China End-Use Energy Demand Modeling

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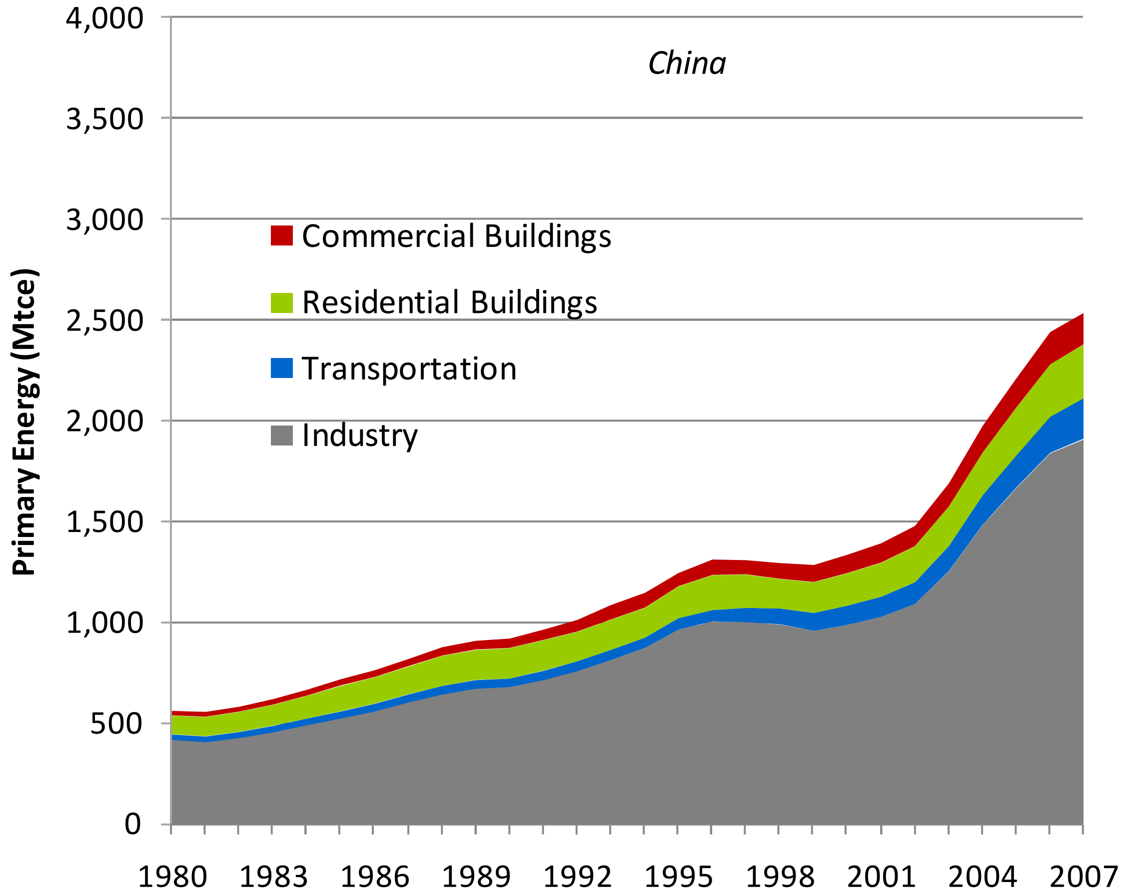
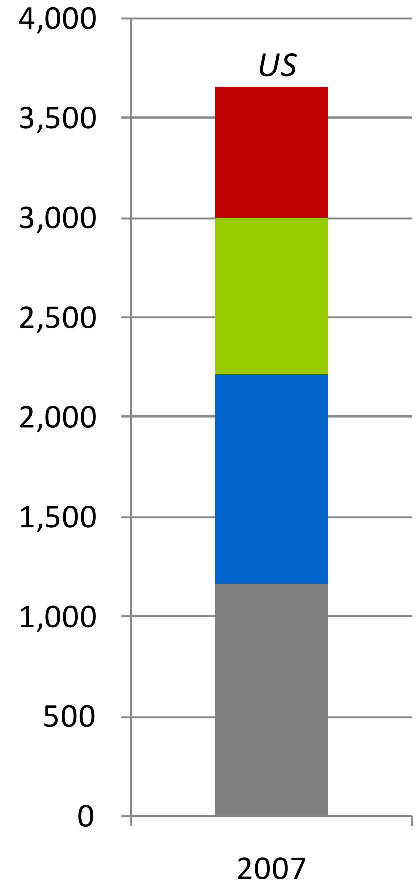
Overview

- Context: Energy Use in China
- LBNL's China End-Use Energy Modeling
- Applications of the China End-Use Energy Model
  - ➢ Understanding China's Energy Data
  - ➢ Development of Baseline for China 2020 Energy Future
  - ➢ Evaluating Policies
- Uniqueness and Impacts

Context: Energy Use in China





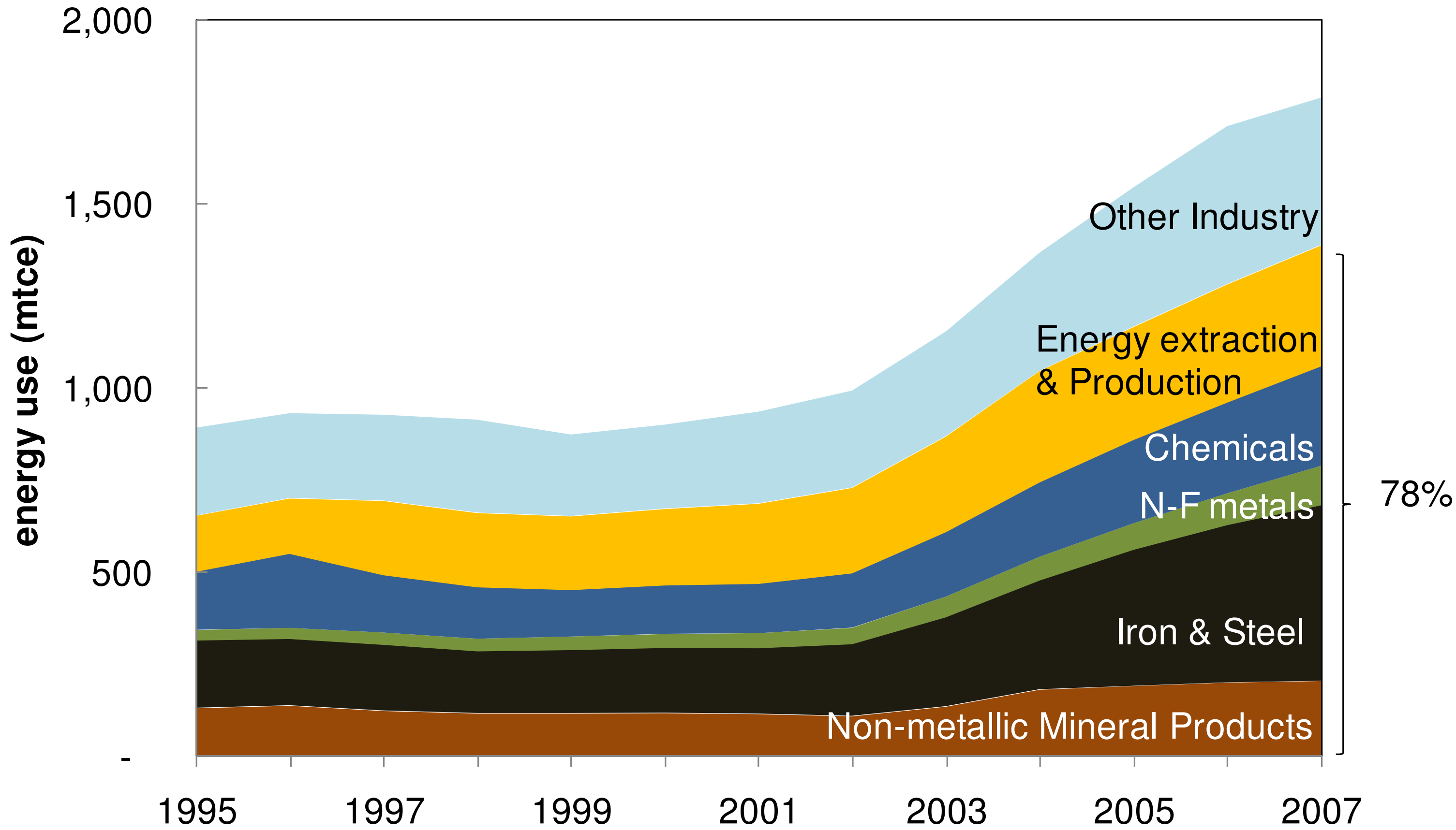
Source: National Bureau of Statistics, various years, *China Statistical Abstract*.
National Bureau of Statistics, 2007, *China Energy Statistical Yearbook*.

Source:
U.S. Energy Information Administration,
2008. *Annual Energy Outlook.*

Mtce stands for Million ton of coal equivalent . Note: Mtce >> EJ = 0.0293; EJ >> Quads = 0.9478

Context: Industrial Energy Use in China

Production of energy-intensive commodities soared in recent years



Source: NBS. Mtce stands for Million ton of coal equivalent

LBNL's China End-Use Energy Model Motivation

Motivation

- Chinese policy makers are heavily focused on energy-efficiency improvement
- U.S. government needs to understand China's energy dynamics

Needs

- Need end-use detail to plan and evaluate energy efficiency policies and programs for
  - Short term 20% energy/GDP target 2005-2010
  - Long term strategic planning

Reality

- **but** globally only few energy models have the capacity to model energy demand by end use

LBNL model

- LBNL's bottom-up model provides ability to capture:
  - potential for efficiency improvement by technology
  - impacts of efficiency programs
  - impact of technology trends
- Energy intensity improvement potential disaggregated by:
  - End use sector
  - Saturation, usage
  - Technology size/scale
- Benefit is more insight into long-term dynamics and impact policies

LBNL's China End-Use Energy Model Approach

- Based on LBNL's long term experience in working with Chinese collaborators over many years
- Model constructed using LEAP model (**accounting framework**)
  - Transparent with respect to assumptions made
  - Structure allows for data-rich analysis
  - "Bottom-up" **demand-driven** approach related to socio-economic drivers
  - Sectors highly **disaggregated**
- Detailed consideration of **technologies**
  - End-use equipment modeled
- Drivers: population + urbanization, saturation, construction floor area, and others.

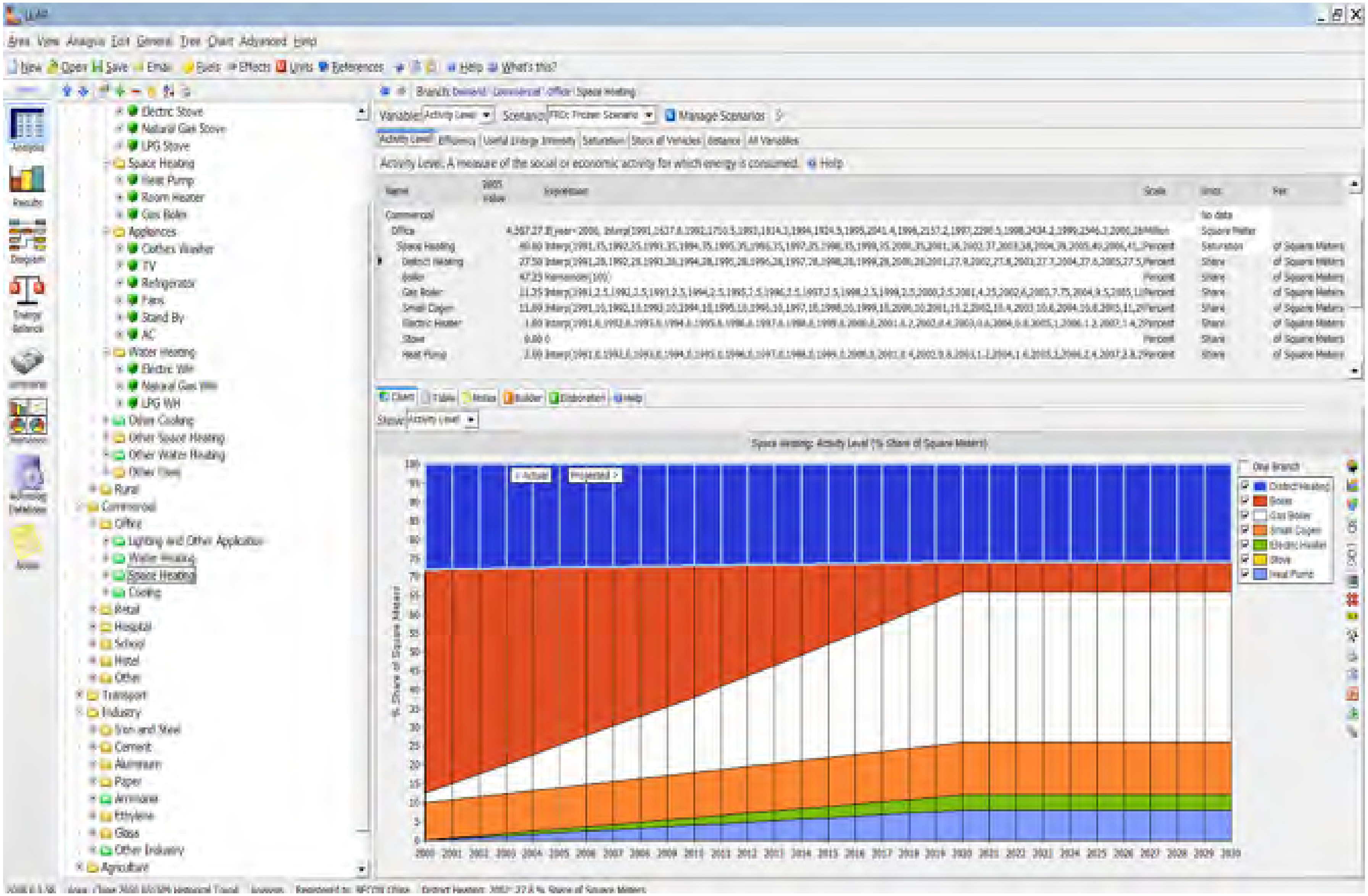
LBNL's China End-Use Energy Model Methodology: Residential Sector

$$E_{RB} = \sum_{i}^{OPTION} \sum_{m}^{OPTION} \frac{P_{m,i}}{F_{m,i}} \times \left[\left(H_{m,i} \times \left(SH_{m,i} \right) \right) + \left(\sum_{j} p_{i,j,m} \times UEC_{i,j,m} \right) + C_{m,i} + W_{m,i} + L_m + R_m \right]$$

m	=	locale type (urban, rural)
$P_{m,i}$	=	population in locale *m* in region *i*
$F_{m,i}$	=	number of persons per household (family) in locale *m* in region *i*,
$H_{m,i}$	=	average floor area per household in locale type *m* in region *i* in m^2
SH_i	=	space heating energy intensity in residential buildings in region *i* in kWh/m^2-year,
j	=	type of appliance or end-use device,
$p_{i,j}$	=	penetration of appliance or device *j* in region *i* in percent of households owning appliance (values in excess of 100% would indicate more than one device per household on average),
$UEC_{i,j}$	=	energy intensity of appliance *j* in region *i* in MJ or kWh/year,
C_i	=	cooking energy use per household in region *i* in MJ /household-year,
W_i	=	water heating energy use per household in region *i* in MJ /household-year,
L_m	=	average lighting energy use per square meter in locale type *i* in kWh /square meter-year, and
R_m	=	residual household energy use in locale type *i* in MJ /household-year.

Reference: Nan Zhou, Michael A. McNeil, David Fridley, Jiang Lin, Lynn Price, Stephane de la Rue du Can, Jayant Sathaye, and Mark Levine, 2007. *Energy Use in China: Sectoral Trends and Future Outlook,* Lawrence Berkeley National Laboratory, LBNL- 61904

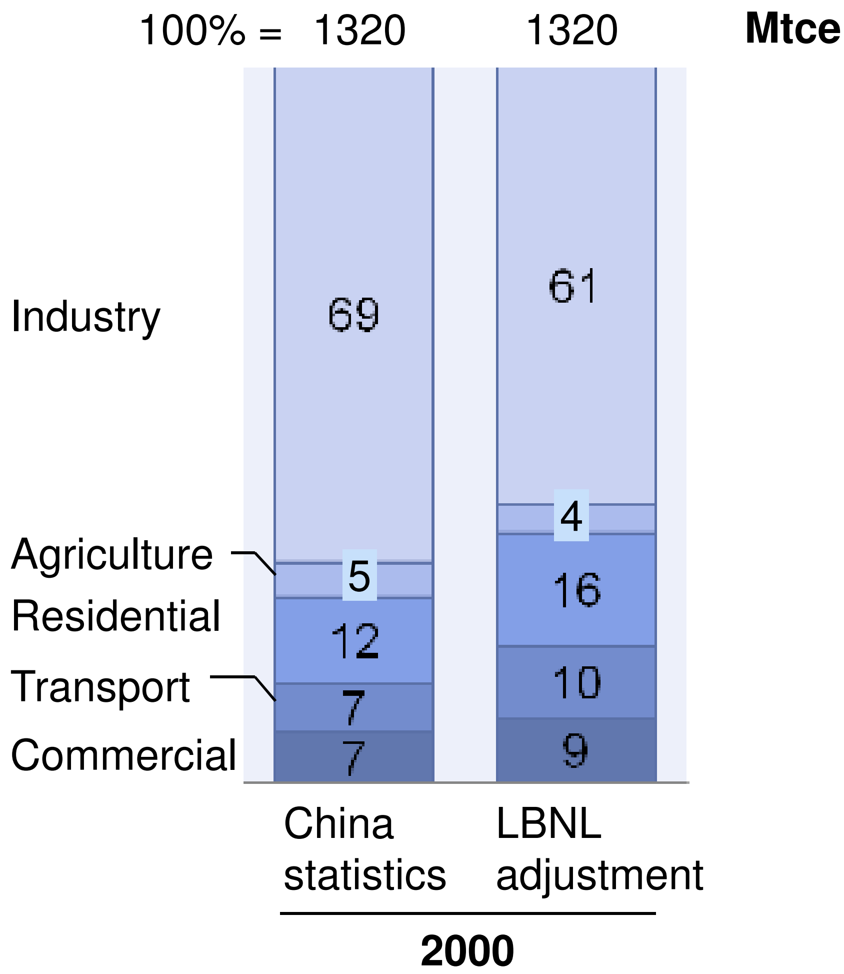
Bottom-Up LEAP Accounting Model



LBNL's China End-Use Energy Model Methodology

	Buildings	Industry	Transport
Activity (A)	- population - # households (electrified/non, urban/rural) - m^2 residential - m^2 commercial	-Production - physical (tonnes) -economic (VAGDP)	- Personal income -person-km - Freight /economic activity -ton-km
Structure	- By sub-sector -residential -commercial - By end-use - heating, cooling - refrigeration - appliances - equipment - lighting	- By sub-sector - iron & steel - aluminum - cement - pulp & paper - chemicals - etc… -Product mix	- By Mode - Road - Rail - Air - Water - By Vehicle Type - Passenger car - Truck -- etc…
Energy Intensity (EI)	- Technology -saturation/ stock accounting -energy intensities • efficiency • usage • size/features	- Technology -share -energy intensities •Energy use/ton of product •Fuel share	-Technology -ownership -energy intensities • efficiency • usage

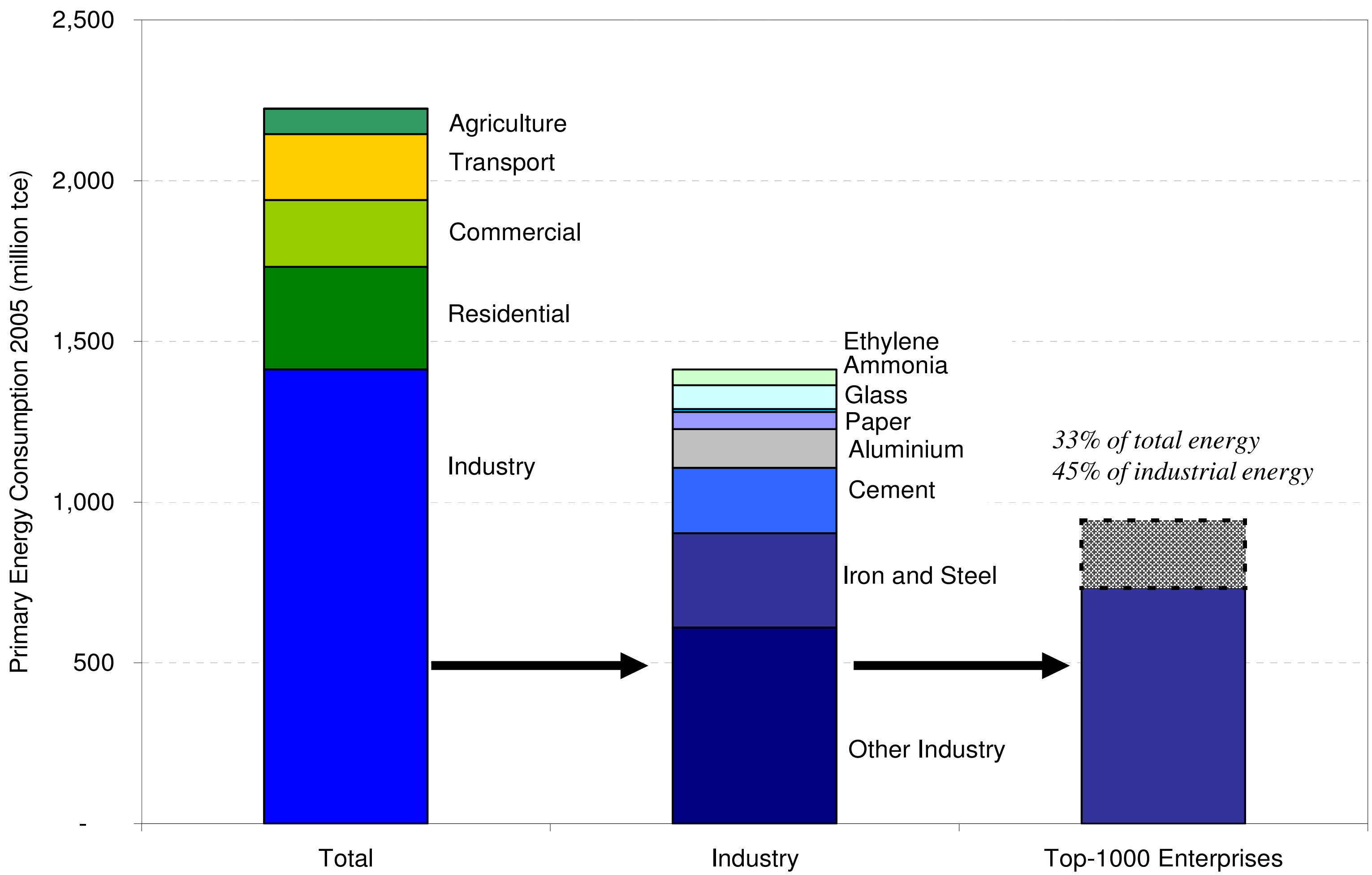
Understanding Current End-Use Consumption in China



Source:China Energy Databook 2005

Reference: Nan Zhou, and Jiang Lin. The Reality and Future Scenarios of Commercial Building Energy Consumption in China, Energy& Buildings, June 2008. LBNL-1036E

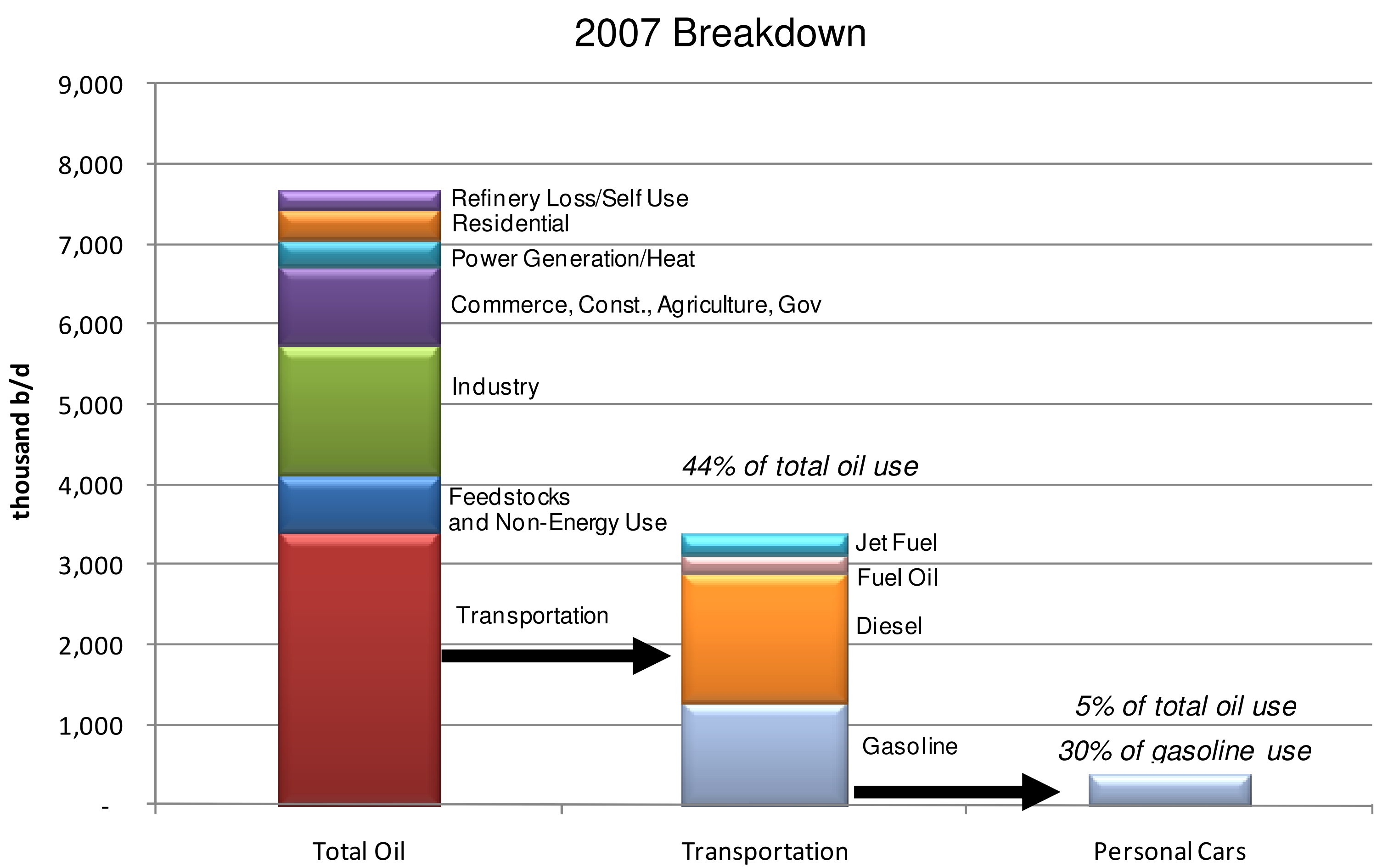
Understanding Current End-Use Consumption in China Industry



Note: Mtce>> EJ = 0.0293; EJ >> Quads = 0.9478

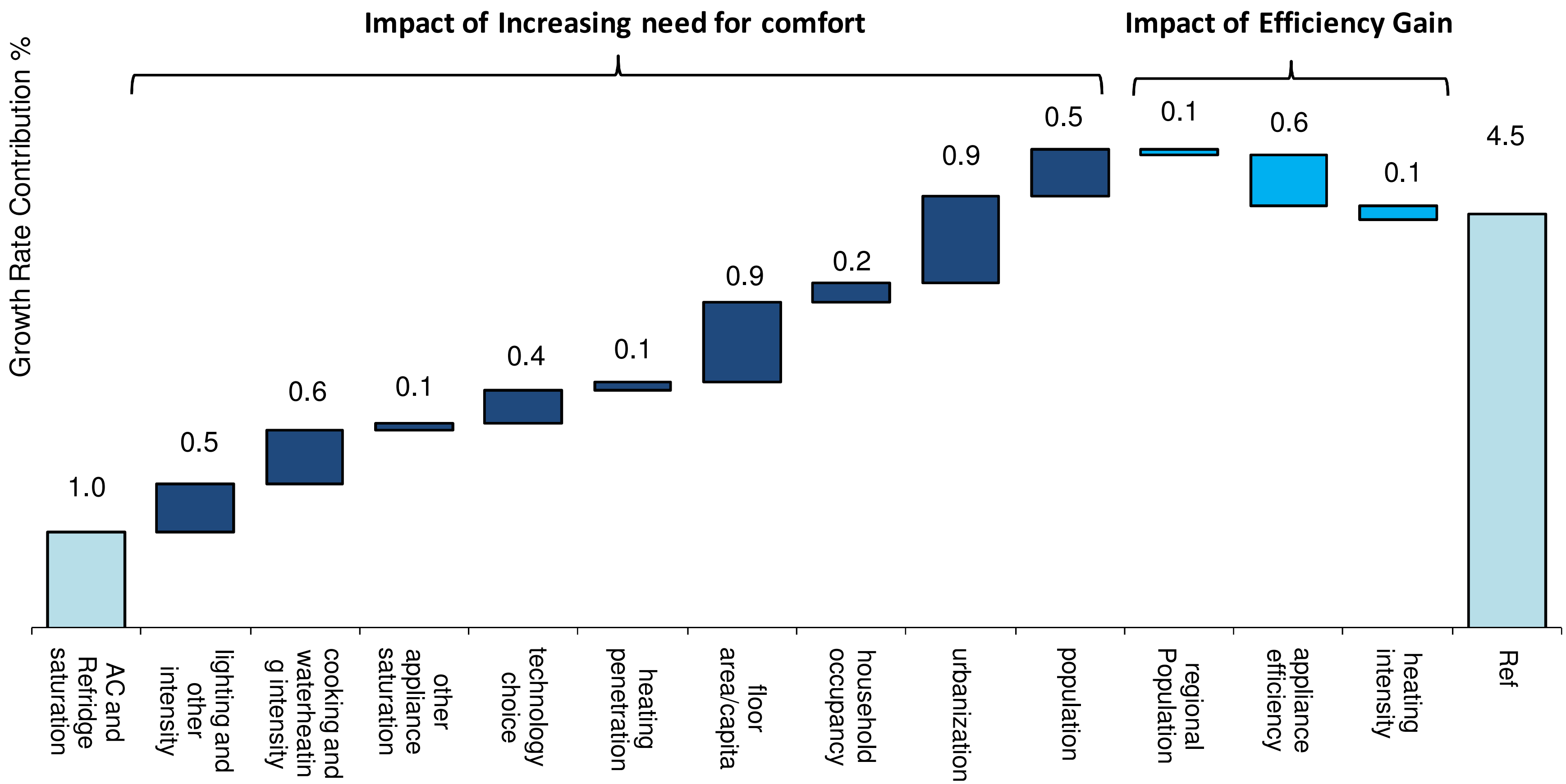
Reference: Price, Lynn; Wang, Xuejun; Jiang, Yun, 2008. China's Top-1000 Energy-Consuming Enterprises Program: Reducing Energy Consumption of the 1000 Largest Industrial Enterprises in China, Lawrence Berkeley National Laboratory Report (LBNL-519E)

Model Used to Understand Drivers and End-uses of China's Oil Consumption



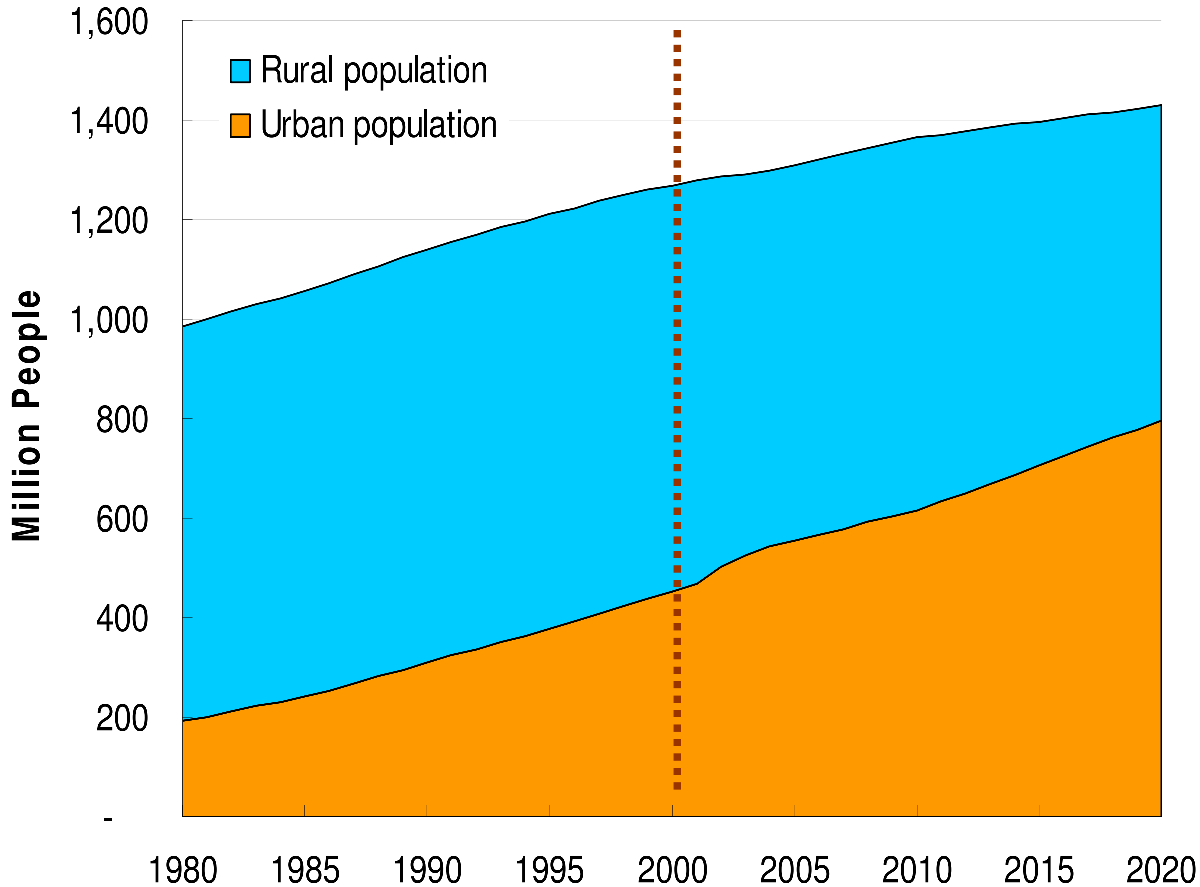
Development of the Baseline Scenario for China 2020 Energy Future: Residential Energy

Many forces drive building energy up faster than efficiency can improve. The largest contributions to the growth rate are: appliance saturation, increased floor area per capita and urbanization



Development of the Baseline Scenario for China 2020 Energy Future: Residential Energy

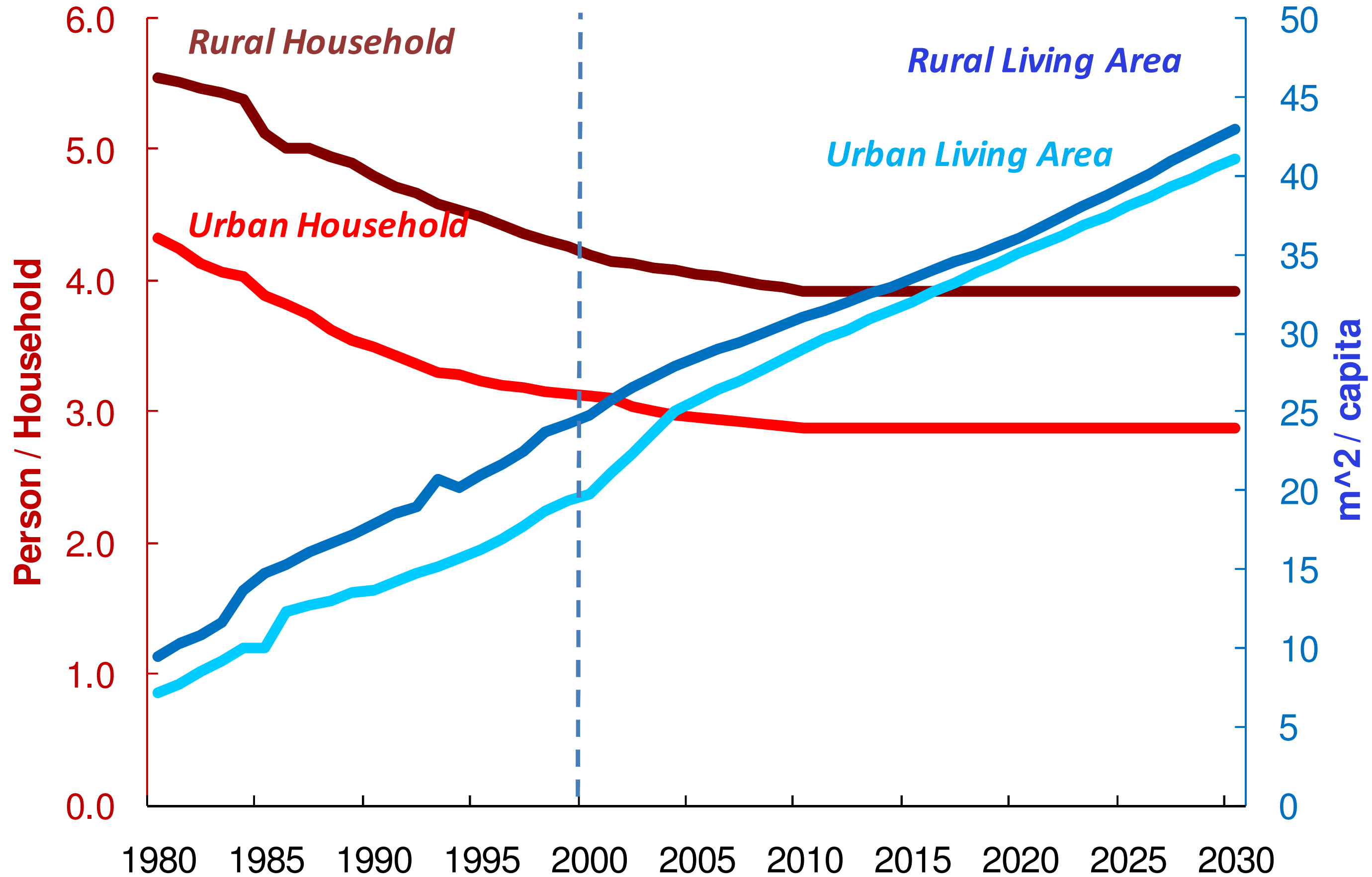
Continued urbanization drives rapid rise in city residential energy consumption



- 290 million new urban residents from 1990 to 2007
- 375 million new urban residents expected 2007 to 2025
- All to be provided with housing, energy, water, transportation, and other energy services

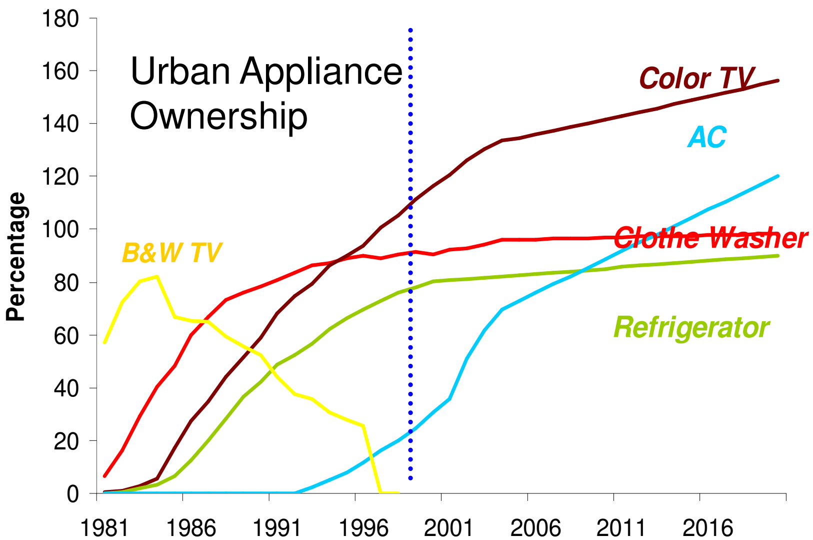
Development of the Baseline Scenario for China 2020 Energy Future: Residential Energy

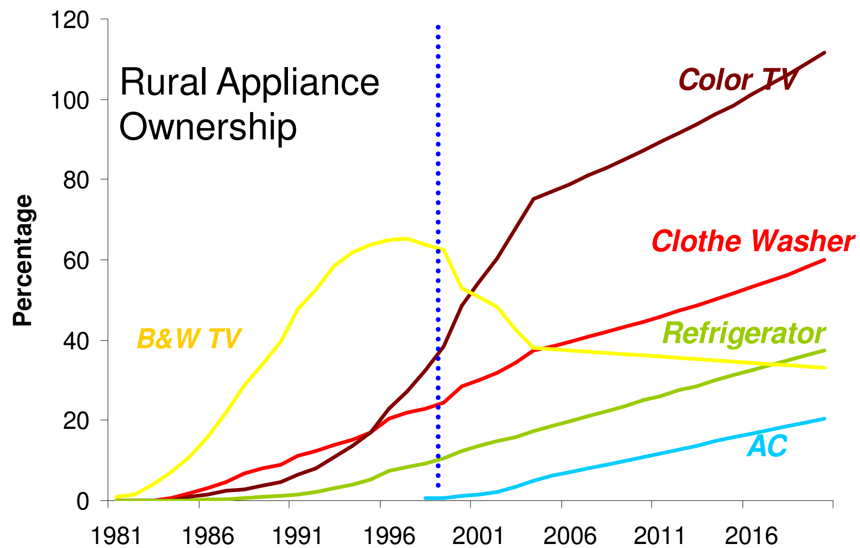
The decline in household size together with the increase in living area will multiply the contribution of energy demand from households.



Development of the Baseline Scenario for China 2020 Energy Future: Residential Energy

Increased income levels and decreasing appliance prices drive the growth of the ownership of appliances, but will slow down when reaches a high saturation rate.





- **Most urban areas have full saturation of appliances by 2007**
- **New subsidies for rural appliance purchases will further boost the saturation in rural areas**

Development of the Baseline Scenario for China 2020 Energy Future: Residential Energy

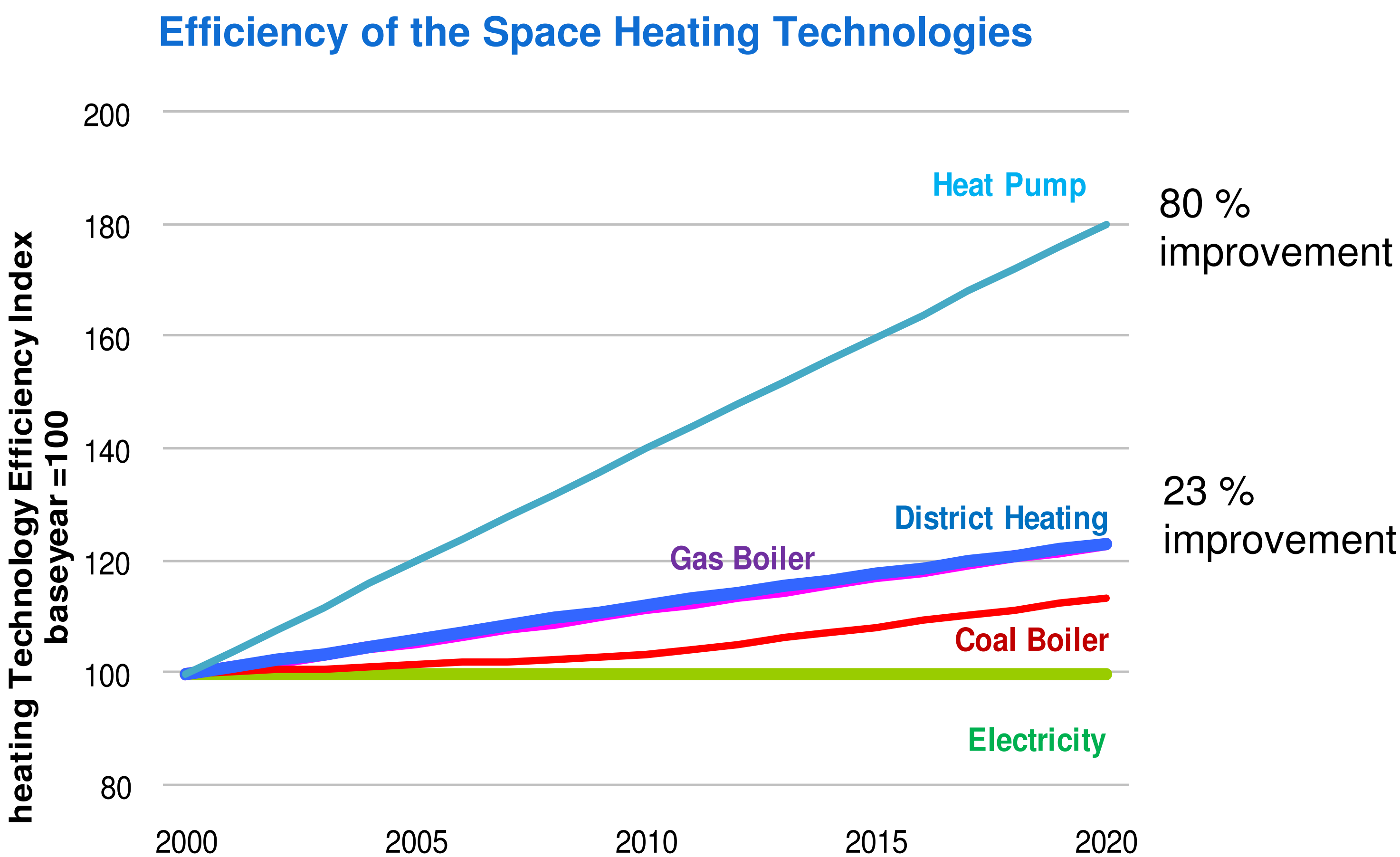
Energy intensity will increase in order to accommodate the demand for higher levels of comfort except space heating.

Residential Energy Intensities by End-use

		Urban enduse intensity 2000	Urban enduse intensity 2020	Rural enduse intensity 2000	Rural enduse intensity 2020	Japanese 2004 most efficient technology	note
Space Heating							
North	kWh/m^2-year	79	64	5.85	30.6		
Transition	kWh/m^2-year	29.6	28.8	5	9.6		
Cooking	MJ/household-year	901.2	1421	997	1349		
water heating	MJ/household-year	3605	5685	3988	5396		
Other use	kWh/year	100	420	50	150		
lighting	kWh/m^2-year	3	4.5	1.5	2.2	4Wh/m^2 in 1998	
Refrigerator UEC	kWh/year	461.2	421.9	458.9	422.3	380	for 250L-300L
Clothes washer							
vertical	kWh/year	35.88	32.9	23.9	28.1		
horizontal	kWh/year	92.4	60.9	61.36	51.5	21.9 to 40.2	for 4.2 kg
TV							
black& white	kWh/year	38	63.8	38	63.8		
color	kWh/year	125	243	125	243	79	for 29 inch
Air Conditioner UEC	kWh/year	387.6	245.6	375	248.9	47 kWh/month for cooling, 116 kWh/month for heating	for capacity of 2.5 kW

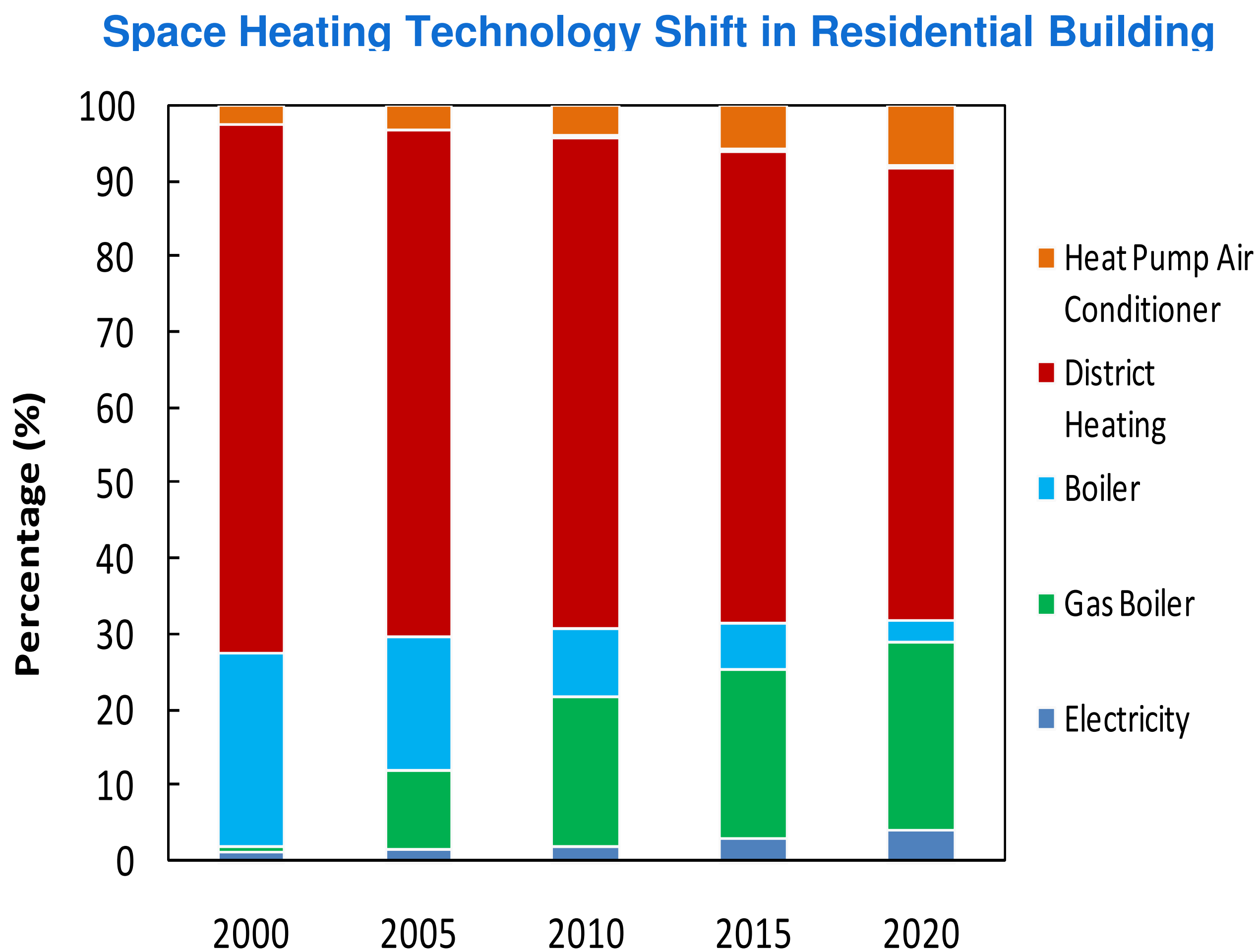
Development of the Baseline Scenario for China 2020 Energy Future: Residential Energy

The efficiency of the different technologies will be improved over time due to the improved efficiency standard as well as technology development



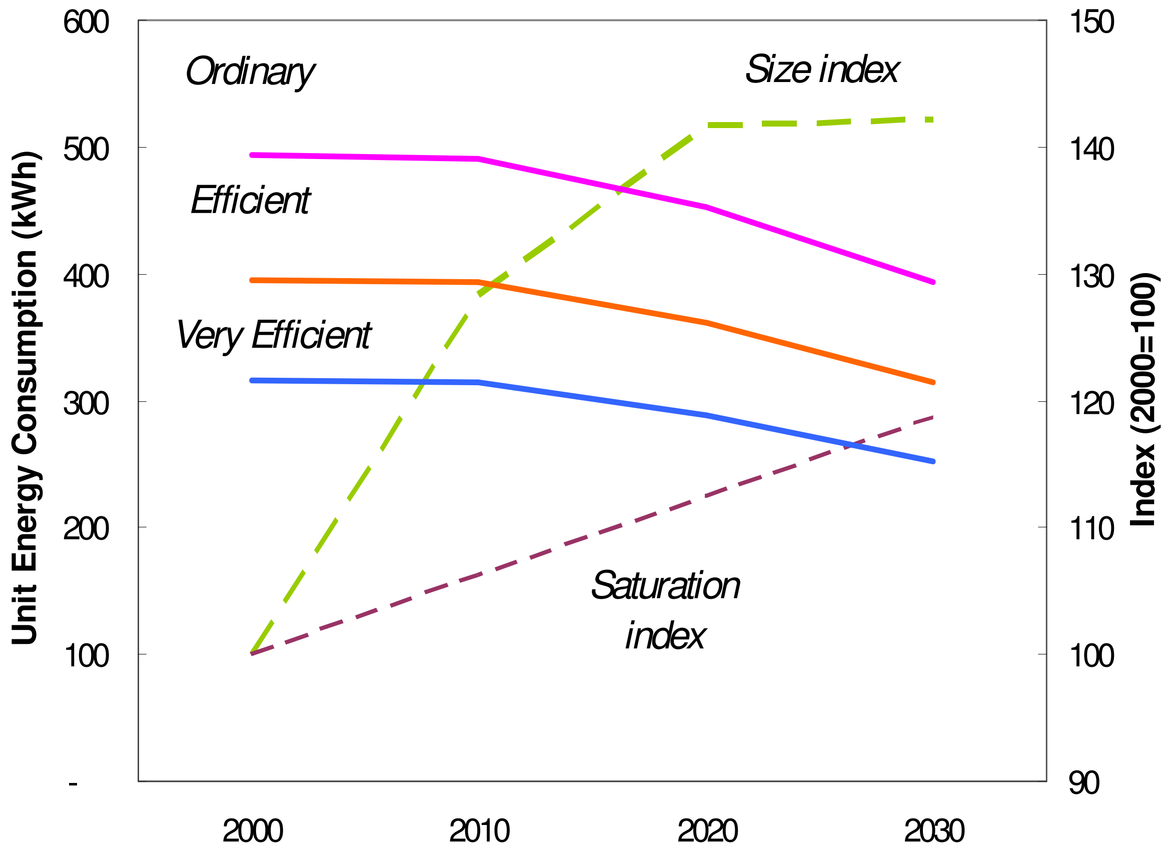
Development of the Baseline Scenario for China 2020 Energy Future: Residential Energy

The market share of efficient and cleaner technology also rises according to the current government policy.



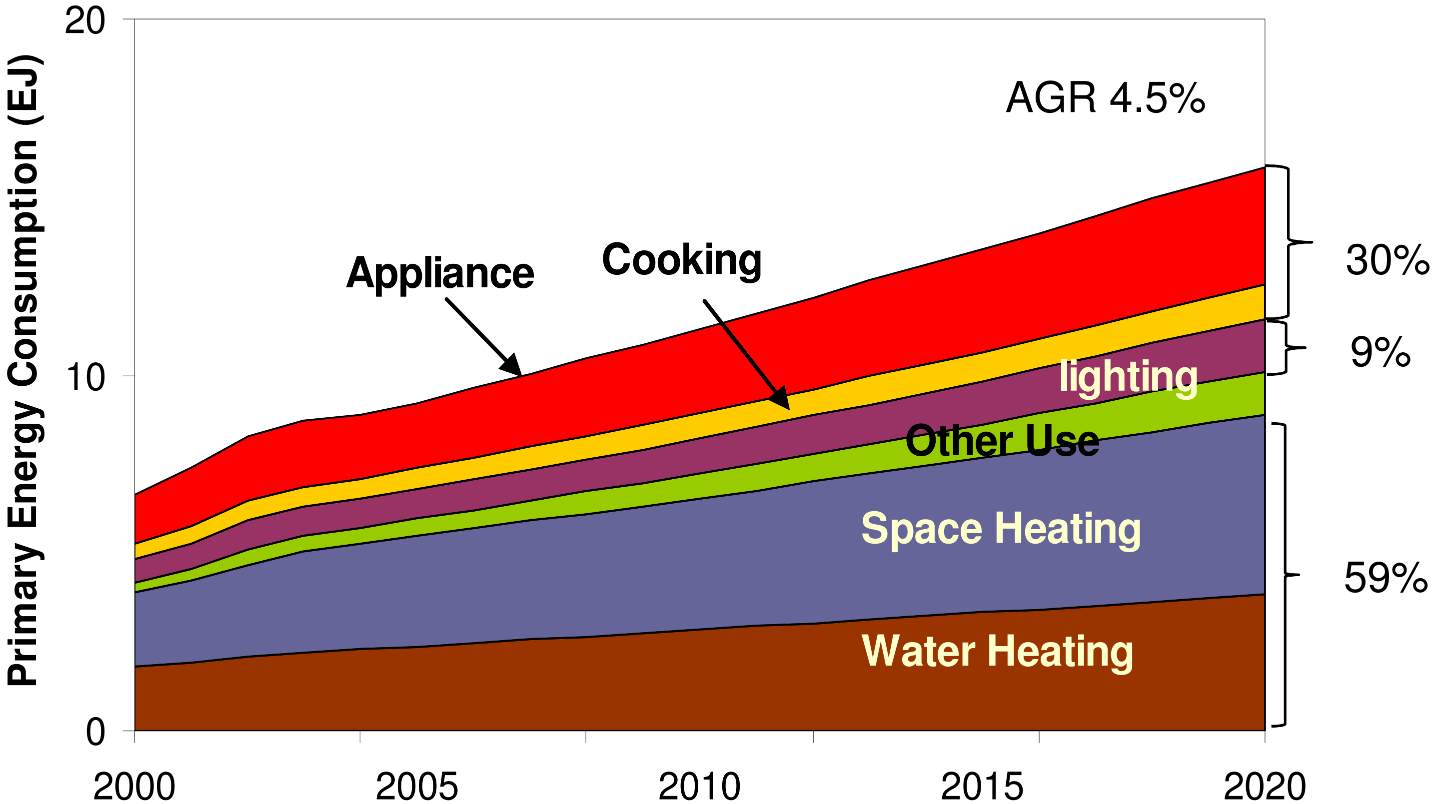
Development of the Baseline Scenario for China 2020 Energy Future: Residential Energy

The rise of the size of refrigerators offsets the efficiency improvements, that the average UEC of refrigerators would have more significant reduction otherwise.



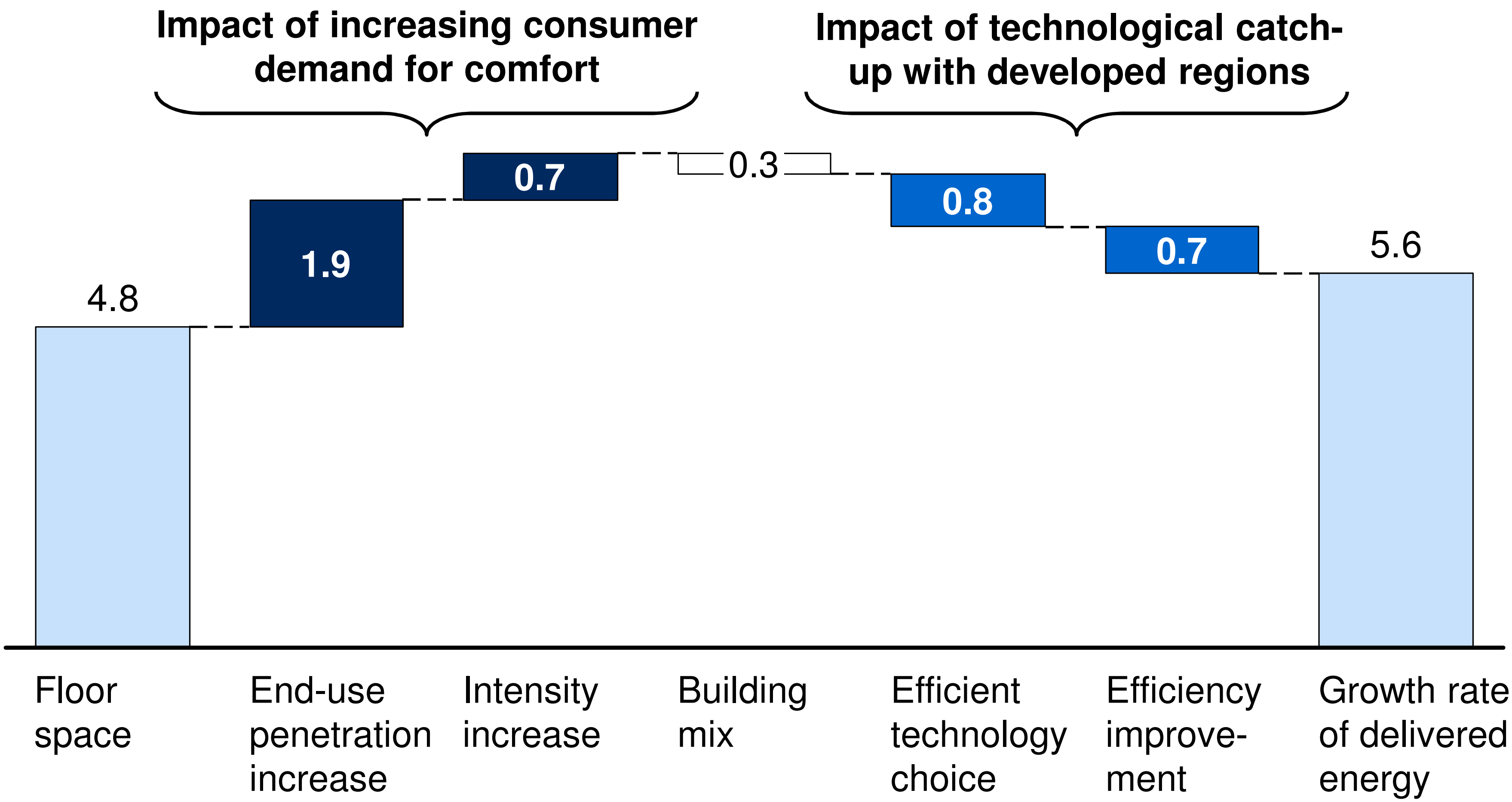
Development of the Baseline Scenario for China 2020 Energy Future: Residential Energy

Most of the energy is used for space heating and water heating. The four major appliances use about 21% of household energy. The share of appliance use increased to 25% from 30%.



Development of the Baseline Scenario for China 2020 Energy Future: Commercial Energy

Increased penetration and intensity will more than offset projected energy-efficiency improvements

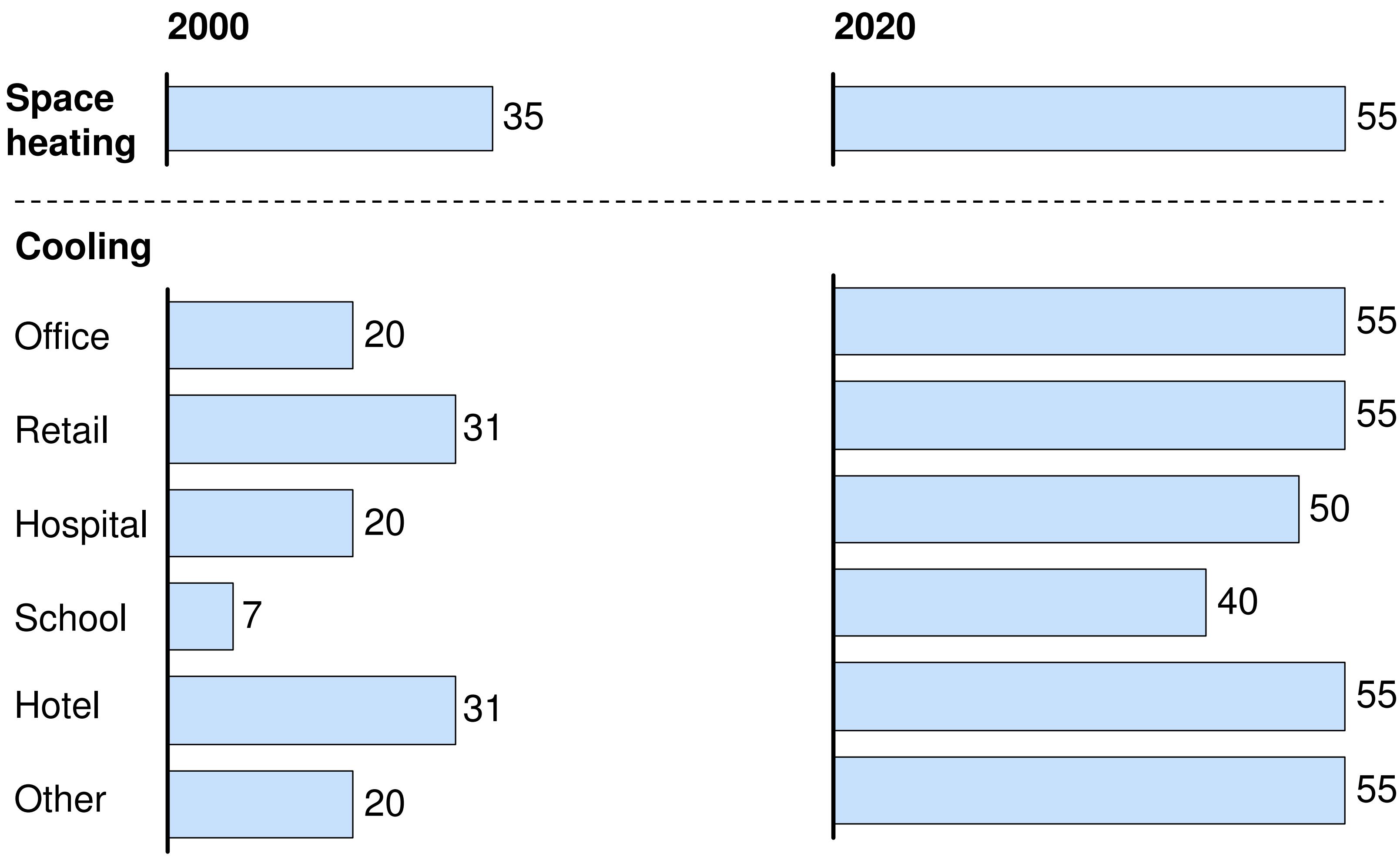


Key drivers of China commercial sector energy demand growth, 2003–2020 Percent

Source: LBNL, China Energy Group

Development of the Baseline Scenario for China 2020 Energy Future: Commercial Energy

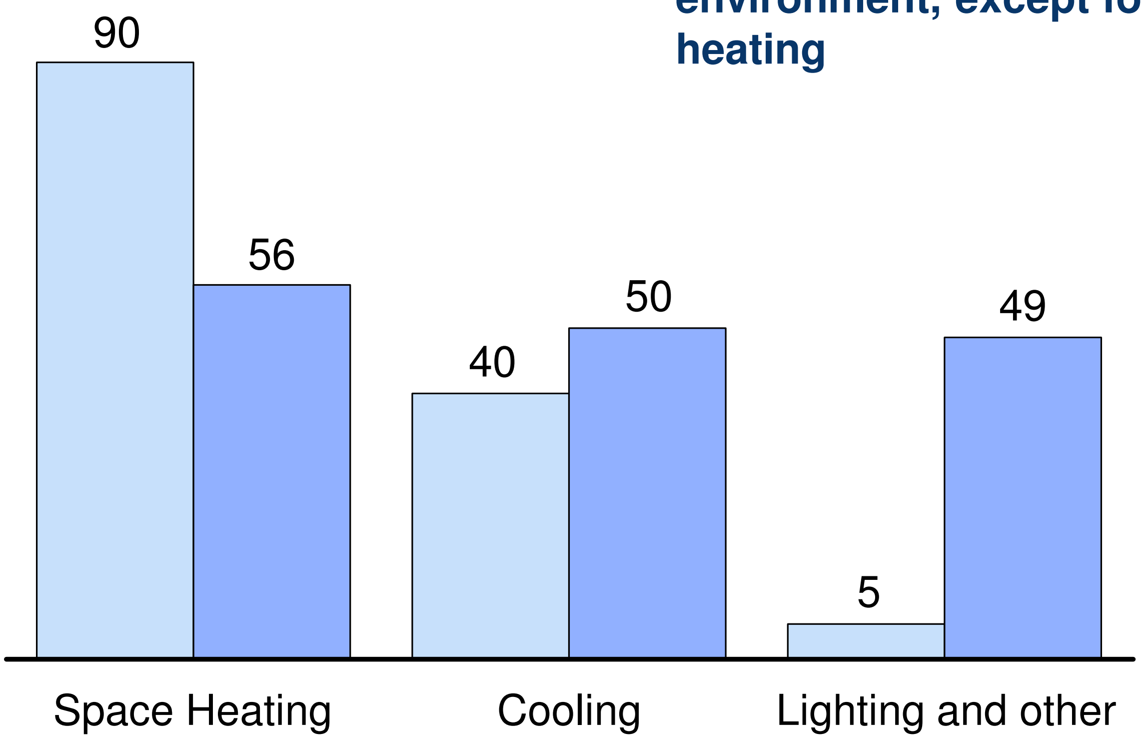
End-use penetration in China commercial sector, 2000–2020
Percent



Source: LBNL, China Energy Group; ERI

Development of the Baseline Scenario for China 2020 Energy Future: Commercial Energy

Energy intensity in 2000 and 2020
Kilowatt-Hour per Square Meter



- **Energy intensity will increase to maintain a suitable working and living environment, except for space heating**

Source: LBNL China Buildings model

Development of the Baseline Scenario for China 2020 Energy Future: Commercial Energy

Share of demand, 2005 (Percent)		Energy demand abatement potential*	Examples of efficiency improvements
49	Space heating	47	• Strong shift away from coal boilers to natural gas boilers • Efficiency of natural-gas boilers increases from 70% to 90% • Increased share of heat pumps
26	Water heating	29	(same as above)
9	Cooling	9	• Increased share of room A/C and heat pumps vs. centralized A/C
17	Lighting and other applications	5	• Increased share of CFL
	Weighted total	**35**	

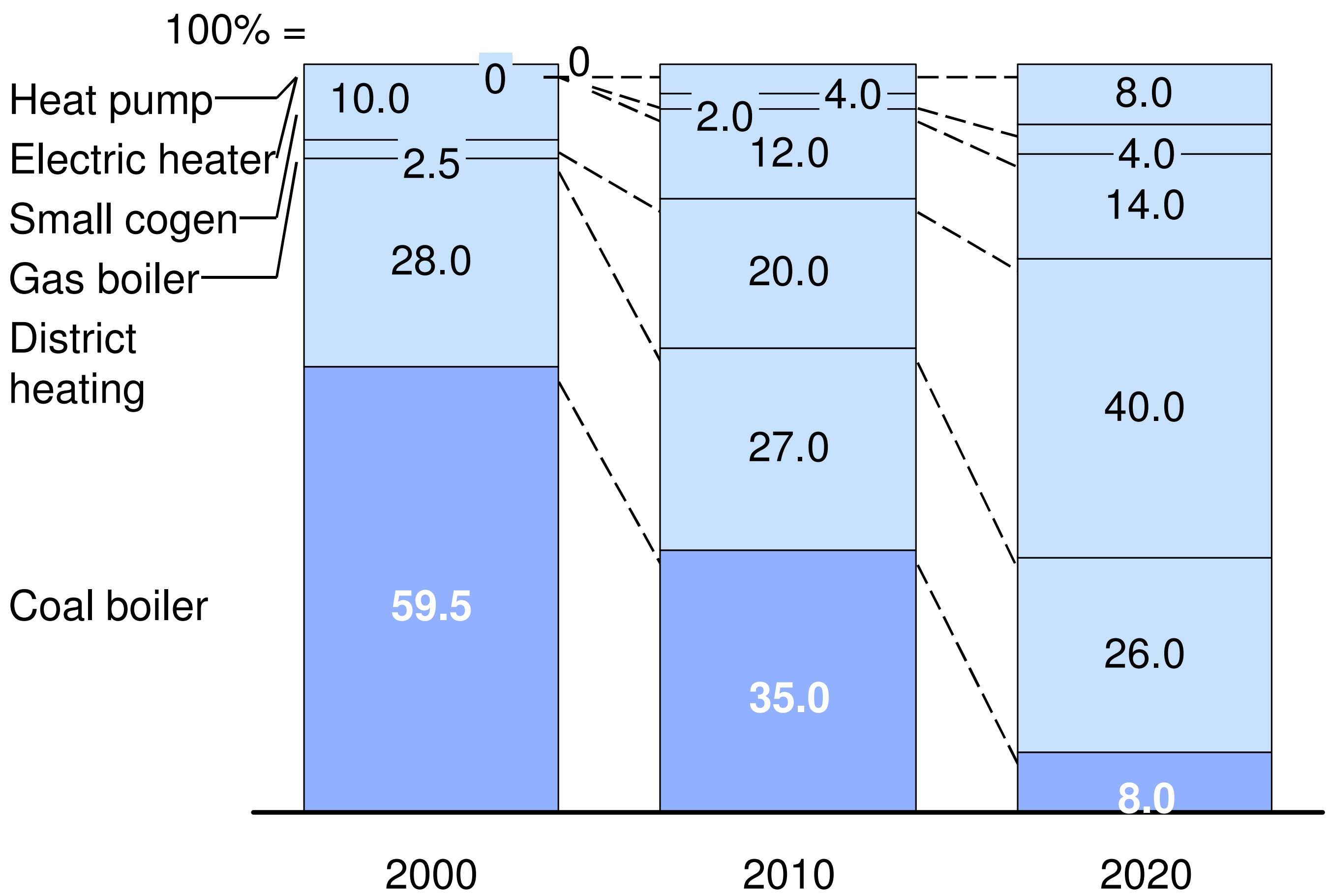
Assuming enforcement of current energy-efficiency policy to 2020 allows the capture of 25%, leaving a 10% potential

* As an example, doubling energy efficiency for a given end use leads to a demand reduction of 50%.

Source: LBNL, China Energy Group; MGI analysis

Development of the Baseline Scenario for China 2020 Energy Future: Commercial Energy

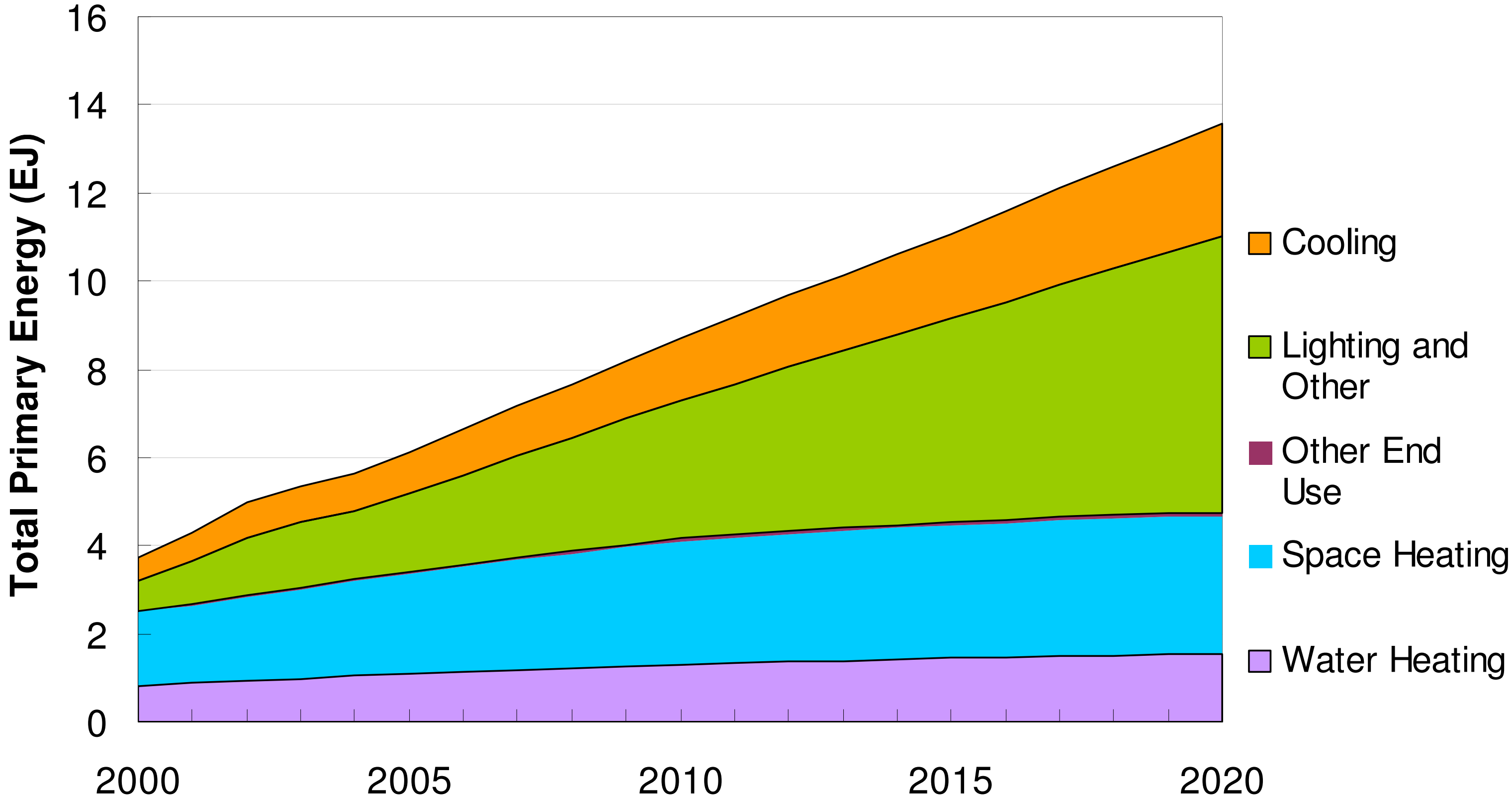
A radical shift in space-heating technology choices lead to a dramatic change in fuel mix



Source: LBNL, China Energy Group

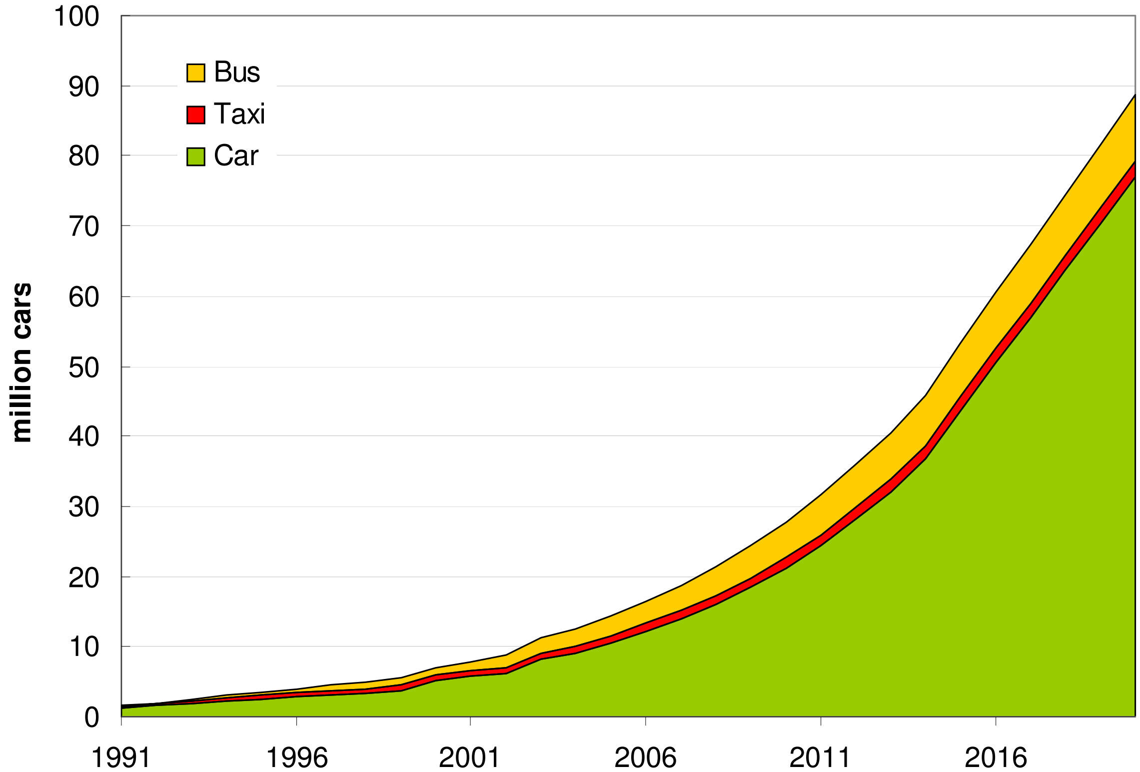
Development of the Baseline Scenario for China 2020 Energy Future: Commercial Energy

Commercial energy use grows for all end uses, but particularly for lighting & appliances



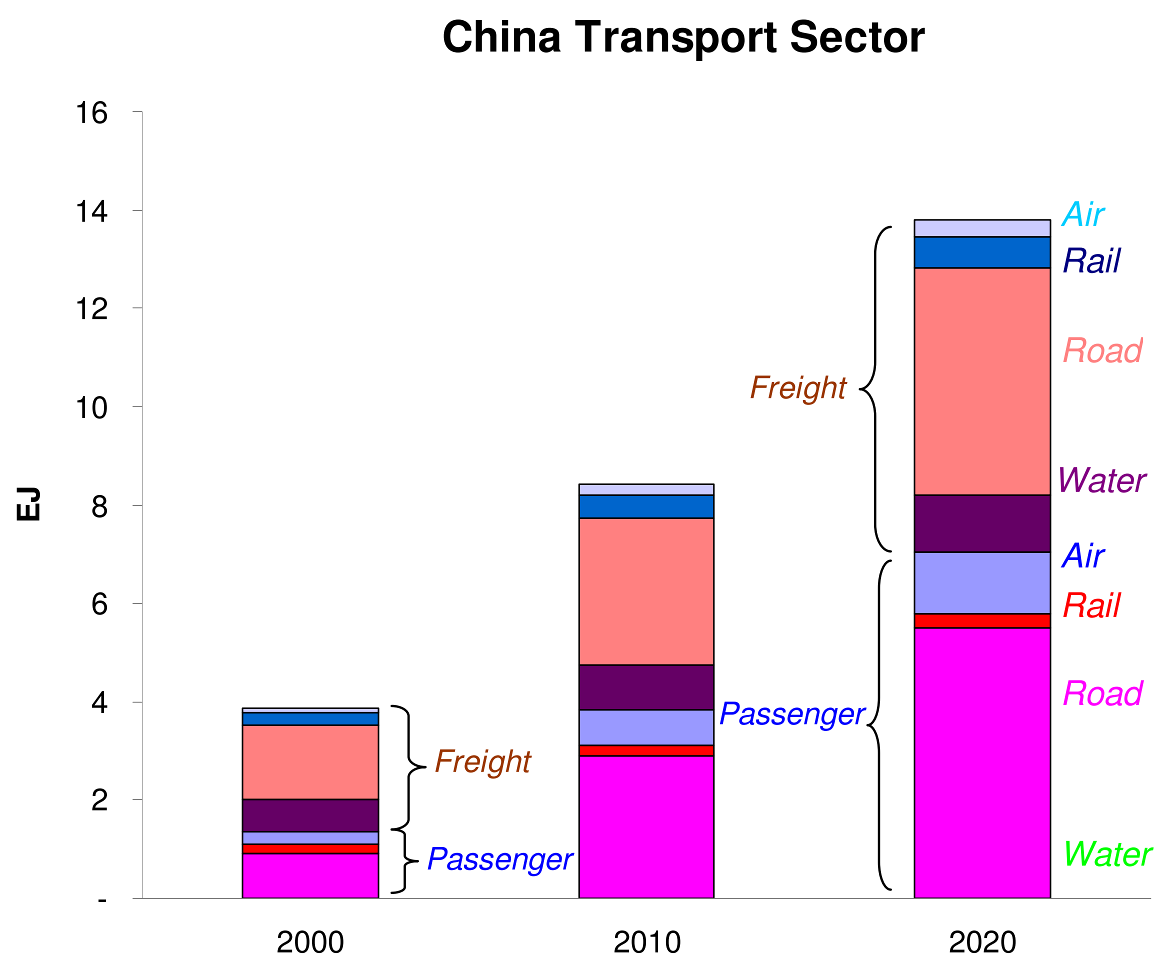
Development of the Baseline Scenario for China 2020 Energy Future: Transportation Energy

96 million vehicles includes 72 million personal cars in 2020



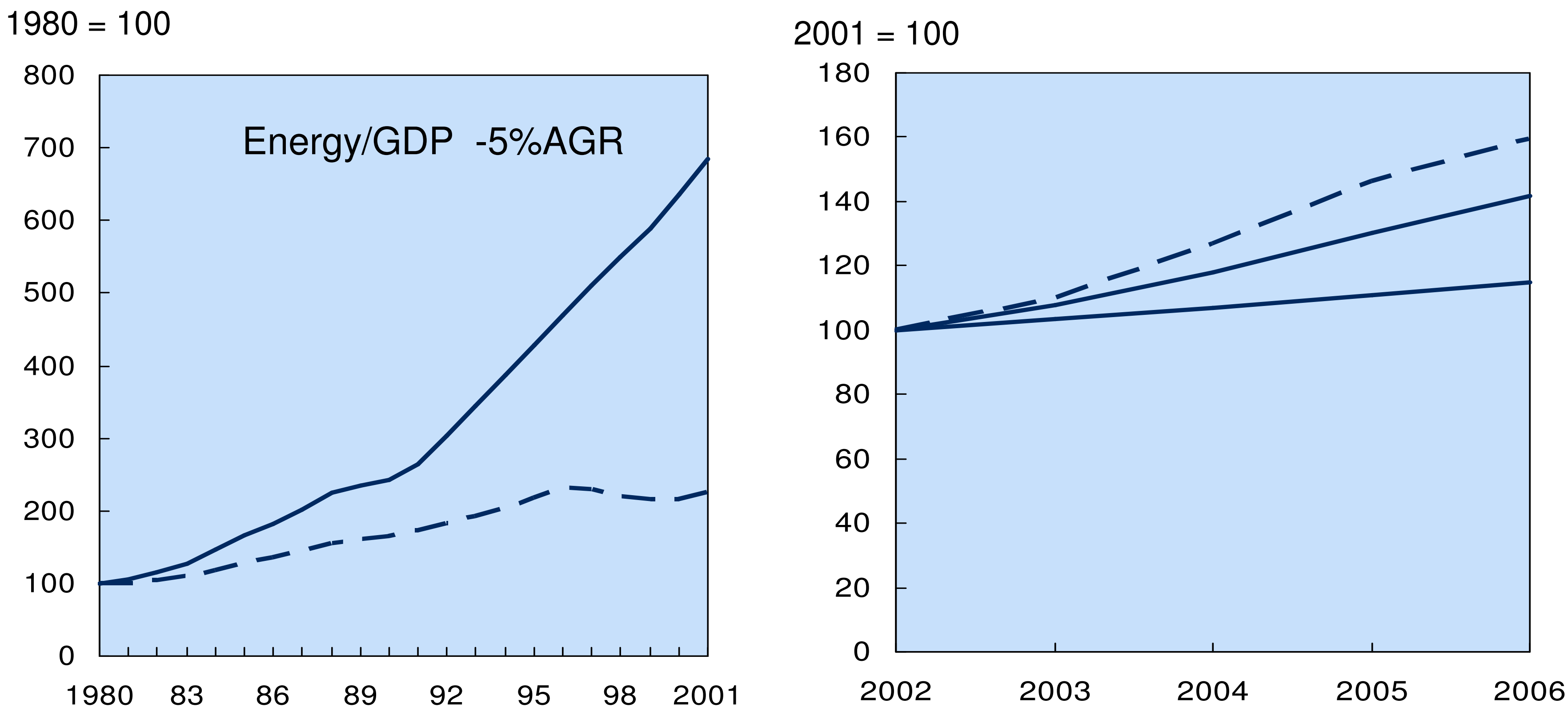
Development of the Baseline Scenario for China 2020 Energy Future: Transportation Energy

Passenger road transport will overtake freight in 2018



Other Applications
Evaluating Policies: 20% Energy/GDP Target

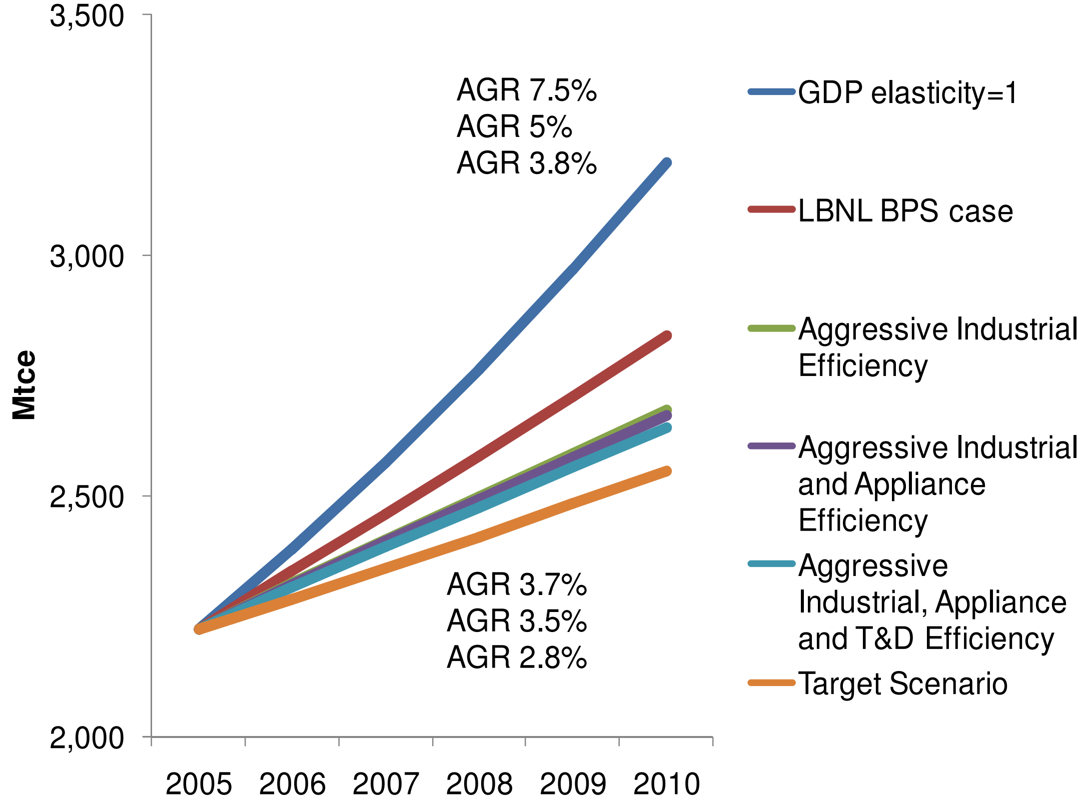
- Between 1980-2000, energy/GDP declined an average of 5%/year.
- Between 2002-2005, energy/GDP increased for the first time in over 20 years
- Threatened China's goal of quadrupling GDP between 2000-2020 while only doubling energy use
- Government set aggressive target to reduce energy/GDP by 20% between 2005-2010
- China End-Use Energy Model used in 2006/2007 to evaluate how this target could be achieved



Evolution of real GDP and total energy demand

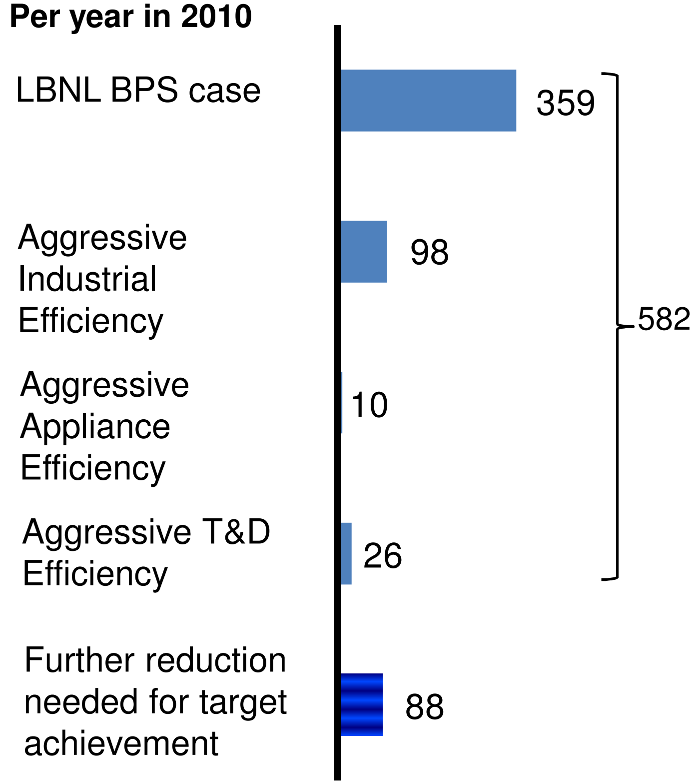
Evaluating Policies: 20% Energy/GDP Target

Possible efficiency scenarios



Energy saving potential (Mtce)

Per year in 2010



Reference: Lin, Jiang, Zhou, Nan, Levine, Mark, and Fridley, David. Taking out one billion tons of CO2: the magic of China's 11th five year plan? *Energy Policy*, No. 26. 2008, December 2007. LBNL-757E.

Evaluating Policies: China Lightens Up 2025

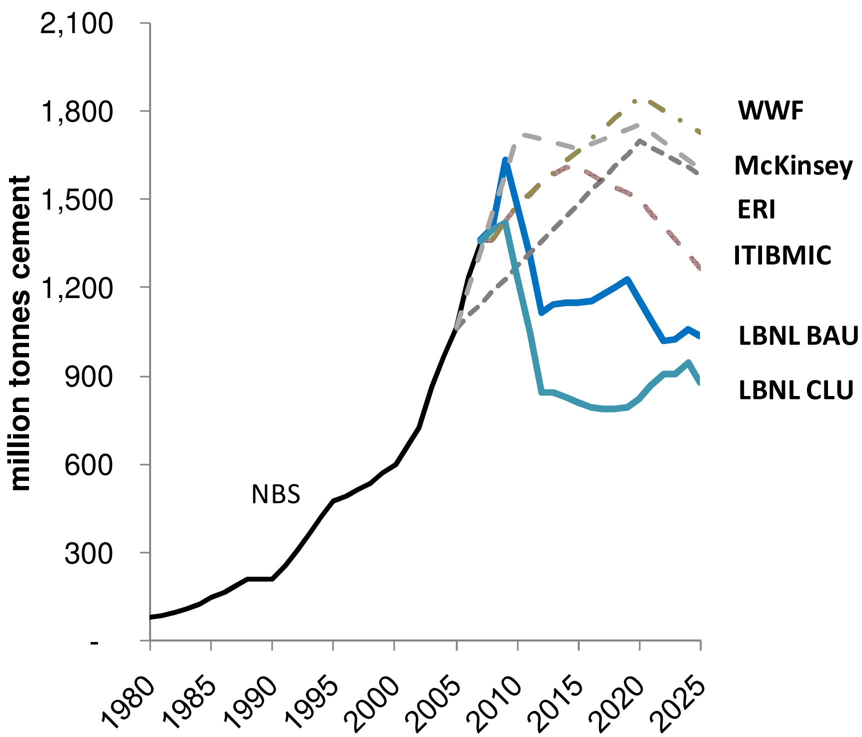
Cement Subsector Model Assumptions

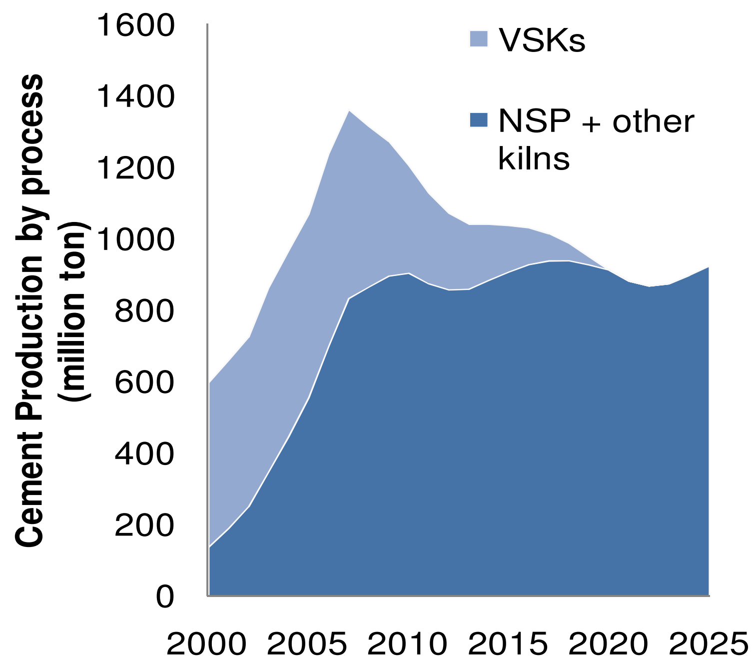
Production assumption:

- Urbanization
- Per-capita building area
- Cement use structure
- Cement intensity if building construction
- Exports of cement

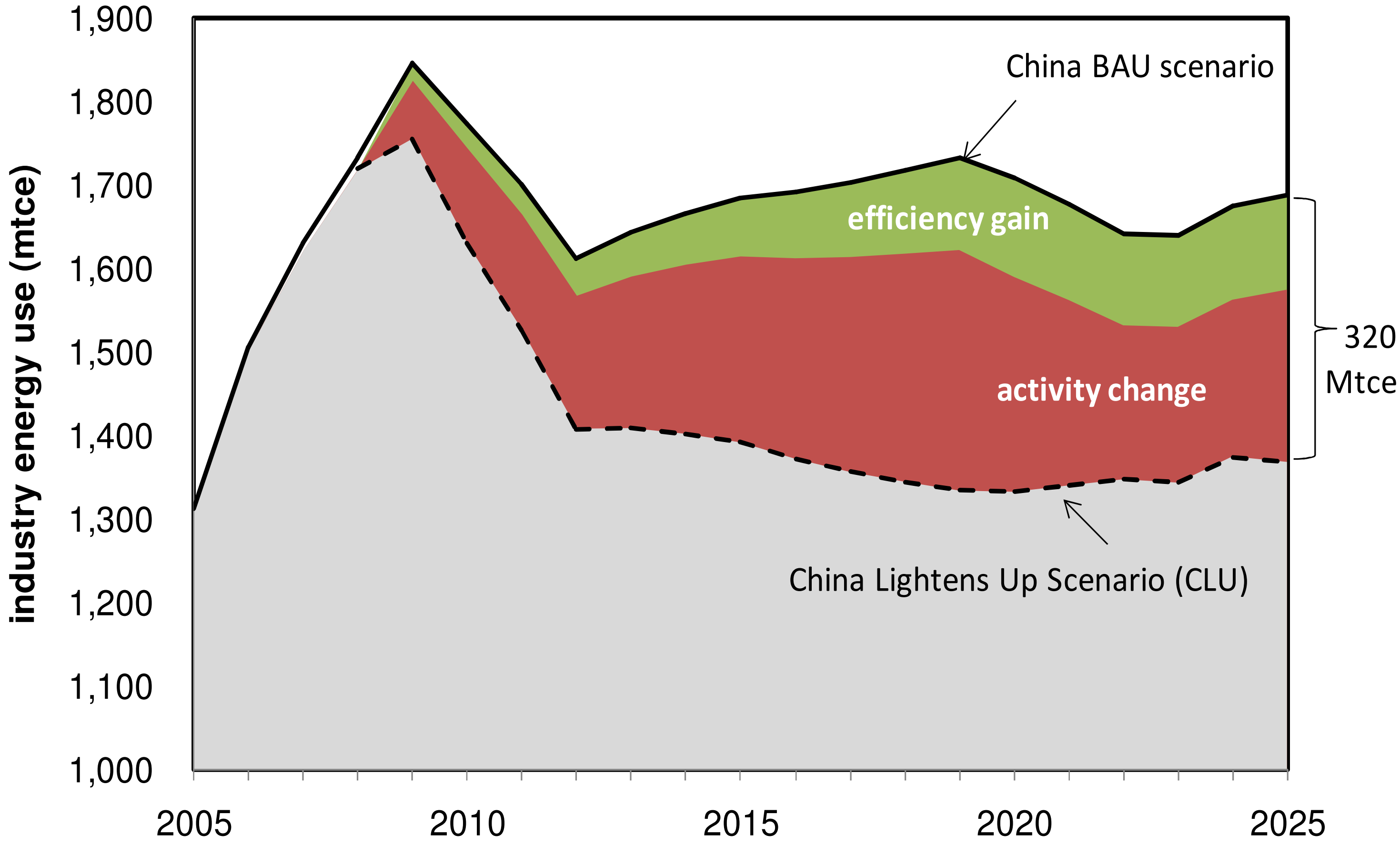
Energy Assumptions:

- Technology shift
- Fuels
- Energy Intensity





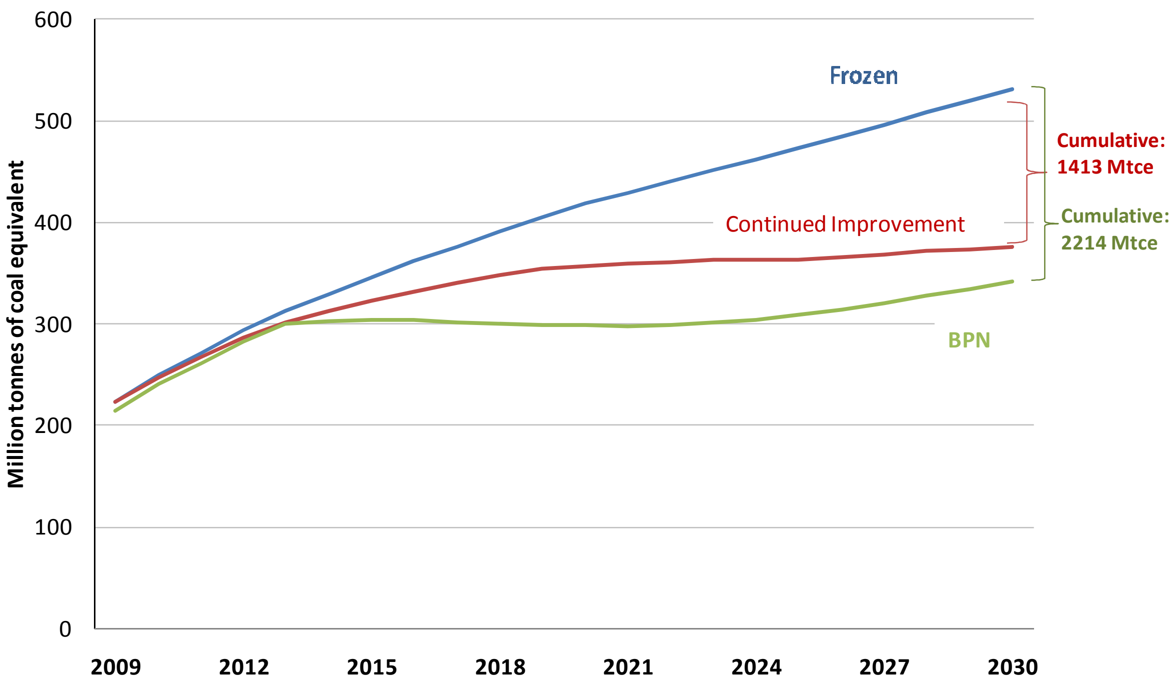
Evaluating Policies: China Lightens Up 2025



Source: LBNL CLU model. Note: Y-axis not zero scaled.

Evaluating Policies: Impacts of Appliance Standards

- Under a "continued improvement" of regularly scheduled MEPS revisions to 2030, , cumulative electricity consumption could be reduced by 3990 TWh
- Annual electricity savings would be equivalent to the output of 78 1-GW power plants
- Annual CO_2 emissions would be 16% lower than in the frozen scenario.
- Under a "BPN" scenario, cumulative electricity saving would be 5450 TWh



•"Continued Improvement" scenario, reflect the likely pace (every 4 to 5 years) of post-2009 MEPS revisions, and the likely improvement (5-10%, depending on the product) at each revision step considering the technical limitation of the technology.

•"BPN Scenario", product efficiency was maintained at the 2009 level until 2014, when it was improved to a level consistent with best-practice MEPS found internationally.

Evaluating Policies: 2050 Energy and Carbon Emissions Outlook

Goal:

Develop a *China Energy Outlook* through 2050 that could be used to assess the role of energy-efficiency in potential GHG emissions abatement policies for transitioning China's economy to a lower-GHG trajectory

Model improvement:

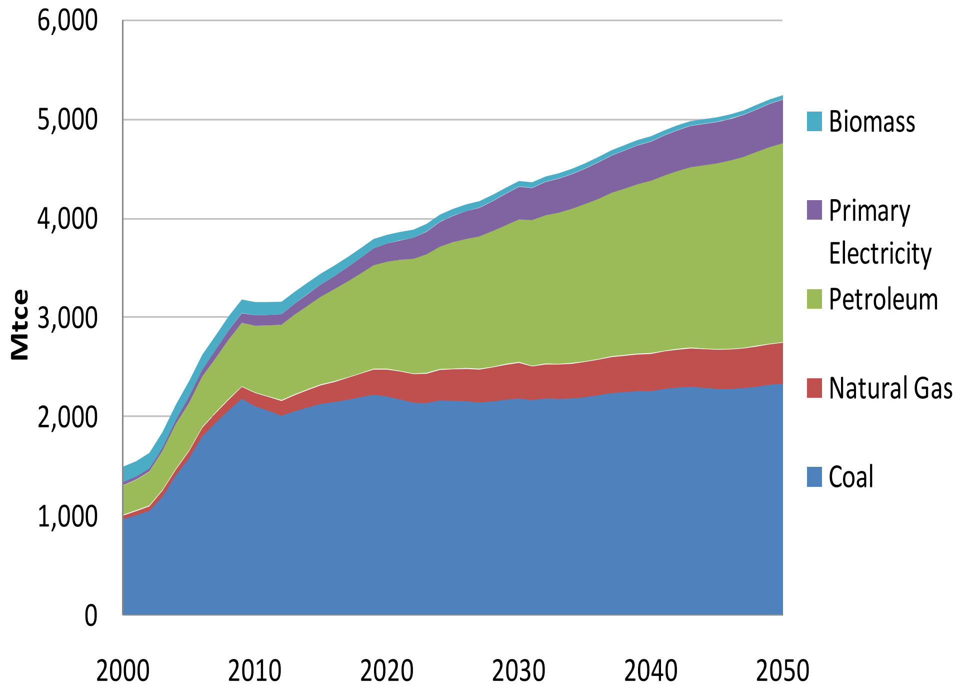
- Developing econometric algorithms that will forecast key drivers of energy demand (e.g., equipment saturation, commercial floor area, and industry production)
- Developing resource supply curve

Status:

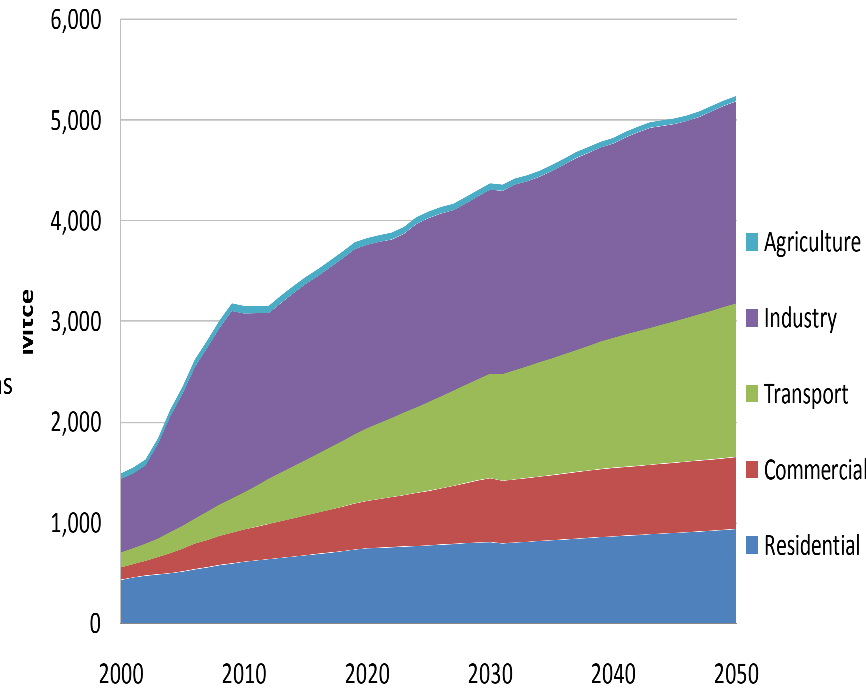
Underway. Preliminary results expected to be completed in October

Industry sector has likely peaked, and the future driver of energy growth is mainly transportation and buildings.

Primary Energy Demand by Fuel



Primary Energy Demand by Sector



The demand scenario is our reference scenario , which incorporates existing policies and policies underway, and also reflects the current government power generation fuel mix targets

1000 Mtce (29 EJ, 28 Quads) = ~3000 MtCO2

LBNL's China End-Use Energy Model Uniqueness

Based on a thorough understanding of Chinese data and end-use technologies

- many years of experience with Chinese statistics
- significant collaboration with Chinese research organizations and industry associations

Focuses on sector-specific end-uses

- production levels based on end-use specific drivers
- penetration of technologies or processes within sectors
- technology energy intensity trends

Provides sector-specific information to policy-makers

- efficiency potential of specific end-use sectors
- energy-efficient technology penetration levels
- future energy consumption and intensity trends

LBNL's China End-Use Energy Model
Impacts and Future Work

Impacts

Inform non-governmental organizations such as Energy Foundation and ClimateWorks Foundation

Provide independent invited reviews of Chinese energy-efficiency policies and scenarios to Chinese energy policymakers

Present insights to the U.S. Government into current and future end-use energy consumption trends in China

Future Work

Training Chinese collaborators in use of the model for their policy evaluations

Collaborate with ClimateWorks Foundation to integrate the China model into the global model on impact of appliance standards and carbon emission implications

Decarbonization of the power sector and transportation sector

Provide analysis and suggestions on target setting methodologies, energy efficient policies for China's upcoming 12th Five Year Plan

Thank you!

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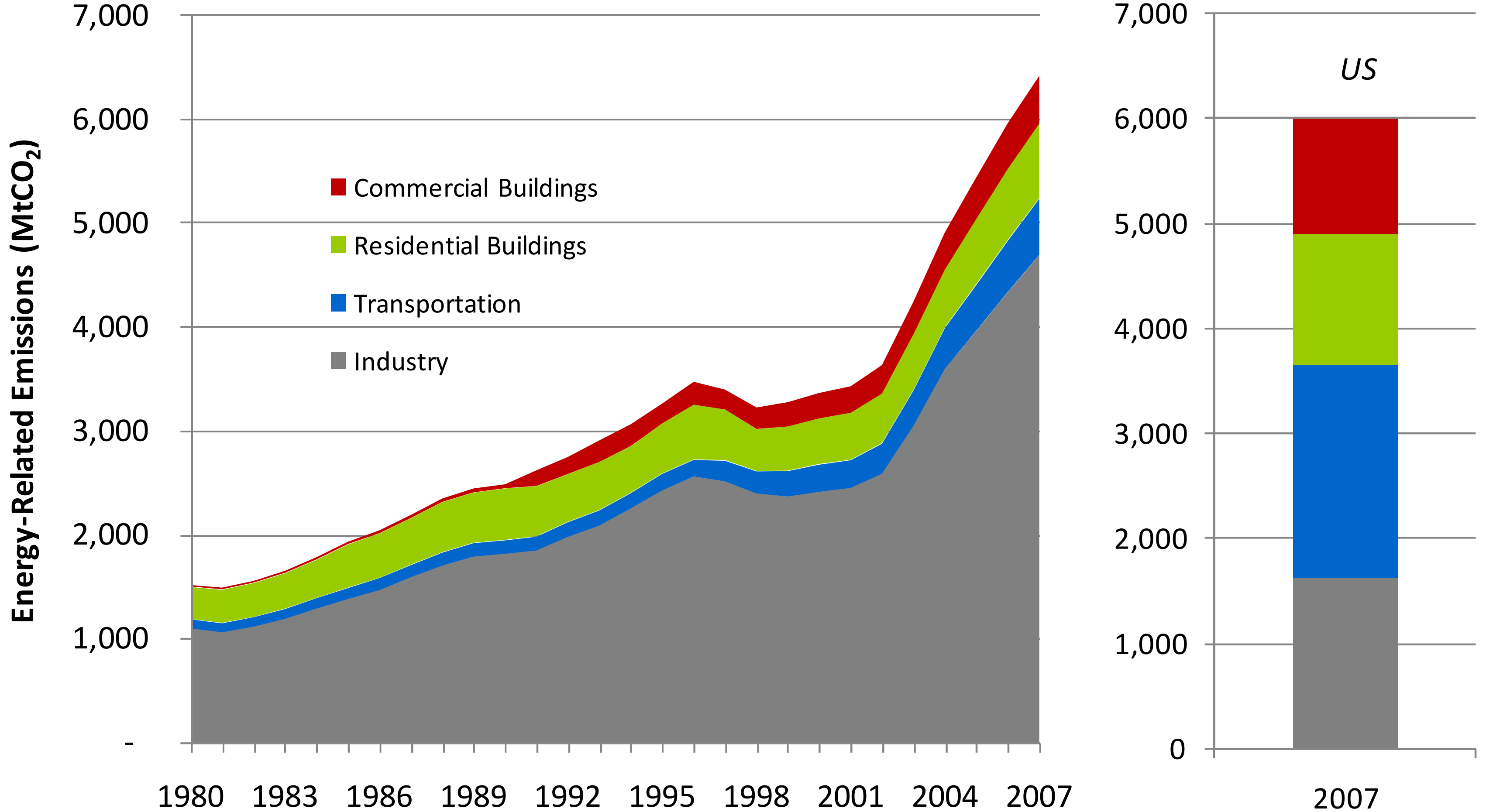
China's Carbon Emissions by Sector



LBNL's China End-Use Energy Model Methodology: Commercial Sector

$$E_{RB} = \sum_{k}^{OPTION} \sum_{n}^{OPTION} \sum_{q}^{OPTION} \left[A_{CB,n} \times P_{q,n} \times \left(\sum_{k} Intensity_{q,n} \times Share_{k,q} / Efficiency_{k,q} \right) \right]$$

k = energy type (technology type)

q = type of end-use,

n = building type

ACB,n = total commercial floor area in commercial building type *n* in m2

Pq,n = penetration rate of end-use *q* in building type *n*

Intensityq,n = intensity of end-use *q* in building type *n*

Sharek,q = type of technology *k* for end-use type *q*, and

Efficiencyk,q = efficiency of technology *k* for end-use type *q*

LBNL's China End-Use Energy Model Methodology: Transportation Sector

$$E_{TR} = \sum_{k}^{OPTION} \sum_{t}^{OPTION} \sum_{r}^{OPTION} \sum_{j}^{OPTION} Q_{t,r,m,i} \times s_{t,r,j,i} \times f_{k,t,r,j,i} \times EI_{TR,k,t,r,j,i}$$

j	=	transport technology class (e.g., vehicle classes),
$s_{t,m,i}$	=	share of transport services *t*, delivered through the mode *m* employing the transport end-use technology *j*, and
$f_{k,t,m,j}$	=	share of fuel *k* used for technology *j* in providing transport services of type *t*.
r	=	mode type (road, rail, water, air, pipeline)
m	=	locale type (rural, urban)
$Q_{t,r,m}$	=	quantity of transport service of type *t* in mode *r* and in locale *m* of region *i* in passenger-km and tonne-km, and
$EI_{TR,k,t,,m}$	=	average energy intensity of energy type *k* for transport service of type *t* in mode *r* and in locale *m* in MJ/(passenger-km-year) and MJ/(tonne-km-year).
k	=	fuel type
t	=	transport type (passenger, freight)

LBNL's China End-Use Energy Model Methodology: Industry Sector

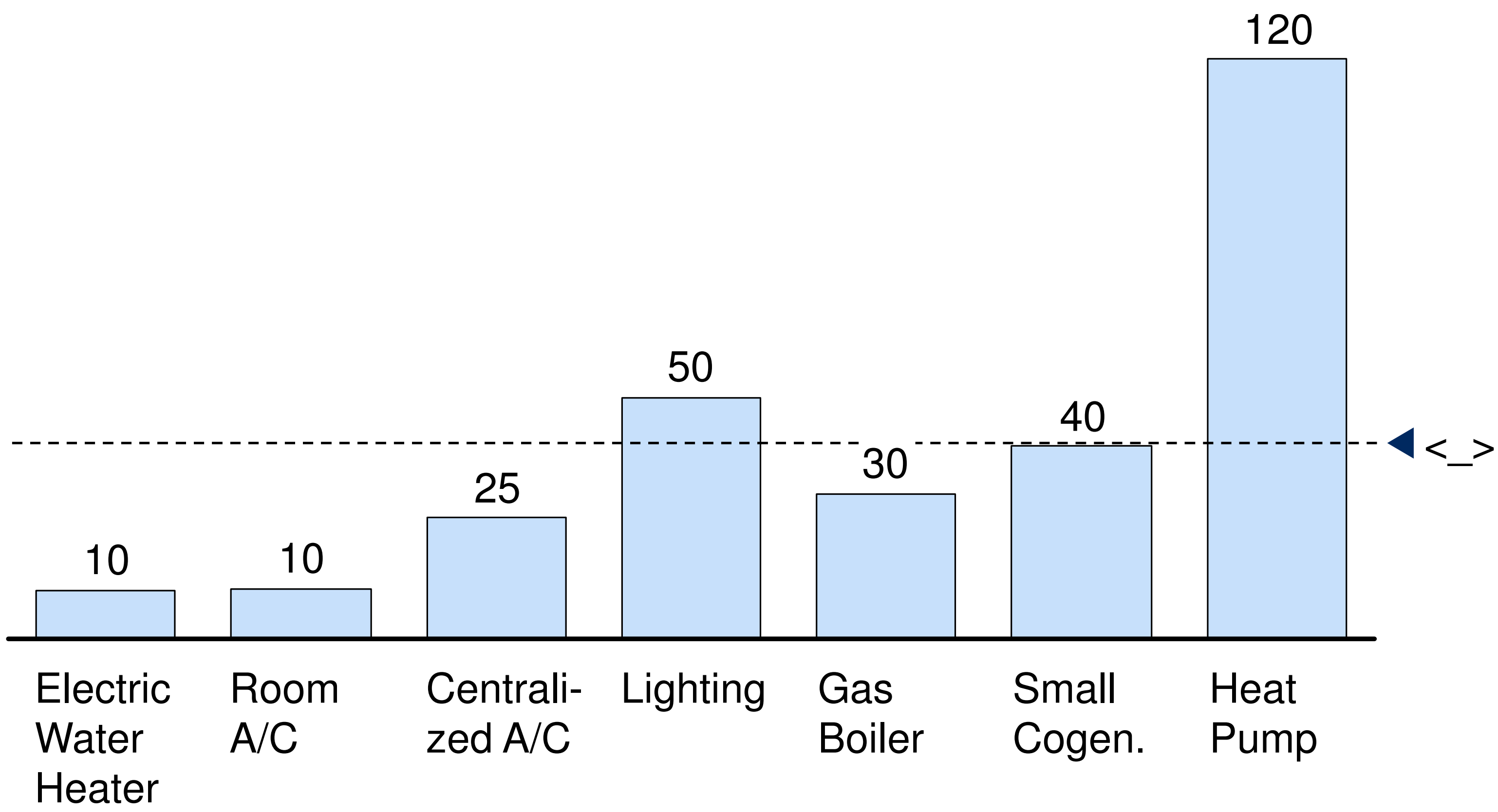
$$E_{IN} = \sum_{k}^{OPTION} \left[\sum_{c}^{OPTION} A_c \times EI_{c,k} \right] + G_v RI_k$$

c	=	commodity type
A_c	=	quantity of energy-intensive commodity *c* produced,
$EI_{c,k}$	=	average intensity of fuel type *k* for producing energy-intensive industrial commodity *c* in GJ/metric ton (or other physical unit),
G_v	=	Industrial value added GDP, and
$RI_{,k}$	=	average intensity of energy type *k* for producing residual, i.e. remaining industrial GDP.

Reference: Nan Zhou, Michael A. McNeil, David Fridley, Jiang Lin, Lynn Price, Stephane de la Rue du Can, Jayant Sathaye, and Mark Levine, 2007. *Energy Use in China: Sectoral Trends and Future Outlook,* Lawrence Berkeley National Laboratory, LBNL- 61904

EFFICIENCY IMPROVEMENTS BY TYPE OF EQUIPMENT

Technical efficiency improvement, 2003-2020
Percent



Source: LBNL China Buildings model