Superefficient Appliances and Equipment:

Untapped Energy Savings for Chinese Buildings

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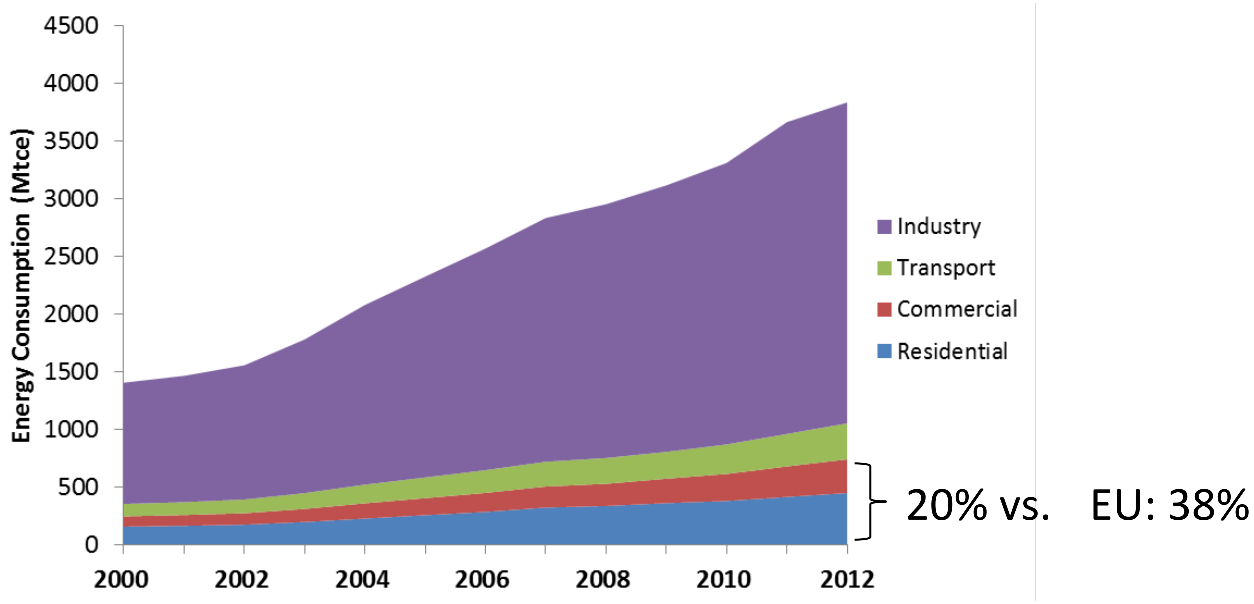
Introduction

- China is the world's largest energy consumer and CO_2 emitter
- China has set targets to reduce its energy consumption and CO_2 per unit of GDP for 2015 and 2020
    - Energy/GDP: 16% from 2010 by 2015
    - CO_2/GDP: 17% from 2010 by 2015, 40-45% from 2005 by 2020
- Buildings has been a key sector for China's energy efficiency efforts, but continued urbanization and economic growth will continue to drive building sector energy use



Note: 1 Mtce = million tonnes of coal equivalent = 29.27 mil GJ

Background: China's Appliance Efficiency Programs

1989: Minimum Energy Performance Standards (MEPS) limit energy use for equipment
Now: covers 57 products

1999: Voluntary endorsement label
Now: covers 64 products

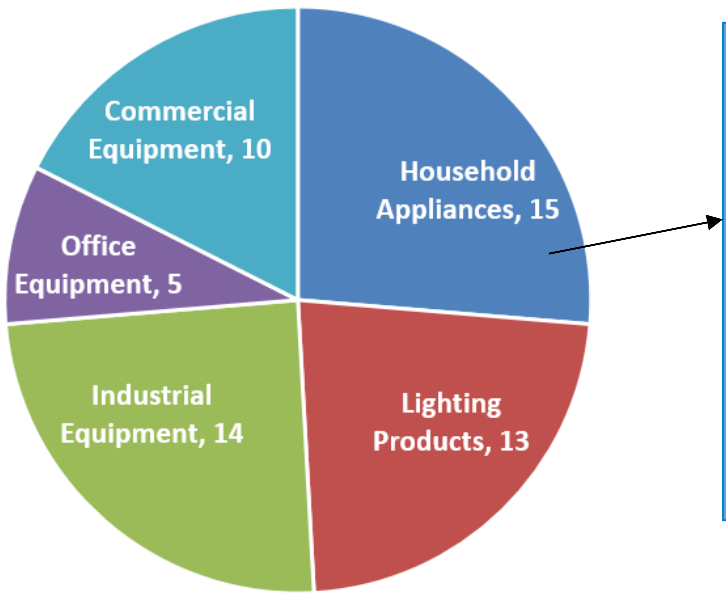
2005: Mandatory China energy information label
Now: covers 27 products

- Standards are set by the China National Institute of Standardization
- China historically adopted 3-4 new or revised standards per year, but ramped up standards development recently with 6 in 2012 and 12 in 2013
- No pre-set schedule for new or revised standards, but revisions typically occur every 5 years

China's MEPS program and Implications for Efficiency

- New/revised standards aim to eliminate bottom 20% efficiency of market, with some two-period, two-tiered "reach" standards
- Standards are set through techno-economic analyses, but China lacks many key data inputs, sufficient resources, and wide-ranging stakeholder participation → minimum efficiency standards are not stringent enough!

What is the gap between minimum efficiency in existing mandatory standards and maximum technically feasible and cost-effective technologies on the market today?



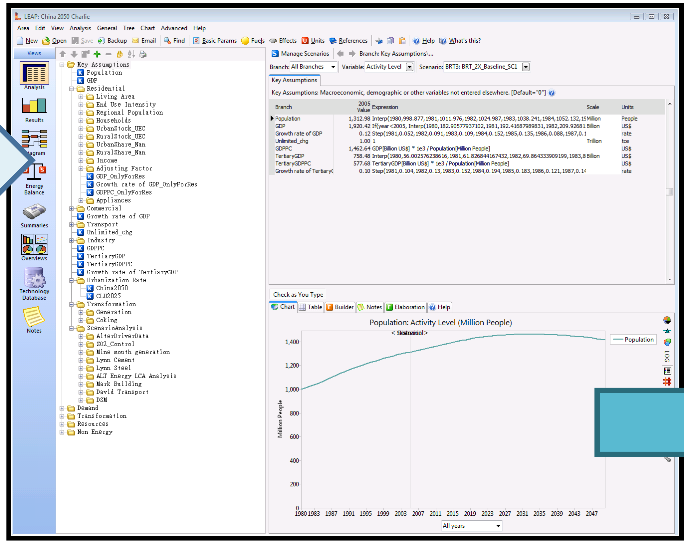
Selected products: 10% of 2010 residential energy use

- Refrigerators
- Room air conditioners
- Clothes washers
- Televisions
- Natural gas water heaters
- Electric water heaters

Overall Modeling Methodology

- Study used bottom-up energy end-use LEAP model developed as part of two-year collaborative "Reinventing Fire: China" study with Rocky Mountain Institute and China's Energy Research Institute,
- Macroeconomic and physical drivers determine residential energy demand outlook
- Model parameters and assumptions derived from published statistics, extensive literature review of Chinese and English publications, and interviews with Chinese experts

Inputs
Macroeconomic data, demand drivers, technologies, scenarios



Outputs
Primary and final energy, emissions, savings potential

Key Data Inputs

Energy Drivers:
- Total urban household
- Residential floorspace
- Ownership or saturation
- Increased usage and equipment size

By end-use:
- Stock turnover models
- Technology shares
- Energy intensity
- Technology-specific efficiency

Historical data: calibrated to statistical and survey data

Projections: Chinese plans and trends, experts' input, international comparisons

For each of the 6 products, we collected energy efficiency and cost data for:

- **Existing technology:** representing our best estimate of the most common market-average efficiency model in the Chinese market, and
- **Superefficient technology:** representing the most efficient technology model in the international market (including China) that is currently considered cost-effective

Bottom-up Modeling of Selected Residential Equipment

$$ECB = \sum_{n} \left\{ FSB_n \times \sum_{q} \left[P_{q,n} \times \left(\sum_{k} Intensity_{q,n} \times Share_{k,q,n} / Efficiency_{k,q,n} \right) \right] \right\}$$

Where:

k	=	Energy/technology type
q	=	End use
n	=	Building type
FSB_n	=	Floor space of building type n
$P_{q,n}$	=	Penetration of end use q of building type n
$Intensity_{q,n}$	=	Energy intensity of end use q of building type n
$Share_{k,q}$	=	The share of the kth technology of end use q
$Efficiency_{k,q}$	=	Efficiency of the kth technology of end use q

Key Data Inputs

Clothes Washer

- MEPS introduced in 1989, 2003, 2013
- 38 million sold in 2012, with 58% front-load washers
- Existing: 143 kWh/year
- Superefficient: Top Ten USA washer consuming 90 kWh/year

Natural Gas Water Heater

- MEPS introduced in 2007, with rising usage in cities
- 10 million sold in 2012
- Existing: 60% efficiency
- Superefficient: 80% efficiency

Electric Water Heater

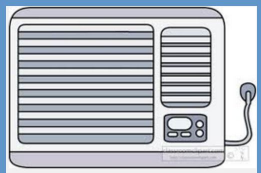
- MEPS introduced in 2008
- 45% growth in annual sales from 2008-2012, with 19 million sold in 2012
- Existing: 89% efficiency
- Superefficient: 93% efficiency

Key Data Inputs 2

Refrigerator

- MEPS introduced in 1989, 1999, 2003, 2008
- 64 million sold in 2012
- Existing: CEL Level 5, 270 liters model consuming 445 kWh/year
- Superefficient: ENERGY STAR, 252 liters model consuming 352 kWh/year

Room air conditioner



- MEPS introduced for variable-speed AC in 2008, 2013 and fixed-speed AC in 1989, 2000, 2004, 2010
- Variable-speed AC most common, 24 million sold in 2012
- Existing: 257% efficiency
- Superefficient: 364% efficiency

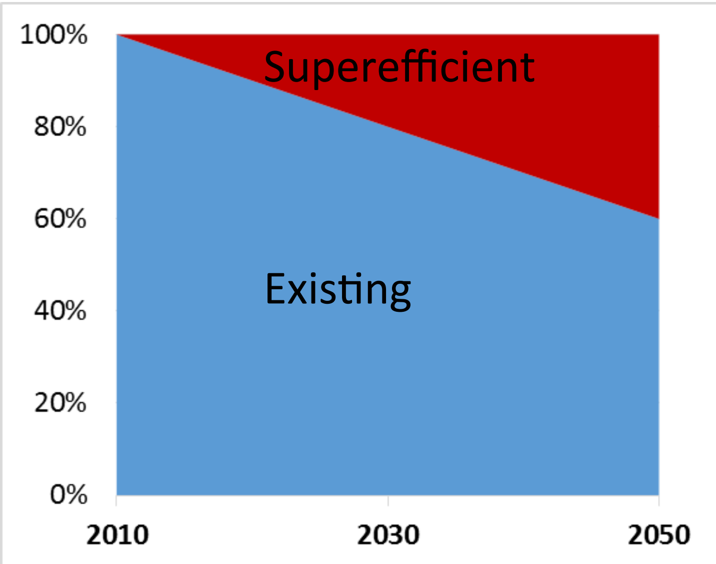
Televisions

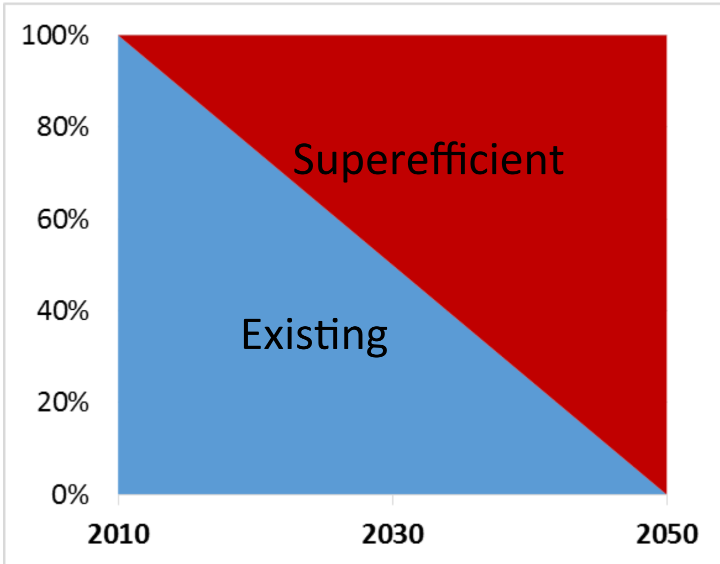
- MEPS introduced in 1989 and 2006, replaced by revised MEPS specifically for flat-panel TVs in 2010 and 2013
- TV screen size assume to increase: 33 inches → 40 inches by 2050
- Assume efficiency of each TV technology improve over time ***and*** market shares shift to most-efficient LED TVs
- Existing technology: LCD TVs consuming 76 kWh/year and LED TVs consuming 58 kWh/year
- Superefficient technology: 40% more efficient than LCD TVs

Scenario Analysis

We used 2 scenarios to evaluate the maximum cost-effective energy savings potential:

- **Reference Scenario:** a business-as-usual pathway considering policies in place by 2010 and autonomous technological improvement
- **Transformative Scenario:** China meets its energy needs and improve energy security and environmental quality using the maximum feasible share of cost-effective energy efficiency





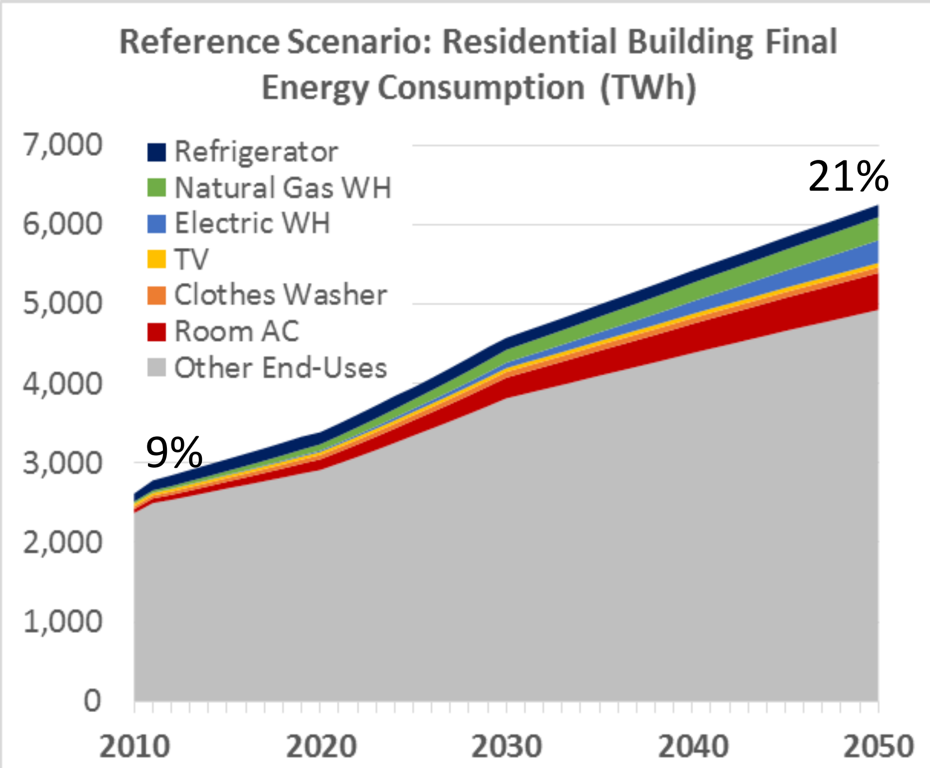
Results: different trends expected in different end-uses

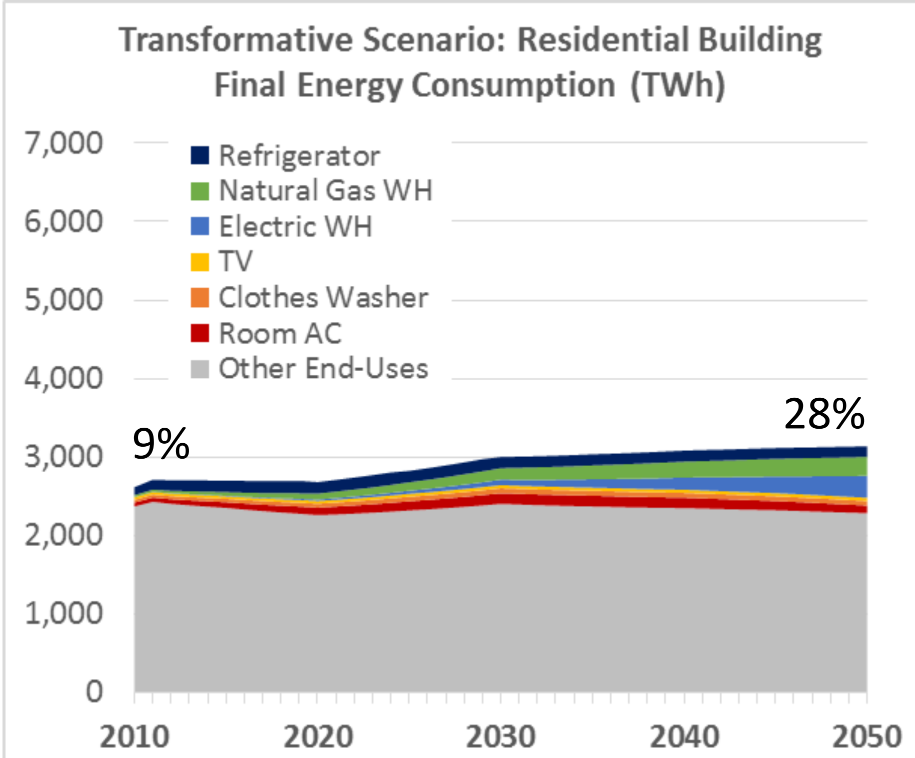
	Energy Consumption Metric	2010 Base Value	2050 Reference Scenario	2050 Transformative Scenario
Refrigerators	kWh/unit/year	445	325.3	283.8
Room air conditioners	kWh/m²/year	5.9	16.1	13.3
Clothes washers	kWh/unit/year	143	140.8	109.1
Television	kWh/unit/year	77	100	88
Natural gas water heater	MJ/m²/year	9.4	41.9	35.6
Electric water heater	MJ/m²/year	9.4	46.7	45.5

Higher demand for more thermal comfort, heated water

Larger screen sizes

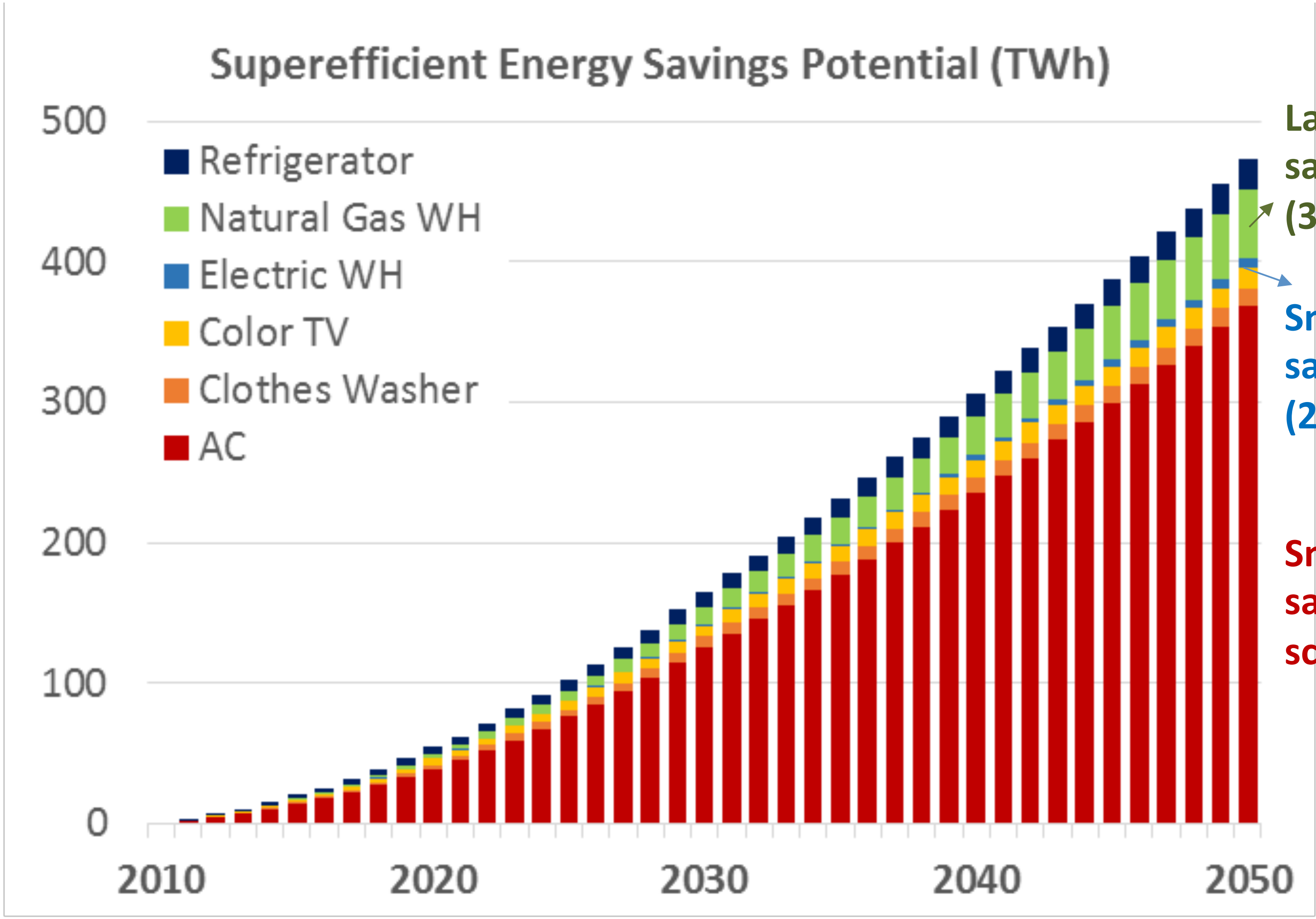
Key end-uses will continue to consume more energy, with 5x increase under Reference Scenario but only 1.2x increase under Transformative





Note: Other end-uses include all heating, cooking, and lighting end-uses as well as other minor cooling and water heating end-uses. See Nan Zhou talk (Thursday, Panel 6) for more details.

Adopting 100% superefficient levels by 2050 would result in 36% savings compared to Reference scenario, with varying potentials

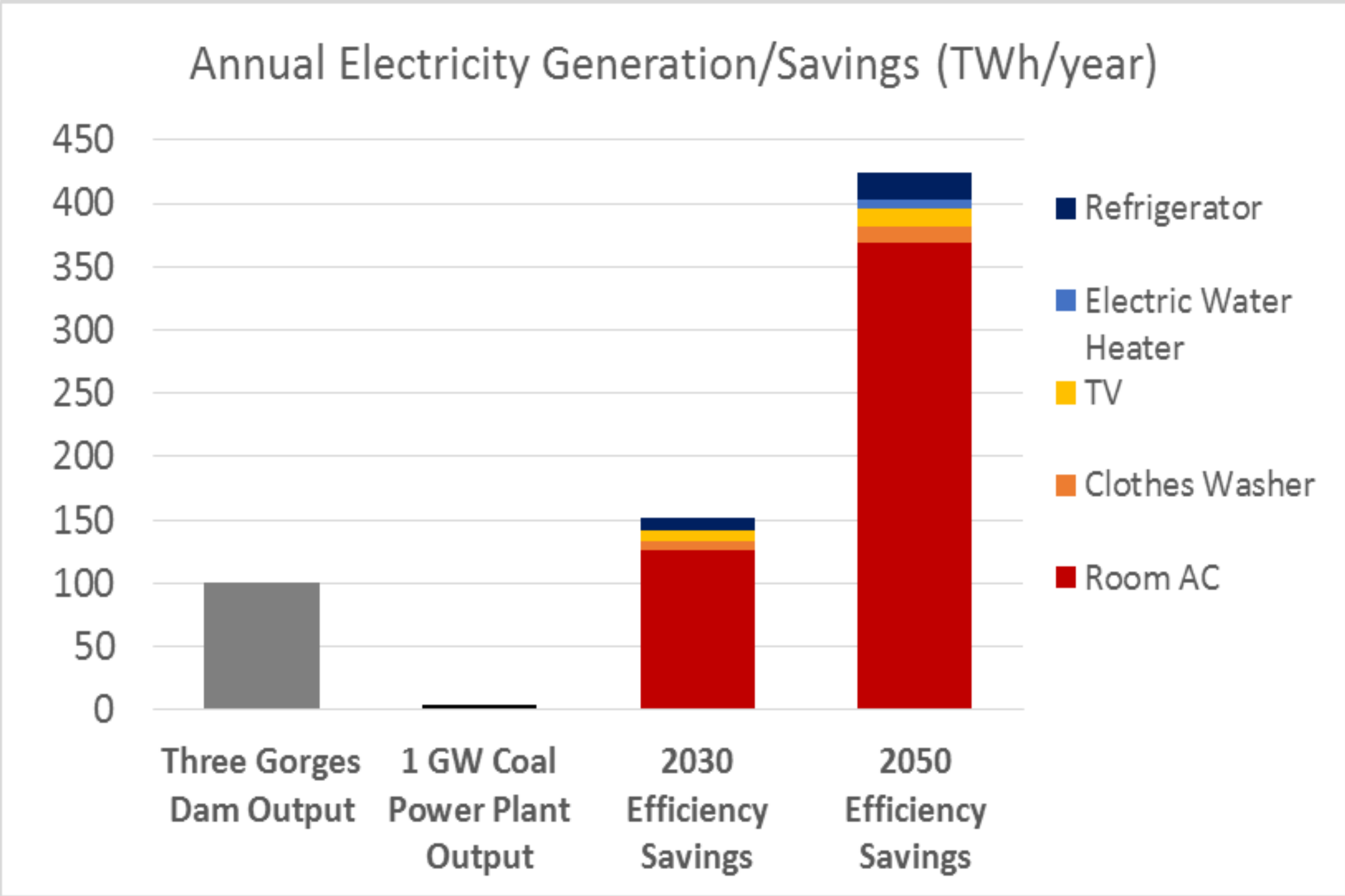


Large incremental savings, large scale (30% of urban area)

Small incremental savings, large scale (20% of urban area)

Small incremental savings but large scale: 63 billion m2

Adopting higher efficiency MEPS can offset the electricity output of 4 Three Gorges Dam equivalent, or 88 coal-fired power plants by 2050



Limitations of Current Study

- Costs and efficiency data for some technologies taken from U.S. market due to Chinese data limitations → cost-effectiveness defined by U.S. retail and electricity prices
- Cost-effectiveness may change with Chinese capital costs and electricity prices, but not likely significantly
  - Capital costs in China likely lower due to lower manufacturing costs
  - Residential electricity prices currently lower due to subsidization, but likely to rise with market reform of power sector
- Detailed China-specific cost data for all superefficient technologies can enable
  - Detailed cost-effectiveness analysis of total energy savings potential
  - Cost-curve comparing cost of conserved energy for six products

Key Findings and Conclusions

- Despite a high number of MEPS, significant untapped efficiency gains exist in each new MEPS due to funding and data limitations
- Iterative standards that typically eliminate bottom 20% efficiency lead to uncaptured cost-effective efficiency improvement potential
- Full adoption of highest cost-effective level of efficiency for 6 products can reduce energy use by 36% or 473 TWh annually by 2050
    - Air conditioners have the largest savings potential due to increased ownership, usage and scale
    - Natural gas water heaters second largest savings due to prevalence and large uncaptured efficiency improvement potential
- Total savings possible could offset electricity output of 4 Three Gorges Dam equivalent, or 88 GW of coal-fired power plants annually by 2050
- Untapped efficiency gains could be captured through more aggressive and regular MEPS revisions, or other market-based mechanisms like subsidies

Acknowledgments and Contact Information

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Thank you!

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