重塑能源：中国

面向2050年能源消费和生产革命路线图

REINVENTING FIRE: CHINA

A Roadmap for China's Revolution of Energy Production and Consumption to 2050

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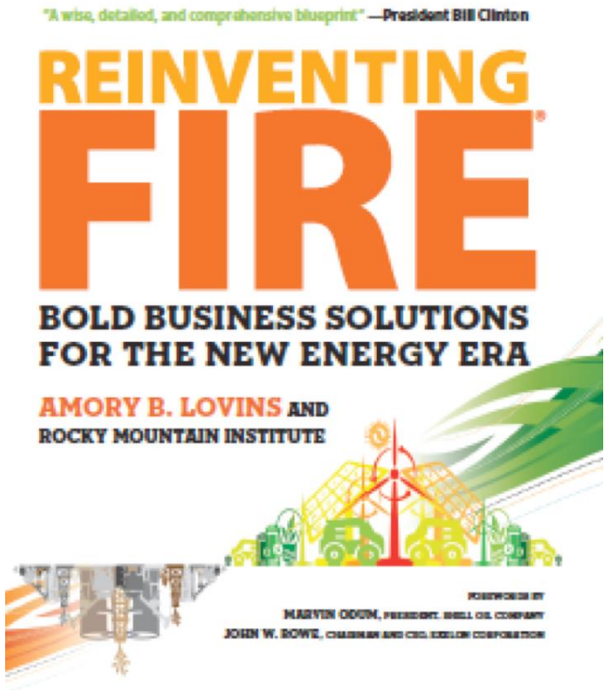
重塑能源-美国
REINVENTING FIRE – U.S.

2.6 times larger economy 2010 to 2050
经济总量达到目前的2.6倍

No oil, no coal, no nuclear energy, and one-third less natural gas
无需使用石油、煤炭、核能，并减少使用三分之一的天然气

$5-trillion lower net-present-value cost of energy services than business-as-usual
与基线相比，节约五万亿美元成本

Transition led by business for profit
依靠市场实现转换



迈向生态文明
THE PATH TOWARDS AN ECOLOGICAL CIVILIZATION

- 3 years of scientific research
  历时3年研究
- 4-partner joint US-China research team
  4家机构合作
- Analyzed cost-effective technology opportunities
  基于现有技术
- Identified policy options
  分析政策路径

2050 Vision
构建2050美丽中国愿景

Identify an economic path for China to meet its future energy needs using the maximum share of efficiency and clean energy

在**最大化能源效率与清洁能源使用的**情境下，为中国建立满足其能源需求的经济路径。

重塑能源的实施效果
INNOVATIVE SOLUTIONS PRODUCING A LOW CARBON PATHWAY

7× GDP
2050年经济规模比2010年增长6倍

+1% Primary Energy一次能源
能源消费需求仅比目前水平略增

34% Non-emitting* 能源零排放
1/3以上的能源来自非化石能源

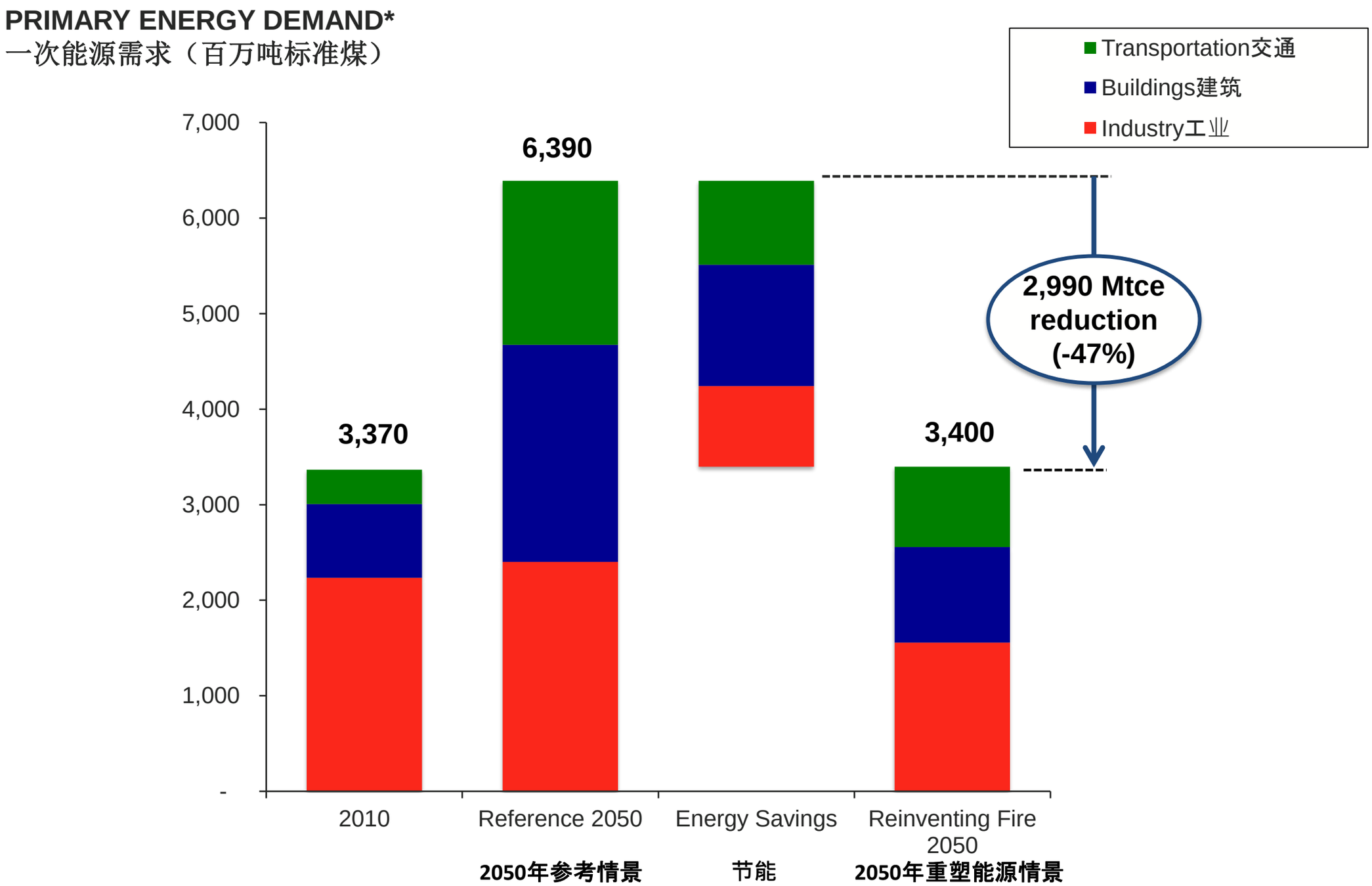
-42% CO_2 emission 减排
CO_2 排放比2010年水平减少42%

21 Trillion net benefit万亿元人民币净收益
总投资46万亿元，总收益68万亿，不包括环境效益

100% Technically feasible, cost-effective and socially acceptable
技术可行
经济合理
社会可接受

*35% if using direct equivalent method (consistent with IPCC); 55% if primary electricity converted using coal power plant e quivalent, in accordance with China's pledged target.
Source: Reinventing Fire: China team analysis

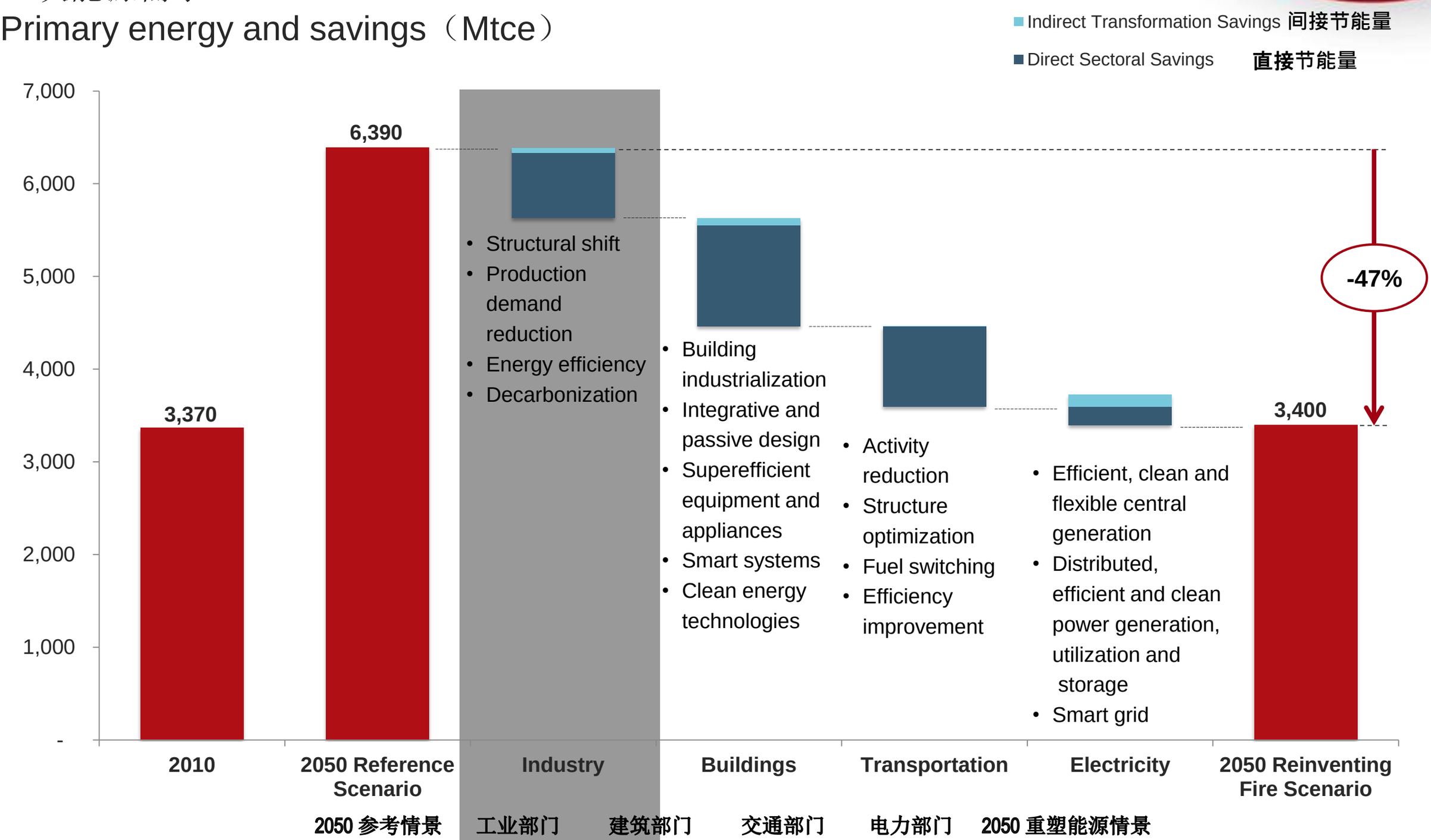
大幅提高能效，降低不合理能源需求
SIGNIFICANT RESOURCE DEMAND REDUCTION



*Primary electricity converted using IPCC method. 按照电热当量方法计算，
Source: Reinventing Fire: China team analysis

重塑能源部门贡献及主要途径
2050 SECTOR REDUCTION OPPORTUNITIES

一次能源需求
Primary energy and savings（Mtce）



Source: Reinventing Fire: China team analysis

使用高质量材料降低资源使用需求
USING HIGH-QUALITY MATERIALS TO REDUCE RESOURCE REQUIREMENTS

- 使用创新材料替代波特兰的水泥
  Use innovative admixture to replace Portland cement

- 耐压强度提高**75%**；水泥使用量降低**40%**
  Compressive strength increased by 75%; cement material reduced 40%

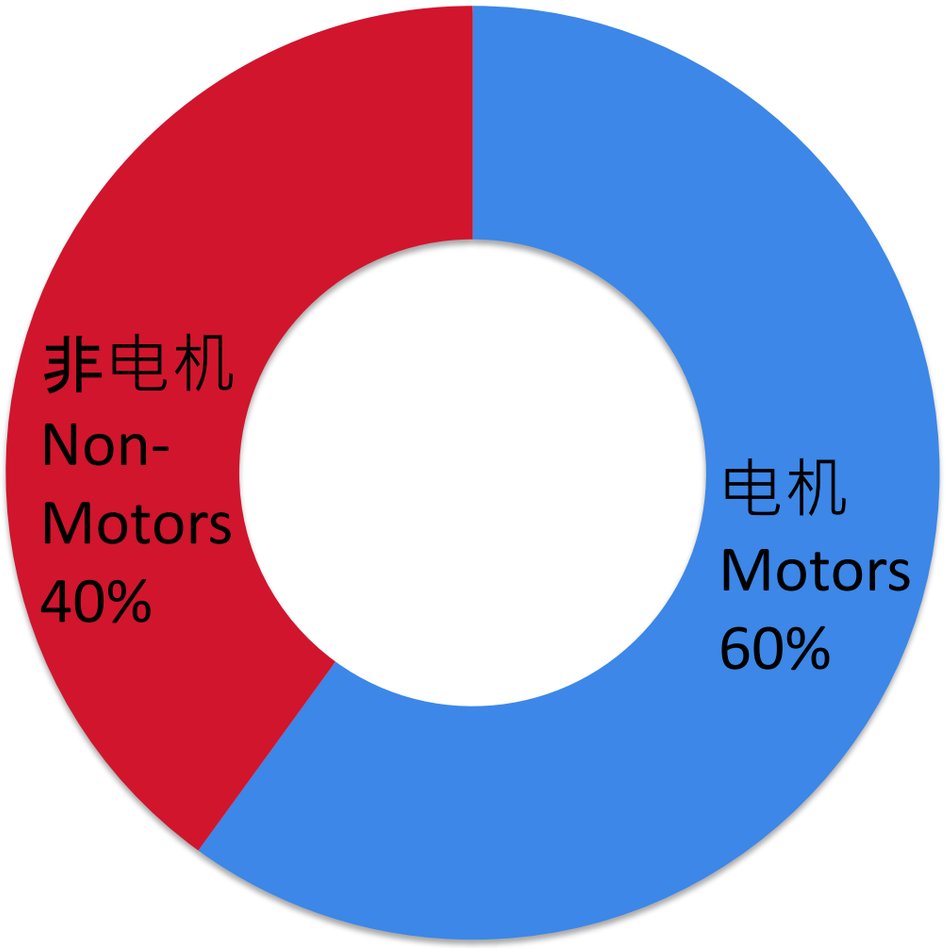
- 更高强度的混凝土也带来了更好的保温性能，降低建筑的暖通空调系统需求
  Stronger concrete also has better thermal performance, reducing building HVAC requirements

- 材料减少带来了以下节省
  Material reduction saved
  - **110,000**升净水
    110,000 liters of fresh water
  - **8**千兆瓦时电力
    8 gigawatt hours (GWh) of electricity
  - **240**吨标煤燃料
    240 tce of fuel
  - **33,000**吨二氧化碳
    33,000 tCO_2

Source: Reinventing Fire: China team analysis

抓住工业领域能效机会
CAPTURING ENERGY EFFICIENCY OPPORTUNITIES IN INDUSTRY

全球工业电力使用
Global Industrial Electricity Use



35 approaches can be used to save 50% of energy used
35种方法可以带来50%的能源节省

Source: Rocky Mountain Institute analysis

通过一体化整合设计理念可以带来更大的节能
EVEN BIGGER SAVINGS POSSIBLE THROUGH INTEGRATIVE DESIGN

Source: Rocky Mountain Institute analysis

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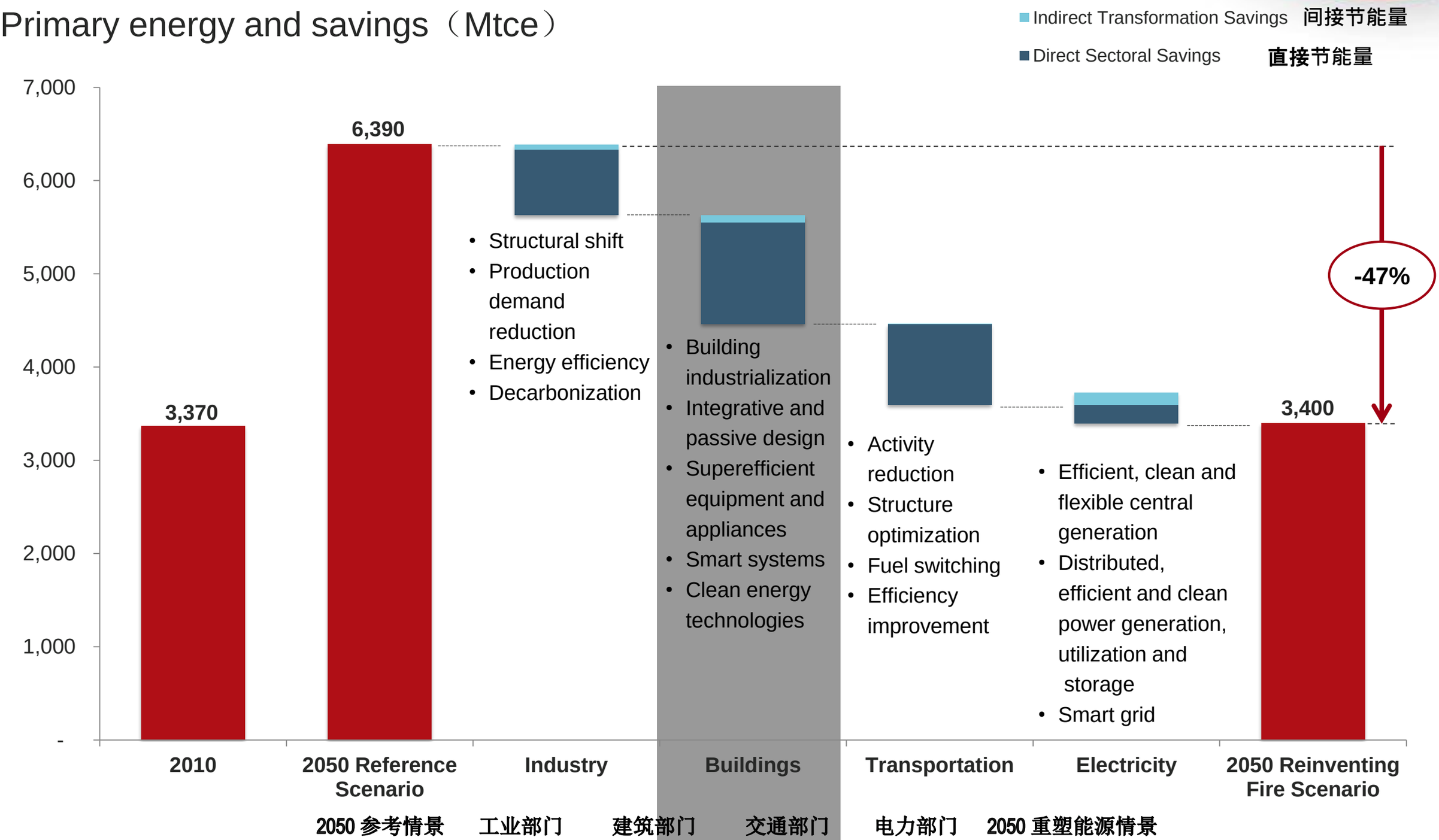


Source: Reinventing Fire: China team analysis

建筑一体化设计应用于新建筑
INTEGRATIVE DESIGN CAN ALSO BE APPLIED IN BUILDINGS BOTH NEW…

“Passive building” – Qinhuangdao, Hebei Province
河北省秦皇岛市被动房项目

- Passive house demonstration project in cold climate zone
  寒冷气候地带被动房试点示范项目
- Good envelope and thermal integrity **高性能保温隔热**
- High performance air-tightness
  气密性好
- 62% reduction in heating energy
  采暖能耗降低62%
- Disconnected from district heating system **与区域供暖系**统分离
- 10% increase in incremental cost
  成本仅增加10%
- Measured indoor PM 2.5 pollution 10x lower than neighboring buildings **室内PM2.5**浓度比附近建筑低10倍

Source: Reinventing Fire: China team analysis

建筑一体化设计应用于已有建筑
…AND OLD

节省的能源与成本：

Energy and cost savings

- **整体节能38%，3年回收成本**
  Save 38% of energy use with a 3-year payback

- **建筑外墙改造加上内部负荷缩减，使楼宇可使用更小型的制冷设备**
  Envelope improvements and reduced internal loads allowed for a smaller cooling system

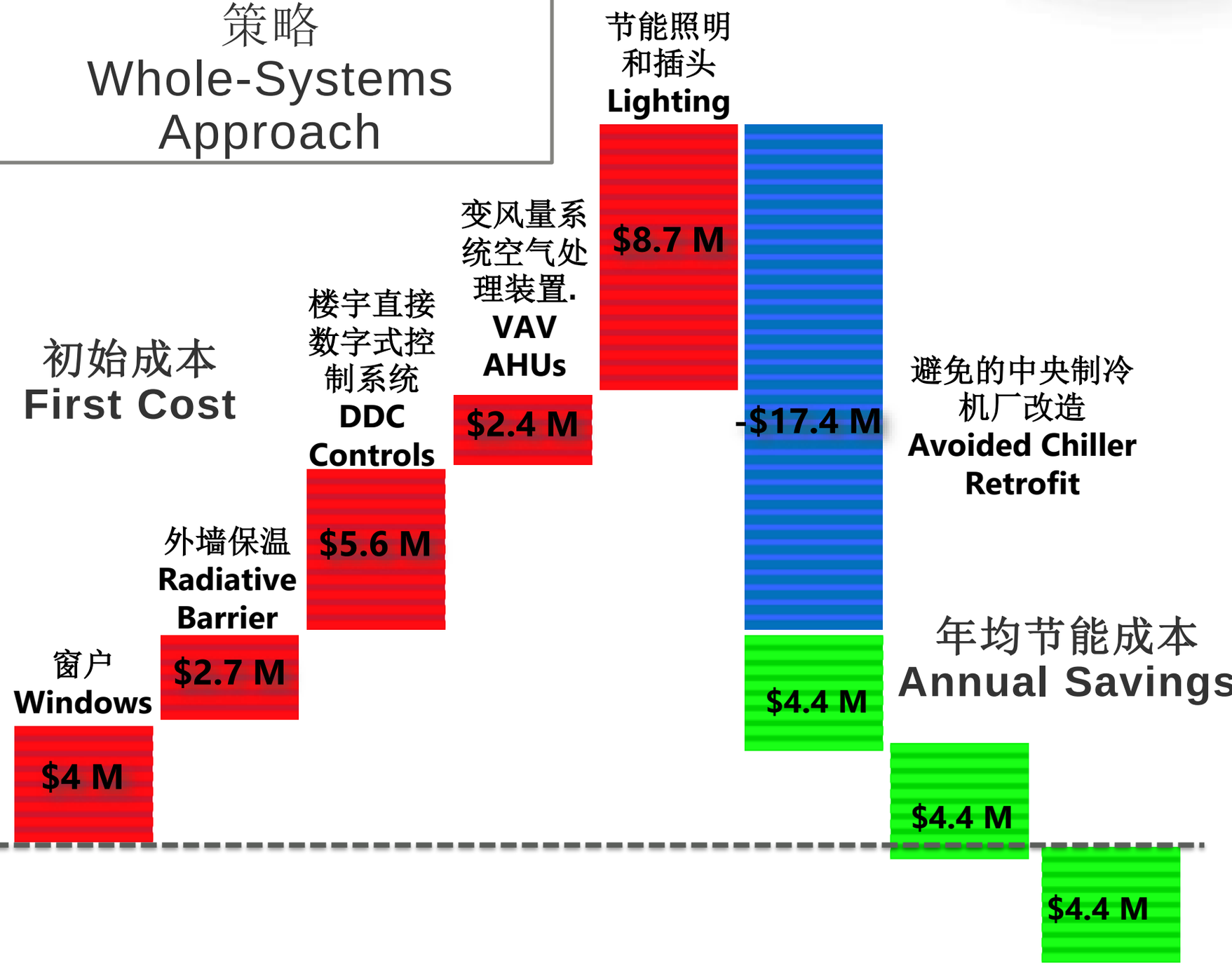
- **将6500扇窗户改装为密闭性更好的超级窗**
  Remanufacturing 6,500 windows onsite into super windows

- **安装能效性能更佳的照明和设备**
  Installing better lights and equipment

Source: Rocky Mountain Institute analysis

建筑一体化设计应用于已有建筑
...AND OLD

全系统整体优化的改造策略
Whole-Systems Approach



Source: Rocky Mountain Institute analysis

FIVE-YEAR EVOLUTION OF RETROFIT AND NEW-BUILD PROGRESS

U.S. office buildings: ~2× efficiency target in the past 5 y
(site energy intensities in kWh/m2-y; U.S. office median ~293)

~277→173
(–38%)
2010 retrofit

284→85
(–70%)
2013 retrofit

…→108
(–63%)
2010–2011 new

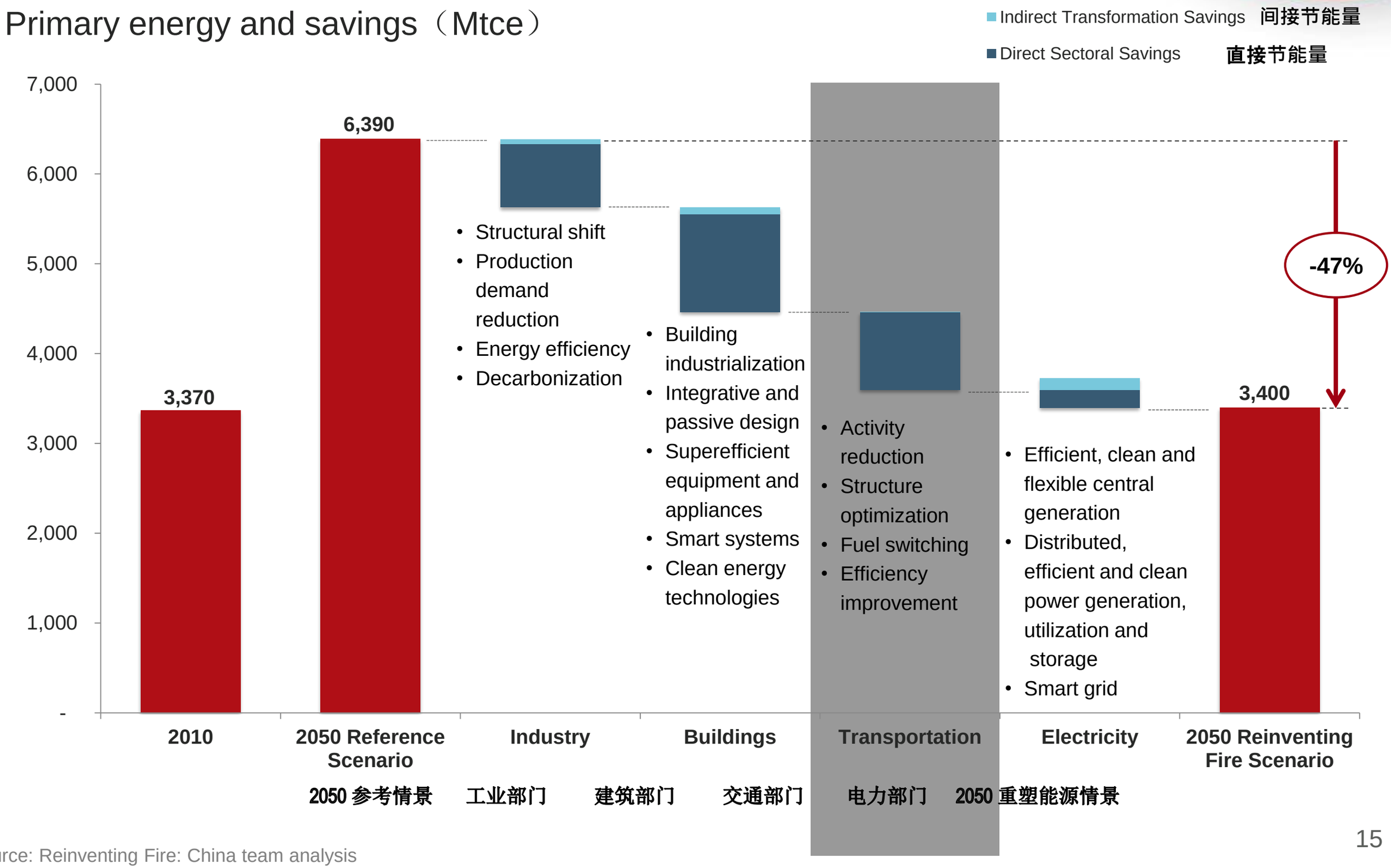
…→≤47
(–84%)
2015 new

Yet all the technologies in the 2015 example existed well before 2005!

Source: Rocky Mountain Institute analysis

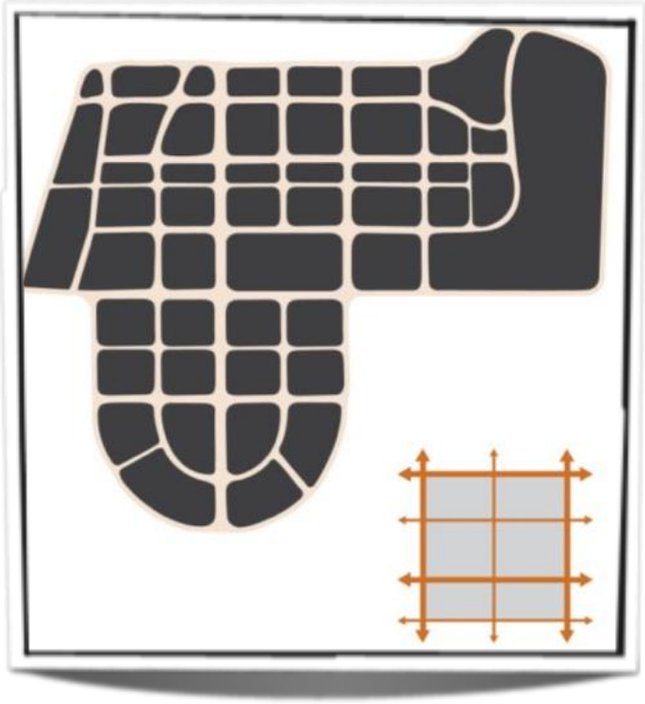
重塑能源部门贡献及主要途径
2050 SECTOR REDUCTION OPPORTUNITIES

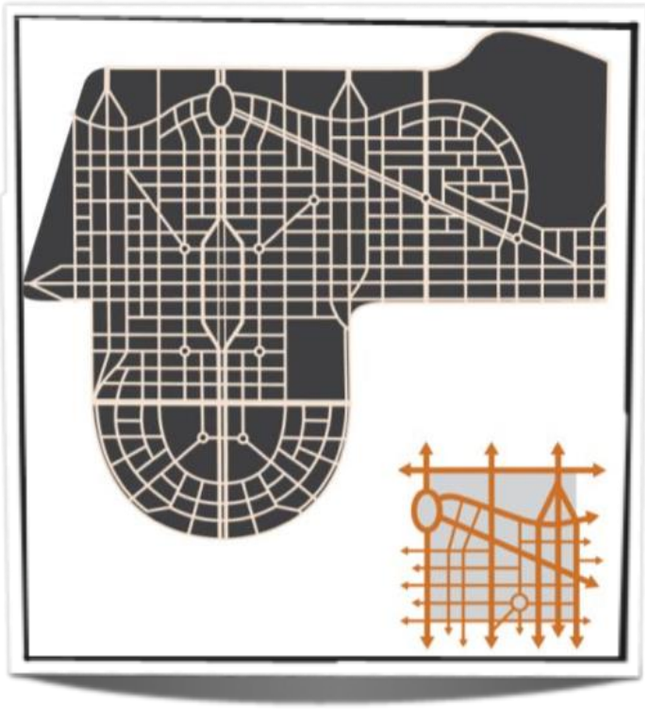
一次能源需求
Primary energy and savings（Mtce）



Source: Reinventing Fire: China team analysis

城市设计定义了交通需求
URBAN DESIGN DEFINES MOBILITY DEMAND





低碳货运解决方案
LOW-CARBON FREIGHT SOLUTIONS

Markets & Logistics
市场&物流

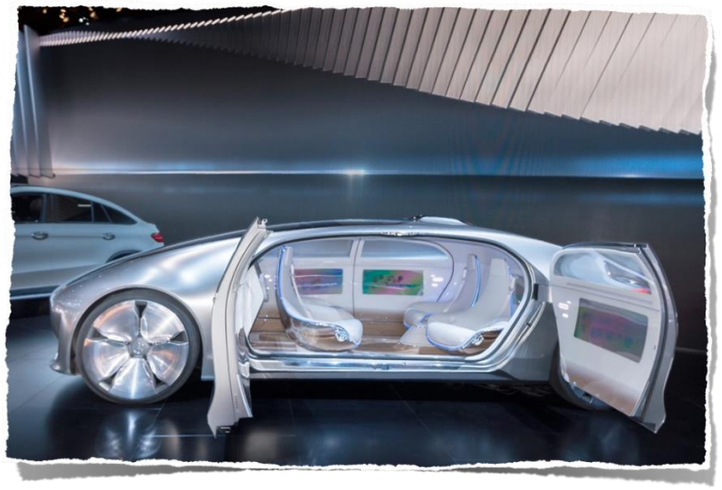
Problem: *Over two thirds of China's transport energy is dedicated to moving freight with trucks. Yet China's trucks drive empty 40% of the time (double the rate of the US and EU)*
问题：卡车货运占据了中国交通部门用能的三分之二。与此同时，中国的卡车有40%的空驶率（是美国和欧洲的两倍）

Solution: More efficient freight markets and IT enabled logistics alone can cut empty driving by 50%, avoiding 100 million tons of CO_2 emissions annually

解决方案：更高效的货运市场和IT技术能使物流部门降低空驶率50%，每年减少二氧化碳排放100兆吨

Source: Reinventing Fire: China team analysis

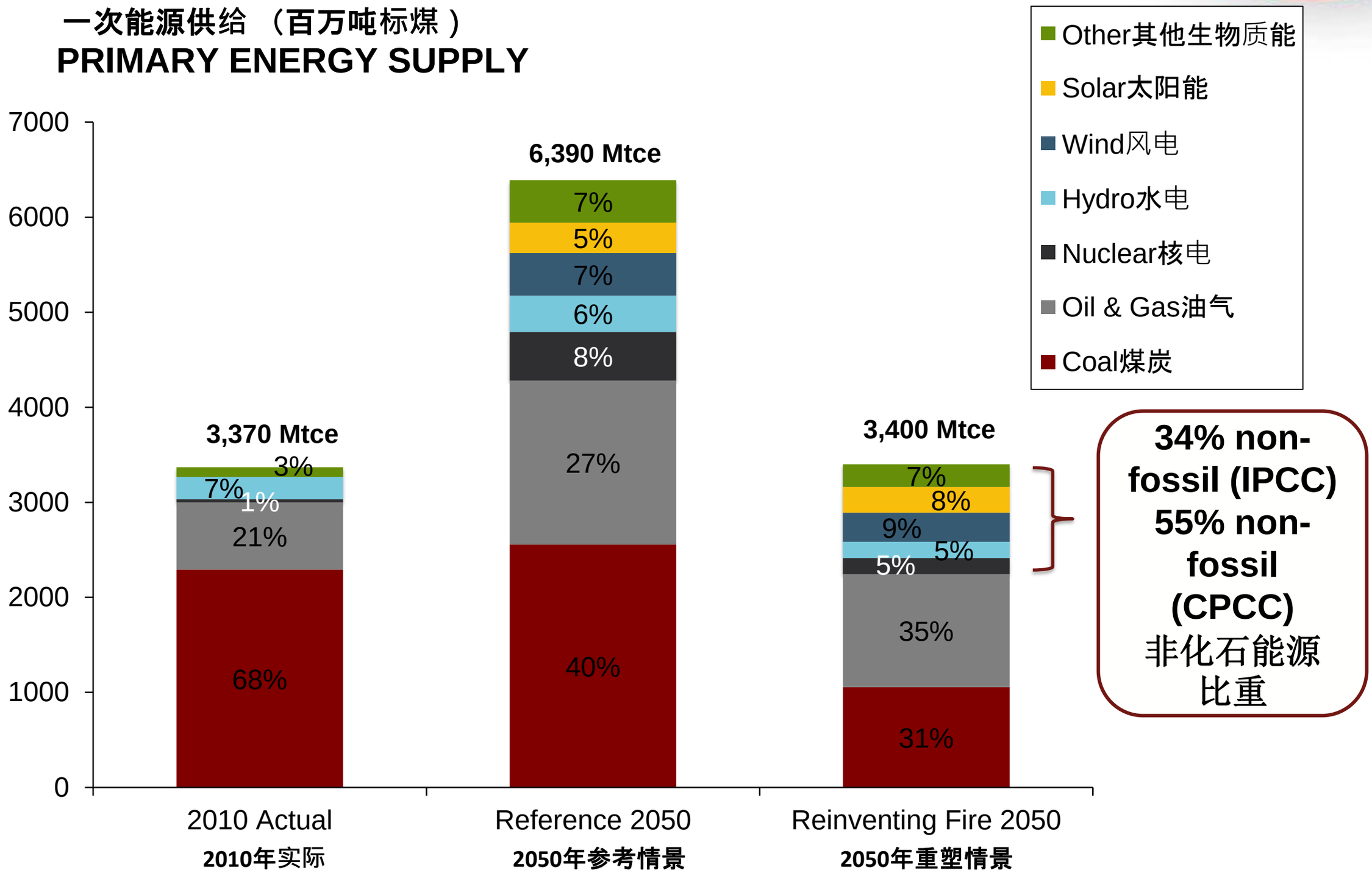
技术进步推动汽车排放量的减少
TECHNOLOGY IMPROVEMENTS CAN HELP VEHICLES EMIT LESS



- 效率提高2-3倍
  2-3X improvement in efficiency
- 运营成本降低高达75%
  Up to 75% lower operating cost

Source: Rocky Mountain Institute analysis

优化能源结构，低碳能源成为供应主体
RESTRUCTURING OF SUPPLY



*Primary electricity converted using IPCC method. 按照电热当量方法计算，按照发电煤耗方法计算为55%。
Source: Reinventing Fire: China team analysis

迈入新电气时代，电力系统绿色低碳智能化
NEW ERA OF ELECTRICITY, GREENER AND SMARTER POWER SYSTEM

电气化加快发展 Development of electrification

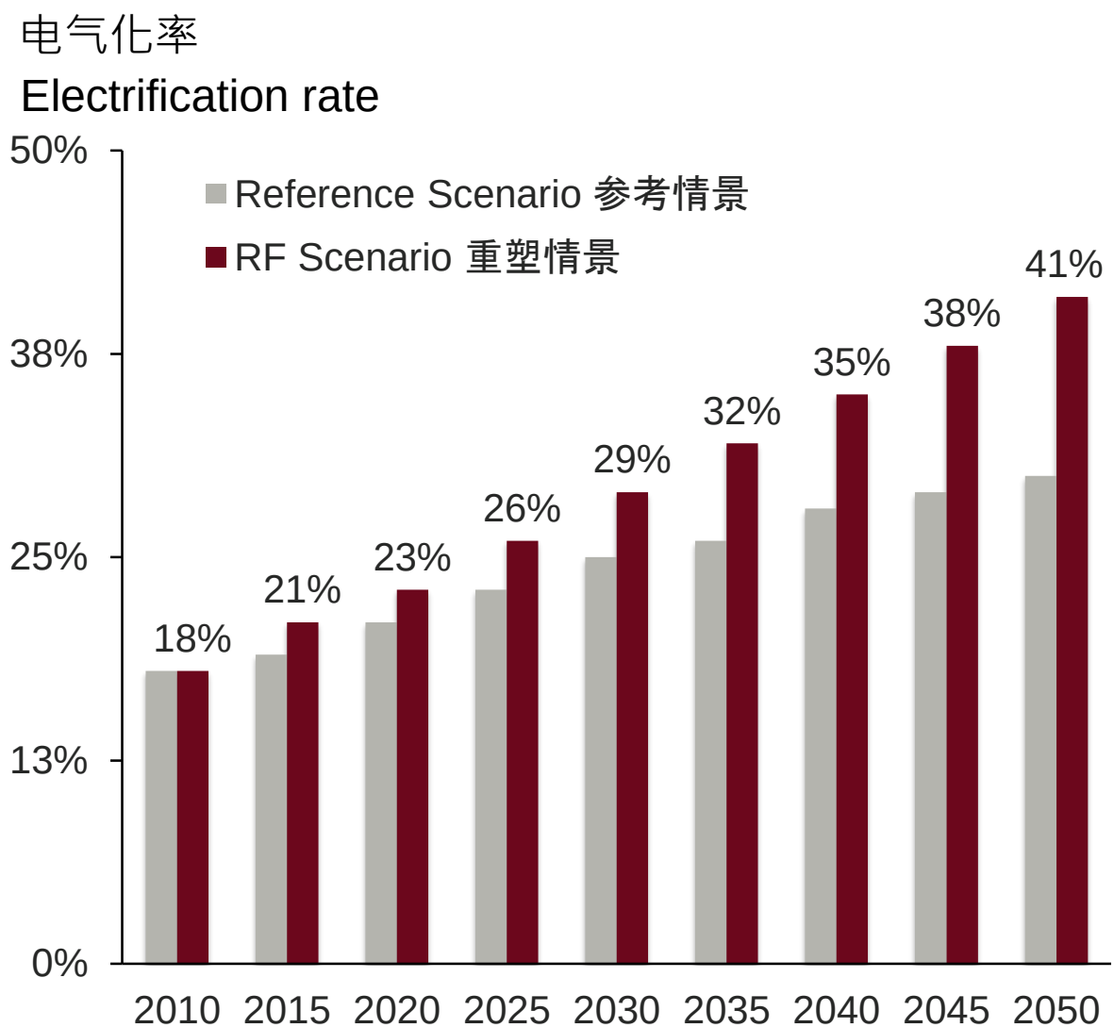
2050年超过欧盟电气化水平

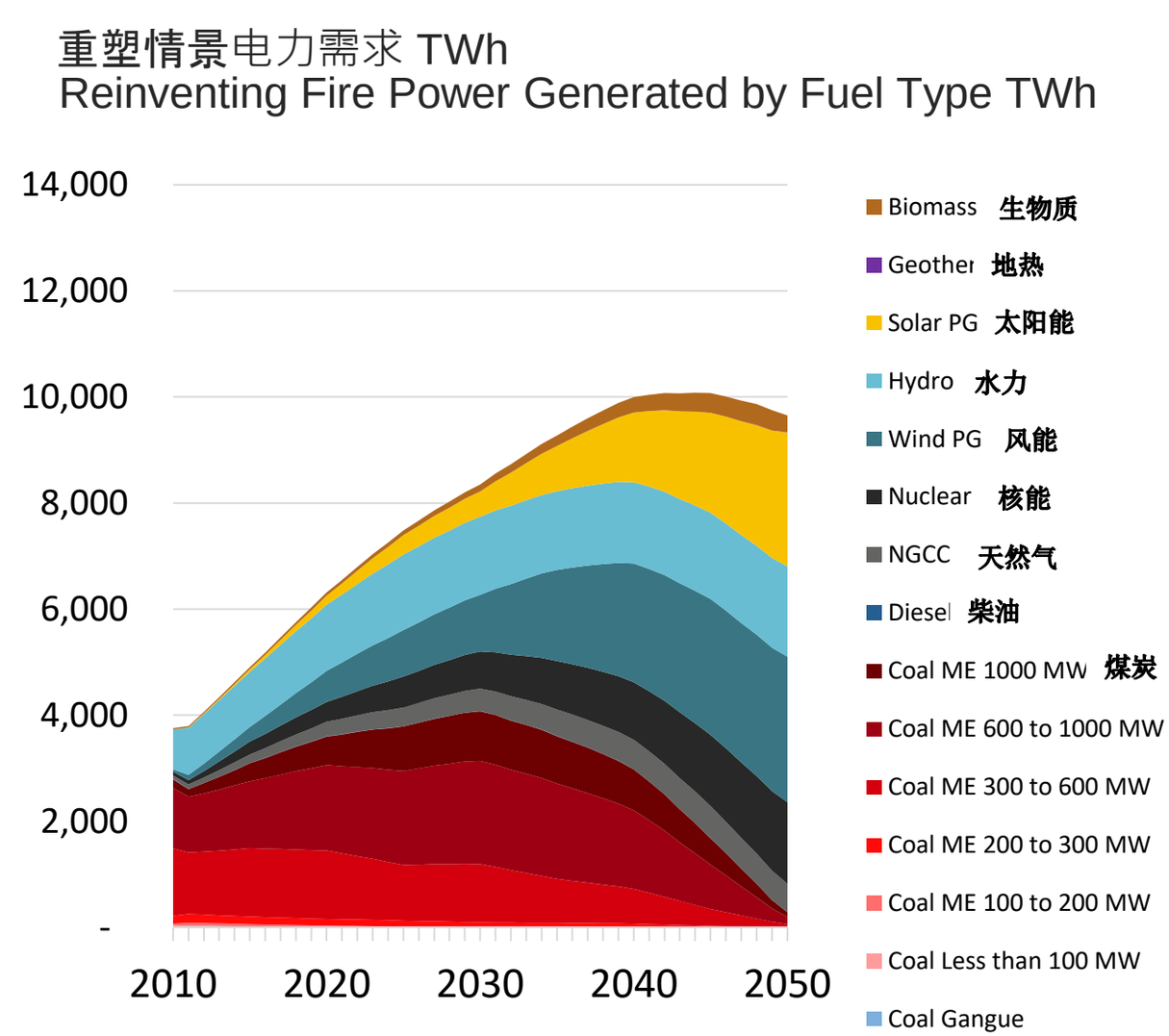
Electrification rate exceeds EU in 2050

人均电力需求：3132kWh到8300kWh

非化石电力比重 Non-emitting：24%到83%

可再生电力比重 Renewable：22%到69%



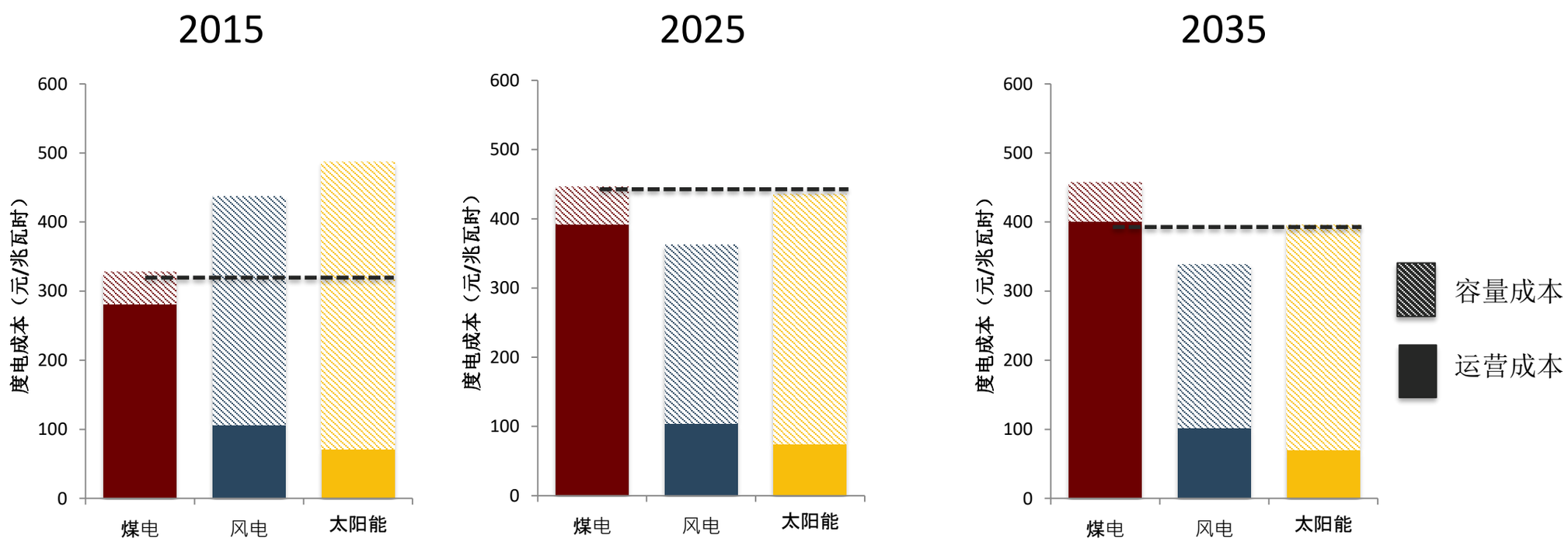


Source: Reinventing Fire: China team analysis

电力供给侧经济性变革
TRANSITION IN THE ECONOMICS OF ELECTRICITY SUPPLY

2035年，新建风能和太阳能的度电成本将会低于现有煤电厂，煤电将大量被可再生能源取代，导致煤电资产搁置，资金配置效率降低

By 2035, new-build wind and solar in China will on average be cost-competitive with existing coal-fired power, resulting in stranded coal-fired assets and inefficient capital allocation



可再生能源的度电成本高于煤电厂

New wind and solar is more expensive than new coal

可再生能源的度电成本低于新建煤电厂

New Solar and wind become cost competitive with new coal plants

可再生能源的度电成本低于现有煤电厂

New solar and wind are cost competitive with EXISTING coal plants

Source: Reinventing Fire: China team analysis

取消新建煤电厂需求
ELIMINATING NEW COAL POWER PLANT DEMAND

Limited new coal required if…
我们只需要少量的煤炭...

Today
今天

Coal cheaper than competition
煤炭比替代品便宜

DEMAND需求
- Create demand response market
  建立需求响应市场
- Capture energy efficiency
  捕获能源效率

GENERATION发电
- Meet existing renewable targets
  满足可再生能源目标
- Reduce renewable curtailment
  减少可再生能源弃电
- Increase utilization of existing coal plants
  提高现有煤电厂利用率

GRID电网
- Build transmission to connect renewables
  连接可再生上网
- Expand dispatch regions
  扩大调度区域
- Reward flexible grid assets
  给电网中的灵活性资源予以补偿

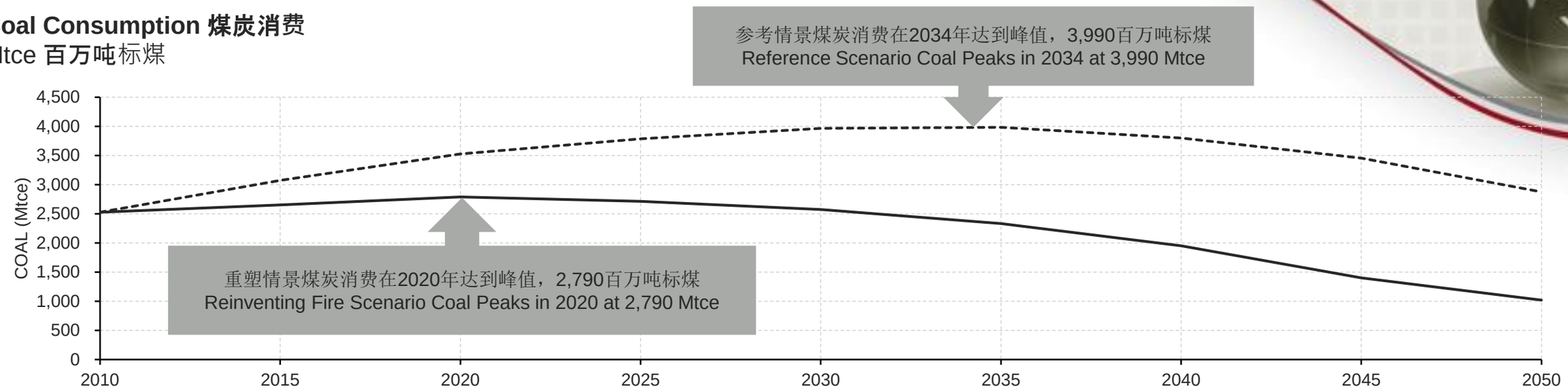
2025

Alternatives cheaper than coal
替代能源比煤炭便宜

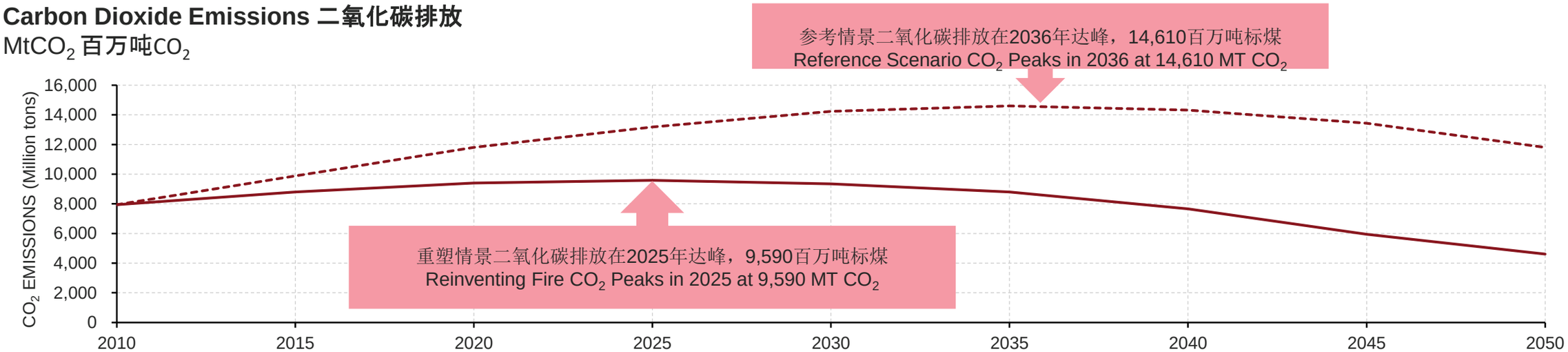
Source: Reinventing Fire: China team analysis

煤炭、二氧化碳、一次能源提前达峰
THREE TRENDS OF CHINA'S ENERGY

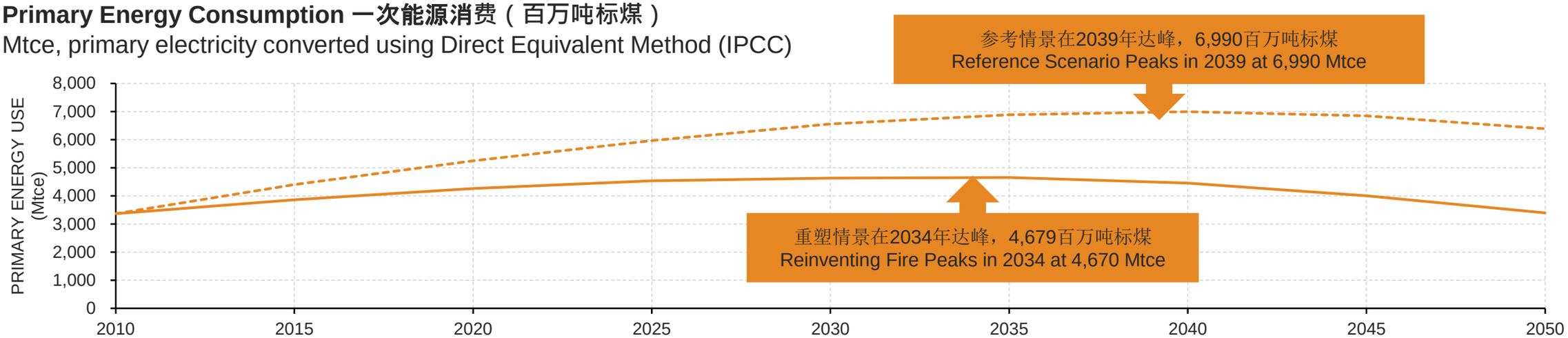
Coal Consumption 煤炭消费
Mtce 百万吨标煤



Carbon Dioxide Emissions 二氧化碳排放
$MtCO_2$ 百万吨CO_2



Primary Energy Consumption 一次能源消费（百万吨标煤）
Mtce, primary electricity converted using Direct Equivalent Method (IPCC)



Source: Reinventing Fire: China team analysis

能源强度和碳排放强度大幅下降
ENERGY INTENSITY AND CARBON INTENSITY REDUCTION

与2010年相比，2050年能源强度下降85%
2050年能源强度比目前OECD国家水平低30%

Energy intensity in 2050

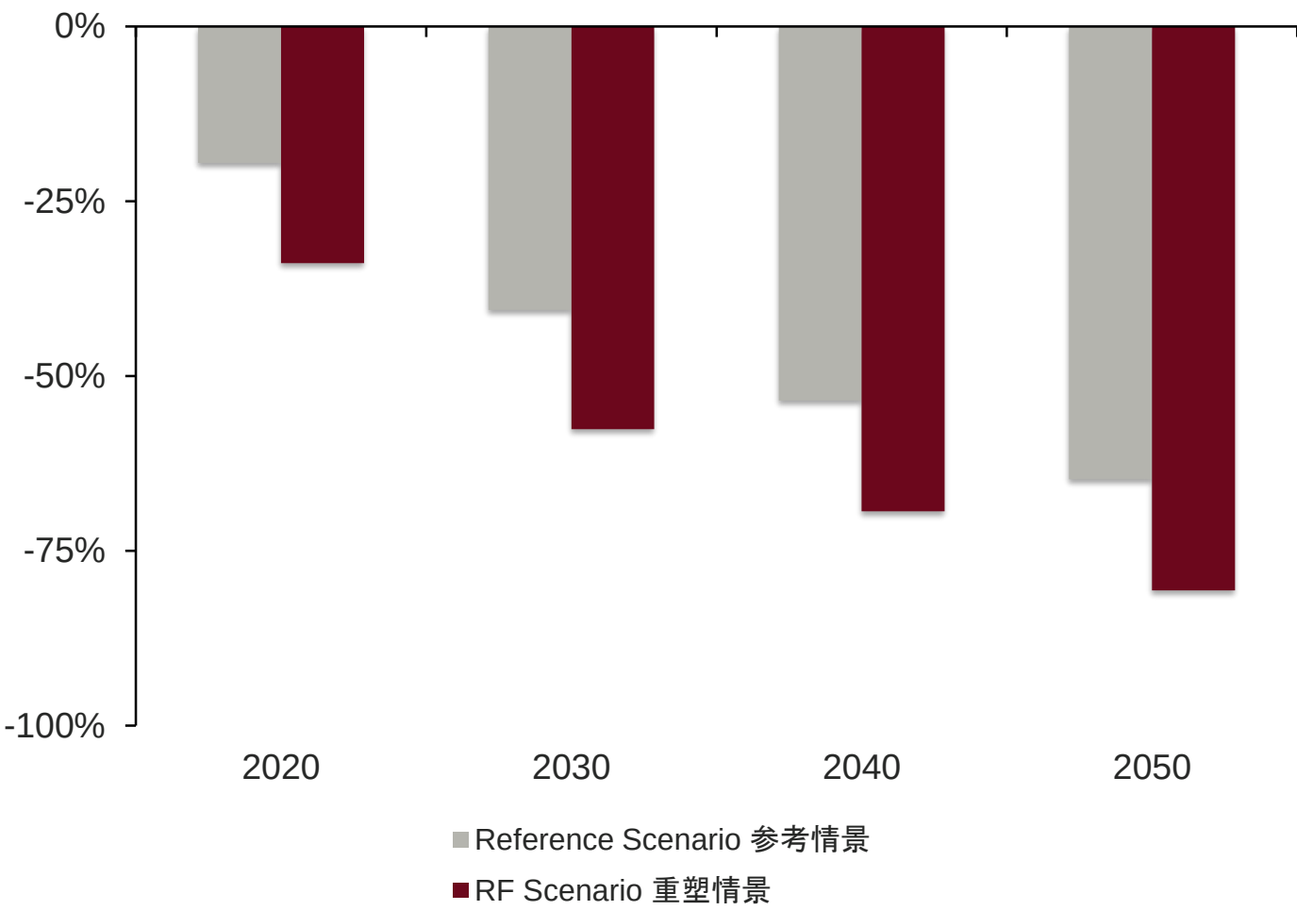
- Reduced by 85%, compared to 2010
- 30% lower than current OECD levels

与2005年相比，2050年碳强度下降93%
2050年碳强度比目前OECD国家水平低80%

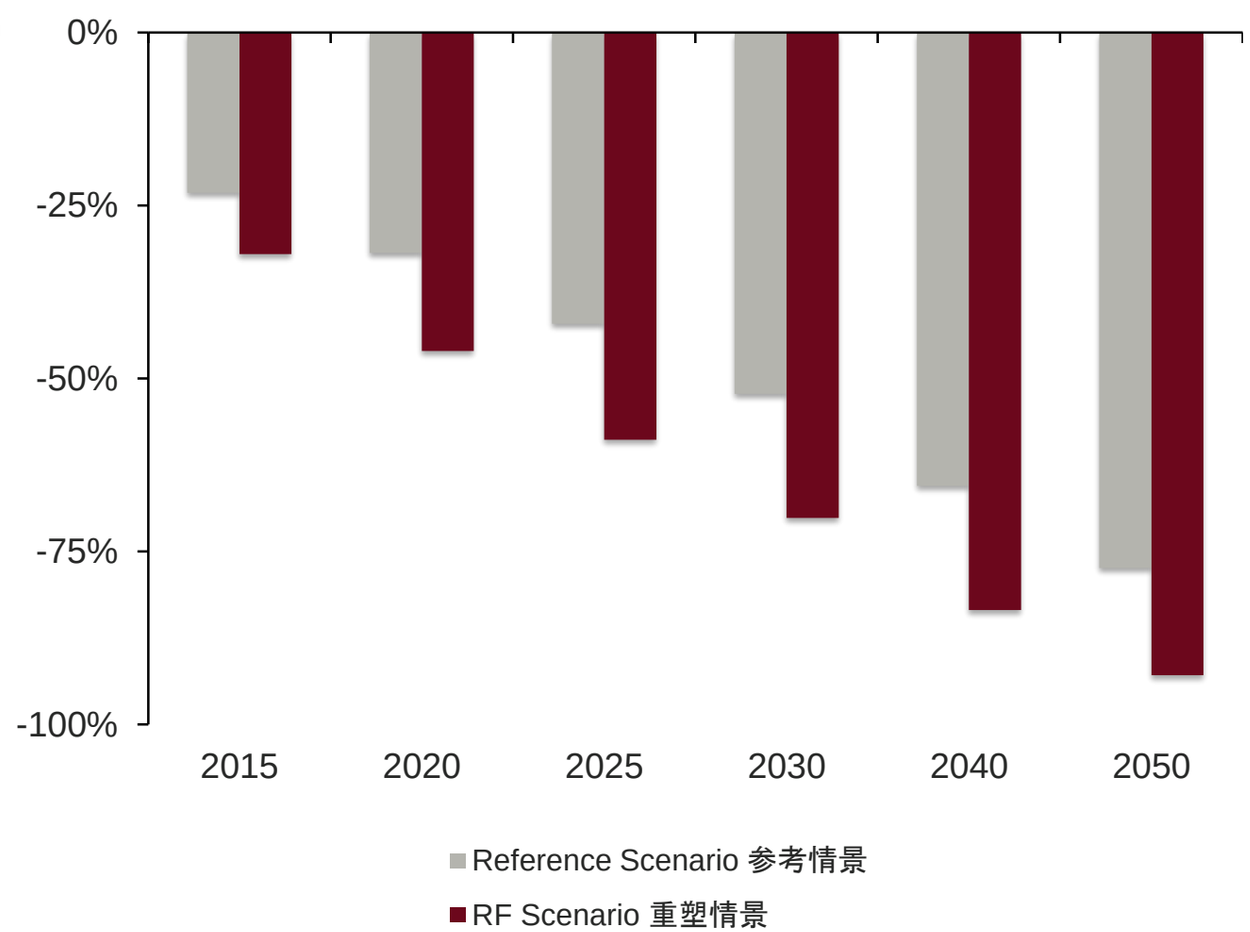
Carbon intensity in 2050

- Reduced by 93%, compared to 2005
- 80% lower than current OECD levels

能源强度下降幅度（与2010年相比
Energy Intensity Reduction (Relative to 2010)



碳强度下降幅度（与2005年相比）
Carbon Intensity Reduction (Relative to 2005)



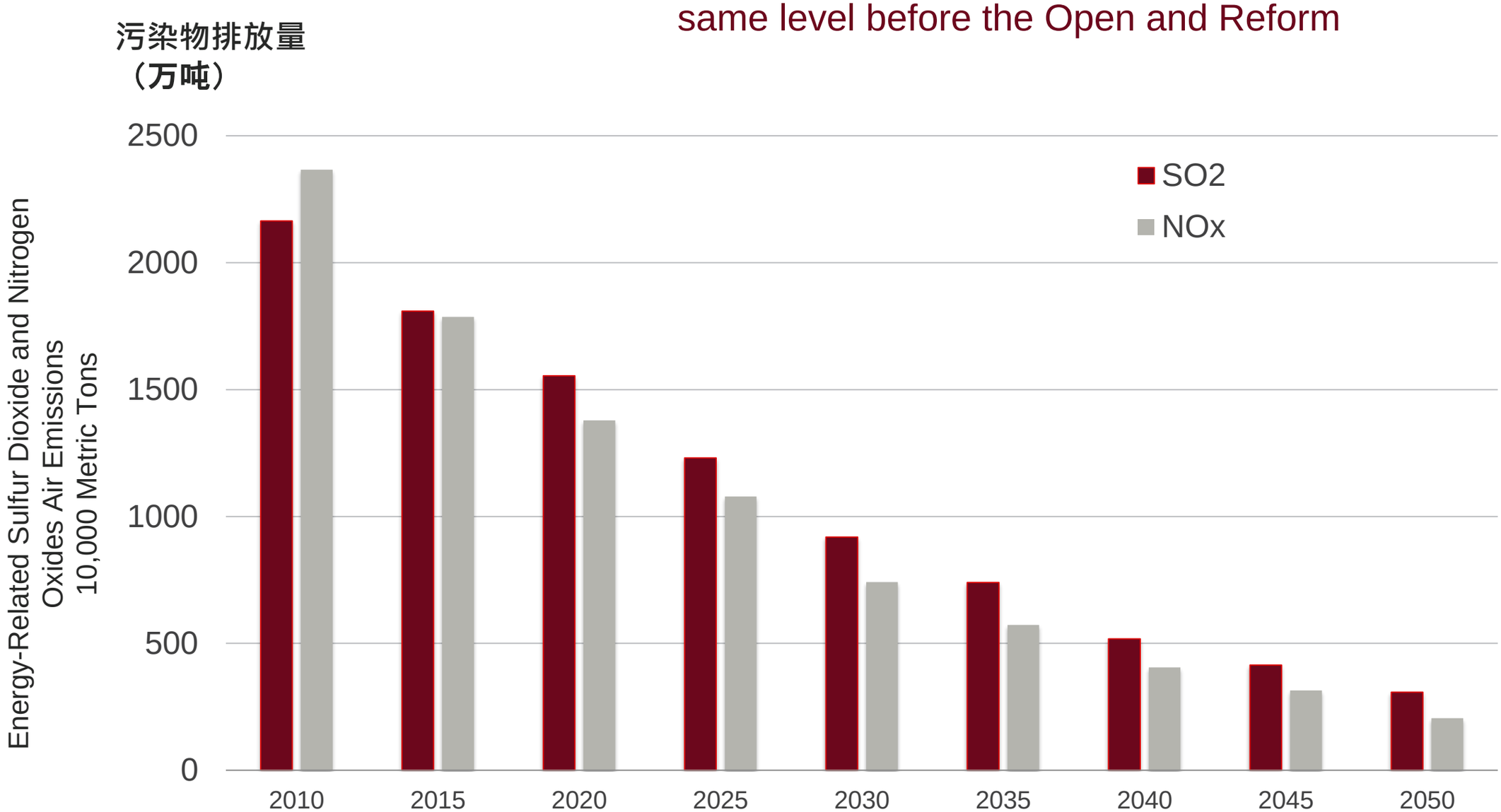
Source: Reinventing Fire: China team analysis

环境效益显著，实现碧水蓝天目标
REINVENTING FIRE SO_2 AND NO_X REDUCTIONS OVER TIME

SO_2和NO_x排放分别削减85%、90%

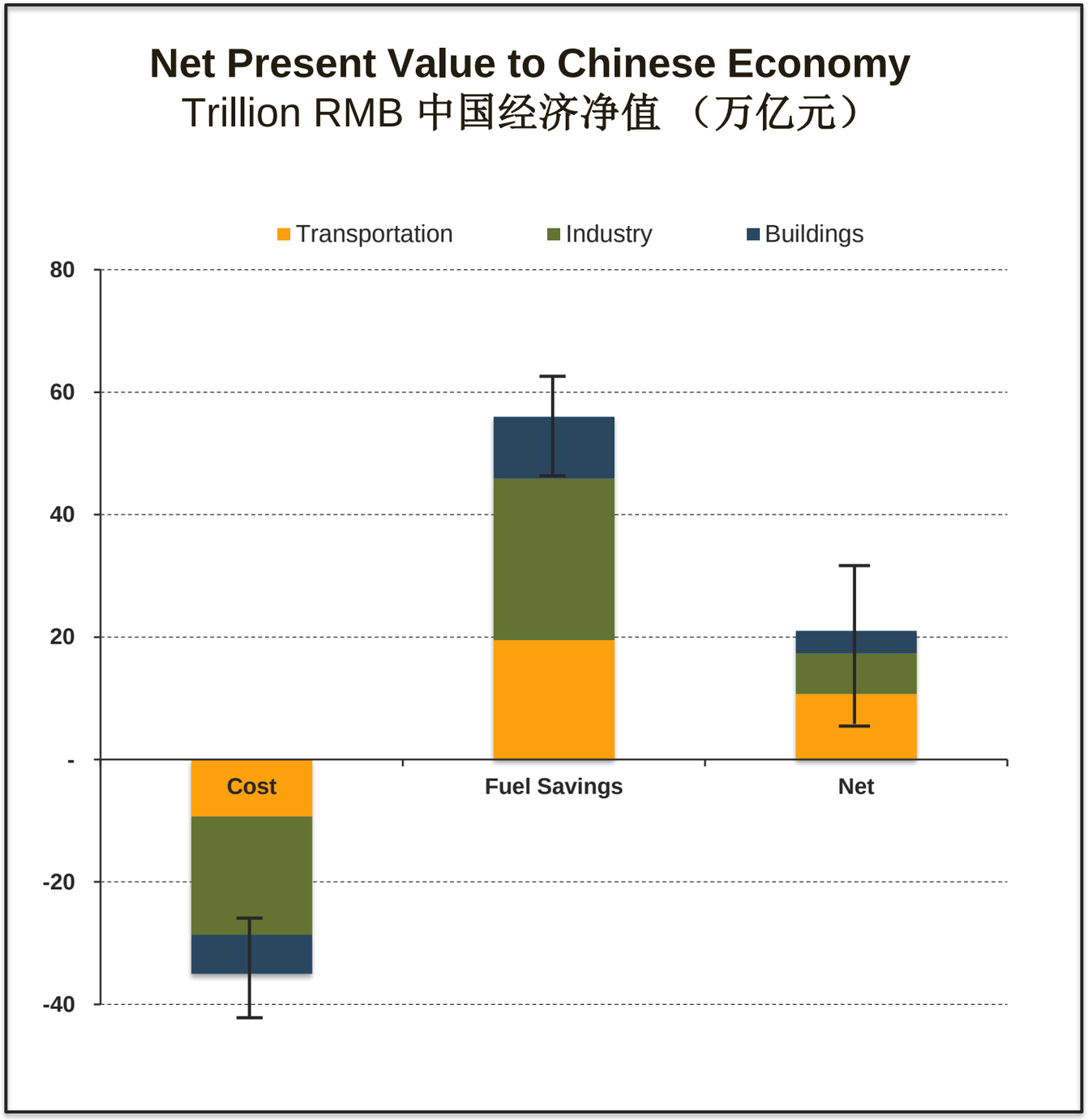
污染物排放量下降到改革开放以前水平

SO_2 and NO_X emissions will reduce by 85% and 90%, respectively. Emissions will reduce to the same level before the Open and Reform



Source: Reinventing Fire: China team analysis

重塑能源经济可行、效益显著
INVESTMENT AND SAVINGS TO PRODUCE REINVENTING FIRE RESULT



- 投入包括前期投资、运行成本、维护费用，不包括交易成本 Accounts for upfront capital, ongoing operations, and maintenance costs and benefits
- 收益包括节约能源支出，不包括环境效益、健康收益Excludes benefits due to pollution reductions or public health; also excludes transaction or program costs
- 重塑情景下，中国总投入42万亿元人民币，总收益68万亿元人民币，净收益22万元人民币Shows that China can achieve Reinventing Fire Scenario at a profit; an investment of 35 Trillion RMB secures 56 Trillion RMB in savings, with 21 Trillion RMB NPV
- 重塑情景下蕴含经济效益显著、有益民生的商业机遇Highlights opportunity for markets to support investment in driving the transformation, supplementing traditional government policies

Source: Reinventing Fire: China team analysis

主要结论与政策建议
KEY CONCLUSIONS AND OVERALL RECOMMENDATIONS

明确重塑能源发展战略，形成高效绿色低碳发展新动力
Launch Reinventing Fire strategies to facilitate low-carbon transformation

大幅提高能效，节能成为满足需求的第一能源
Improve energy efficiency as the First Fuel

加快技术变革，实现能源生产力6**倍增**长、碳生产力13**倍增**长
Facilitate technology advancement to improve energy productivity by 6 times, carbon productivity by 13 times

迎接新电气时代，推动能源系统低碳化、电气化
Promote development of electrified, low-carbon energy system

加快整合创新，实现基础设施“**一体化**”**系**统升级
Promote integrative design and upgrade infrastructure

推动商业模式创新，实现经济、社会和环境共赢
Facilitate commercial innovation and build dynamic markets

加快体制机制改革，释放**新的改革**红利
Unleash reform and ecological dividend through institutional transformation

Source: Reinventing Fire: China team analysis

中国转型的三个阶段
THREE HORIZONS OF CHINA'S TRANSFORMATION

	Stage 1: Waging a war on pollution; post-industrial transition **阶段1：对战污染；后工业转型**	**Stage 2:** Peaking carbon emissions and post-industrial growth **阶段2：碳排放达峰，后工业增长**	**Stage 3:** Green and intelligent development, completing low carbon energy transition **阶段3：绿色智能发展，完成低碳能源转型**
Timing **时间**	• 2010-2020	• 2020-2030	• 2030-2050
Targets **目标**	• Peak coal by 2020 2020年煤炭达峰 • 25% reduction in SO_2/NO_X from 2010 SO_2/NO_X 排放相比2010年降低25%	• Peak carbon dioxide emissions by 2030 2030年二氧化碳排放达峰 • Peak oil demand by 2030 2030年石油需求达峰	• Primary energy peaks and reduces to 2010 levels 一次能源达峰，并降低至2010年水平 • Carbon dioxide emissions at 5 GT by 2050 二氧化碳排放在2050年达到50亿吨

Source: Reinventing Fire: China team analysis

重塑能源：中国

面向2050年能源消费和生产革命路线图

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ご静聴ありがとうございます