Environmental Energy Technologies Division Lawrence Berkeley National Laboratory

Transformative Pathway for Chinese Buildings by 2050

For ECEEE 2015 Summer Study on energy efficiency

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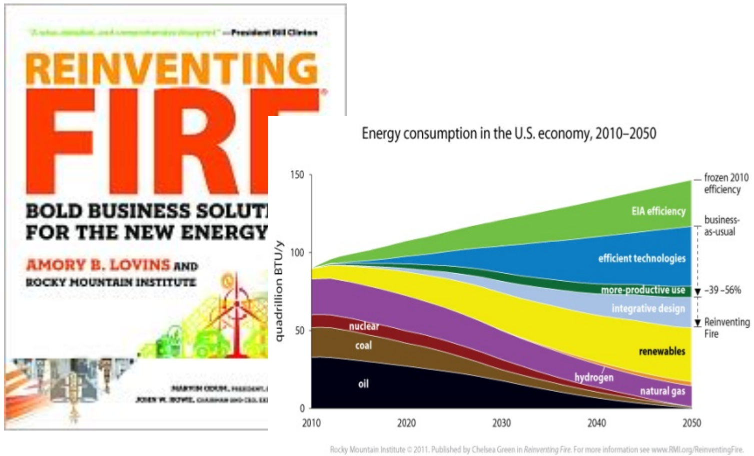
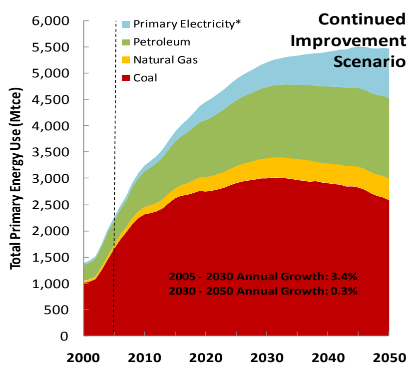
June 3, 2015

Reinventing Fire: China- sustainable energy infrastructure to preserve environmental quality and support future growth





- *Reinventing Fire* U.S. : **2.6-fold bigger economy** by 2050, with **no oil, no coal, no nuclear energy**, **one-third less natural gas**, with a **$5-trillion lower net-present-value cost** than business-as-usual—with the transition led by business for profit
- Emergence of China leaves a large opportunity for visioning and assessing new energy futures
- Objective: Identify a pathway in which China meets its energy needs and improves its energy security and environmental quality using the maximum feasible share of cost-effective energy efficiency and renewable supply through 2050

SCENARIO DEFINITIONS

Reference Scenario

A business-as-usual energy and emissions pathway in which only policies in place by 2010 continue to have impact and autonomous technological improvement occurs

Transformative Scenario

A pathway in which China meets its energy needs and improve its energy security and environmental quality using the maximum feasible share of cost-effective energy efficiency and renewable supply through 2050

Overview of Building Energy Consumption in China

Current Situation of Chinese Buildings

- China has been building ~2 billion m^2 of new buildings annually
- Buildings' current energy use accounts for 20%-25% of national total
- Building energy intensities in China are low due to culture, behavior, and operation of technologies
- Buildings and appliances are less efficient
- Envelope thermal integrity and infiltration are key causes of inefficient buildings
- Distributed energy and renewable application in buildings is less common

Key challenges facing building energy efficiency in China

- As economy develops, demand for more comfort and energy services increase
- Current energy pricing mechanism doesn't't incentivize energy saving
- Building retrofits often focus on single technology, lack integrative approach
- Upfront costs, very short payback period expectation
- Split incentive between builders, owners, and tenants
- Fragmented markets, etc…

Drivers for future growth

- ✧ Population growth,
- ✧ Urbanization,
- ✧ Floor area per capita
- ✧ Income rise
- ✧ Appliance ownership
- ✧ More usage and human behavior,
- ✧ More demand for heating and cooling, lighting due to comfort level increase

Transforming buildings in china--*vision 2050*

By 2050, buildings and communities in China will be self sustained and resilient with increased comfort levels

Passive Buildings

- Passive House for Northern residential building
- Natural ventilation and shading for Southern buildings
- Day lighting

Integrative Design

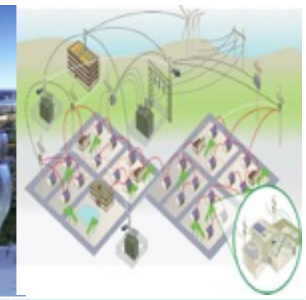
- Bundled and optimized measures
- Maximum whole building system energy efficiency in a cost effective way

Super efficient appliances and space conditioning systems

- Super efficient heating and cooling systems
- Super efficient AC, refrigerator, clothes washer, LED, and other equipment

Renewables, Fuel Switching and Net Zero Energy Buildings

- Onsite generation
- PV, solar thermal, geothermal
- From coal to natural gas and electricity



Smart Control, Micrograds and Demand Response

- Microgrid with distributed generation
- Storage such as battery, EV, fuel cells
- Demand response
- Smart control

Prefabricated buildings

- Longer building lifetime
- Durable, recyclable material
- Less material intensity
- Speedy and high quality construction

Research is supported by numerous real world case studies

Shenzhen IBR office Building , Shenzhen

Features: integrative design, natural ventilation, high performance envelope, day lighting

Energy: 60% lower energy intensity,

Cost: same cost or lower

Passive House project, Qinhuangdao

Features: passive design, better envelope, air-tightness, dedicated outdoor air system (DOAS)

Energy: 74% less heating. 10 times lower indoor PM2.5

Cost: 10% incremental, recovered by price premium

Integrative Design Retrofit for Empire State Building

Features: chiller, direct digital control, radioactive barrier, energy management, windows, VAV AHU's and Day lighting/ plugs

Energy: 277 to 189 kWh/m2

Cost: payback of 3 years.

Prefabricated buildings

Light-weight parting wall

Net Zero Energy Buildings

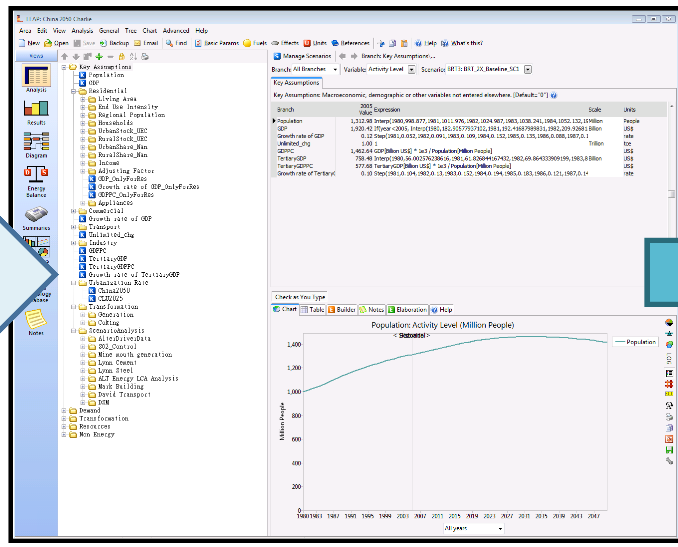
Simulation results shows Net Zero Energy Buildings is possible for high-rise apartment buildings (~20F) by employing both EE measures and RE integration in all climate.

Modeling methodology

- LBNL CEG has developed and continually refined China 2050 Demand Resources Energy Analysis Model (DREAM) for 10 years
- Bottom-up energy end-use model built using LEAP software, and able to:
  - Incorporate stock turnover models
  - Major appliances sales and stock by efficiency, size, performance, and usage
  - Buildings by climate, urban/rural, type, new/retrofit, thermal performance, equipment choice and efficiency, etc.

Inputs

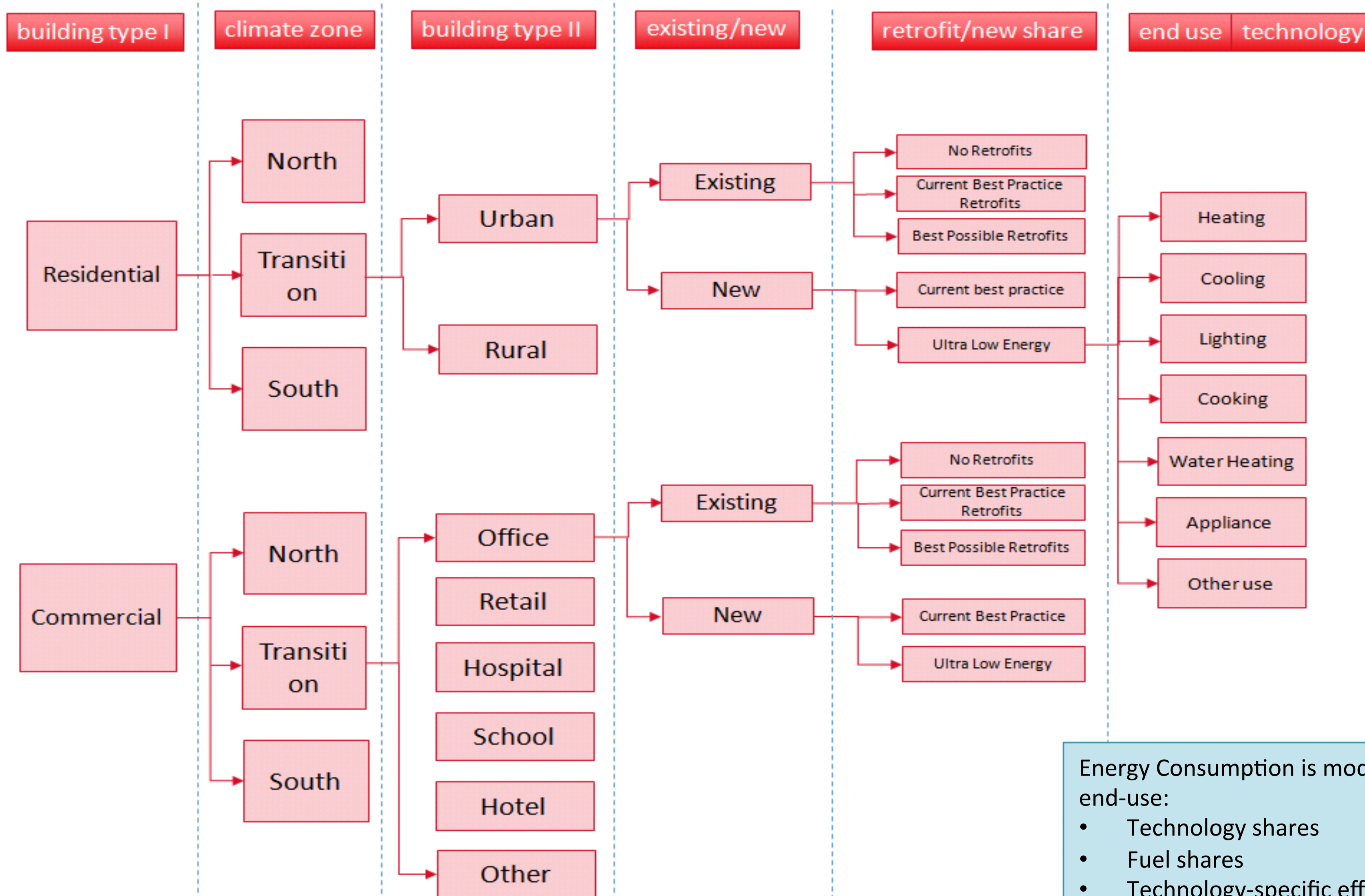
Macroeconomic data, demand drivers, technologies, scenarios



Outputs

Primary and final energy, emissions, savings potential

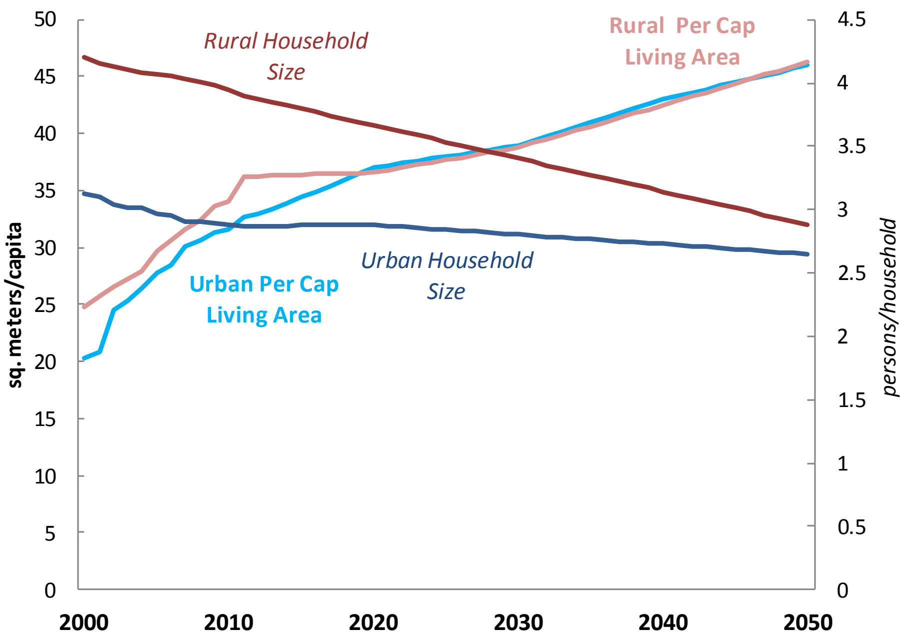
Building model significantly improved with distinctions between climate zones, new construction vs. retrofits and different performance levels

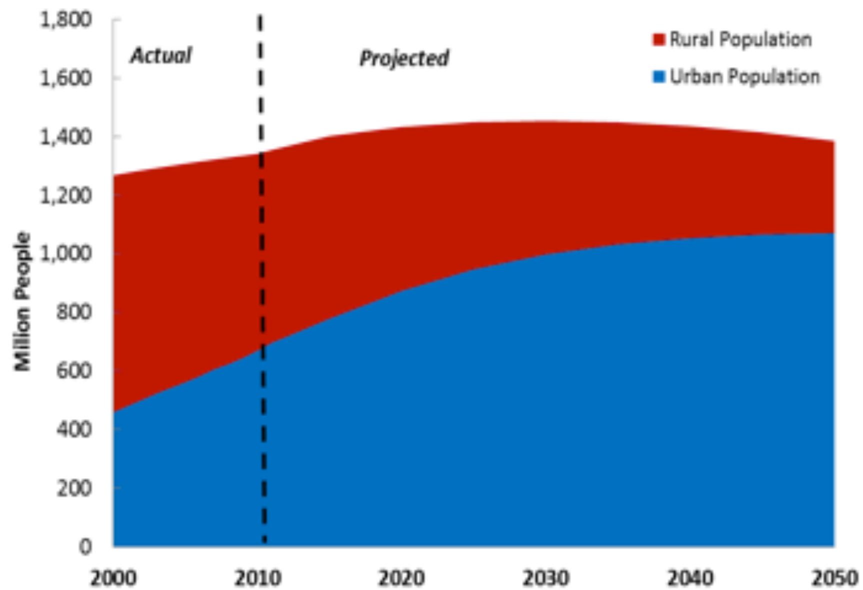


Energy Consumption is modeled by by end-use:

- Technology shares
- Fuel shares
- Technology-specific efficiency

Residential floorpsace driven by population, urbanization and increased living area



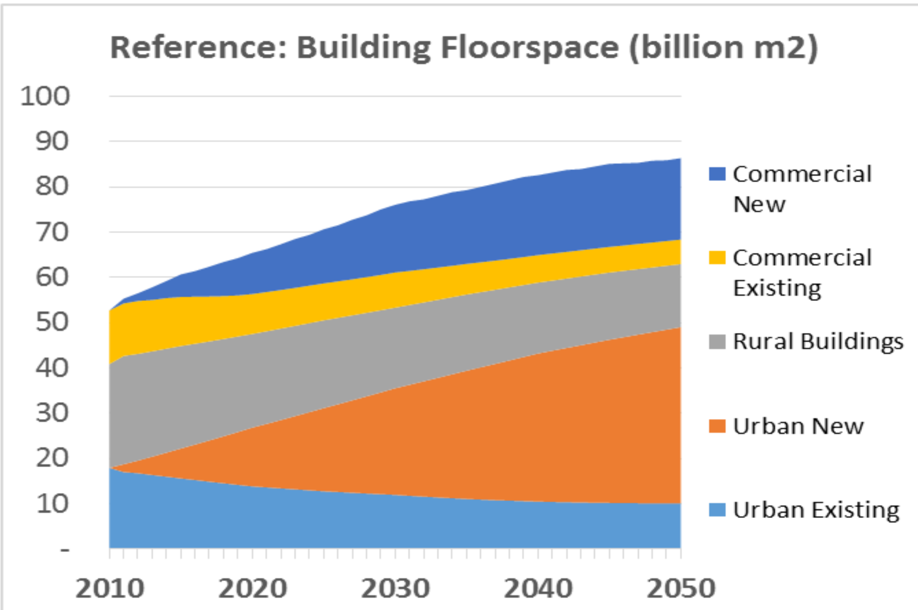


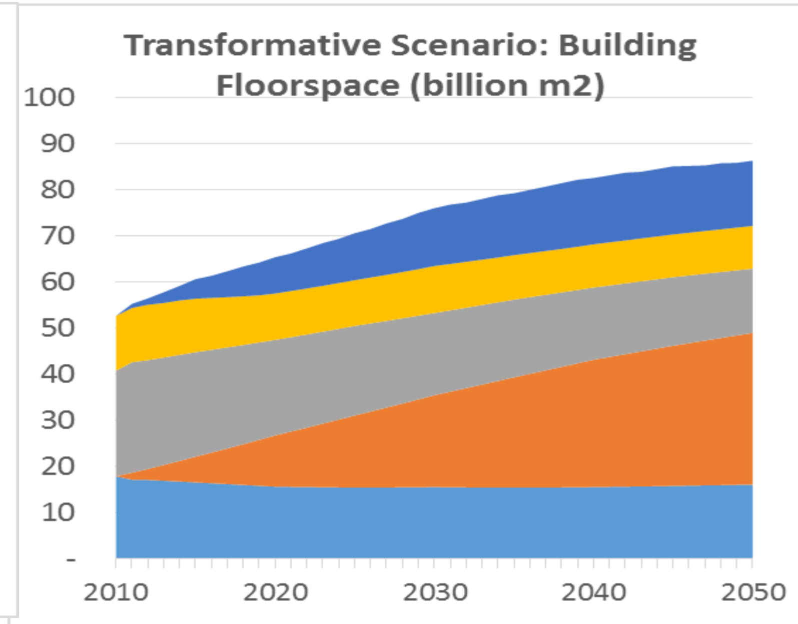
- Living area of 46 m^2/capita by 2050
- Declining household sizes

78% urbanization by 2050

Residential floor space will increase 50% and Commercial will double, transformative scenario result in more existing building

Reference Scenario **Transformative Scenario**



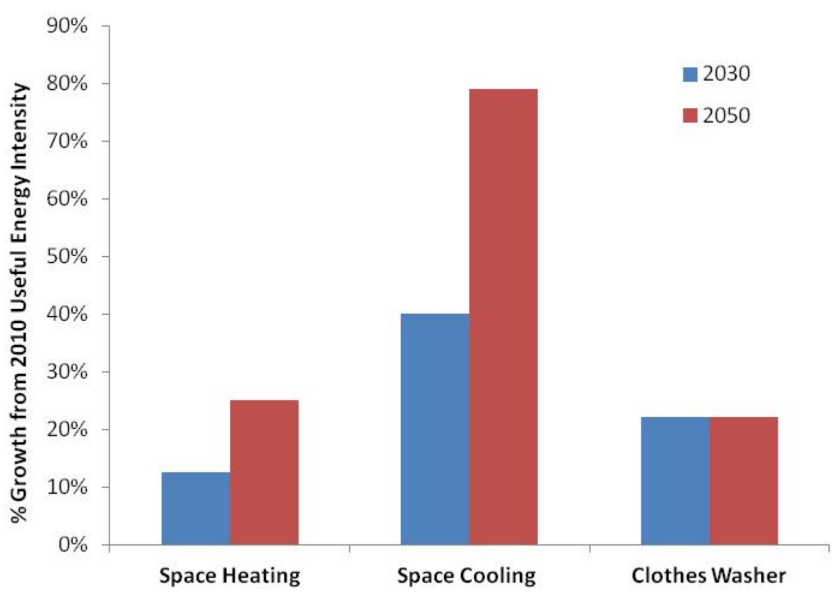


Total Building Floorspace by Building Sector and Vintage, Reference (left) and Transformative Scenario (right)

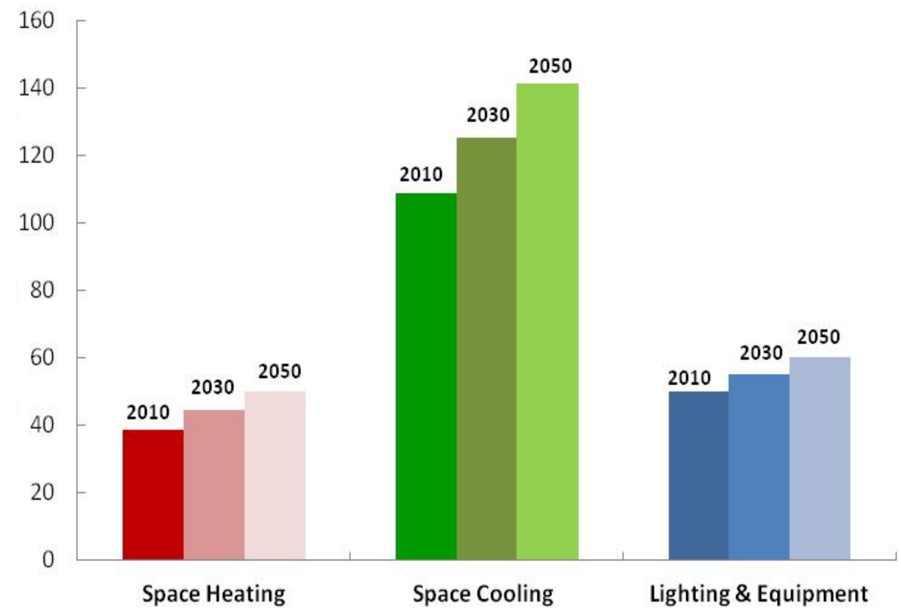
Greater demand for thermal comfort and energy services will increase building loads

Continued economic development expected to result in demand for greater thermal comfort:

- Residential heating loads increase in transition and south climate zones, where district heating is not available
- Residential and commercial cooling loads increase in all climate zones due to higher temperature setpoints and/or longer periods of operation



Urban residential buildings in Transition Zone



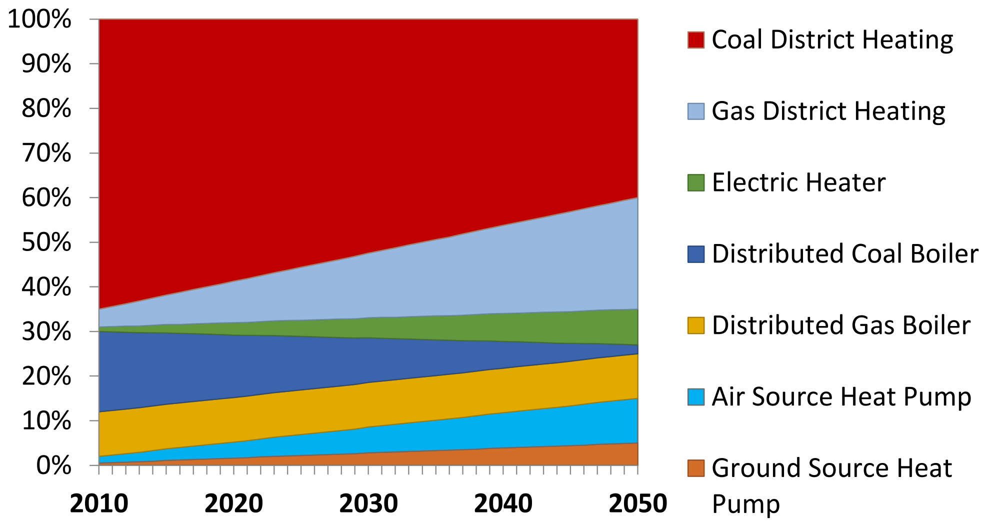
Office buildings in Transition Zone

Autonomous improvements in technology efficiency over time are modeled for the baseline scenario

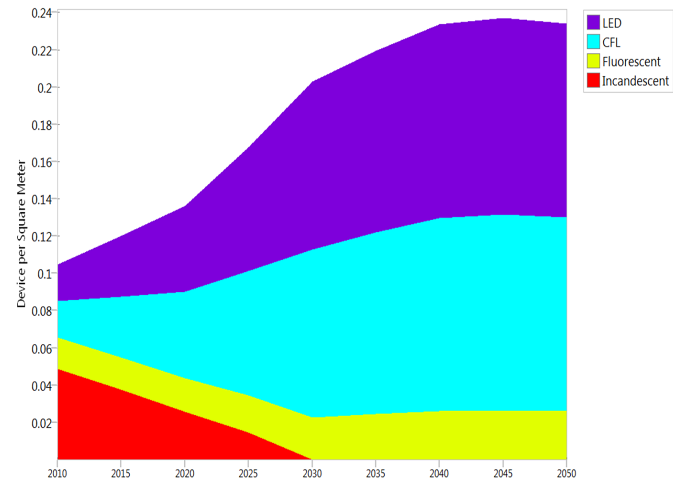
End-Use Category	Technology Name	2010 Efficiency (%)	2050 Efficiency (%)
Heating	District Heating	76	84
	Electric Heater	90	93
	Coal Boiler	62	76
	Gas Boiler	78	86
	Air Source Heat Pump	237	245
	Ground Source Heat Pump	300	360
	Coal Stove	40	63
Cooling	Air Conditioner	257	311
Cooking	Coal Cooker (Anthracite)	33	59
	Coal Gas Cooker	60	78
	Biomass Cooker	17	31
	Biogas Cooker	47	56
Water Heating	Natural Gas Water Heater	60	70
	Electric Water Heater	89	91
	Air Source Heat Pump	237	245
	Ground Source Heat Pump	360	390

Autonomous switching to more efficient technologies and cleaner fuel technologies are also modeled

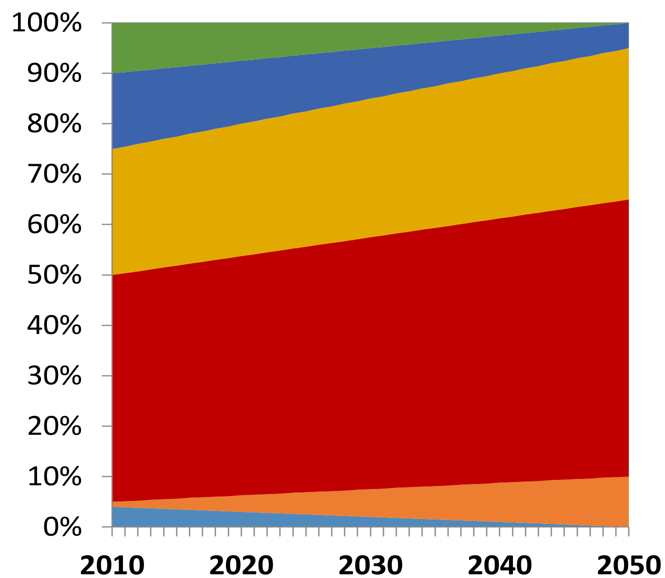
North Urban Heating



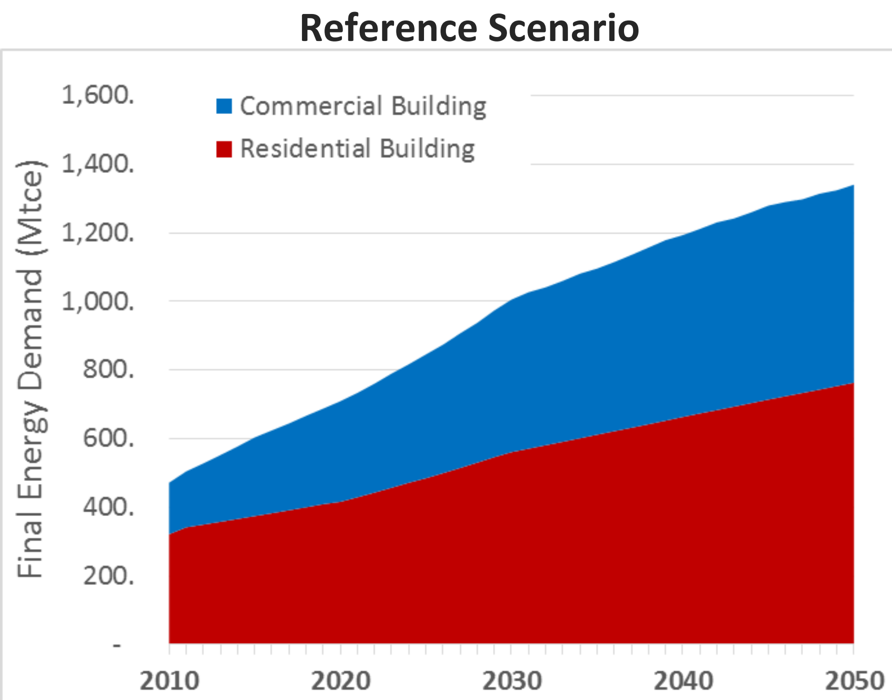
Lighting technology shift

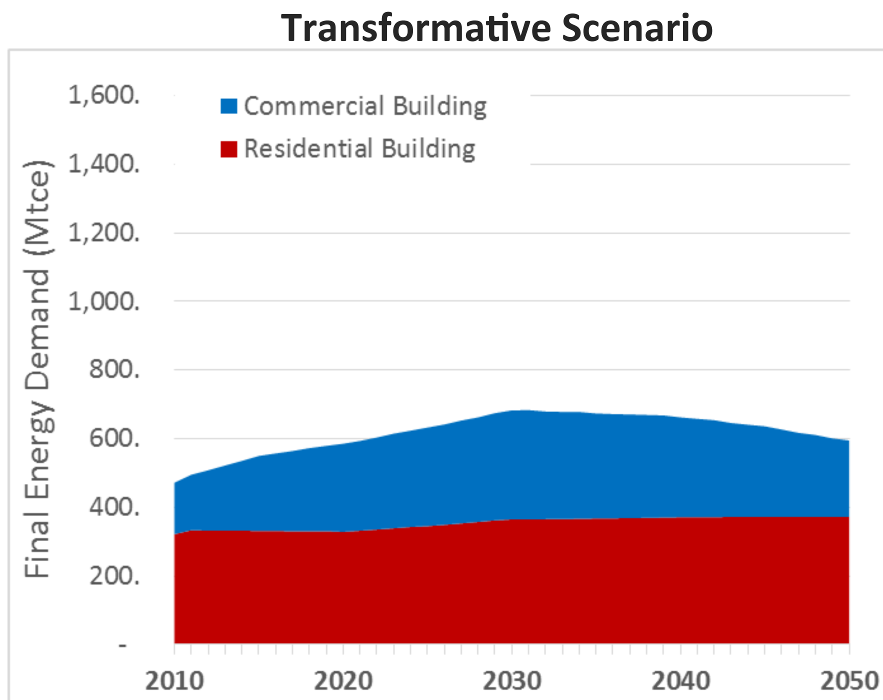


Transition Commercial Heating



Building Final Energy Consumption By Building Type

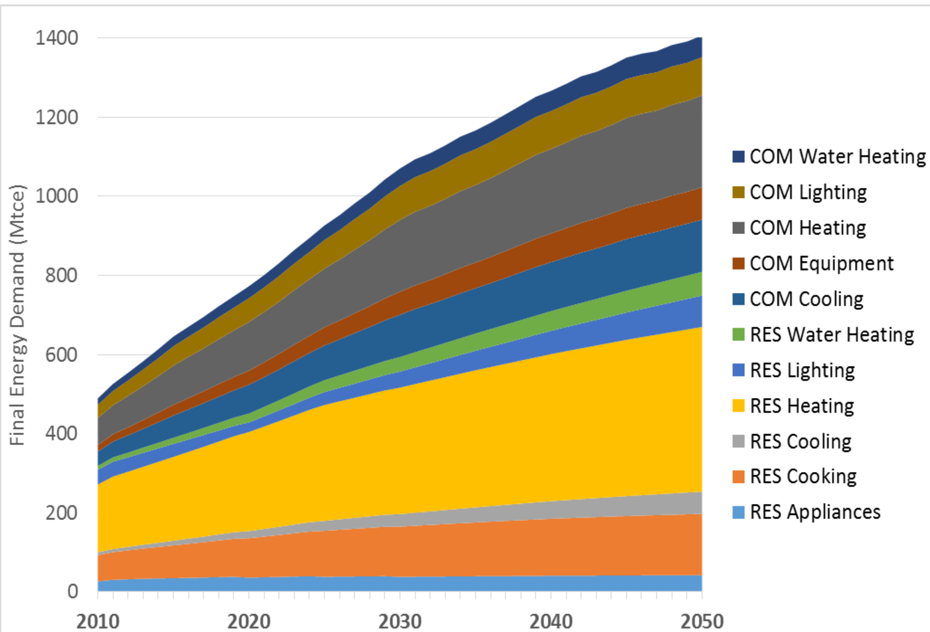




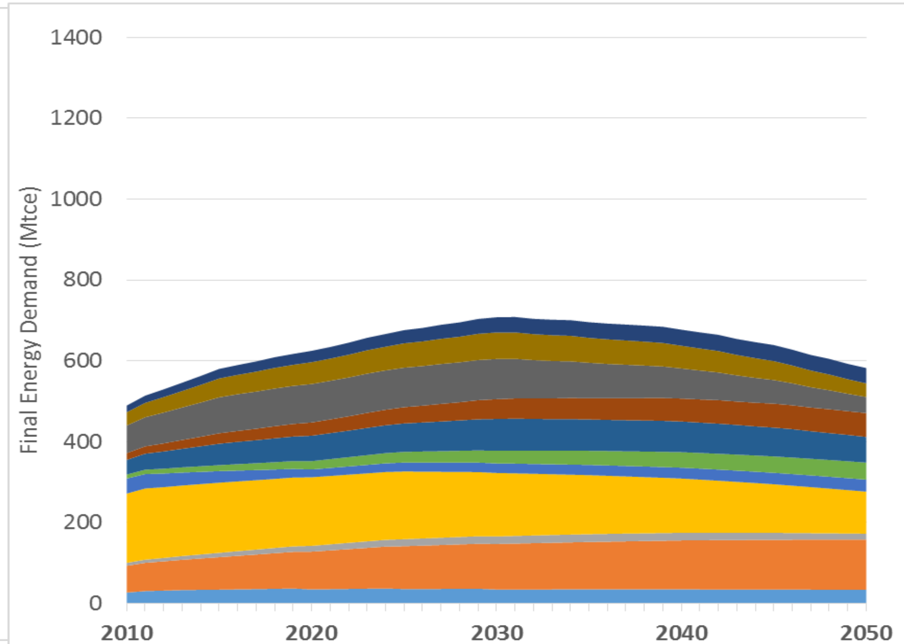
- RF 2050 case shows **savings potential of >= 50%** for both commercial and residential segments
- 2050 residential energy use almost double commercial but RF savings reductions about equal for each sector

Building Sector energy Consumption by End-use

Reference Scenario



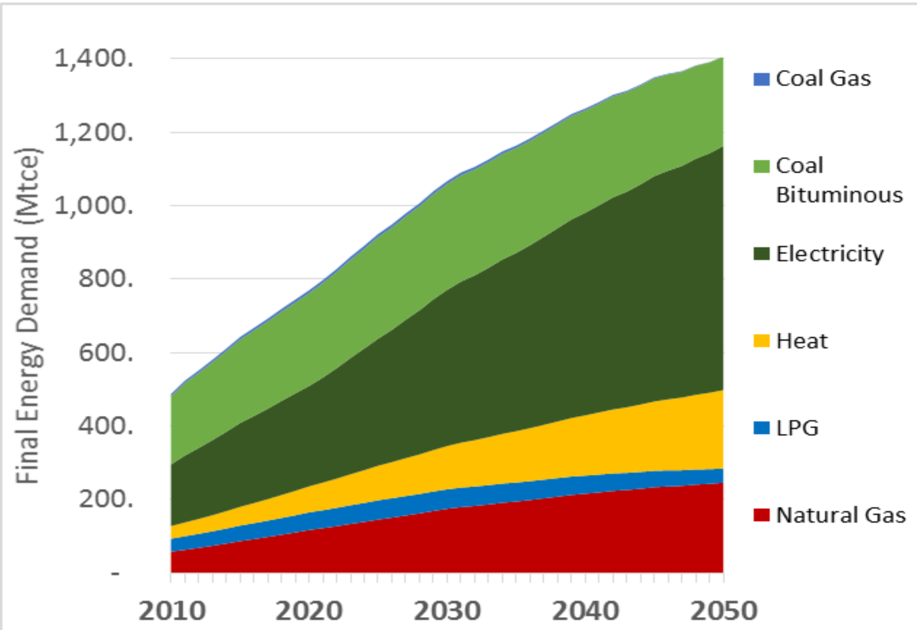
Transformative Scenario



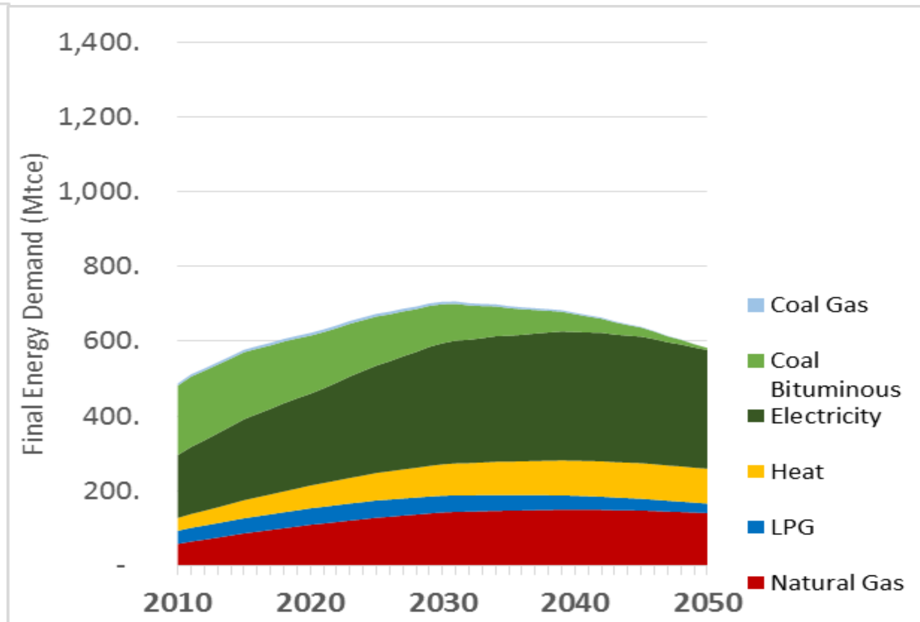
- Modernization of residential cooking and water heating increases use of purchased fuel (replaces firewood)
- Improved thermal comfort in residential buildings increases heating and cooling energy use; **RF case achieves improved comfort with reduced consumption**
- Increased cooling in commercial buildings results in large energy use increase; **RF case achieves increased comfort with nominal increase in energy use**

Overall Sector Results – Fuel Mix

Reference Scenario

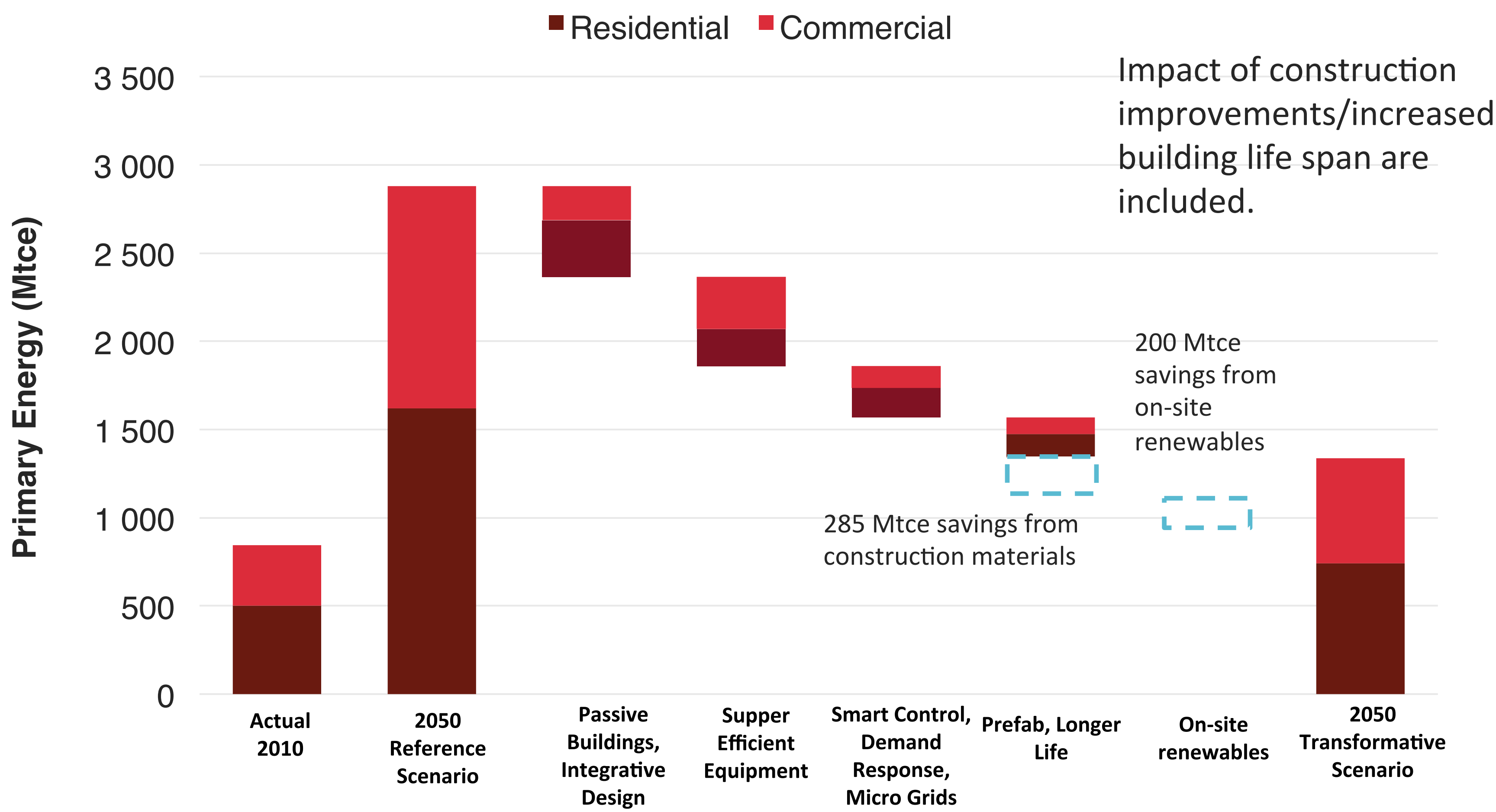


Transformative Scenario



- **Coal greatly reduced/eliminated** by 2050
- RF case **dramatically reduces electricity** requirements by > 50% by 2050
- Significant **growth in natural gas** use in both scenarios

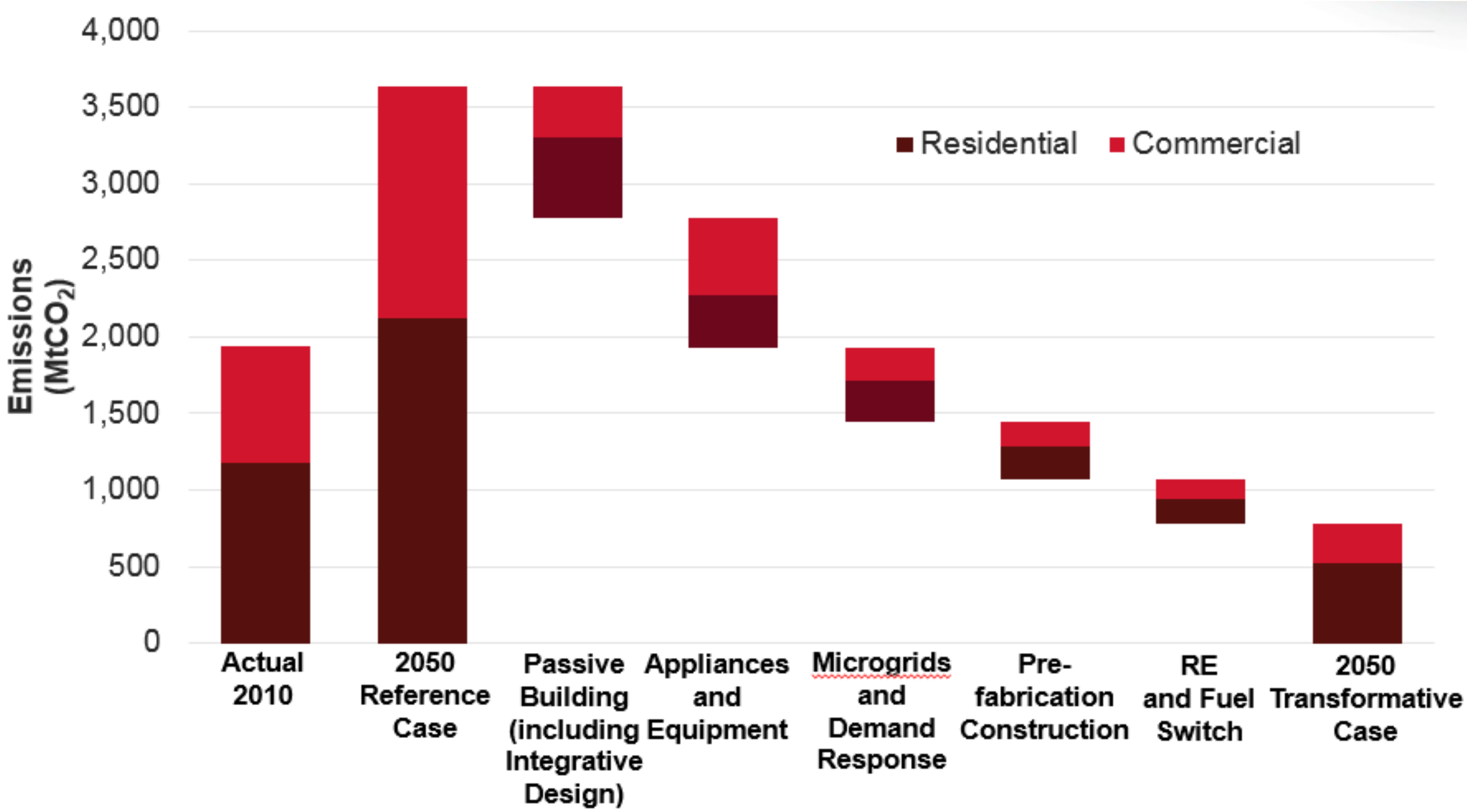
Primary Energy Waterfall Chart



Note: Primary (non-fossil) electricity converted at Chinese convention of using coal-fired power plant equivalent

Preliminary results – not to be cited or distributed

Buildings Sector CO_2 Emissions Reduction Potential Waterfall Chart



China Buildings Sector CO_2 Emissions Reduction Potential Waterfall Chart

Barriers To Realization

		Technical Lever			
	Key Barrier	**Integrative Design**	**Super-efficient Equipment**	**Smart Systems**	Renewables and Fuel Switching
Structural	Split incentives	✔	✔	✔	
	Energy pricing distortions	✔	✔	✔	✔
	Transaction costs	✔			✔
	Lack of legal framework and code	✔	✔		✔
Behavioral	Custom and habit	✔		✔	
	Lack of information/familiarity	✔		✔	✔
	Uncertainty/risk of investment	✔			✔
	Lack of requirements or enforcement	✔	✔		
Availability	Insufficient supply	✔	✔	✔	
	Improperly installed or operated	✔		✔	
	Lack of capital	✔	✔		✔

Summary of Barriers and Solutions

Focus Areas	Barriers	Solutions	Metrics
Prefabraication/ Longer Life Buildings	• Development emphasis on scale and quantity (“sprawl”) • Replacing old with new “landmark” buildings	• National and local coordinated construction planning • Promote the industrialization of buildings (“prefab”)	• Rate of new construction and demolition
Passive Building & Integrative Design	• Owners/developers are unaware • Non-supportive codes and enforcement • Designers and builders are unfamiliar • Upfront cost	• Codes based on whole-building energy use • Legal basis for regular energy code improvement • Workforce training to reduce cost and risk • Building energy use transparency	• Residential and commercial building energy use intensity
Efficient Appliance and Equipment	• Low efficiency standards • Lack of information on and consumer trust of energy label • Upfront cost	• World-class appliance labeling • Energy efficiency project financing	• Super-efficient equipment percent market share
Microgrid and Demand Response	• Historic use of inexpensive labor • Lack of skills to install and use	• Train operators for pro-active maintenance • Create market for demand response	• Percent share of buildings with load flexibility
Reneawble and Fuel Switch	• Upfront cost • Non-supportive markets	• Fuel switching project financing • Energy pricing and tariff structure reform • Subsidies and incentives	• Share of biomass in rural residential, solar water heating in urban residential, solar PV and heat pumps all buildings

Measures And Policies

Measures and Policies

C — Codes and Enforcement

1. Develop and implement more stringent building energy efficiency codes
2. Establish legal basis for regular code updates
3. Enforce codes through standardized compliance tools, including actual building performance
4. Expand code inspections beyond the largest cities

D — Disclosure and Transparency

1. Improve efficiency standards and promote performance labeling for equipment and devices
2. Promote energy monitoring for performance improvement use of Three Star voluntary standard to enable market differentiation
3. Disclose building performance to stimulate growth of the buildings service industry

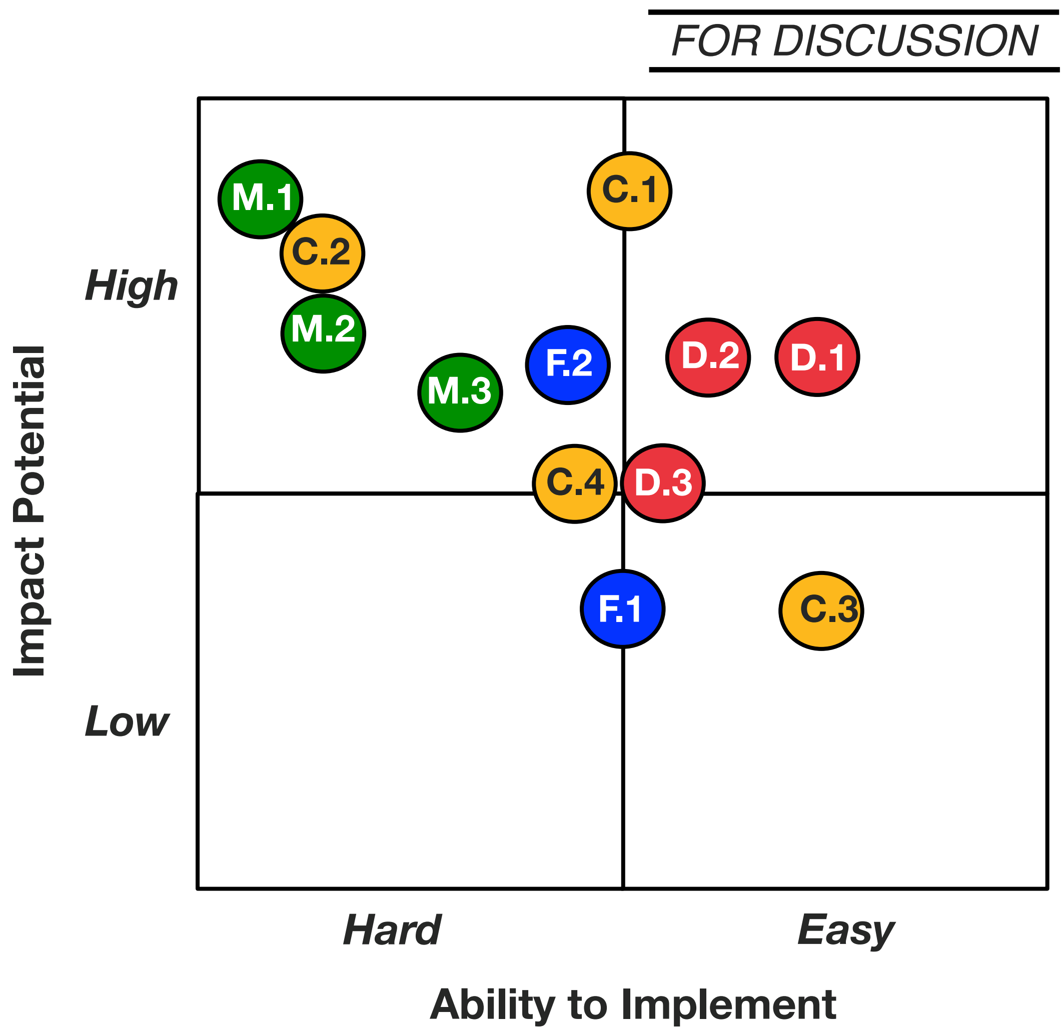
M — Market Forces

1. Decouple utilities' sales from their profits
2. Reform electricity rates to more fairly represent the true cost-to-serve
3. Introduce metered heat and cooling to link customer behaviors directly to service costs

F — Financing and Investment

1. Stimulate efficiency service demand through (a) workforce training and (b) broader sector knowledge of co-benefits
2. Increase capital availability through (a) innovating financing mechanisms, (b) subsidies and rebates, and (c) affordable housing program efficiency standards

Evaluation Of Solutions By Impact And Ease



Key

C	**Codes and Enforcement**
C.1	More stringent building codes
C.2	Legal basis for code updates
C.3	Standardized compliance tools
C.4	Expand inspections to smaller cities
D	**Disclosure and Transparency**
D.1	Equipment/device labeling
D.2	Building metering and labeling
D.3	Building energy performance disclosure
M	**Market Forces**
M.1	Decoupling
M.2	Energy pricing reform
M.3	Heat reform
F	**Financing and Investment**
F.1	Stimulate service demand
F.2	Capital availability

Acknowledgments

We are grateful to the Rocky Mountain Institute (RMI) and China Sustainable Energy Program of the Energy Foundation (EF) for funding this work. This study was supported by RMI and EF through the U.S. Department of Energy under Contract No. DE-AC02-05CH11231

We thank our project collaborators from China's Energy Research Institute, and experts who have provided valuable feedback, including individuals from:

- China's Ministry of Housing and Urban-Rural Development
- Chinese Academy of Building Research
- Tsinghua University
- Energy Foundation
- Shenzhen Institute of Building Research

Thank you!

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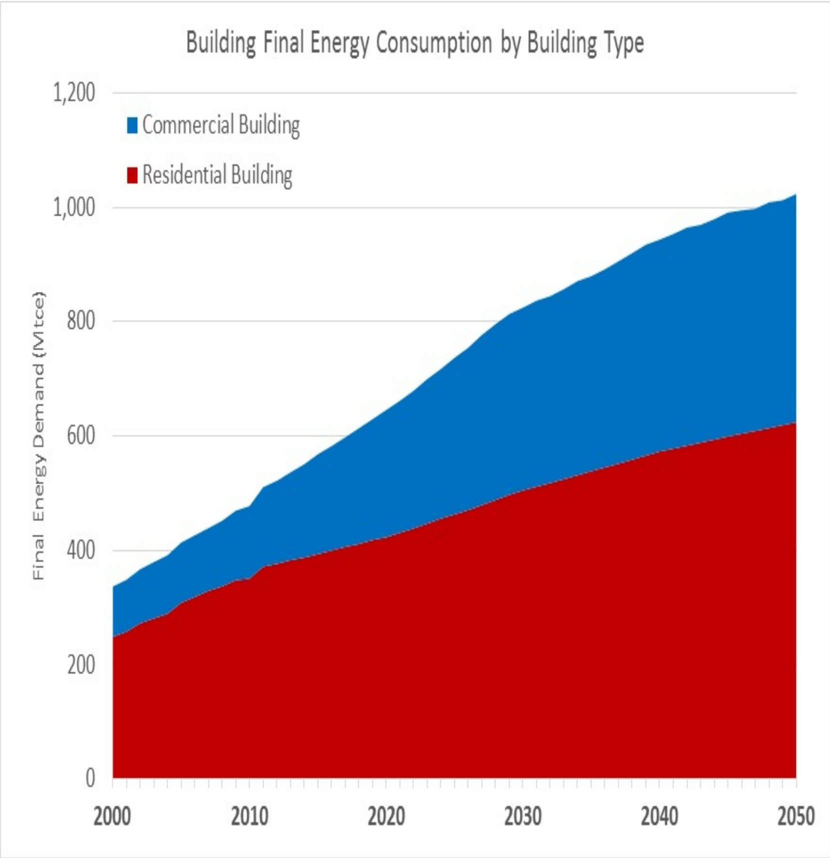
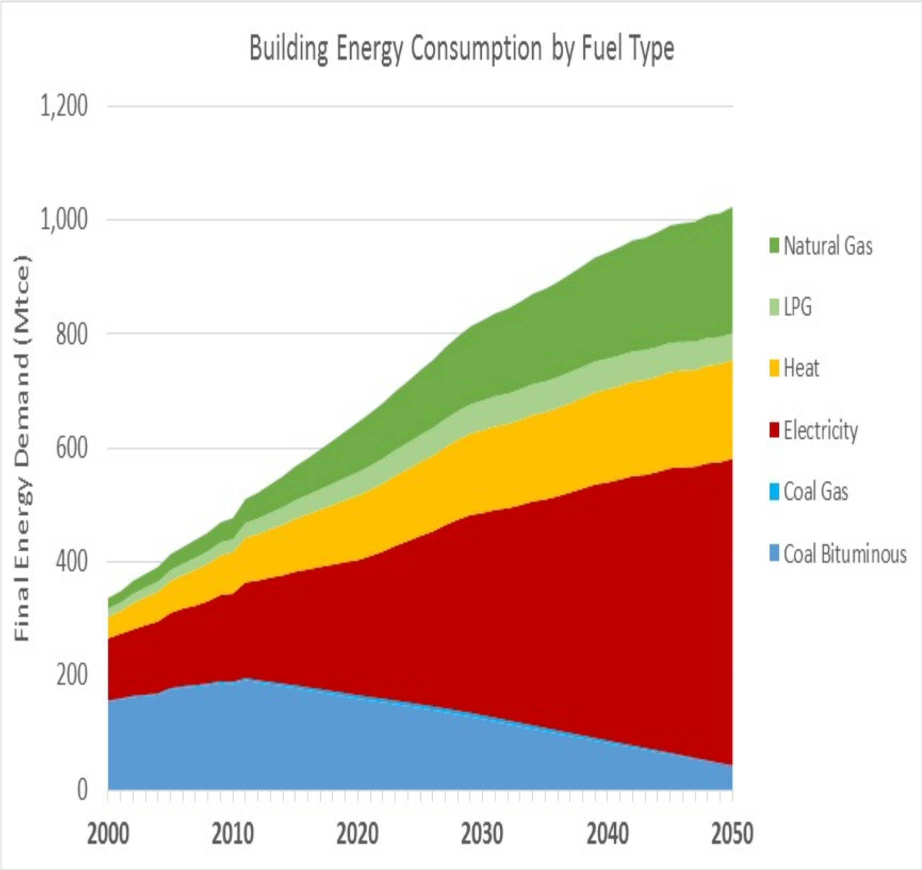
Policy Recommendations

- Greater information and data disclosure and transparency to better inform decision-making through
  - promoting labelling of green buildings and energy-consuming products
  - sharing building performance data through disclosure programs
- Establish and effectively enforce performance standards, mandatory energy reduction requirements, and codes through
  - establishing legal basis for regular update and improvement of energy codes
  - developing and implementing more stringent energy codes
  - making codes more effective through standardized compliance tools and a focus on actual building performance
  - expanding code inspections beyond just the largest cities
  - providing adequate resources for effective enforcement
- Support the reform of the power sector and energy prices to help correct wrong pricing signals and promote innovation that can bring greater efficiencies and significant cost savings through
  - decoupling utilities' sales from their profits
  - pricing reform to ensure electricity rates represent the true cost-to-serve
  - introducing metered heat and cooling to link customer behaviors directly to costs
- Increase access to private capital through greater financing and investment opportunities to help stimulate behavioral change and stakeholder demand for efficiency, through
  - developing workforce competence
  - supporting broader knowledge of the co-benefits of building energy efficiency, such as comfort, health and productivity
  - supporting private sector investment through innovative financing mechanisms
  - establishing subsidies and rebate programs
  - setting minimum targets for ensuring a percentage of newly constructed affordable housing meets energy efficiency standards

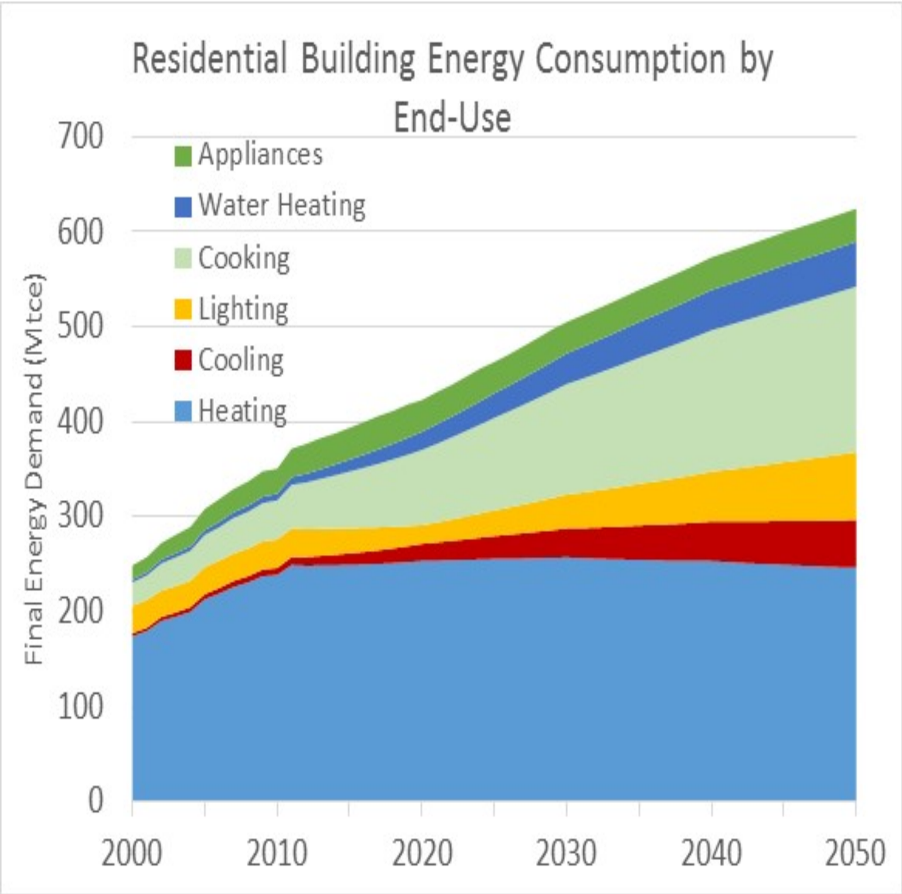
Building final energy consumption doubles, with fuel switching to cleaner resources

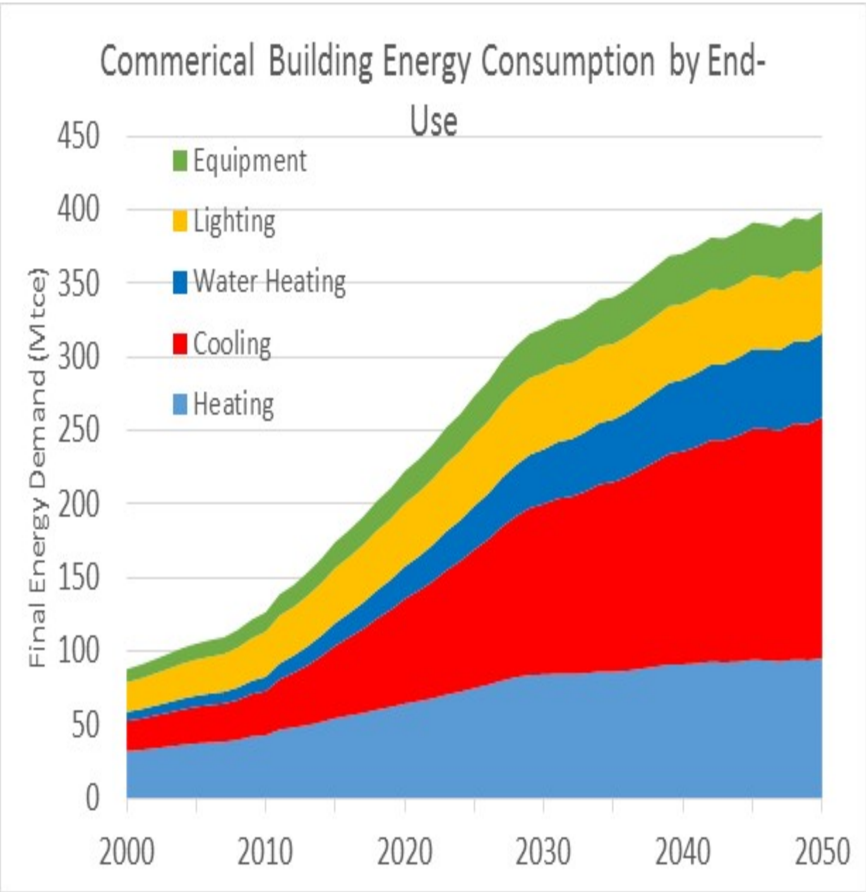




- Residential buildings account for 60% of building energy consumption, but commercial energy consumption growing at faster rate
- Direct coal consumption by buildings will decline rapidly, replaced by growing electricity, natural gas and heat consumption

Heating remains the largest energy end-use, followed by cooking, lighting and cooling

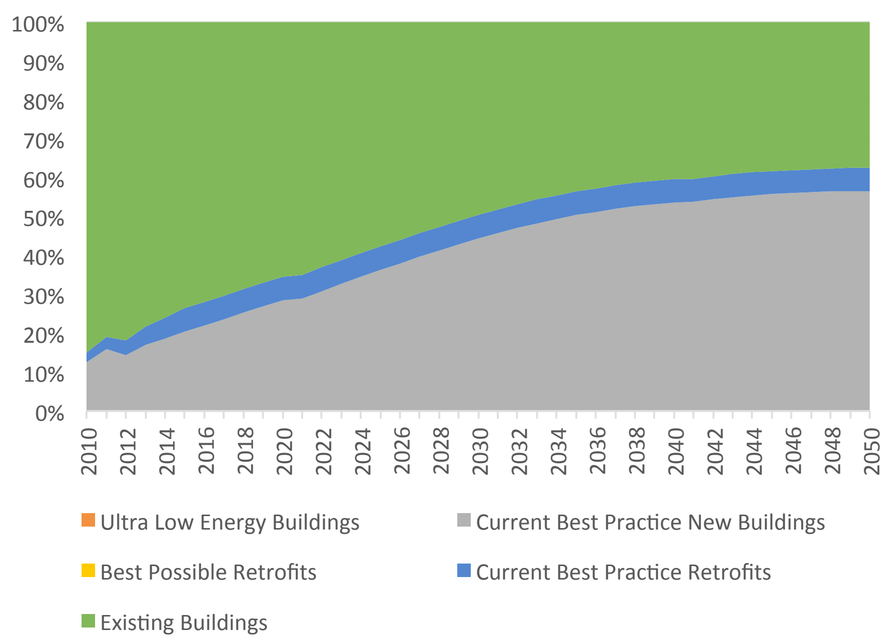




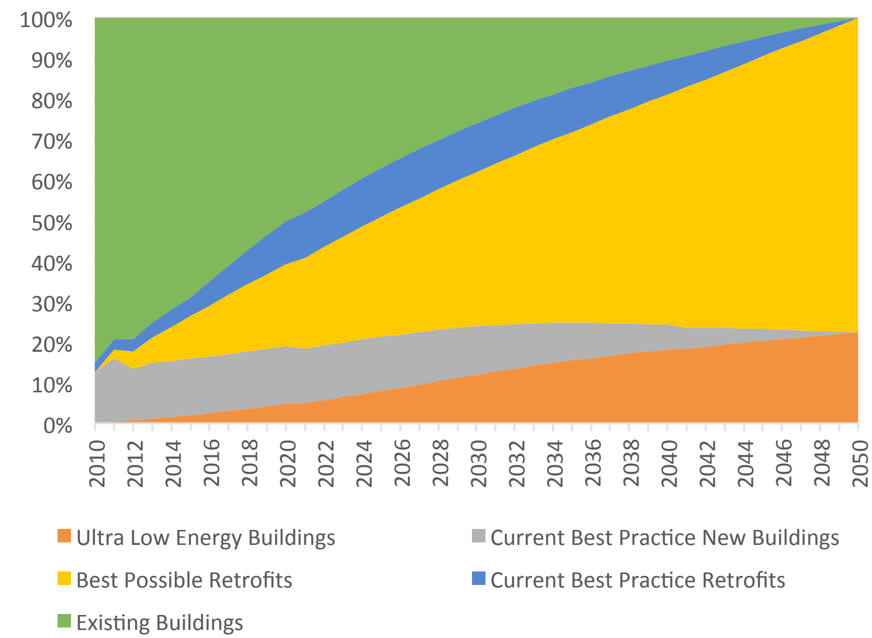
Cooling and heating account for 65% of commercial buildings energy consumption

DEEP BUILDING RETROFITS AND ULTRA

Reference Case



Reinventing Fire Case

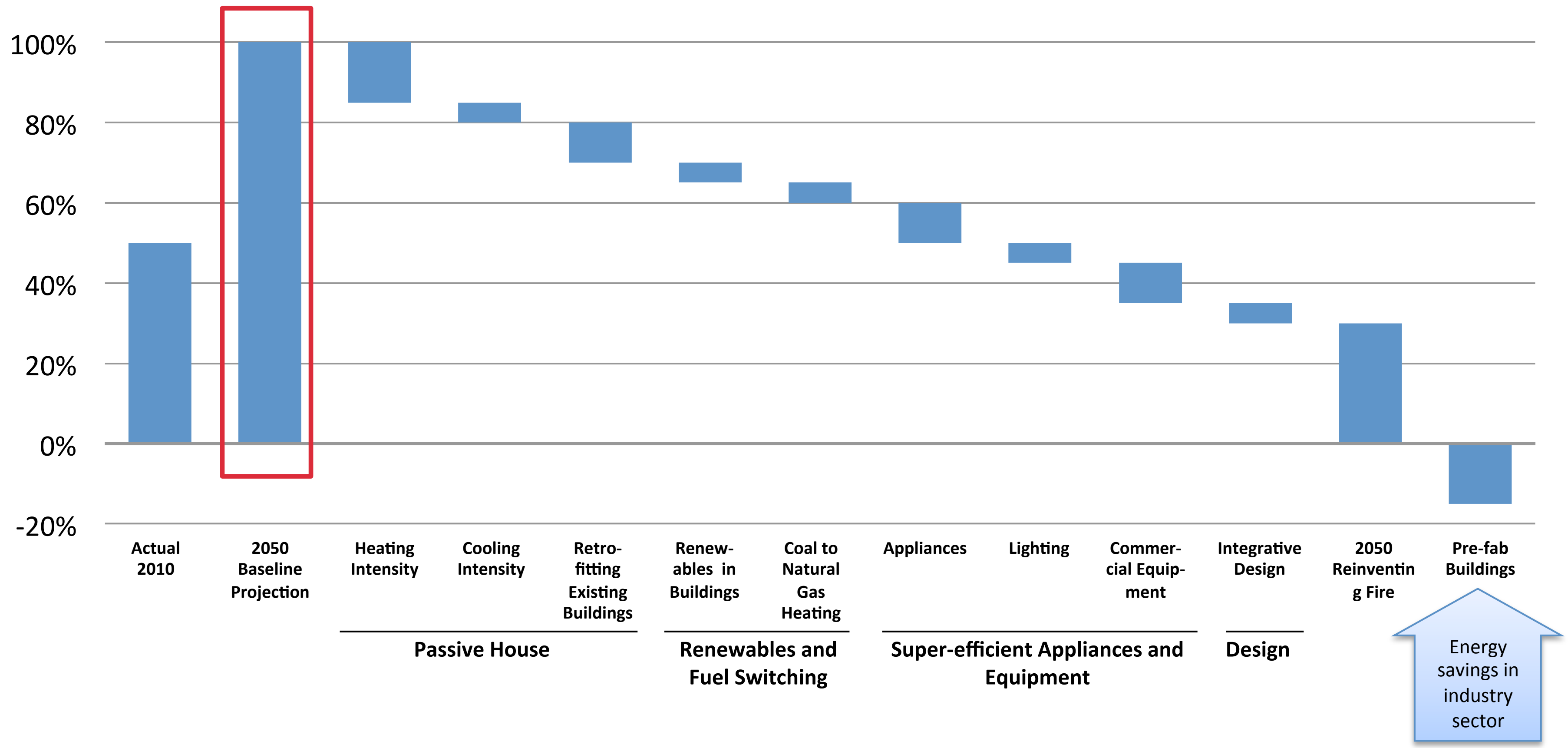


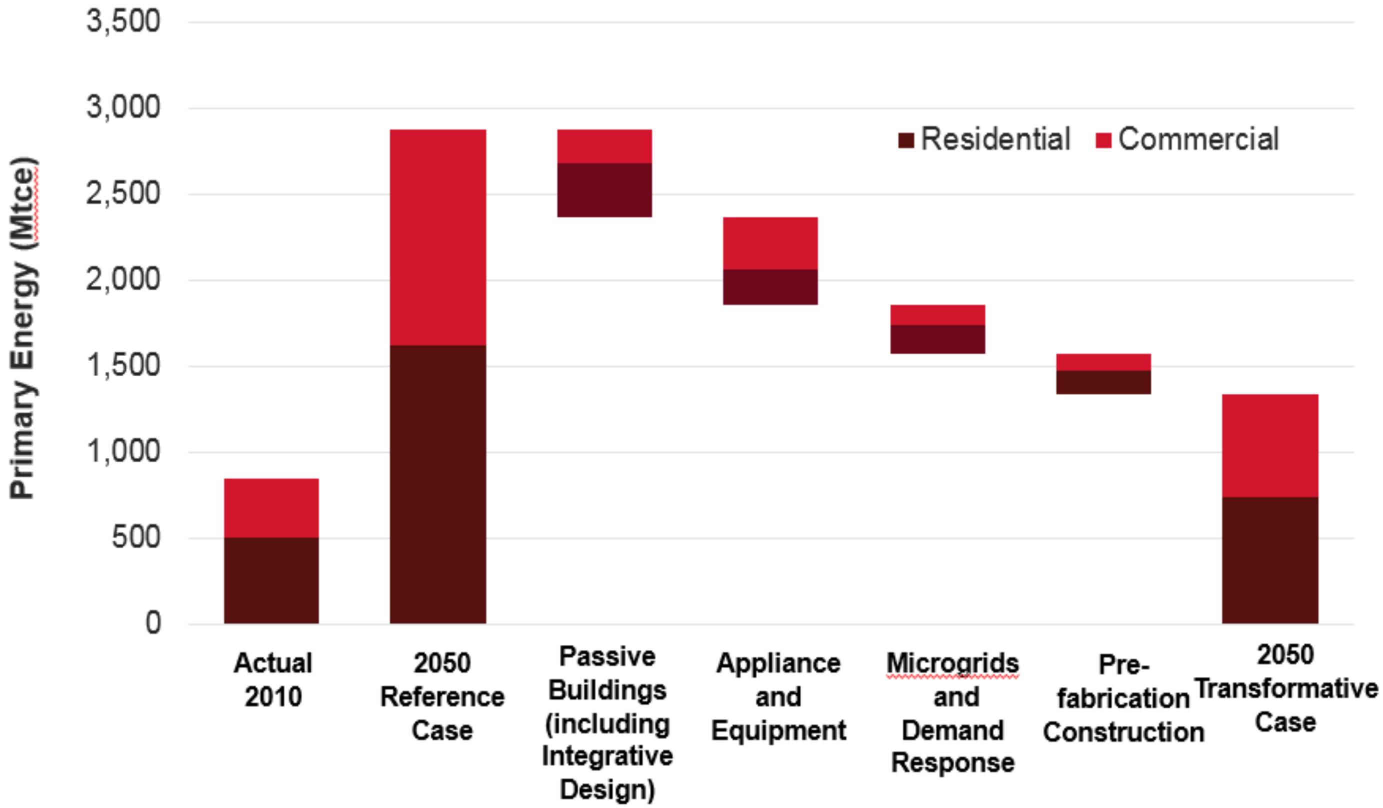
2050 SCENARIOS ILLUSTRATIVE RESULTS

Buildings energy use can likely be reduced to less than half

ILLUSTRATIVE – ANALYSIS NOT COMPLETE

Energy Reductions in the Reinventing Fire Scenario
Indexed (100% = Baseline energy use in 2050)





China Buildings Sector Energy Savings Potential Waterfall Chart