Why the energy use of Chinese steel industry may peak as early as 2015?

Presenter:

Ali Hasanbeigi, Ph.D.

China Energy Group
Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory

Co-authors: Zeyi Jiang,, Lynn Price

BERKELEY LAB
Lawrence Berkeley National Laboratory

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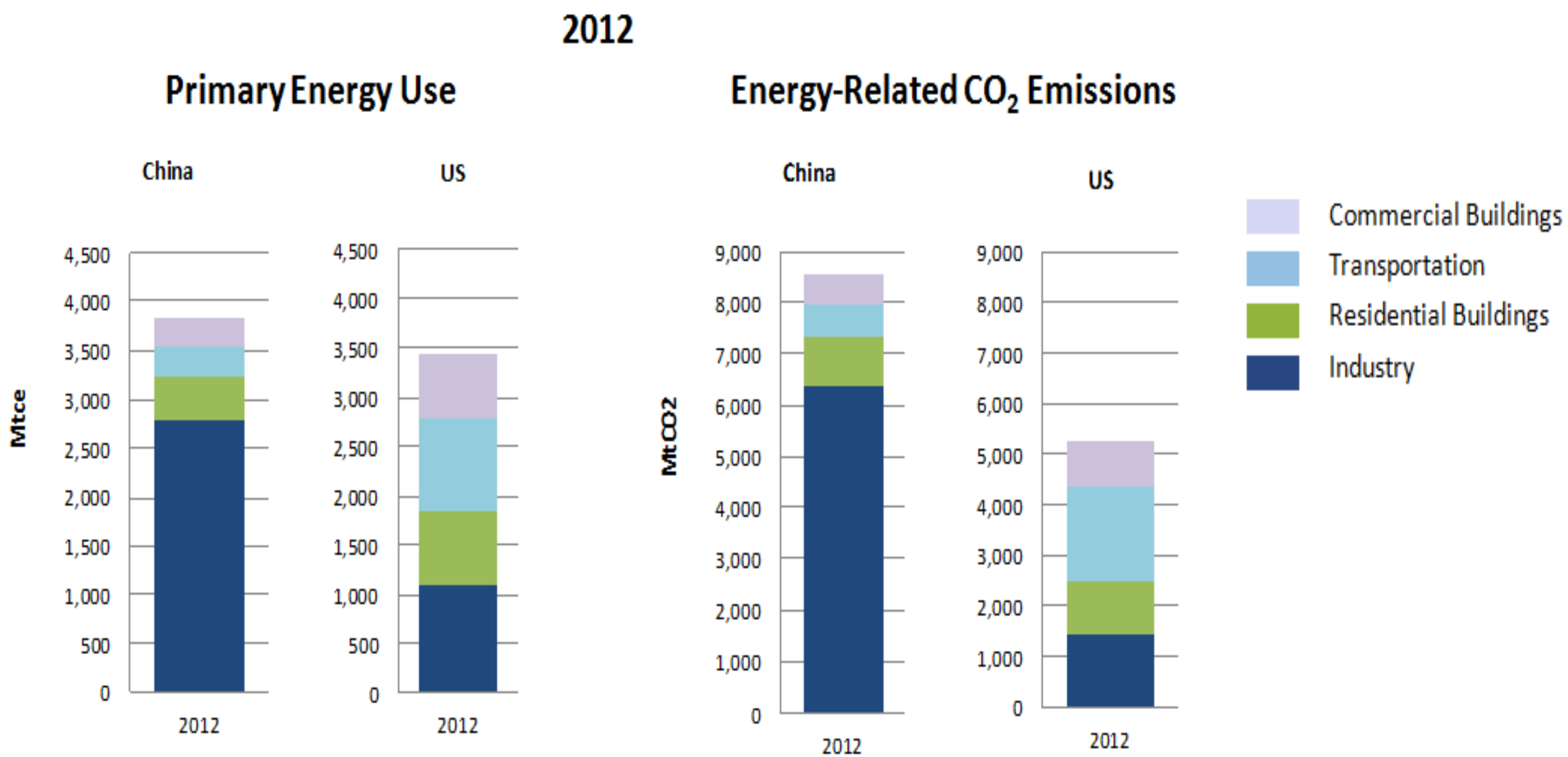
Outline

- Energy use in China and Chinese Industry
- Chinese steel industry
- Modifying decomposition analysis formulas for the steel industry
- Energy intensity analysis and forecast
- Results of the energy use and decomposition analysis
- Concluding remarks

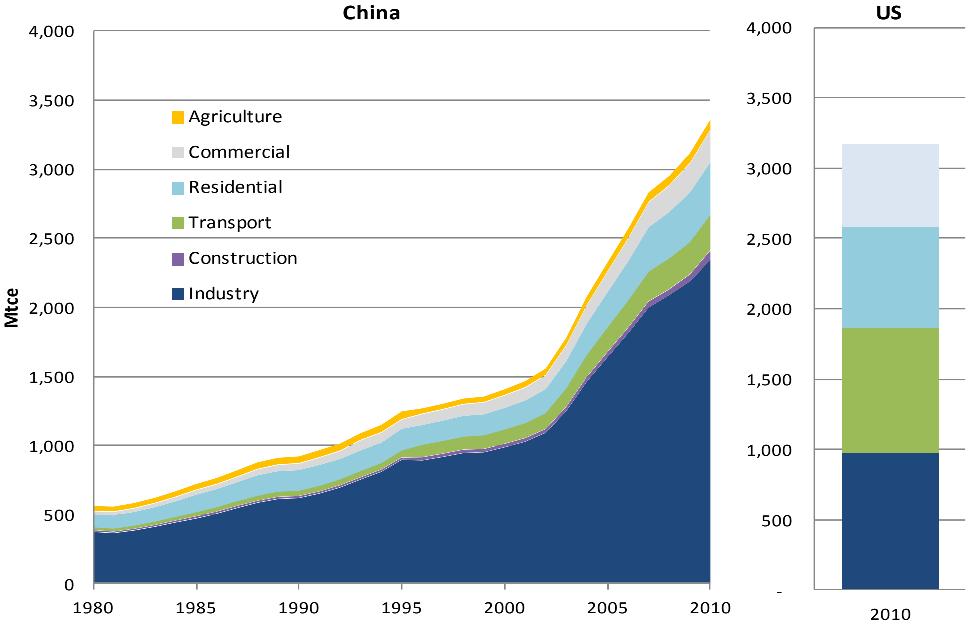
Introduction

Energy Use in China

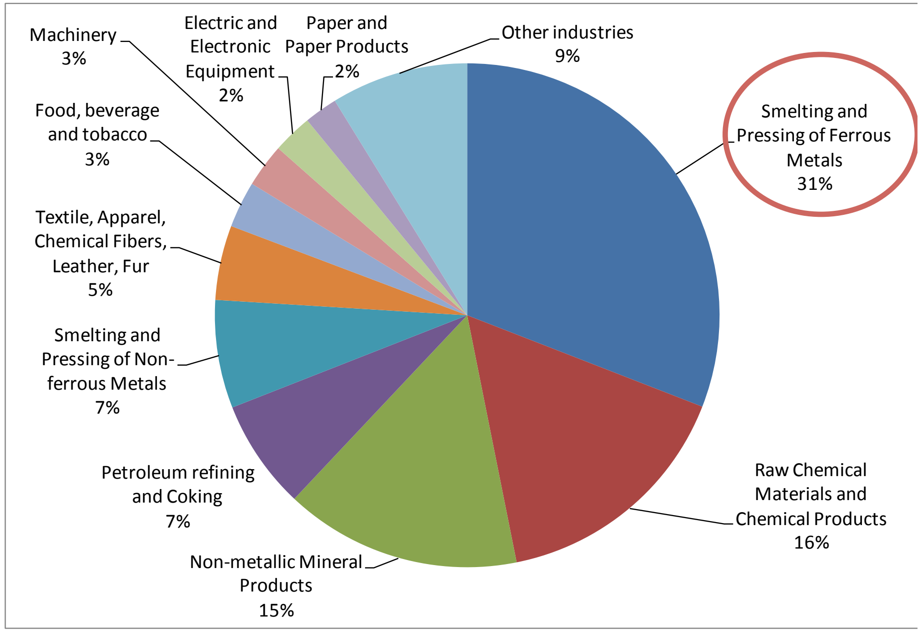


CO_2 emissions from China's industrial sector
> total US CO_2
> total EU CO_2
= 5 times Japan's total CO_2

Energy Use in Chinese Industry

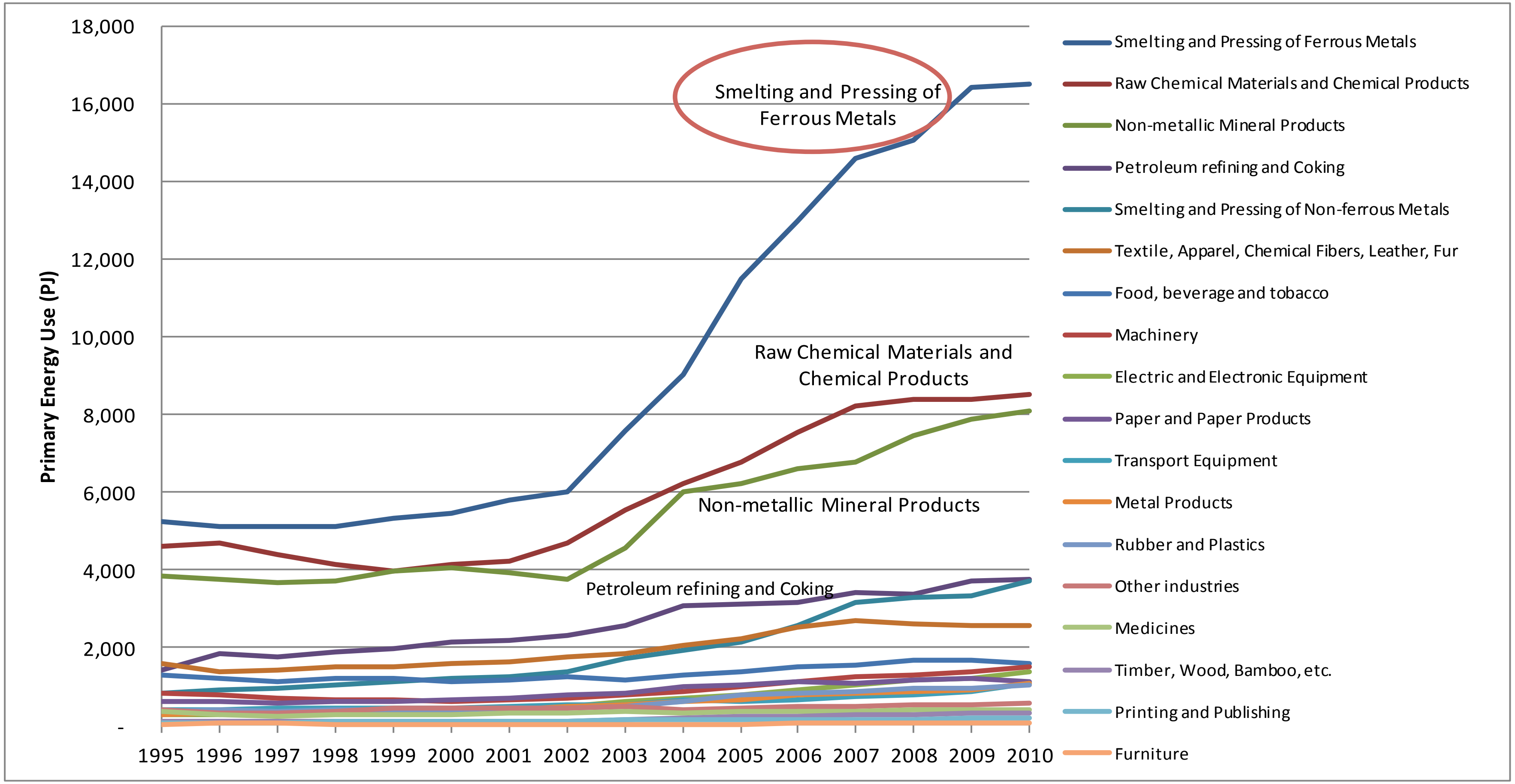


Primary energy use by sector in China and the U.S. (source: NBS, various years; US EIA 2011)



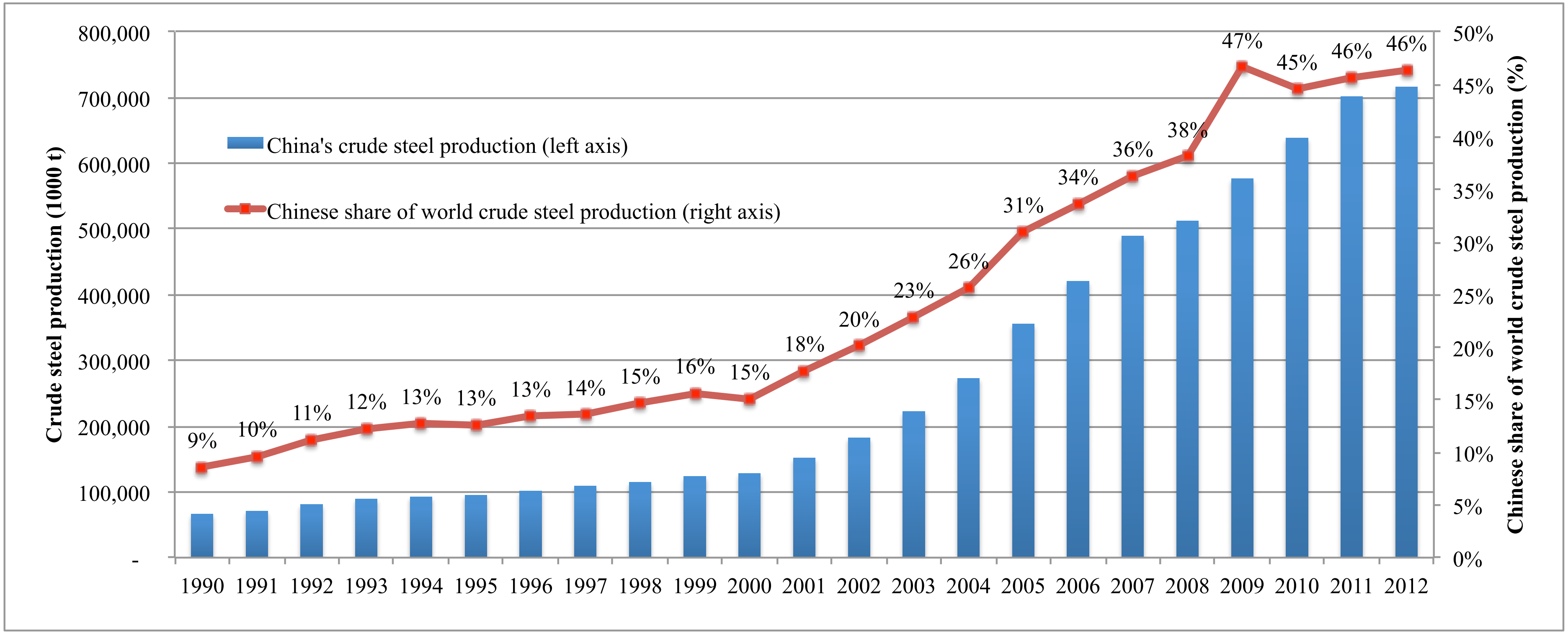
Share of each manufacturing subsector energy use in the total primary energy use of the manufacturing in China, 2010 (source: NBS 2011)

Energy Use in Chinese Industry



Primary energy use of manufacturing subsectors in China, 1995-2010 (NBS, 1996-2011)

Chinese steel Industry



Source: worldsteel, 2013

Context and Content

- Chinese government targets for 12th FYP (2011-2015):
  - 16% reduction in primary energy intensity of the country (energy use per GDP)
  - 17% reduction in CO_2 intensity of the country (CO_2 emissions per GDP)
  - **21% reduction in primary energy intensity of the industry (energy use per GDP)**
- Steel industry energy use trend can play significant role in meeting the 12th FYP and future FYPs targets

This Study

1. Analyzes China's steel industry past energy use and also makes projections up to 2030
2. Analysis is done at the process level
3. Conducts retrospective as well as prospective decomposition analysis

Modifying decomposition analysis formulas for the steel industry

Decomposition analysis

- Decomposition analysis separates the effects of key components on energy use trends over time. Three main components usually considered are:
  - aggregate activity
  - sectoral structure
  - energy intensity
- Different studies have used different mathematical techniques for decomposition analysis.
- We used the Logarithmic Mean Divisia Index (LMDI) method.
- **We modified the decomposition analysis formulas for the steel industry**
- We conducted both **retrospective** (2000 – 2010) as well as **prospective** (2010 – 2030) decomposition analysis
- Key medium- and large-sized Chinese steel enterprises

Generic LMDI decomposition analysis formulas

$$\Delta E_{tot} = E^T - E^0 = \Delta E_{act} + \Delta E_{str} + \Delta E_{int} \quad (6)$$

$$\Delta E_{act} = \sum_i \frac{E^T_i - E^0_i}{\ln E^T_i - \ln E^0_i} \ln\left(\frac{Q^T}{Q^0}\right) \quad (7)$$

$$\Delta E_{str} = \sum_i \frac{E^T_i - E^0_i}{\ln E^T_i - \ln E^0_i} \ln\left(\frac{S^T_i}{S^0_i}\right) \quad (8)$$

$$\Delta E_{int} = \sum_i \frac{E^T_i - E^0_i}{\ln E^T_i - \ln E^0_i} \ln\left(\frac{I^T_i}{I^0_i}\right) \quad (9)$$

Where:
i: subsector
T: last year of the period
T=0: base year of the period
E: total energy consumption
ΔE_{tot}: aggregate change in total energy consumption

The subscripts "act," "str," and "int" denote the effects associated with the overall activity level, structure, and sectoral energy intensity, respectively.

$$Q = \sum_i Q_i \text{ : total activity level} \quad (10)$$

$$S_i = Q_i/Q \text{ : activity share of sector } i \quad (11)$$

$$I_i = E_i/Q_i \text{ energy intensity of sector } i \quad (12)$$

Modifying the LMDI decomposition analysis formulas for the steel industry

We considered four major factors that could influence the steel production energy use:

- ***Activity***: Represents the total crude steel production.
- ***Structure***: Represents the activity share of each process route (BF-BOF or EAF route).
- ***Pig iron ratio***: The ratio of pig iron used as feedstock in each process route.
- ***Energy intensity***: Represents energy use per tonne of crude steel

Total energy use of the iron and steel industry, then, is represented by:

$$E_t = \sum_i E_{PI,i,t} + \sum_i E_{Oth,i,t}$$

- i: process route (BF-BOF or EAF route)
- t: year
- $E_{PI,i,t}$ = Energy use for production of pig iron used for steel production in process route i in year t
- $E_{Oth,i,t}$ = Total energy use for steel production minus the energy use for production of pig iron used for steel production in process route i in year t

Modifying the LMDI decomposition analysis formulas for the steel industry

Using the basic LMDI decomposition analysis method, we can derive:

$$E_t = \sum_i Q_{Crude,t} \frac{Q_{Crude,i,t}}{Q_{Crude,t}} \frac{Q_{PI,i,t}}{Q_{Crude,i,t}} \frac{E_{PI,i,t}}{Q_{PI,i,t}} + \sum_i Q_{Crude,t} \frac{Q_{Crude,i,t}}{Q_{Crude,t}} \frac{E_{Oth,i,t}}{Q_{Crude,i,t}}$$

- $Q_{crude,t}$: total crude steel production in year t
- $Q_{crude,i,t}$: crude steel production by process route i in year t
- $Q_{PI,i,t}$: pig iron used by process route i in year t

$$\Delta E_{tot} = E^T - E^0 = (\Delta E_{act.PI} + \Delta E_{Str.PI-} + \Delta E_{ratio.PI} + \Delta E_{int.PI}) + (\Delta E_{act.Oth} + \Delta E_{Str.Oth-} + \Delta E_{int.Oth}) \qquad (3)$$

- T: last year of the period
- T= 0: base year of the period
- E: total final energy consumption of the key medium- and large-sized steel enterprises
- ΔE_{tot}: aggregate change in total final energy consumption of the key medium- and large-sized steel enterprises

Modifying the LMDI decomposition analysis formulas for the steel industry

$$\Delta E_{tot} = \Delta E_{act} + \Delta E_{Str} + \Delta E_{ratio} + \Delta E_{int} \quad - \quad (4)$$

$$\Delta E_{act} = \Delta E_{act.PI} + \Delta E_{act.Oth} \quad (5)$$

$$\Delta E_{Str} = \Delta E_{Str.PI} + \Delta E_{Str.Oth} \quad (6)$$

$$\Delta E_{shar} = \Delta E_{ratio.PI} \quad (7)$$

$$\Delta E_{int} = \Delta E_{int.PI} + \Delta E_{int.Oth} \quad (8)$$

$$\Delta E_{act.PI} = \sum_i \frac{E_{PI,i}^T - E_{PI,i}^0}{\ln E_{PI,i}^T - \ln E_{PI,i}^0} \ln\left(\frac{Q_{crude}^T}{Q_{crude}^0}\right) \quad (9)$$

$$\Delta E_{str.PI} = \sum_i \frac{E_{PI,i}^T - E_{PI,i}^0}{\ln E_{PI,i}^T - \ln E_{PI,i}^0} \ln\left(\frac{St_i^T}{St_i^0}\right) \quad (10)$$

$$\Delta E_{ratio.PI} = \sum_i \frac{E_{PI,i}^T - E_{PI,i}^0}{\ln E_{PI,i}^T - \ln E_{PI,i}^0} \ln\left(\frac{Ra_{PI,i}^T}{Ra_{PI,i}^0}\right) \quad (11)$$

$$\Delta E_{int.PI} = \sum_i \frac{E_{PI,i}^T - E_{PI,i}^0}{\ln E_{PI,i}^T - \ln E_{PI,i}^0} \ln\left(\frac{I_{PI,i}^T}{I_{PI,i}^0}\right) \quad (12)$$

$$\Delta E_{act.Oth} = \sum_i \frac{E_{Oth,i}^T - E_{Oth,i}^0}{\ln E_{Oth,i}^T - \ln E_{Oth,i}^0} \ln\left(\frac{Q_{crude}^T}{Q_{crude}^0}\right) \quad (13)$$

$$\Delta E_{str.Oth} = \sum_i \frac{E_{Oth,i}^T - E_{Oth,i}^0}{\ln E_{Oth,i}^T - \ln E_{Oth,i}^0} \ln\left(\frac{St_i^T}{St_i^0}\right) \quad (14)$$

$$\Delta E_{int.Oth} = \sum_i \frac{E_{Oth,i}^T - E_{Oth,i}^0}{\ln E_{Oth,i}^T - \ln E_{Oth,i}^0} \ln\left(\frac{I_{Oth,i}^T}{I_{Oth,i}^0}\right) \quad (15)$$

Modifying the LMDI decomposition analysis formulas for the steel industry

$Q_{crude} = \sum_i Q_{crude,i}$: total activity level (16)

$St_i = \frac{Q_{crude,i}}{Q_{crude}}$: activity share of process route i (17)

$Ra_i = \frac{Q_{PI,i}}{Q_{crude,i}}$: ratio of pig iron used as feedstock in process route i (18)

$I_{PI,i} = \frac{E_{PI,i}}{Q_{PI,i}}$: energy intensity associated with the pig iron used in process route i (19)

$I_{Oth,i} = \frac{E_{Oth,i}}{Q_{crude,i}}$: energy intensity associated with all other processes in process route i except the pig iron used (20)

Energy intensity analysis and forecast

Energy intensity analysis

Final energy intensity of the main steel-making processes in key medium- and large-sized Chinese steel enterprises (2000-2010)

Year	Coking (GJ/t coke)	Sintering (GJ/t sinter)	Pelletizing (GJ/t pellet)	Ironmaking (BF) (GJ/t pig iron)	BOF (GJ/t crude steel)	EAF (GJ/t crude steel)	Rolling (GJ/t finished steel)
2000	4.3	1.8	1.1	13.5	0.3	3.2	2.5
2001	4.1	1.8	1.1	13.1	0.3	2.8	2.3
2002	4.0	1.7	1.1	13.2	0.3	2.7	2.1
2003	4.0	1.7	1.1	13.5	0.3	2.6	2.1
2004	3.8	1.7	1.1	13.5	0.3	2.5	2.0
2005	3.8	1.7	1.1	13.2	0.3	2.4	1.9
2006	3.6	1.6	1.0	12.7	0.3	2.4	1.9
2007	3.6	1.6	0.9	12.5	0.2	2.4	1.8
2008	3.5	1.6	0.9	12.5	0.2	2.4	1.7
2009	3.3	1.6	0.9	12.0	0.1	2.2	1.7
2010	3.1	1.5	0.9	12.0	0.0	2.2	1.8

Source: (EBCSY 2001-2011; Zhang and Wang 2006)

Energy intensity analysis

Final energy intensity for the production of one tonne of pig iron (or hot metal) can be calculated from the following equation:

$$EI_{PI} = EI_{coke} * F_{coke} + EI_{sint} * F_{sint} * Sh_{sint} + EI_{pell} * F_{pell} * Sh_{pell} + EI_{BF}$$

Next the final energy intensity of BF-BOF and EAF steel production excluding "Auxiliary" energy use, can be calculated as follows:

- $EI_{BF\text{-}BOF\text{-}X} = EI_{PI} * F_{PI,BOF} + EI_{BOF} + EI_{roll} * F_{roll}$
- $EI_{EAF\text{-}X} = EI_{PI} * F_{PI,EAF} + EI_{EAF} + EI_{roll} * F_{roll}$

the combined final energy intensity of steel production excluding "Auxiliary" can be calculated as:

$$EI_X = EI_{BF\text{-}BOF\text{-}X} * Sh_{BOF} + EI_{EAF\text{-}X} * Sh_{EAF}$$

Energy intensity analysis

Final energy intensities (GJ/t crude steel) calculated for key medium- and large-sized Chinese steel enterprises (2000-2010)

Year	Final energy intensity of EAF route excluding "Auxiliary" energy use (EI_{EAF-X})	Final energy intensity of BF-BOF route excluding "Auxiliary" energy use ($EI_{BF-BOF-X}$)	Combined Final energy intensity of key enterprises excluding "Auxiliary" energy use	Comprehensive final energy intensity [a]	Final energy intensity of "Auxiliary" category [c]	Final energy intensity of complete EAF route	Final energy intensity of complete BF-BOF route	Combined Final energy intensity of key enterprises
2000	10.2	20.6	19.3	N.A. [b]	0.9	11.1	21.5	20.3
2001	9.4	19.9	18.4	N.A. [b]	0.9	10.3	20.8	19.3
2002	10.1	19.7	18.2	N.A. [b]	0.9	11.0	20.6	19.2
2003	9.9	19.8	18.3	N.A. [b]	0.9	10.8	20.8	19.2
2004	10.8	19.7	18.5	N.A. [b]	0.9	11.7	20.7	19.4
2005	11.9	19.3	18.4	N.A. [b]	0.9	12.8	20.2	19.4
2006	12.6	18.6	18.0	18.9	0.9	13.4	19.5	18.9
2007	12.0	18.2	17.6	18.4	0.8	12.8	19.0	18.4
2008	11.5	18.1	17.5	18.5	0.9	12.4	19.0	18.5
2009	12.3	17.4	17.0	18.1	1.1	13.4	18.5	18.1
2010	11.3	17.2	16.7	17.7	1.0	12.2	18.1	17.7

$$EI = EI_{BF-BOF} * Sh_{BOF} + EI_{EAF} * Sh_{EAF}$$

Forecasts

Energy intensity of main steel-making processes assumed for 2030 (MIIT 2010)

Year	Coking (GJ/t coke)	Sintering (GJ/t sinter)	Pelletizing (GJ/t pellet)	Ironmaking (BF) (GJ/t pig iron)	BOF (GJ/t crude steel)	EAF(GJ/t crude steel)	Rolling (GJ/t finished steel)
Advanced value of energy intensity from national standard	3.1	1.4	0.7	11.1	-0.4	2.1	1.6 [a]

We assumed that the reduction in energy intensity of processes between 2010 and 2030 will be linear and based on that calculated the energy intensity for each process in 2015 and 2020.

Then, similar steps as described in previous slides were taken for calculation of energy use for decomposition analysis.

Forecasts

1. **Scenario** 1: **Low scrap** usage: the share of EAF steel production grows slower and the pig iron feed ratio in EAF drops slower than other scenarios
2. **Scenario** 2: **Medium scrap** usage: the rate of growth in the share of EAF steel production and the drop in the pig iron feed ratio in EAF production is medium (between scenario 1 and 3)
3. **Scenario** 3: **High scrap** usage: the share of EAF steel production grows faster and the pig iron feed ratio in EAF production drops faster than other scenarios.

Year	Pig iron ratio in EAF (t pig iron/t crude steel)			Share of EAF steel production from total steel production in *Key Enterprises*			Share of sinter from total iron ore used	Share of pellet from total iron ore used
	Scenario 1	Scenario 2	Scenario 3	Scenario 1	Scenario 2	Scenario 3		
2015	0.40	0.40	0.40	10%	10%	10%	85%	15%
2020	0.35	0.30	0.30	13%	15%	18%	85%	15%
2030	0.30	0.20	0.10	20%	25%	35%	85%	15%

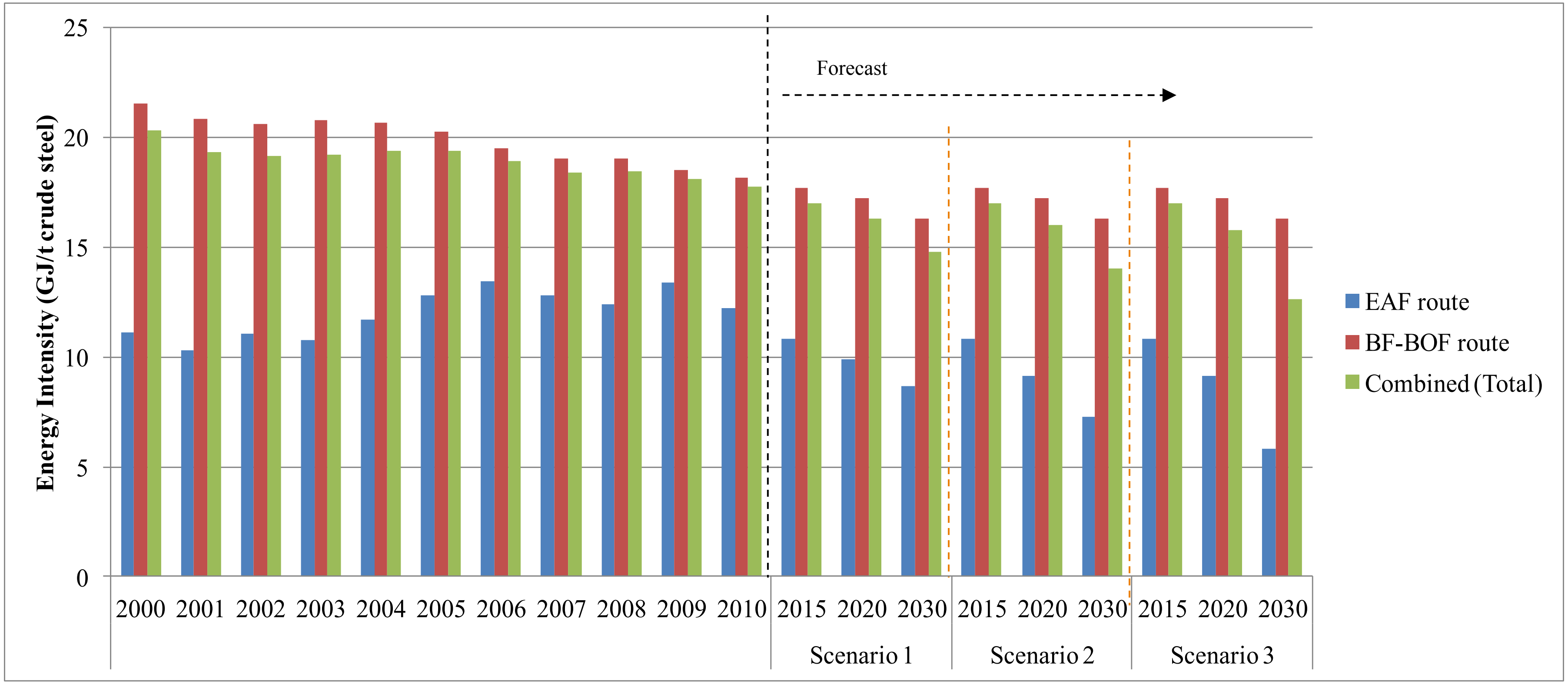
Assumptions on AAGR used to forecast total steel production in key enterprises (Fridley et al. 2011)

	2010-2015 based on 2010 production	2015-2020 based on 2015 production	2020-2025 based on 2020 production	2025-2030 based on 2025 production
AAGR	2.1%	1.4%	0.4%	0.2%

Results

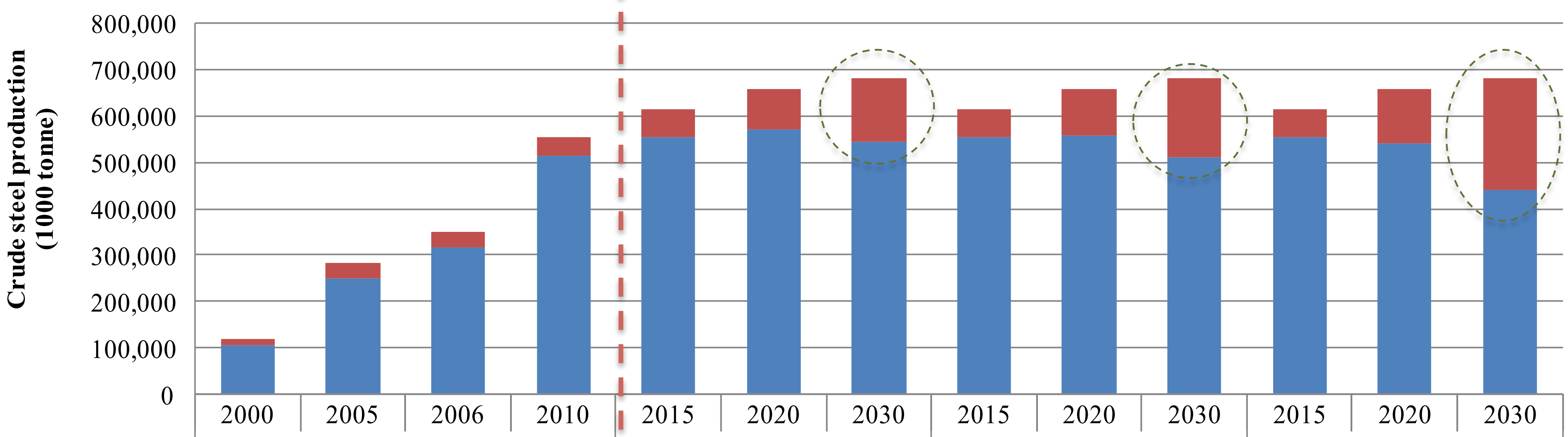
Final energy intensities

Final energy intensities calculated for key medium- and large-sized Chinese steel enterprises (2000-2030)



Crude steel production

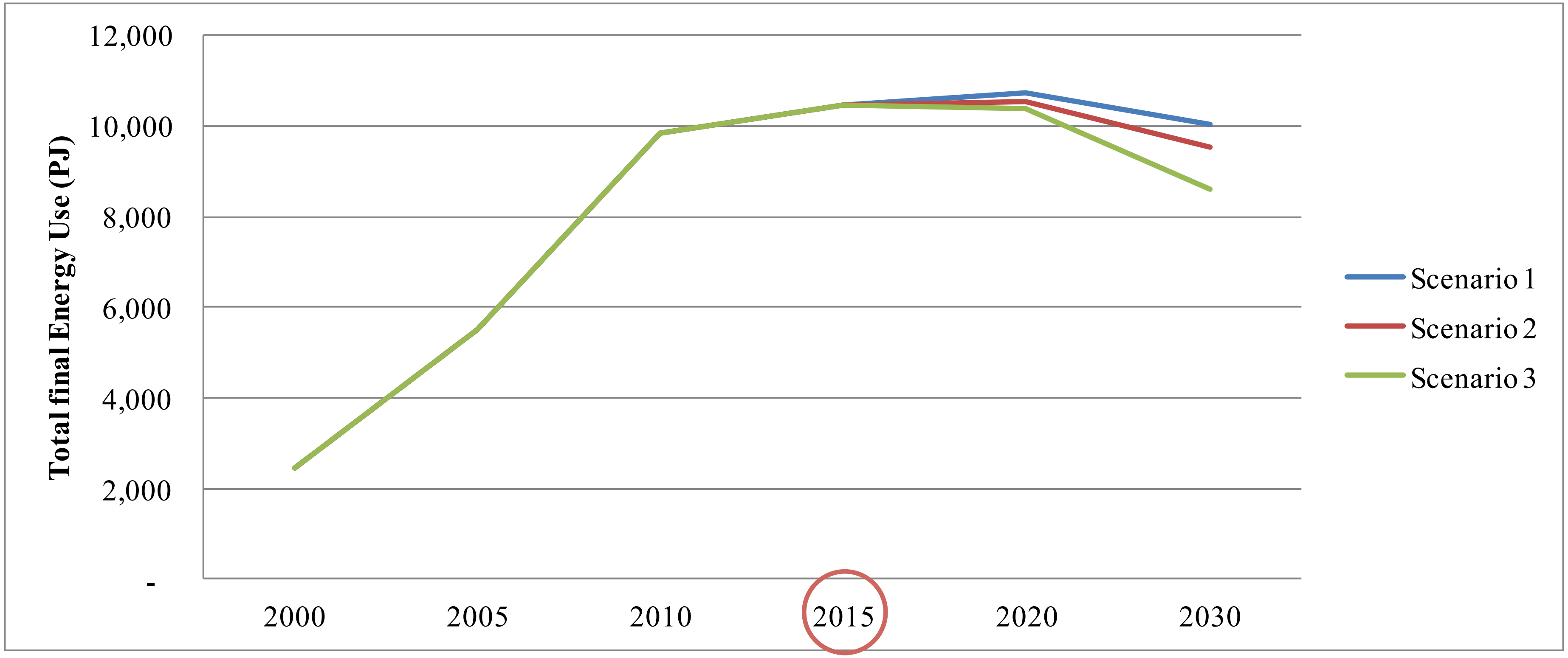
Total crude steel production by EAF and BF-BOF steel production routes in key enterprises under different scenarios (2000-2030)



	2000	2005	2006	2010	2015	2020	2030	2015	2020	2030	2015	2020	2030
					Scenario 1			Scenario 2			Scenario 3		
EAF Route	14,574	33,275	33,843	39,699	61,455	85,576	136,078	61,455	98,742	170,097	61,455	118,490	238,136
BF-BOF Route	105,779	250,624	315,602	514,585	553,097	572,703	544,311	553,097	559,537	510,291	553,097	539,789	442,252

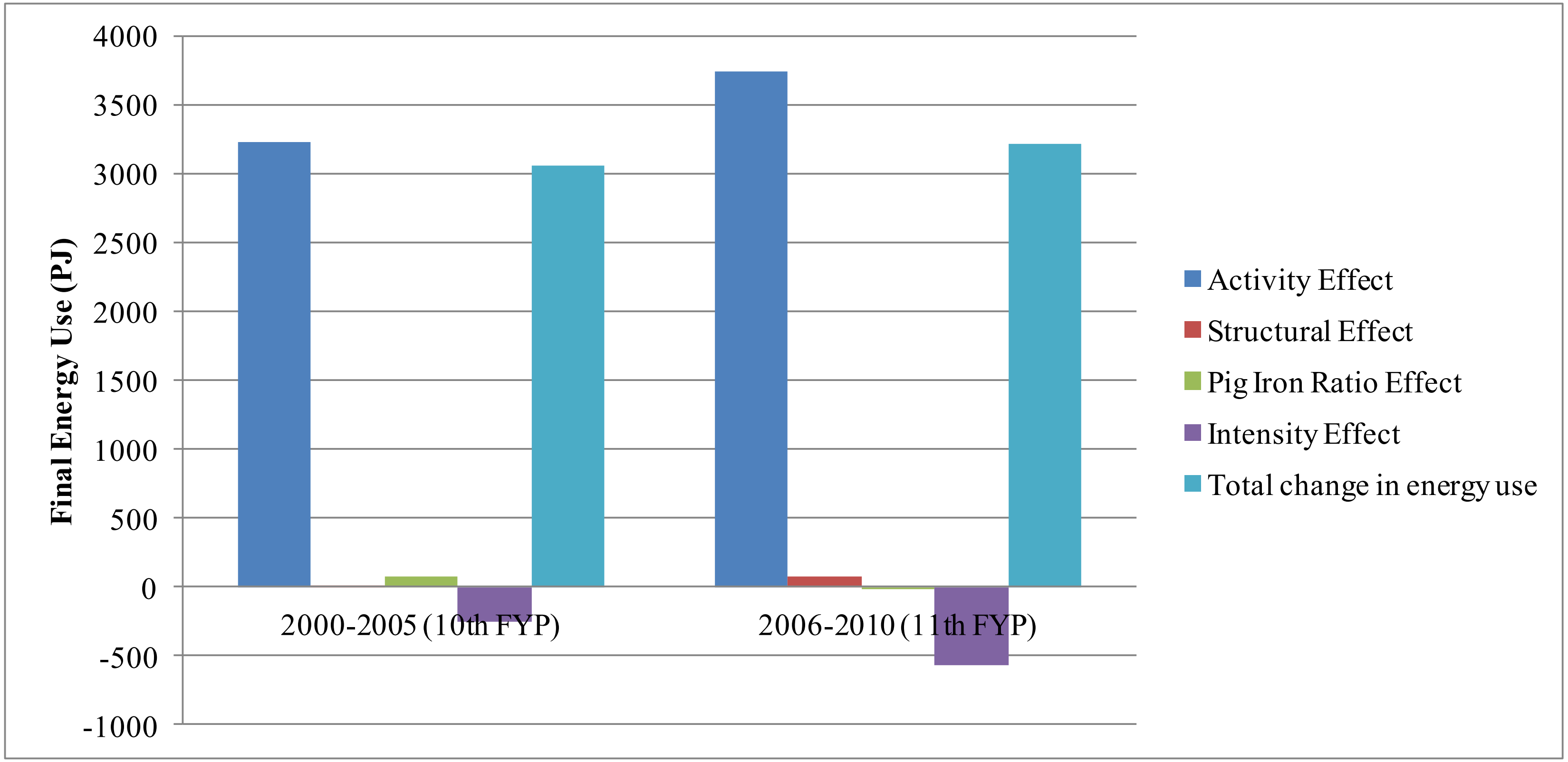
Total final energy use

Total final energy use in key medium- and large-sized Chinese steel enterprises under each scenario (2000-2030)



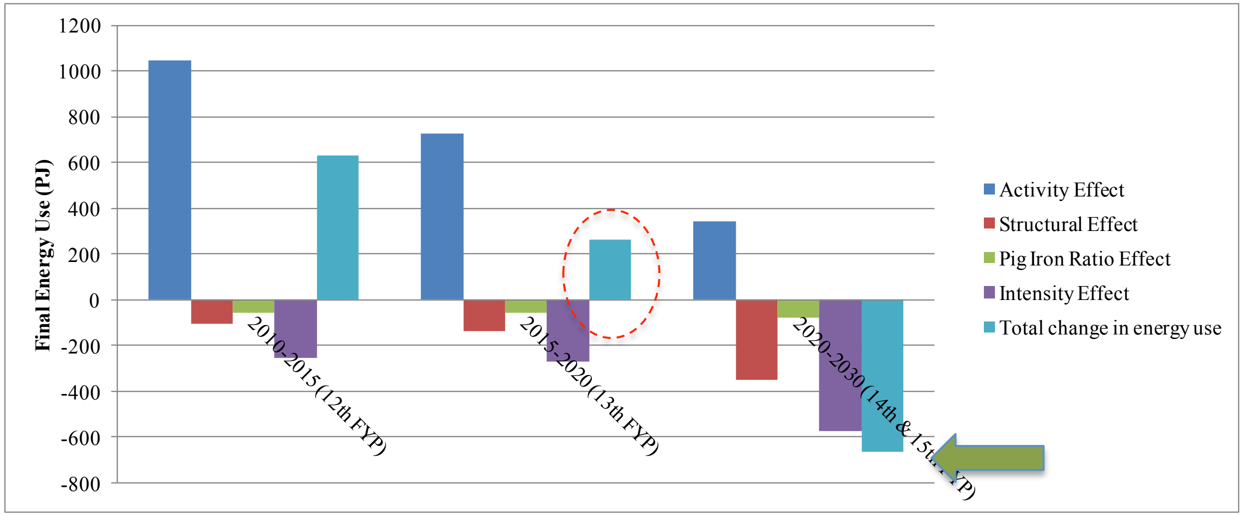
Retrospective Decomposition analysis

Results of the retrospective decomposition of final energy use of key medium- and large-sized steel enterprises, 2000- 2010



Prospective Decomposition analysis

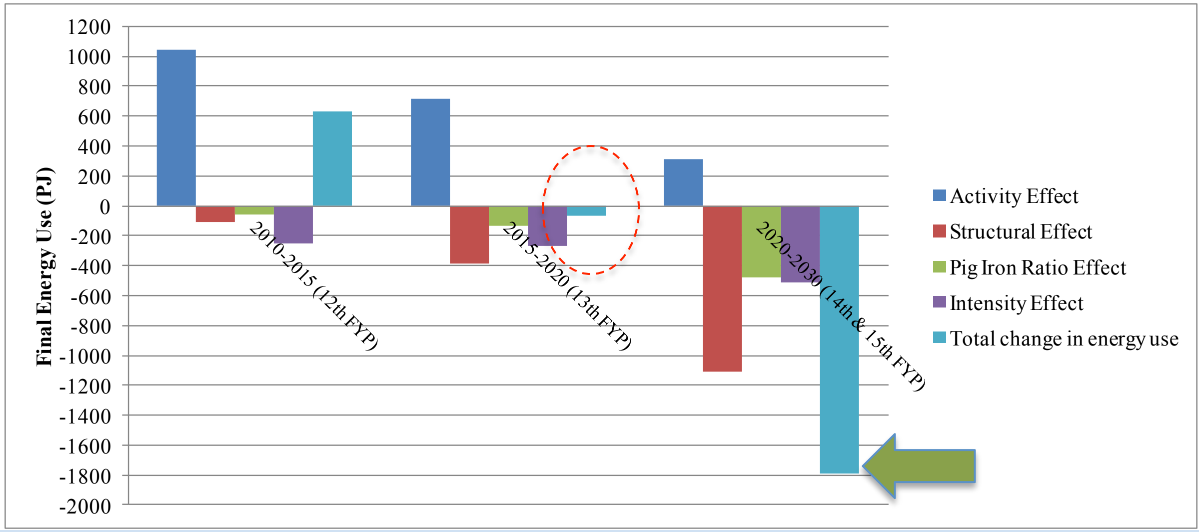
Scenario 1



Scenario 3

Difference between total change in energy use in period 2020-2030 in scenario 1 and 3:

- 128% 2010 energy use in Denmark
- 95% of 2010 energy use in Portugal
- >82% of 2010 energy use in Switzerland or Finland



Conclusions

- Under all scenarios, the total annual crude steel **production** of key steel enterprises (and most likely entire Chinese steel industry) **peaks in 2030**. Peak may happen earlier!
- Total final energy use of the key Chinese steel enterprises peaks earlier, i.e. in year 2020 under scenario 1 and scenario 2 and **in 2015 under scenario 3**
- Retrospective decomposition: energy intensity reduction was almost the only factor that helped to reduce final energy use
- Prospective decomposition: Energy intensity reduction of the production processes and structural shift from BF-BOF to EAF steel production played the most significant role
- More scrap availability in the near and long term can make scenario 3 quite viable

Thank You!

Questions and Comments?

Ali Hasanbeigi

Ahasanbeigi@lbl.gov

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