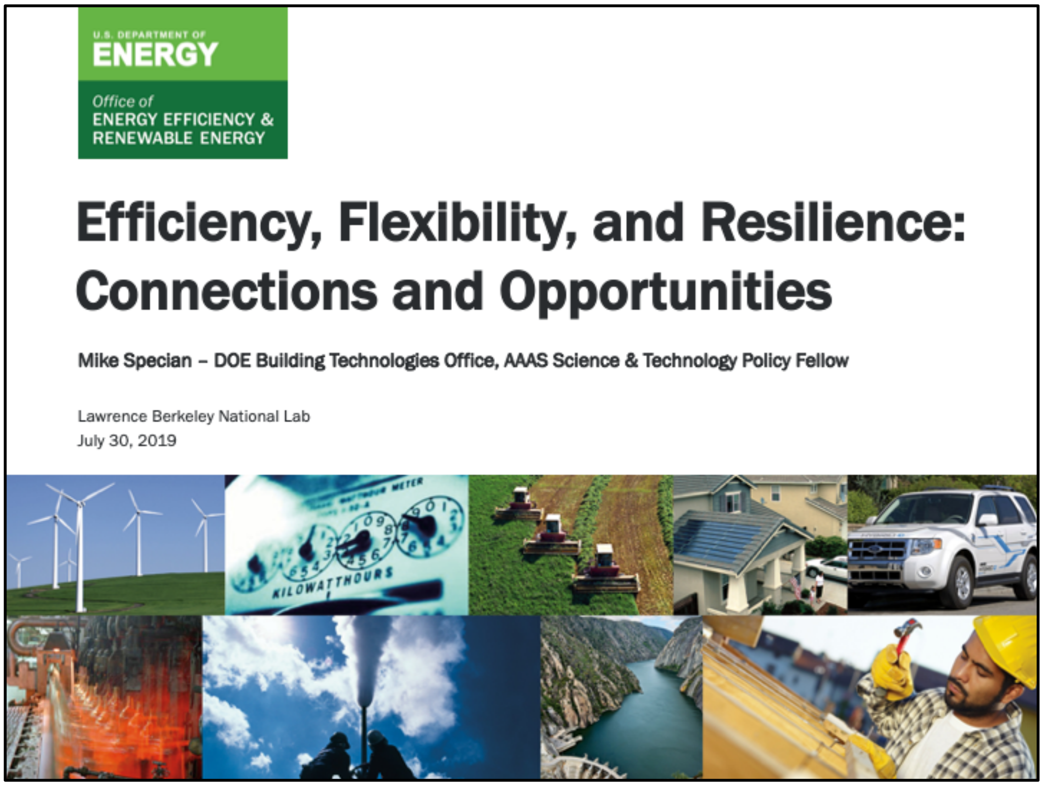
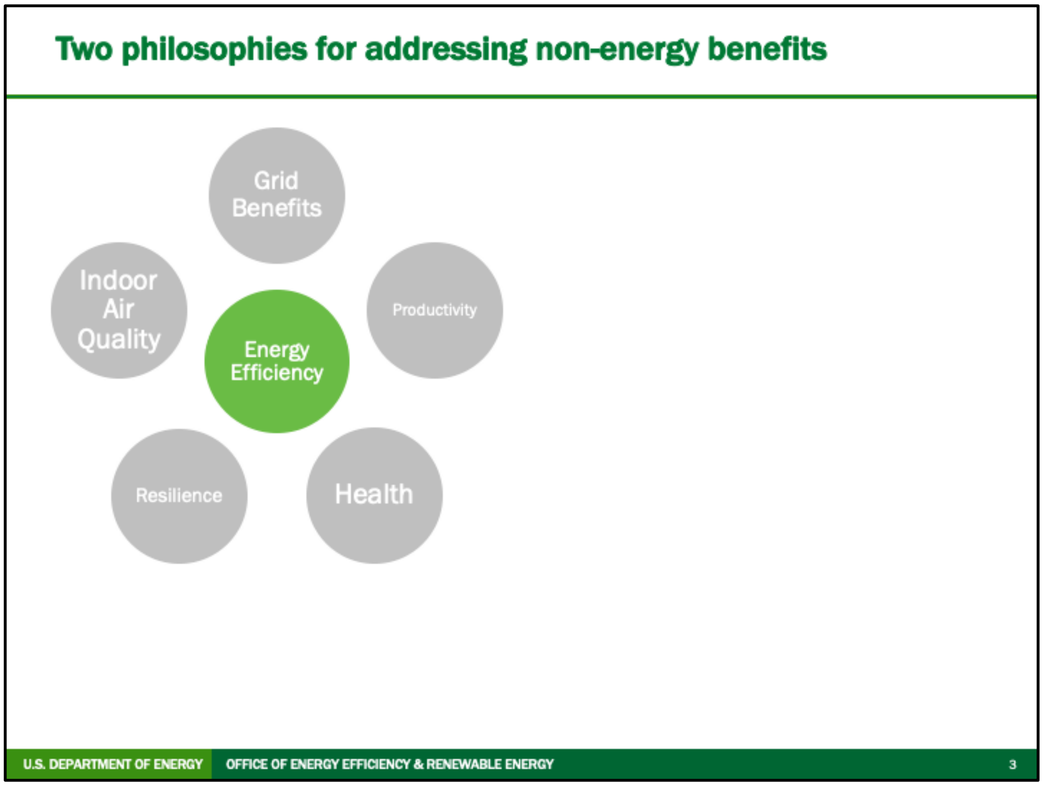


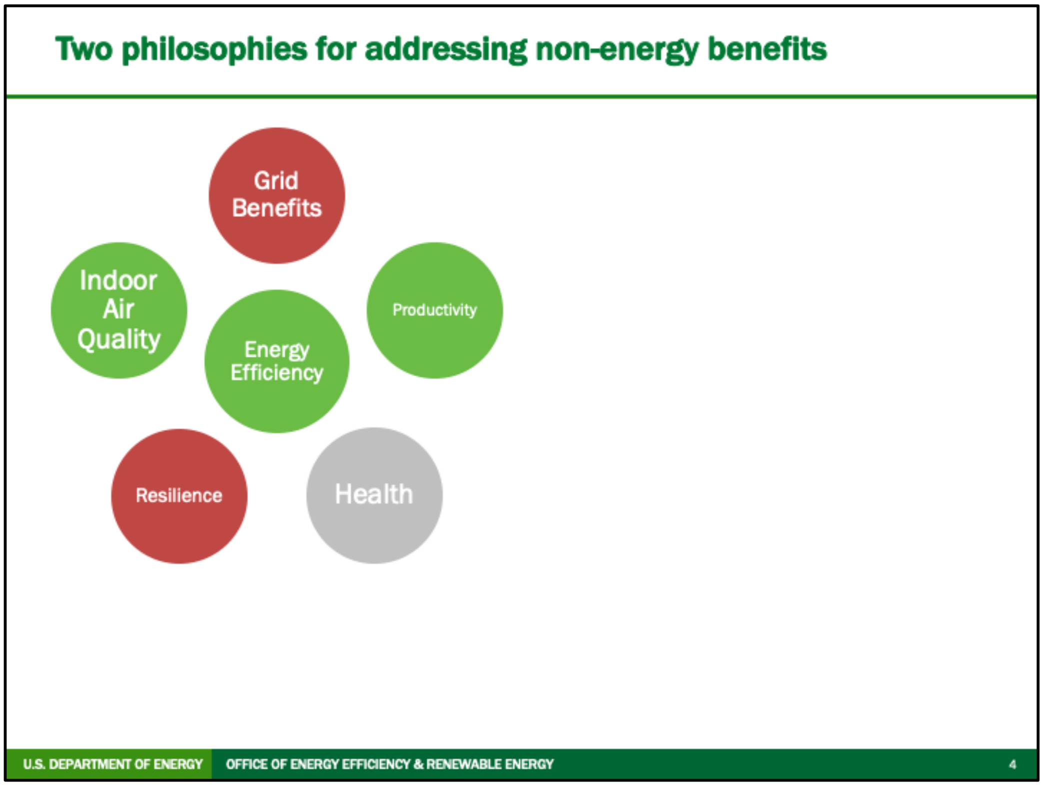
Organizations like RMI, NASEO, NREL, and others are drawing connections between resilience and energy efficiency in buildings. Their publications largely assume that energy efficiency is uniformly beneficial for resilience. However, there's a level of detail and complexity to these interactions that we would all benefit from exploring. We can do this through technology, but we should also consider the ripple effects in other sectors. This is still an emerging area. There is much left to learn.

Agenda

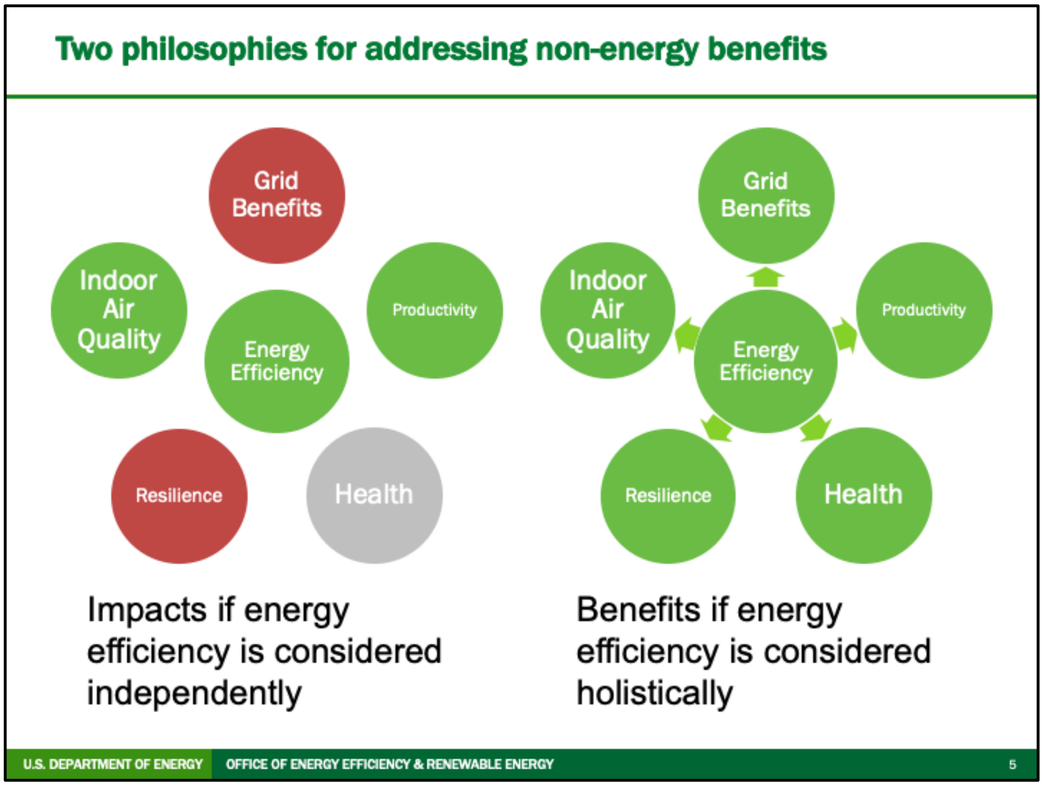
- Introduction to resilience
- Stakeholders in resilience and how buildings fail
- Co-optimizing efficiency, flexibility, and resilience in building technologies
- Policy considerations
- Challenges and opportunities



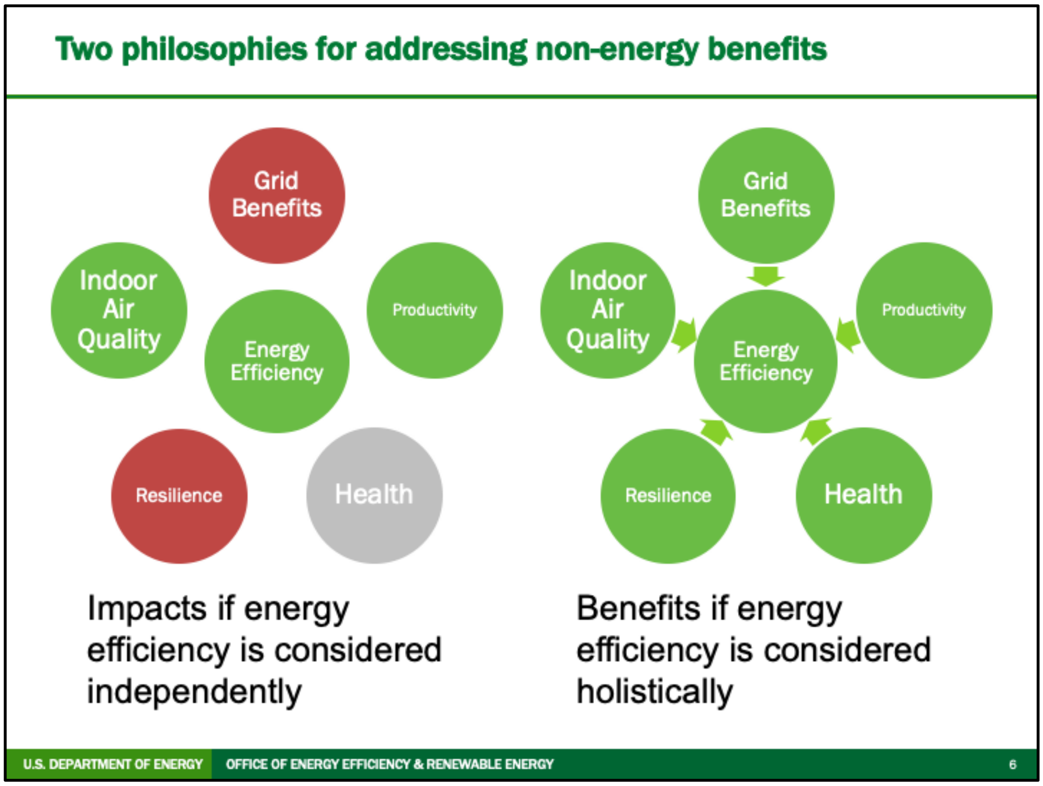
We know that energy efficiency brings with it some non-energy benefits. One philosophy is to not consider them.



Yet if we fail to consider those co-benefits, it's possible that we accidently improve some features, but no nothing or potentially even compromise others.

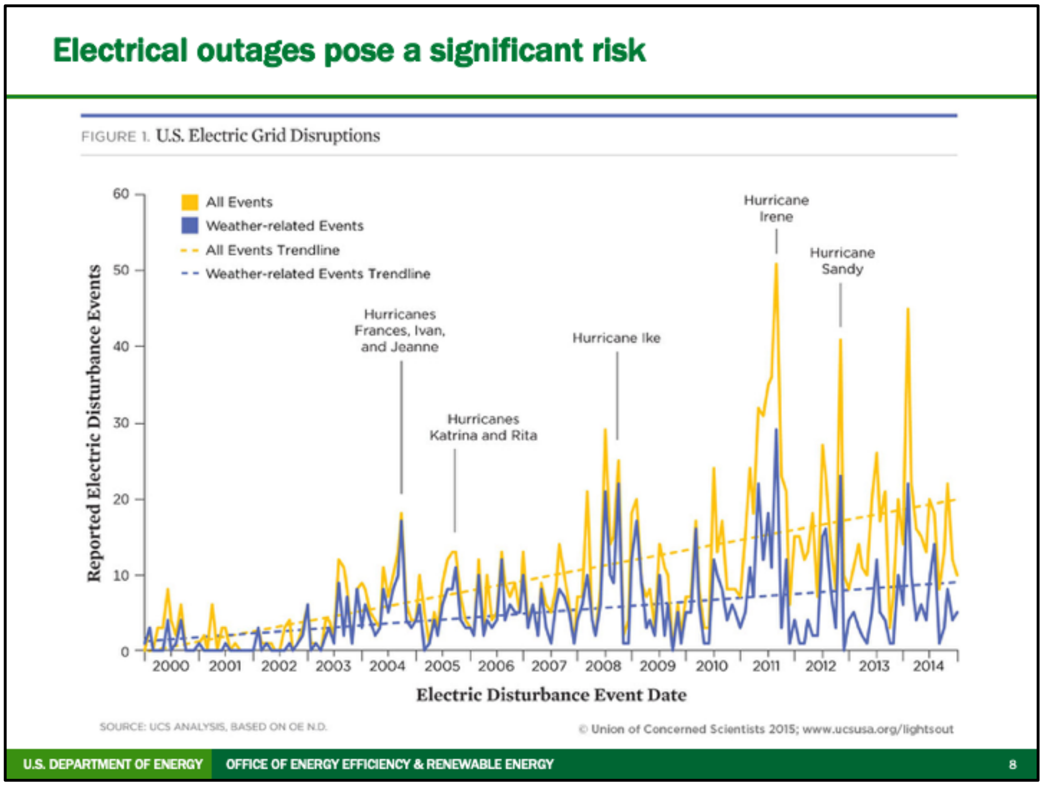


The other philosophy is that we could acknowledge the relationships between energy efficiency and these other aspects, and coordinate our R&D and related activities so that we're benefiting all of them at the same time. And there are plenty of people for whom energy efficiency is not the driver of their investment decisions. Energy is inexpensive, etc.

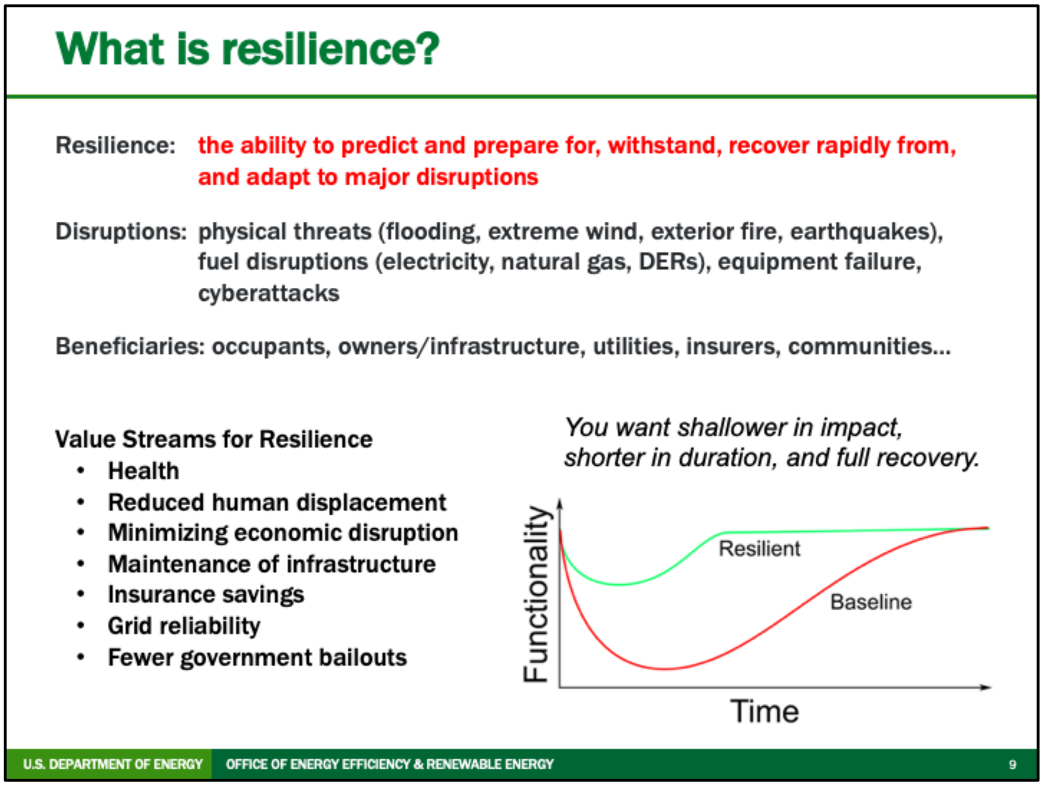


But if we can tap into these other aspects as selling points we can turn these arrows the other way and bring people to our energy efficient technologies by appealing to the aspects they might care more about.

How do we address climate change? Conventional wisdom: 1) Energy efficiency. 2) Decarbonize the grid. 3) Electrify everything. But how do we do that as weather events are becoming more frequent and intense?



Evidence suggests grid reliability is decreasing. This comes through Form OE-417. Utilities submit information about incidents, when and where they occurred, what triggered them, and how many customers were affected.



In short, high-performance buildings are highly valuable to a range of stakeholders.

Value Stream Example: Grid-interactive efficient buildings (GEBs) could help Midwest grid resilience during polar vortex

NAVIGANT
RESEARCH

Turning Thermostats Down Keeps the Heat on During Polar Vortex 2019

JESSIE MEHRHOFF

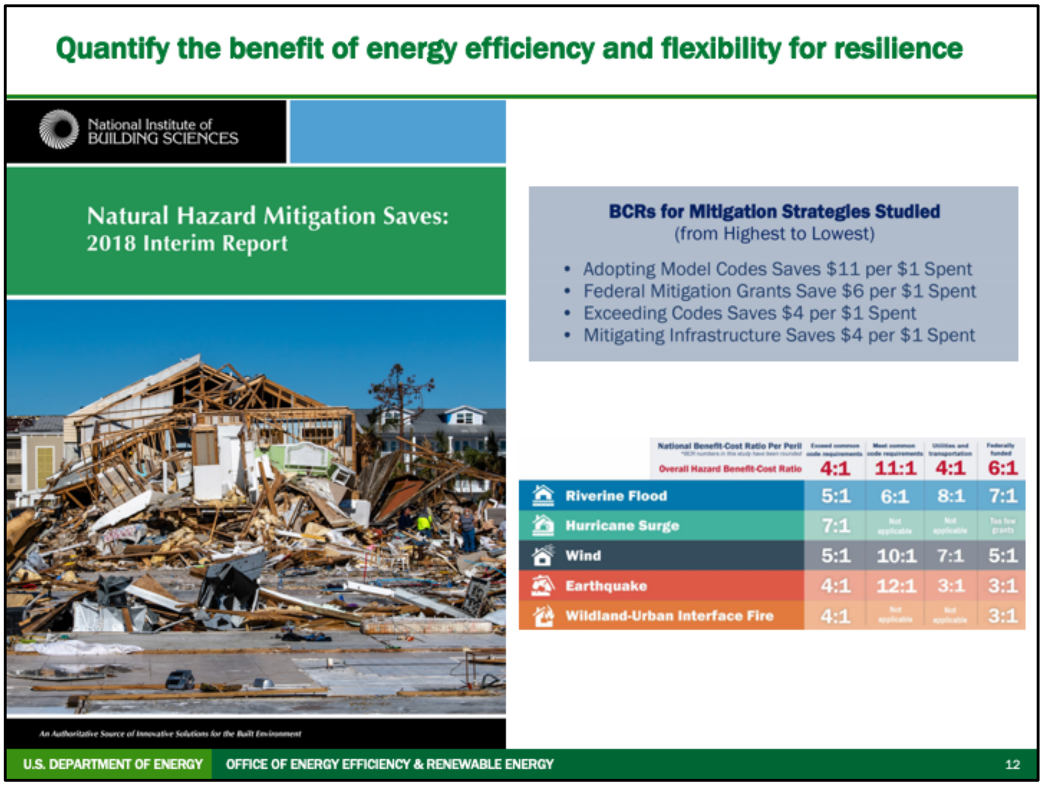
FEB 26, 2019

The final week of January brought sub-zero temperatures to three-quarters of the continental US and much of Canada as a polar vortex bore down. Polar vortexes gained fame during 2014, when record-breaking low temperatures strained electricity grids across the US as residents tried to stay warm. During the 2019 polar vortex, natural gas and electricity demand were straining grid resources again. Residents of Michigan and Minnesota were called upon to turn down their thermostats and reduce use of electricity-intensive appliances.

So here’s a real world example of how flexible loads can help grid resilience. During the polar vortex in the Midwest this past winter, utilities asked customers to turn down their thermostats and reduce use of electricity-intensive appliances as a way to reduce strain on the grid. This is an example where flexible loads could have provided resilience value to utilities in helping maintain a reliable supply of natural gas and electricity during a weather emergency.

There are two different types of resilience – structural resilience and operational resilience. Structural resilience is about making sure a building can stay standing and minimize damage during an extreme weather event.

Fortified Homes is like an asset score. Based on the steps you take during construction, you can be awarded bronze, silver, or gold designation. These designations can be used to obtain reduced insurance premiums. DOE's Zero Energy Ready Homes program encourages all partners to build to FORTIFIED standards, and hopes to eventually add them as program prerequisites alongside ENERGY STAR and Indoor airPLUS in the next major spec change. We're currently working with FORTIFIED Home and IBHS adding a comprehensive package of guides for resilience in the Building America Solution Center.



National Benefit-Cost Ratio Per Peril	Exceed common code requirements	Meet common code requirements	Utilities and transportation	Federally funded
Overall Hazard Benefit-Cost Ratio	4:1	11:1	4:1	6:1
Riverine Flood	5:1	6:1	8:1	7:1
Hurricane Surge	7:1	Not applicable	Not applicable	Too few grants
Wind	5:1	10:1	7:1	5:1
Earthquake	4:1	12:1	3:1	3:1
Wildland-Urban Interface Fire	4:1	Not applicable	Not applicable	3:1

And in a study that came out late last year, the National Institute of Building Sciences quantified just how valuable structural resilience is. They found that for every dollar spent getting to 2018 codes, you get $4 in return. But, search, 400+ pages, no "energy" reference. So we're getting a handle on structural resilience. Now it's time to deal with operational resilience. So solutions are in order, but what are we trying to solve for?

******

They consider four different mitigation strategies, two of which matter for us. They are:

Going beyond code requirements: [left column] The costs and benefits of designing all new construction to exceed select provisions in the 2015 IBC and the 2015 IRC and the implementation of the 2015 International Wildland-Urban Interface Code (IWUIC). **This results in a national benefit of $4 for every $1 invested.** (See Box 3-1 on page 109 for examples of how the codes changed between 2015 and 2018.)

Adopting I-Code Requirements: [next column to the right] Design based on meeting the 2018 IRC and IBC versus codes represented by 1990-era design and National Flood Insurance Program (NFIP) requirements—**results in a national benefit of $11 for every $1 invested.**

Their definitions for costs and benefits are:

Cost: the up-front construction cost and long-term maintenance costs to improve existing facilities or the additional up-front cost to build new ones better.
Benefit: the present value of the reduction in future losses that mitigation provides

But losses due to what? They break this down further by analyzing 5 separate hazards in different geographical locations:

• Riverine flood
• Hurricane surge
• Wind
• Earthquake
• Wildland-urban interface fire

To determine the value provided they look at a number of things including reductions in:

• Future deaths, nonfatal injuries, and PTSD.
• Repair costs for damaged buildings and contents.
• Sheltering costs for displaced households.
• Loss of revenue and other business-interruption costs to businesses whose property is damaged.
• Loss of economic activity in the broader community.
• Loss of service to the community when fire stations, hospitals, and other public buildings are damaged.
• Insurance costs other than insurance claims.
• Costs for urban search and rescue.

Two things to note here. First, this is almost (if not entirely) about new construction. (Retrofits are apparently coming in 2019.) Second, it's about *structure*, not *equipment* (aka building technologies). **For all of its analysis about building structure, as best as I can tell, it does not analyze energy efficiency or the IECC as a tool for resilience. That means that there is still an important gap to fill.** But rather than focus exclusively on helping the physical building survive, we would be concerned with helping people make use of limited electrical power. This could certainly be due to a natural disaster-induced outage, but also to a fuel storage, equipment failure, or even a deliberate attack.

Ways in which residential buildings fail operationally during major disruptions

- Food spoils due to lack of refrigeration
- Medicine spoils due to lack of refrigeration
- Sanitation compromised (clean water, sewage disposal)
- Thermal survivability threatened (heat stroke/hypothermia)
- Buildings burn due to fires lit indoors (cooking, light, heat)
- Carbon-monoxide poisoning from improper generator/grill/kerosene use
- Medical equipment rendered inoperable
- Falls resulting from poor lighting in stairwells and passages
- Leisure time lost
- Elevator outages for high rises
- Water can't be pumped up to high floors in high rises
- Frozen pipes
- Water intrusion – mold and fungal growth
- Forced evacuation – neglect and looting
- Elevators become inoperable

5 million Americans use insulin – proper storage requires refrigeration

Ways in which commercial buildings fail operationally during major disruptions

Hospital/Medical Facility

- Inability to access electronic records
- Inability to transport patients/equipment between floors
- Inability to sterilize instruments
- Food preparation and preservation losses
- Diagnostic equipment loss (x-ray, CT, etc.)
- Support equipment outage (breathing machines, etc.)

Retail/Office

- Lost revenue from idle resources
- Shutdown and restart cost
- Spoilage of inventory
- Cascading effects on firms that are supplied by impacted facility
- Computer data loss

Data Center/Telecommunications

- Temperature regulation challenges if backup power not also available for HVAC
- Degradation of storage media if temperatures rise
- Downstream losses to firms that require connectivity for business
- Backup batteries not designed to fully drain in cases of long term power outage

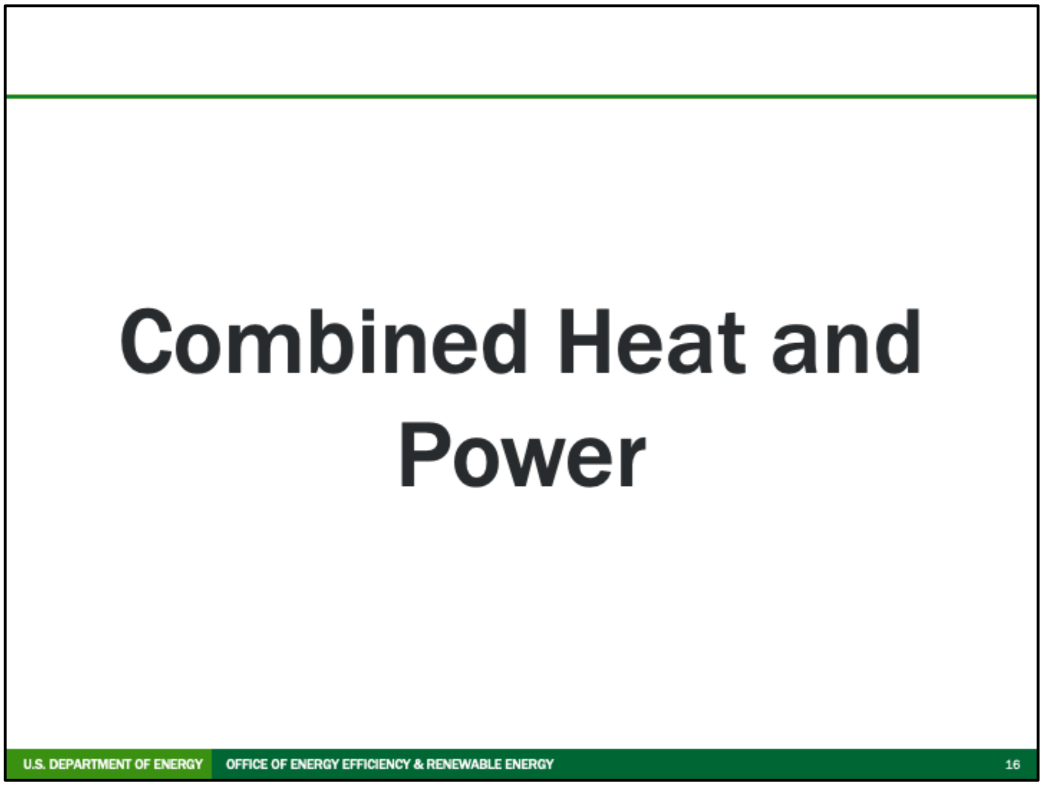
Hospitals are perhaps the buildings that most require operational resilience during disasters. But there are plenty of other critical facilities that we could throw up here as well including police stations, fire stations, military bases, hazardous material storage sites, schools (which often double as emergency shelters), and others.

Elsewhere in the commercial sector we have a range of losses that are often characterized by the term “business interruptions”. You see a number of them listed here. In southern Manhattan following Sandy, business interruptions were among the greatest sources of loss.

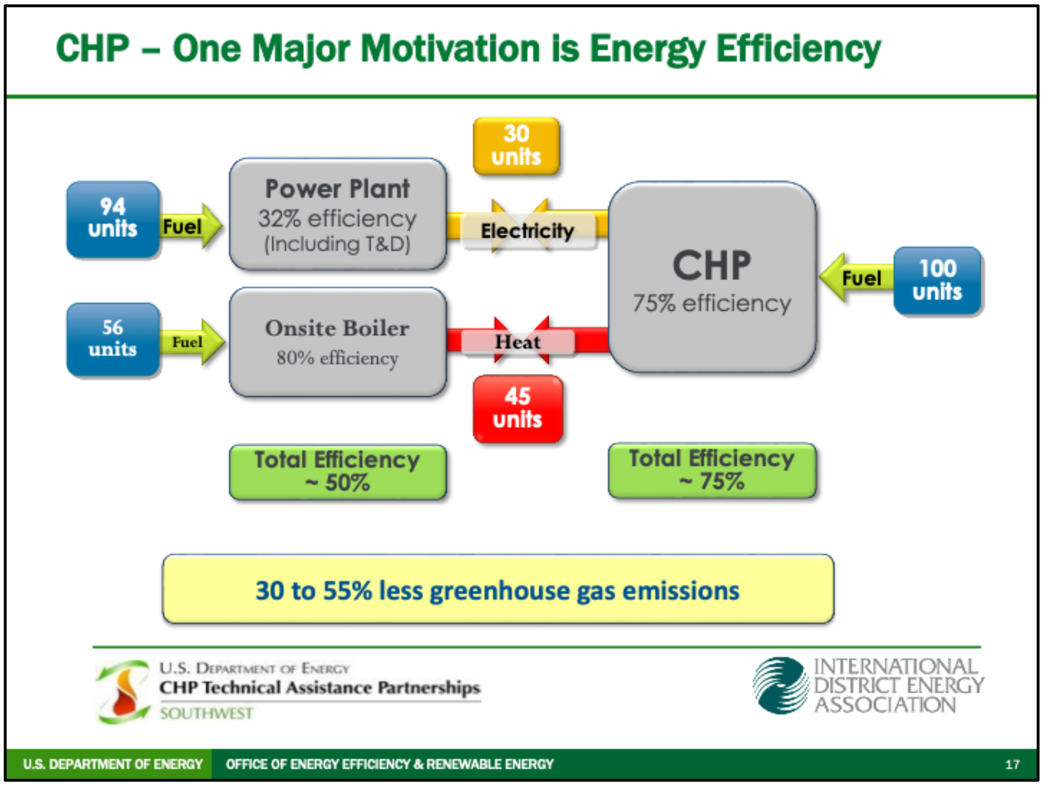
If you take one point away from all of all this, let it be this: the issue of operational resilience in buildings touches a lot of sectors.

Resilience demands that we collaborate with many different sectors

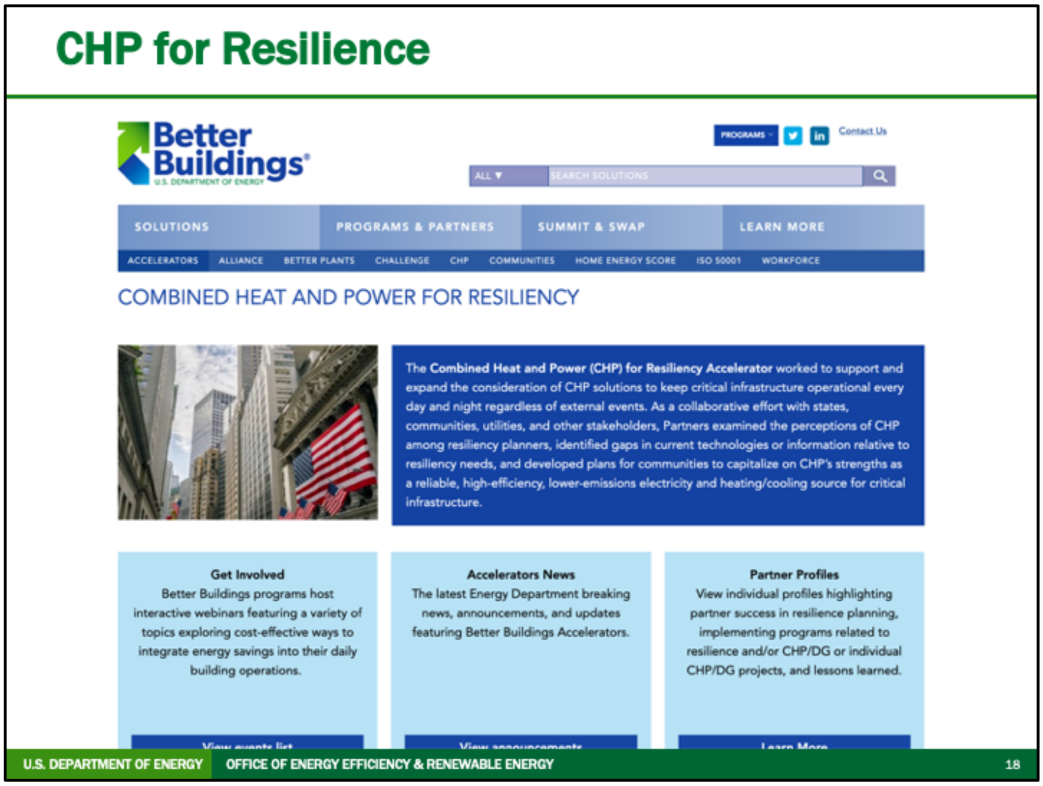
- Scientific research community
- Equipment manufacturers
- Utility/grid
- State governments
- Municipal resilience/sustainability officers
- Codes
- Insurance
- Architects/designers
- Affordable housing/equity
- Federal agencies/military
- Financing/lending
- DERs and storage
- Real estate



This is one of the clearest examples of a technology that connects efficiency and resilience benefits, and that's combined heat and power, or CHP.



The characteristic that make CHP an efficient is the co-location of generation and load in a way that allows you to utilize waste heat. It’s that same co-location that provides resilience through bypassing the T&D system and the power, which can be 100 miles away.



DOE already recognizes this value stream, and assists buildings in installing CHP through its Combine Heat and Power for Resiliency accelerator.

This is Montgomery County, Maryland's Public Safety Headquarters. A number of critical county departments are housed here including County Police, County Fire and Rescue Services, Office of Emergency Management and Homeland Security, and Department of Transportation. So it's imperative that in the event of a power outage, this place stays up and running.

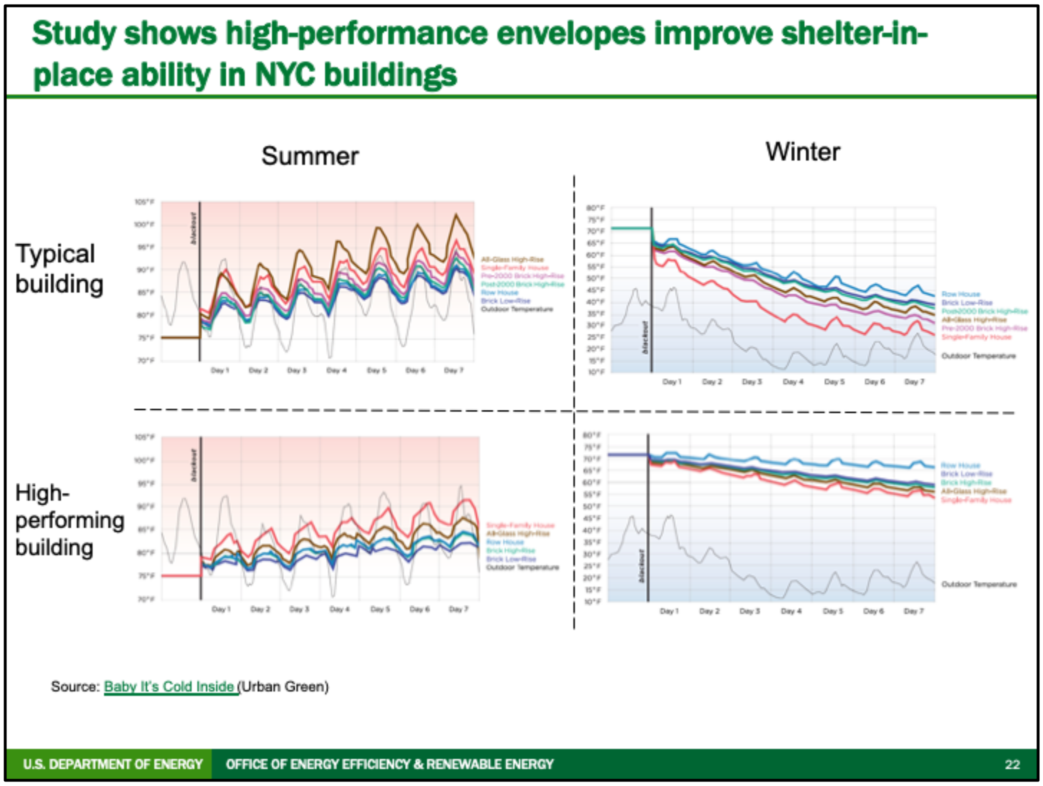
There are a number of elements to their resilience strategy, but 2 stand out. 1) a full energy efficiency upgrade of the building and 2) installation of an 800 kW CHP system. They knew the resilience that could be provided by CHP and understood that the system becomes more valuable when energy efficiency reduces the total load that it would need to service. It could also help them downsize the system = save on up-front costs.

Paradigms for Resilient Response

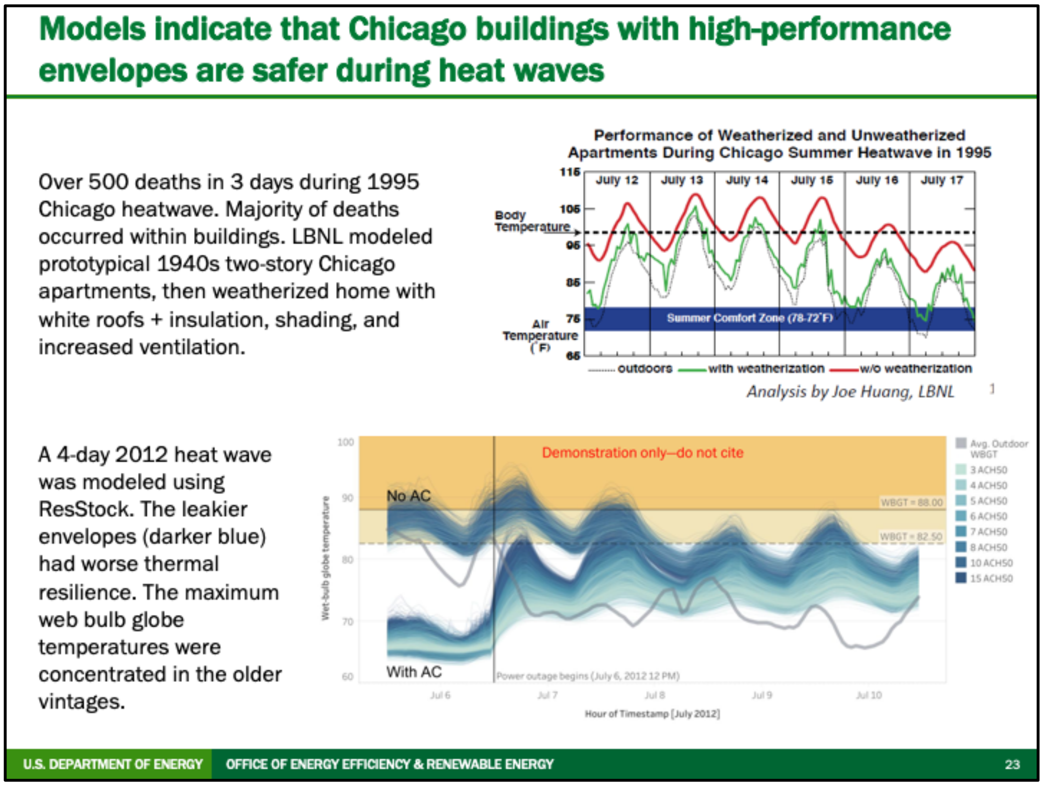
	No knowledge of impending outage	Knowledge of impending outage
Backup power onsite	Generation services critical loads without benefit of fully charged electrochemical or thermal storage	Generation services critical loads with advantage of fully charged storage and space preconditioning
Building relies on passive measures	Efficient envelope and energy acquired in environment must be sufficient to shelter-in-place	Building preconditioning with enhanced ability to shelter-in-place

thermally precondition your space by turning your thermostat either up or down and by turning decreasing the temperature of your refrigerator. So knowledge allows you to give your building a boost, which allows it to press on longer during a major disruption than it would have been able to otherwise.

Envelope



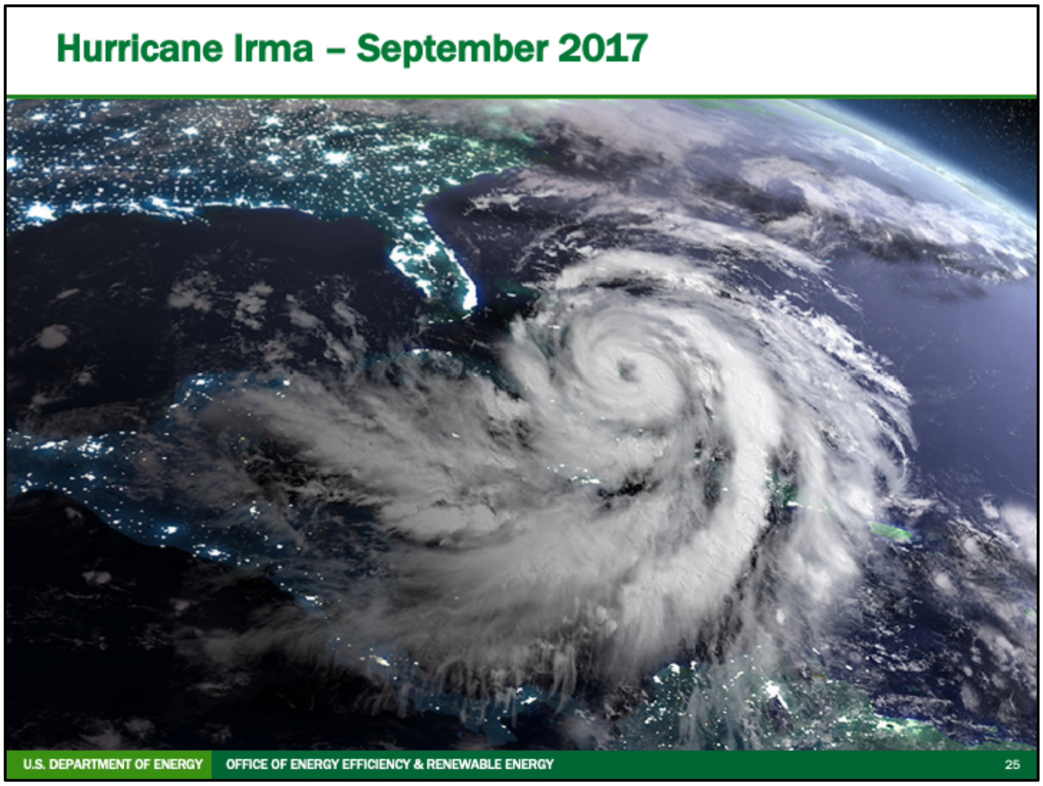
These are the results of a study conducted by Urban Green in which they simulated power outages in NYC buildings during the summer (on the left) and the winter (on the right). In both cases the black line represents the exterior temperature and the colored lines represent indoor temperatures for a variety of building types. On the top row, you see the performance of typical buildings. High performance buildings perform better.



Here we see analysis from two Chicago heatwaves. On the top right, the red line represents the indoor air temperature of unweatherized homes during a 1995 heatwave that killed more than 500 people. When energy conservation measures like white roofs, insulation, shading, and increased ventilation are introduced, the indoor temperature (in green) drops to more closely match the exterior temperature (black dotted line). Not comfortable, but certainly safer.

On the bottom is brand new analysis out of NREL. Eric Wilson used ResStock to determine how insulation and air leakage affect the thermal resilience of typical single-family detached homes during a 2012 Chicago heatwave. Dark blue are leakier homes, and the vertical line is the onset of a power outage. Leaky homes that had air conditioning running see their thermal resilience compromised fairly quickly, while in homes without AC the results are a bit more mixed. And this goes back to the idea that there is a real difference in outcome depending on whether the building has had a chance to precondition itself (with AC) or not.

This is an image of the Belfast Cohousing & Ecovillage in Belfast, Maine. Belfast Eco-village was built to Passivhaus standards. In December 2013 an ice storm hit Maine and temperatures in Belfast, Maine reached -5F. 160,000 homes and businesses were left without power. Shelters saw hundreds of overnight stays and had to serve meals and snacks. And yet, after 4½ days without power the temperature inside one of the Ecovillage homes was recorded at 58F. So when we talk about the value streams that energy efficiency can provide, this is an example of that.

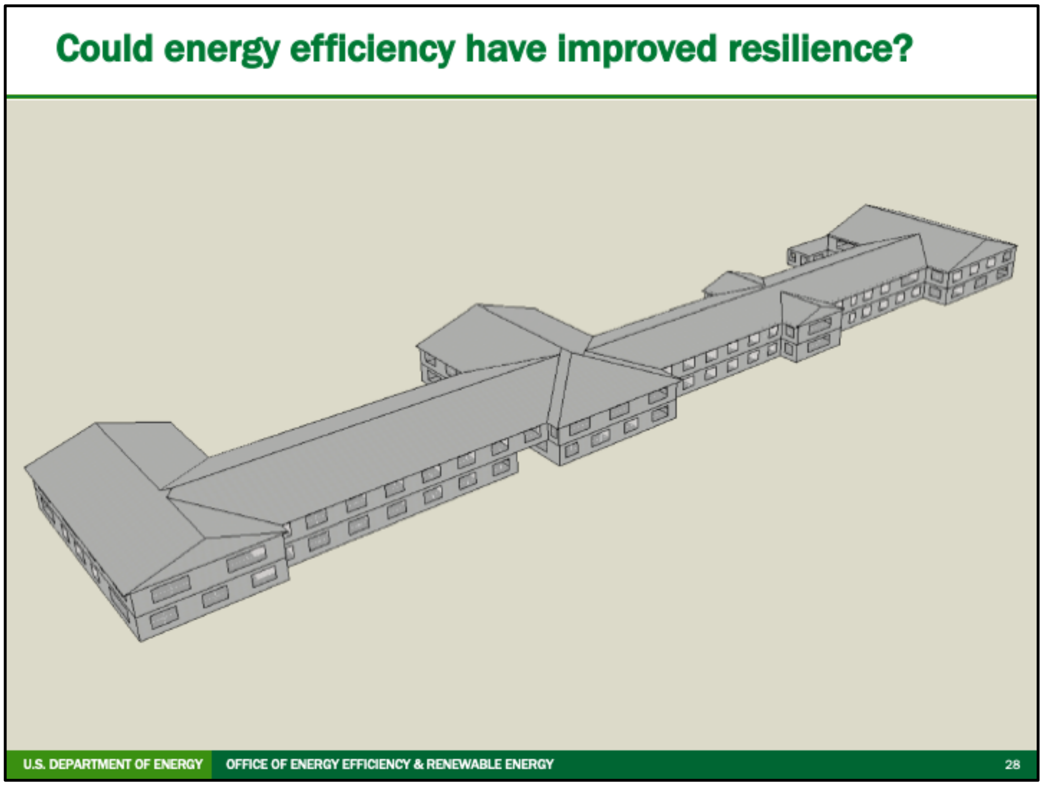


In September 2017 during Hurricane Irma, a tree branch hit a transformer and knocked out the air conditioning to a nursing home in Hollywood, Florida.

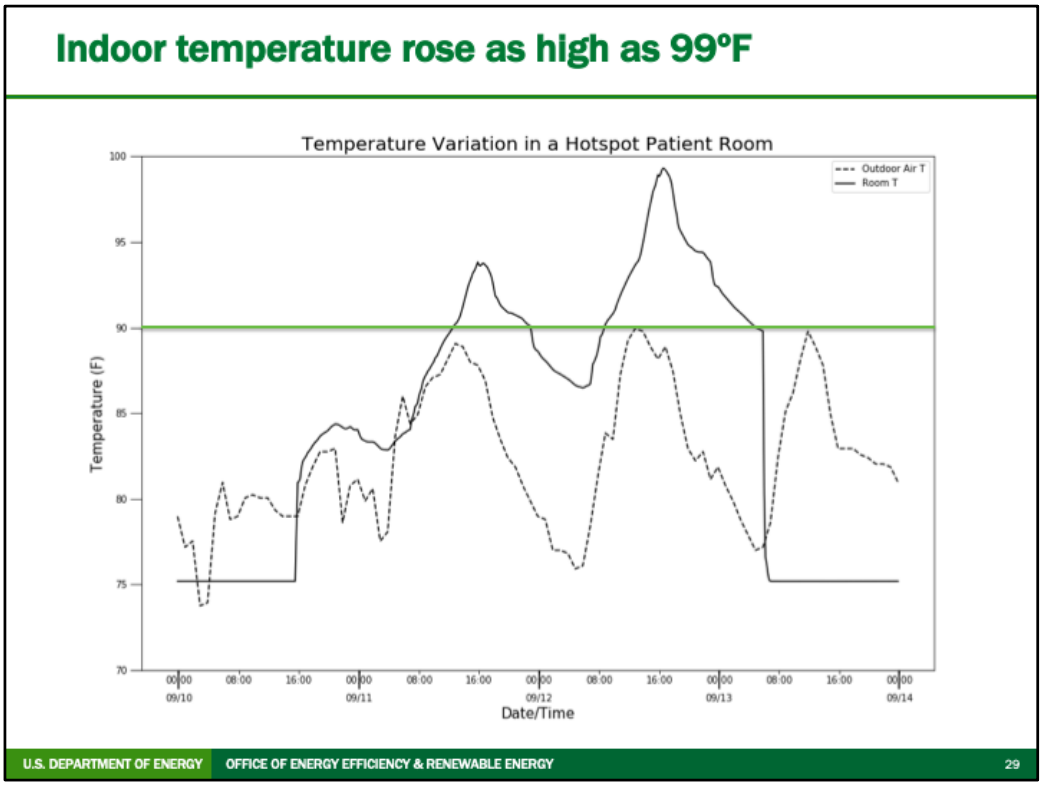
Nursing home lost main air conditioning system

The building didn't lose all power. They were still able to service other loads. A limited number (~8) of portable air conditioners were on site, but they proved go be insufficient.

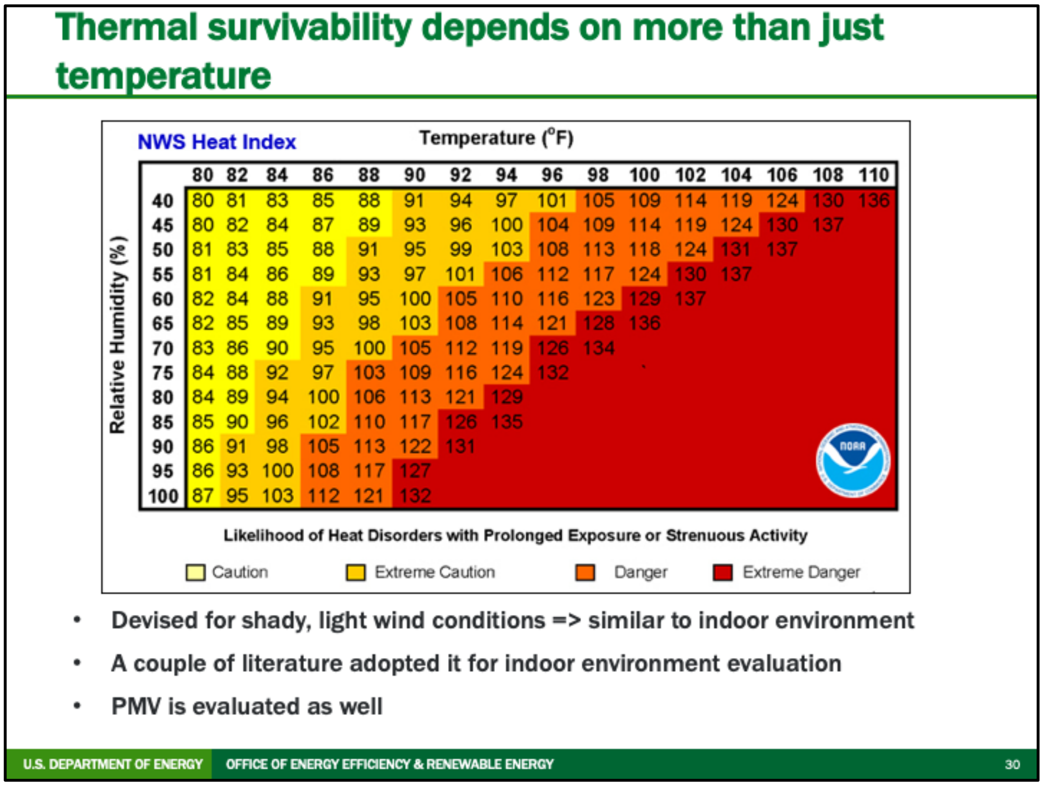
After a 3-day power outage, interior temperatures rose to close to 100 degrees in some rooms.



So I wondered, “Could energy efficiency investments have saved these people’s lives…and if so, at what cost?” So working in conjunction with Tianzhen and Kaiyu, we went to the city of Hollywood, FL, pulled the building records, and created a detailed model of the facility in Energy Plus, which we then calibrated with real data.



By midnight on the 3rd night of the outage the temperature difference between the inside and outside was about 20 degrees.



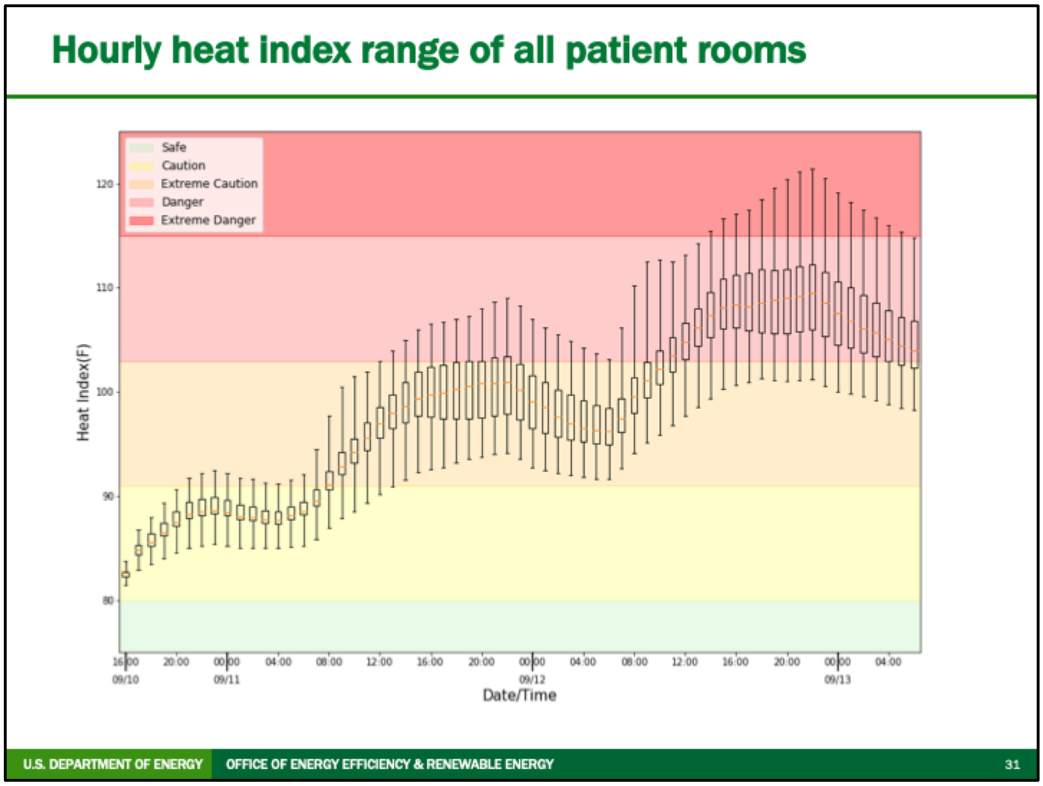
Temperature is not the only thing that matters, though. Factors that influence thermal comfort are 1) temperature 2) humidity 3) solar radiation 4) air flow 5) clothing 6) metabolism. We can't capture all of these, so we looked at heat index.

27–32 ° C 80–90 ° F Caution: fatigue is possible with prolonged exposure and activity. Continuing activity could result in heat cramps.

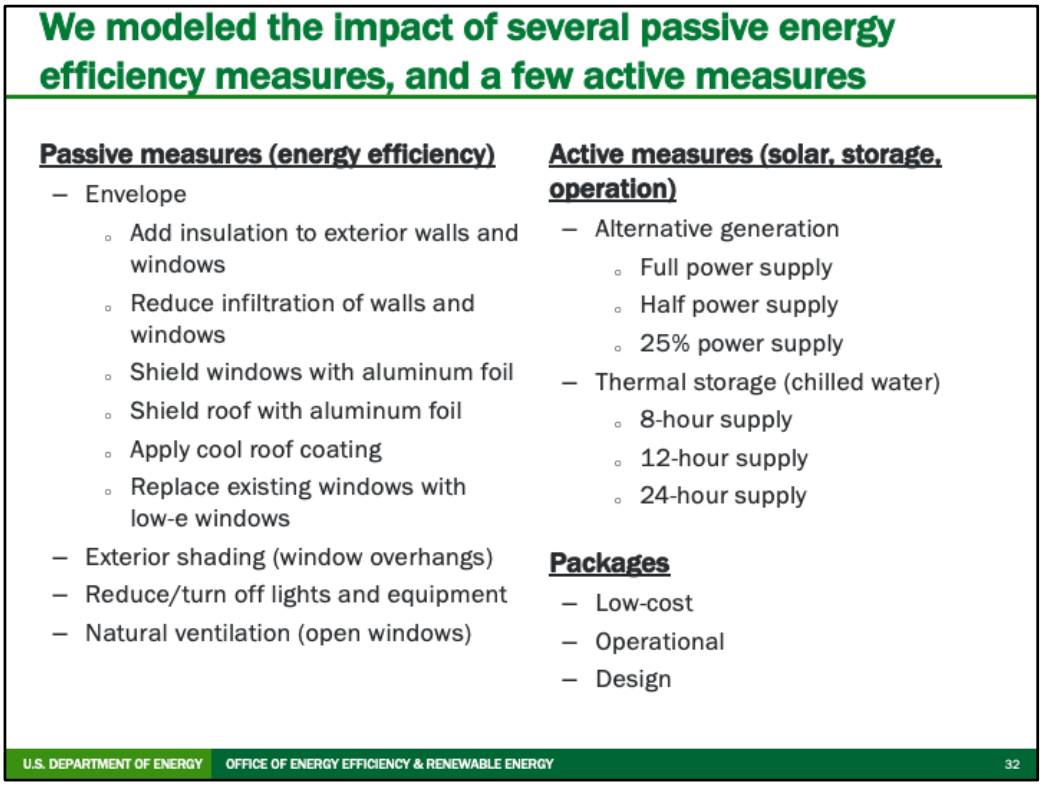
32–41 ° C 90–105 ° F Extreme caution: heat cramps and heat exhaustion are possible. Continuing activity could result in heat stroke.

41–54 ° C 105–130 ° F Danger: heat cramps and heat exhaustion are likely; heat stroke is probable with continued activity.

over 54 ° C over 130 ° F Extreme danger: heat stroke is imminent.



This is our best model of what really happened. Boxes are 25/75 percentiles. Whiskers edges include all rooms. By the second day almost all rooms are "extreme caution". By the third day almost all are "danger". Some are "extreme danger".



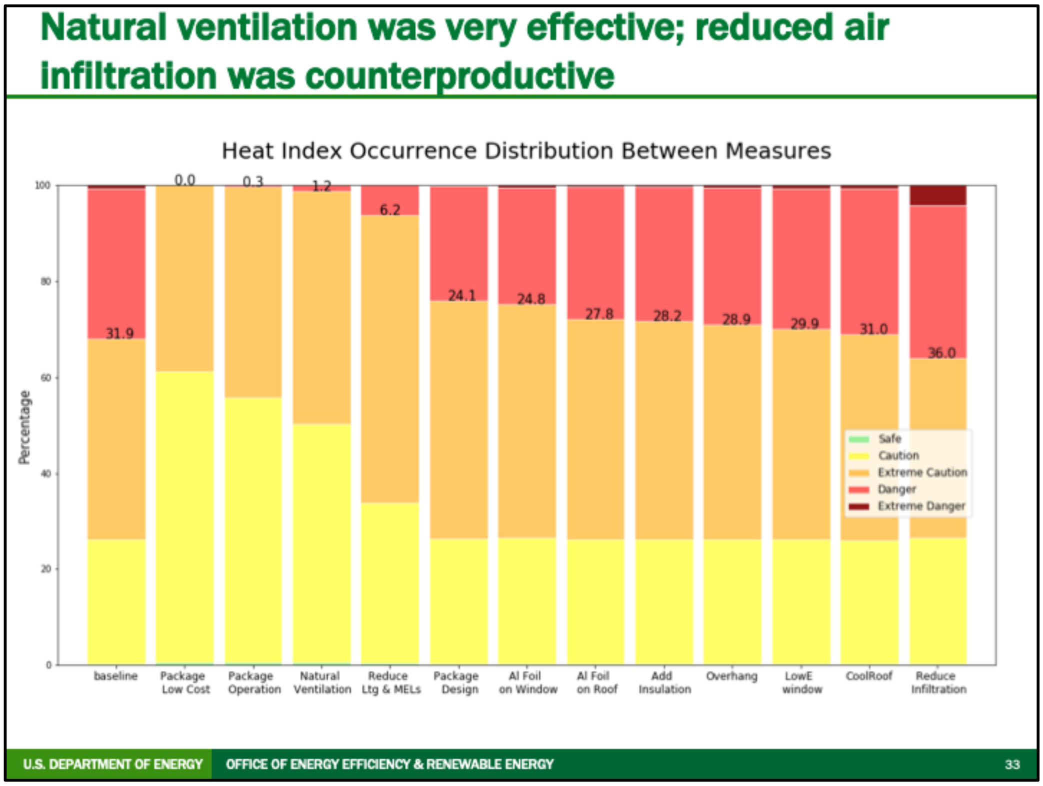
So here are the passive energy efficiency measures that we implemented. We also tested how effective backup generation would have been, as well some packages of measures.

8-hour supply of thermal storage means 8 hours full capacity supply.

Low-cost: Natural Ventilation + Reduce MELs + Al foil window + Al foil roof

Operational: Natural Ventilation + Reduce MELs

Design: Add insulation + CoolRoof + Overhang + LowE window



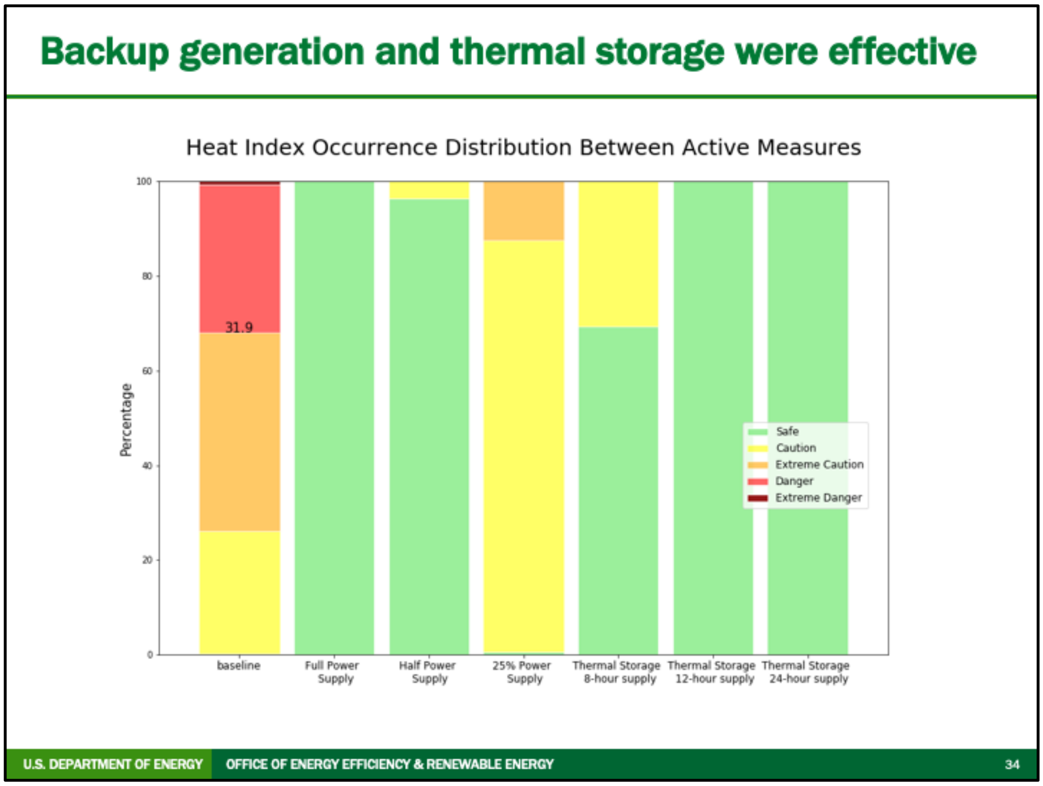
There were 89 patient rooms and we have the hourly temperature in each room. We stacked those room-hours up and looked at the fraction that were in each of these heat index danger zones.

And that's what you see in the the left column here. This is the baseline. As best we can tell, this is what actually happened.

All but one of the passive measures made things better. Natural ventilation (4th column) was the most effective. (This suggests – but we don't know for certain – that building operators kept the windows closed and ran the portable air conditioners to their detriment.) Window standards in Florida are already fairly high, so there wasn't as much gain there (3rd to last column). Reduced air infiltration (final column) – a standard of energy efficiency practices – would have on its own compromised resilience.

In reality, for the vast majority of hours, the rooms were in the zone of "extreme caution", and over 15% were fully in the danger zone. Had the building been able to exercise a passive ventilation capacity, it would have greatly ameliorated the problem. You see other measures here as well, but I'd like to direct your attention to the final column. What we discovered is that one of the facets of energy efficient buildings that we almost take for granted these days is air tightness. However, had this building been air tight, the situation would have been even worse than it was in reality.

So, we haven't come here to say that all energy efficiency measures benefit resilience. The picture appears to be more complicated than that. Sometimes efficiency measures help, and sometimes they hurt. The point is that if we don't understand these interactions better, we may be creating and promoting technologies that are actively dangerous during situations are that projected to become more common.



Here we see how much our scenario changes when we have some form of backup generation or energy storage.

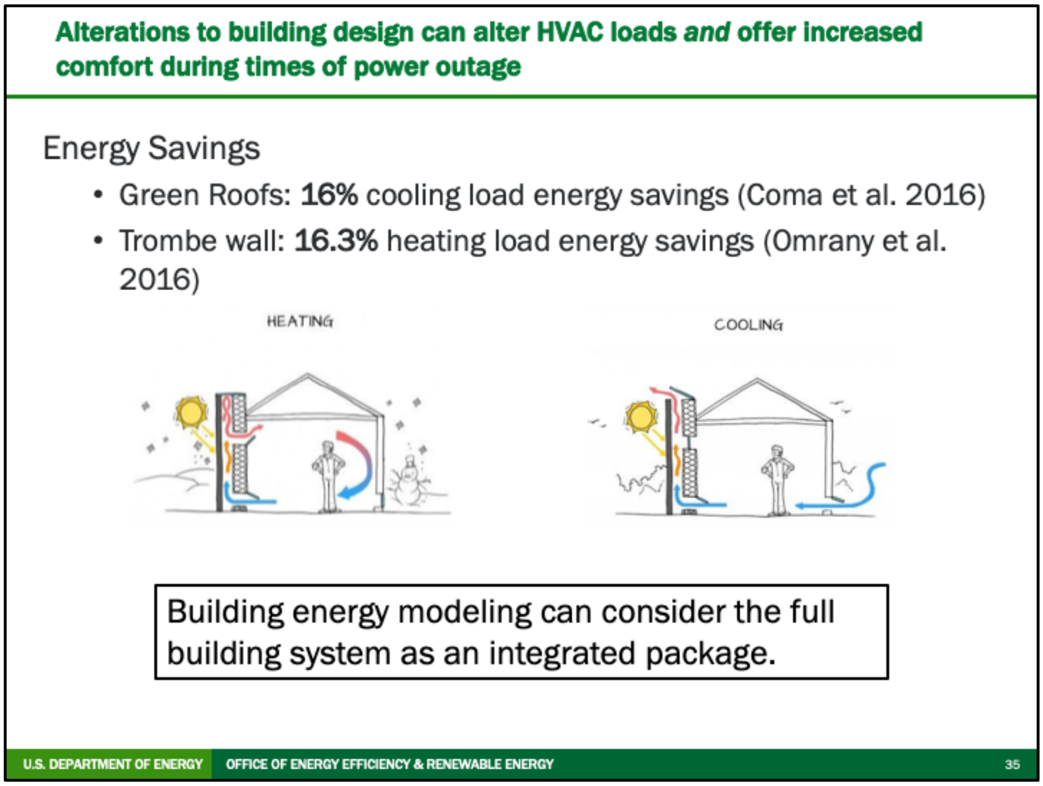
With either a full-power or half-power backup generation, we are able to meet almost all thermal comfort needs. Half power supply works because you don't need the full chiller capacity to maintain safe thermal conditions during average circumstance (conditions following Irma were not extreme). We do see, however, that when we're down to 25% power supply we get significantly into the caution region.

I need to mention some important caveats. This assumes you can get the system up and running again. You need more (inrush) current to turn on the chiller than to operate it. Perhaps there's a technology solution here to address this issue. Another caveat is that generators have been known to fail following disasters. Fuel access is a constraint, and fuel can spoil after 6-12 months. And they must be regularly maintained.

Finally, I'll point out that have thermal energy storage in the form of chilled water that can be fed into the building cooling coils would also have been an effective strategy.

We also looked at what would happen if we moved the nursing home to San Francisco or Chicago during a heat wave. We got similar, but not identical results. Cool roofs were more effective in SF because there was more incident solar radiation during the heat wave. Windows were also more effective, largely because window standards in Florida are pretty high already.

The "right thing to do" will probably differ based on local building codes, exterior conditions, interior building loads, and more.



Given those results, it's worth considering whether some older designs like trombe walls might have a place in the resilience/efficiency conversation. I would suggest that it may be worthwhile to rethink of some of our building designs to see if a hybrid approach that combines some measure of air sealing with passive ventilation may be appropriate.

We have to be careful not to go too far there, because here's another example where resilience and efficiency are at odds with one another.

Here on the left we see a couple soffit vents. The upper-right image illustrates how these vents facilitate passive cooling by drawing in cool air from underneath the gabled roof, and expelling hot air out the top – an energy efficient cooling strategy. However, as many California residents have painfully learned recently, soffit vents can also act as vectors for embers to enter during wildfires.

High R-value insulation and fire resistance do not always go hand-in-hand

Envelope Insulation Technology	R-value	Thermal Stability	Toxic Smoke	Ignition Risk
EPS (Expanded Polystyrene)	Medium	Low	High	High
XPS (Extruded Polystyrene)	Medium	Low	High	High
PIR Foam (polyurethane)	Medium	High	High	High
Phenolic foam	High	High	Medium	Low
Silica Aerogels	Medium	Medium	Low	Low
Polymeric nano-foams (aerogels)	High	High	High	High
Vacuum-insulated panels	High	Medium	Medium	Medium

U.S. DEPARTMENT OF ENERGY OFFICE OF ENERGY EFFICIENCY & RENEWABLE ENERGY 37

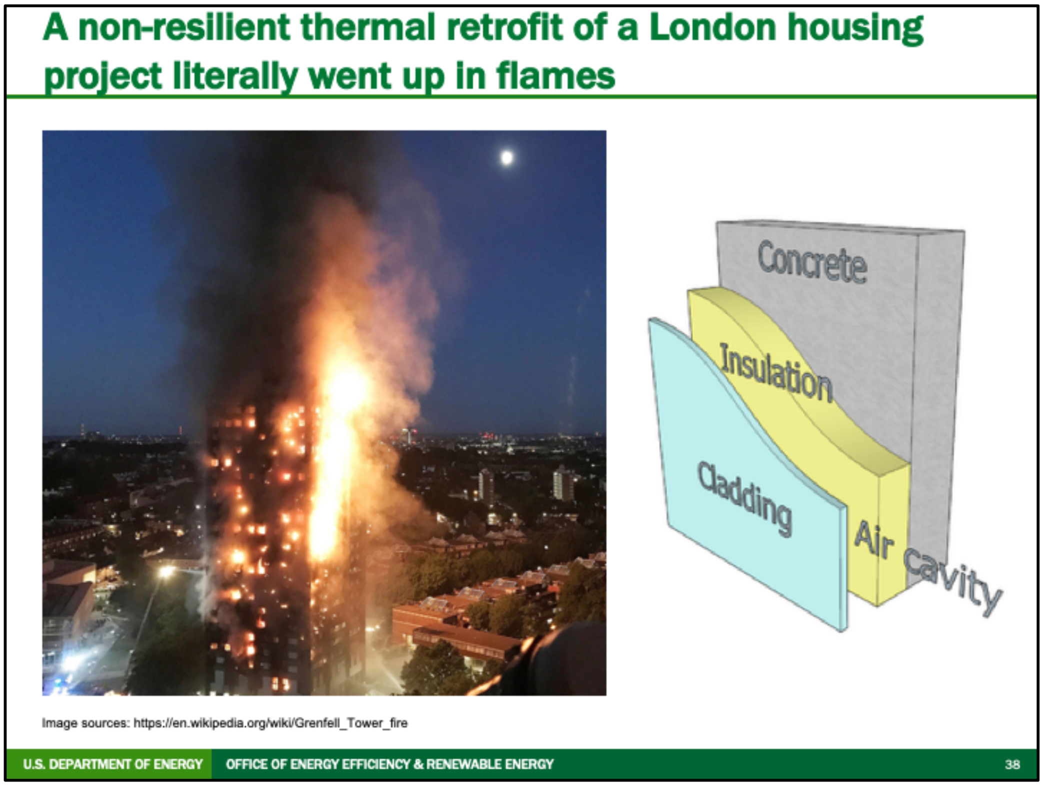
Here's a table containing 7 types of insulation with their R-values presented alongside other fire-related characteristics. You'd like to see green across the board, but you don't. This is a space where efficiency and resilience have yet to be co-optimized.

**

Flammability based on two tests for surface burning characteristics/ flame spread (ASTM E84 test) and room fire growth (NFPA 286 test)

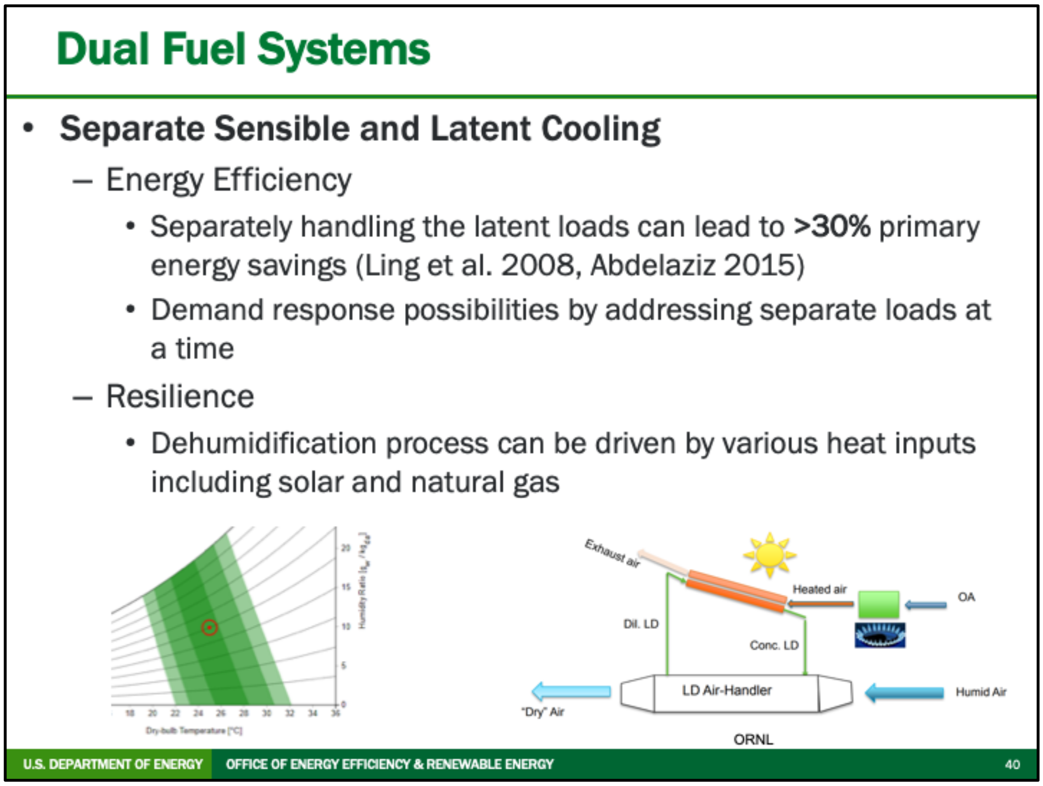
https://www.ahfc.us/iceimages/manuals/building_manual_ap_1.pdf

https://www.pilkington.com/en/global/residential-applications/types-of-glass/energy-efficient-glass/low-emissivity-glass



And just as with some of the other examples I've shown, this is not theoretical. Grenfell Tower – June 14, 2017. Seventy-two people died. The cause was a newly installed thermal cladding on the exterior that was clearly not resilient to fire. And this isn't just a one-off. A 2011 report (carried out jointly by the Chief Fire Officers Associate and Chartered Institute of Housing) found that ¾ of Britain's social housing blocks were potentially unsafe in a fire.

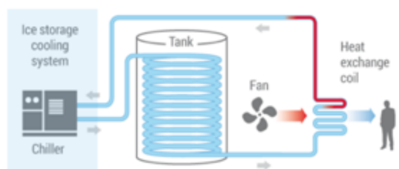
HVAC and Appliances



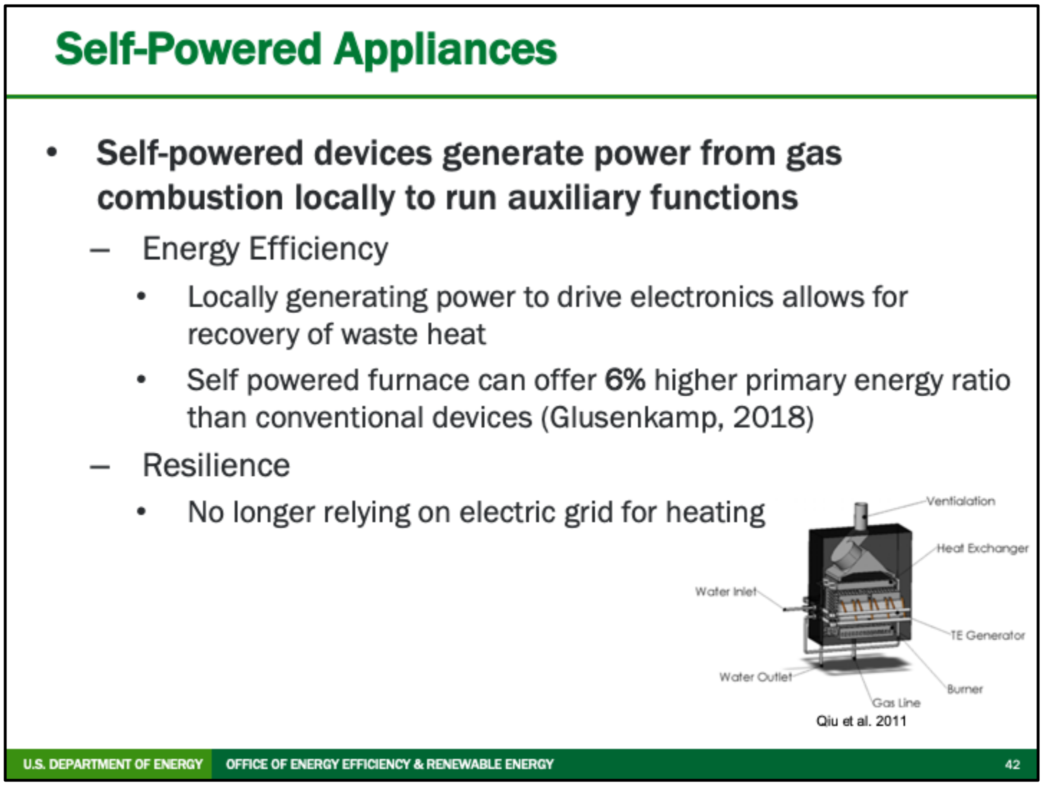
There's a project being funded at BTO right now that achieves efficiency gains by separately handling sensible and latent cooling. And if you had a power outage, you could conceivably drive dehumidification using solar energy passively obtained from the environment, thereby aiding people to shelter-in-place during high temperature events.

Thermal Storage

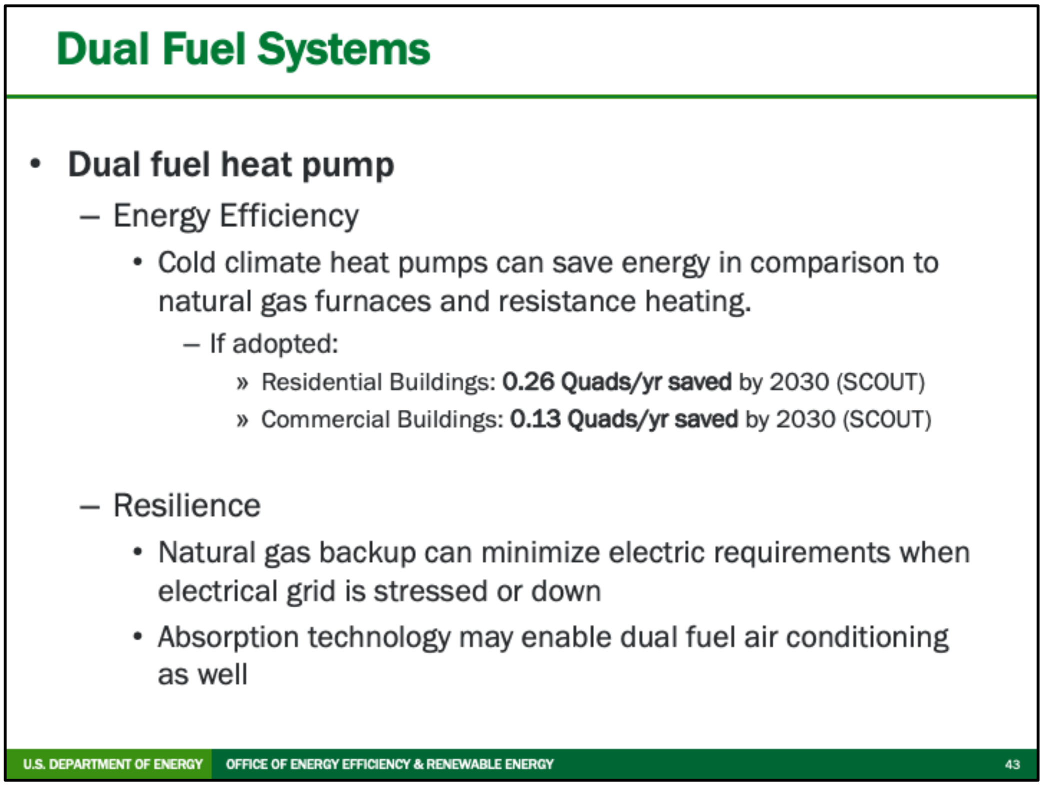
- **Store thermal energy for use during peak demand times**
  - Energy Efficiency
    - Shifting cooling load to night hours can lead to energy savings of **9-12%** (Powell et al. 2013, Deetjen et al. 2018)
    - Can aid in demand response for building flexibility
  - Resilience
    - Persistent thermal load after power outage can preserve food stores and prolong comfort



We already saw how useful thermal storage could be for **resilience** in the Florida nursing home study. But if you charge at night, you can get an energy efficiency benefit. And there's clearly a load shifting capability to this as well.

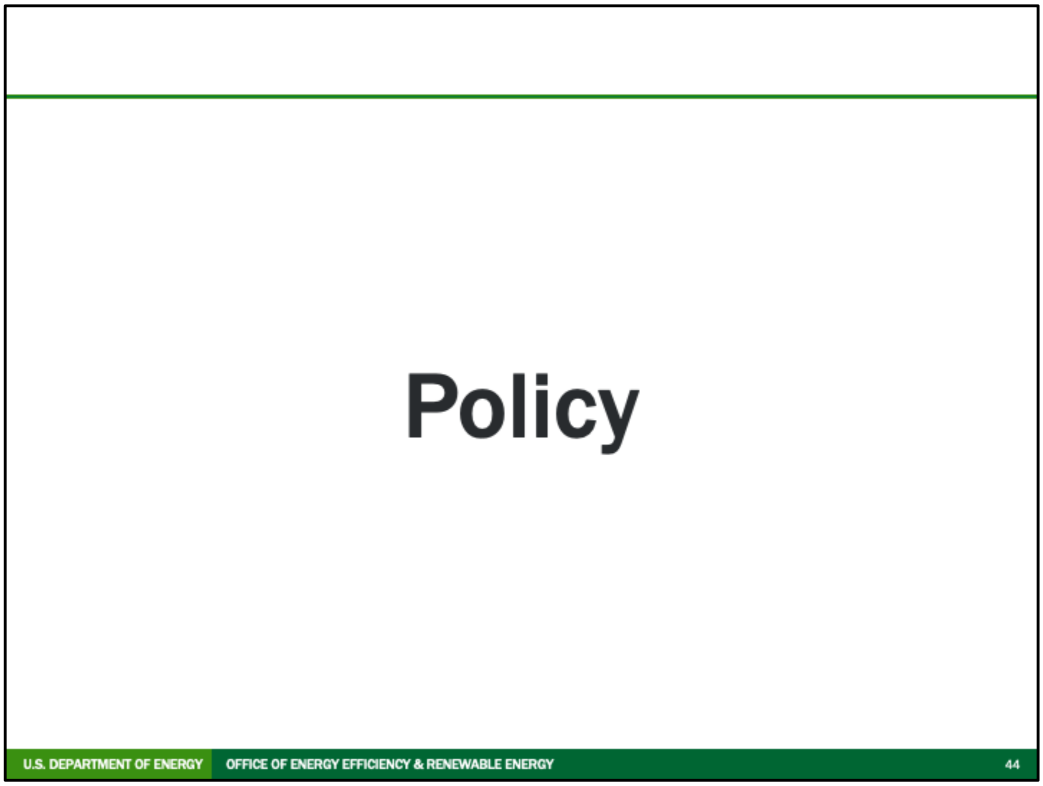


Just like CHP, we have can appliances that locally recover waste heat, and if these appliances are also fueled by natural gas…



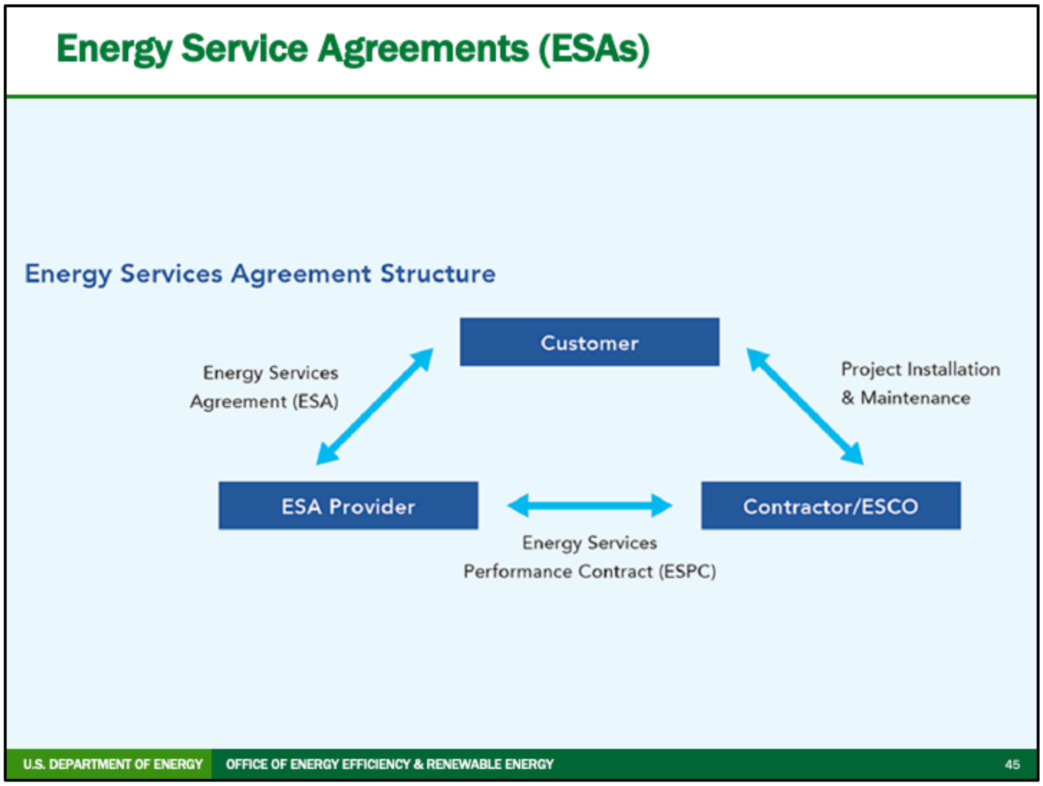
…you can utilize two different fuel streams, like the dual fuel cold climate heat pump described here. The heat pump technology gives you the energy savings, the the duel fuel system gives you the flexibility to engage in demand response without dropping all of your load, and have a second fuel stream adds resilience in the event that one of the other is lost.

But we’re eventually going to have to come to terms with a pretty substantial conflict, in that we often think of natural gas as the enemy of decarbonization, yet having another fuel source offers both a flexibility and a resilience benefit. So we need to figure out how to navigate this trade-off.



Let’s talk about how efficiency and resilience intersect from a policy perspective.

We want to get energy efficiency into as many buildings as possible. To do that we have building codes, appliance standards, voluntary labeling programs like ENERGY STAR. But we also have policy mechanisms to address up-front costs and payback periods of energy efficiency retrofits.

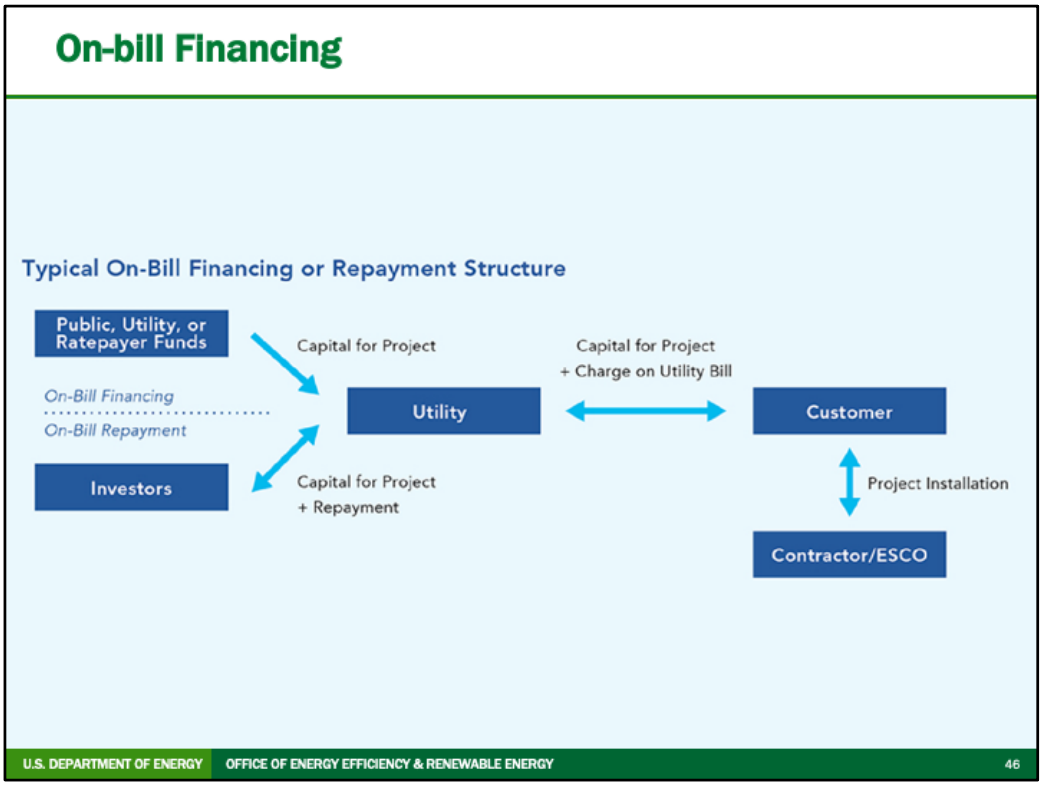


Some examples of these are **energy service agreements** (ESAs) where a service provider delivers energy-saving services using equipment it owns and operates.

***

"**Energy service agreements (ESAs**), a type of financing, are growing in popularity. Under an ESA, a service provider delivers energy-saving services using equipment it owns and operates. Recent projects include multimillion dollar investments by financial institutions (Citi and Generate Capital) and a large utility (National Grid). While most ESAs target large businesses and institutions such as hospitals and universities, at least one vendor now provides these services to homeowners.

"The examples above involve standardized types of measures (lighting, commercial building "retrocommissioning," and residential weatherization packages) that can be expected to result in a medium level of savings (roughly 10-25%). These standardized packages are offered to well-understood customer segments, helping to keep costs in check and making marketing easier. Thus far ESAs have not been used for deep retrofits that save 30% or more. However we talked to one company that aims to break this barrier by combining ESA financing with utility incentives, allowing the execution of larger projects and correspondingly larger savings. Not all customers will want to commit to 10- or 20-year contracts and not all will meet program requirements."



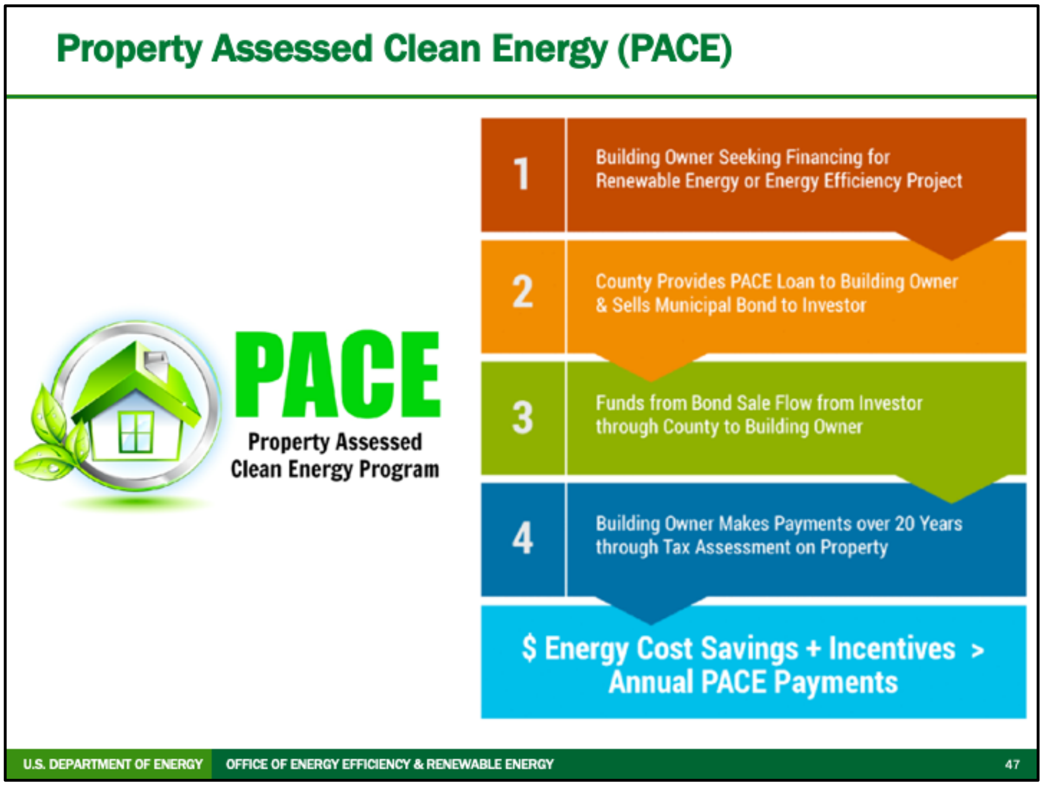
There's **on-bill financing** where where a utility will add a small, monthly line item to a customer's bill as the repayment vehicle for energy efficiency upgrades.

***

"More rural cooperatives and cities are now paying for energy efficiency upgrades with **on-bill financing**, which adds a small, monthly line item to a customer's utility bill as the repayment vehicle. Yet this financing has not scaled up quickly, prompting efforts in several states to break down its remaining barriers.

"On-bill financing programs can bring the up-front costs of energy efficiency upgrades down to zero, particularly when paired with rebates and incentives. They help customers make comprehensive energy improvements, with immediate savings on their energy bills. Because these loans are backed by a utility's borrowing power, they often have lower interest rates than market-rate lending options.

"So why isn't it taking off? Only a minority of utilities offer such programs. Many utilities are not interested in using their capital, are concerned about losses, or are reluctant to enter what they see as the banking business. These programs still have a long way to go to scale up. Even successful on-bill financing programs are reaching only a small percentage of customers."



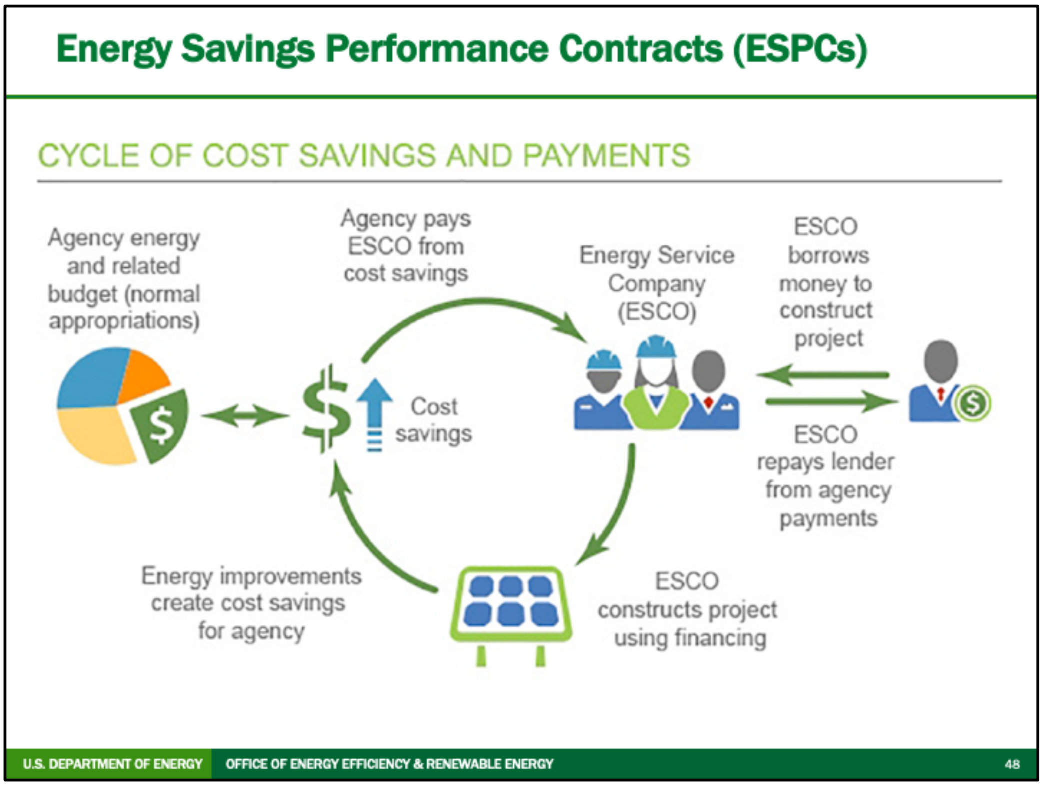
There's **PACE financing**, where efficiency projects are repaid as an assessment on a property's tax bill.

***

"PACE financing, used for energy efficiency and clean energy projects, is repaid as an assessment on a property's tax bill. This financing mechanism means the loan stays with the property rather than the customer, even if the property is sold. To date, 36 states and the District of Columbia have passed PACE-enabling legislation, the first step in giving customers access to this financing tool. Local governments in these states then establish programs, which may be run by third parties.

"The PACE market increased by 75% from 2016 to 2017, completing $251 million in funding by the end of 2017, according to PACENation, a private advocacy group. The impact is significant. Commercial PACE funding has cumulatively saved 6.3 billion kWh, which equals the electricity used by about 25,000 commercial office buildings each year.

"Unlike the commercial sector, the residential space still has important details to iron out. R-PACE has gained a major foothold in California, Florida, and Missouri, with more than $5 billion in financing across 220,000 home upgrades. But some policymakers are concerned that there are inadequate consumer protections in place to defend homeowners from predatory lending. California passed legislation in 2017 meant to address these concerns by placing residential PACE administrators under the regulatory oversight of a state agency, establishing licensing requirements for contractors, and adopting new underwriting guidelines that emphasize ability-to-pay standards."



There are **Energy Savings Performance Contracts** where a company known as an ESCO will design and finance an efficiency project, and they pay themselves based a fraction of the realized savings.

***

"So what we see if that there are a number of vehicles to get energy efficiency over the hurdle and into as many buildings as possible. So to me this begs the question 1) what are the comparable vehicles for getting resilience into as many buildings as possible, and 2) if we can demonstrate that energy efficiency provides resilience, can we use those vehicles as *additional* mechanisms to energy efficiency into buildings. To begin answering that question, I think it pays to look at the ways cities are approaching the issue of resilience.

"The US government is using one kind of financing tool for deep building projects – **Energy Saving Performance Contracts (ESPCs)**. With ESPCs, an energy service company (ESCo) designs projects, finances them, and oversees both their initial installation and ongoing maintenance. The ESCo is paid based on the actual energy savings."

FEMA requires All Hazards Mitigation Plans

Public Law 106–390
106th Congress

An Act

Oct. 30, 2000
[H.R. 707]

To amend the Robert T. Stafford Disaster Relief and Emergency Assistance Act to authorize a program for predisaster mitigation, to streamline the administration of disaster relief, to control the Federal costs of disaster assistance, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

Disaster Mitigation Act of 2000.

SECTION 1. SHORT TITLE; TABLE OF CONTENTS.

42 USC 5121 note.

(a) Short Title.—This Act may be cited as the "Disaster Mitigation Act of 2000".

(b) Table of Contents.—The table of contents of this Act is as follows:

TITLE I—PREDISASTER HAZARD MITIGATION

42 USC 5133 note.

SEC. 101. FINDINGS AND PURPOSE.

(a) Findings.—Congress finds that—

This is a portion of the Disaster Mitigation Act of 2000. Cities need to satisfy the conditions of this act in order to be eligible for disaster-related assistance from FEMA (Federal Emergency Management Agency).

FEMA requires that you check certain boxes

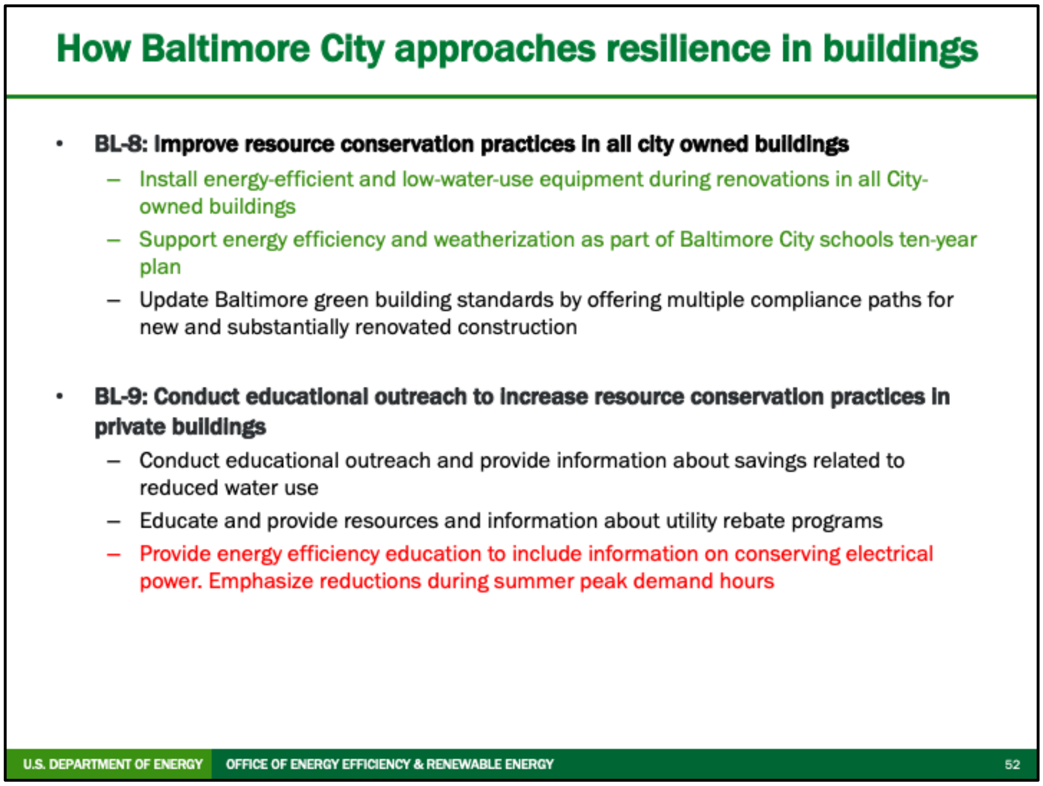
1. REGULATION CHECKLIST **Regulation** (44 CFR 201.6 Local Mitigation Plans)	Location in Plan (section and/or page number)	Met	Not Met
ELEMENT B. HAZARD IDENTIFICATION AND RISK ASSESSMENT			
B1. Does the Plan include a description of the type, location, and extent of all natural hazards that can affect each jurisdiction(s)? (Requirement §201.6(c)(2)(i))			
B2. Does the Plan include information on previous occurrences of hazard events and on the probability of future hazard events for each jurisdiction? (Requirement §201.6(c)(2)(i))			
B3. Is there a description of each identified hazard's impact on the community as well as an overall summary of the community's vulnerability for each jurisdiction? (Requirement §201.6(c)(2)(ii))			
B4. Does the Plan address NFIP insured structures within the jurisdiction that have been repetitively damaged by floods? (Requirement §201.6(c)(2)(ii))			
ELEMENT B: REQUIRED REVISIONS			
ELEMENT C. MITIGATION STRATEGY			
C1. Does the plan document each jurisdiction's existing authorities, policies, programs and resources and its ability to expand on and improve these existing policies and programs? (Requirement §201.6(c)(3))			
C2. Does the Plan address each jurisdiction's participation in the NFIP and continued compliance with NFIP requirements, as appropriate? (Requirement §201.6(c)(3)(ii))			
C3. Does the Plan include goals to reduce/avoid long-term vulnerabilities to the identified hazards? (Requirement §201.6(c)(3)(i))			
C4. Does the Plan identify and analyze a comprehensive range of specific mitigation actions and projects for each jurisdiction being considered to reduce the effects of hazards, with emphasis on new and existing buildings and infrastructure? (Requirement §201.6(c)(3)(ii))			
C5. Does the Plan contain an action plan that describes how the actions identified will be prioritized (including cost benefit review), implemented, and administered by each jurisdiction? (Requirement §201.6(c)(3)(iv)); (Requirement §201.6(c)(3)(iii))			
C6. Does the Plan describe a process by which local governments will integrate the requirements of the mitigation plan into other planning mechanisms, such as comprehensive or capital improvement plans, when appropriate? (Requirement §201.6(c)(4)(ii))			
ELEMENT C: REQUIRED REVISIONS			

Meeting these conditions means you literally have to check off these boxes. There's a few steps. You need to identify what hazards your city is exposed to, how vulnerable you are to those hazards, a risk assessment, and a mitigation strategy. In the end, the city produces a report that contains 231 recommended actions in here. I want to focus just on the ones that deal with buildings.

How Baltimore City approaches resilience in buildings

- BL-1: Develop and implement hazard protections for critical facilities including hospitals, fire stations, police stations, hazardous material storage sites, etc.
- BL-2: Enhance building codes that regulate buildings within floodplains or near the waterfront
- BL-3: Strengthen city zoning, floodplain and construction codes to integrate anticipated changes in climate
- BL-4: Update a list of flood prone and repetitive loss buildings to consider for acquisition
- BL-5: Improve wind resiliency of new and existing structures
- BL-6: Evaluate various seismic design enhancements using prototypical Baltimore City building types
- BL-7: Retrofit existing buildings in the designated Flood Area to increase resiliency
- **BL-8: Improve resource conservation practices in all city owned buildings**
- **BL-9: Conduct educational outreach to increase resource conservation practices in private buildings**
- BL-10: Use HAZUS-MH computer modeling to determine losses generated by coastal storms

These are the recommendations that to do with buildings. Of these, 2 have something to do with energy efficiency.



The actions in green all talk about energy efficiency:

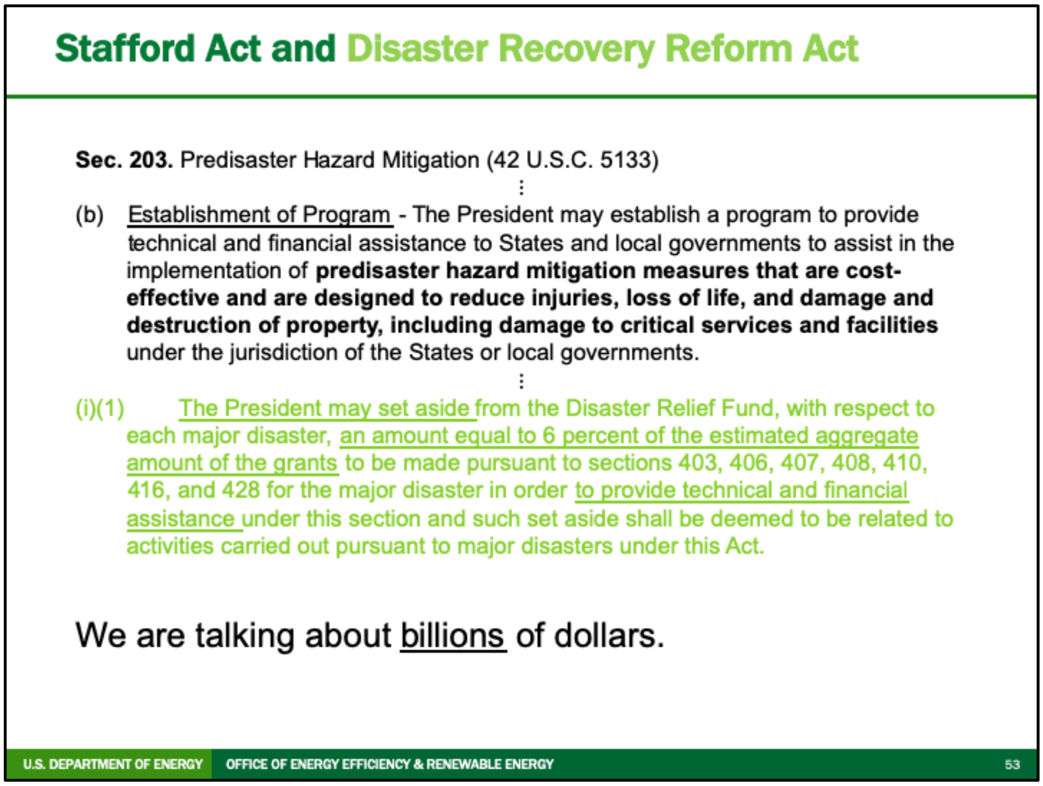
- Energy efficient equipment during renovations
- Weatherization of schools

The action in reds talks about load flexibility. And there may be efficiency plays in the other items in black as well, depending on how they are implemented.

This is a major American city telling FEMA, our nation's preeminent resilience agency, that energy efficiency and load flexibility are important components of its resilience strategy. Cities want this. And it's an opening that we can take advantage of.

But if you read the full report, you'll notice there isn't a lot of detail about how to implement these recommendations. There's no reference to energy efficiency in residential or commercial buildings. There is no reference to energy benchmarking or building portfolio standards. There's no granularity about particular types equipment or places where energy efficiency may compromise resilience. There is no reference to any of the financing mechanisms like PACE that I mentioned earlier. And the truth is many of these offices are extremely bandwidth limited. So I would contend that this is a place where we as members of the scientific community can step in and offer that detailed level of technical assistance. Places like NYC and Washington DC are very much on top of this, but there's still a lot of work to be done in many other areas of the country.

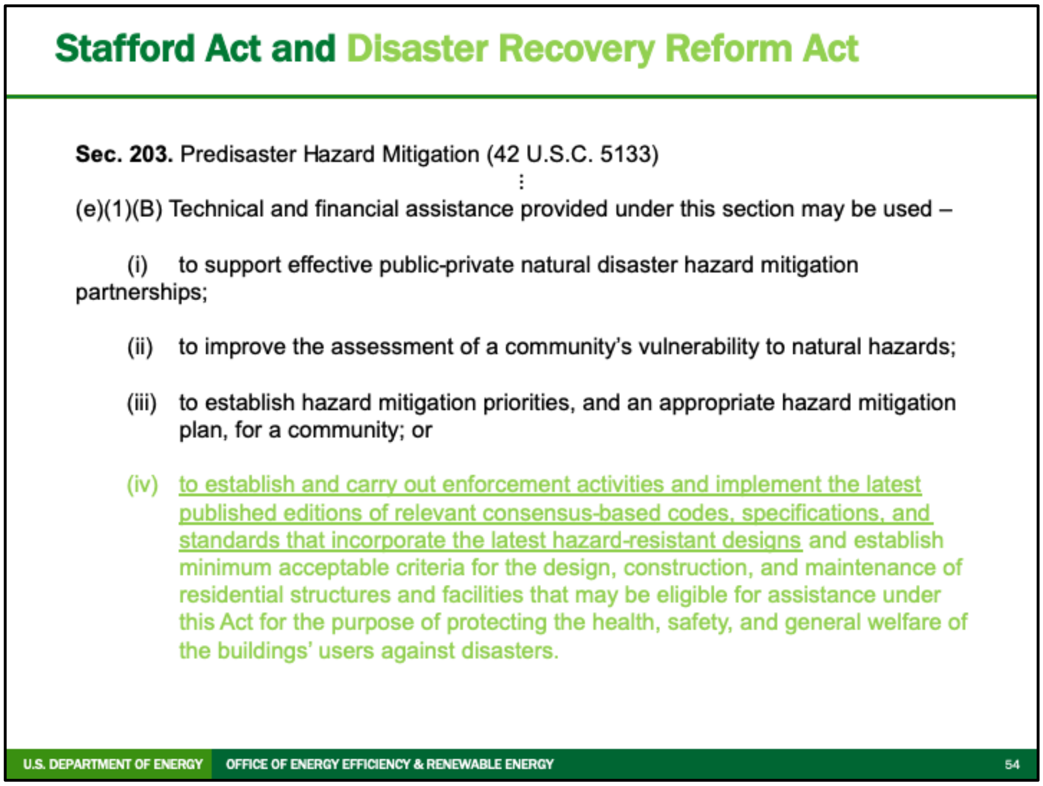
But that's the city level. Let's flip this around and see how the federal government thinks about this.



The Stafford Act lays out the system through which the federal government, in conjunction with states, responds to disasters. It was passed in 1988, but there was a "game changing" amendment in October 2018. I want to read through some of the new language on predisaster mitigation highlighted in green.

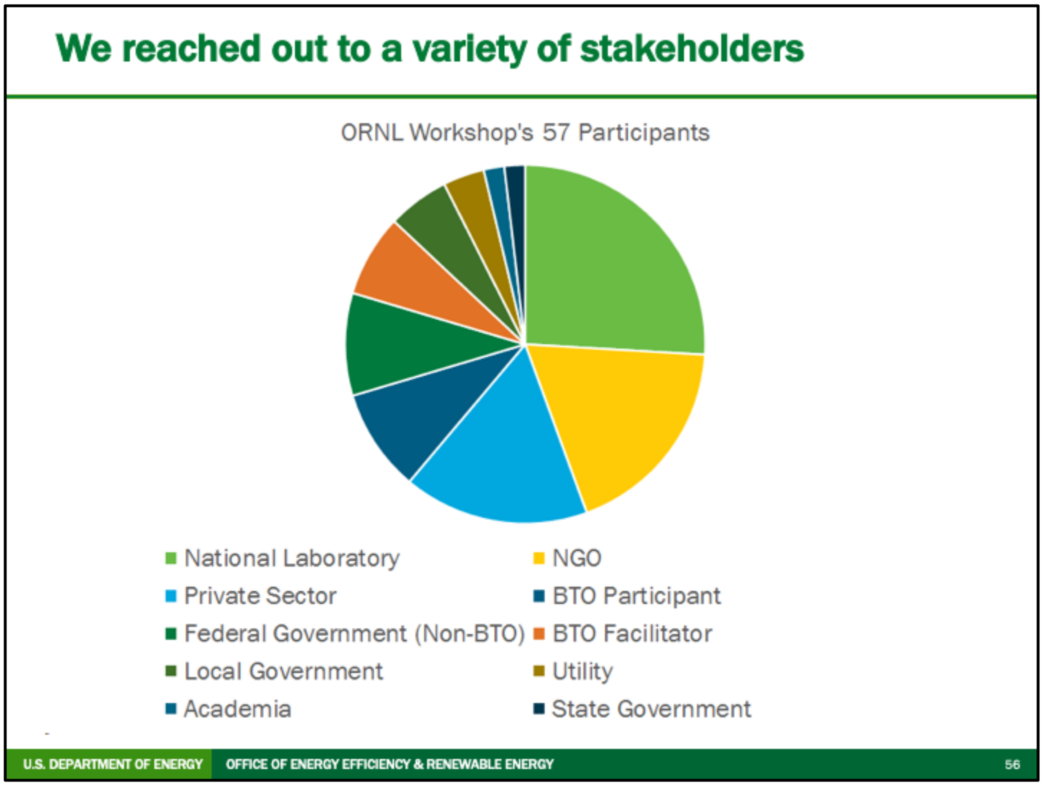
[FEMA has $250 million allocated for PDM this year.] After Hurricane Katrina, $53 billion went to FEMA's Disaster Relief Fund. 6% of numbers like that is an absolutely massive amount of money. There's a worry that states won't know what to do with this money when it lands in their lap. It's an opportunity to advance both resilience and energy efficiency at the same time, as long as we figure out how to co-optimize them.

The other thing is that – when we try to justify something like energy efficiency to FEMA, it needs to pass a rigorous cost-benefits test. But that would require that we quantify how valuable energy efficiency is as a resilience resource. And that's not easy to do. It's also something they're not thinking about now. They just held a series of webinars a few weeks ago basically asking stakeholders, "How should we be implementing the DRRA?" My recommendation would be to do our homework, establish the value of energy efficiency, walk in parallel, have conversations, then eventually merge.

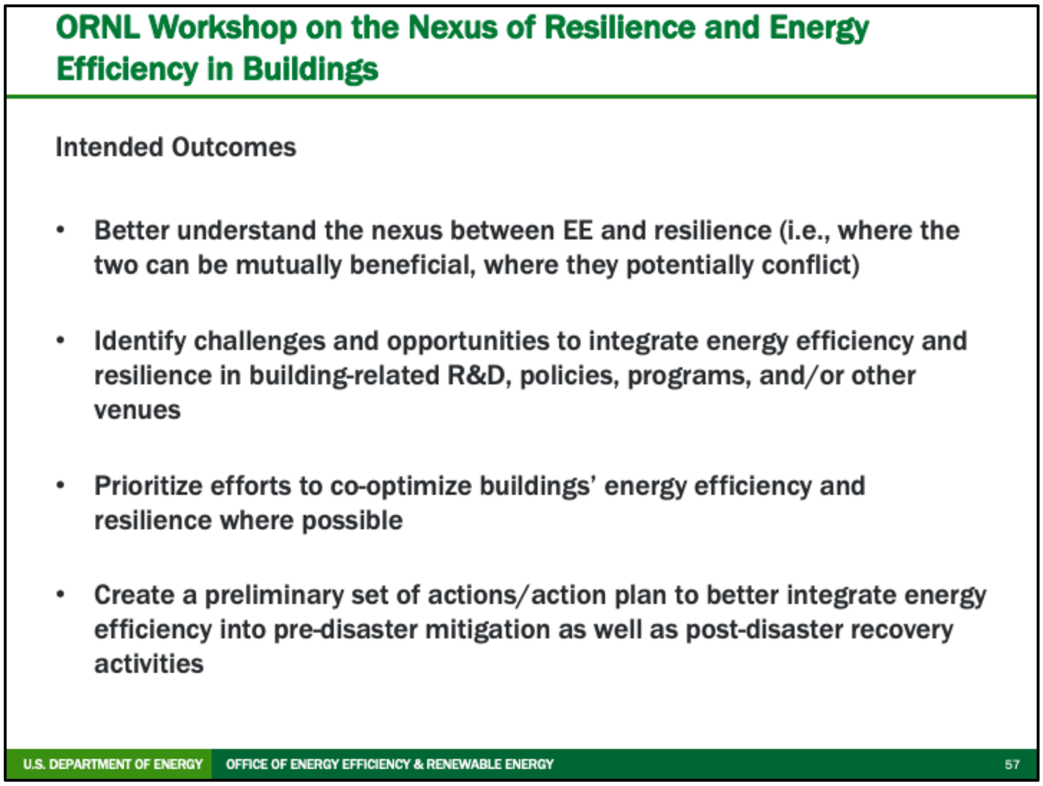


Right now FEMA interprets this to mean the latest editions of the IECC and ASHRAE 90.1 residential and commercial codes. As I mentioned earlier, we've made good progress on resilience in construction, but not so much on operational resilience. So the question, "What is a resilient building code?" is still not sufficiently answered.

Workshop on the Nexus of Resilience and Energy Efficiency in Buildings. So on June 12 and 13th we gathered a number of stakeholders.



You can see the distribution of people who attended. This diversity was intentional. We understand that resilience is a holistic issue. There are a number of value streams. And we wanted their views to be represented.



The full report will be released in August 2019, but I wanted to give you a preview of what they came up with.

Some ways efficiency/flexibility and resilience complement each other

- High R-value insulation increases the chance of thermal survivability
- On-site solar PV with DC circuits/microgrids can save energy and offer backup power
- Flexible storage supports electrical loads
- Anti-shatter window films could reduce heat gain
- Increased attic insulation improves energy efficiency and risk of wind damage
- LED lights save energy and require less energy as a critical load
- ECMs can subsidize more expensive resilience measures under certain contract types
- Separating sensible and latent loads can save energy and utilize different fuel streams
- Advanced controls facilitate both energy savings and intelligent operation of critical loads
- Natural gas offers efficient site-to-source advantages and a reliable non-electric energy stream
- Combined heat and power
- Mass timber (CLT) compliments resilience of buildings and forests (through land management and resource utilization)
- Air sealing benefits indoor air quality
- Load flexibility aids grid black starts

Some ways efficiency/flexibility and resilience conflict with each other

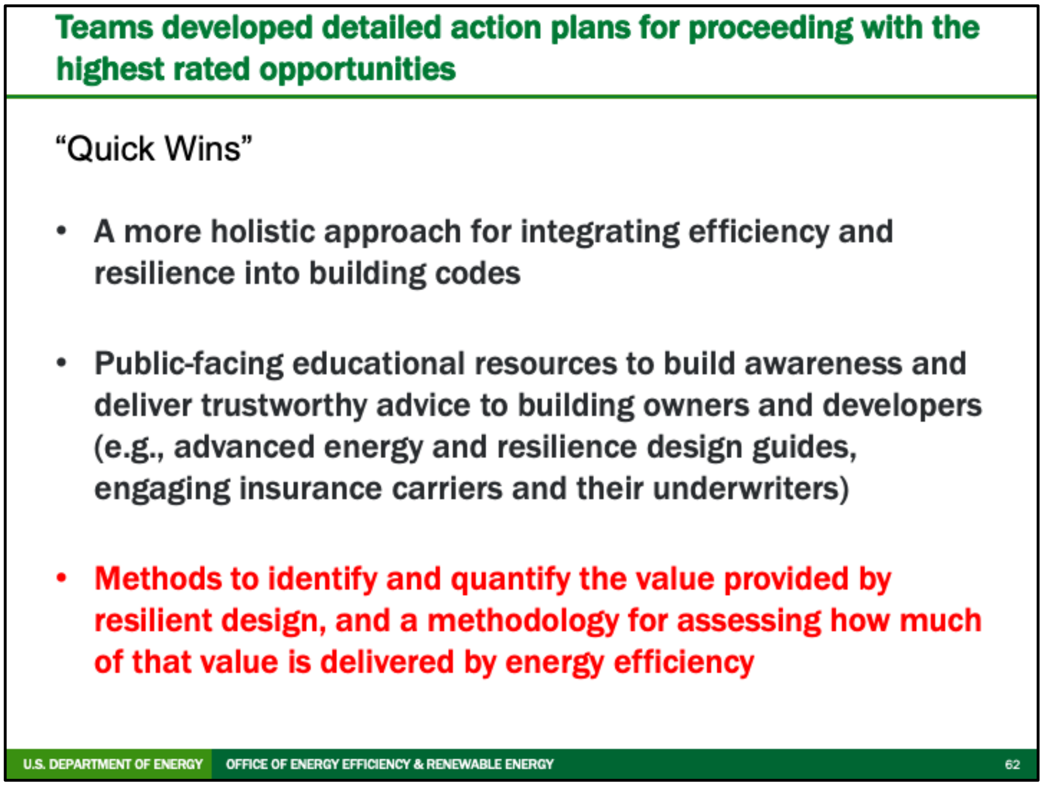
- Unvented attics susceptible to severe winter weather, while vented attics susceptible to wind and fire
- Thermal survivability may be compromised if envelope is too tight to eject excess heat
- Electrochemical batteries pose fire or explosion hazard
- Connected devices increase cybersecurity risk
- Efficiency enabled by connectivity may introduce vulnerabilities if Wi-Fi goes out
- Natural ventilation may reduce building's structural strength
- Best insulation doesn't necessarily offer best fire/toxicity properties
- Tighter envelope impedes building's ability to dry out after an intense water event
- Advanced wall assemblies may be more vulnerable to fire, flood, impacts, and pests
- Shading overhangs are susceptible to wind
- Complex building controls may make it harder to restart building systems after a disruption
- Advanced efficiency measures more difficult to restore/rebuild after a regional disaster
- Systems may fail when one of multiple components (EV, solar PV, home automation, HVAC) is compromised during a disruption
- Interconnection agreements for solar PV connections can create resilience conflicts in that power can't be supplied

Participants identified challenges to co-optimizing energy efficiency, flexibility, and resilience

- Costs and benefits unknown
- Programs, policy, funding, etc. operate in siloes
- Lack of time, money, and planning
- Broad scale implementation will struggle without codes setting the floor
- Utilities inability to control behind-the-meter storage
- Raising awareness, changing mindsets, and providing training for designers, contractors, and owners
- Lack of adequate modeling tools
- Lack of low-carbon concrete binders
- Complexity
- Inability to route energy to critical loads
- Split incentives

Participants identified opportunities to co-optimize energy efficiency, flexibility, and resilience

- Development of rating systems that can have a market impact
- Creation of hazard-based energy efficient codes and standards
- New professional certifications
- Design guides and educational websites
- Leveraging disasters as opportunities (pre- and post-)
- Utility transparency in grid planning to encourage DERs, energy efficiency, and flexibility
- Workforce training
- Pilot projects with homeowners and insurers
- Comprehensive structural guidelines
- Raising awareness
- Expansion of financial vehicles
- Development of smarter controls, equipment

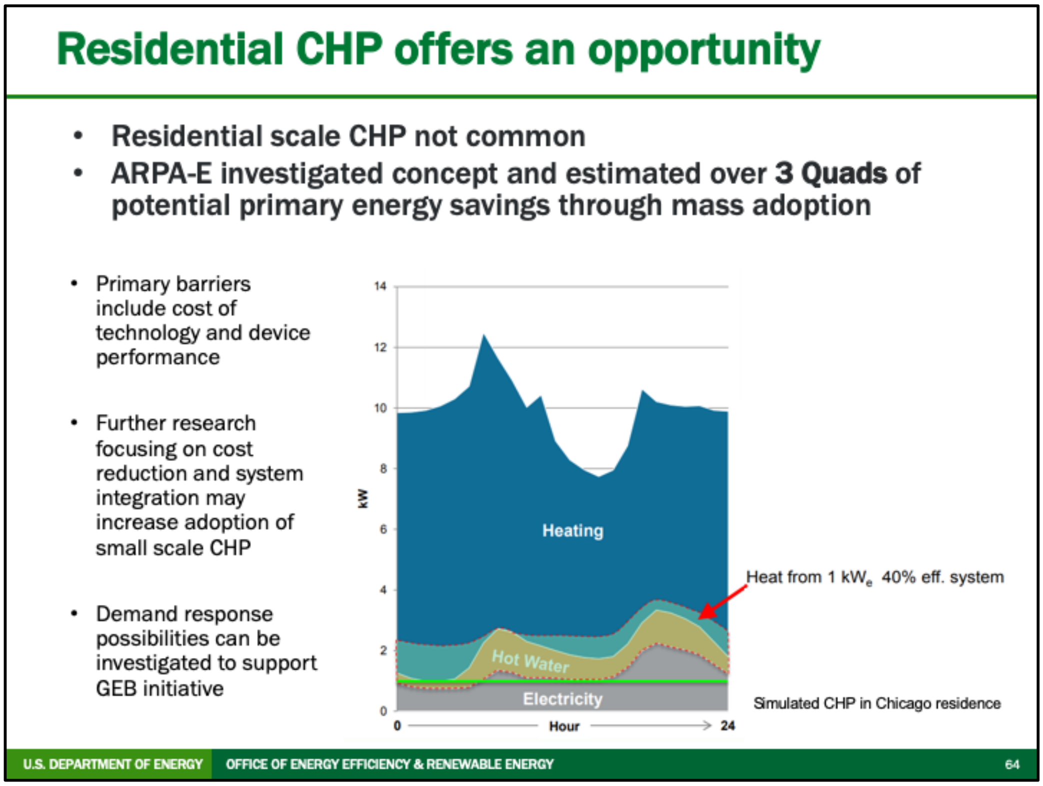


In my opinion, the final bullet is one of the most important things we can be considering right now. It allows us to better meet the requirements of agencies like FEMA and HUD. For both businesses and homes this can change the ROI for energy efficiency improvements. It may get energy efficiency in places it wouldn't otherwise be if that value wasn't recognized.

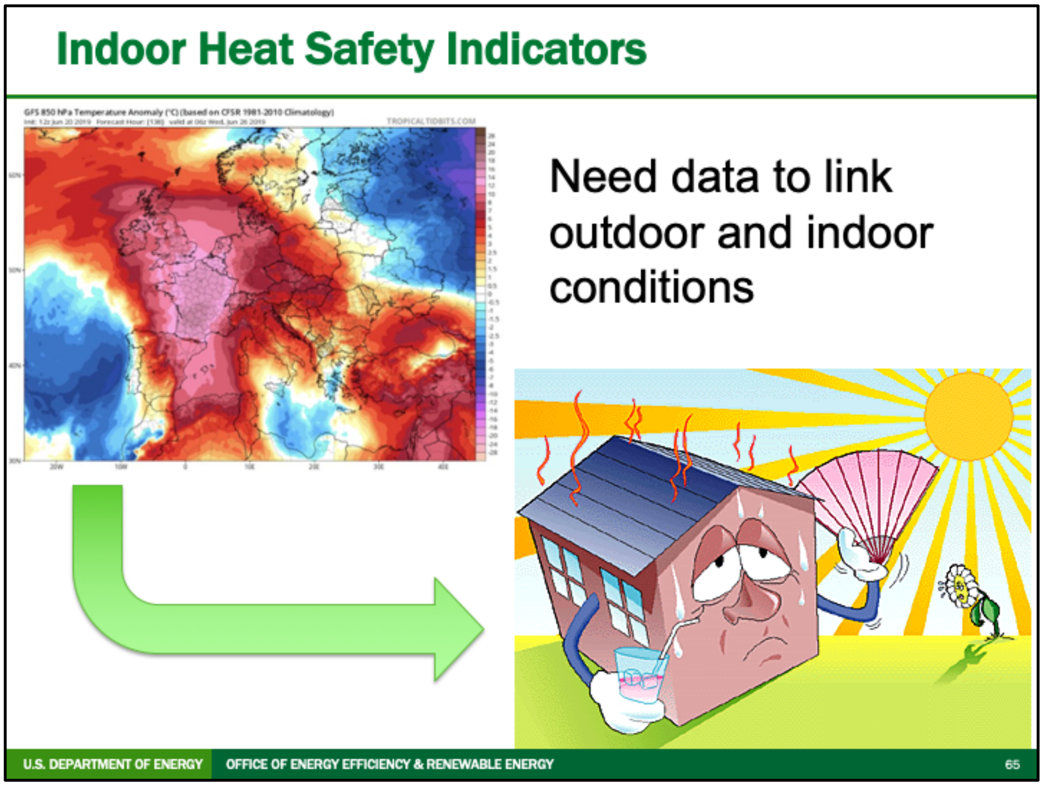
Teams developed detailed action plans for proceeding with the highest rated opportunities

Longer-term, high-impact actions

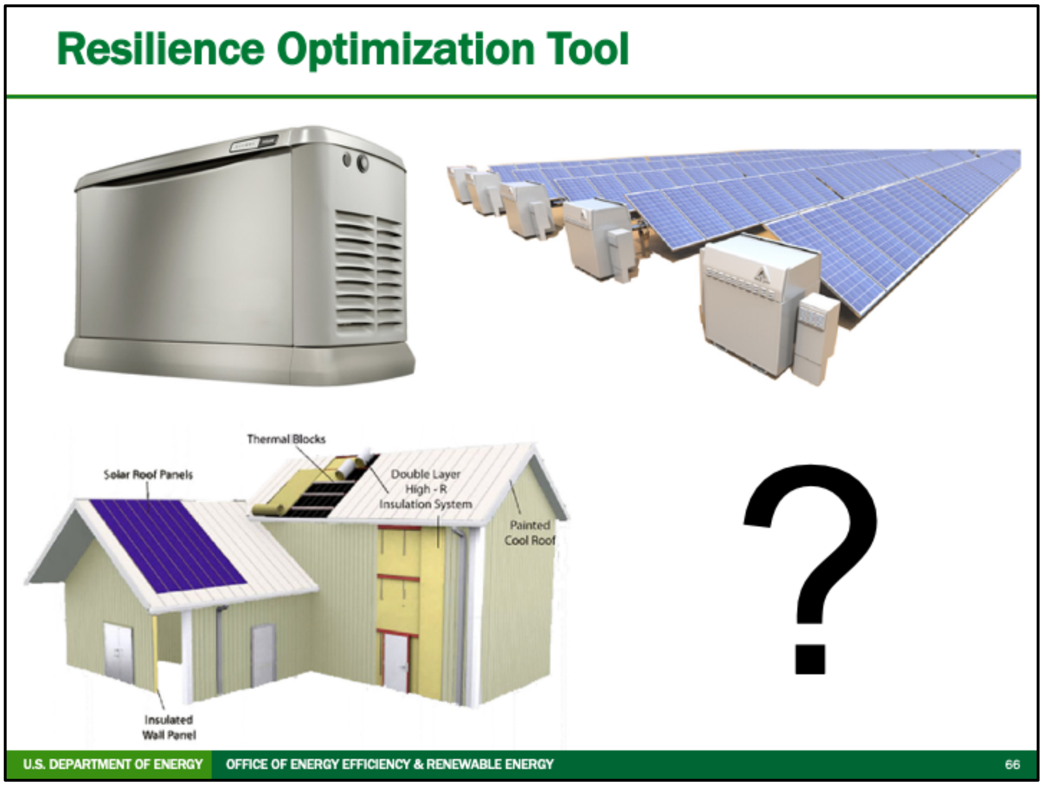
- **Next-generation HVAC/RTU/HW that are efficient, grid-interactive, and support resilience**
- **Tools that characterize the linkages between energy efficiency, load flexibility, and resilience**
- **Resilience metrics and asset rating systems**
- **New models to optimize efficiency, flexibility, and DERs to deliver energy savings, grid benefits, and resilience**



And more food for thought: opportunities for residential CHP. Right now it's not common, but ARPA-E analysis shows the potential for huge energy savings. There's also a Scout analysis underway to assess the technical potential of CHP in buildings, including residential buildings. And from the best we can tell, this is a technically possible – we just need to get the costs down. But again, another way to justify the cost is tapping into an additional value stream – like resilience.



We need a data collection effort to gather the indoor environmental conditions of buildings during major disruptions like power outages, heatwaves, or other disruptions that impact thermal resilience. The goal would be the creation of an analysis tool that can predict and calculate major indoor heat events using a combination of building energy models, environmental conditions (internal and external), and estimated personal variables that could impact thermal comfort (e.g., metabolism, age). I envision that this analysis could be used to identify vulnerable buildings and populations, and to launch targeted efficiency/resilience interventions. We could also use this to inform improved building designs and performance optimizations, as well as to assess which heat metrics are most relevant for thermal survivability.



We know that there are a variety of resources that one could use to achieve resilience including standalone generators, solar plus storage, or improvements in energy efficiency, the ideal combination for a building owner or operator is not always clear. We can also talk about how to solve these problems in the context of multi-building systems and microgrids. We also want equipment/buildings that can have "soft fails" and "soft starts". iPhones go into low-power modes when battery is low, for example. Same for moderns cars, trucks, and SUVs that have "engine failsafe modes" or "limp modes".

Consider energy efficiency and resilience holistically, ideally with respect to the Sustainable Development Goals (SDGs).

Contact Info

Mike Specian

AAAS Science & Technology Policy Fellow

Department of Energy Building Technologies Office

michael.specian@ee.doe.gov

mspecian@gmail.com

www.mikespecian.com