Advanced Building Construction

Plenary Panel

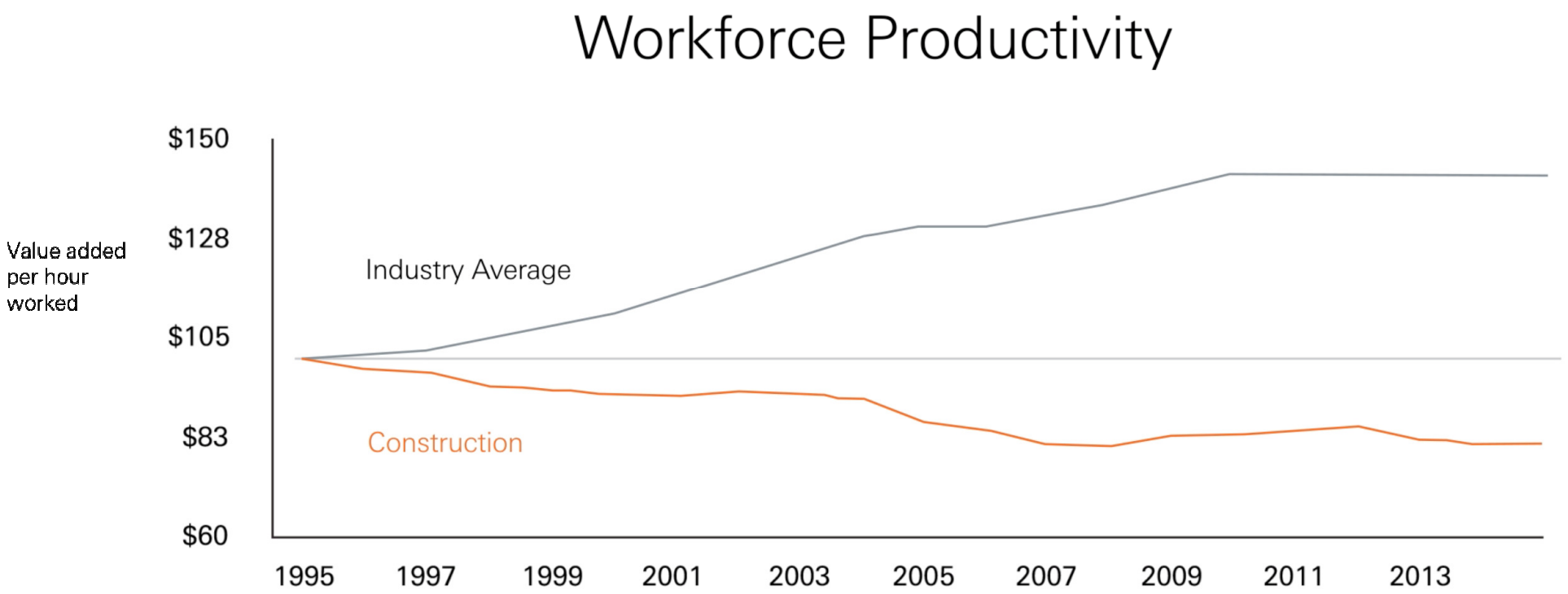
BTO Peer Review

Average multifamily construction and development timeline is **29 months.**

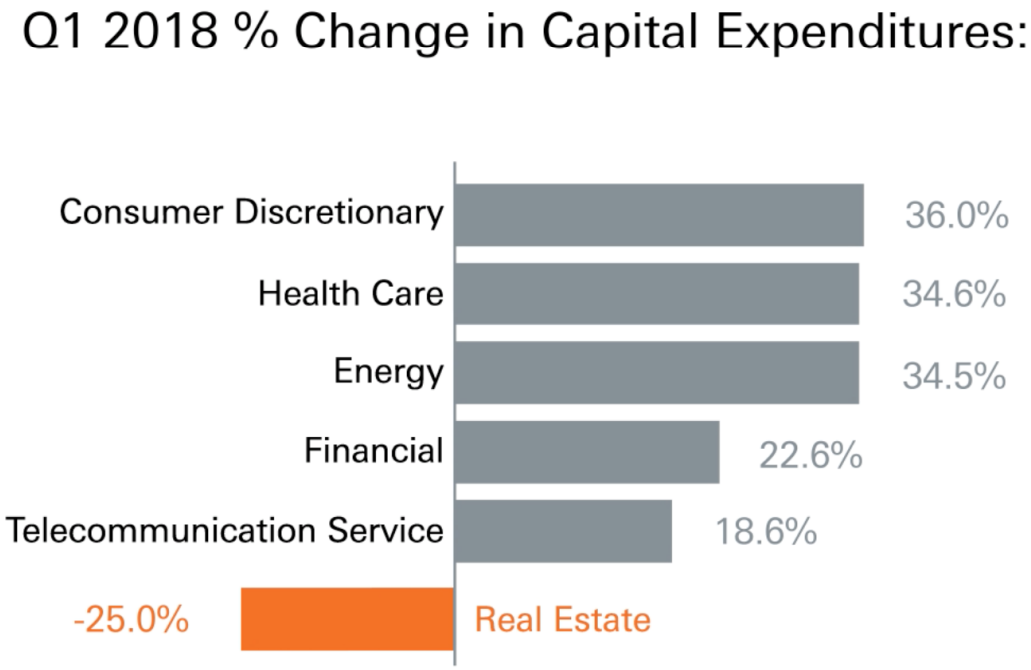
Construction labor productivity has been declining for **40 years**.

Construction costs have increased on average **2.3% per year**.

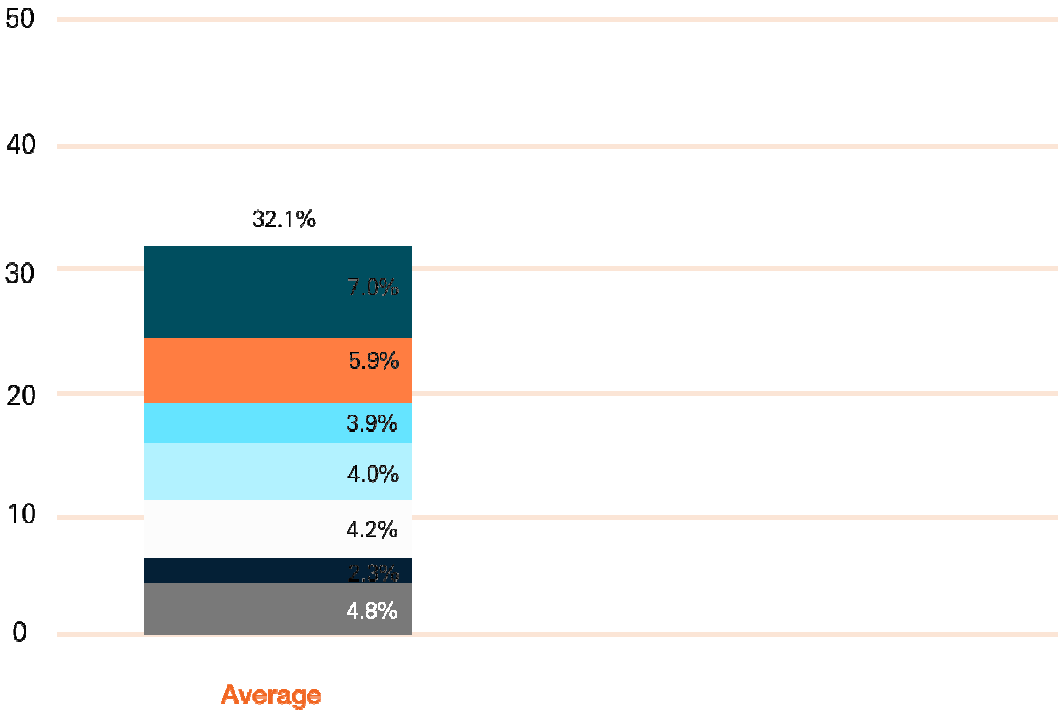
Workforce Productivity Industry Comparisons



Low Technology Investment



Government Regulations as Share of Development Costs



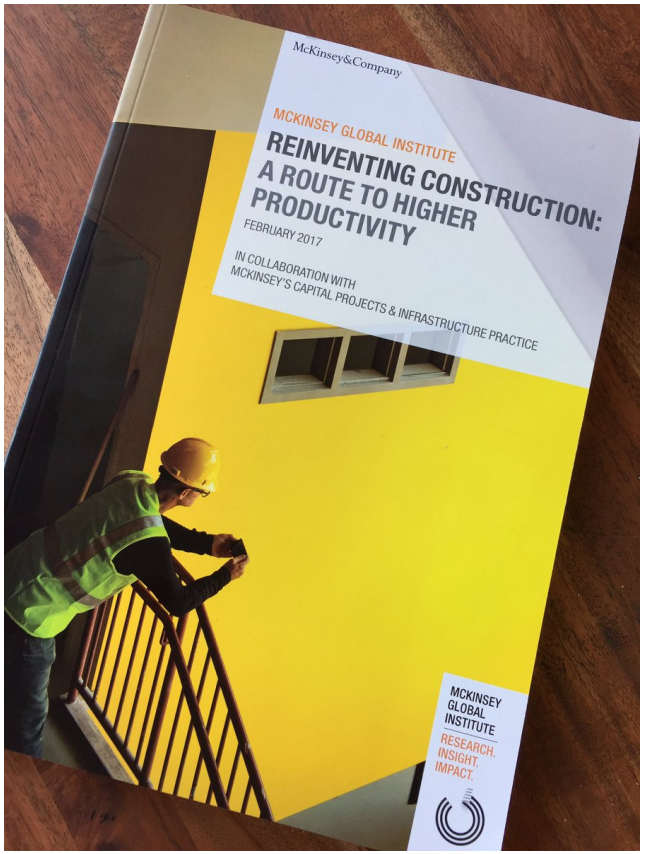
- Cost increases from changes to building codes over the past 10 year
- Development requirements beyond what the developer would ordinarily do
- Fees charged when building construction is authorized
- Cost of applying for zoning approval
- Non-refundable fees charged when site work begins
- Cost of complying with OSHA requirements
- Other

From National Association of Home Builders' Eye on Housing: "Regulation: Over 30 Percent of the Cost of a Multifamily Development" June 14, 2018

Influence Productivity Gains

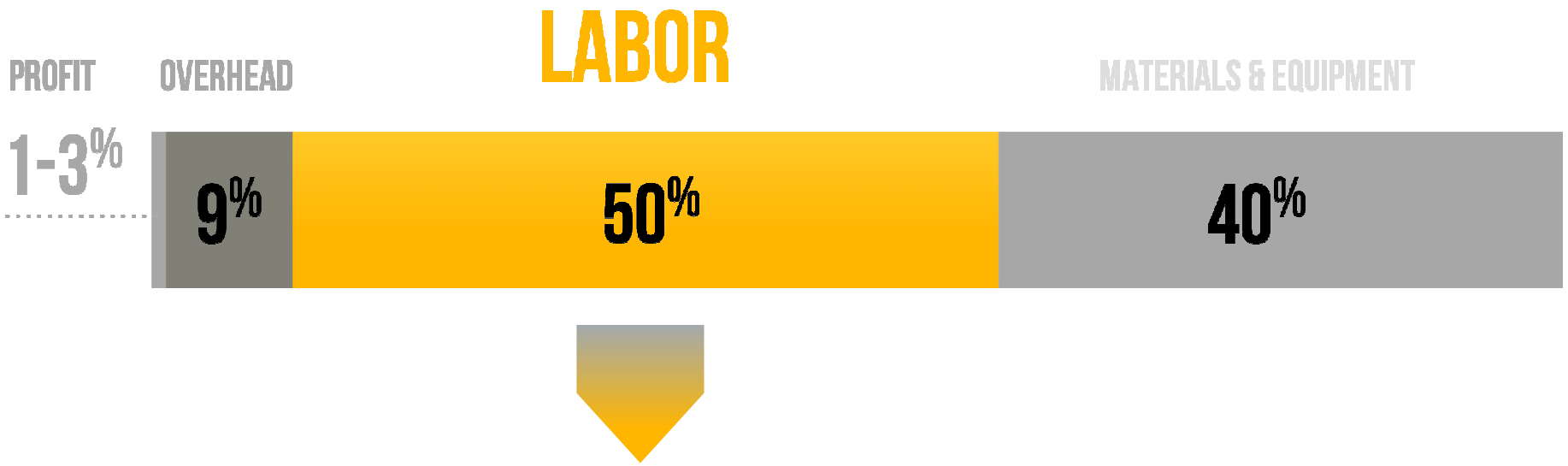
McKinsey's Seven Construction Productivity Drivers

Rethink design and engineering process and increase standardization
Improve procurement and supply-chain management
Infuse digital technology, new materials and automation
Improve on-site execution
Rewrite the contractual framework
Reskill the workforce
Reshape regulations and raise transparency



- McKinsey & Company, February 2017

Where to Start? Construction Cost?



LARGEST AND LEAST UNDERSTOOD PROJECT COST

Develop

Cost: Capital 10 to 35%
Land 5 to 15%

Schedule: 10 to 30% of time

Performance: 80 to 90% of Value

Risk: Market Demand, Government approval (Entitlements), Site Conditions

Design

Cost: < 10%

Schedule: iterative with development

Performance: 80 to 90% of value

Risk: design failure in aesthetic, structural, functional

Build

Cost: 80% of overall cost
50% Labor + 40% Materials

Schedule: 30 to 60% of time

Performance: 10 to 20%

Risk: Improper install, default, accidental, weather

Cost: 30 to 40% of overall cost

Schedule: 10 to 30% of time

Performance: 10 to 20% varies from materials to volumetric modules

Risk: design failure, timing

Benefits of Panelization

- Reduction of on-site time
- High quality
- Reduced waste

- The amount of work using prefab nearly tripled between 2010 and 2016
- 169% increase in build tech investment from 2012 – 2016

FMI/BIM Forum; CBInsights

Areas of Technology Impact

Internet of Things
Process optimization via a network of sensors and other devices for data collection, monitoring, etc.

Advanced Robotics
Human augmentation and/or task automation that enhances precision and speed of delivery

Artificial Intelligence
Replicating or replacing knowledge-work tasks

Modularization/ Prefabrication
Off-site fabrication and kitting services

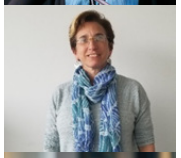
Iterative Manufacturing
Increased customization, creation of unique products, and reduction of waste

Autonomous Vehicles
Machine-to-machine communication and elimination of human operation

Text questions to
202-421-6091

Panel Members

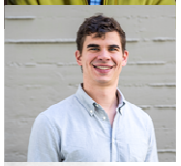
Jennifer Castenson
Vice President of Programming, Hanley Wood



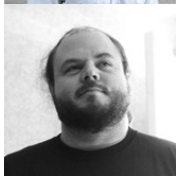
Joan Glickman
Acting Program Manager, Residential Buildings Integration, U.S. DOE

Mikhail Haramati
Building Efficiency Research Program Supervisor, California Energy Commission

Tedd Benson
Author, Building Pioneer, Founder and CEO, Bensonwood & Unity Homes



Vince Romanin, PhD
CEO, Treau, Inc.



Nathan King, DDes
Senior AEC Industry Engagement Manager, Autodesk, Inc.

U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

Advanced Building Construction

Joan Glickman
Building Technologies Office
April 16, 2019

Remember BTO Peer Review 2018?

What A Difference A Year Makes…

- July 2018
  - Coordinated lab workshop to share expertise with NYSERDA teams
- October 2018
  - Hosted first workshop on ABC concept with NYSERDA
  - Lab review & feedback provided to NYSERDA projects; attended peer review for RetrofitNY projects
  - Participation in Housing Innovation Alliance Roundtable and tour of Bluepoint Robotics
- November 2018
  - Manufactured housing workshop (Alabama)
  - MA Triple Decker Homes meeting
- Dec 2018
  - CEC workshop and industry tours/discussions
- March 2019
  - Sto workshop on pre-fab construction with federal agencies
  - SBRA Energy Committee Meeting (manufactured homes) in TN

Learned A Lot, and Developed Some Areas of Focus

- **Off-site manufacturing**
  - New construction (manufactured housing, modular buildings)
  - Retrofit technologies
    - Envelope (panels, other)
    - Integrated systems (windows, combined HVAC)
- **Automation**
  - Bringing digitalization to construction/retrofit trades and industry
  - Robotics, end-to-end digital design and construction
- **Simplified installation**
  - Focused on enhanced reliability, performance, speed of delivery and installation
- **Workforce**
  - Addressing need for trained/skilled workforce in manufacturing facilities (off-site) and at building (on site)
- **Value Add**
  - Integration of sensors, automated default detection and diagnostics

It's ABC…Not Quite as Easy as 1,2,3

Make net-zero energy retrofits ***the defacto choice for modernizing existing buildings.***

Deep energy efficiency is integrated into new methods of construction, off-site manufacturing, automation.

New Construction & Retrofit Solutions Must Be…

Comfortable

Resilient

Visually appealing

Provide grid services

Scalable

Minimally invasive

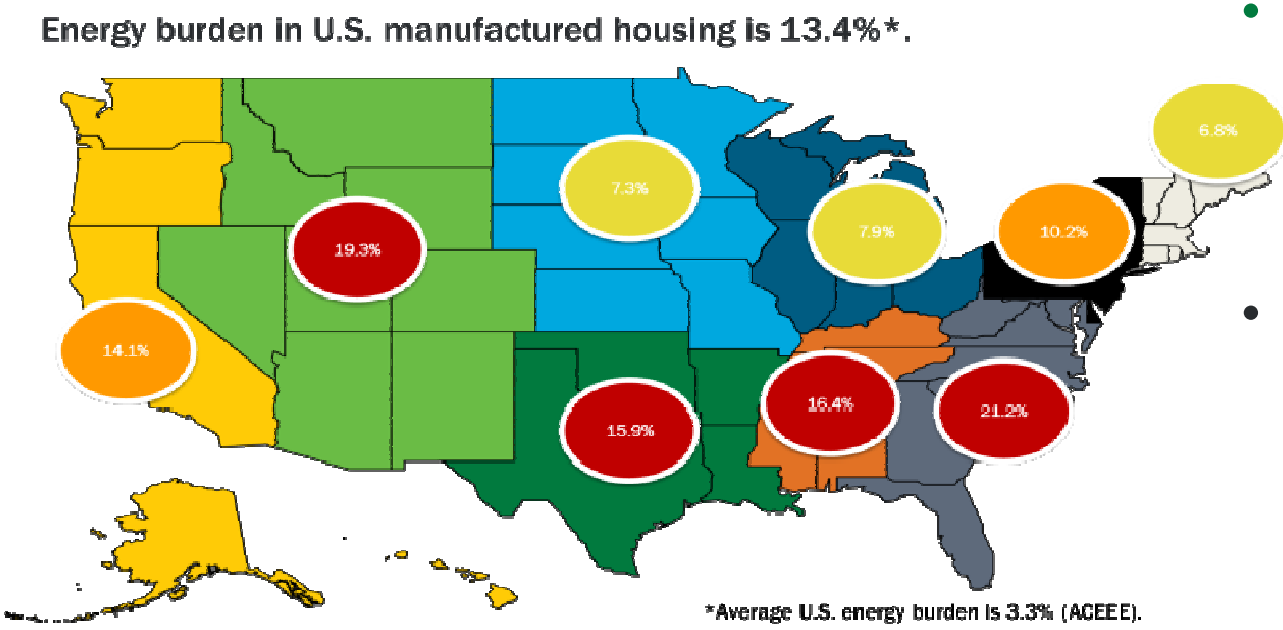
Competitively priced

Easy to Install, High Performing

What's Wrong with this Picture???

The 20-story, 300-room project at 185 Bowery was **constructed in Poland** and shipped to New York in 210 pieces.

Manufactured Housing



- Thirty percent of occupied manufactured homes were built prior to 1976 (ACEEE).
- Manufactured housing residents spend 70% more on energy per square foot than site-built homes (ACEEE).

Manufactured Homes – A Case Example

	Factory Condition		With Efficiency Upgrades	
	Liberty, Texas	Wilkesboro, North Carolina	Liberty, Texas	Wilkesboro, North Carolina
Square Footage	2,100	2,100	2,100	2,100
Bedrooms	3	4	3	4
Home Energy Score	4	3	9	9
Annual Energy Cost	$1,803	$2,019	$1,314	$1,329
Annual Energy Cost Per Square Foot	$0.85	$0.96	$0.63	$0.63
Cost Savings Compared to Typical Factory Condition			$490 / year	$690 / year
Cost Savings over 15 year mortgage term			$7,300+	$10,300+

- Mini-split installation (8.5 HSPF / 15 SEER)
- Rigid floor insulation (foam or SIPs) (R-22)
- Heat pump water heater (2.5 EF)

Stakeholder Convening November 2018

Meeting Attendees

Alabama Power
Cavalier Homes
CAVCO Industries
Champion Homes
Clayton Homes
U.S. DOE
Electric Power Research Institute
Florida Solar Energy Center
Freddie Mac
Georgia Power
National Electric Rural Cooperative Association
National Renewable Energy Laboratory
Nicor Gas
Oak Ridge National Laboratory
Oglethorpe Power
Southern Company
Systems Building Research Alliance
The Electric Cooperatives of South Carolina
TVA (EE R&D)
Washington State University Energy Extension

- Good discussion, good ideas
  - Technologies offer promise
  - Improved production techniques offer promise, BUT
- But, a lot needs to happen outside of technical solutions
  - Insurance, financing…

Post Meeting Success Story

November 27:

✓ Mini-splits were not on HUD's approved list of appliances for manufactured homes. (Required an application from manufacturer.)

December 19:

✓ Mini-split heat pumps added to HUD's approved list of appliances for manufactured homes.

Ultimately, it's about people and perseverance.
Thanks to those who made it happen!

Why I'm excited about ABC…

It's An Opportunity to Address Multiple ~~Challenges~~ NEEDS

- ✓ Climate Change
- ✓ Improved Quality & Performance
- ✓ Modernization of Existing Buildings
- ✓ Grid Reliability
- ✓ Disaster Mitigation
- ✓ Disaster Relief
- ✓ Economic Competitiveness
- ✓ Aesthetics

Also, I happen to love buildings…

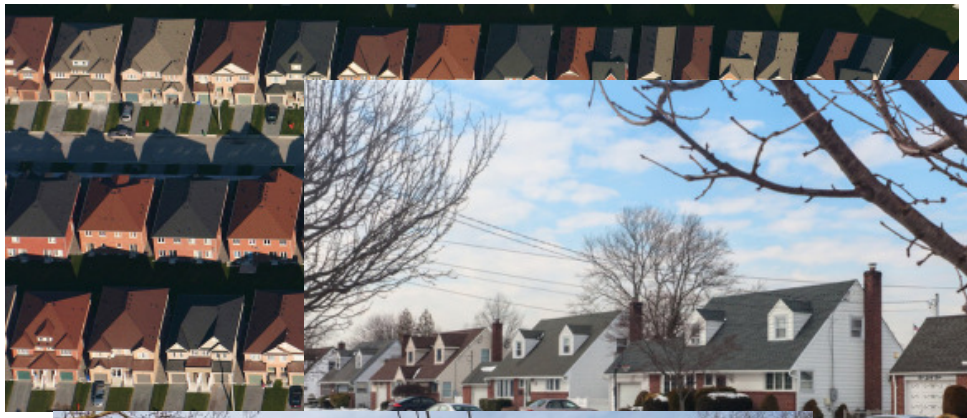
Buildings Have Meaning

- Yesterday's tragedy
- Unavoidable?
- Reminds us of our vulnerability and the need to build in safeguards

Some Inspire Us...

Others do not…

You don't have to look very far…(Crystal City/Arlington, VA)



Let's Aim High – and Not Forget about Disruptive Innovation

Why was the iPhone Transformational?

- ✓ **It didn't just give us what we thought we wanted.** It convinced us to want more…**created value**…not just functional, but emotional and social.
- ✓ It addressed (or created) **a "need" that most consumers didn't know they had.**
- ✓ **A "need" that translates today into $1000 phones** – even though calls drop more frequently than they did with landlines in 1970s.
- ✓ Who could predict that people would want their phones to be **cameras**? Allow them to **surf the net**, **read** a book, play **games**, obsessively **"connect"** with friends?

Joan Glickman

Program Manager (Acting)
Residential Buildings Integration
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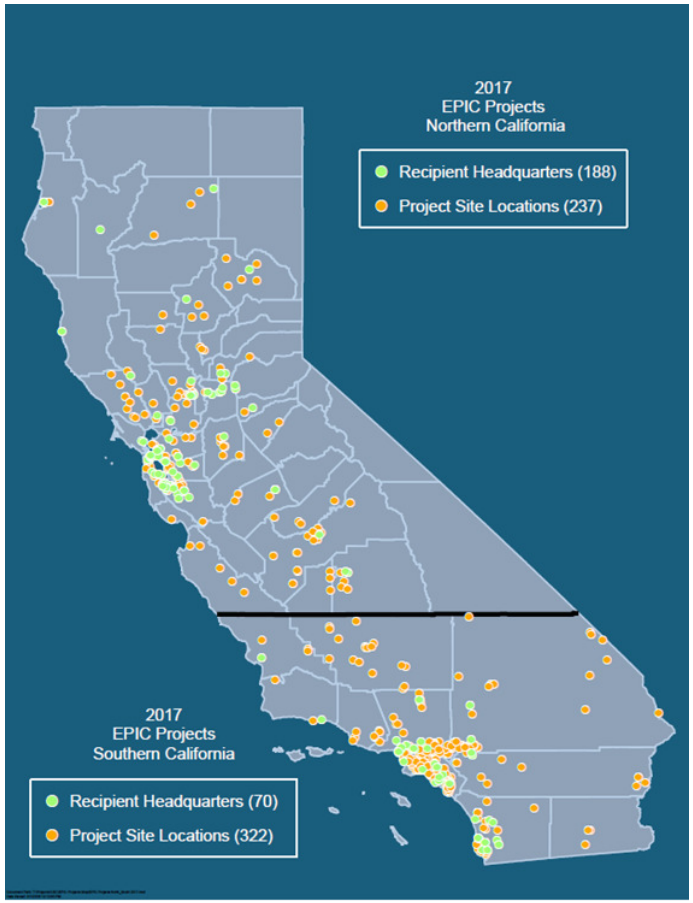
202.586.5607 (office) / 202.492.5080 (cell)

Mikhail Haramati

CEC R&D: Fostering Innovation Across the Energy Sector

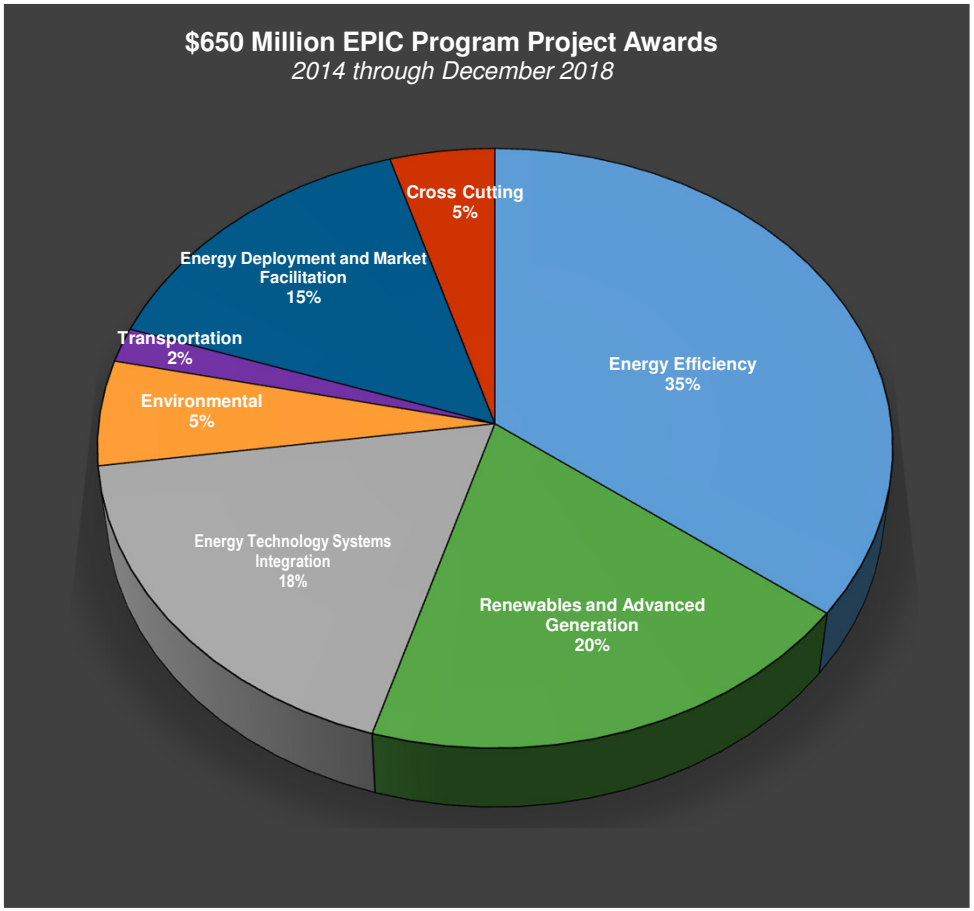


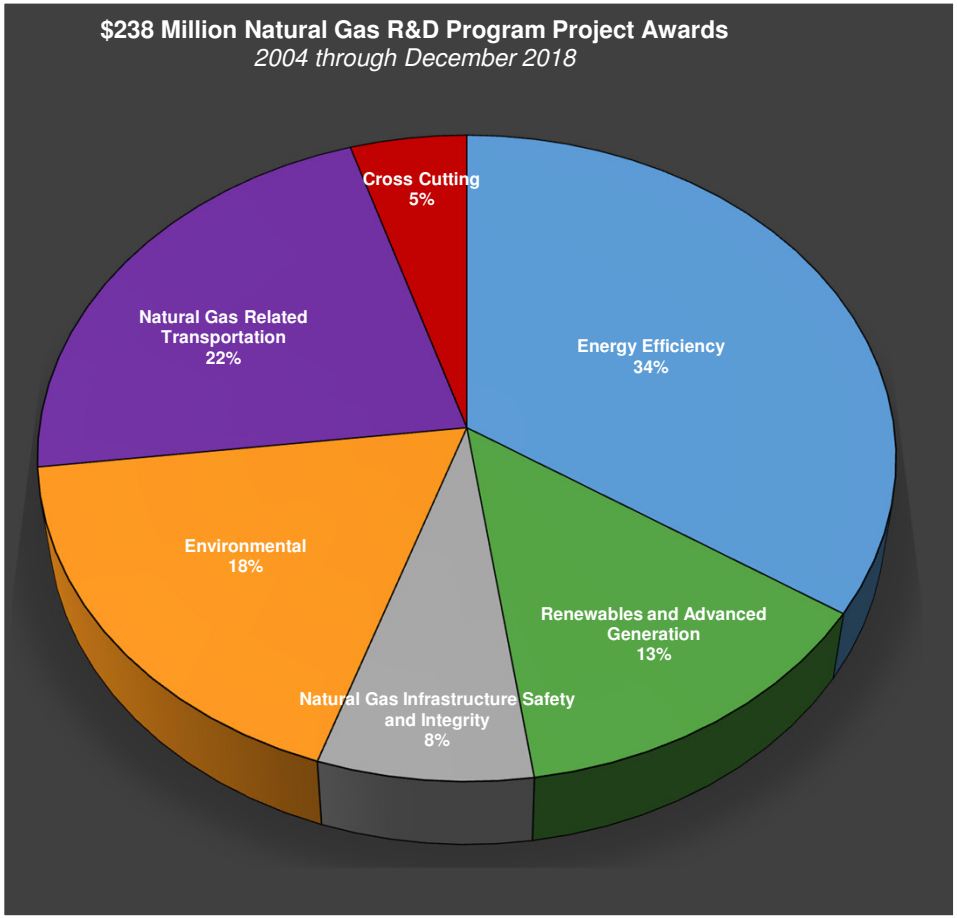
Two public goods charge funded research programs:

1. **EPIC:** *Electric* Program Investment Charge
   - $133 million annually
   - ~300 active projects

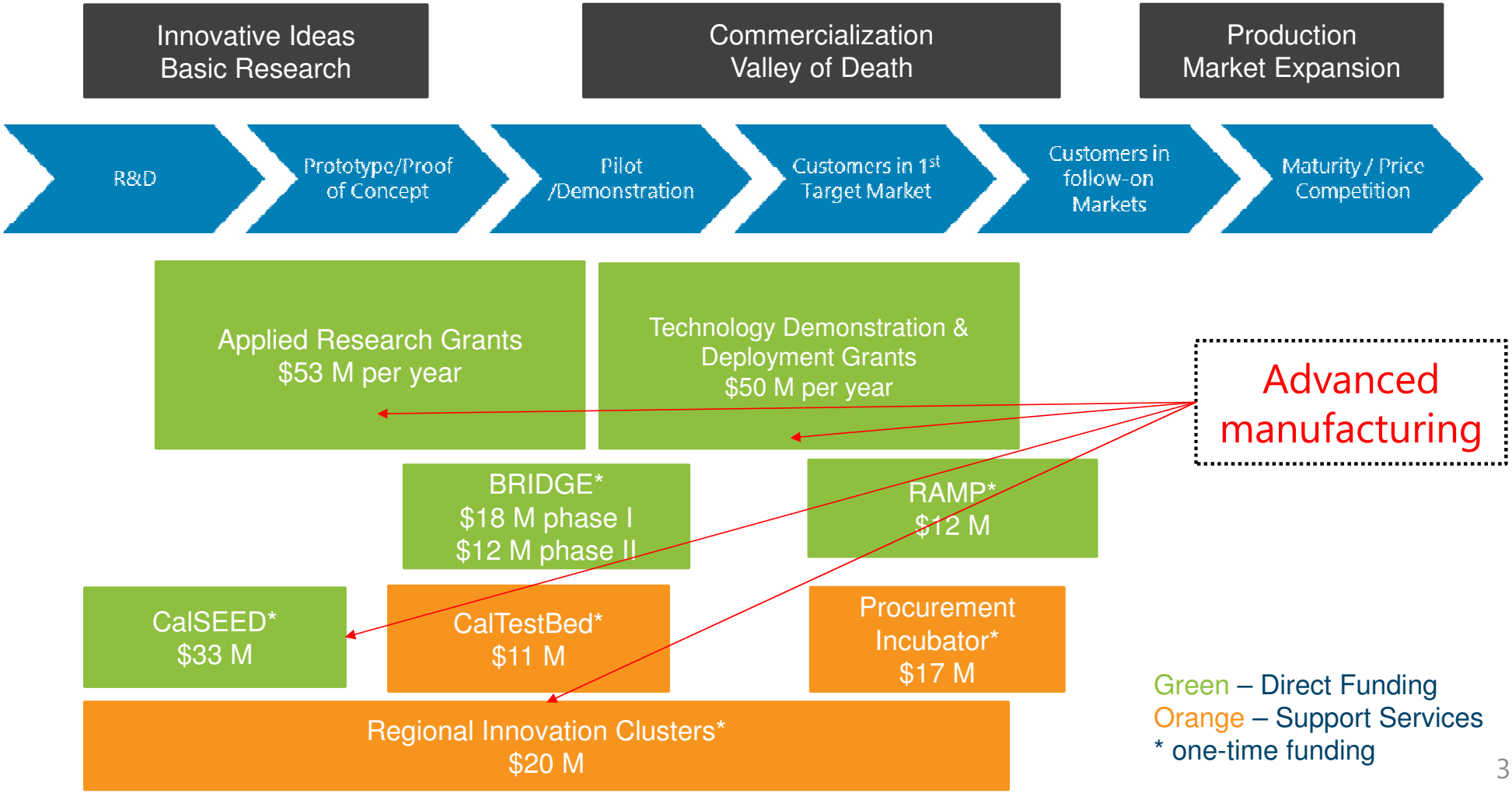
2. **Natural Gas:** Research, Development and Demonstration Program
   - $24 million annually
   - ~90 active projects

Funding Allocations





EPIC Investment Portfolios



Green – Direct Funding
Orange – Support Services
* one-time funding

CEC R&D Efforts in Advanced Manufacturing

Current

EPC-17-040: Mass Deployment of EE Retrofits in MF homes in CA

- Research team: RMI, AEA, PSV
- CA version of EnergieSprong
- Retrofits of low-income apartment buildings across CA

Planned

FY 2019-2020 Natural Gas Efficiency Funding focused on:

1. Façade Retrofits with Manufactured Solutions
2. 3D Printed Facades
3. Individual Envelope Measures

Recently Completed Project

Manufactured Home Efficiency

Added wall and roof insulation at minimal cost (+$2,700/home)

Recipient: Levy Partnership

Promising Approaches

Factory OS in Vallejo CA

Contact

Mikhail Haramati: Mikhail.haramat@energy.ca.gov
Building Energy Efficiency Research Program
California Energy Commission

More info on our projects

Tech Innovation Showcase

CEC Research Funding RFPs

CalSEED small grants


USA

Benson Woodworking Co, Inc.

Unity Building Technologies, Inc.

OBCad


BENSONWOOD

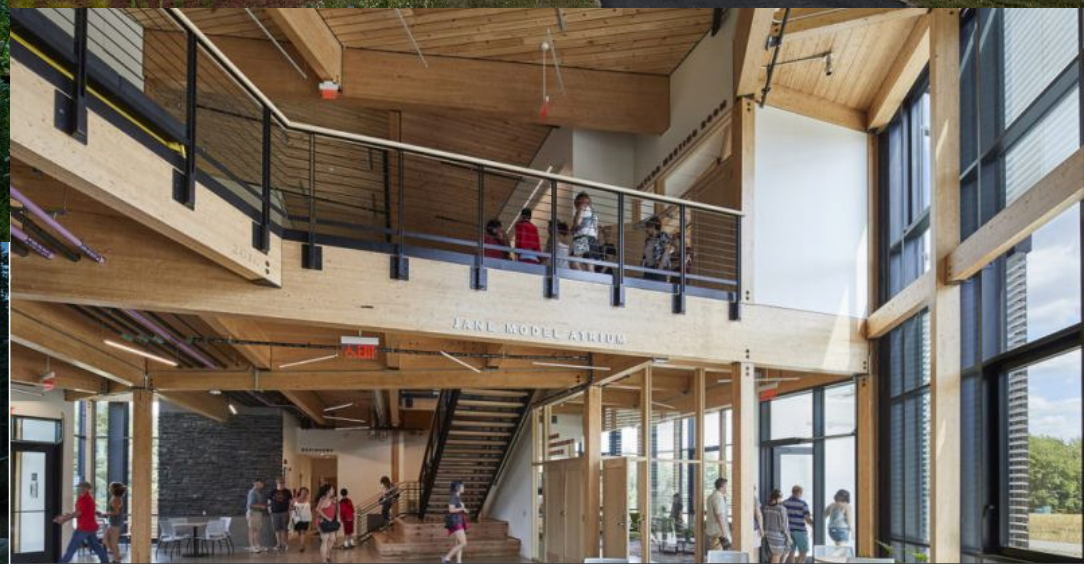
TB1

aclay Architects

Gray Organschi Architecture

Bruner / Cott

BENSONWOOD

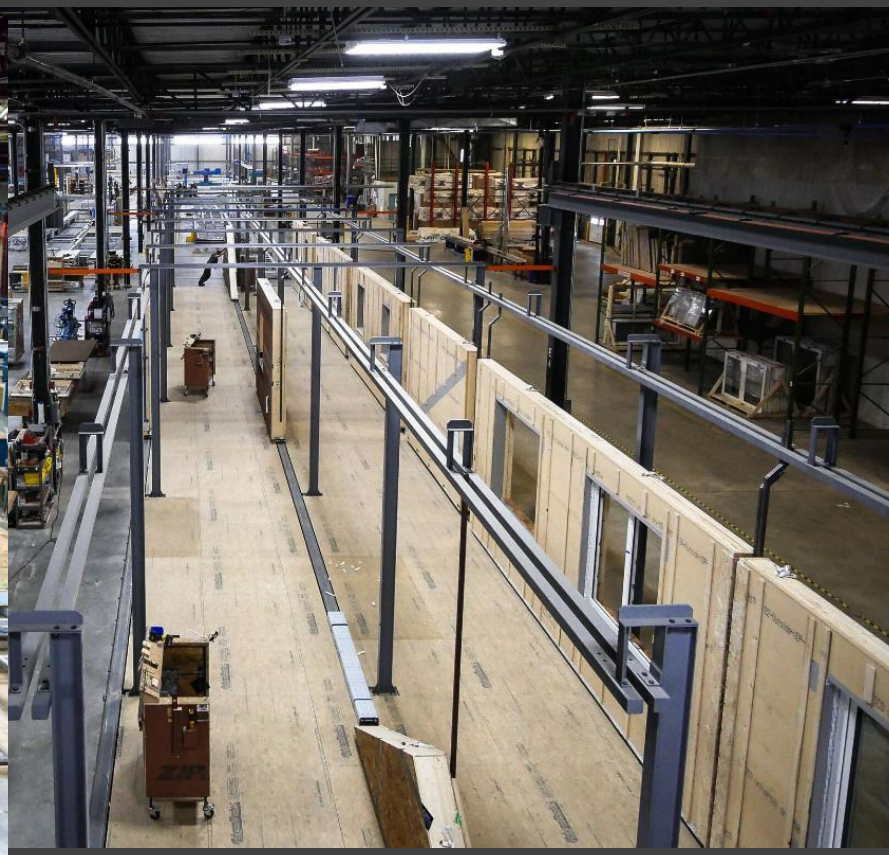


Slide 45

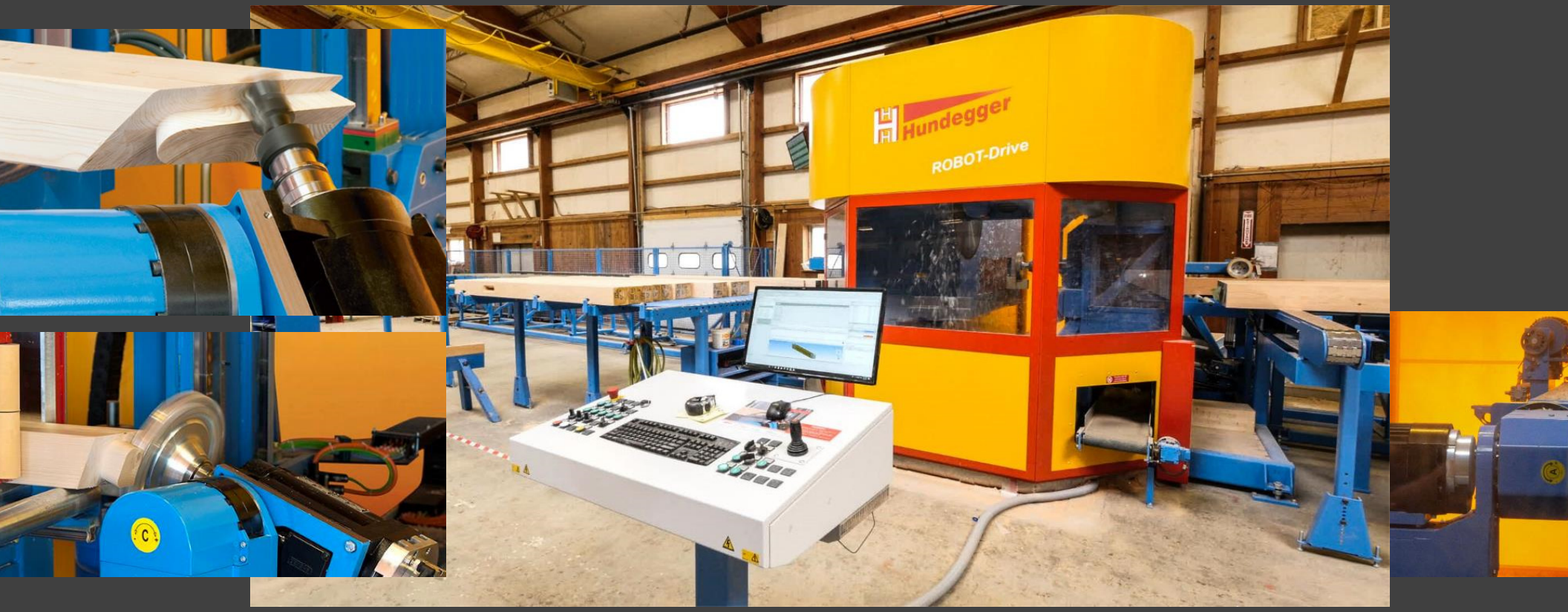
TB1 Tedd Benson, 4/10/2019


unity
homes

High Performance Homebuilding Factory



6 Axis Robotic Timber Fabrication



BW2B Family Tree

1970's-1980's

Search for a *Better Way to Build* leads to

Revive Timberframe

Insulation System Innovation (SIPs)

Off Site Fabrication

Deep Craft Skills

Software Innovation (Building Geometry)

Invent Specialized Machinery

Craft of Business
Culture trumps Strategy

Establishing the Core

1990's

Open Built Disentanglement

Dimensional Coordination Standards

3D Models / Virtual Fabrication

CNC Automation

Whole House Building Systems Innovations

Elements of the Platform

2000's

Lean Manufacturing

Interface Stds

Modularization of Integrated Assemblies

Advancing BIM to BPM Software
w/ Component Library

Iterative Development;
Rapid *real time* Prototyping

OBCad Configurator

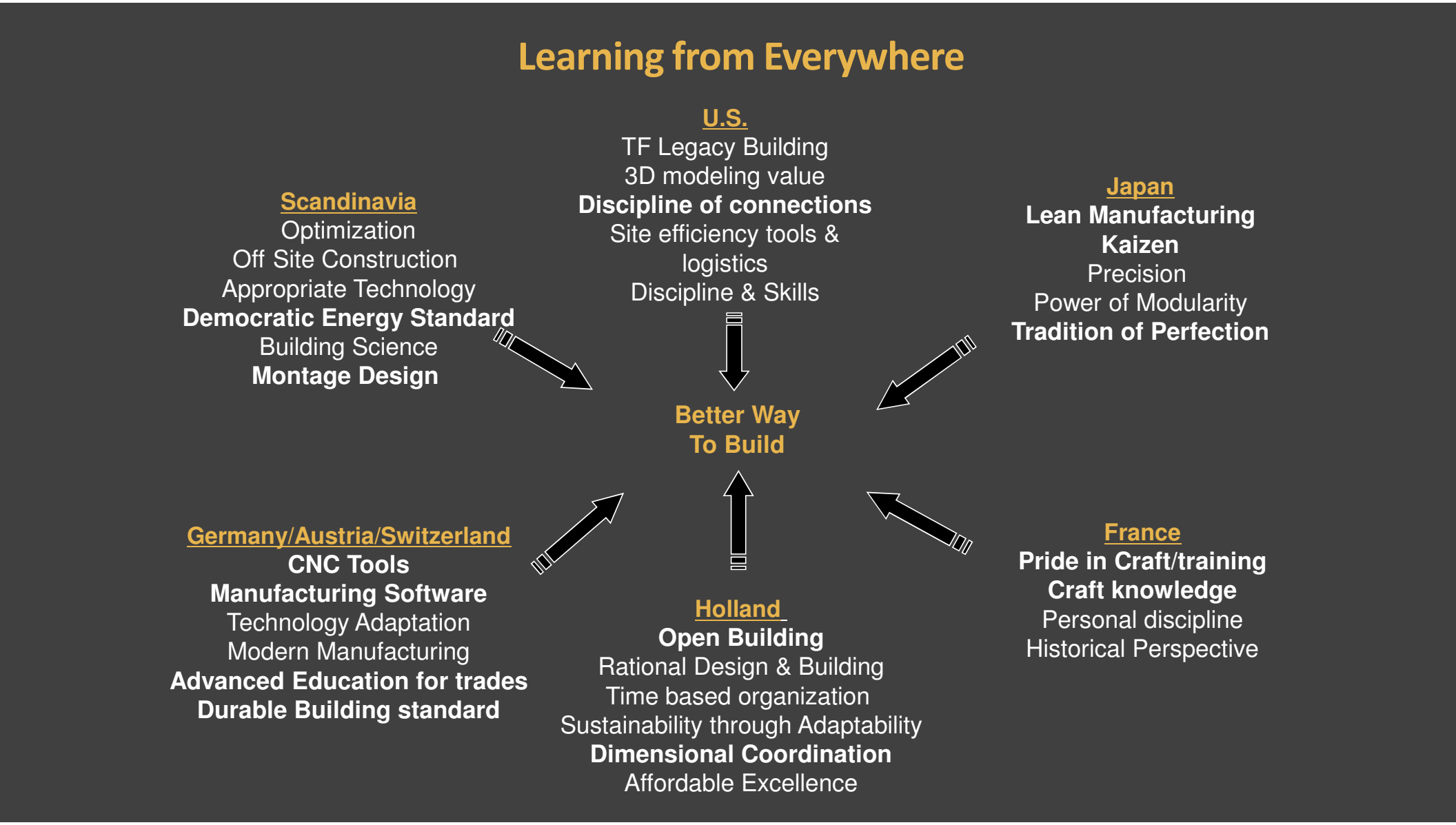
Supply Chain Integration

Develop Network of Montage Teams

Distributed Manufacturing

Developing Tech Platform

Learning from Everywhere



Strategic Partnerships & Collaborations

1970's

- **Total Environmental Action (TEA)**
  - Energy Audits, Evaluations, HVAC design

1980's

- **TEA refugees**
  - Energy Audits, Evaluations, HVAC design
  - All homes built

Strategic Partnerships & Collaborations (cont)

1990's -- now

- **Compagnon du Devoir**
  - Mastercraft building apprentices
- **University of Rosenheim**
  - Internship program
    - Wood technology
    - Structural engineering
    - Mechanical engineering
- **Cadwork**
  - 3D Production software > Architectural Design Integration

Strategic Partnerships & Collaborations (cont)

2000-2008

Huber Engineered Woods

- Joint Development Agreement (JDA)
- Building Product R&D

DOW

- JDA– Building Product R&D

MIT-Bensonwood Collaboration "Open Prototype Initiative"

- **T**hrough *Open Source Building Alliance,* multiple contributing corporate partners
  - *Prototyping better ways to design and b*uild
- 2006- multi-unit home for brain injury center
- 2008- multi-functional, net zero home for college campus

2006-KieranTimberlake—Loblolly House project

- Innovate in off-site fabrication design-build partnership

Strategic Partnerships & Collaborations (cont)

2012—now

Keene State College (BUILDING TECHNOLOGY DEPARTMENT)

- Partnership on class projects
  - Moisture migration in building systems
  - Impact of “drying out” construction period in rapidly built, tight homes

2018: ST GOBAIN/CERTAINTEED

- *Joint Development Agreement (JDA)*
  - *“OBCad” software platform*
  - *Standardize building components*
  - *Auto-configuration of home “compositions”*
  - *Innovate integrated building systems –digital to actual*

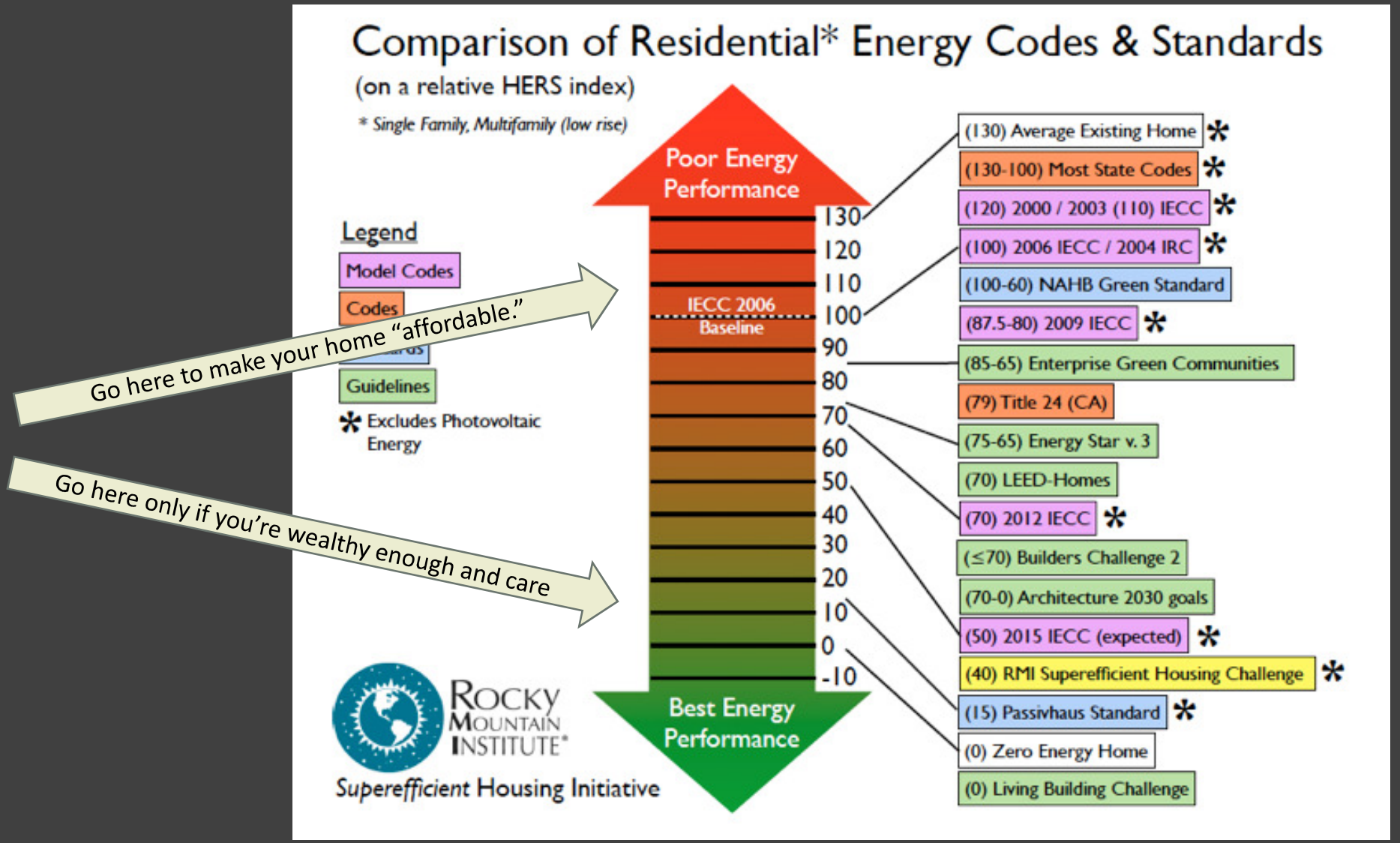
Strategic Partnerships & Collaborations (cont)

2019

Paragon Initiative:

Lake/Flato, KieranTimberlake & Bensonwood Partnership

- CoDevelopment of products, processes
- Building Standards analysis and development
- Digital System auto integration



Go here to make your home "affordable."

Go here only if you're wealthy enough and care


C.P. WARD

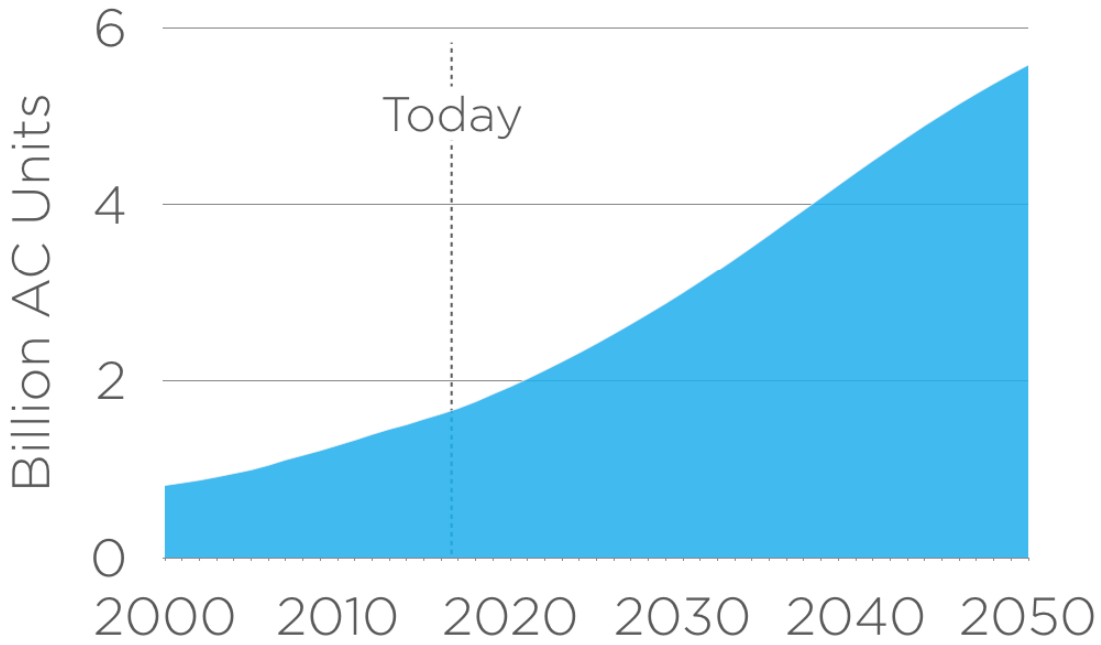

301

TREAU

Comfort without Compromise

Vince Romanin
April 2019

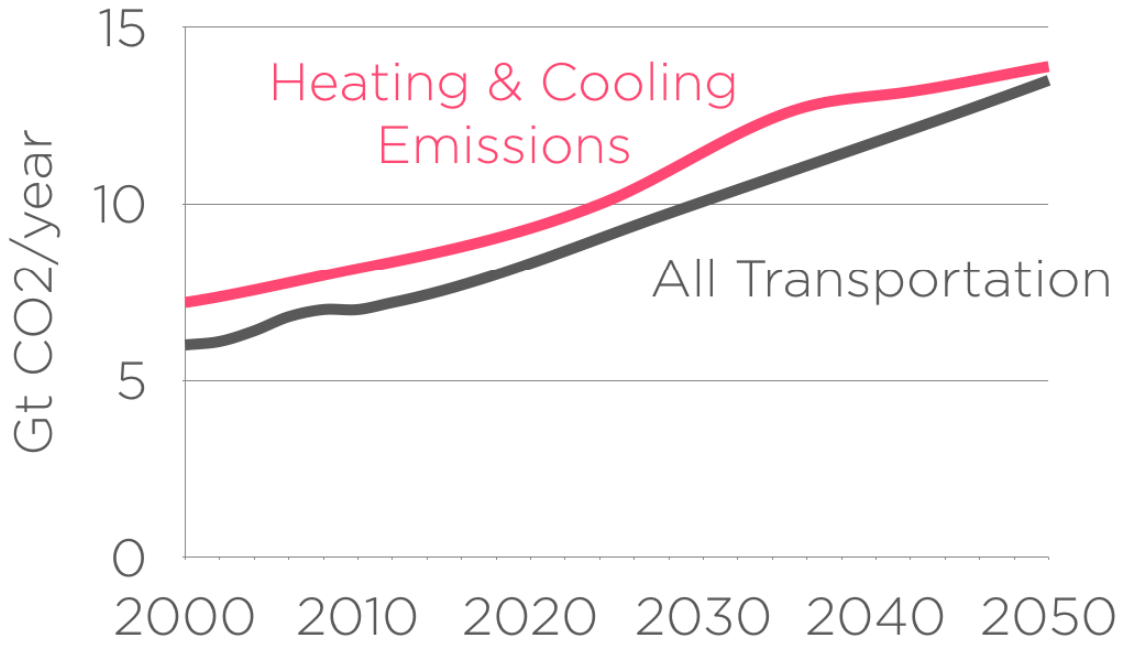
4 Billion More Air Conditioners by 2050



www.iea.org/cooling

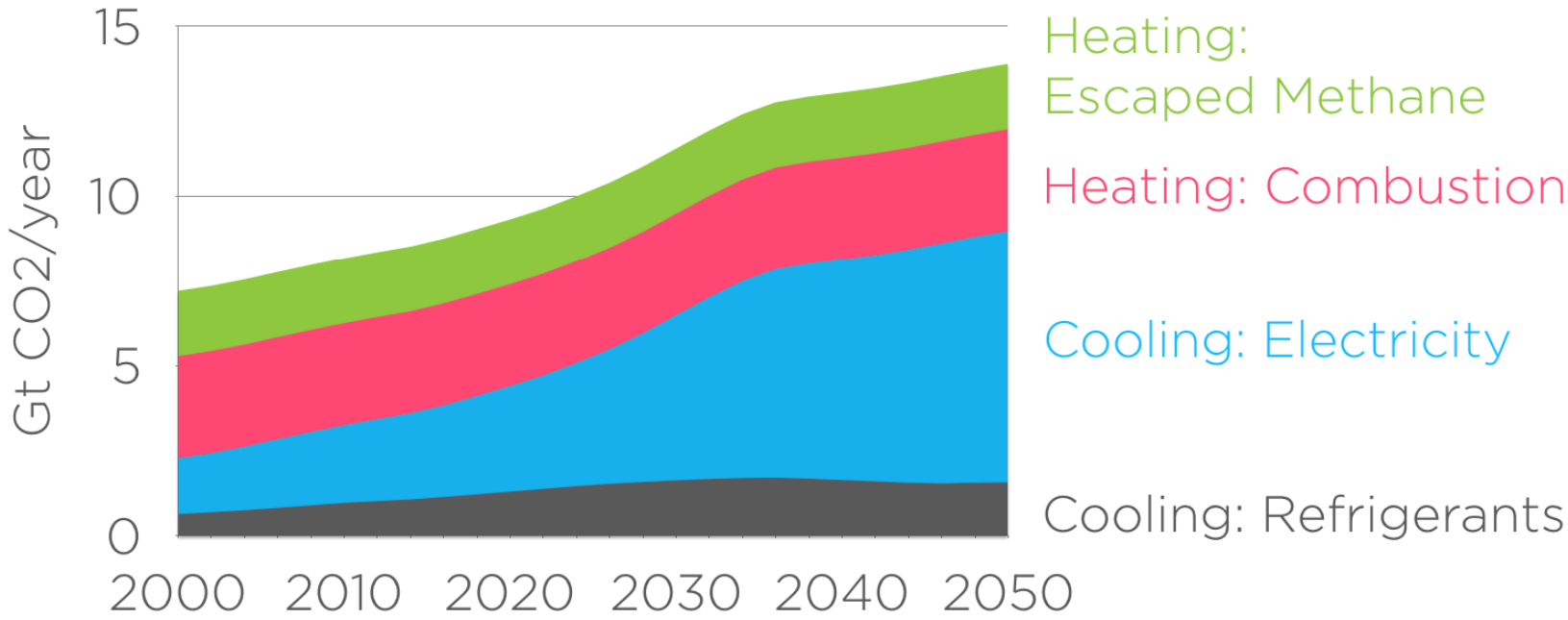
1. Climate Control is Killing the Climate

A Transportation-Sized Problem



www.green-cooling-initiative.org and https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter9.pdf
Transportation from: http://dx.doi.org/10.2760/30158 and https://www.iea.org/topics/transport/

Climate Control is Killing the Climate



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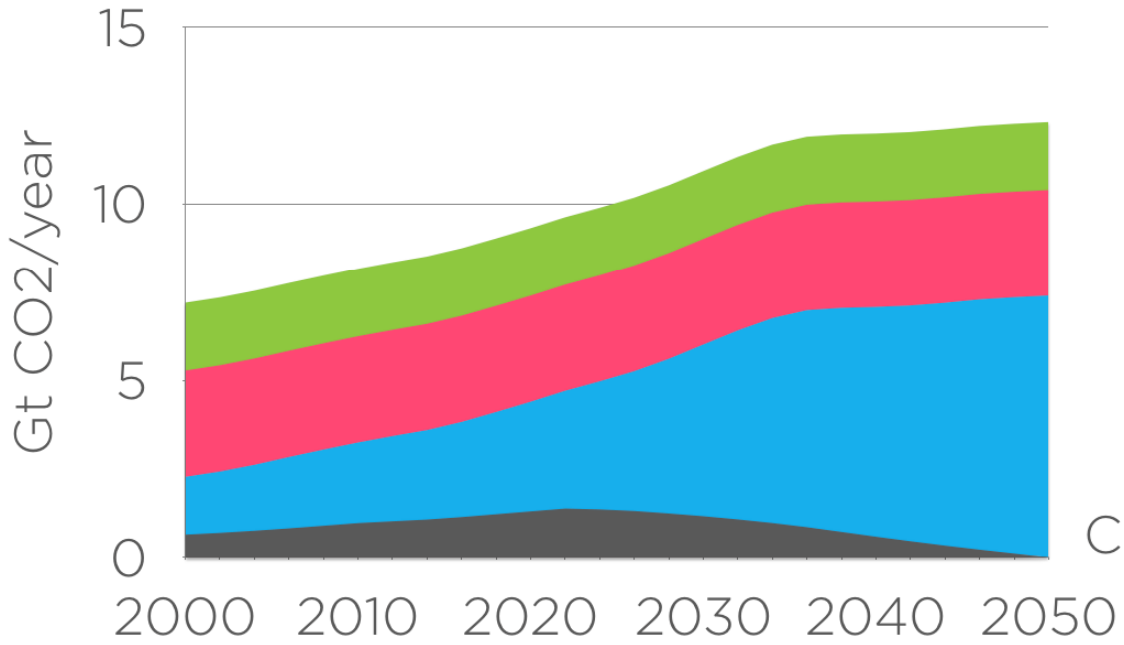
Transportation from: http://dx.doi.org/10.2760/30158 and https://www.iea.org/topics/transport/

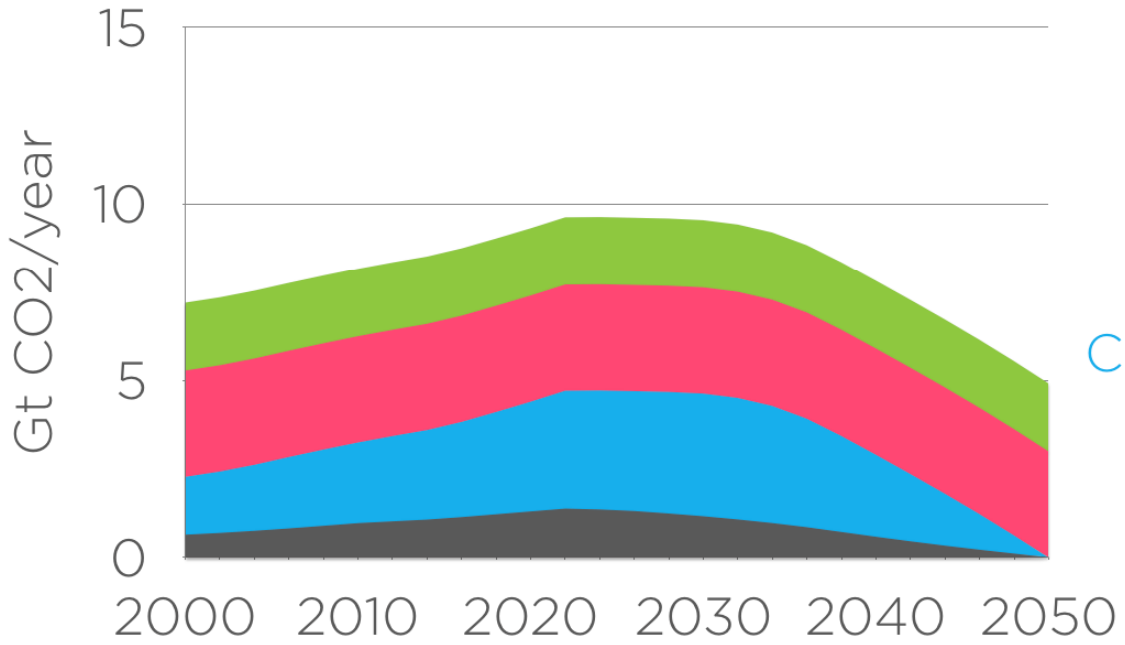
Low-GWP refrigerants: **1.5 $GtCO_{2,e}$/year**



Cooling: Refrigerants

www.green-cooling-initiative.org and https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter9.pdf
Transportation from: http://dx.doi.org/10.2760/30158 and https://www.iea.org/topics/transport/

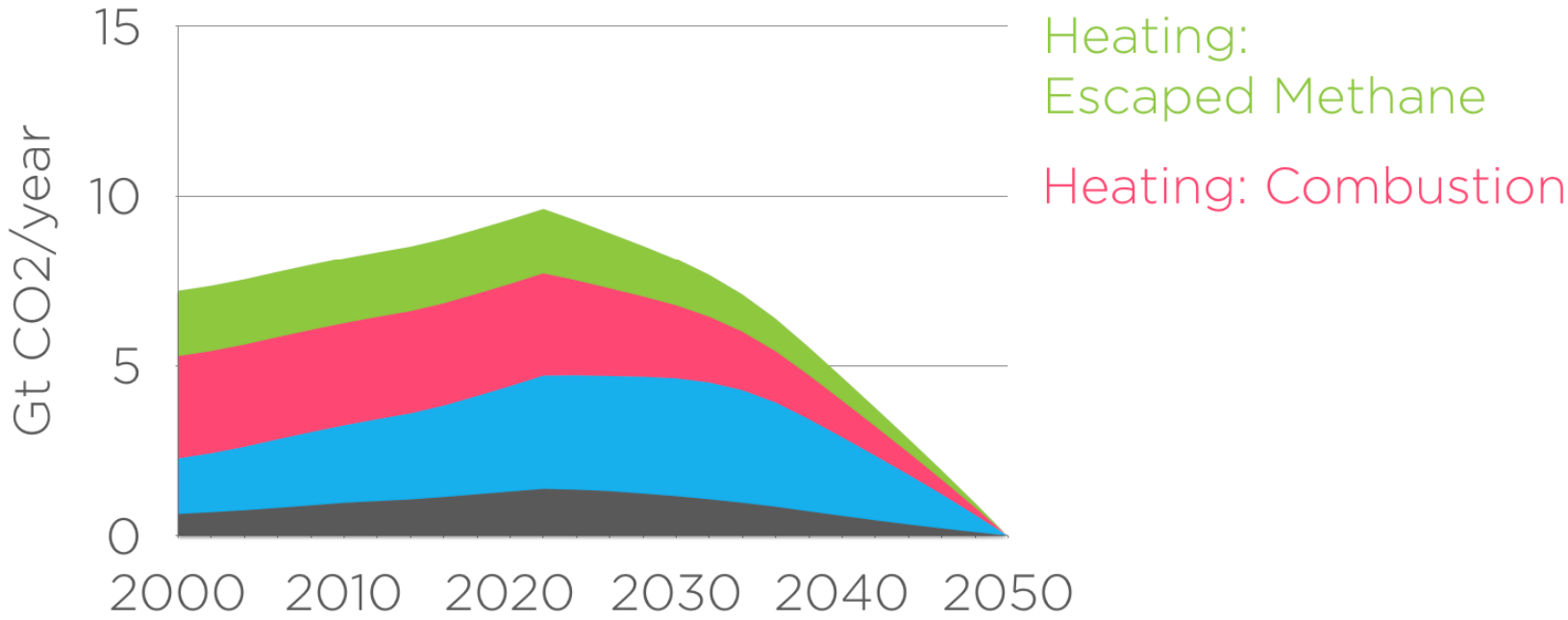
Renewables + Efficient Cooling: **7.4 $GtCO_{2,e}$/year**



Cooling: Electricity

www.green-cooling-initiative.org and https://www.ipcc.ch/pdf/assessment-report/ar5/wg3/ipcc_wg3_ar5_chapter9.pdf
Transportation from: http://dx.doi.org/10.2760/30158 and https://www.iea.org/topics/transport/

Heat Pumps: **5 $GtCO_{2,e}$/year**



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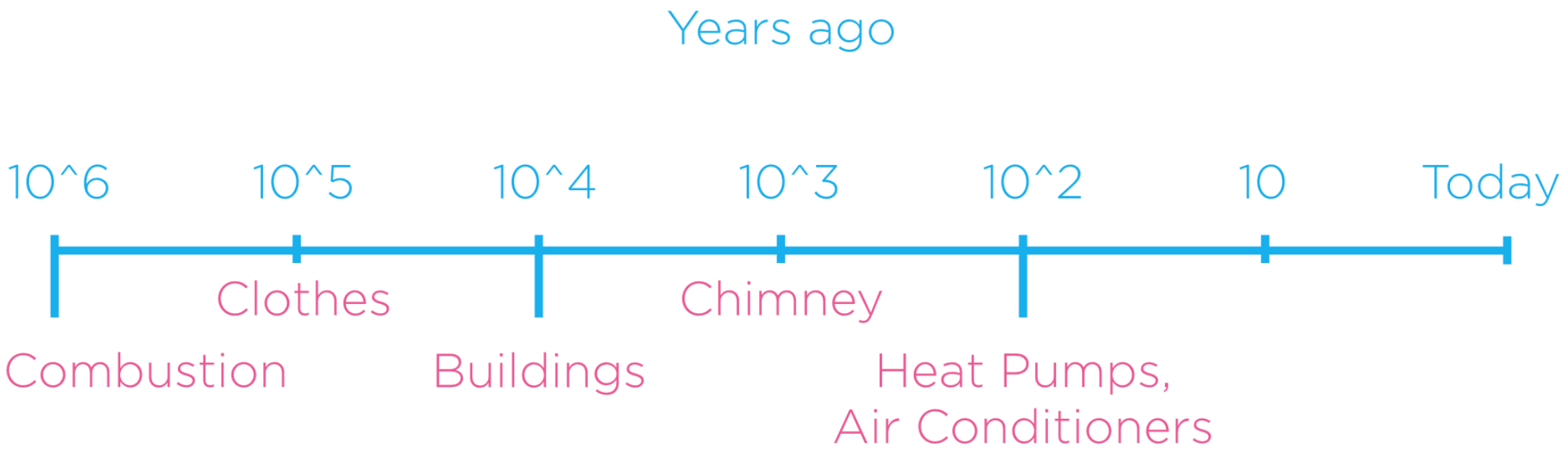
Transportation from: http://dx.doi.org/10.2760/30158 and https://www.iea.org/topics/transport/

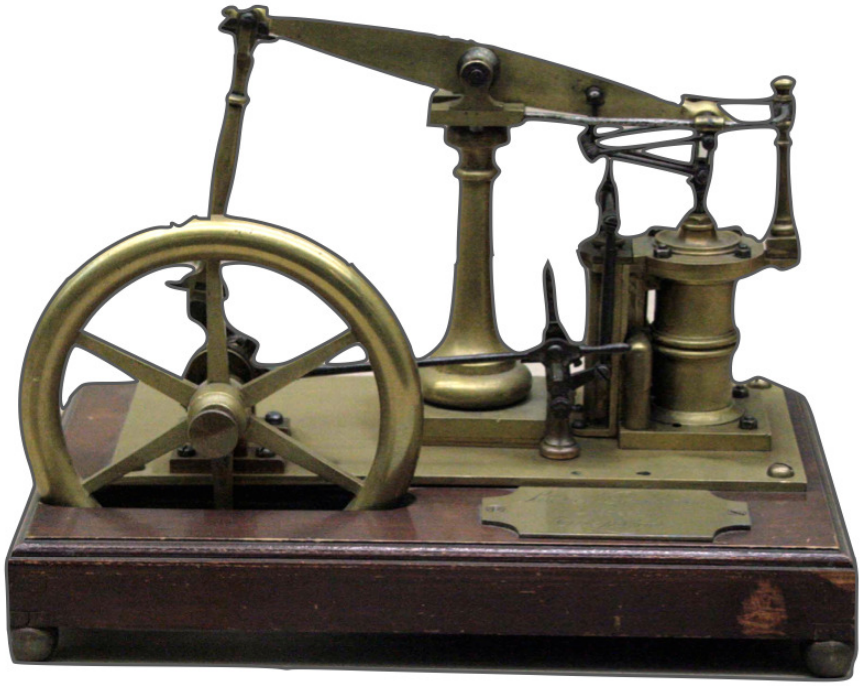
2. Heat Pumps

Why Now?

A (log-scale) Timeline of Thermal Comfort



1824

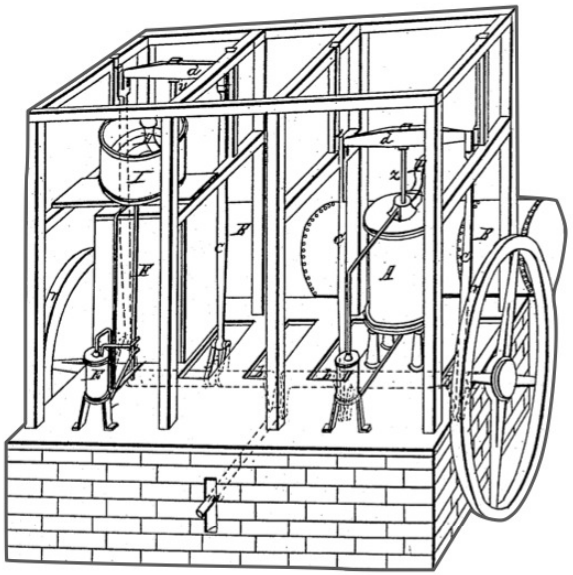


Heat Engine:

$\eta = 1 - T_H/T_C$

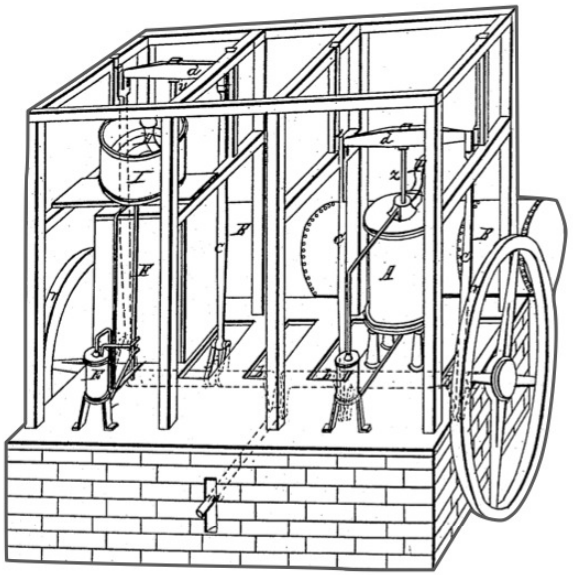
Heat Pump:

$COP = T_H/(T_C - T_H)$

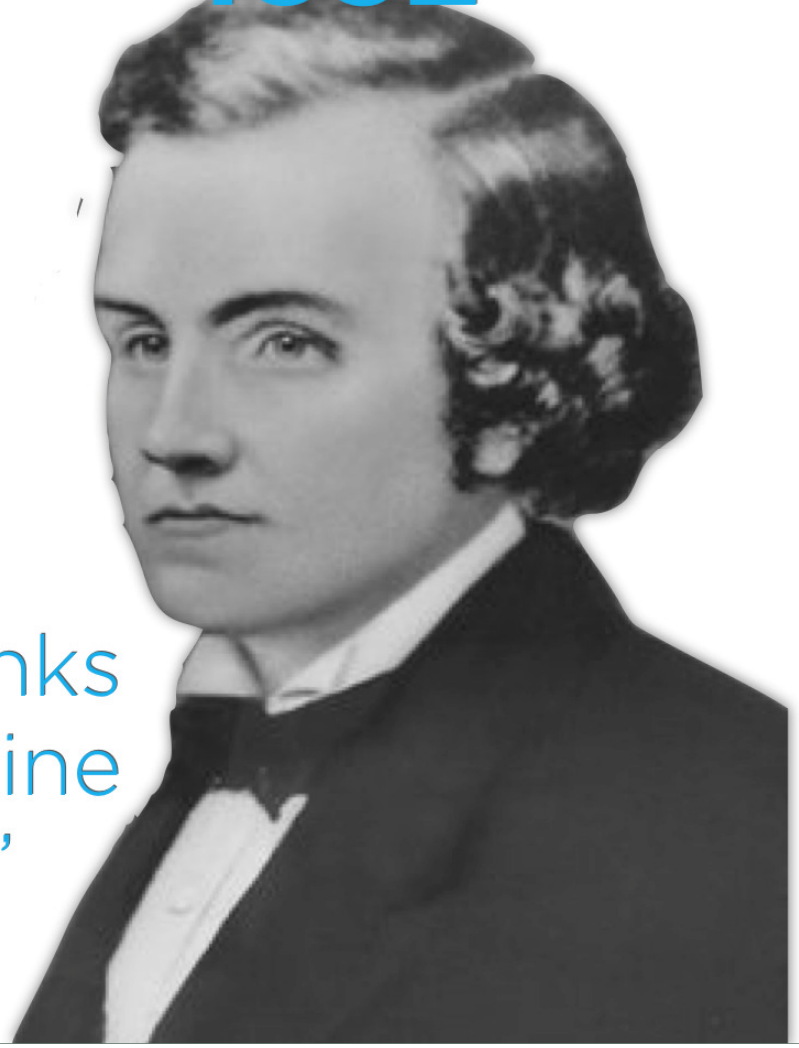


1852

Patent No. 8,080:
“Ice Machine”



1852

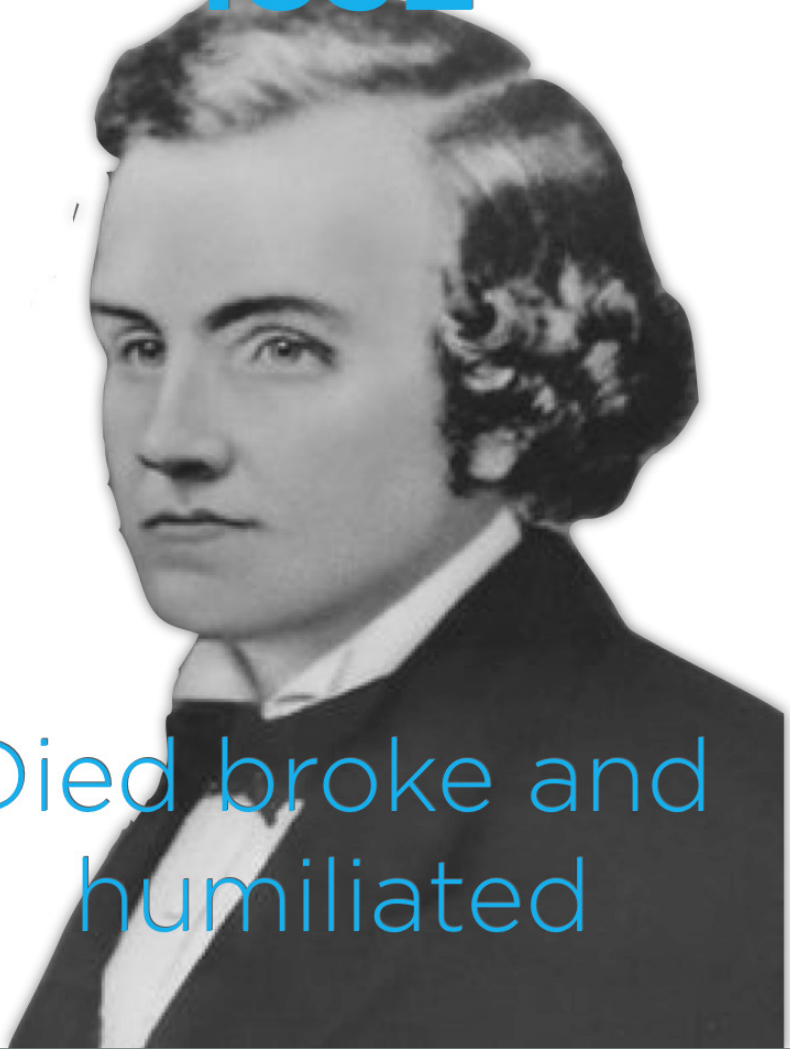


"There is a crank down in Apalachicola Florida that thinks he can make ice by his machine as good as God Almighty."
New York Globe 1852

1824

Father of Thermodynamics

1852



Died broke and humiliated

Heat Pumps

Why Not?

Image from: http://3tonairconditioner.net/

Image from: http://3tonairconditioner.net/


Smart Wi-Fi


$3,000

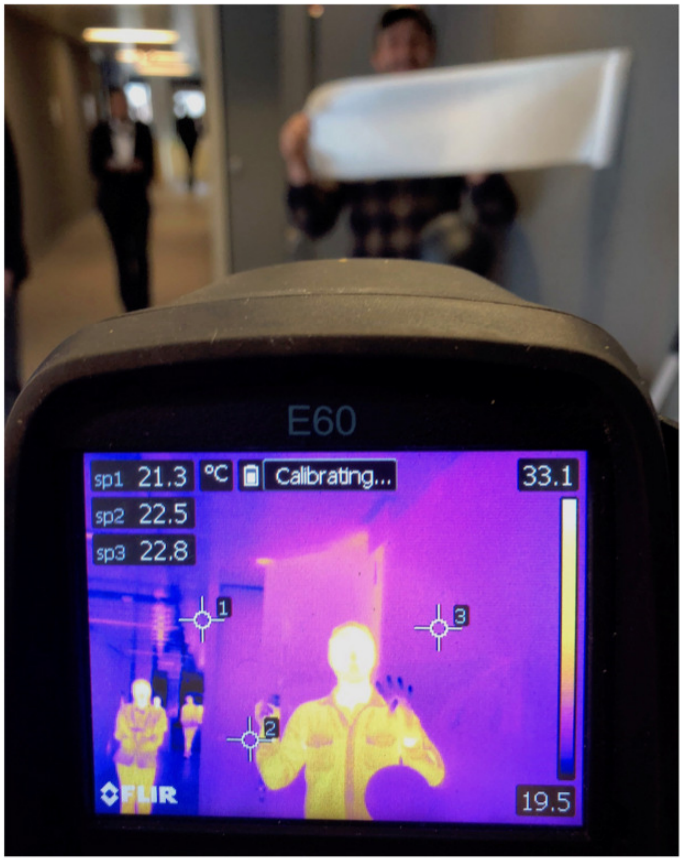
Install: $2,000

Hardware: $1,000

3. Comfort Control not Climate Control

Radiant Temperature is Half of Thermal Comfort

The Cold Tube



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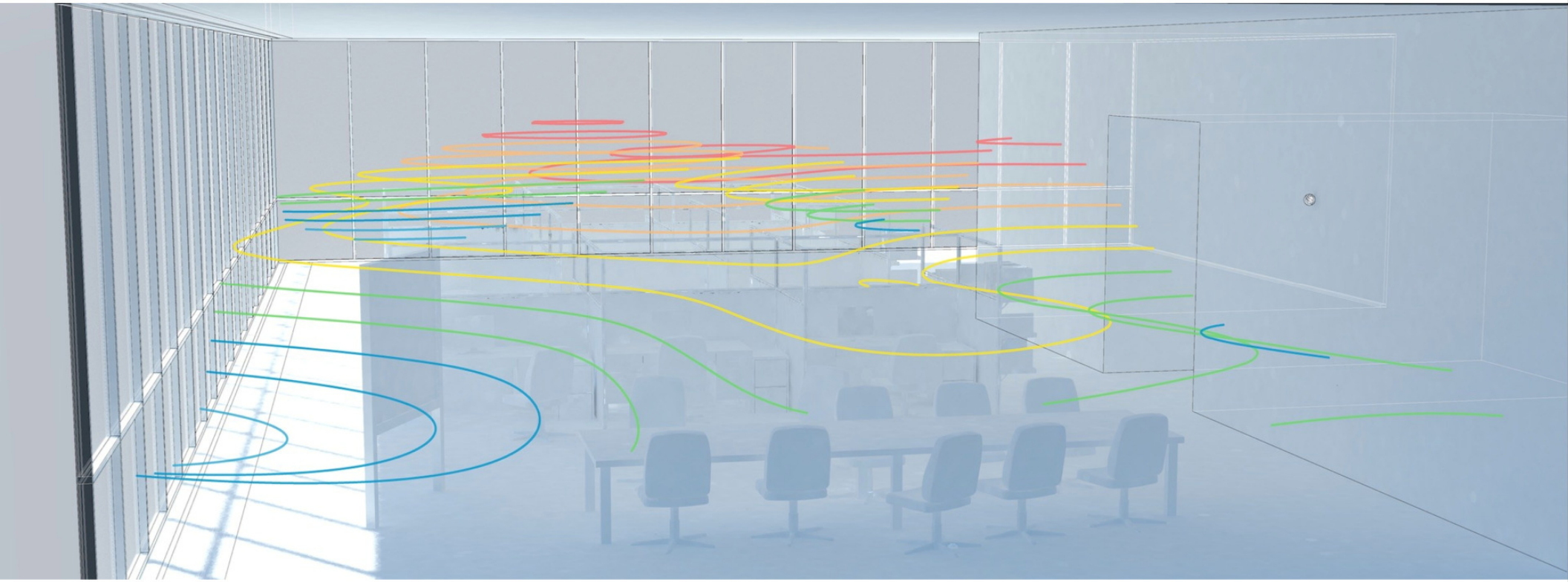
SMART Thermostats: Measure Radiant Temperature



No-Condensation Radiant Panels

Heat Pumps + Radiant Panels: More Comfort with Less Energy

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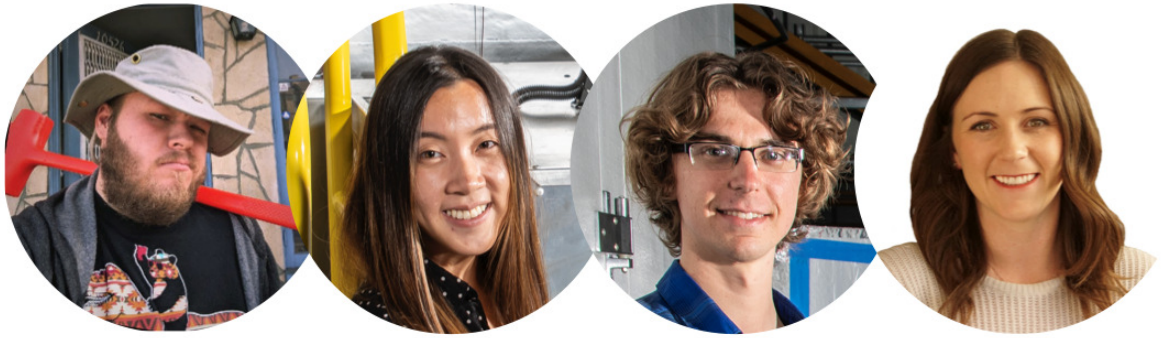
PhD UC Berkeley

Kipp Bradford

CTO
Thermal Avenger, MIT



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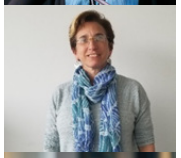

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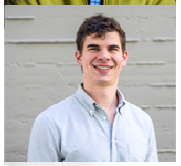
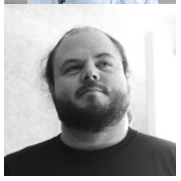


Vince Romanin, PhD
CEO, Treau, Inc.



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