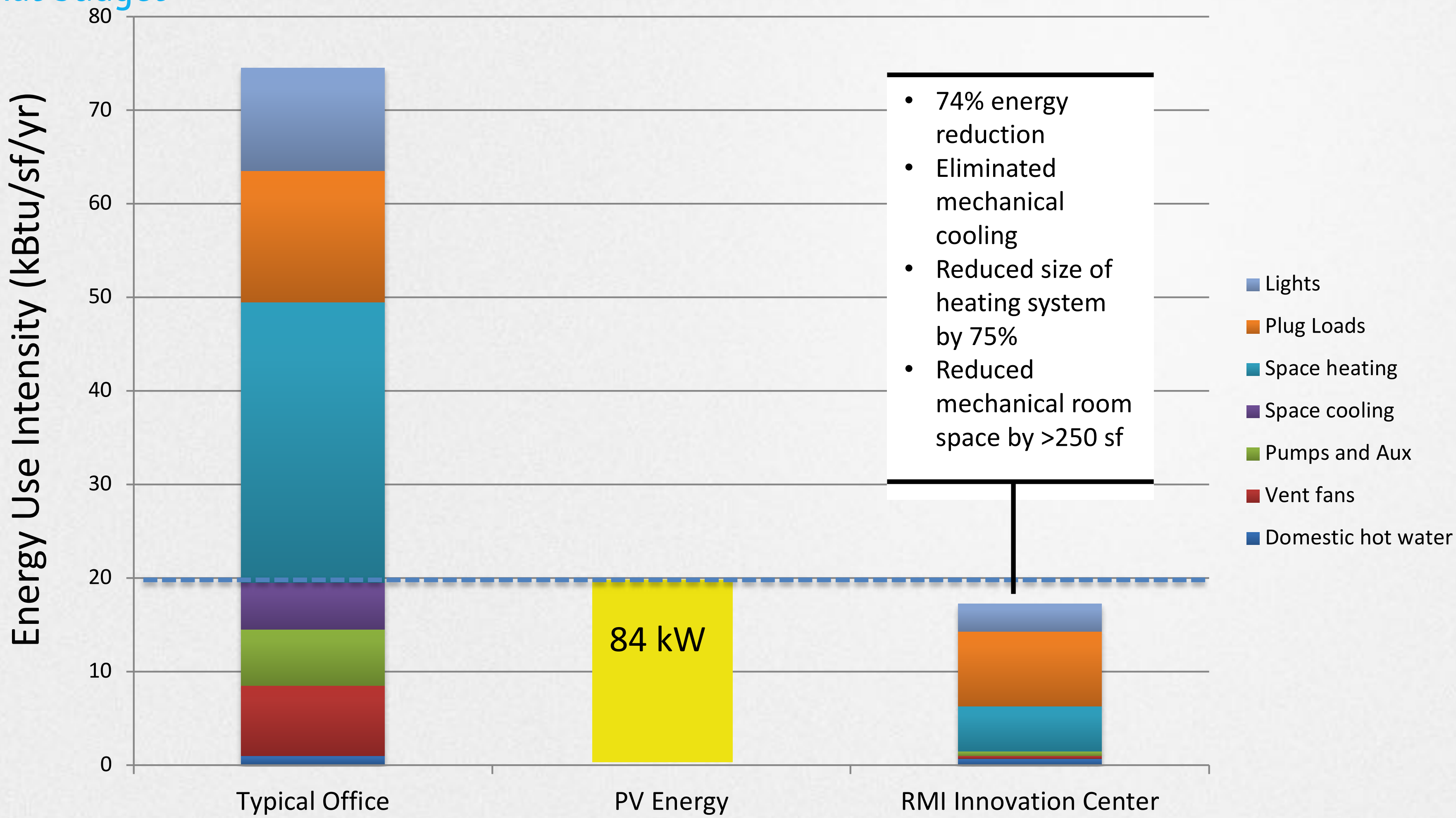
Winter	Spring	Summer	Fall
39	36	41	38

Low/High Temperatures at Max (°F)

Winter	Spring	Summer	Fall
-14	36	37	30
24	72	79	68

Getting to zero

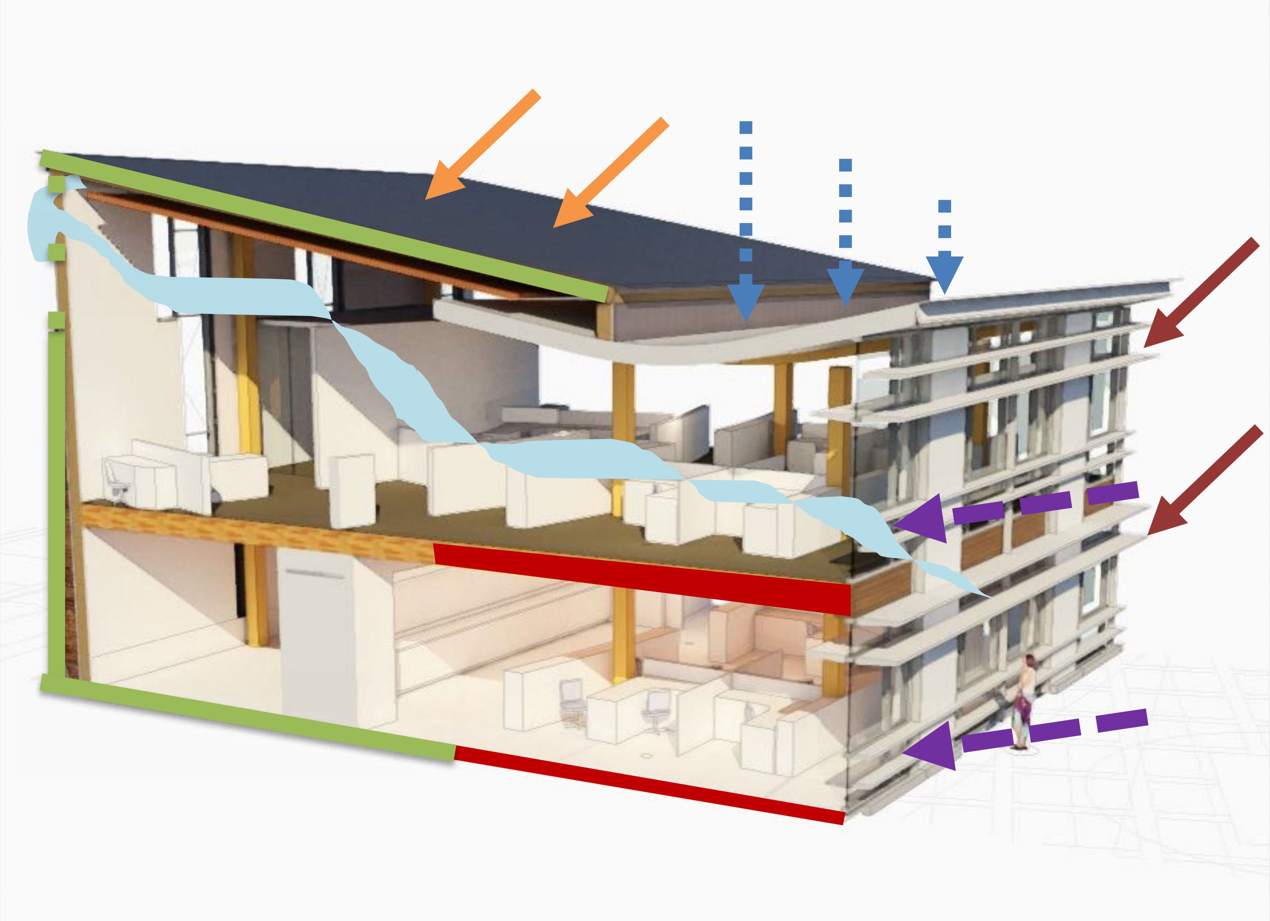
Start with the amount of energy that can be generated on site. Then align the design with that budget



Passive features at-a-glance

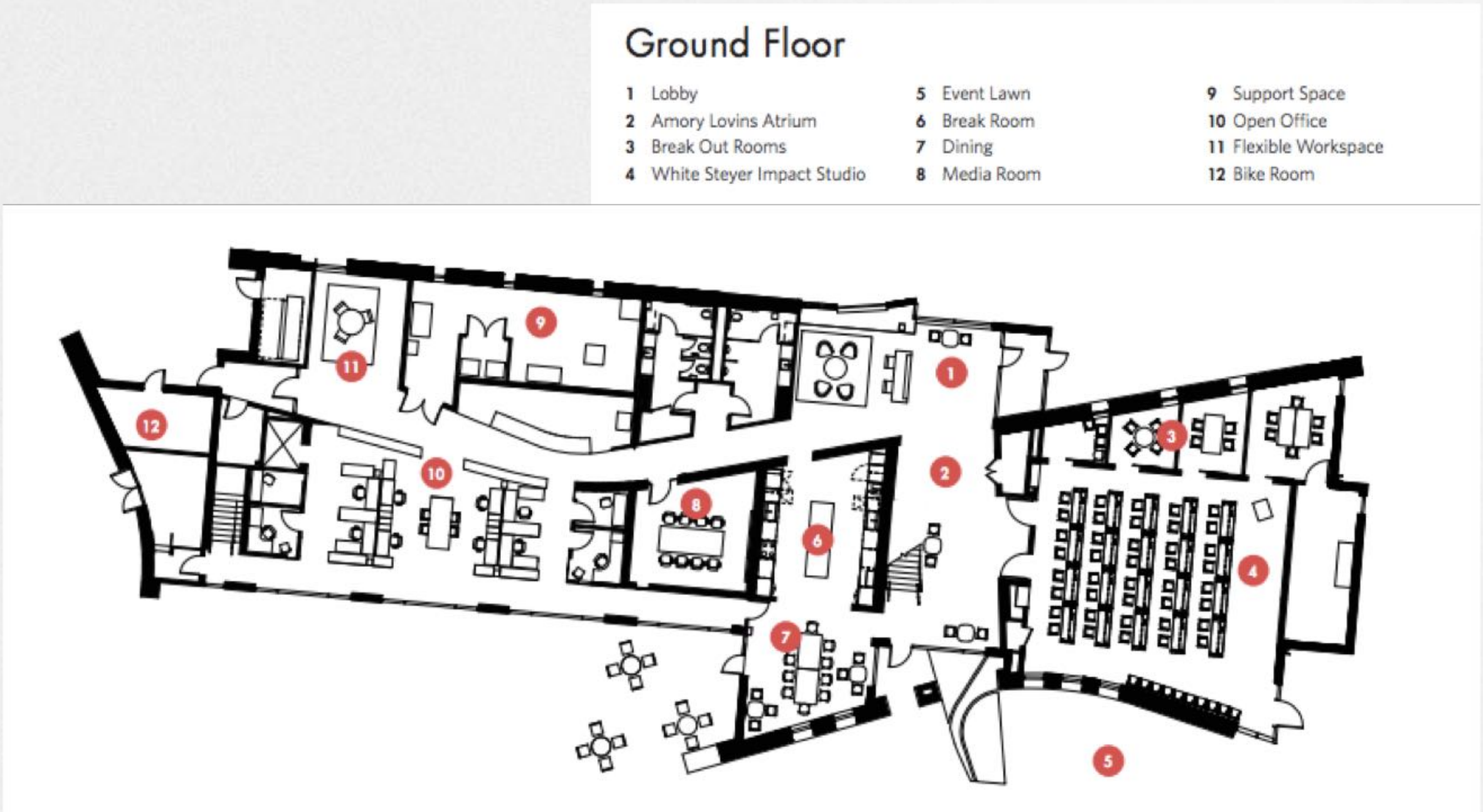
'Like wearing a down coat and sunglasses'

1. Aggressively insulate
2. Create airtight weather barrier
3. Capture winter solar gain
4. Shade from summer heat
5. Engage thermal mass
6. Provide natural ventilation
7. Daylight the space and control glare
8. Collect solar energy



Building layout – 1st floor

Long, narrow building to maximize natural ventilation, daylight, and solar gain



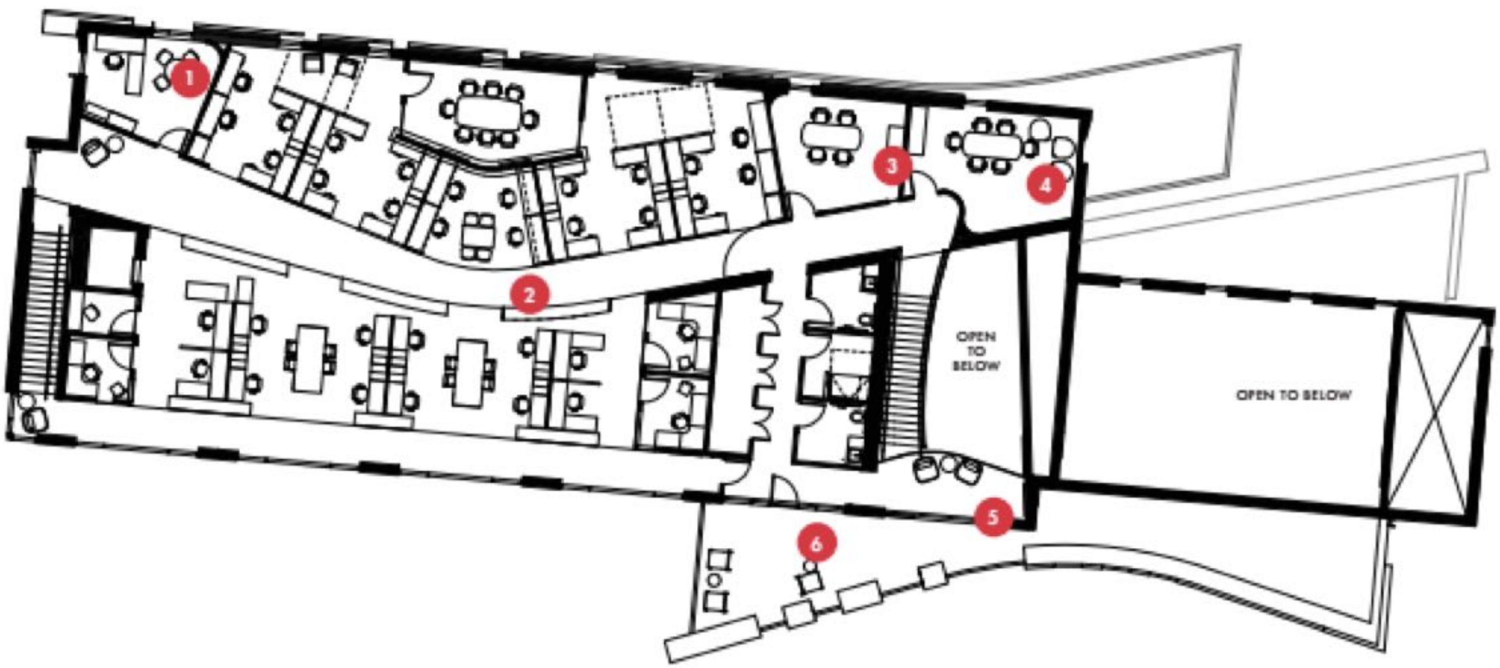
Transforming global energy use to create a clean, prosperous, and secure low-carbon future.

Building layout – 2nd floor

Long, narrow building to maximize natural ventilation, daylight, and solar gain

Second Floor

1 Office
2 Open Office
3 Conference Room
4 Reading Room
5 Perch
6 Terrace

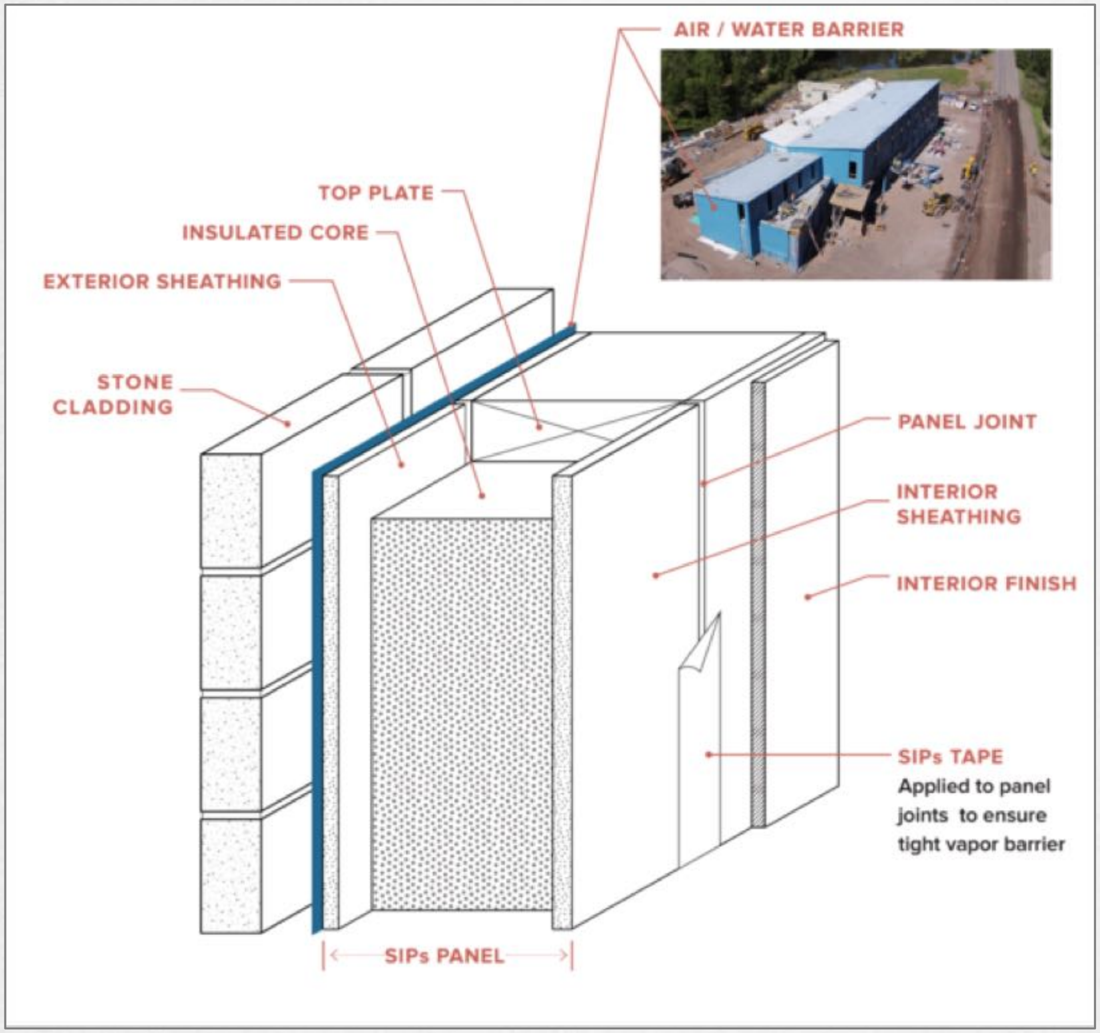


Passive performance: Aggressively insulate

The Innovation Center has more than triple the code required levels of insulation

This is due to:

- **R-50 walls**, achieved with structural insulated (SIPs) panels
- **R-67** roof
- **R-20** below slab
- **R-5.6** windows (with frame) overall (with a range of 4.8--7.1)



ANATOMY OF A SIP

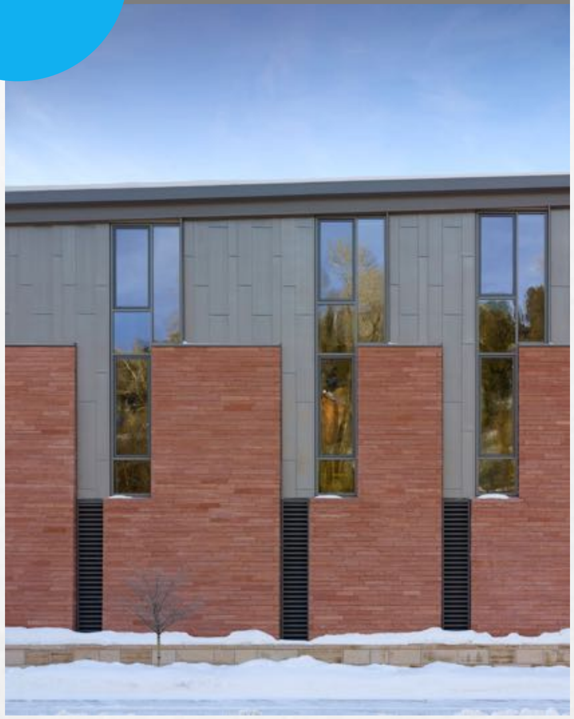
SIPs provide the dual benefits of **insulation and airtightness**

Passive performance: Aggressively insulate

Windows are optimized on the south to let in more light and heat than the windows on the north which insulate even more effectively.

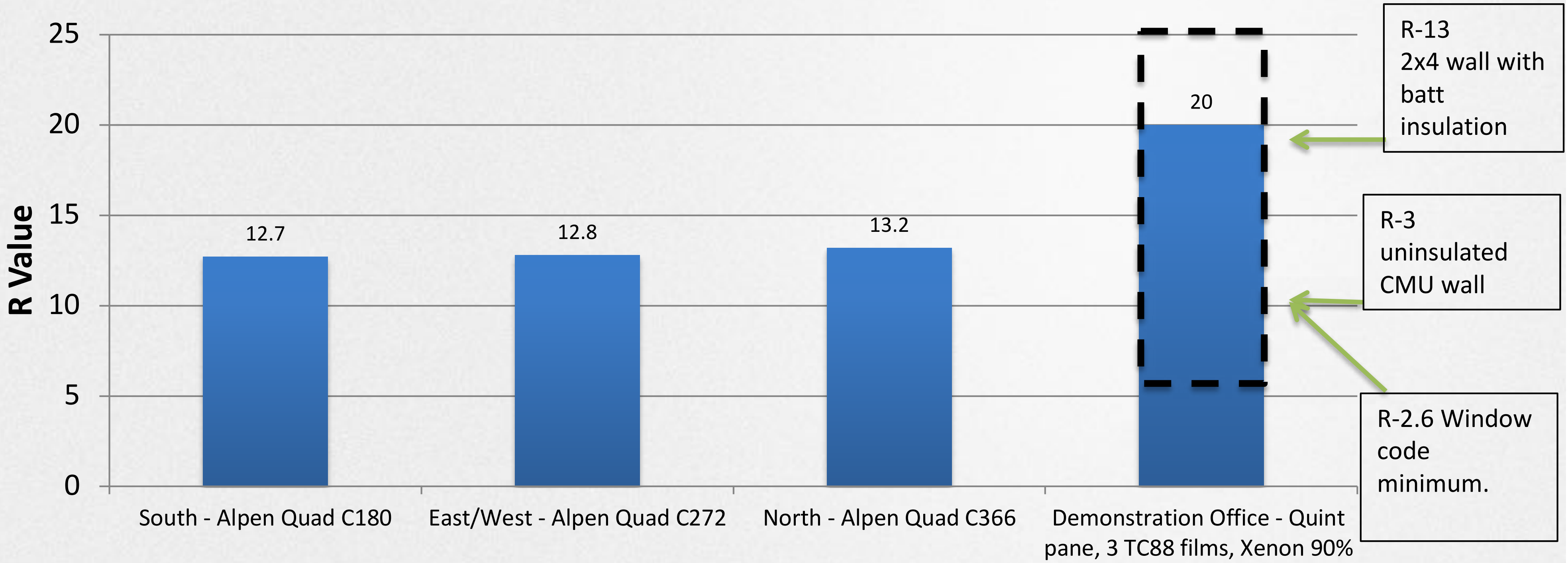
52% Window-to-wall ratio on the South, vs.

18% on the north



Passive performance: Aggressively insulate

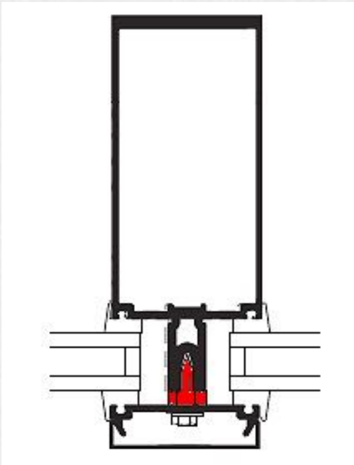
Windows, typically the largest source of heat loss in a building, help keep the Innovation Center well-insulated and are 5x better than code requirements



- Alpen QuadPane C100 - 2 HM88 films, 3 air gaps with 90% Krypton
- Windows also serve other passive functions including daylighting, airtightness, and cooling and air quality

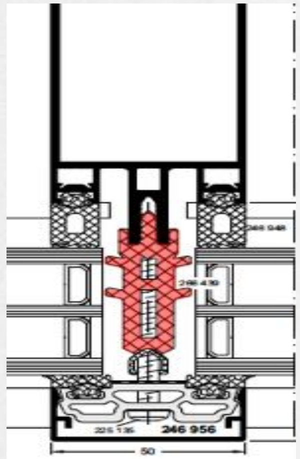
Window frame comparison

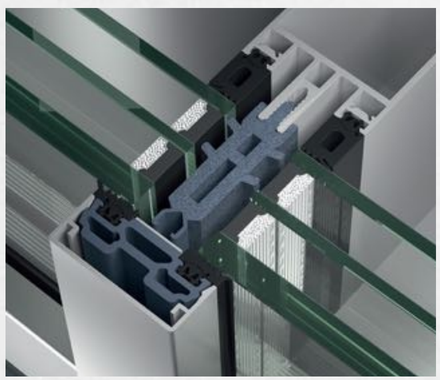
Typical frame and spacer:



VS.

RMI's frames: better thermal break





- Polyamide spacer - Much larger, stiffer thermal break than typical with foam to prevent convective heat transfer.
- Very low infiltration - One actuator to open/close, one to latch and seal. Schuco operable units actually measure infiltration (contrary to US brands)
- Schuco Frames: FW50+ SI system for fixed windows AWS 75 for casement mounted operable units. (first time this system was used in the US)
- Frame R value of 3

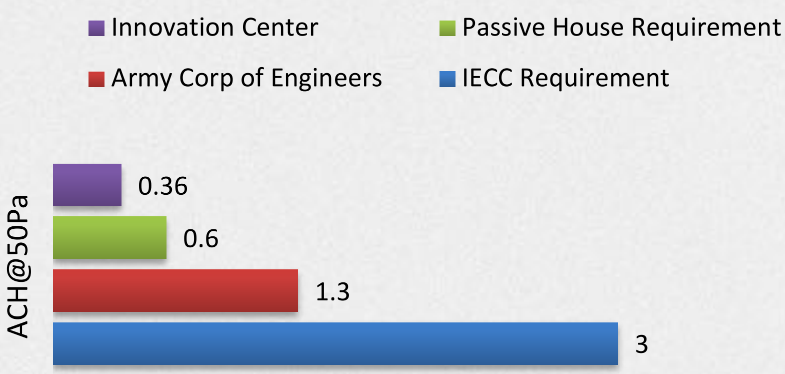
Passive performance: Air tightness

Essential for both energy efficiency and comfort

The Innovation Center is one of the most airtight office buildings measured

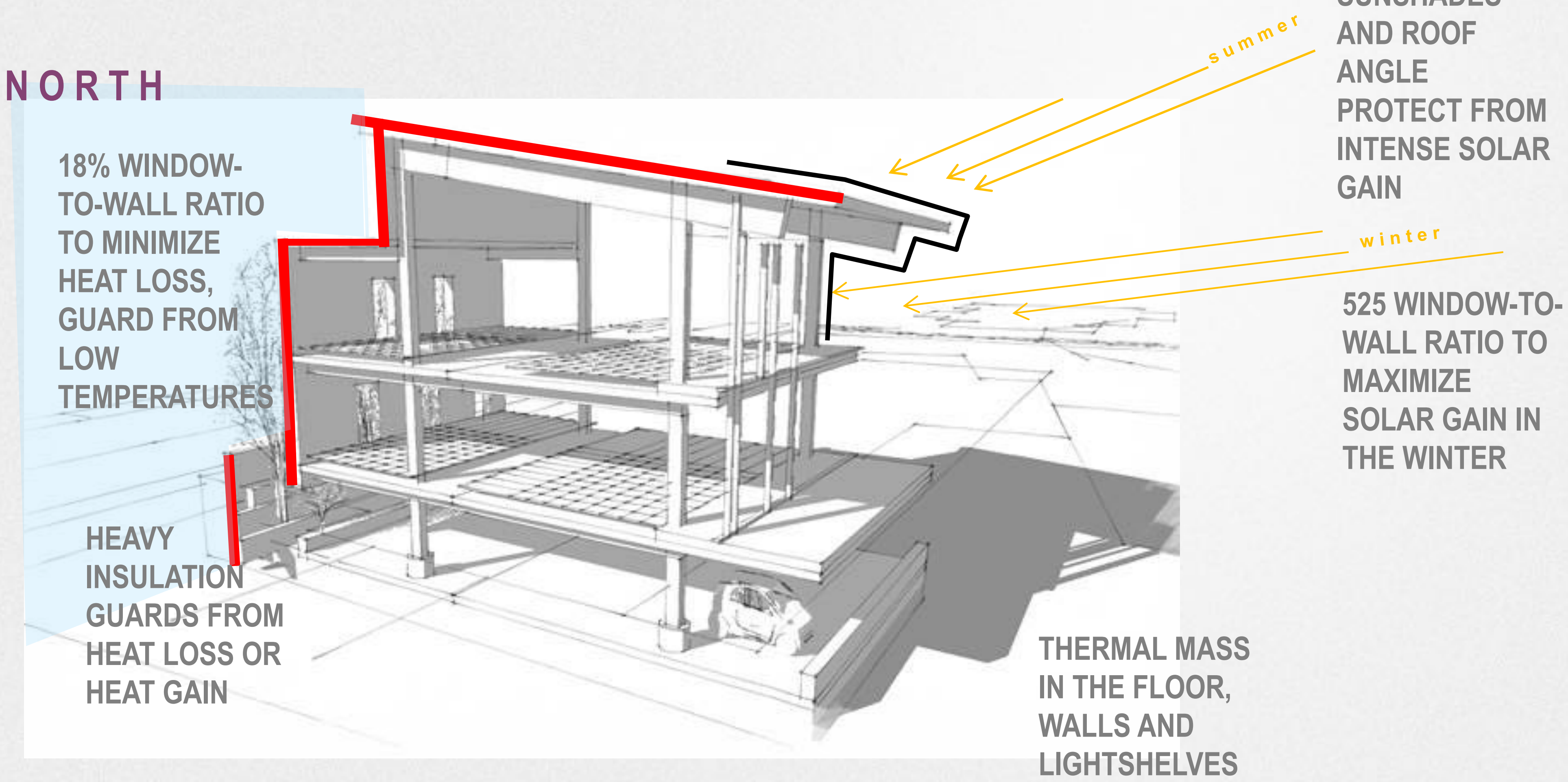
with **0.36 air changes per hour**, and is **97% more airtight** than the conventional commercial building.

Advanced materials combined with strict construction details avoided leakage and made the building's incredible air tightness possible.



Passive performance: Heat gain

Capturing in the winter, and guarding the building from in the summer



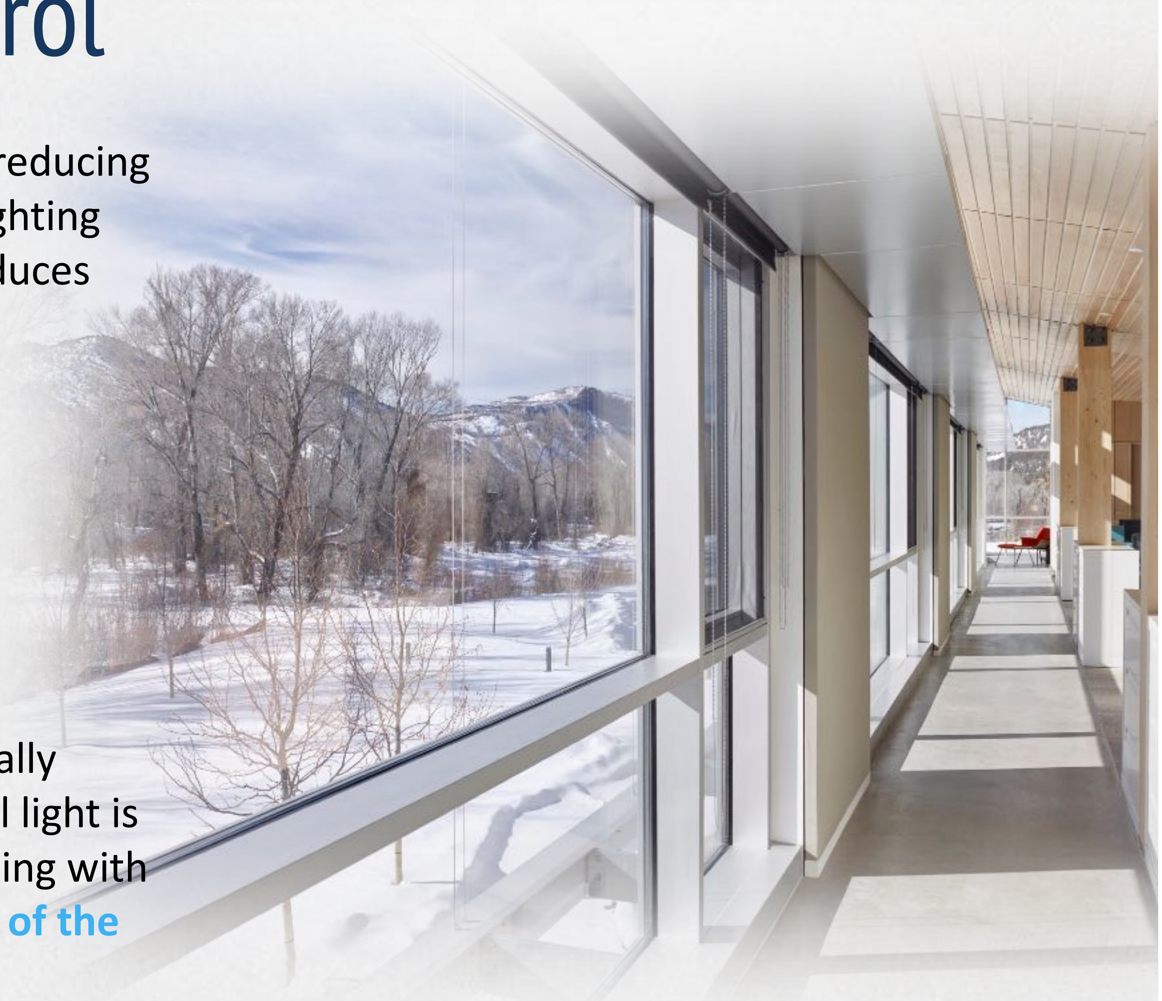
Passive performance: Daylight autonomy & quality + glare control

The Innovation Center is entirely daylit, reducing the need for energy-intensive internal lighting while also increases productivity and reduces stress.

Strategies

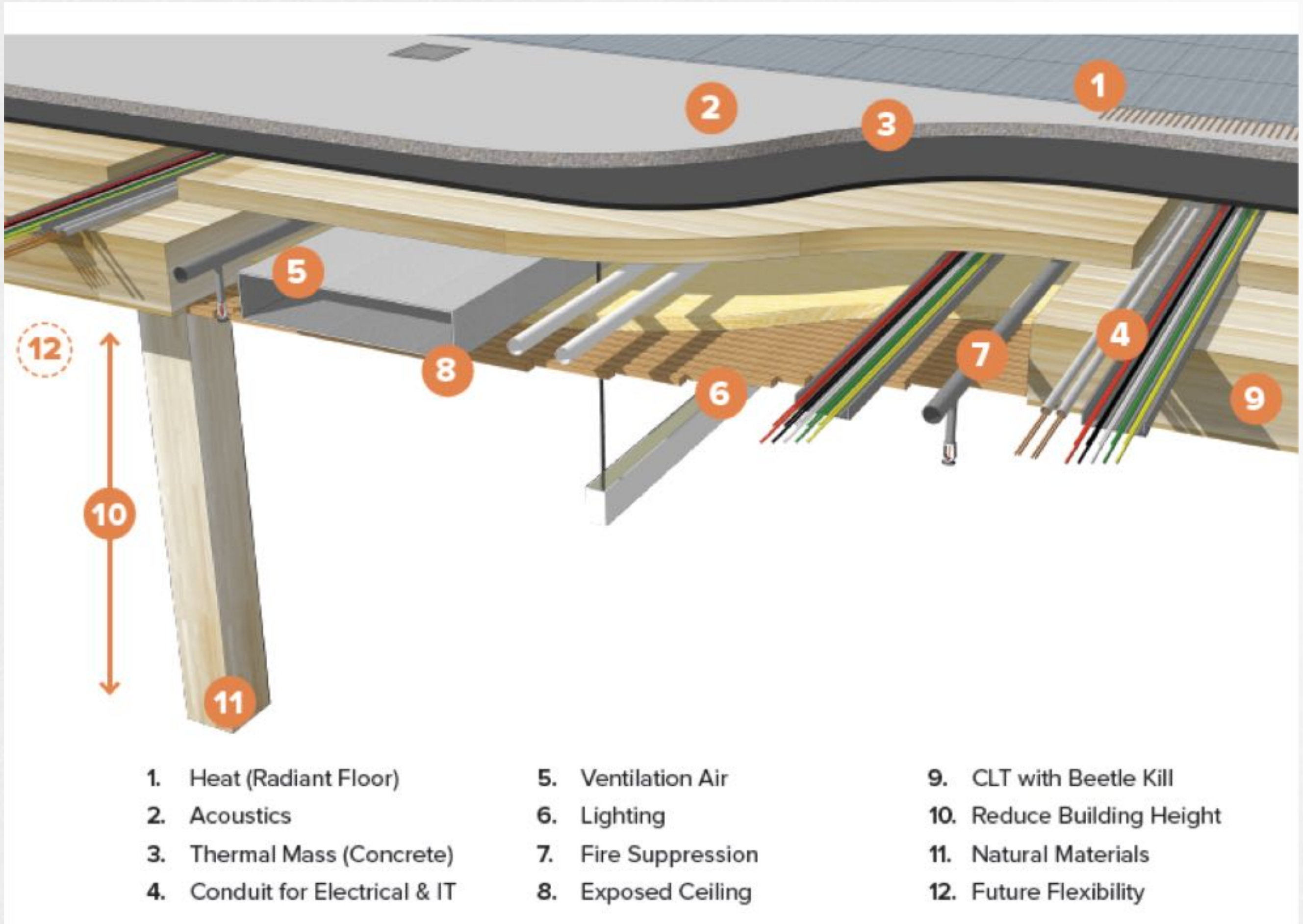
- narrow floor plate
- butterfly roof design
- Lightshelves
- Manual blinds

Interior backup LED lights are automatically adjusted according to how much natural light is present. The result: A well lit office building with **lighting power density of 0.27 W/sf, 9% of the lighting load of an average office**.



Passive performance: Daylighting

Cross-laminated timber (CLT) structure allows the ceilings in the Innovation Center to be a foot higher without increasing the overall building's height

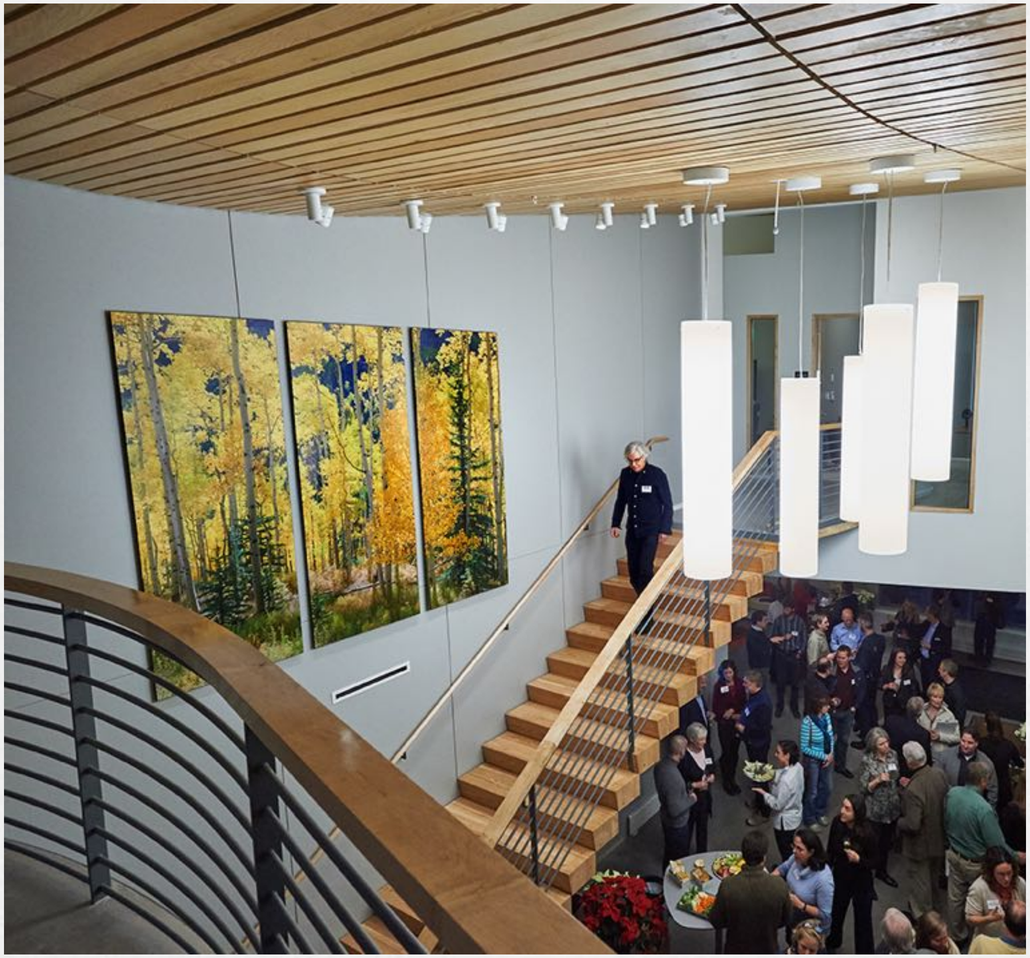


- CLTs are engineered wood beams that reduces the need for conventional concrete or steel support pillars and floor plates, helping achieve an open floor plan
- They allow for higher ceilings on the first floor, maximizing the benefits of daylighting and natural ventilation because all data, mechanical, and electric infrastructure can fit in spaces between CLTs

Passive performance: Thermal mass

Thermal mass also allows the building to absorb excess heat generated from internal sources such as **computers, lights, and people**.

Because the building is so efficient in its use of heat sources, the thermal mass which is designed to keep occupants comfortable by helping to regulate interior temperatures, partially relies on the heat those warm-blooded occupants generate.

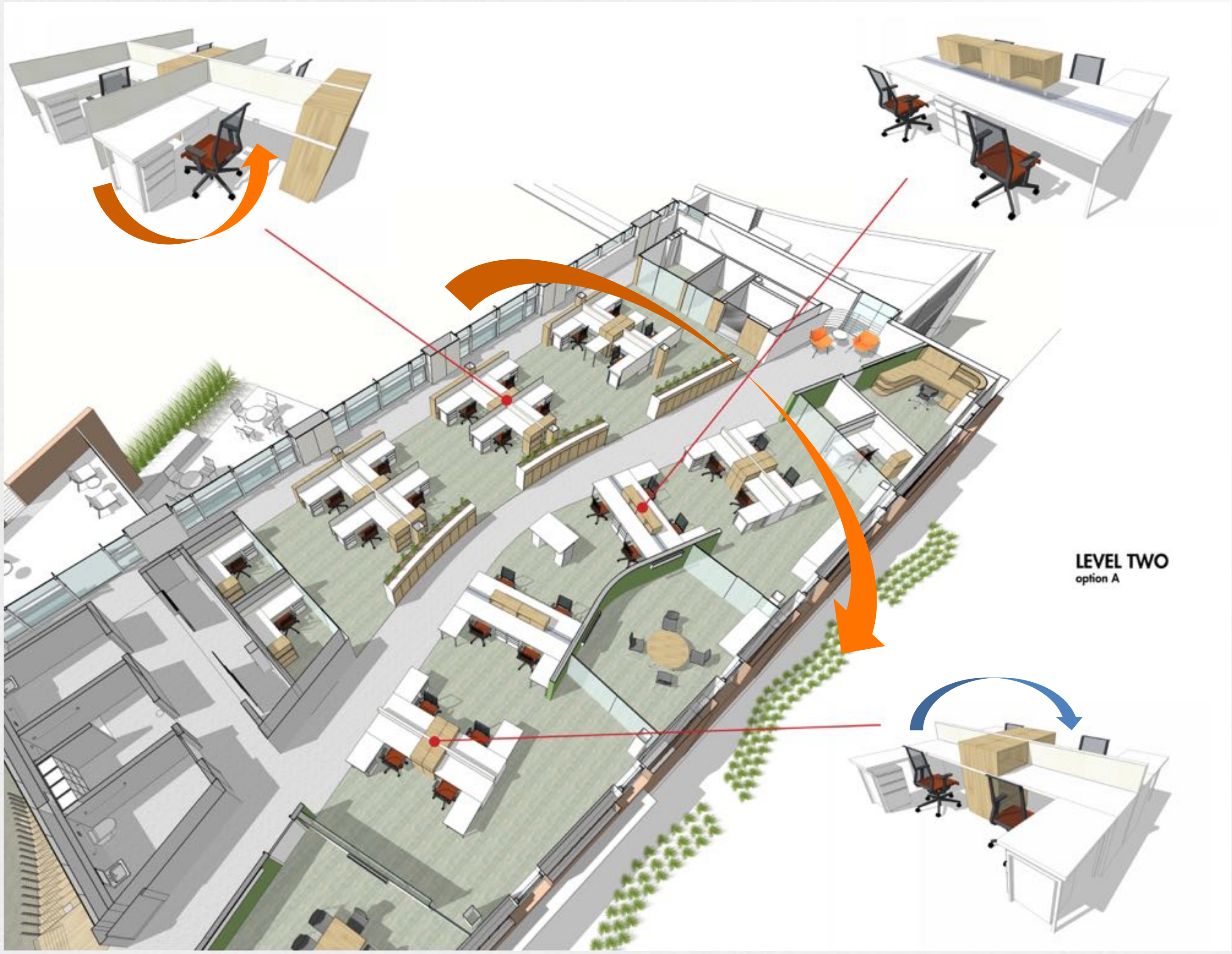


Passive performance: Thermal mass

Thermal mass is crucial to passive heating and cooling because it stabilizes interior temperatures in the IC despite significant exterior daily and seasonal outdoor temperature swings, saving energy.

- Concrete floors, walls, and phase change materials (PCM) all provide thermal mass
- PCM embedded in the light shelves and walls release stored heat to the cool air and solidify.
- During warm afternoons, this vegetable-based wax absorbs an incredible amount of excess heat when it melts back into a liquid state.

Passive performance: Natural ventilation, cooling, & air quality



- Passive and active systems
- Passive = windows, open office plan
- Active = air-to-air heat exchanger (90% efficient), and ceiling fans
- Night flush cools the building in anticipation of a hot day

Lessons learned: Passive performance

Overwhelmingly positive feedback

1. Air tightness was critical, having it as a requirement spurred on our contractors.
2. Daylight and spatial qualities are beautiful, and not to be undervalued
3. High performance windows are challenging and still a developing industry
4. Risk mitigation for a reduced HVAC capacity is in the insulation
   a. Usually designers oversize central systems to overcome risk. We didn't. Having such good passive design helped mitigate that risk since the building was so stable. Rather than oversizing heating systems, the building thermal envelope helped protect us.
5. Human controls vs. automation?
   a. The Innovation center has a very sophisticated controls system, and occasionally, occupants can interfere by manually overriding certain systems without knowing the overall strategy (i.e. using the exterior, automated sunshades as glare control rather than heat gain control). Conversely, the automation system is not reliable all the time.
6. There is a big opportunity for controls to use artificial intelligence for predictive control. Instead of setting rigid, preprogrammed control sequences, technology is emerging allowing the system to learn from past performance and tune the future approach.

04

Key Enablers: Thermal comfort, occupant engagement, and controls

Innovative thermal comfort

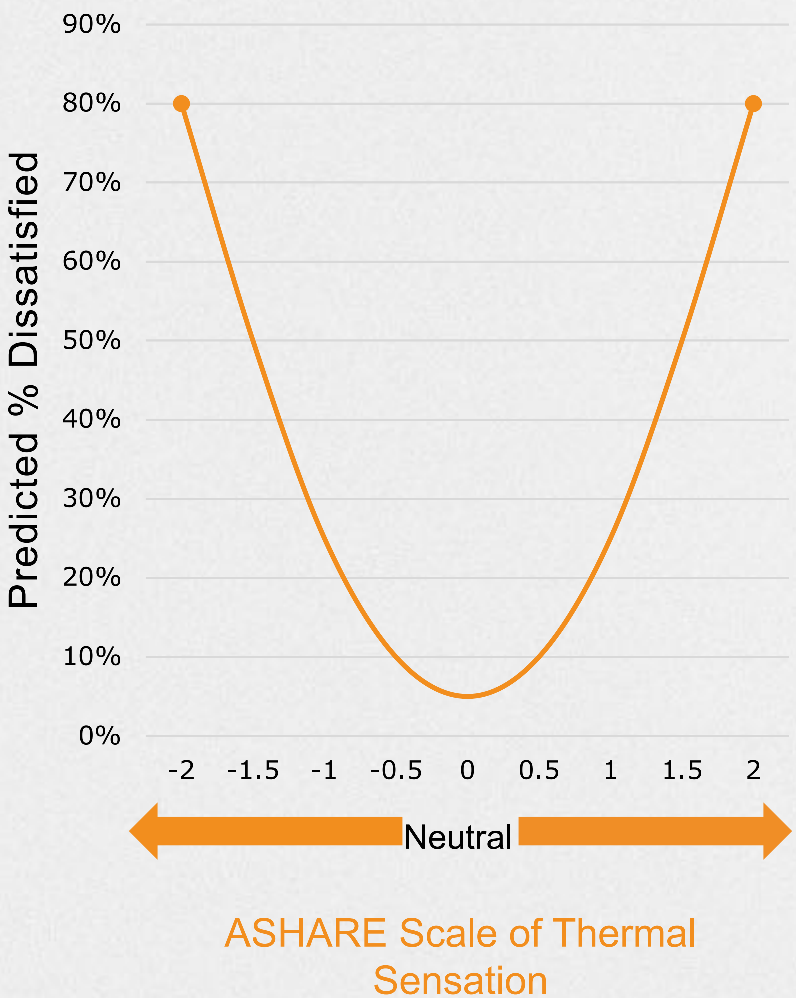
The Innovation Center completely redefines how occupants experience and control their individual comfort. **The building has no traditional heating and cooling system, yet keeps staff and visitors comfortable even in Basalt Colorado's severe climate**.

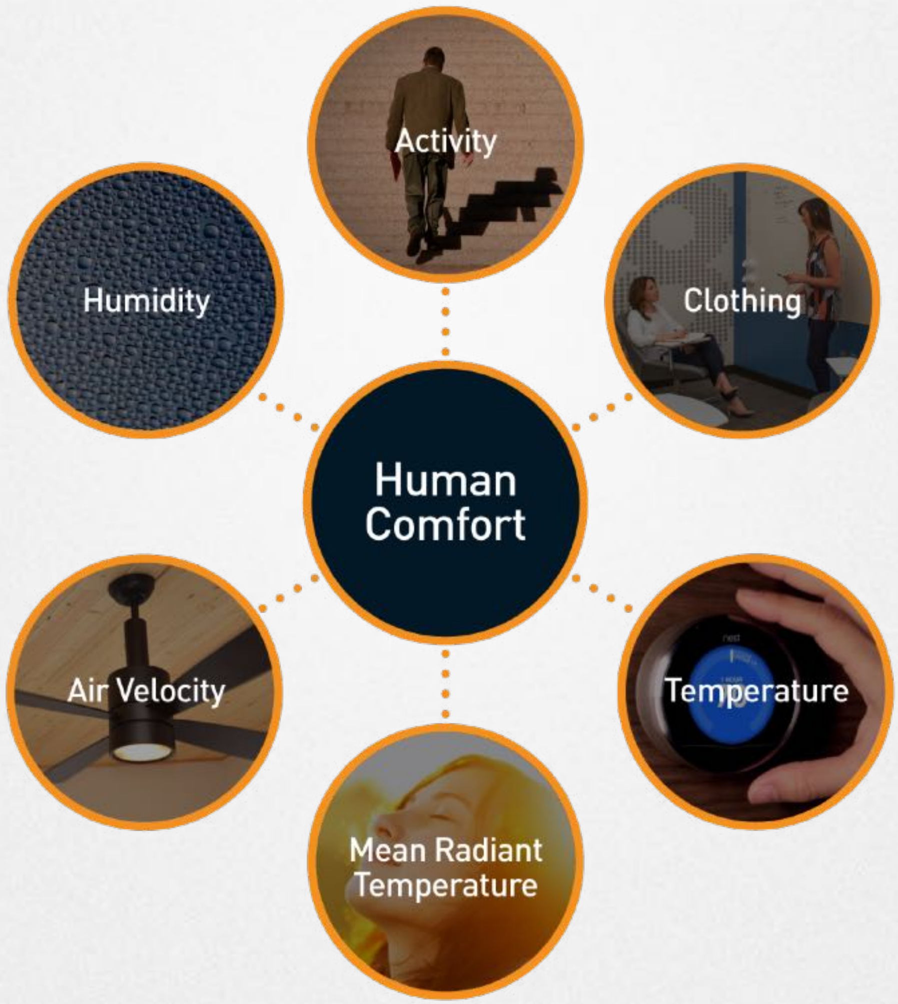
Integrated design eliminated mechanical cooling and reduced the heating system to a small, distributed electric resistance system powered by solar PV panels on the roof.

The only mechanical systems—for air ventilation and localized backup heating—is the **equivalent to the heat used in 1 mid-sized home**.

Innovative thermal comfort

Designing around 6 comfort factors





Designing for comfort

COMFORT CRITERIA	DESIGN STRATEGIES
1. Surface temperature	• Super insulating windows and envelope • Thermal mass • Bio phase change materials in walls and lightshelves • Predictive preconditioning by charging thermal mass with night flush • Hyperchairs
2. Air temperature	• Natural ventilation, operable windows • Distributed, radiant heating mats in floor • Aggressive heat recovery of preheat ventilation air
3. Air velocity	• Fans overhead • USB and standing fans • Fans in hyperchairs
4. Clothing level	• Adaptive dress code for staff and event attendees
5. Metabolic rate	• Designed to activity level of occupants in space
6. Humidity	• Not actively controlled due to low humidity levels in Colorado

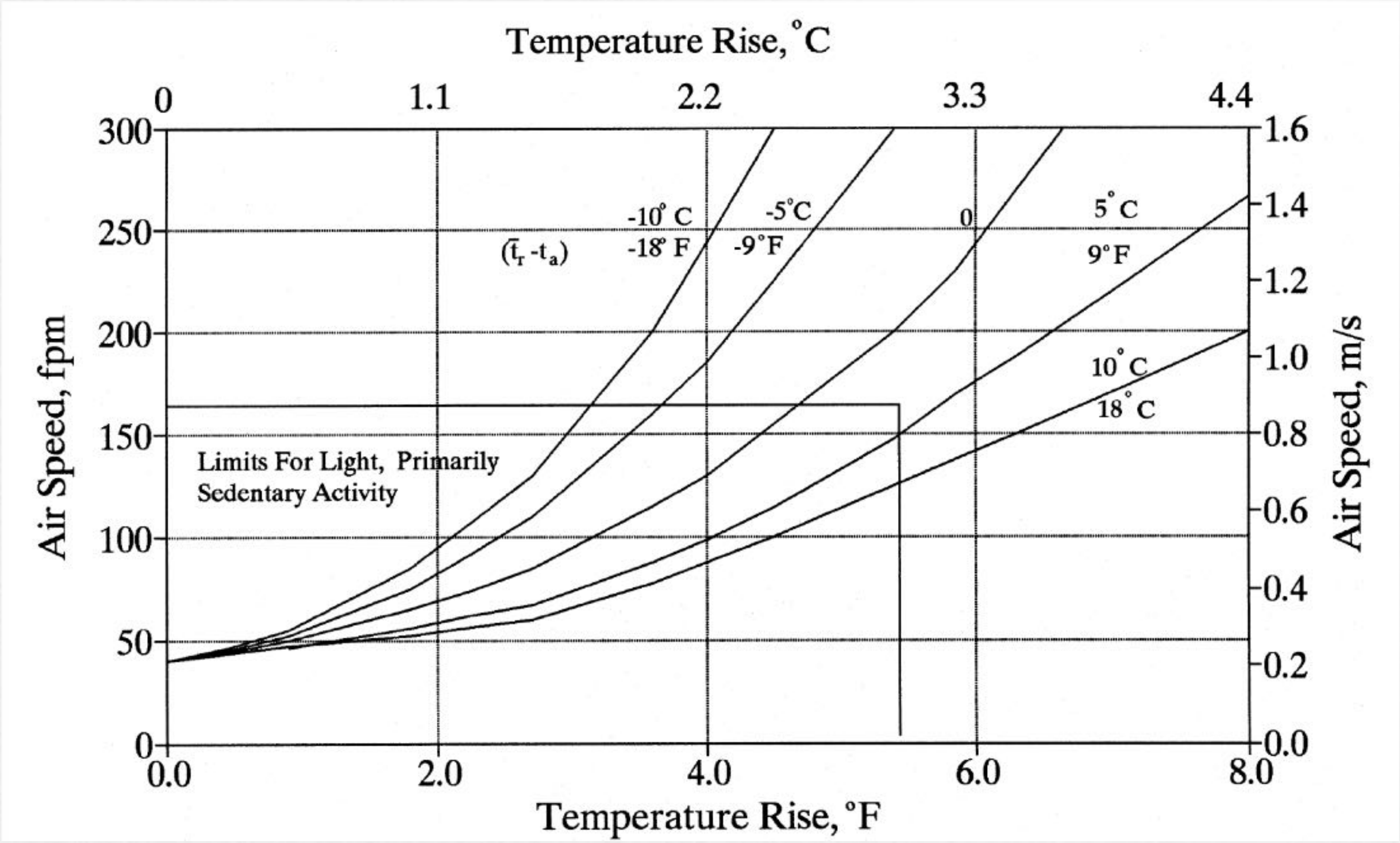
Controlling for PMV

COMFORT CRITERIA
1. Surface temperature
2. Air temperature
3. Air velocity
4. Clothing level
5. Metabolic rate
6. Humidity

Temperature

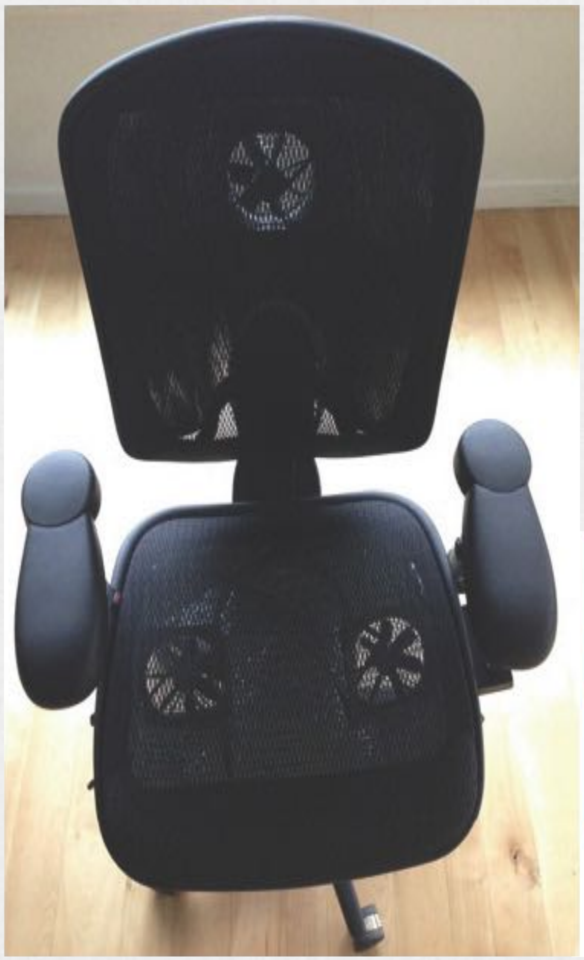
Innovative thermal comfort

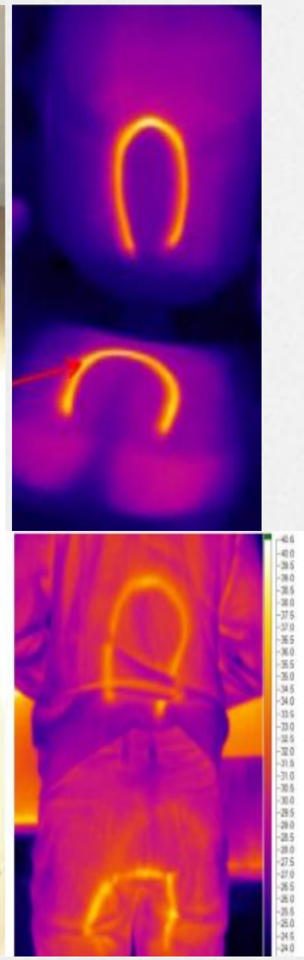
Fans allow for up to 5° F temperature increase

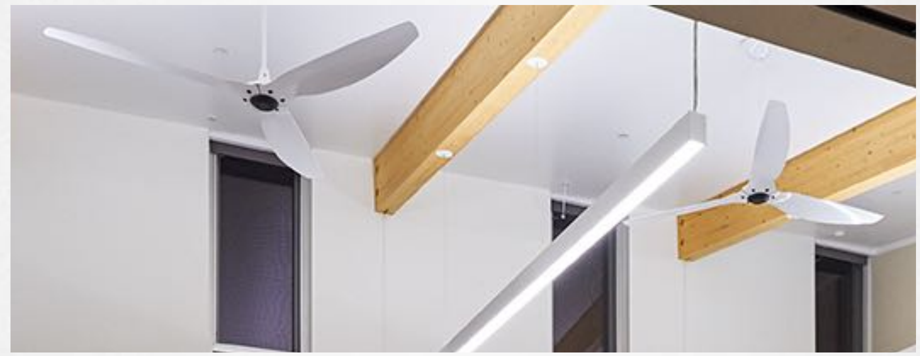


Low energy using technologies for comfort

Individual controls







- Manually controlled ceiling and personal fans allow users to extend their cooling range.
- Fans and heating units in the Hyperchair allow users to occasionally tune their comfort within the existing comfort band.

Occupant engagement

Occupant behavior help achieve ambitious net-zero goals and are important in maintaining performance levels over time

PERSONAL ENERGY USE

- Submetered work stations to manage plug loads
- Public dashboard for real-time feedback
- Personal accountability for energy management
- Automatic shutdown 7 am – 7 pm with manual override at individual workstations

TRAINING & TROUBLESHOOTING

- Extensive training pre-occupancy
- Regular meetings to gather feedback
- Staff ‘green team’ serves as point of contact for real-time questions or concerns

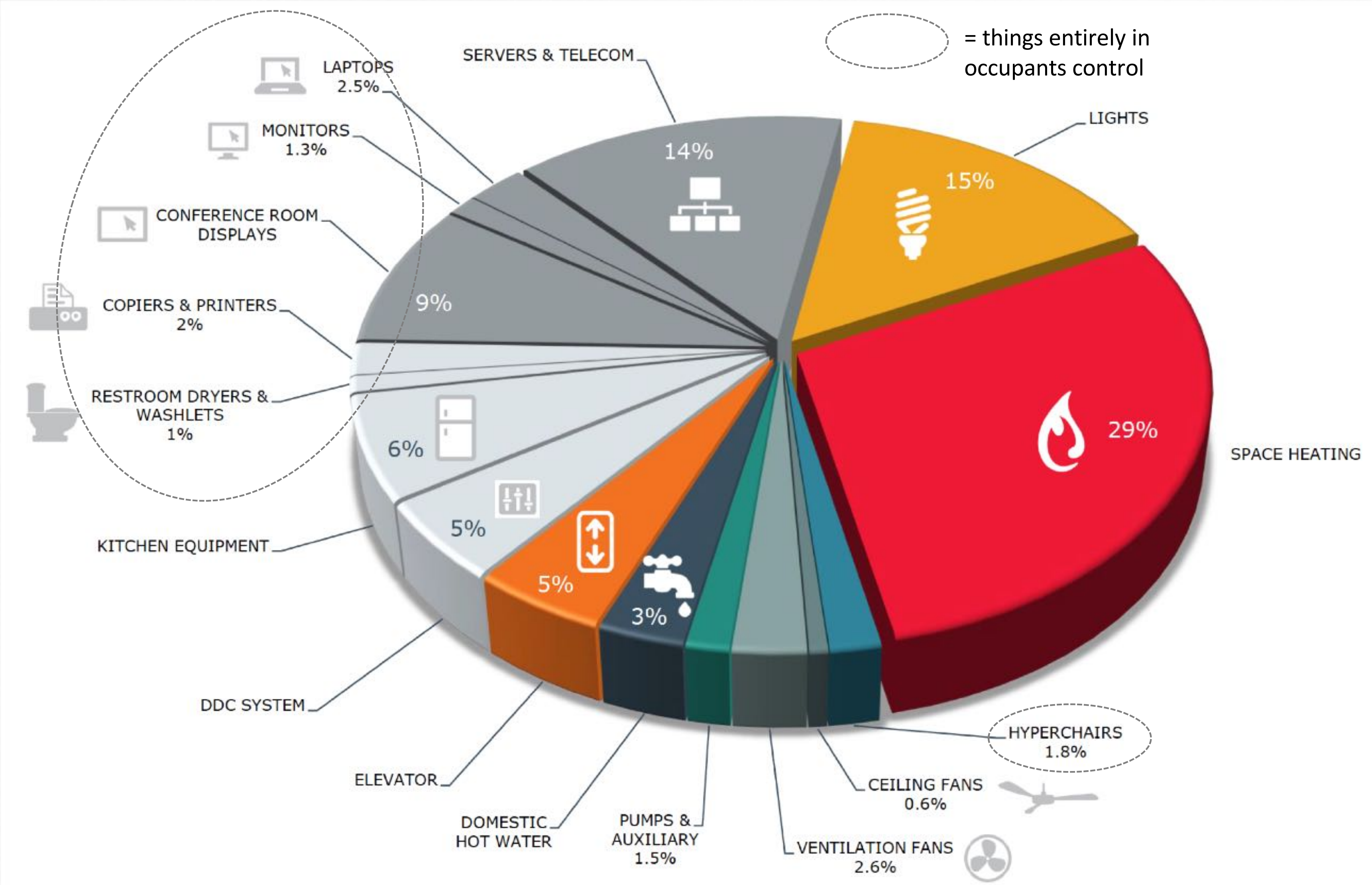
THERMAL COMFORT

- Occupants have greater control over maintaining personal comfort with low-energy using distributed technologies

FLEXIBLE OFFICE & HOTELING

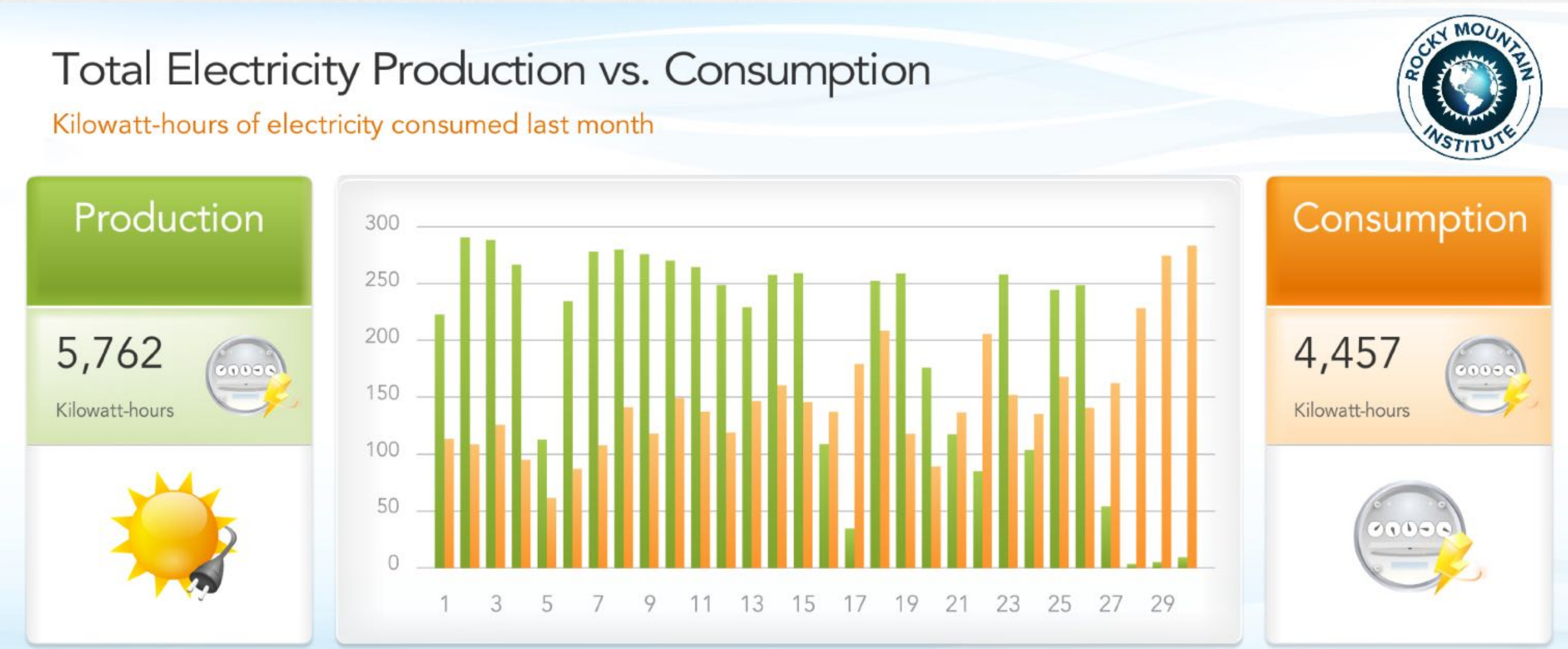
- Increases collaboration and productivity while benefiting building performance
- Saves cost and space, allowing for a smaller building to accommodate more staff
- Maximizes thermal comfort with different desk options (close to a window or stand up desk)

Occupant engagement: Where energy goes



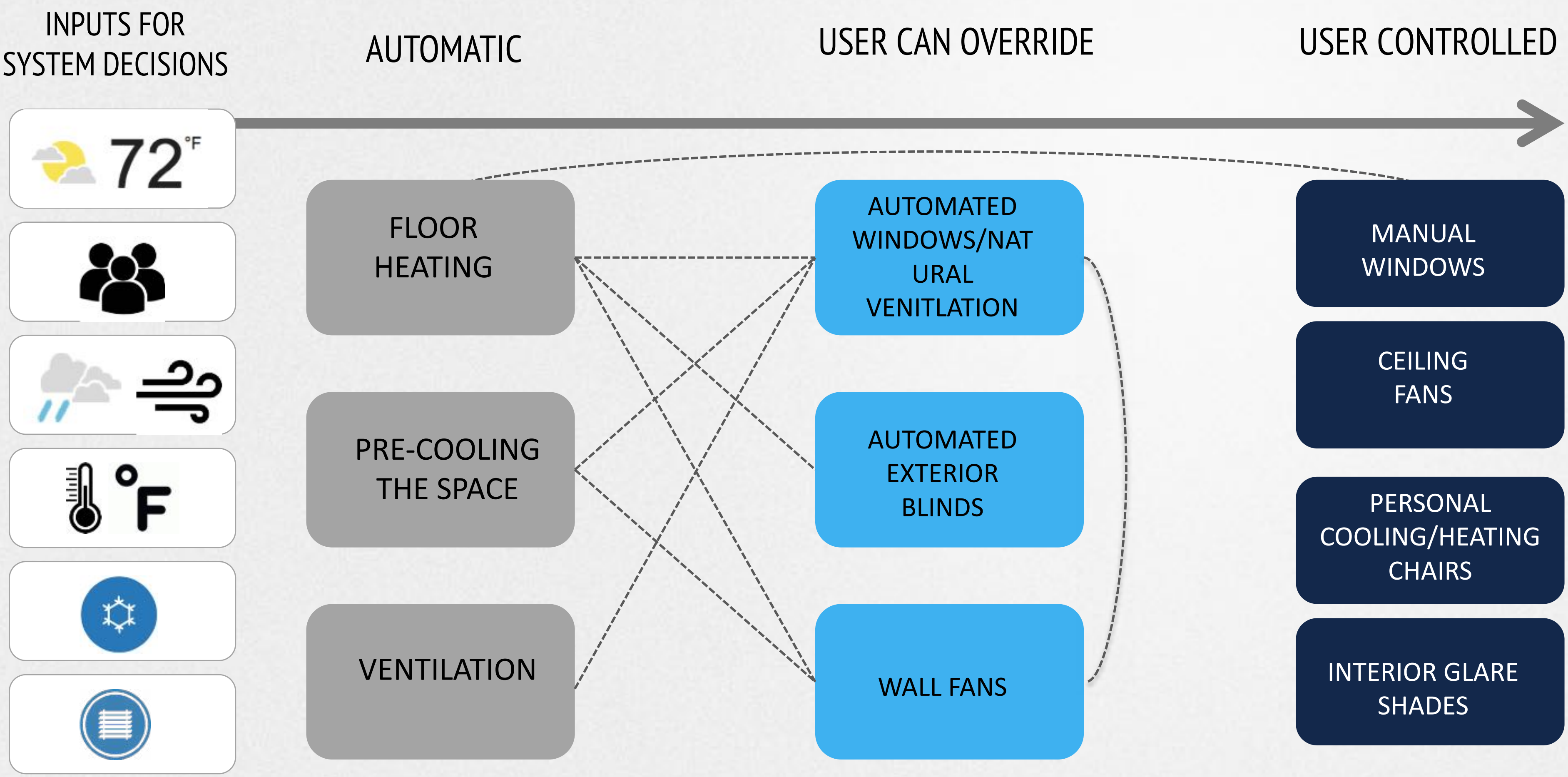
Monitoring and transparency

- Real-time performance data available on energy dashboard
- More than 120 sensors and data monitors
- We collect and monitor data from plug loads, renewable solar production, energy flows (PV to battery to grid), and EVs



Integration and automation

Simple concepts, complex system interplays



Integration and automation

Scenario: Cooling the building before a hot day

NIGHT BEFORE

- System looks at predicted temp. for next day, determining how much to cool the space overnight to maintain a comfortable temp. throughout the day
- System confirms building is unoccupied, and it is not raining or windy
- If all above conditions are satisfied, all automated windows are opened and wall fans in office/conference spaces turn on
- Windows remain open until slab temp. Meets target, air temp. gets too low, morning occupancy approaches

MORNING

- System ensures heat does not turn on as a result of the space being cold and monitors internal temperature
- Occupants encouraged to use personal comfort technologies if cold

AFTERNOON

- As the space warms (measured in slab and interior), system lowers external sunshades
- Automated windows open or close based on external temperature
- Light indicates whether it is too hot/cold outside to open manual windows

Lessons learned: Thermal comfort

- Instead of oversizing systems to reduce risk day 1, right size but plan for and enable a plan B strategy day 1. RMI ended up using our plan B almost immediately.

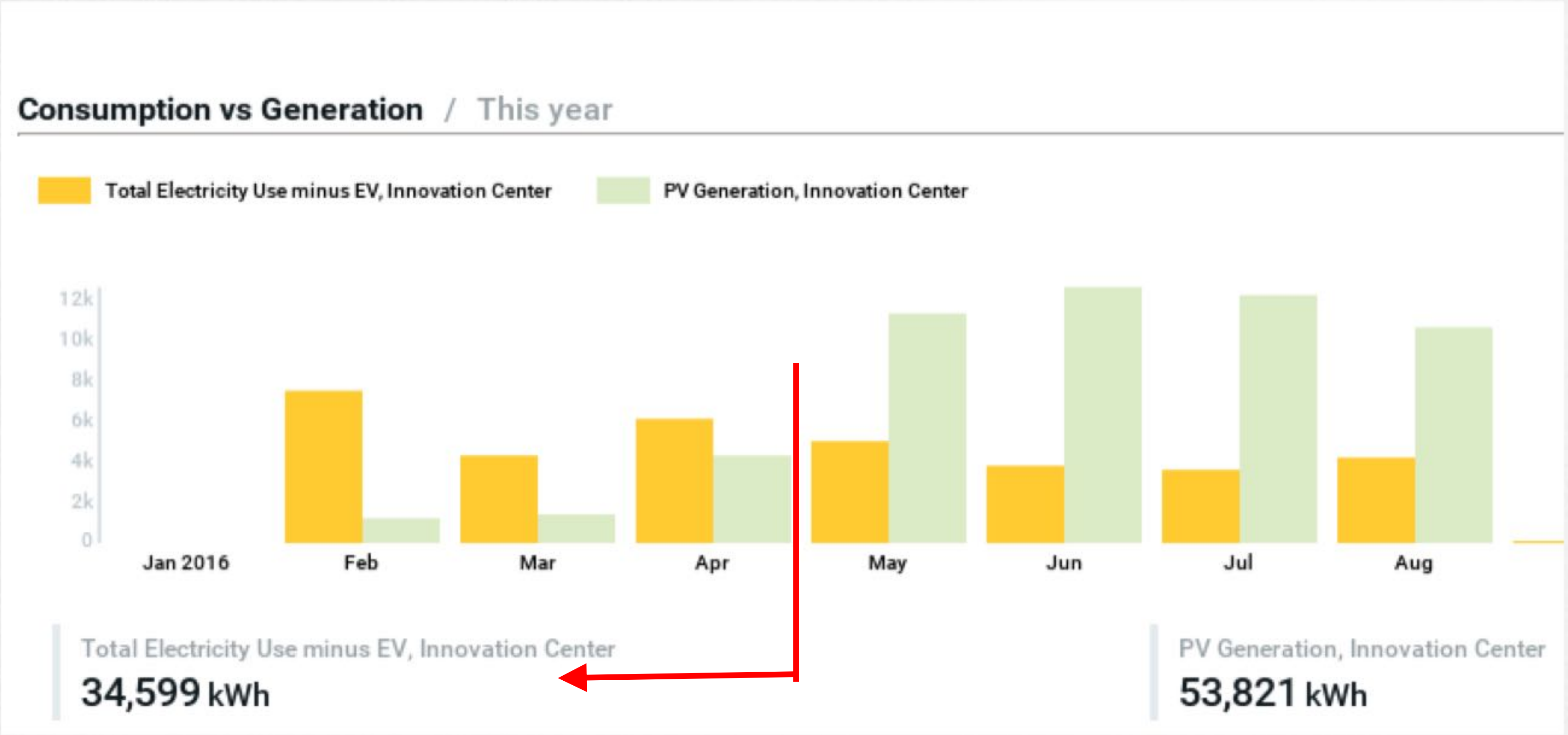
- A big variable affecting thermal comfort is people's hands and feet. This is not well accounted for in PMV research to date.

- Strong passive performance and insulation levels can act as a risk mitigation strategy for HVAC performance risks. We were able to ride out heating issues using our passive performance.

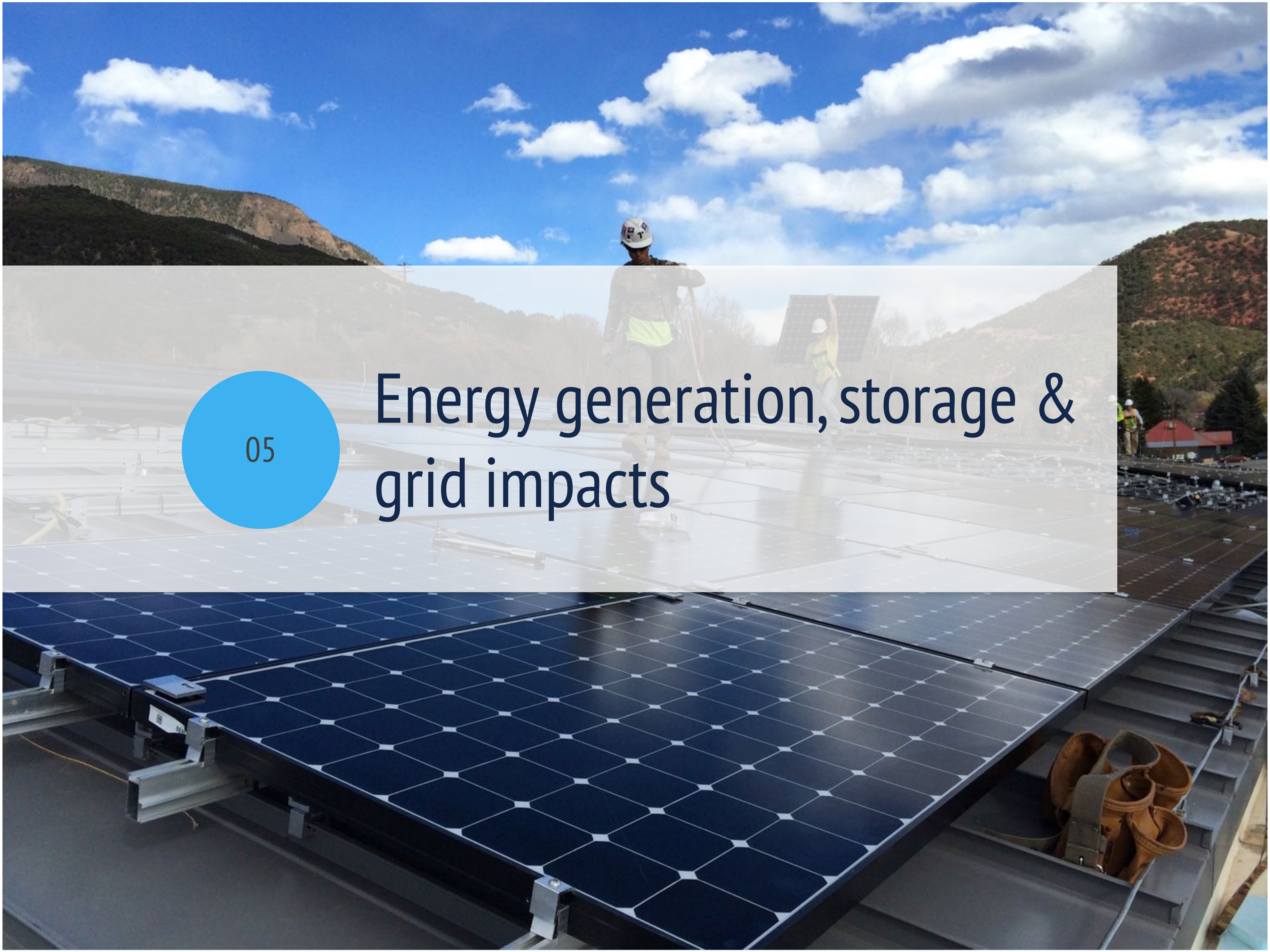
Lessons learned: Controls and metering

- As you increase the number of simple, targeted systems controlling comfort, you exponentially increase the complexity of controls integration and operation.
- Controls industry still not truly “open platform’
- Controls industry needs to adapt to escalating complexity from multi-system, passive design and integrate AI with predictive control. We can no longer use canned sequences.
- Commissioning contracts need to support long term tuning. Could we combine this with M&V 2.0 and remote fault detection?

Meters have had most the issues



CT issue with PV inverter showing low production.

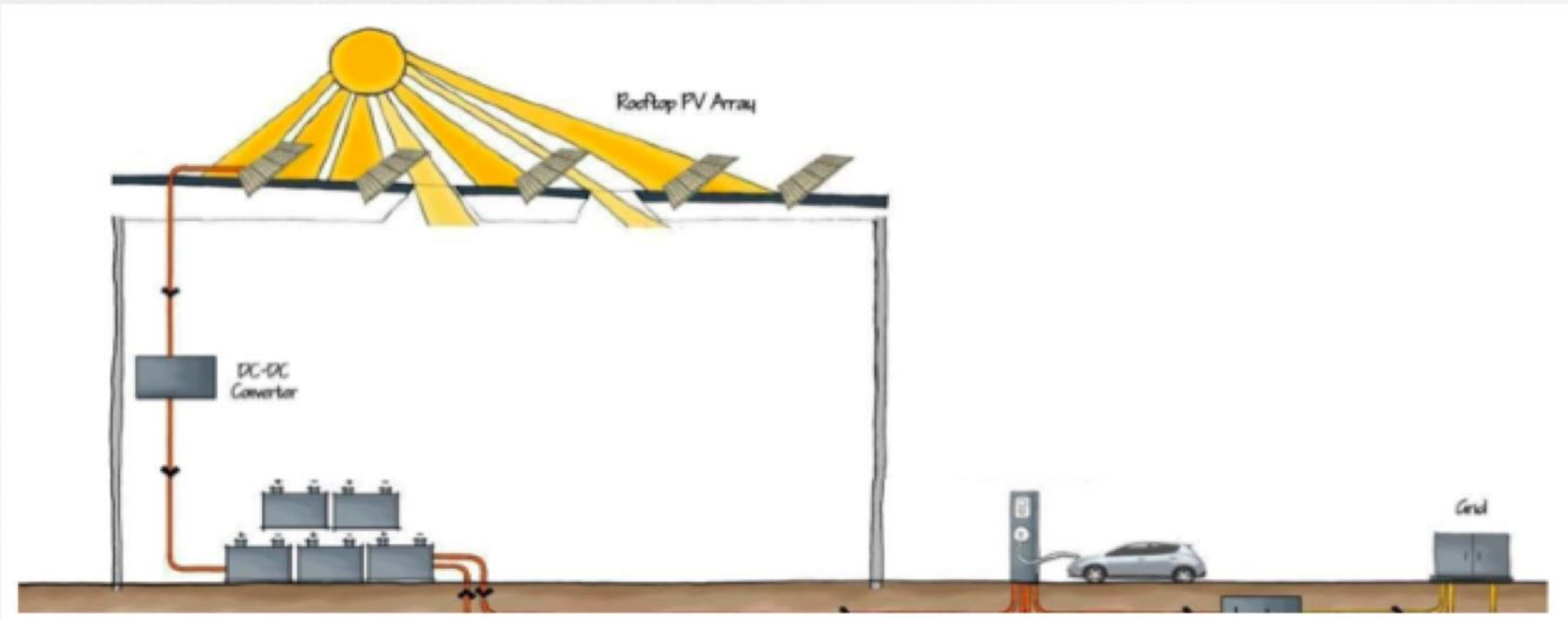


05

Energy generation, storage & grid impacts

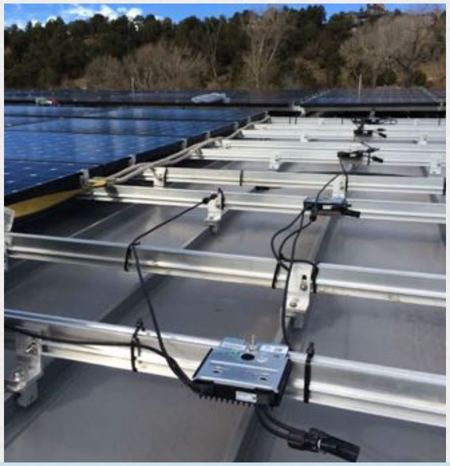
Energy overview

- PV funded through a Power Purchase Agreement
- 83.08 kW sized system mounted on a 10 degree roof: 92% of maximum production
- 248 SunPower X21-335 panels that are 21.5% efficient
- 248 three-phase inverter safety switches
- 8 SolarEdge 120/208 inverters
- 30 kW 45 kWh LI battery storage system
- 4 EV charging stations/capacity for 6



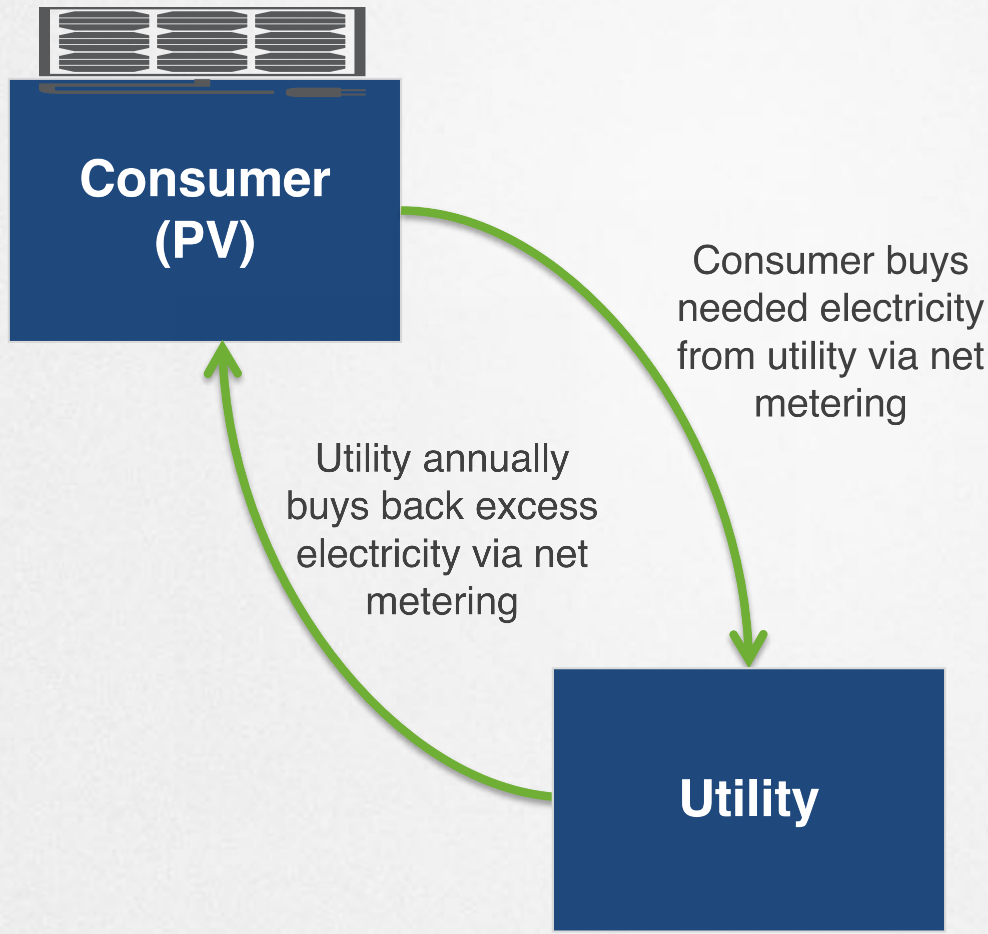
PV production estimates

- Estimated to produce 113,588 kWh on year one
  - This includes a 20% safety factor to account for snow accumulation during winter.
- The Innovation Center's building energy use is estimated to be 77,000 kWh/year
- The electric vehicle load is estimated to be 17,500 kWh/year

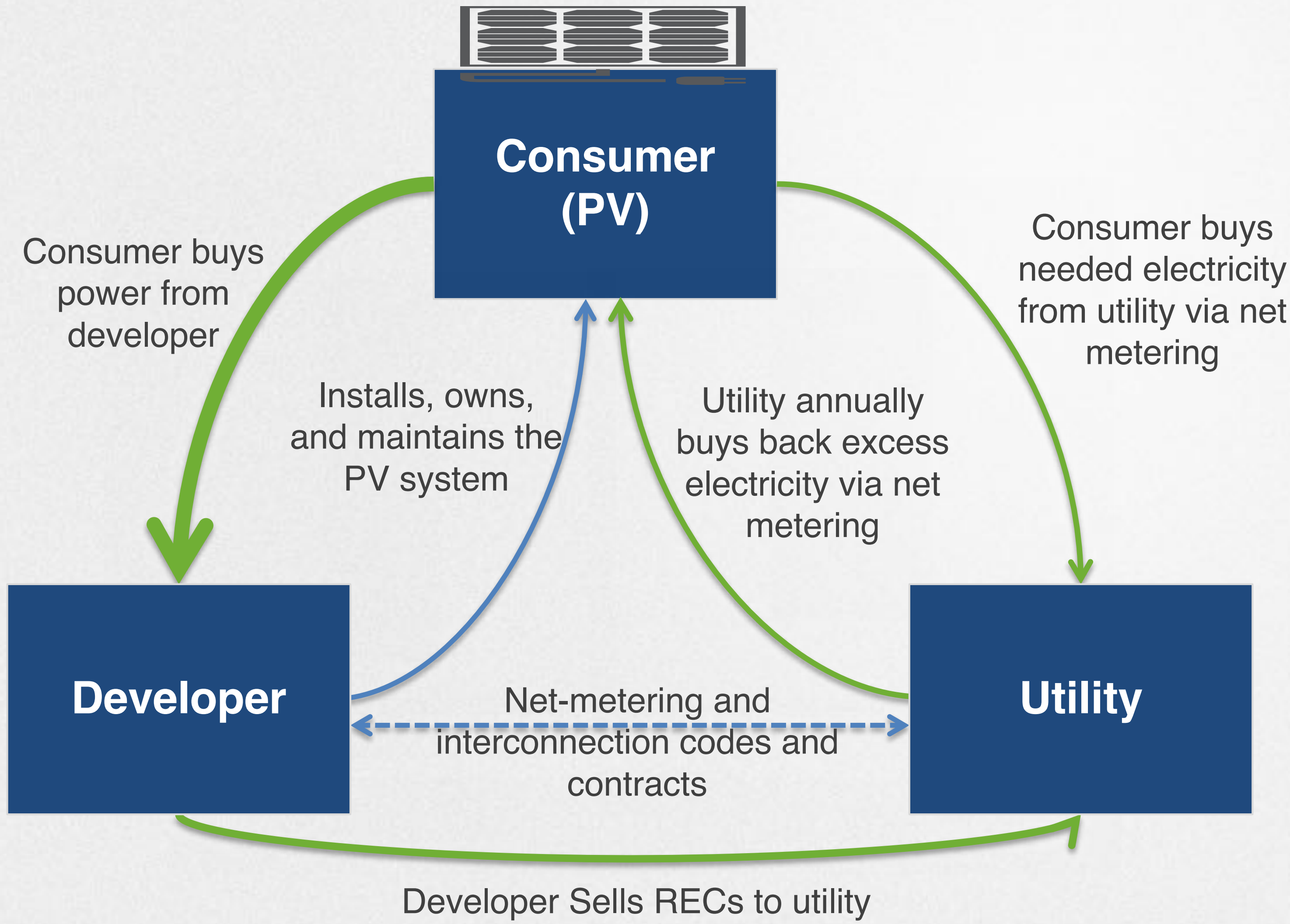


PV will offset 100% of building plus 6 electric vehicles

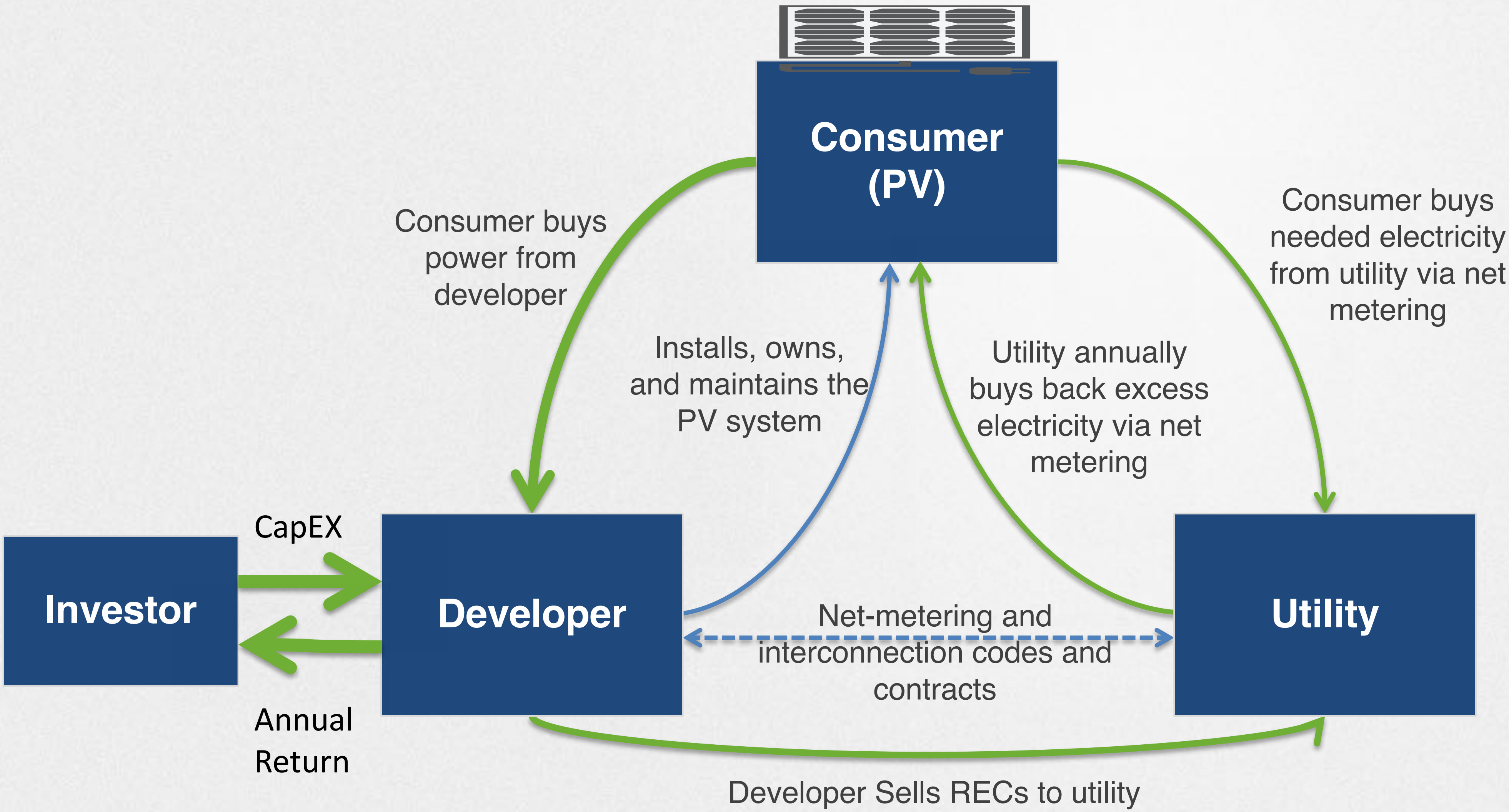
Typical utility: customer business model



Renewable enegy power purchase agreement (PPA) buisness model

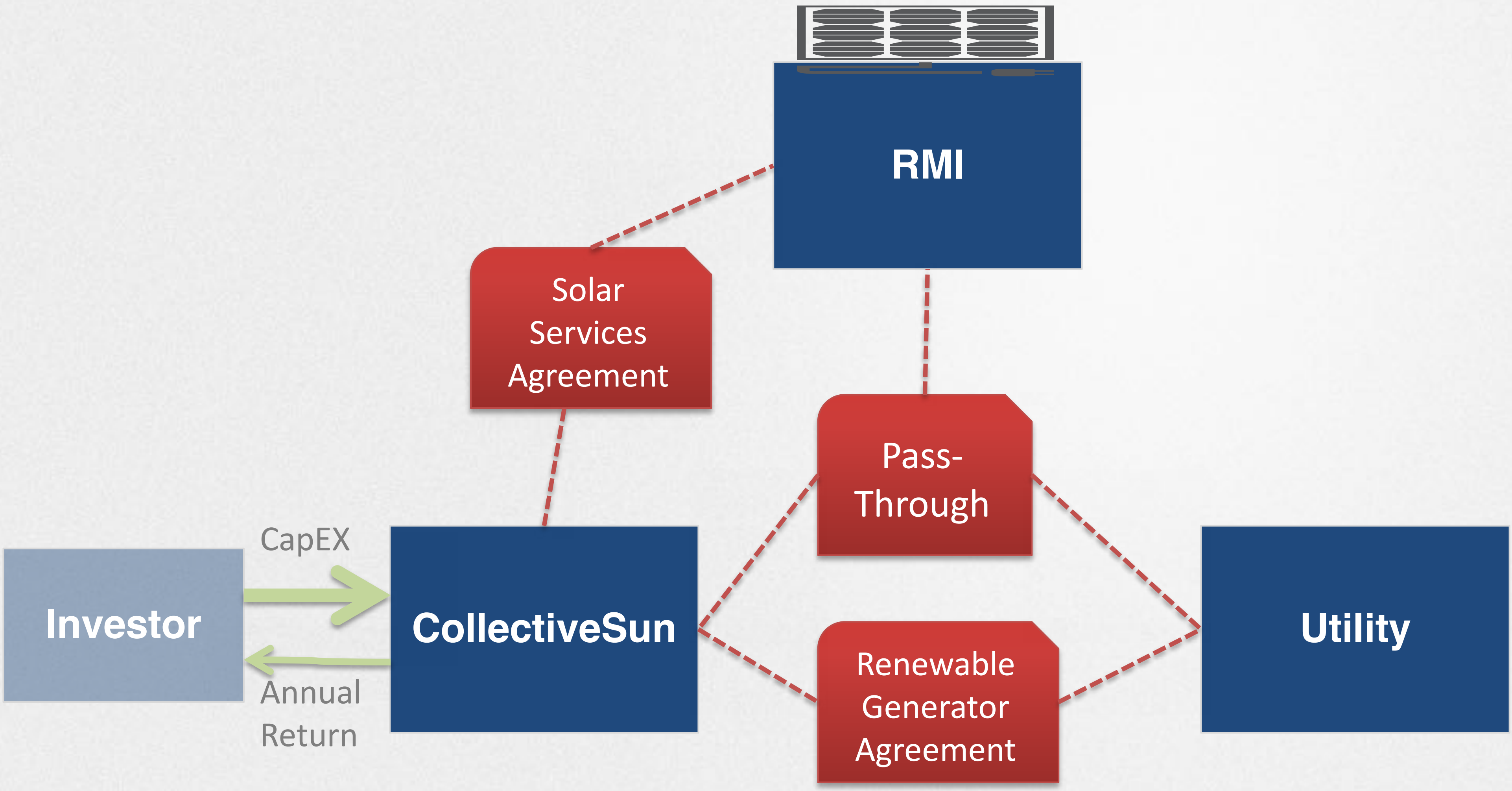


PPA business model: Who profits where?



PPA contract structure

PPAs involve several complicated and multi-party agreements



Goals of the battery system

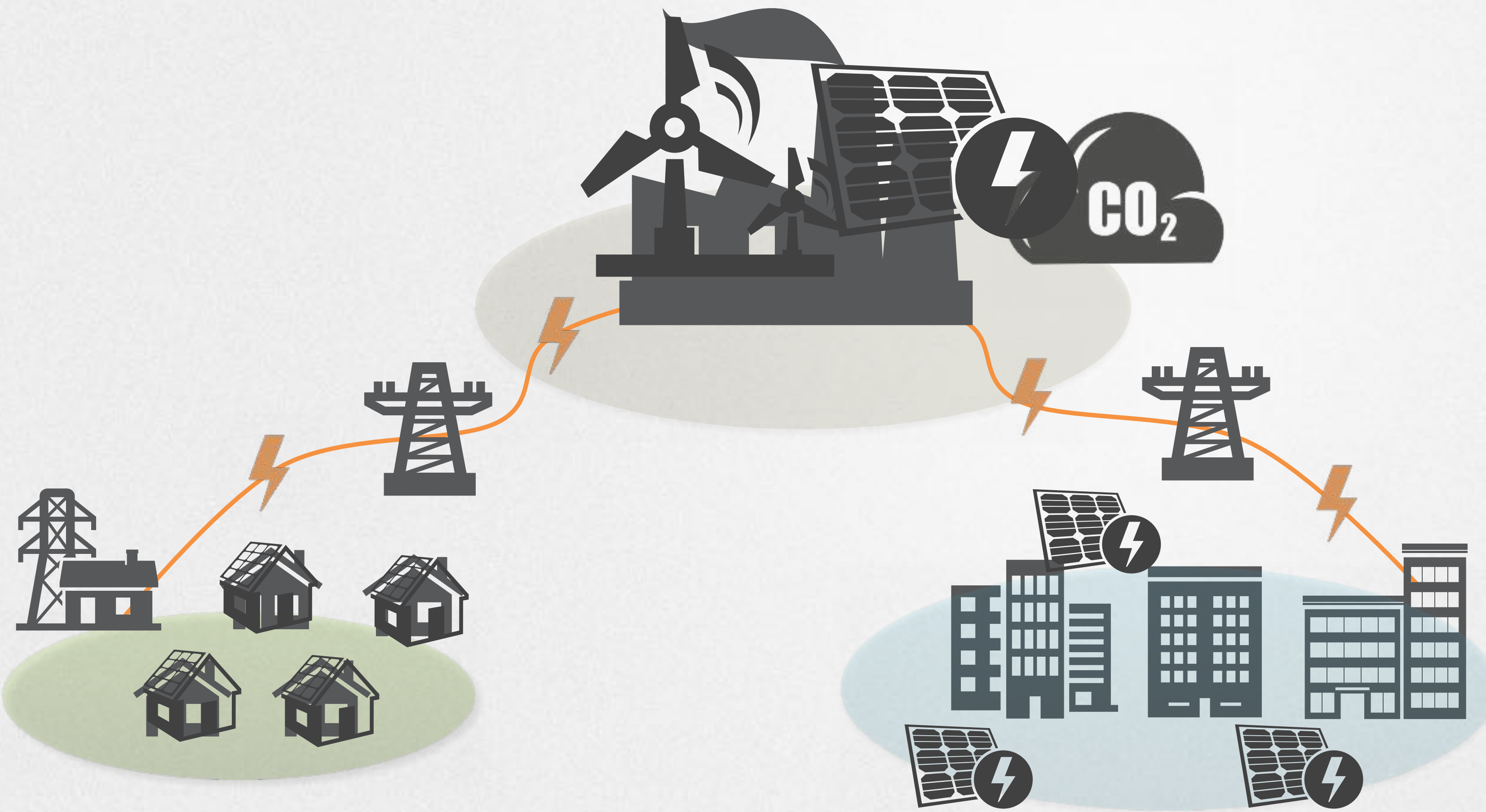
1. The ability to provide peak shaving for demand charge avoidance
    1. In particular, to keep the buildings peak energy use below 50 kW, including EV charging
2. Integration with an 83 kW PV system and utility services
3. Capacity to power critical building services during grid outages via 'islanding' (currently not possible)
4. Ability to test different demand response scenarios
5. Future integration with multiple bi-directional EV charging stations
6. Future integration with a DC loop, that would be installed in a select area of workstations to test savings in DC distribution (requires significant modifications)
7. Ability to test different utility rate structures and how they would affect the function and economics of an energy storage system
8. Provide this with a safe, fully UL listed system

Demand control system (a.k.a. Batteries)

- 30 kW 45 kWh battery storage system
- Reduces the building's peak energy demand, which will help us stay below a peak demand of 50 kw, which keeps us in the small-commercial rate class.
- Lithium ion battery with a customizable controls system that offers a level of power density and flexibility that enhanced the building's capabilities to act as a living lab and teaching tool.

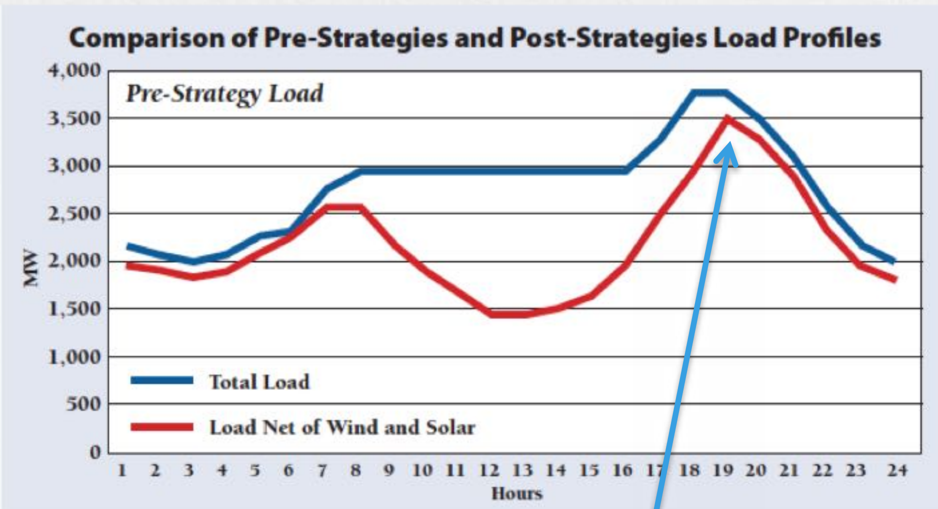
Productive for the electricity grid

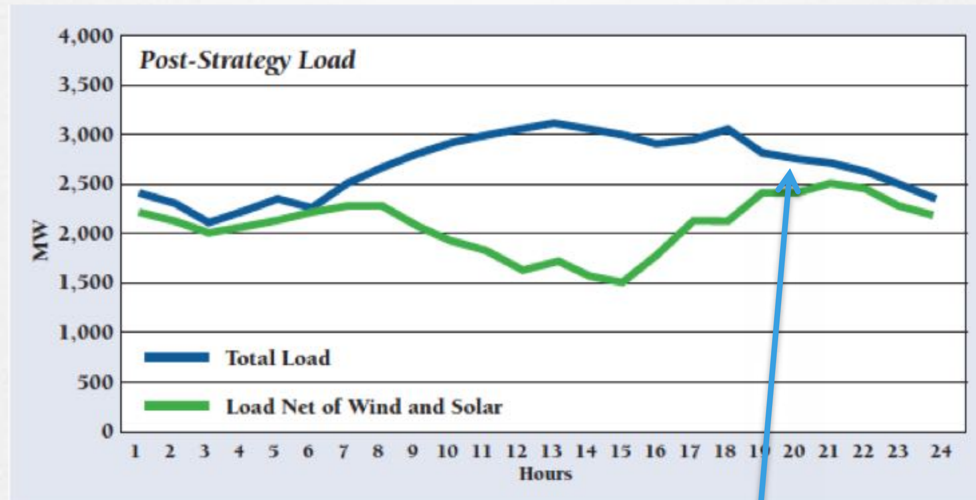
The cost of saving energy is far cheaper than generating it



Productive for the electricity grid

Adjusting building demand to meet supply solves challenges with renewable energy



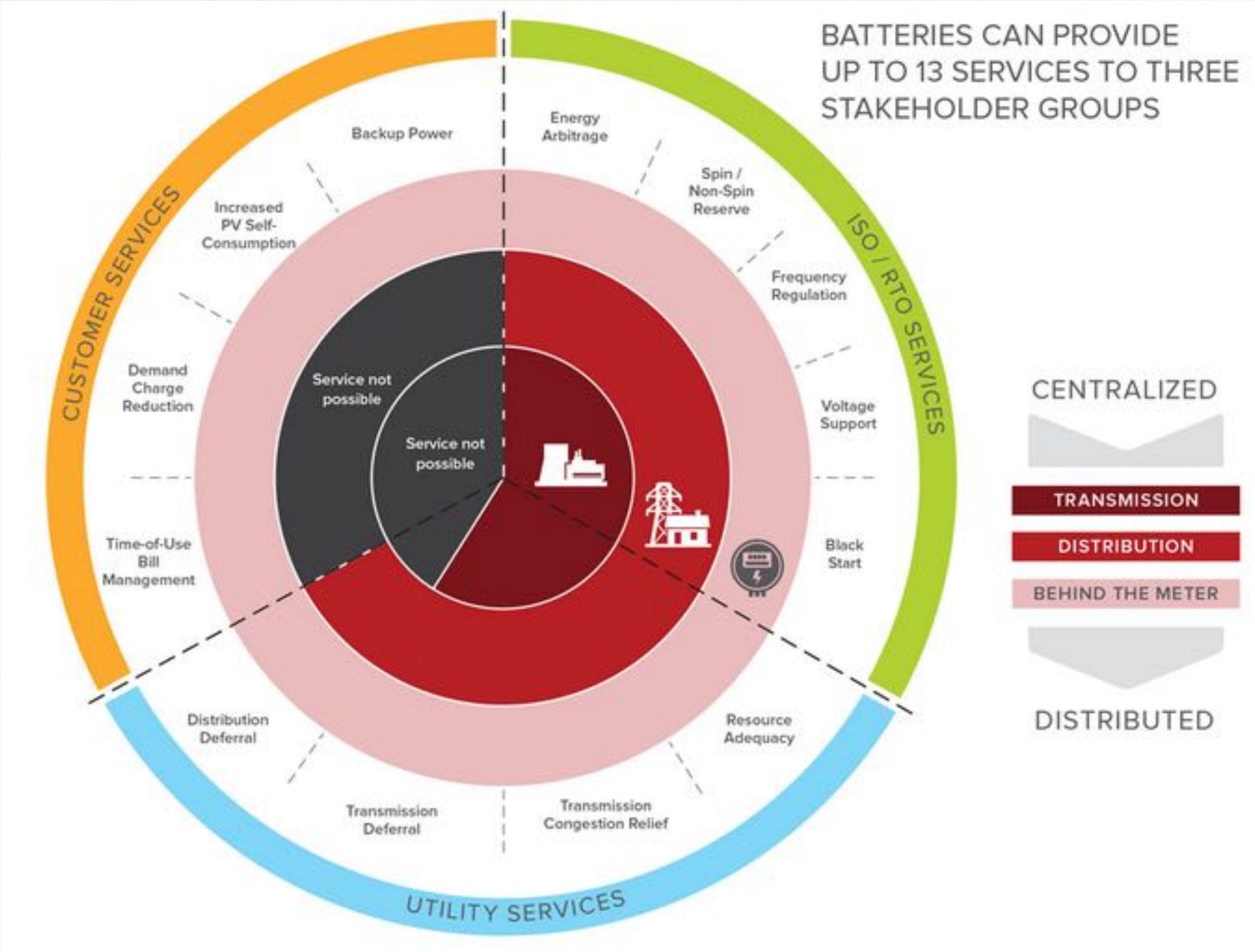


Expensive, flexible electricity

Balance demand to follow supply

Productive for the electricity grid

Batteries can provide up to 13 Services to 3 different stakeholder groups



Lessons learned: Energy generation, storage and grid interface

1. An early and accurate estimate of what PV could generate on site is essential as the basis for zero net carbon.
2. Select and engage the team early (PV system designer and installer, 3rd party financier, utility).
3. Lay out your system requirements first, then select an energy storage system to meet most or all of them.
4. It is essential to ensure there is a subcontractor responsible for connecting every part of the system (PV contractor, battery contractor, EV contractor, utility connection contractor). One line diagram with responsible parties called out is critial.
5. Monitoring is important to ensure we are using our battery system to our greatest advantage.
    - Due to montioring, we can continuously evaluate what rate class is most economic for us
6. Without bi-directional charging, EV usage will continue to be a wildcard for the buildings energy use and peak demand.

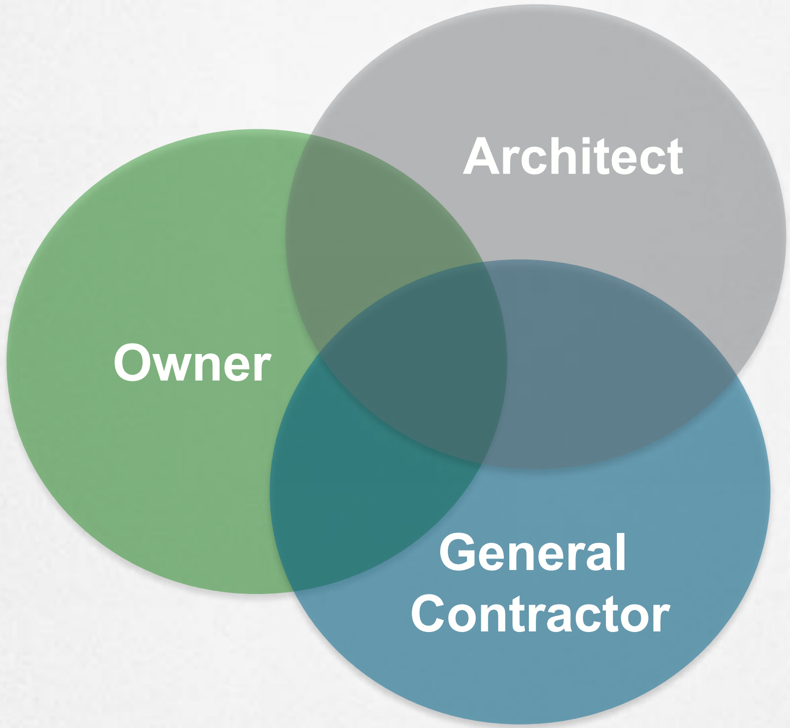
06

Contracting methodology: Integrated Project Delivery

Integrated project delivery (IPD)

Benefits of IPD

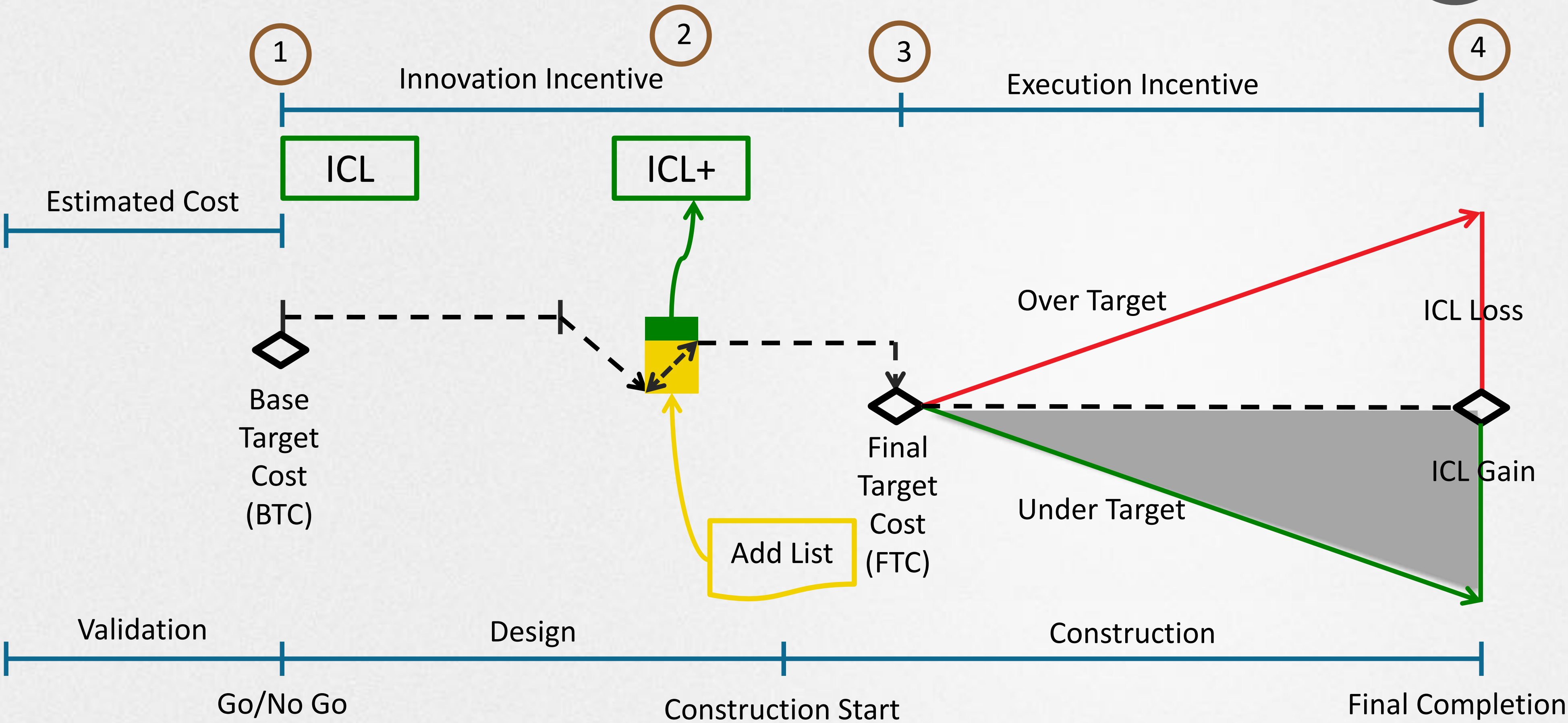
- Aligns motivations and incentives
- Builds highly collaborative design and construction process
- Financial risk mitigation for owner
- Financial reward for design/construction team



"The team was so cohesive, I couldn't tell who was from what discipline. The architect, contractor, engineers were all speaking the same language…"

– Peter Boyer, RMI Trustee, reflecting about RMI design workshop

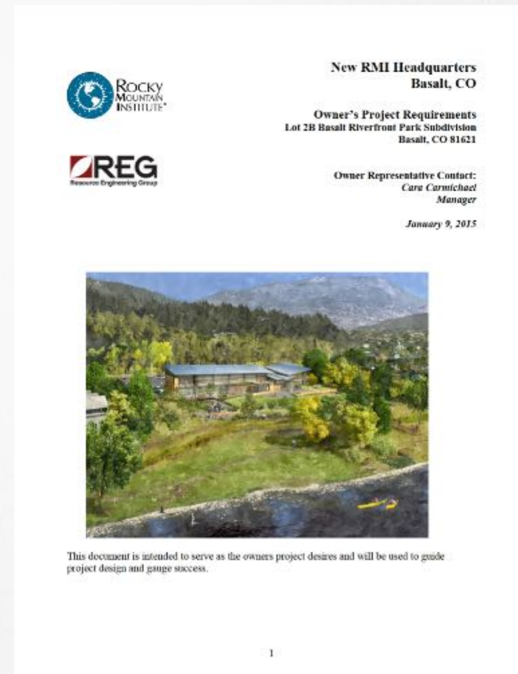
IPD – Multi Party Agreement Value Cost Model



1. At the conclusion of the Validation phase, Base Target Cost (BTC) and Incentive Compensation Layer (ICL) are set.
2. During design, if the projected costs are lowered through innovation, additional scope is added (yellow) and a portion of the savings (green) is added to the ICL. The BTC is adjusted (- savings and + scope). 25% to the ICL and 75% towards the Add List item.
3. At the conclusion of the Design period, the FTC is set.
4. If the actual cost exceeds the FTC, the ICL is reduced dollar-for-dollar but capped at the ICL amount. If the actual cost is less than the FTC, the ICL is increase by a percentage of the savings with 50% going to ICL, 50% going to owner.

Owners project requirements (OPR)

- OPR's are becoming more common, required as part of the commissioning process per LEED.
- Can be leveraged as a powerful tool to convey owners requirements and desires. Can be used as an owner's performance specification.
- Living document, updated throughout design as needs for clarity around approach arose (i.e. metering requirements evolved as the industry matured)
- Key features of the OPR from the Innovation Center:
  - Required an EUI target of 19 kBtu/SF (which was exceeded) and other sustainability and resiliency goals and certifications
  - Required an integrative design approach
  - Required an innovative approach to achieve thermal comfort as established by the PMV methodology (Predictive Mean Vote) and acceptable owner tolerances, methods of confirming design specs were met, responsible parties in the event of failure, etc.
  - Described our 'Plan B' approach to add cooling/heating if needed (approach, costs, responsible parties).


New RMI Headquarters
Basalt, CO

Owner's Project Requirements
Lot 2B Basalt Riverfront Park Subdivision
Basalt, CO 81621

Owner Representative Contact:
Cara Carmichael
Manager

January 9, 2015

This document is intended to serve as the owners project desires and will be used to guide project design and gauge success.

1

Operating performance pool

Created incentives for multiple parties to deliver on ambitious performance targets

- $50,000 reward pool paid out 18 months after occupancy
- Receiving parties include ZGF (architect), PAE (MEP Engineers) and JED (General Contractor)
- Payout based on a sliding scale based on measured energy performance

Measured Energy Use Intensity	% of total pool paid out
19 (Goal stated in OPR)	0
17	25% or $12,500
15	50% or $25,000
13	75% or $37,500
11	100% or $50,000

- *Note: To fund this pool, RMI originally intended to install 80% of the PV that was needed to meet the building loads and purchase the remaining energy from a near by community solar farm during operation. If energy use was lower than anticipated, we would not need to purchase as much or any energy from the solar farm, and we could incentivize the design and construction team to stay very engaged in operation. In the end, we found we could fit all panels needed on the roof and it simplified the transaction fee by having all PV in one location.*

Lessons learned: IPD

1. IPD is an effective to align incentives and decisions.
2. Even more important than the contract structure is selecting a strong and dedicated team.
3. IPD benefitted RMI's bottom line, and all team members participating in the risk/reward pool.
4. In application, the 'Add List' concept of returning savings to the project during design was not practical.
5. Trade partner onboarding to IPD is critical.
6. Getting to a base target cost at conceptual design required very early pricing with preliminary design concepts, which posed a challenge, but also led to productive dialogue.
7. IPD is harder in small buildings since not as many cost elements to play with.
8. Capital costs for efficiency measures and capital cost for PV were separate, making it hard to shift budget from PV toward greater levels of efficiency. Linking these budgets would be advantageous.

07 Biophilia and water use

Biophilia

Through biophilic design, the Innovation Center creates a connection to nature, improving employee alertness, energy levels, overall mood, increased productivity, and employee satisfaction.

Prominent biophilic features include:

- Interior plants
- Nature inspired art
- Site orientation and windows that maximize views of nature
- Curved walls
- Natural building materials throughout the building's interior and exterior
- Dynamic and diffuse light
- Natural colors

Resilience

Durability and longevity were primary requirements for this 100-year building. Resilience influenced multiple components:

DESIGN

- Net-zero-energy reduces risk of electricity-price volatility
- Open office area is flexible and adaptable to evolving work styles and technologies
- Extra conduit in floors and walls allow for inexpensive adaptation to future IT and DC
- Modular heating and cooling systems expand easily to adapt to climate change

SITE

- The site is more than one foot above the 500-year floodplain to avoid flooding that climate change may exacerbate
- The town of Basalt has entitled RMI to a 4,400 square foot addition, should it be needed

BUILDING MATERIALS

- Exterior stone and metal panels age well and ensure low maintenance costs
- Durable interior finishes include easily replaceable carpet tiles, concrete floors, painted walls, and acoustic fabric walls

TECHNOLOGIES

- Flexible and expandable battery system
- Available DC port
- Bi-directional EV charging infrastructure

Water conservation

In the arid west, water is just as important as energy, and the Innovation Center is a pioneer in water efficiency and greywater reuse

Aggressive water efficiency: We save water in our toilets, sinks and showers thanks to the most efficient fixtures on the market.

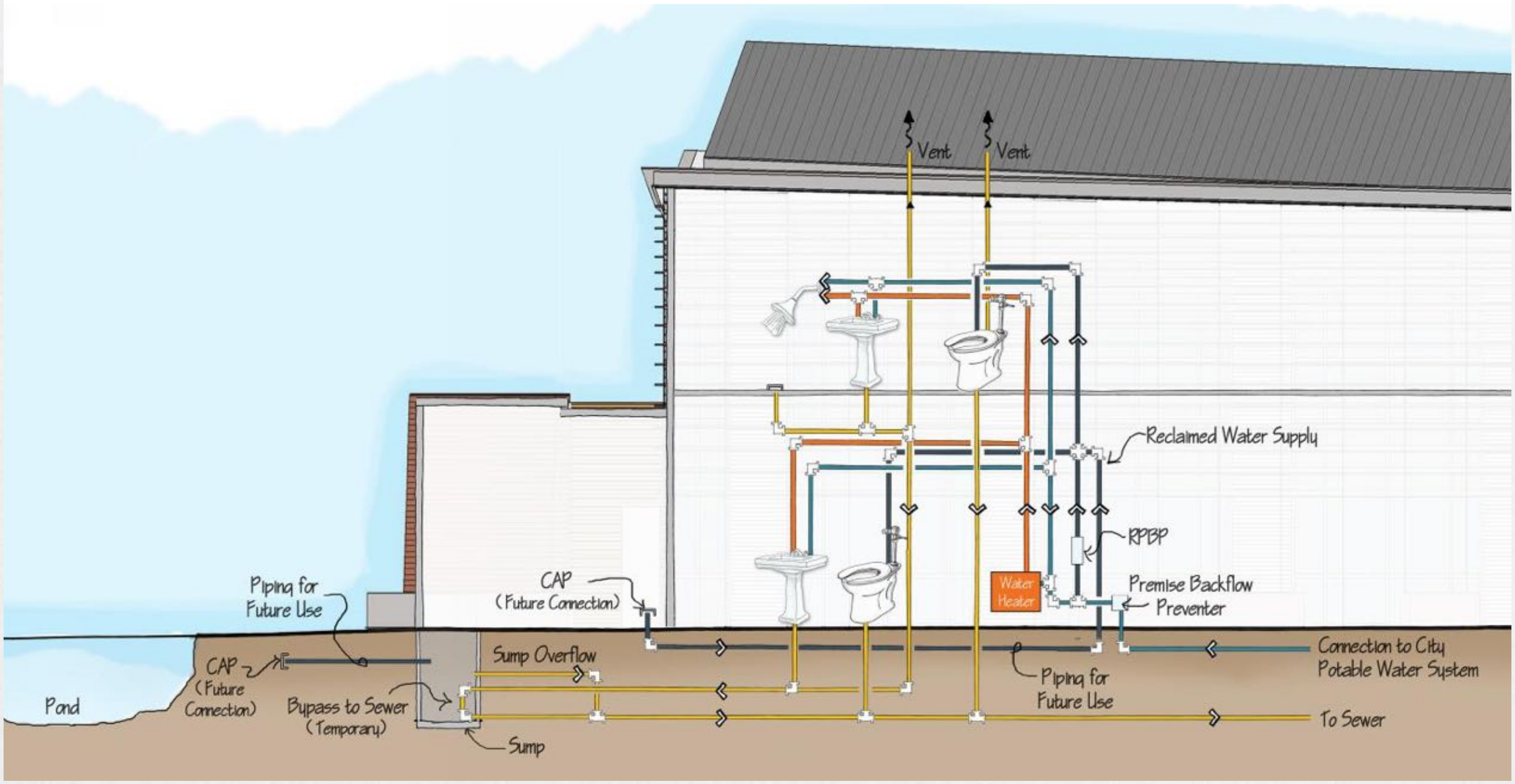
Landscaping: The landscape design of the site has limited turf are and maximized drought-tolerant native species, which require little water.

Landscape Irrigation: Water is used from the same pond west of the building that collects rainwater and snowmelt funneled through the bioswale, instead of the Town of Basalt's potable water system.

Greywater Reuse: Once these requirements are finalized, the Innovation Center plans to complete our greywater treatment system, making it one of the state's first greywater reuse systems in a commercial building. The system will collect, filter, and treat used water from bathroom sinks and shows, and use it for toilet flushing. It will save 19,000-37,000 gallons of potable water annually.

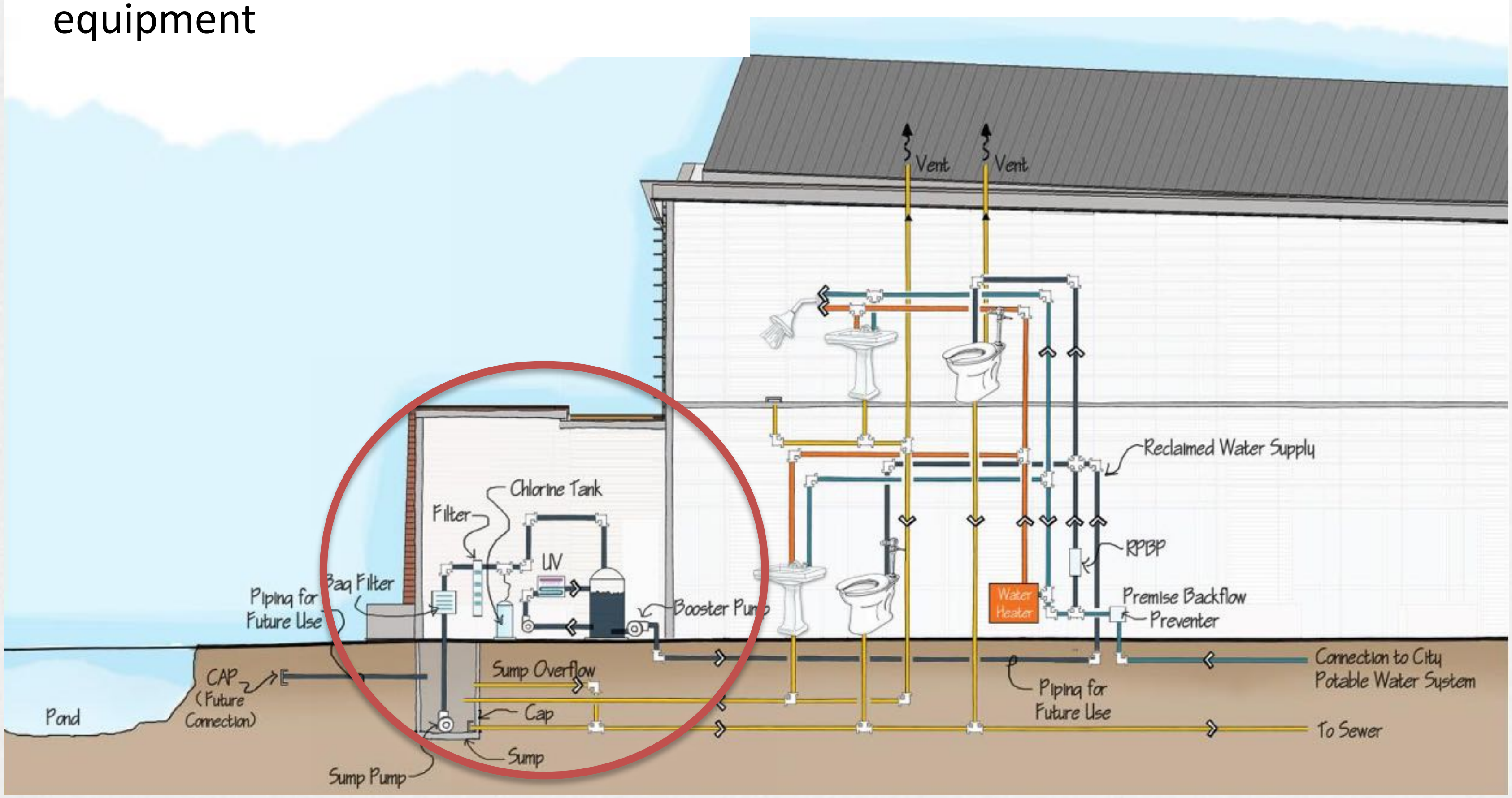
Water use (and reuse!)

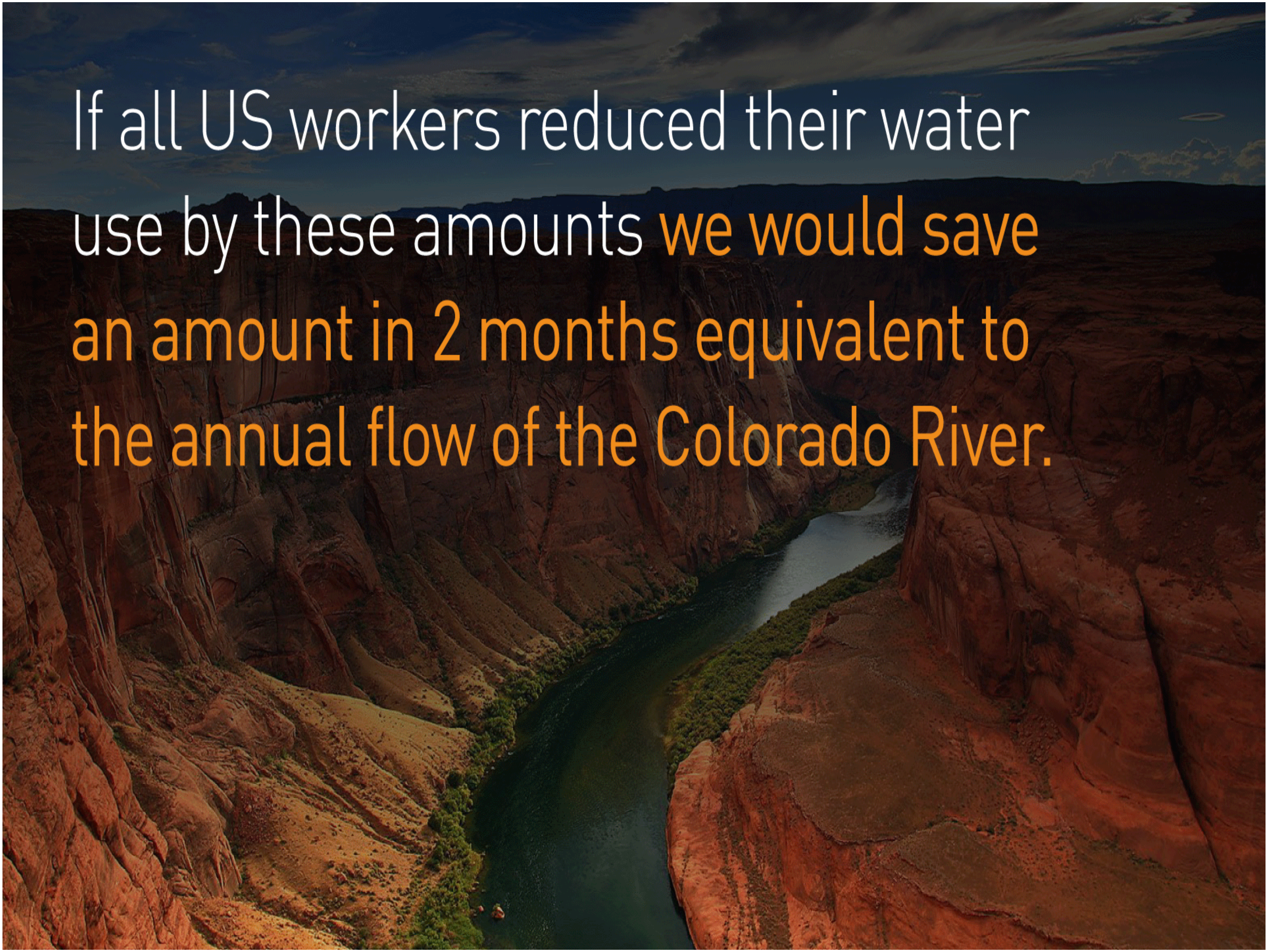
Greywater Day-1



Water use (and reuse!)

Once greywater regulations are finalized in the state of Colorado, easy 'plug n' play' for filtration equipment




If all US workers reduced their water
use by these amounts we would save
an amount in 2 months equivalent to
the annual flow of the Colorado River.

08 Cost, Value and Payback

Cost Executive Summary

The <u>**incremental cost associated with achieving net zero energy was or 10.8%**</u> and will deliver a <u>**simple payback in just under 4 years**</u>. This analysis includes all costs for the site, design, construction and furniture, fixture & equipment costs.

Since RMI had other goals (very low energy use intensity, eliminating mechanical equipment and 100 year lifespan), <u>the cost premium we experienced was higher than if NZE was the only goal</u>. Also our premium could be considered temporary and will be eroded by market forces as scaling occurs. This will provide an even more compelling payback for NZE to those that choose to go down a similar path.

CapEx and OpEx Summary

1. The cost of our building is on par with other national, leading edge, net zero energy buildings at $569/SF for core & shell and tenant fit-out, despite being located in the coldest climate zone in the country. The Roaring Fork Valley carries a 1.5x - 2x cost premium to build due to the exclusive location and distance which contractors and materials need to travel.
2. There was a total premium of $86/SF to achieve NZE, which included $54/SF construction cost premium and a $32/SF design/soft cost premium.
   a. We have assessed that there was a $120/SF construction cost premium (which includes core & shell and tenant fitout) over a baseline LEED Silver office building built in this specific location. There are 2 reasons for this premium:
      a. In order to achieve a world-class convening and collaboration center with a design life in excess of 100 years we spent $67/SF more on interior and exterior features and finishes.
      b. In order to achieve net zero energy performance we spent $54/sf more on insulation, thermal comfort, air tightness, electrical specialties and passive measures. This figure includes savings of $9/SF on HVAC equipment since we have no mechanical cooling system and a small distributed heating system and an additional $7/SF savings from the increased functional square footage that resulted from the reduced size of our mechanical room.
   b. Our design and soft costs (including architect, architectural consultants, owners rep, other consultants and construction trade partner preconstruction fees) totaled $171/SF and we have assessed that there was a $32/SF design cost premium over a baseline LEED Silver office building due to our course being largely uncharted. We used a number of relatively new technologies and approaches necessitating a highly collaborative design process. We used a new method of contracting (Integrated Project Delivery) and engaged with several specialty consultants to achieve the targeted level of performance. We anticipate this design premium quickly dropping to negligible levels as these technologies and processes become more commonplace.
3. Our net zero energy building delivers significantly more long-term value than a typical building. Annual energy use is 74% less than a typical building in this climate zone, and the remaining energy use is offset entirely with onsite PV, which is funded through a PPA. Increased productivity, reduced energy costs and reduced maintenance costs contribute >$2.5 M (on a net present value basis) over a 10 year period.

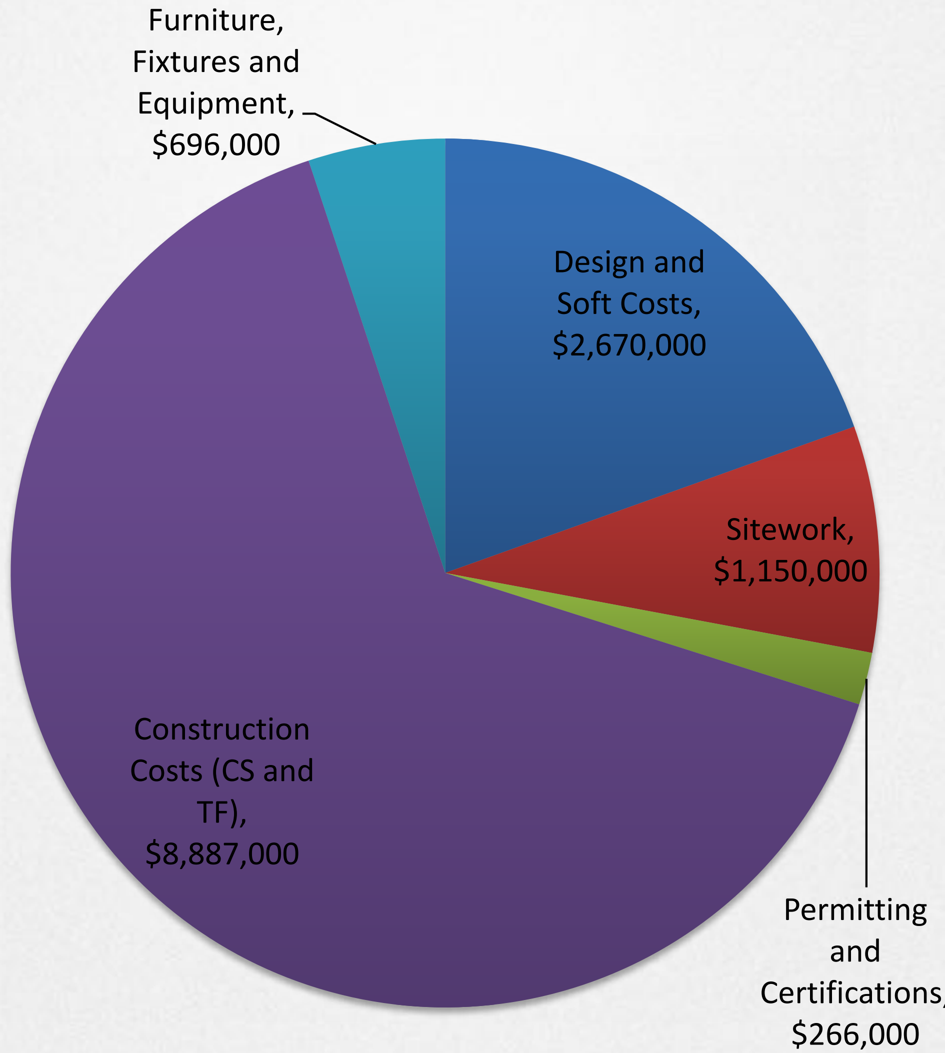
$13,670,000 total cost breakdown

- 15,610 GSF total
- Total budget $13,670,000

- Construction costs were $569/SF (including core & shell and tenant fit out).
- Design and soft costs were $171/SF (including all architectural and architectural consultants, owners rep, other consultants and construction trade partner preconstruction fees).

Notes:

- RMI received over $300,000 in discounts and donations, which have been added back into the costs in order to show real cost impacts on net zero energy.
- The 64 kW PV system that offsets all building energy use was included as an operating expense since it is financed through a Power Purchase Agreement (PPA). We installed an additional 19 kW to offset our EV charging (commuting). The total value of our PV system is $370,000.
- Programming and land costs were not included.



$54/SF Construction cost premium for NZE

- We created a baseline cost model, built in Basalt, in 2015 with LEED Silver design features totaling $448/SF.
- Our total core & shell and tenant fitout costs: $569/SF.

- To isolate our premium for efficiency, we took out $67/SF for premium interior and exterior features & finishes appropriate to a world class convening and innovation center, including:
  - $54/SF in interior construction (curved walls, soffits and ceilings) and interior finishes (custom casework, wall and ceiling paneling, acoustic finish, custom lightshelves, stone countertop and other high end finishes)
  - $13/SF for high end exterior finishes (stone, metal panel, birch).
  - This premium was due to increased longevity and lower maintenance of materials, required by the building program and function.

  This brings us to $502/SF for a high efficiency building with modest finishes and equipment. The difference between $502/SF and the baseline ($448/SF) is the increased level of efficiency.

RMI paid $54/sf more in construction costs (including core & shell and tenant fitout) than a typical LEED Silver baseline to achieve net zero energy.

$54/SF Construction cost premium breakdown

Compared to a typical LEED building, RMI paid a premium of $54/SF for high efficiency and net zero energy. This premium was due in part to first of it's kind technologies that were not yet industrialized, summarized below.

Category	Description of high performance elements	Cost premium above baseline
Wall and Roof Assembly	SIPS, liquid applied air barrier, custom products-learning curve, passive house testing, BIM.	$27/SF
Electrical specialties	Conduit and rough-in, BMS and advanced submetering, automated operable windows, floor heat, ceiling fans	$18/SF
Windows	High performance windows (R-12), curtain wall system from Germany, single sourced suppliers, window controls	$14/SF
Lighting	LED/OLED vs. standard linear fluorescent	$11/SF
HVAC	Less ducts and equipment, no cooling vs. 60 ton split DX system with reheat boxes and AHU's.	Reduction of $9/SF
Space utilization	No cooling system and small, distributed heating system saved 258 SF in mechanical space	Reduction of $7/SF

$32/SF design and soft cost premium for NZE

There are 4 primary reasons for the design cost premium:

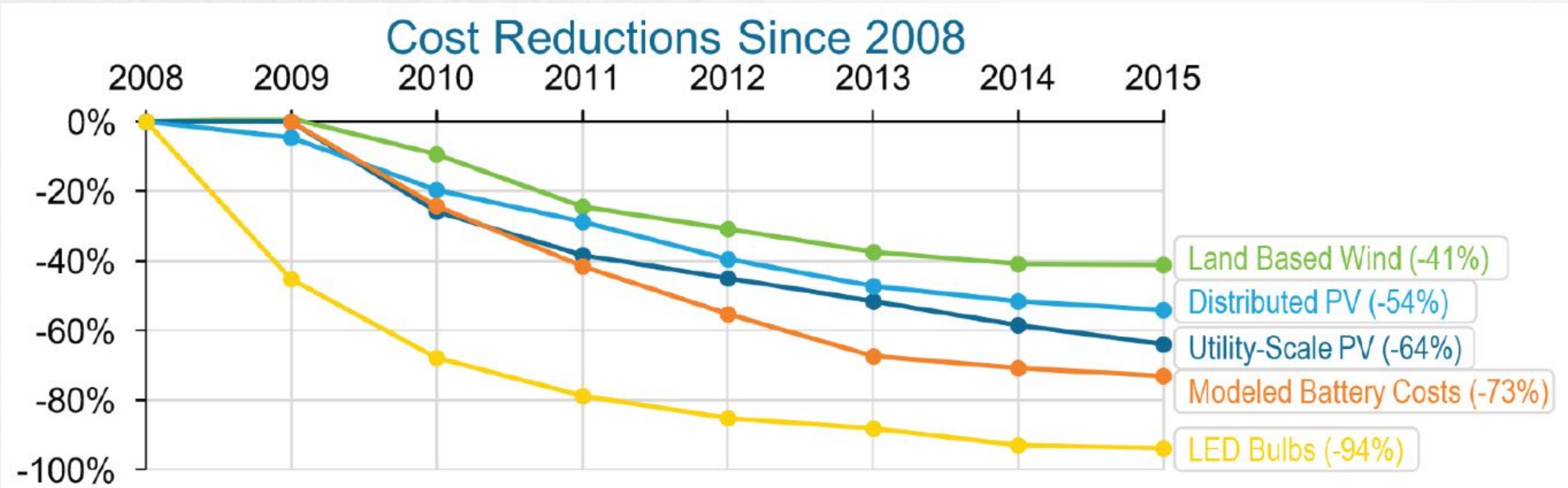
1. Highly integrated design process, which brought in construction trade partners during design
2. Specialty consultants to achieve net zero energy
3. Integrated Project Delivery (IPD) is a relatively new form of contracting, which took additional time
4. The team used Revit and IES VE for modeling, which had a learning curve

Because we are a 'first mover', the cost premium we experienced can be considered temporary and will be eroded by market forces as scaling occurs. This will provide an even more compelling payback to those that choose to go down a similar path.

Category	Design and soft costs	Notes
Premium for architectural and architectural consultants	$240,500	Includes 1 additional design workshop, high performance design and infiltration consultants, premium for MEP and lighting.
Premium for construction preconstruction	$255,600	Includes GC and trade partner preconstruction fees
Total design cost premium	**$496,100**	
	$32/SF	

Premium will decrease as market adoption grows

Similar to the decreasing rate of other sustainable technologies, this premium will reduce as integrative design becomes common place and innovative technologies improve.



Don't wait though. Even though these materials are on this downward curve, the payback is still at an attractive level today.

Source: U.S. DOE "The Future Arrives for Five Clean Energy Technologies – 2016 Update" Released September 2016

Net zero energy Cost Premium Studies

The most recent industry studies show a 3-16% premium for net zero energy buildings. RMI's building incurred an 10.8% premium.

Source	Building Type	Cost Premium	Study Assumptions and Notes
New Buildings Institute: Getting to Zero (2014 Update)	Net-Zero Ready*	3-18%	Considered 21 existing net-zero buildings, primarily small commercial.
New Buildings Institute: Washington, DC Study (2014)	Living Building Challenge	11-16%	Office building, new construction. 6-11% without PV.
New Buildings Institute: Washington, DC Study (2014)	Net-Zero Energy	5-10%	Office building, new construction. Low cost likely influenced by local incentives.
World GBC: The Business Case for Green Buildings (2013)	Net-Zero Ready*	9-10%	Office building, new construction. Taken from findings for Green Star 5-6 rating and BREEAM Outstanding rating.
Cascadia GBC: Living Building Financial Study (2009)	Net-Zero Ready*	10-15%	Low-rise office in Boston, MA. Includes all LBC measures besides solar PV.

* "Net zero ready" buildings do not include the incremental cost of PV required to reach net zero energy certification.

< 4 year payback on NZE

There are 3 factors that provide operational cost savings:

1. Reduced energy costs
2. Reduced maintenance costs
3. Increased productivity and satisfaction

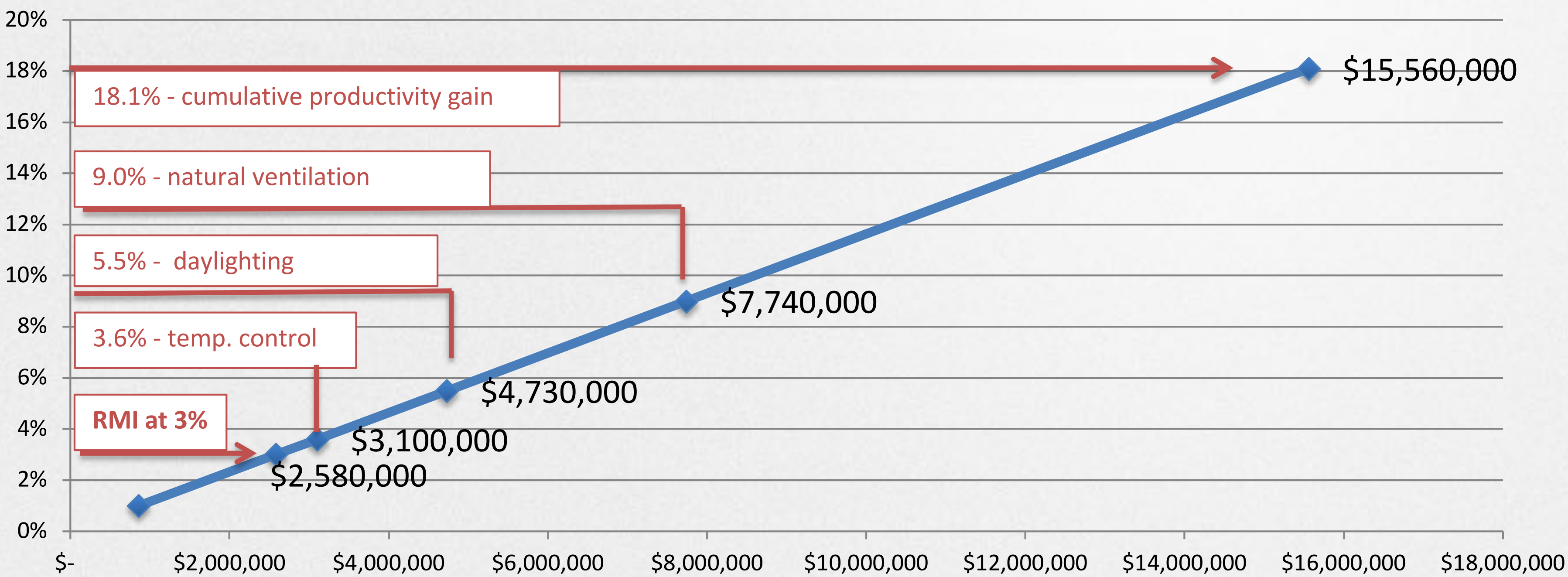
Annual operating costs	Annual Savings
Energy (Compared against a LEED baseline building, includes annual PPA expenses for building related PV, not for PV dedicated to EV charging)	$8,100
Maintenance (reduced exterior repainting, lower HVAC equipment maintenance, reduced lighting bulb replacement)	$3,000
Productivity and Satisfaction (3% gain in revenue per employee due to productivity increase from individualized temperature controls, natural ventilation and increased daylight availability.)	$334,100
Total	**$345,200/year or $22/SF**
Premium for net zero energy (including construction and design/soft costs)	$86/SF
Simple payback	**3.9 years**

3% productivity increase is conservative

34 studies compiled and analyzed by Carnegie Mellon's Center for Building Performance and Diagnostics show…

- **3.6% average productivity gain** for individualized temperature control
- **5.5% average productivity gain** for maximized daylighting
- **9% average productivity gain** for mixed-mode or all-natural ventilation.

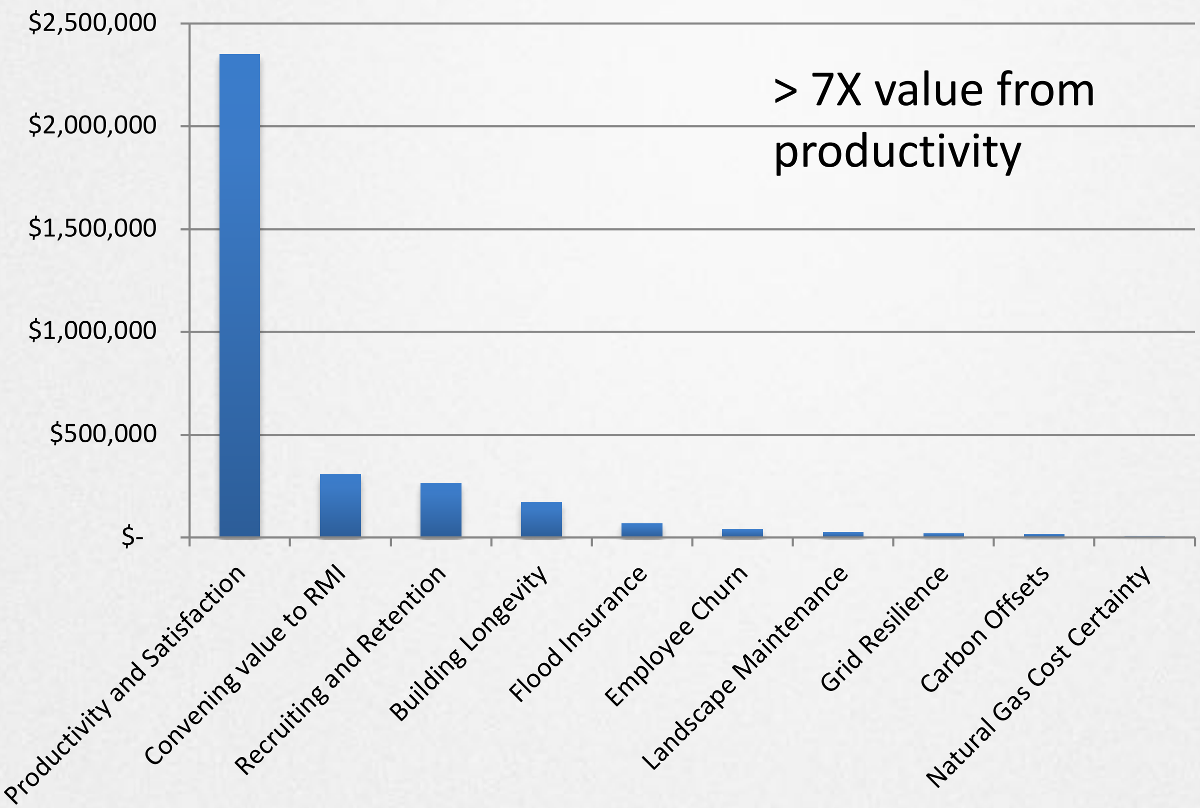
10 year present value for productivity increases



Other Value provided by NZE

Several additional likely sources of value were considered but they are less significant and some are related to aspects of the building other than its energy performance (i.e. high-end finishes, modular design, etc.)

- Value of convening
- Recruiting and Retention
- Building Longevity
- Flood Insurance
- Employee Churn
- Landscape Maintenance
- Grid Resilience
- Carbon Offsets
- Natural Gas Cost Certainty



09 Appendix

Site

Motivations

The Innovation Center was motivated by RMI's desire to:

- ✓ BUILD A STATE-OF-THE-ART OFFICE AND CONVENING SPACE THAT REFLECTS RMI'S VALUES
- ✓ CREATE A REPLICABLE MODEL FOR A NEXT-GENERATION, HIGH PERFORMANCE OFFICE BUILDING
- ✓ ACHIEVE NET-ZERO ENERGY IN AN INTELLIGENT WAY AND SERVE AS A GRID ASSET

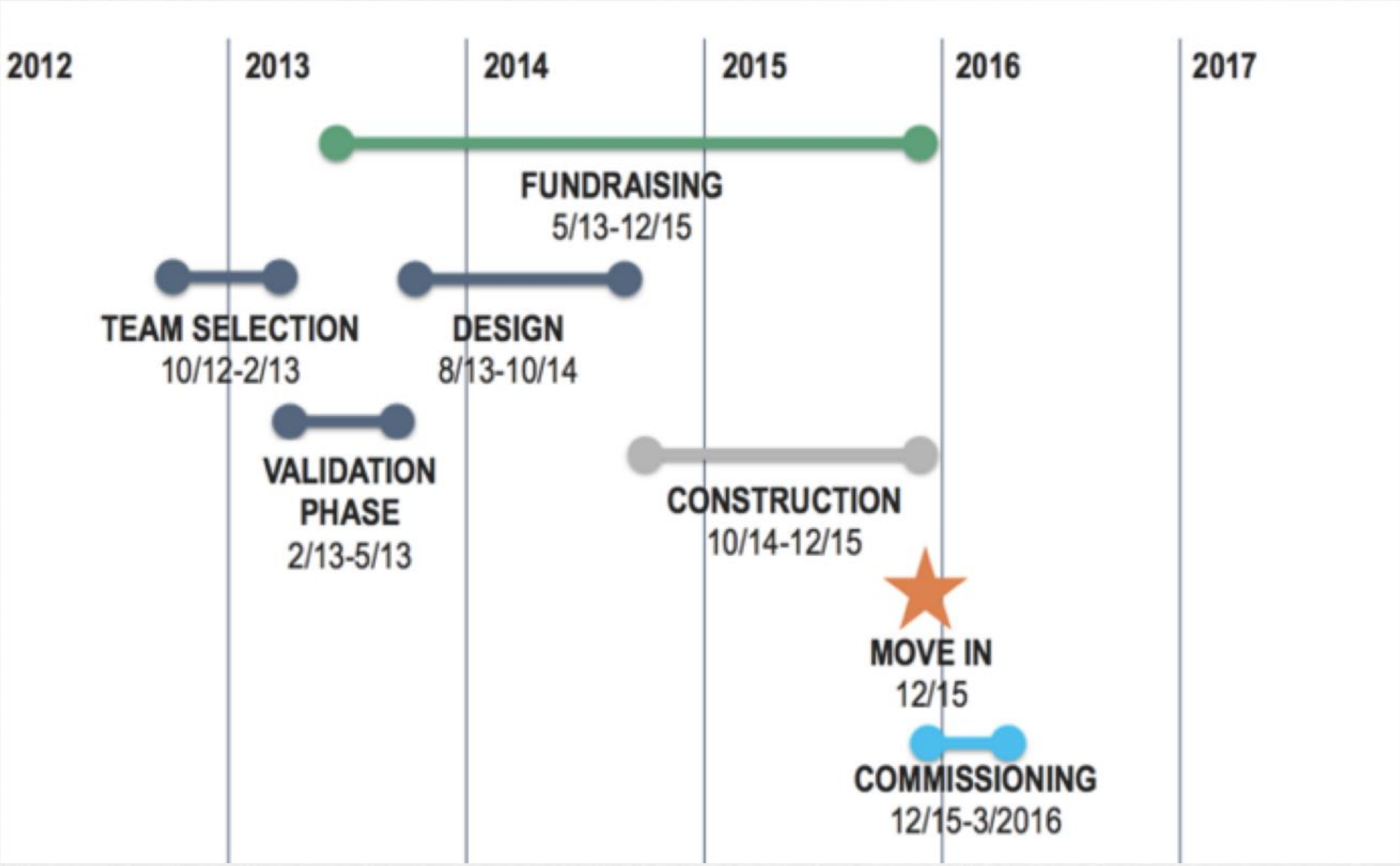
The Team

Core team

- ZGF Architects (architect of record)
- JE Dunn (general contractor)
- Architectural Applications (high-performance design consultant)
- PAE Consulting Engineers (mechanical, electrical, plumbing, IT)
- David Nelson & Associates (lighting)
- True North Management (owners representative)
- Graybeal Architects (local architect)
- TG Malloy (land planner)
- Sopris Engineering (civil engineer)
- KPFF Consulting Engineers (structural engineers)
- DHM Design (landscape architect)
- Resource Engineering Group (commissioning)
- Collective Sun (PPA)
- SunPower (Solar panels)

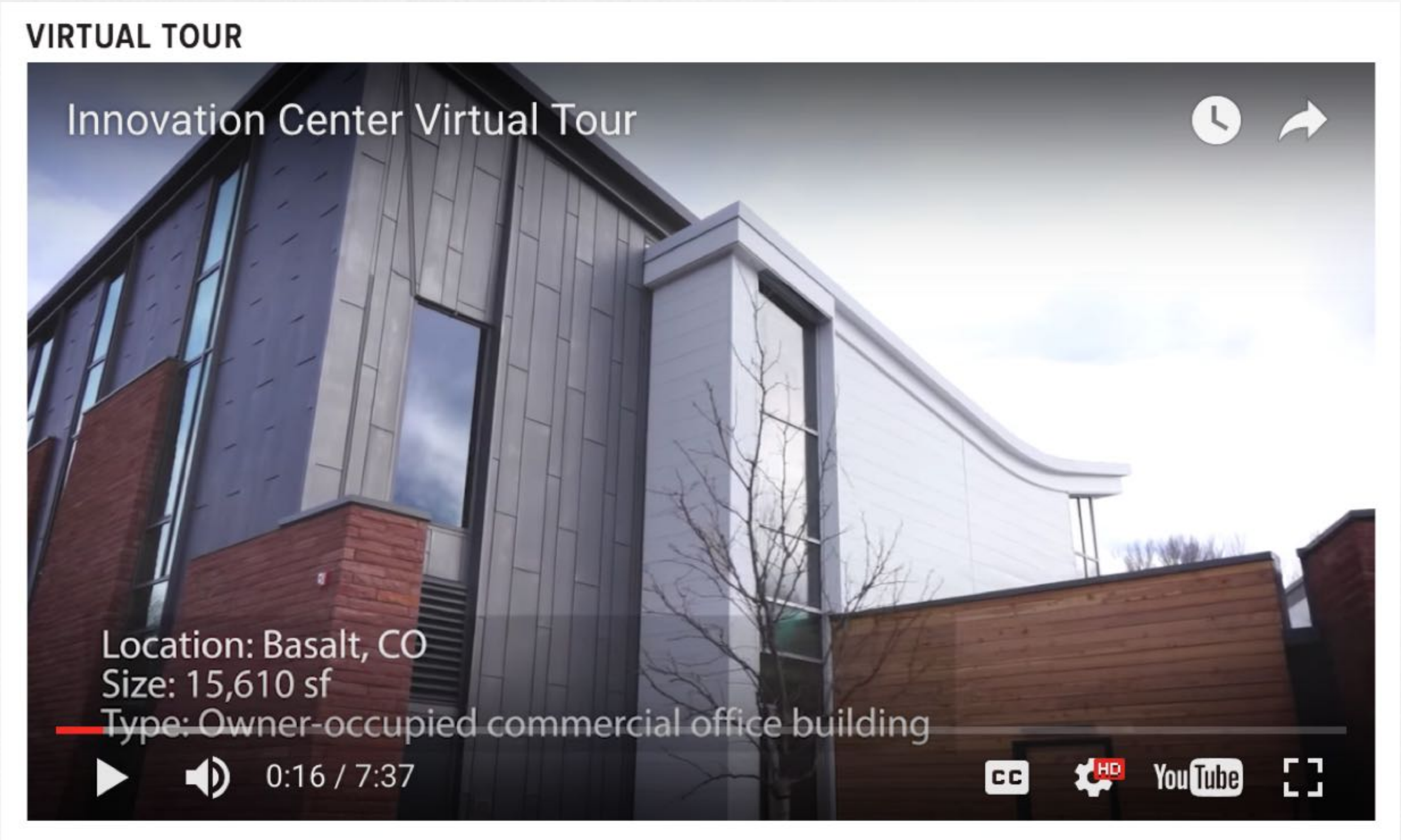
(Obviously, we got along well – and occasionally went skiing together!)

Project Timeline

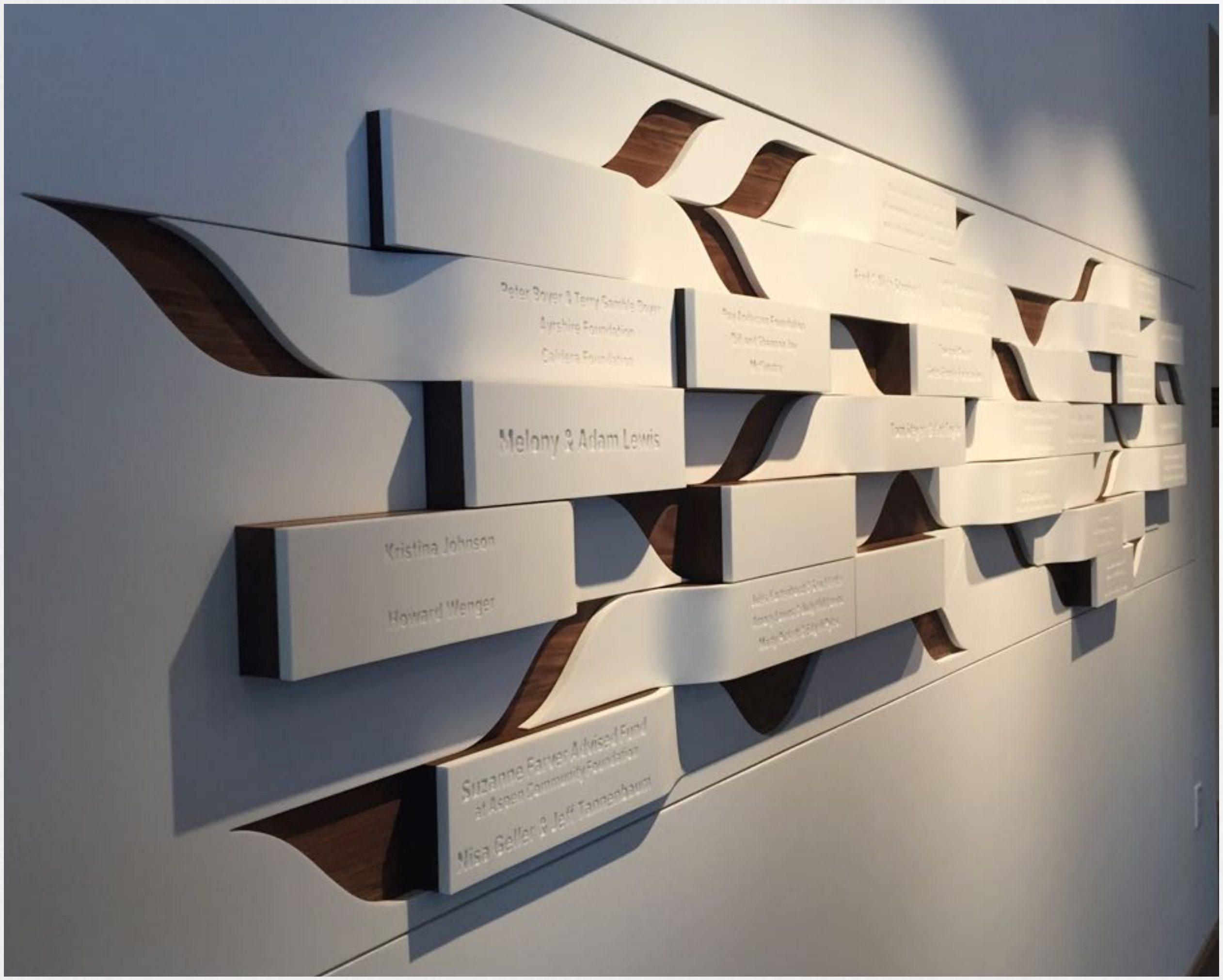


Video Tour

https://youtu.be/m-HnNNOvEwk



Thank you


Peter Boyer & Terry Gamble Boyer
Ayrshire Foundation
Melony & Adam Lewis
Kristina Johnson
Howard Wenger
Suzanne Farver Advised Fund
at Aspen Community Foundation
Misa Geller & Jeff Tannenbaum