



United Technologies

Sustainable and Energy Efficient Urban and
Built Infrastructure Development: Opportunities
and Challenges in Systems Engineering

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United Technologies Research Center

2010 MIT SDM Conference on Systems
Thinking for Contemporary Challenges

October 21-22, 2010

Cambridge, MA

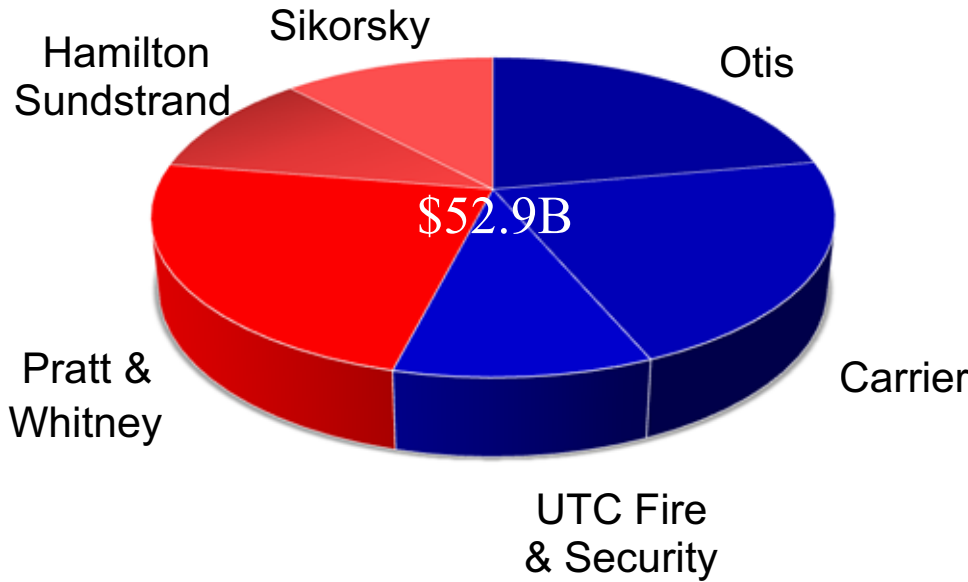
KEY POINTS

- Energy use in buildings matter
 - Efficiency offers the best means to substantial reduction in energy use
 - External drivers defining the market – building energy performance labeling, auditing and reporting

- Highly energy efficient buildings exist
 - 50-70% energy use reduction in buildings is feasible with existing technologies
 - Systems approach to design and operations is key
 - Barriers to market adoption are speed and quality of design and associated costs
 - Systems engineering challenges exist in all phases of building delivery

- System design and delivery methodologies can drive and persist aggressive energy use reduction
 - Integrated design methods and engineering tools
 - Methodologies for extensive validation and verification of system implementations

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aerospace systems



building systems

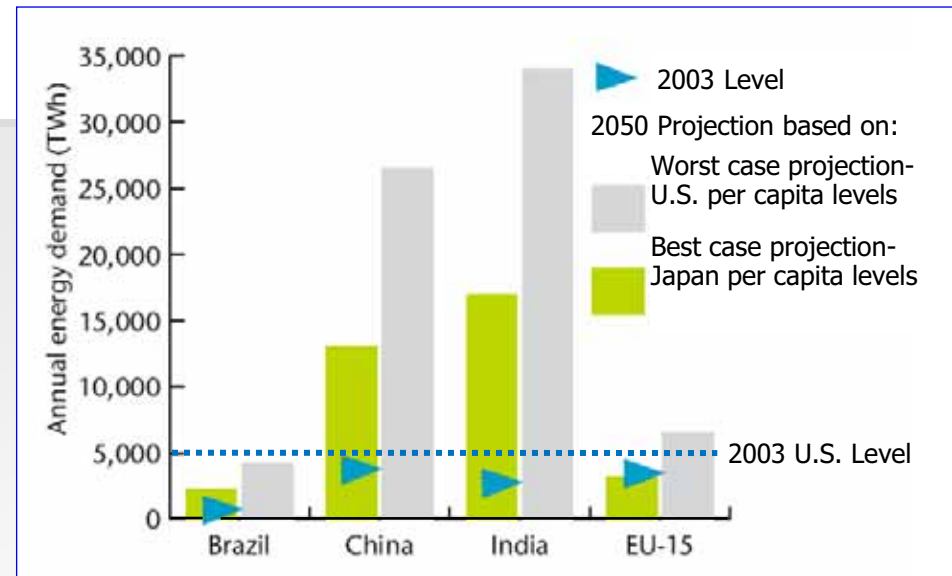
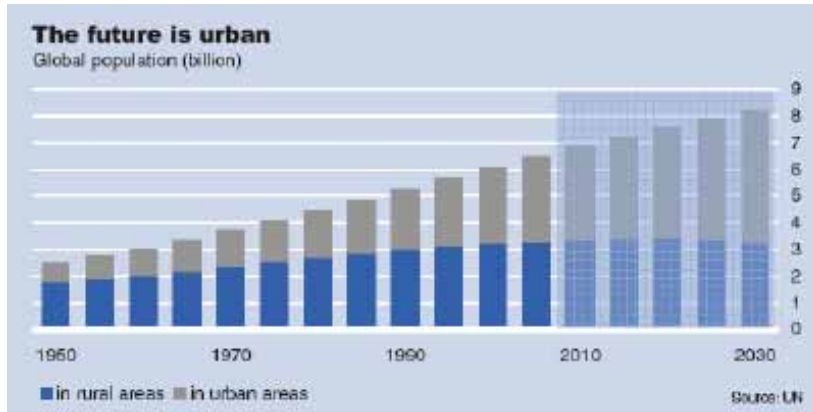


power solutions



The Energy Demand Problem in the Built Infrastructure...

Urbanization and Energy Demand

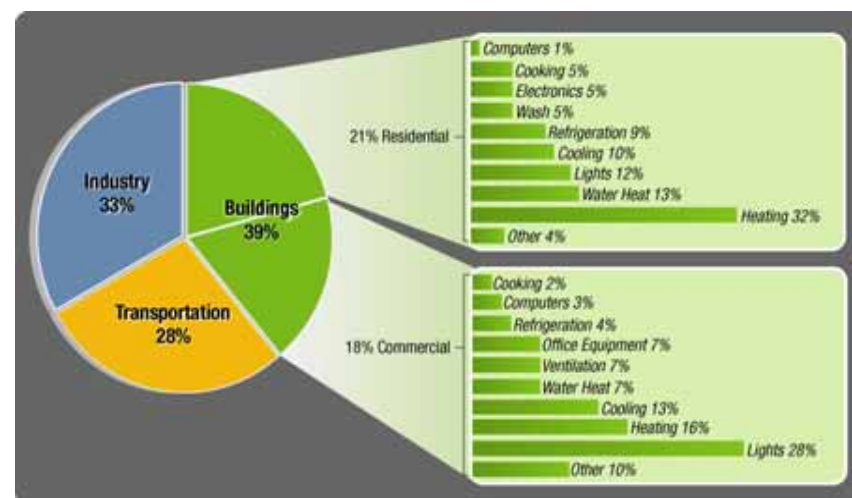
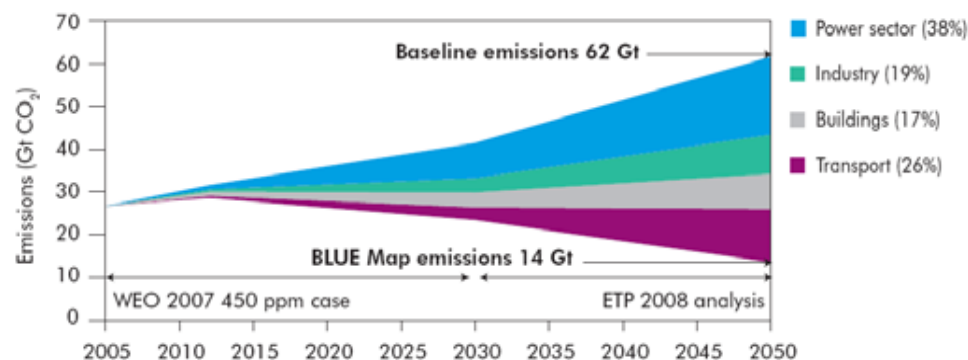


“China is building a new Japan every three years and a new Europe every ten”

- The bulk of the increase in global energy-related CO₂ emissions is expected to come from cities, their share rising from 71% in 2006 to 76% in 2030 as a result of urbanization
- In China alone...
 - 1 billion people will live in cities by 2030
 - 40 billion square meters of office space will be built in 5 million buildings. 50,000 of these buildings could be skyscrapers (the equivalent of 10 New York Citys)
- In the U.S., half the buildings needed by 2030 do not exist

Building Energy Use Matters

IEA Estimates of Emissions Abatement by Source/Sector



Sector	2050 BAU	2050 Blue MAP	Reduction
Power generation	--	--	18.2
Industry	23.2	5.2	9.1
Buildings	20.1	3.1	8.2
Transport	18	5.5	12.5
Total	62	14	48

Buildings consume precious resources:

- 39% of total U.S. energy, similar worldwide
- 71% of electricity & 54% of natural gas in U.S.

Buildings produce 48% of U.S. Carbon emissions and nearly 40% worldwide

75% reduction in Building Sector Energy Use Required

**What Will It Take
and
Is It Feasible?**

WBCSD: Energy Efficiency in Buildings Project



Four year project motivated by increasing global energy crisis

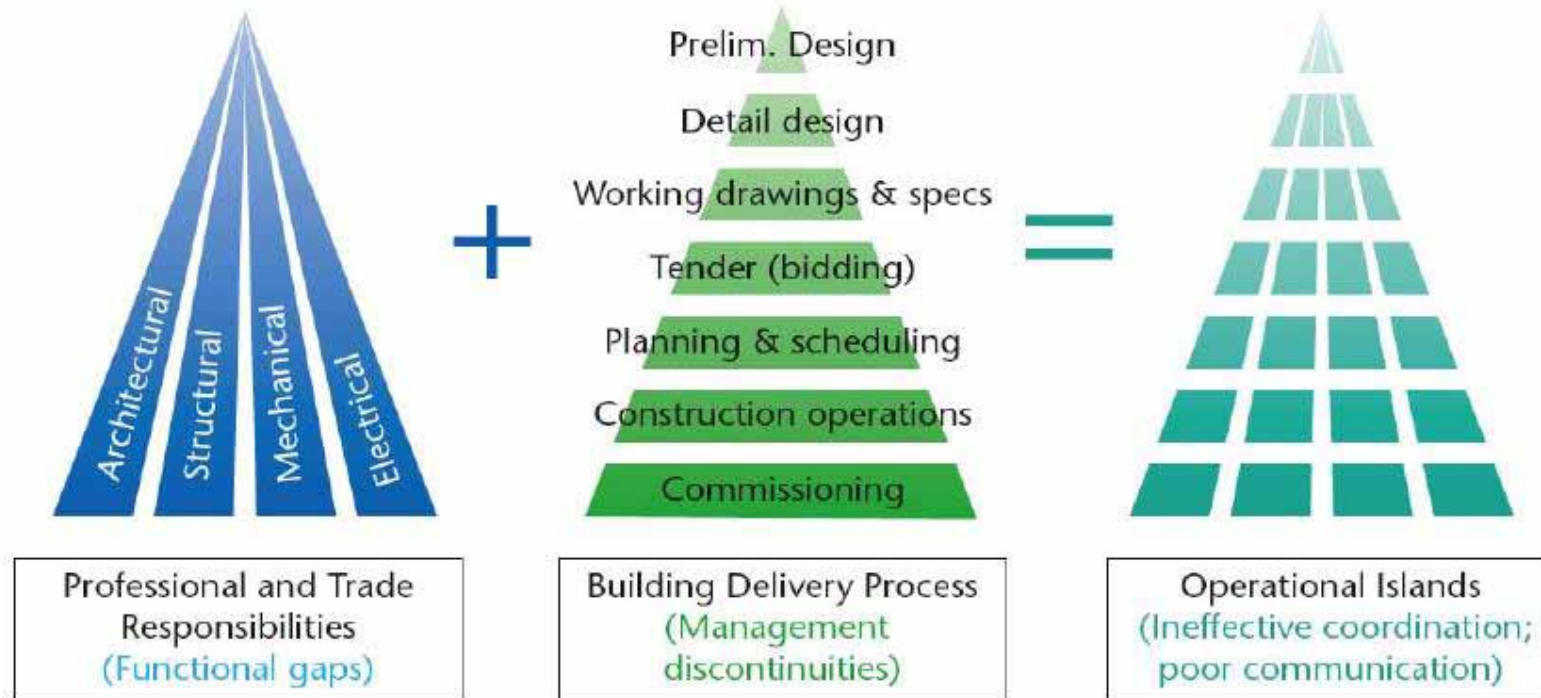
Must transform the way buildings are designed, constructed and operated

Global market perception study revealed market failures

See www.wbcسد.org for more information



Complexity in Building Delivery Practices



Need:

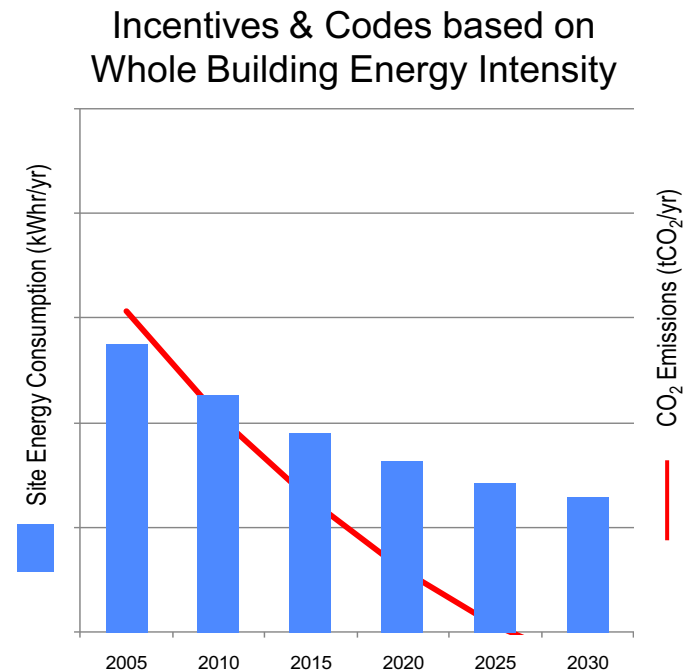
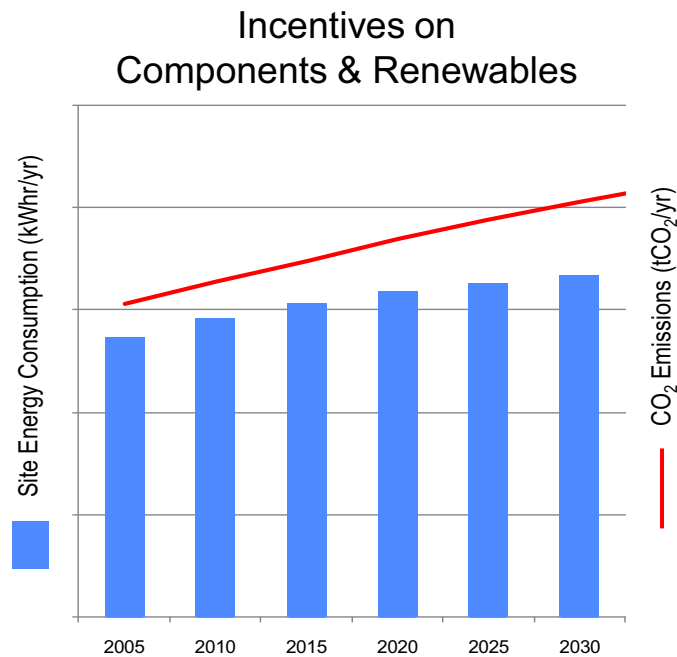
- Tools to integrate process & communities
- Tools to integrate building design and operations
- Align incentives

Courtesy: World Business Council for Sustainable Development (WBCSD) Report on Energy Efficiency in Buildings, July 2008

Building Energy Economic Policies

Economic policies on whole-building energy-intensity are effective

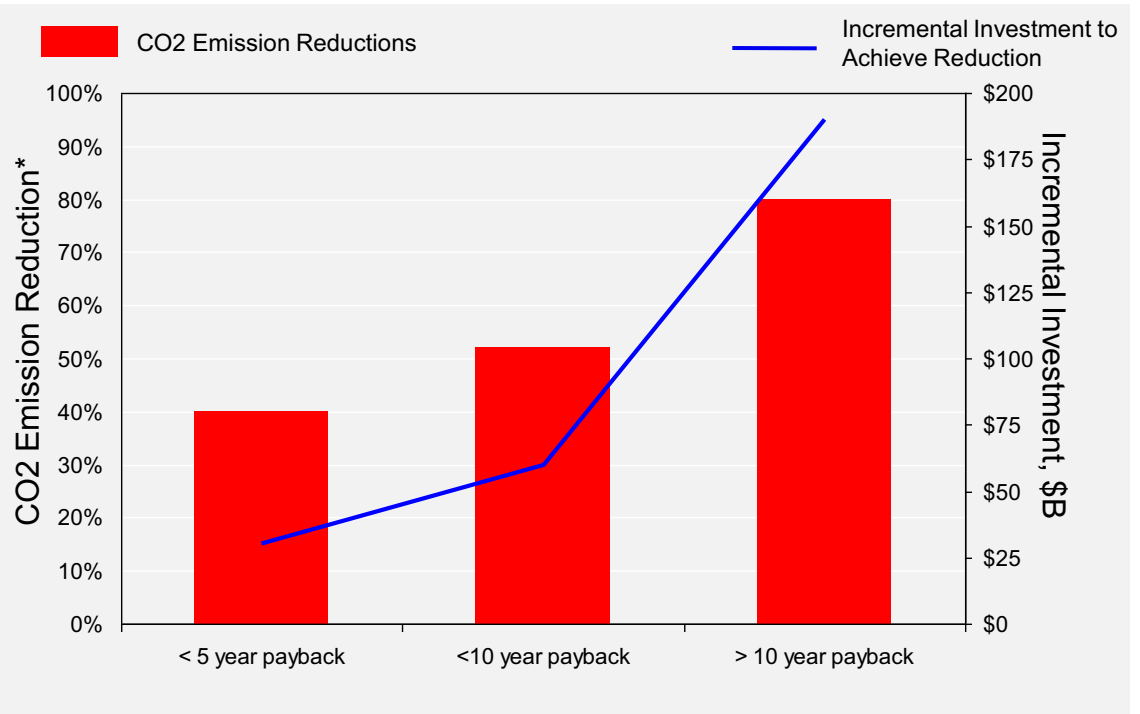
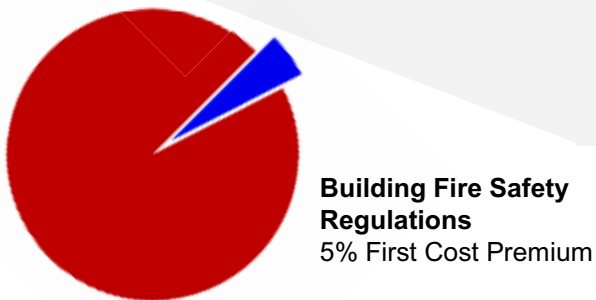
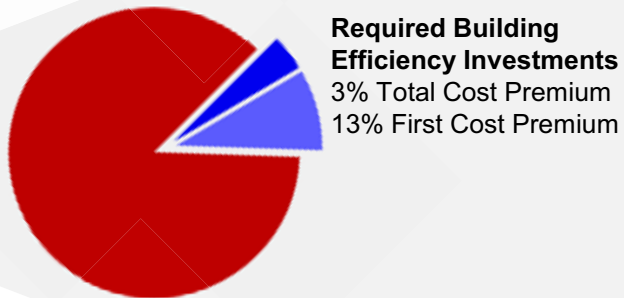
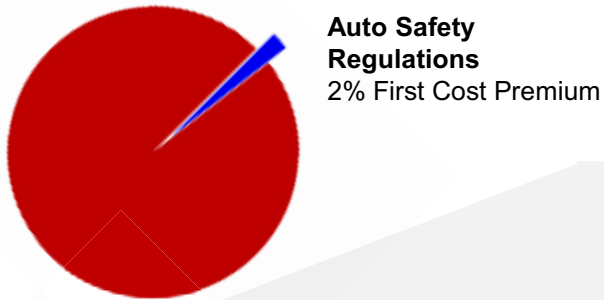
World Business Council for Sustainable Development
Energy Efficiency in Buildings Project



(Analysis is an example result for single family residences.)

Economic Assessment – US Only

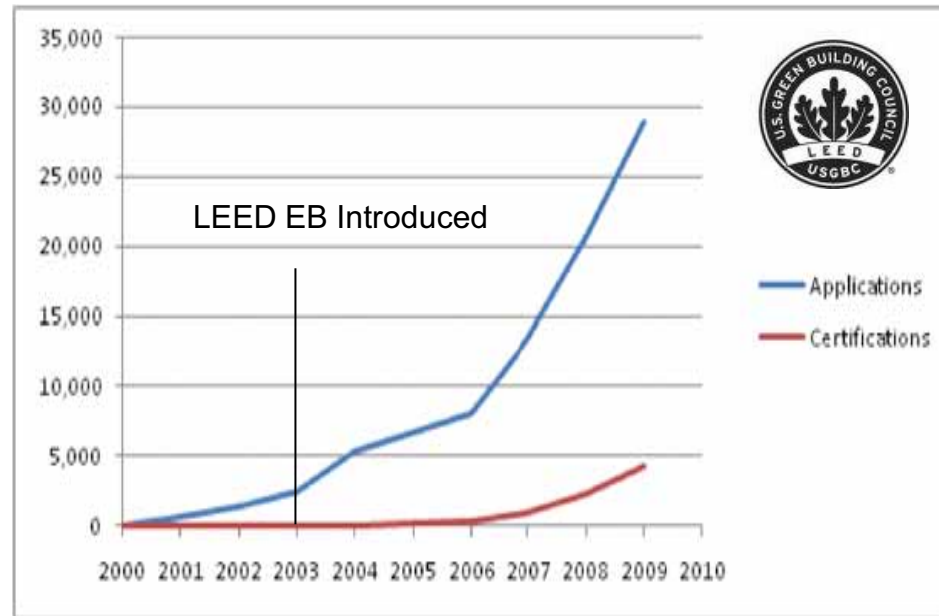
Energy use reductions economically viable



*reflects scale up of buildings contribution to IEA Blue Map scenario, 2050

Market and Regulatory Landscape Changing... Necessitating A Systems Approach

Rapidly Evolving Landscape



U.S. Market Attributes

- LEED Performance: Make Energy Use Visible
- Certified buildings must recertify at least once every 5 years to maintain LEED-EB status” (2009)
- LEED-NC requires measured performance (2010)

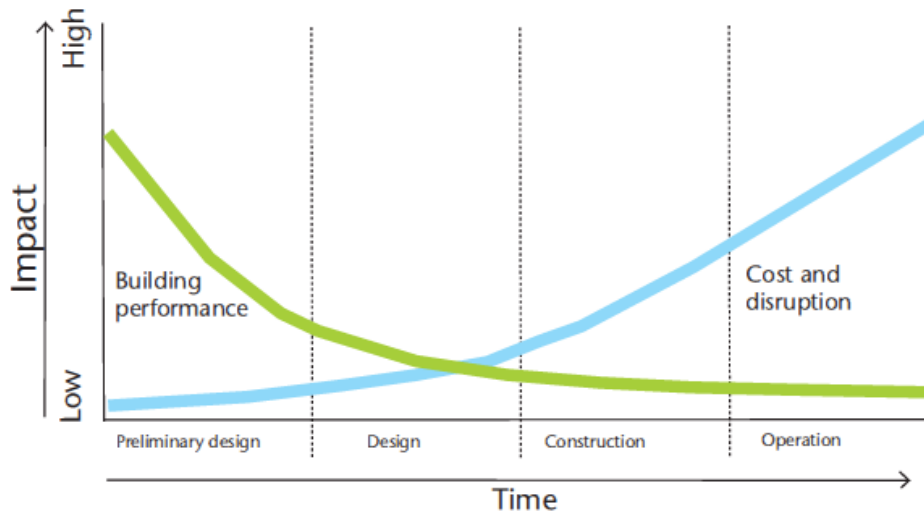
EU Market Attributes

- Energy Use Monitoring : Make Energy Use Visible
 - EU Buildings Directive (EPBD) 2002
 - Building Energy Performance Requirements in Germany Tightened by 30% (2009)
- EU-wide regulation for energy compliance
 - All New Buildings to be Net-Zero by 2018 (EU legislation)

China Market Attributes

- Energy Conservation Regulations 2007
- Poor adherence driving reporting requirements

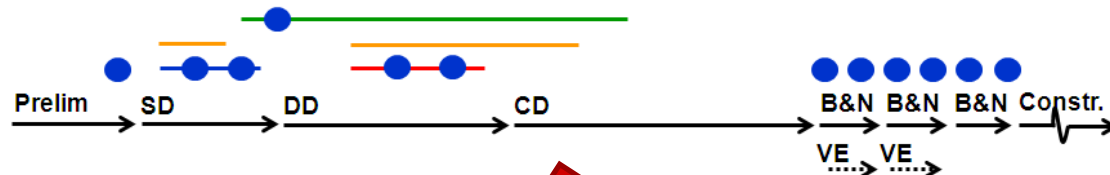
Integrated Design Process Key to Improving Whole Building Energy Performance



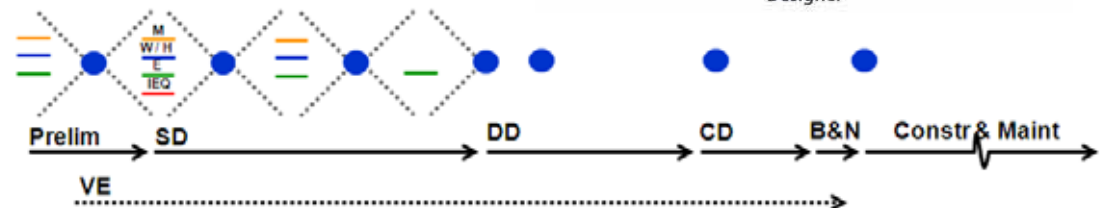
Impact from earlier use of Integrated Design Process

Source: Solidar, Berlin Germany

Linear Design Process

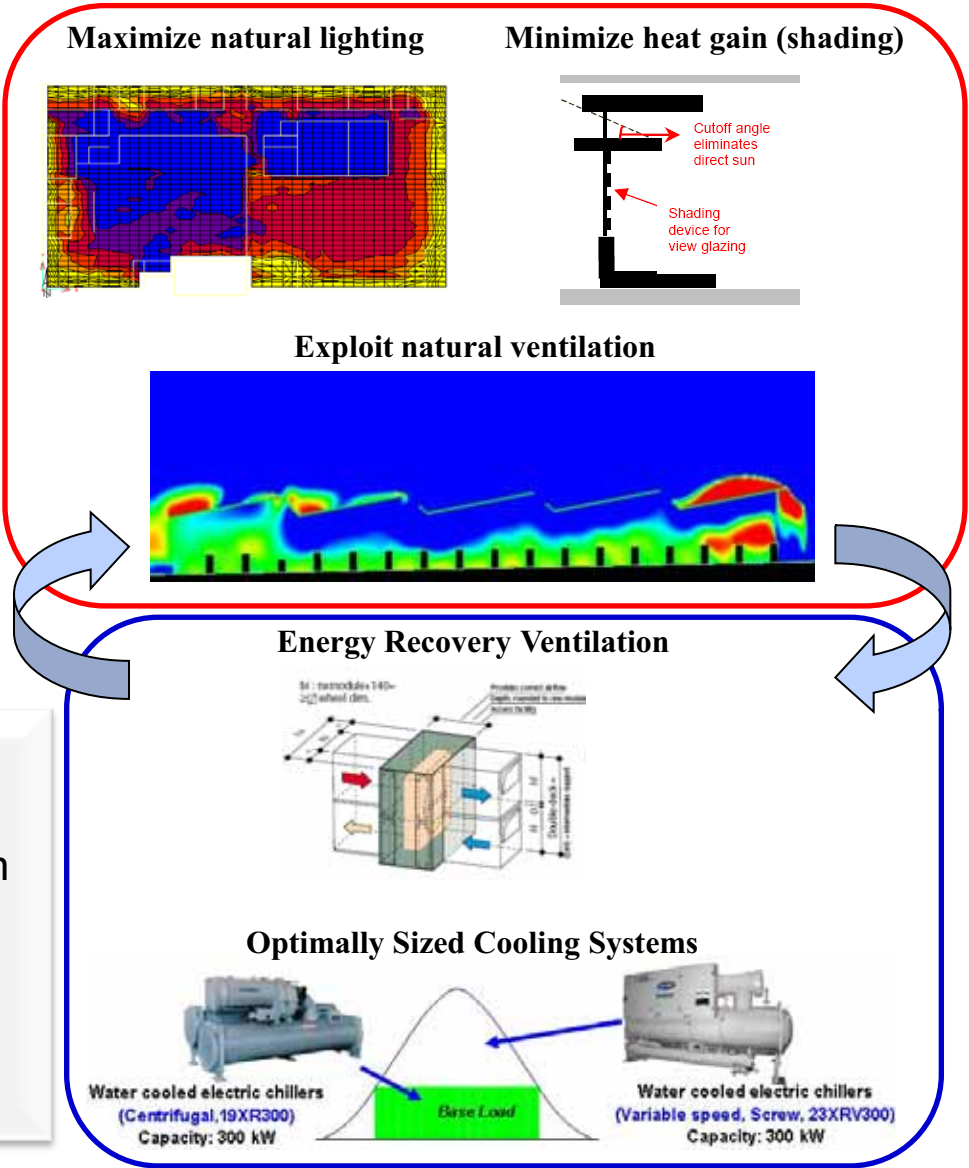
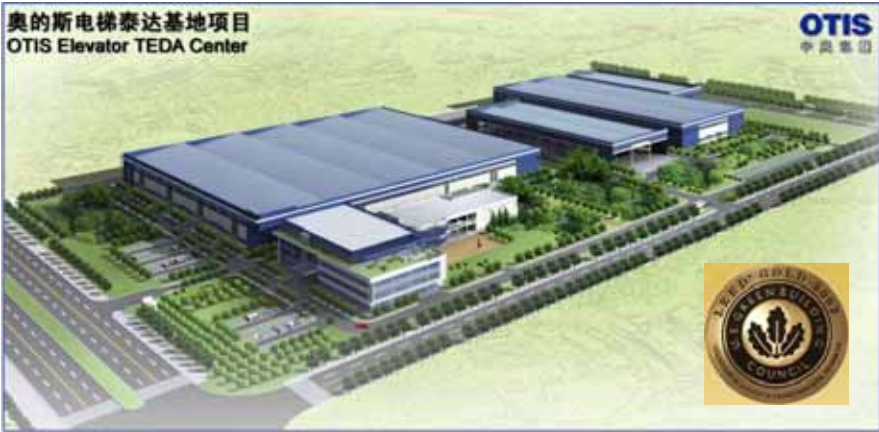


Integrative Design Process



● All Hands Meetings

Integrated Design for Energy Efficient Buildings



Reduce energy demand via integrated design of building envelope and systems

Use of integrated design approach and system modeling and simulation

25% primary energy footprint reduction at less than 7% incremental cost

Payback 4.2 years total / 2.5 years new items

Sustainable and Energy Efficient Facilities in UTC



LEED Platinum
44% energy savings

P&W Shanghai Engine Center



LEED Gold
25% energy savings

Otis TEDA facility



LEED-CI Silver

P&W G Bldg. Renovation



Carrier's Charlotte (-17%),



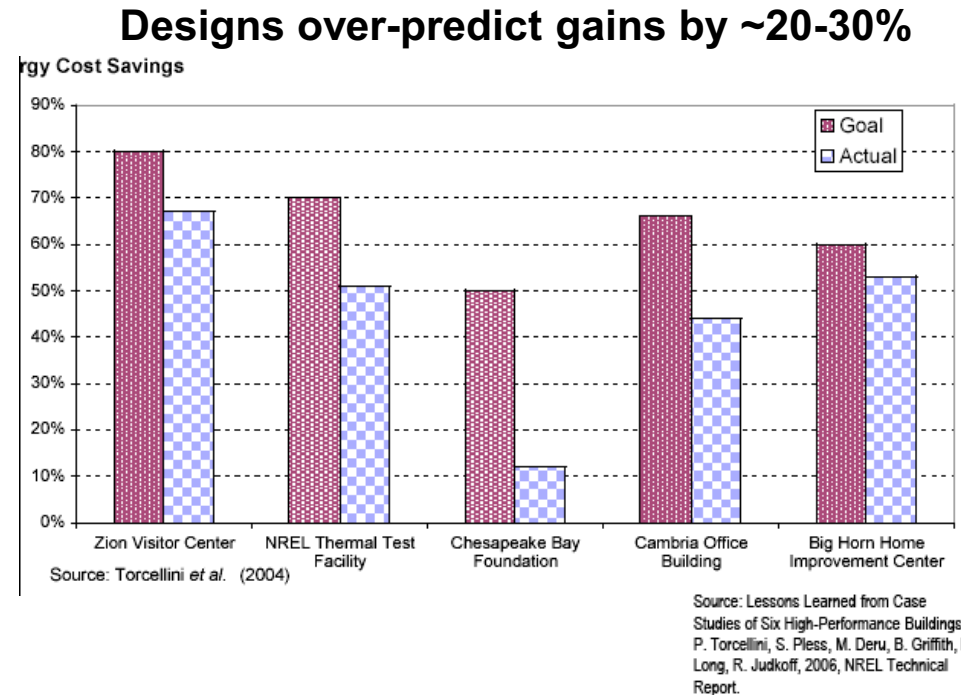
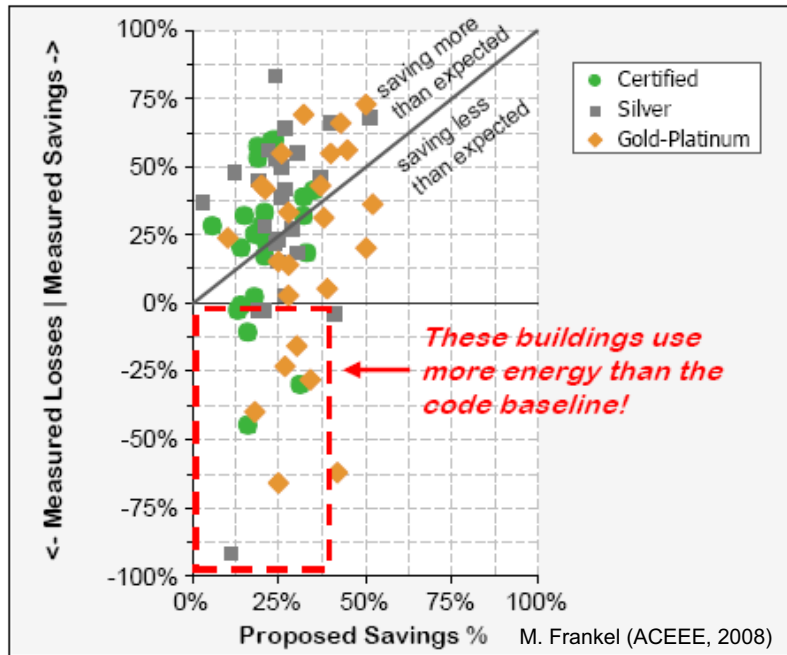
Carrier's Huntington (-31%),

UTC LEED-EB factories
(11 factories worldwide achieving this milestone)

... and 24 additional are registered (2009)

**But Integrated Design is Insufficient
and the Entire Delivery Process
Must Undergo a Transformation...**

Energy Efficient Buildings: Reality



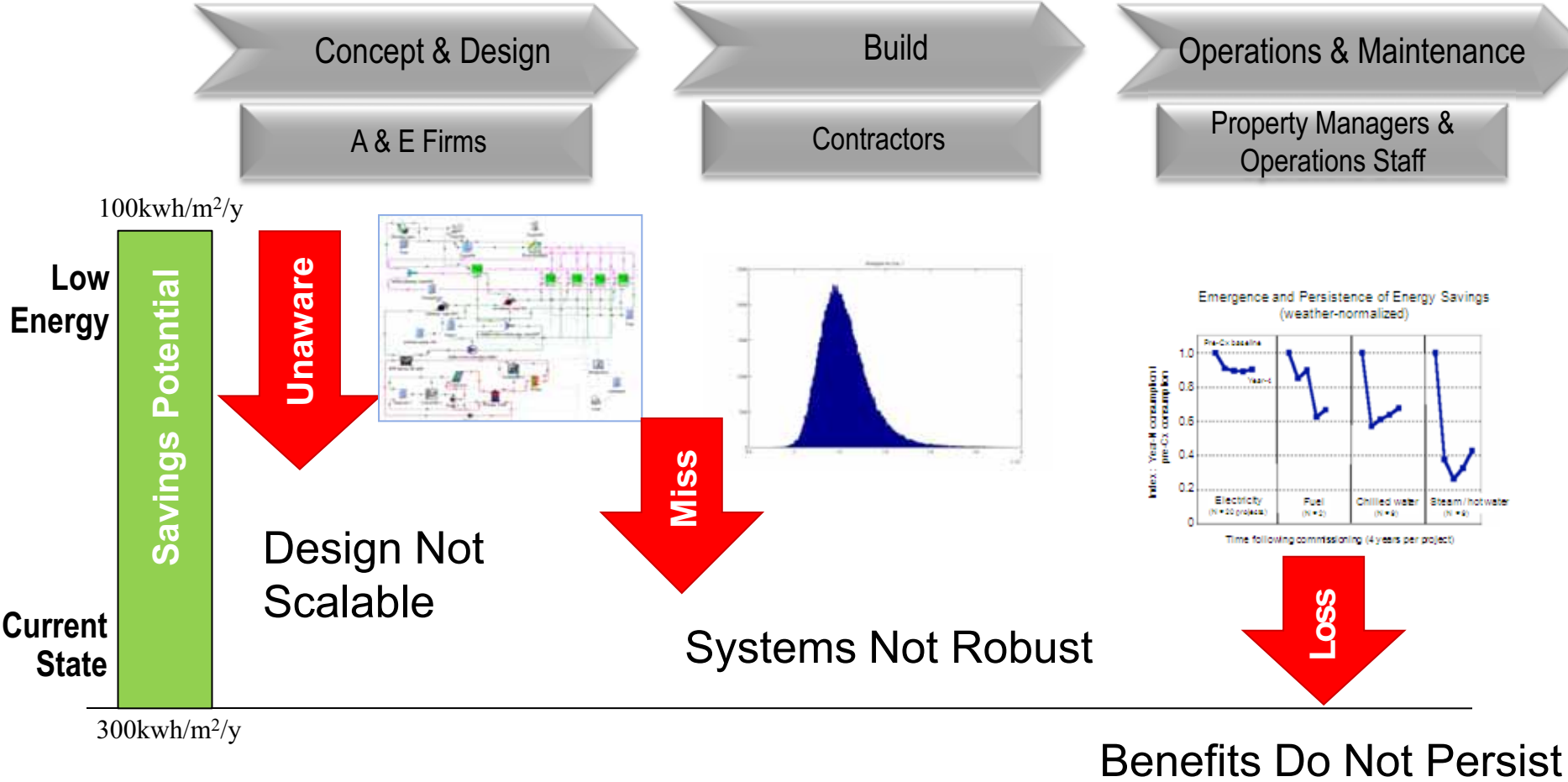
Large Variability in Performance Predictions

Performance simulations conducted for peak conditions

As-built specifications differ from design intent, resulting in compromise of energy performance due to detrimental sub-system interactions

Uncertainty in operating environment and loads

Challenges in Delivering Energy Efficiency



**So, are there proof points for very low
energy consumption buildings?
What do we know about them?**

Highly Energy Efficient Buildings Exist

Energy Retrofit

10-30% Reduction



Cityfront Sheraton Chicago IL

1.2M ft², 300 kW hr/m²
5753 HDD, 3391 CDD

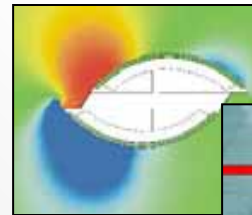
VS chiller, VFD fans, VFD pumps
Condensing boilers & DHW



Deutsche Post Bonn Germany

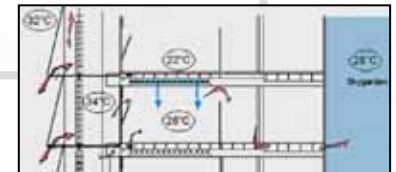
1M ft², 75 kW hr/m²
6331 HDD, 1820 CDD

No fans or ducts, slab cooling,
façade preheat, night cool



Very Low Energy

>50% Reduction



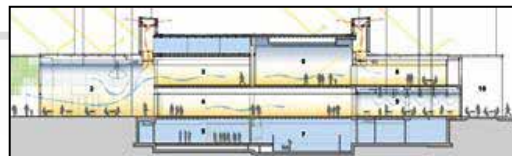
LEED Design

20-50% Reduction

Tulane Lavin Bernie New Orleans LA

150K ft², 150 kW hr/m²
1513 HDD, 6910 CDD

Porous radiant ceiling, humidity control,
zoning, efficient lighting, shading

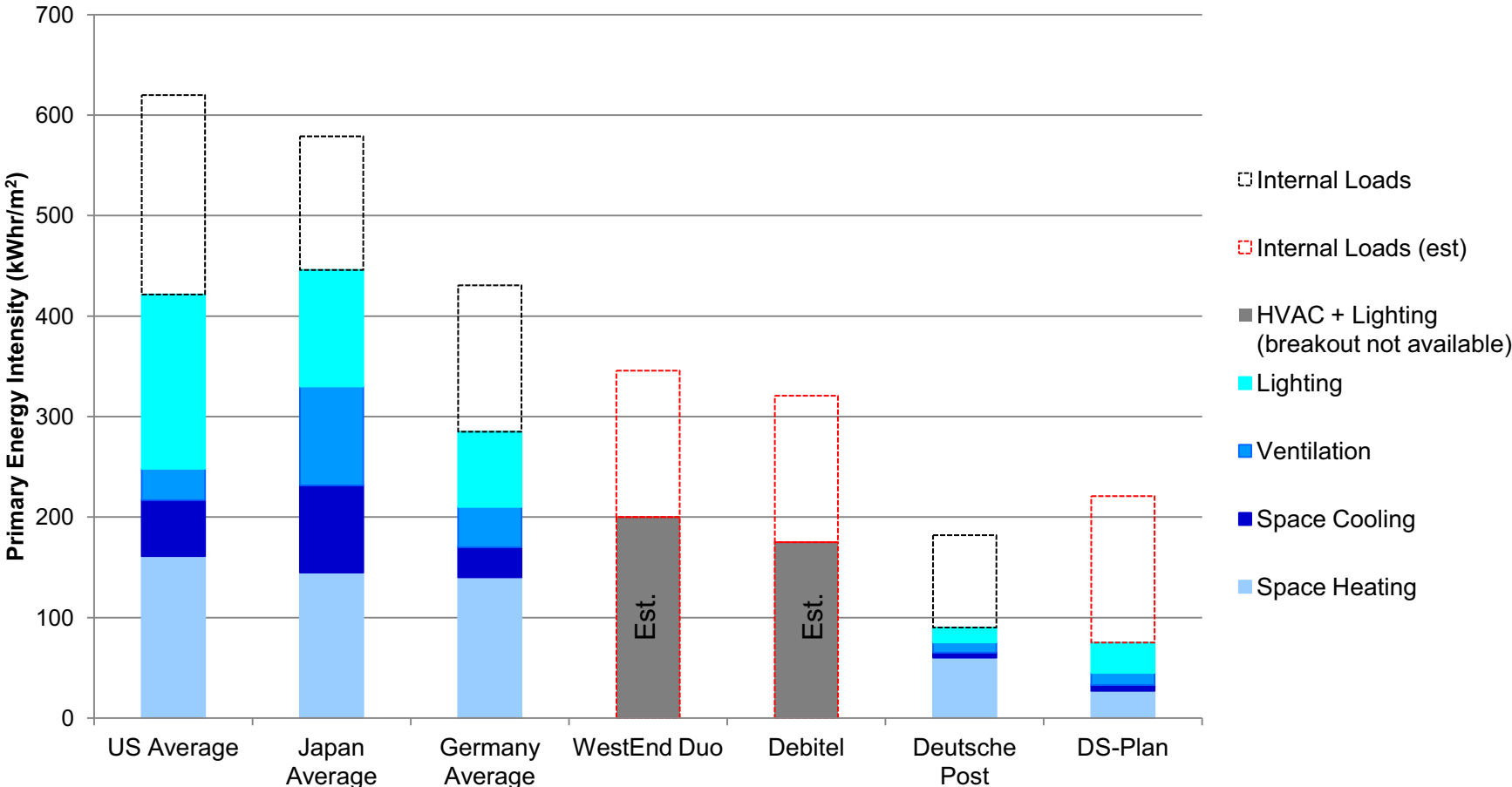


Case Studies in Germany

- Visits to building sites and design companies in Germany and Switzerland conducted July (2009) to understand the design and delivery of low energy buildings
- The buildings typically targeted energy intensity of 100 kWh/m²/year (excludes plug loads); less than half of typical German energy usage and a third of those in U.S.
- Most buildings have sustained, measured low energy performance

KfW Westarcade	KfW Ostarcade	DFS	Westend Duo	Debitel	Theater Haus	Mercedes	DS-Plan	Euweg
								
Frankfurt Germany	Frankfurt Germany	Frankfurt Germany	Frankfurt Germany	Stuttgart Germany	Stuttgart Germany	Stuttgart Germany	Stuttgart Germany	Zurich, Switzerland
Bank campus focused on low energy. Under construction	Bank campus focused on low energy.	National flight training school. Owner occupied office complex.	Green office building. Sustainability with tenant flexibility.	Tower developed for owner occupancy. Now tenant occupied.	Low budget re-use of space for theater complex. Willing to compromise comfort for cost.	Premium space that while using low energy techniques is focused entirely on comfort and style.	A small low energy office building.	A low energy office building.

Commercial Office Building Energy Use



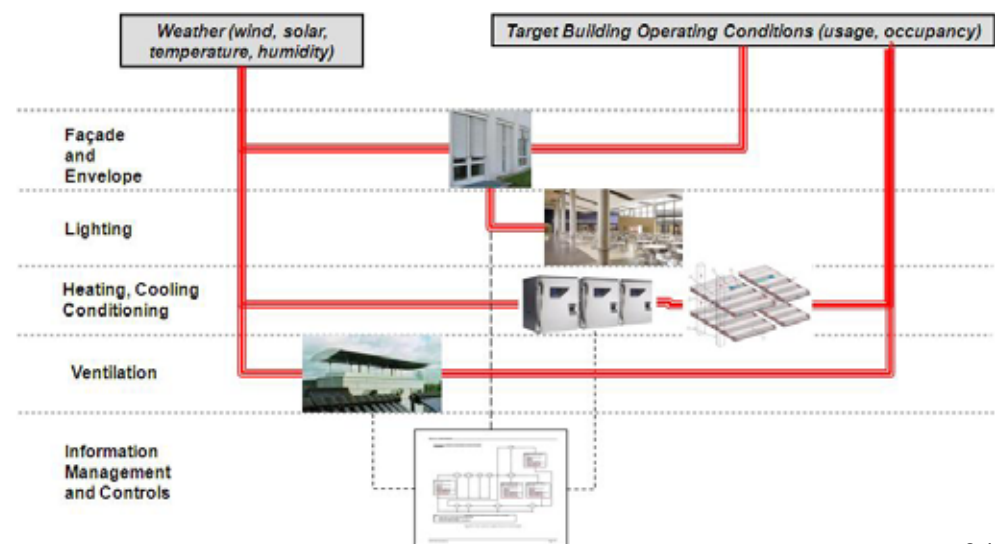
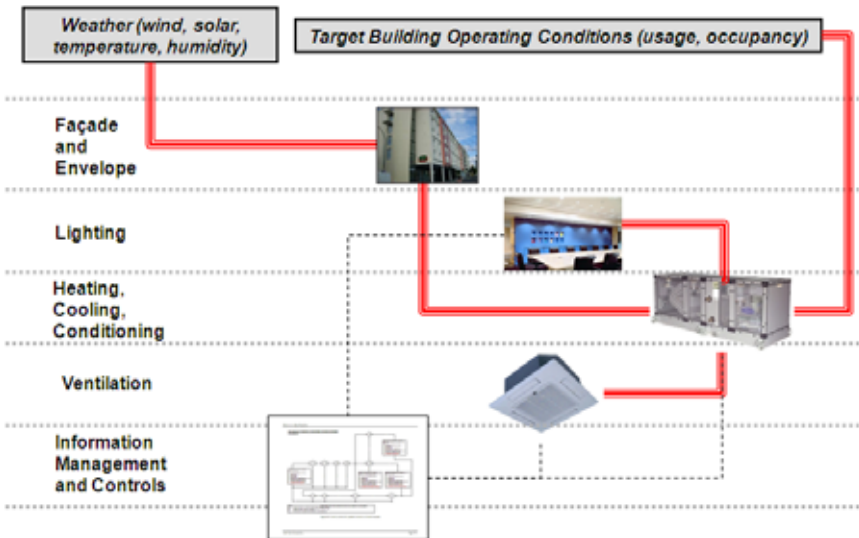
Robust, Low Energy Performance Through “Climate Adaptive” Design



- Standard equipment
- No shading
- Highly sealed envelope



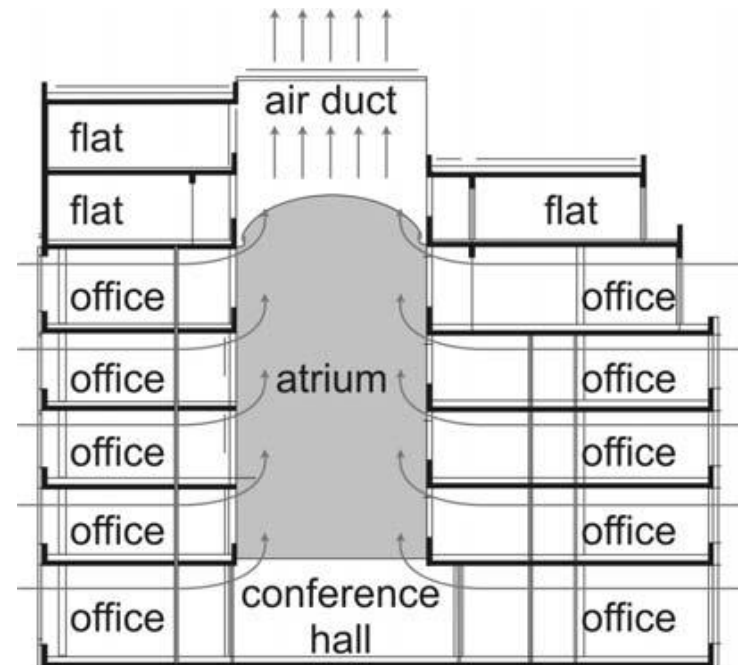
- Dynamic Thermal Storage
- Active shading
- Natural ventilation



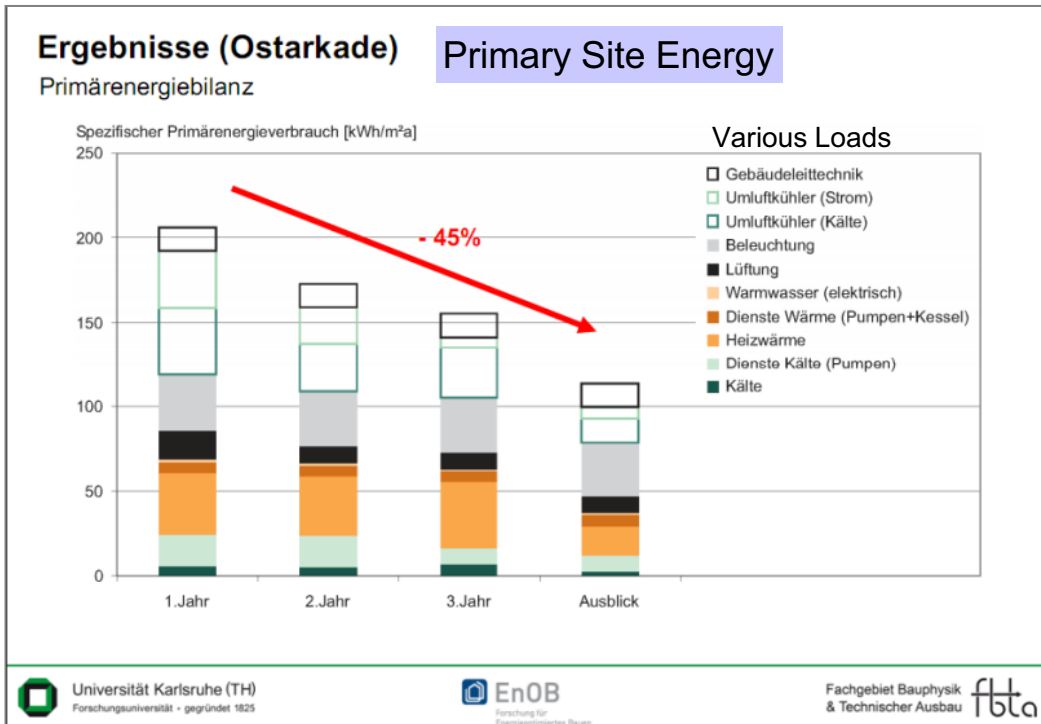
Monitoring and Tuning Necessary to Achieve Energy Performance Targets



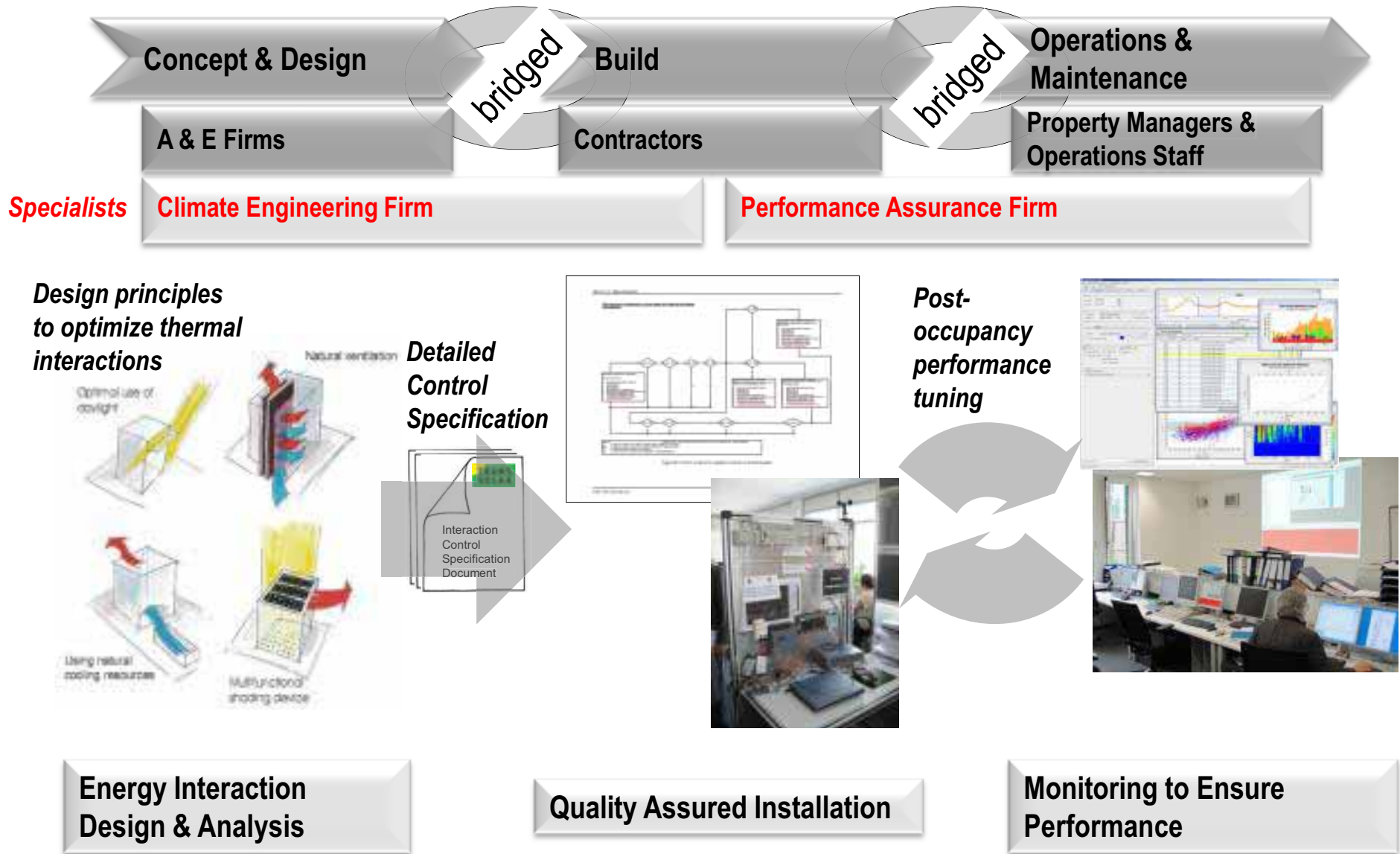
KfW East Arcade Building
Case Study



*Tuning the controls for night purge
(pre-cooling thermal mass)*



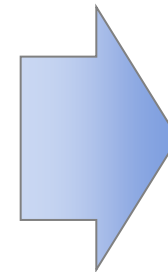
Low Energy Building Delivery Process



Challenges in Delivering Energy Efficiency In The Built Infrastructure

- Integrated design methods, engineering software and tools
 - Tools for architectural tradeoffs and selection with modeling and simulation tools that can handle heterogeneity, uncertainty and multi-scale dynamics
 - Tools for rigorous requirements capture and tracking
 - Uncertainty quantification and risk assessment tools
 - Methodologies and tools for automated system failure analysis to establish tolerances critical to achieving and sustaining target energy performance
 - Capability to update design models with commissioning and operational data (dynamic Building Information Models)
- Methodologies for validation and verification of system implementations
 - Model-based validation and verification of building systems and controls
 - Tools to assist in auditing and regulation of building energy performance

What's Next? Efficient Buildings To Eco Cities



New Songdo City
South Korea



Dongtan
China

Sustainable Development at District – City Scale

- Potential for larger impact and benefit
- More complex decision making
- Larger scope of infrastructure and system alternatives

Thank You...