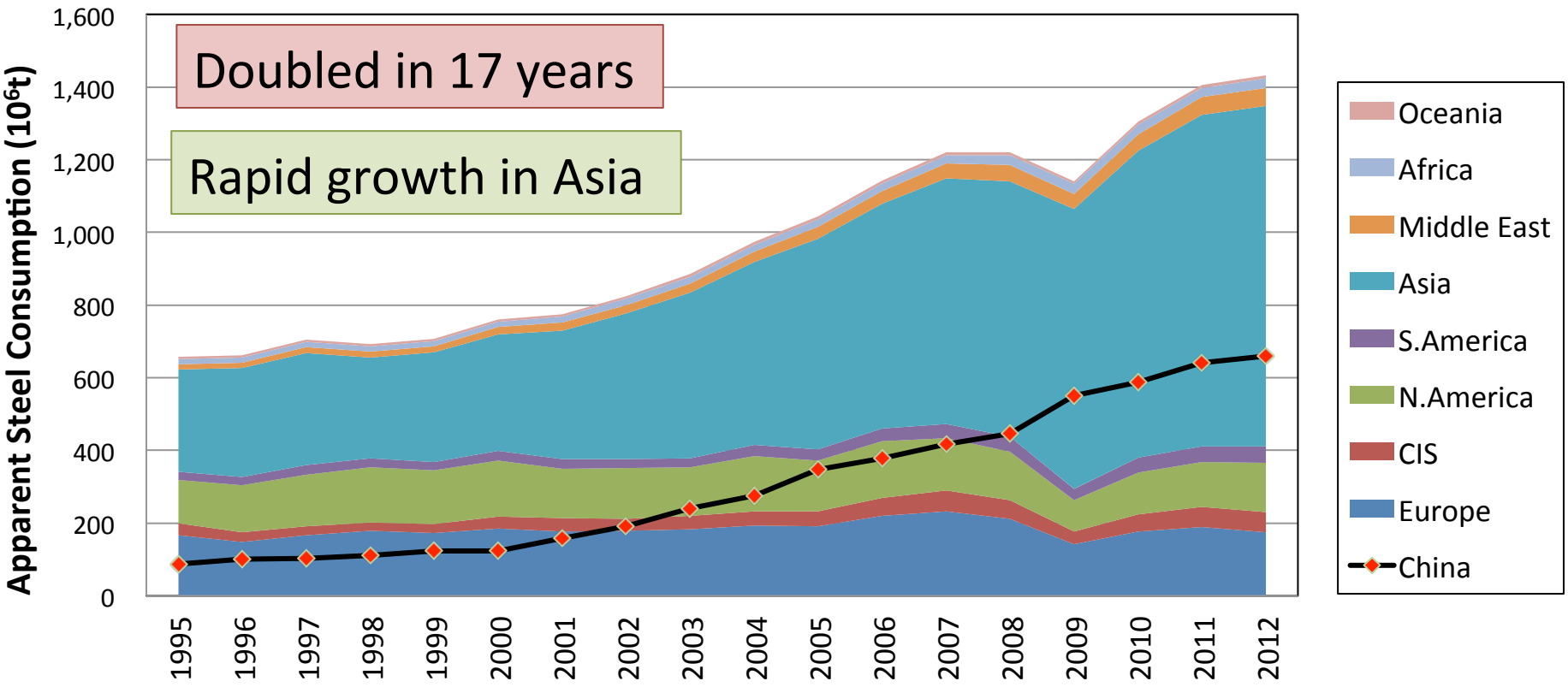
World Steel Consumption



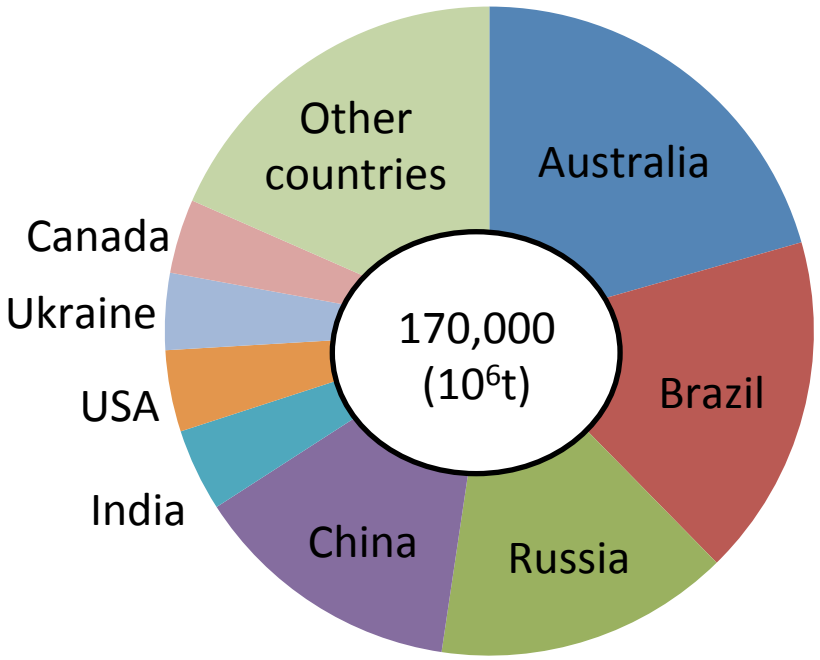
Consumption

In China: Increased to 7 times
In India: Tripled

Demand will grow even more in the future

Minable Iron Ore

In 2013



Reference : Mineral Commodity Summaries

Production in 2013
3,000 (10^6t)

Reserve Production Ratio
about 57 years

Efficient use of secondary resources

Civil Engineering

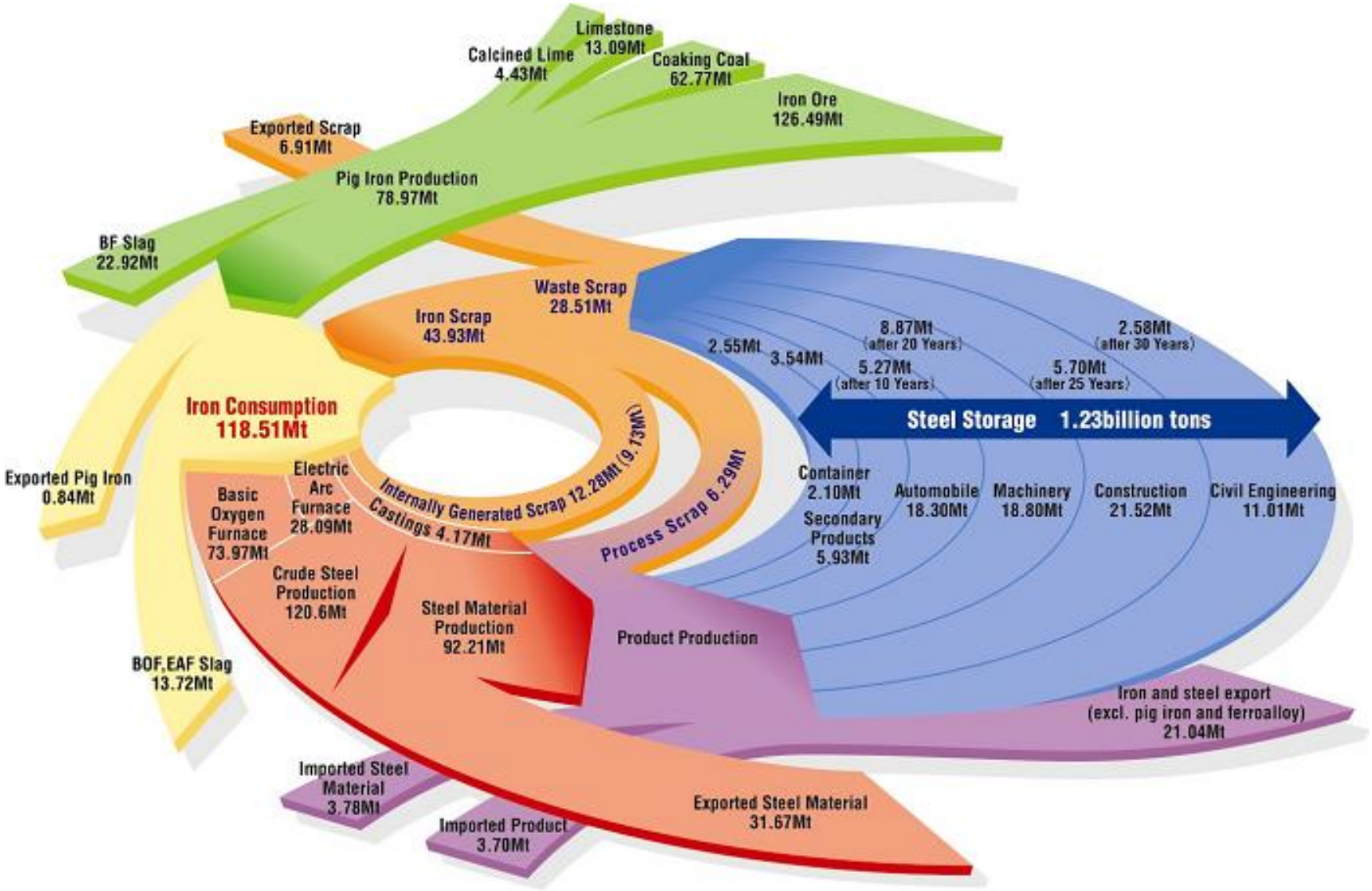
Building

Largest share in steel consumption

Grasping stock is important

Analysis of flow and stock for steel by MFA

Material Flow Analysis (MFA)



Previous Publications on MFA for Steel

Statistics

Authors	Region
Daigo et al., Muller et al., Davis et al.	Japan, USA, UK
Hatayama et al., Pauliuk et al., Muller et al.	World

Only 42 countries

Applicability is dependent on statistical data

Nighttime light

Linked with human activities

Relation between nighttime light and material stock

Takahashi et al. (2009) estimated in-use copper stock
Hsu et al. (2013) estimated in-use steel stock

Objective and Outline

Proposing analysis of future material stock using nighttime light
Estimating in-use steel stock to 2050

Outline

Dynamic MFA

Estimating in-use steel
34 countries
Statistical data is available

Nighttime light

Estimating in-use steel
In the world
1996,1999,200,2003,2004,2006,
2010,2013

Estimating stock to 2050 from

GDP
Current and past stock

Outline

1. Dynamic MFA of steel for 34 countries

2. Nighttime light analysis

3. Forecasting of in-use steel stock to 2050

Outline

1. Dynamic MFA of steel for 34 countries

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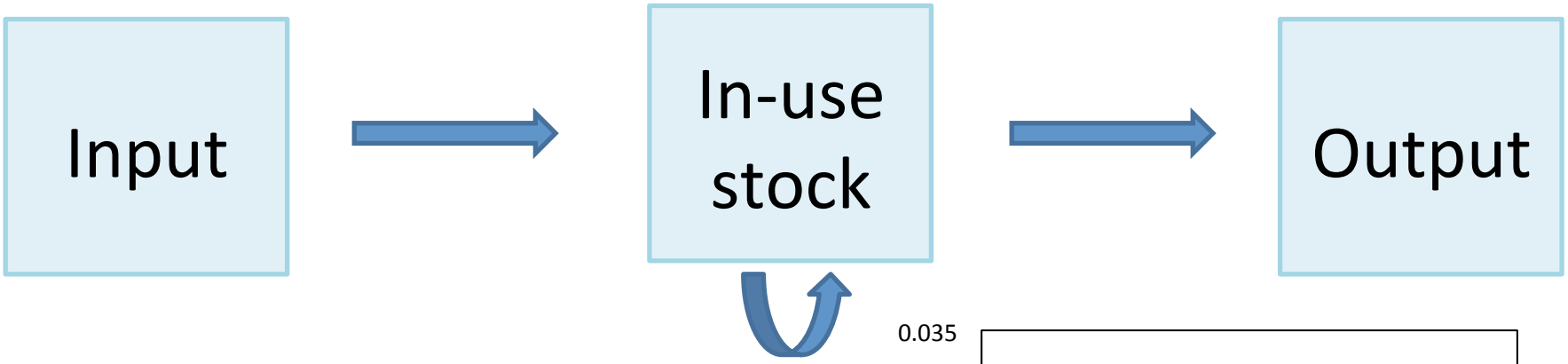
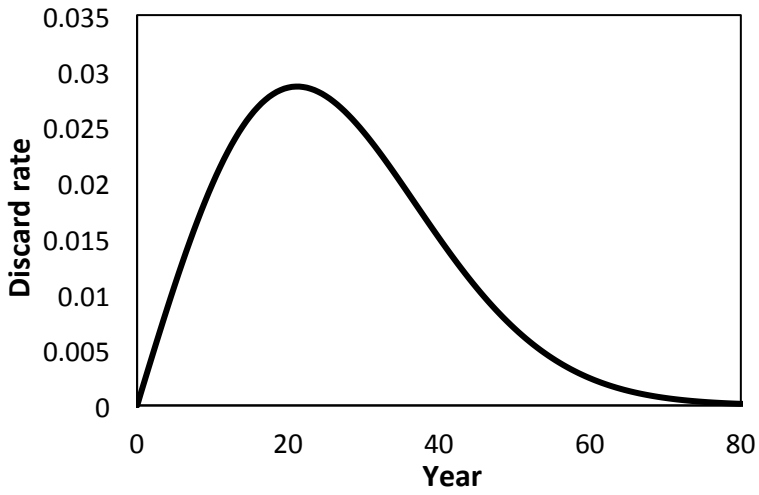
3. Forecasting of in-use steel stock to 2050

Method: Dynamic MFA



Products are discarded along the life time distribution



Details of In-put

Steel Consumption × End Use Share × Yield loss ratio

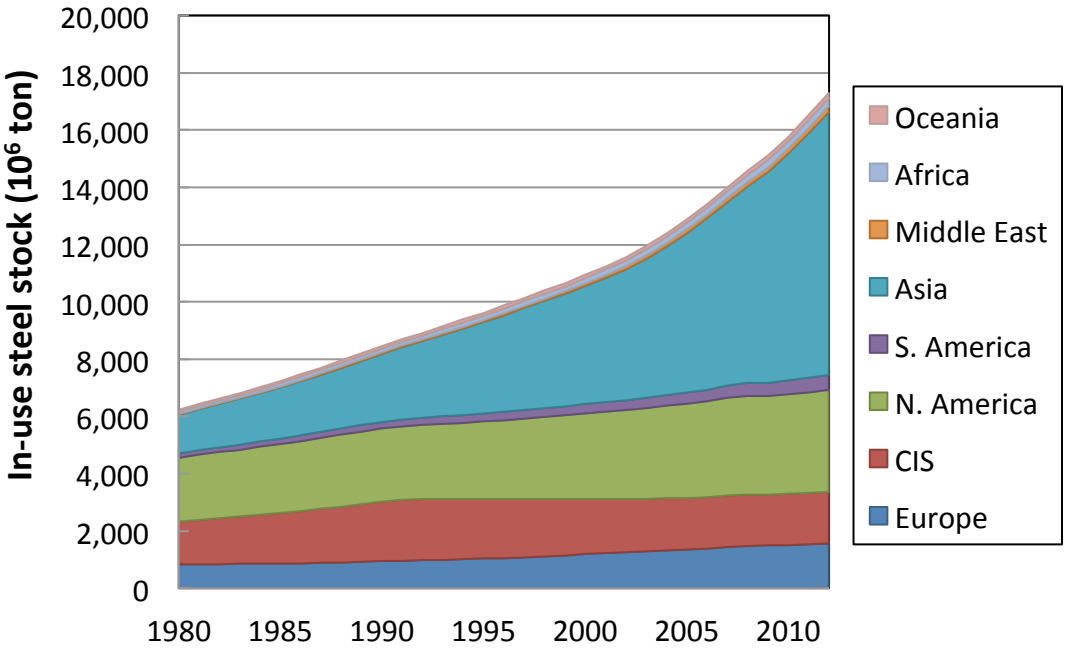
Steel Statistical Yearbook — Tekko handbook etc. — Quarterly Tetsugen

For Example

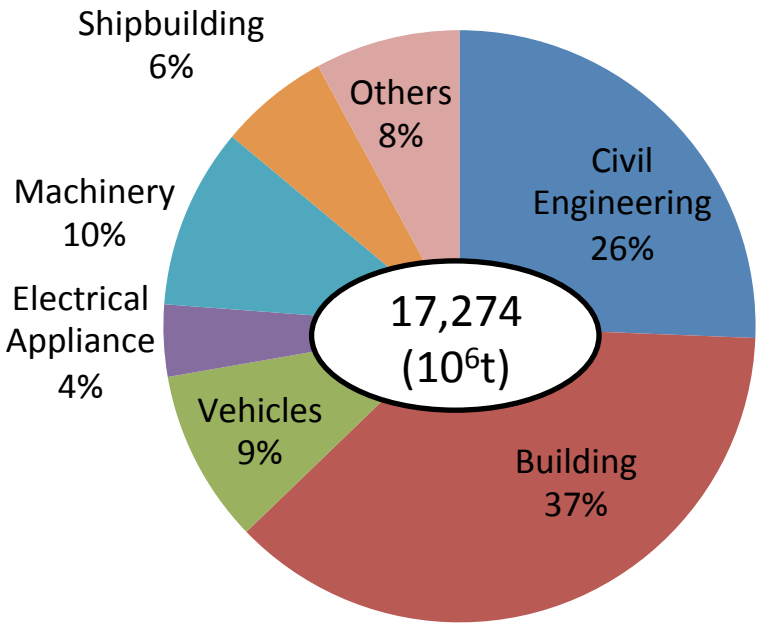
Tekko handbook etc.	Quarterly Tetsugen
Civil Eng. 30%	Civil Eng. 0.94
Building 35%	Building 0.94
Automobile 10%	Automobile 0.81

Results 1: In-Use Steel Stock in 34 Countries

Global in-use steel stock



Steel stock by end uses (2012)



2012 in-use steel stock: 17.3 billion ton
Asia covers about 53 %

Civil engineering & Building covers about 63 %

Need of grasping global CE and building steel stock

Outline

1. Dynamic MFA of steel for 34 countries

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Outline

1. Dynamic MFA of steel for 34 countries

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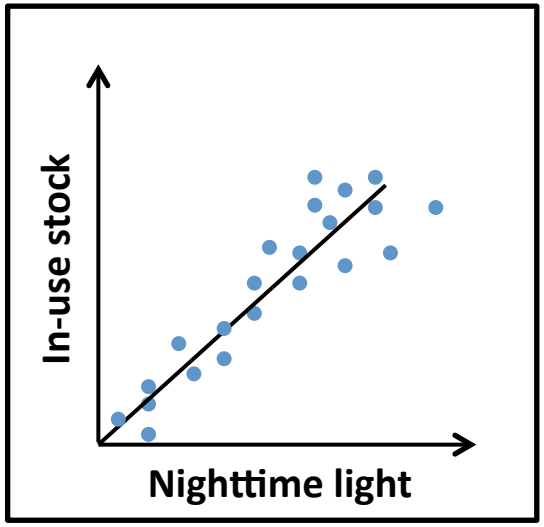
Method: Nighttime Light Analysis



Applying to area without data availability

Correlation between nighttime light and in-use stock

Estimating stock from correlation equation

Composites used in this study

- VIIRS nighttime light composite (Composite of 2013 Jan. and 2014 May)
- DMSP-OLS radiance calibrated composite (1996,1999,2000,2003,2004,2006,2010)

Estimating in-use steel stock in 84 countries

Correction of pixel area

Area of pixel varies by latitude

↓

Overestimate at high latitude

Small

↑

Large

Need for area correction

Length of latitude (m/second)

$$Y = \frac{\pi a}{648000} \times \frac{1 - e^2}{(1 - e^2 \sin^2 \theta)^{1.5}}$$

Length of longitude (m/second)

$$X = \frac{\pi a}{648000} \times \frac{\cos \theta}{(1 - e^2 \sin^2 \theta)^{0.5}}$$

*a: 6378137m, f: 1/298.257223563, e^2 : $2f-f^2$, θ: latitude

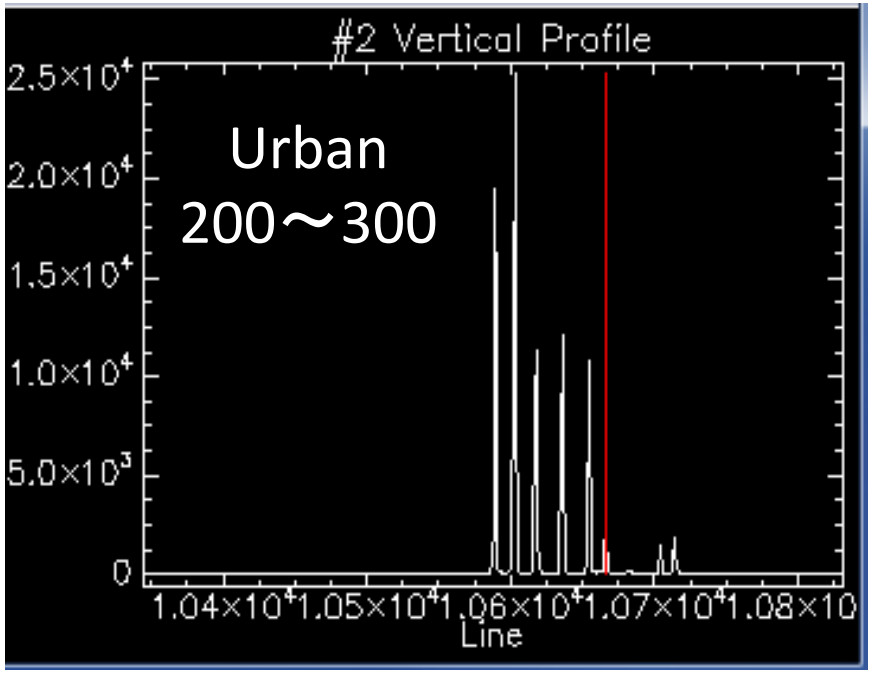
Calculate the are ratio to the equator on each latitude

Excluding Gas Flares

Gas flares in Iraq

Image captured by Google Earth™

Radiance around flare



Surrounding
Little building and Civil engineering

Weak correlation with stock

Extracting population dense area

Civil Engineering (Infrastructure)
Road, Dam, Water pipe, airport, and etc.

Building (Residential or Commercial)
House, Office, Educational (school), and etc.

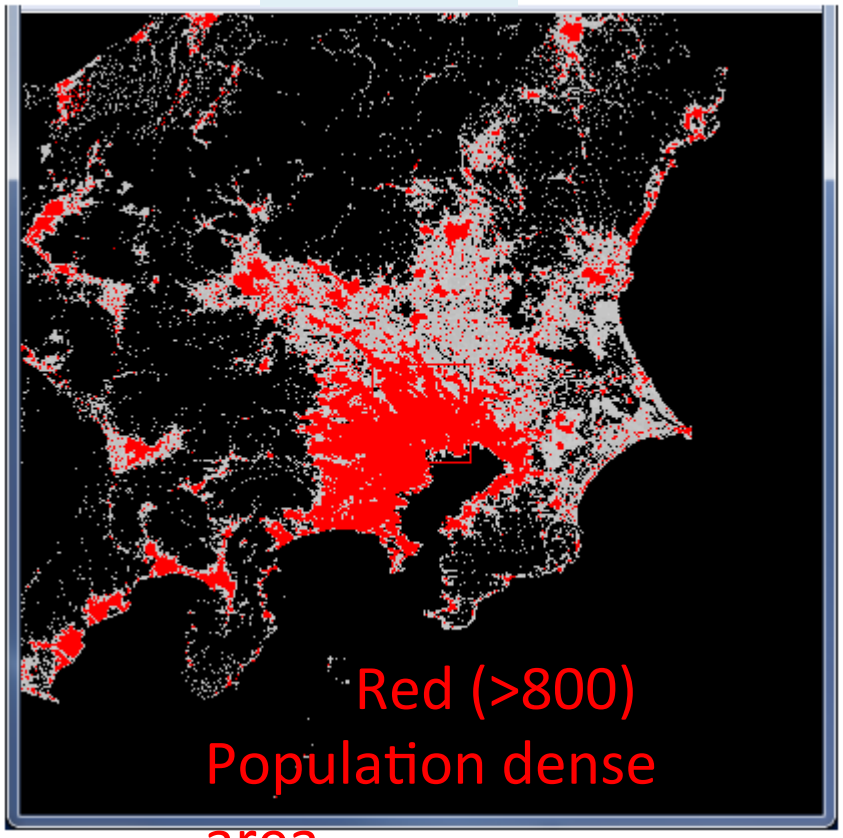
Civil engineering distributes all over the country
Building concentrated where many people lives

For Building

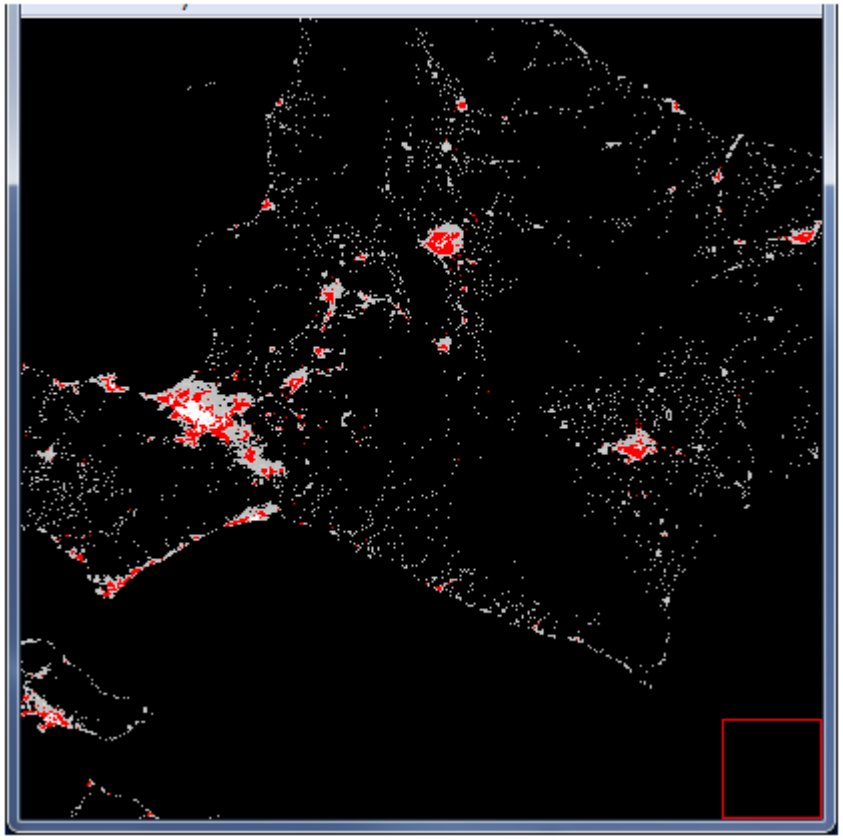
Extract population dense area by using population distribution data (LandScan).

LandScan

Tokyo



Hokkaido



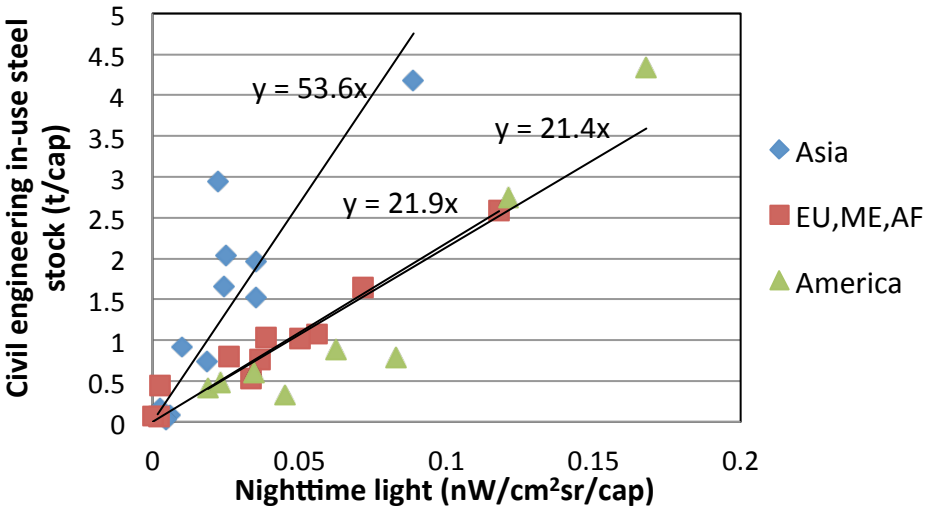
Hokkaido: Low population density → Little Building in area such as Farmland and Forest

Building correlates with light in population dense area well

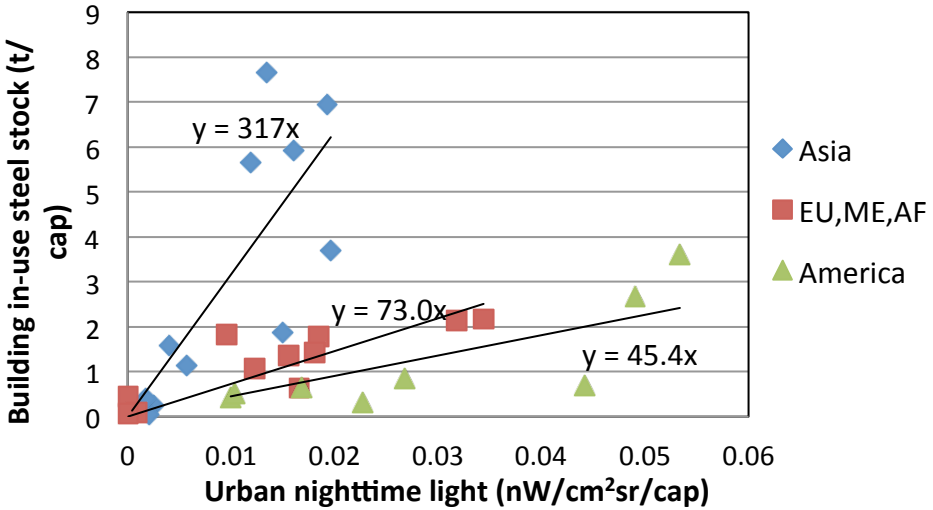
Results 2: 2013 Nighttime Light Analysis

Using VIIRS DNB composite

Civil eng. stock and nighttime light



Building stock and urban nighttime light



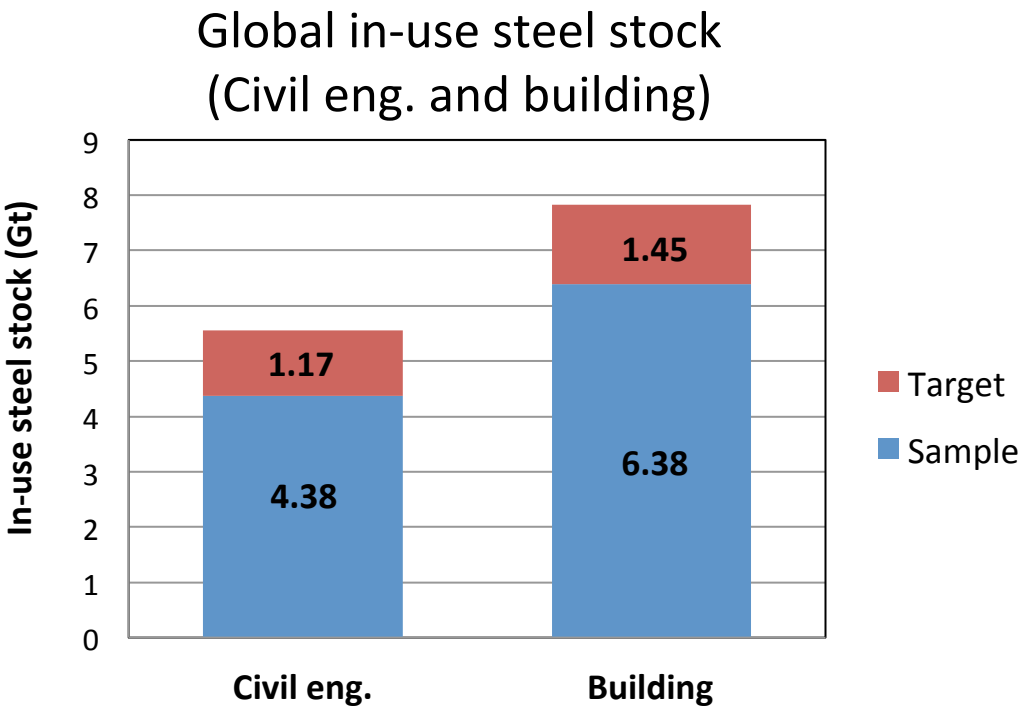
Obtained positive correlation

Results of regression analysis

Region	Civil Engineering		Building	
	Slope	R^2	Slope	R^2
Asia	53.6	0.890	317	0.834
EU, ME, AF	21.9	0.977	73.0	0.897
America	21.4	0.924	45.4	0.822

Results 2: Global in-use Steel Stock in 2013

118 countries which cover 99.5 % of whole nighttime light



Sample
Estimated from statistical data

Target
Estimated from nighttime light

Stock grew about 24 % by nighttime light estimation

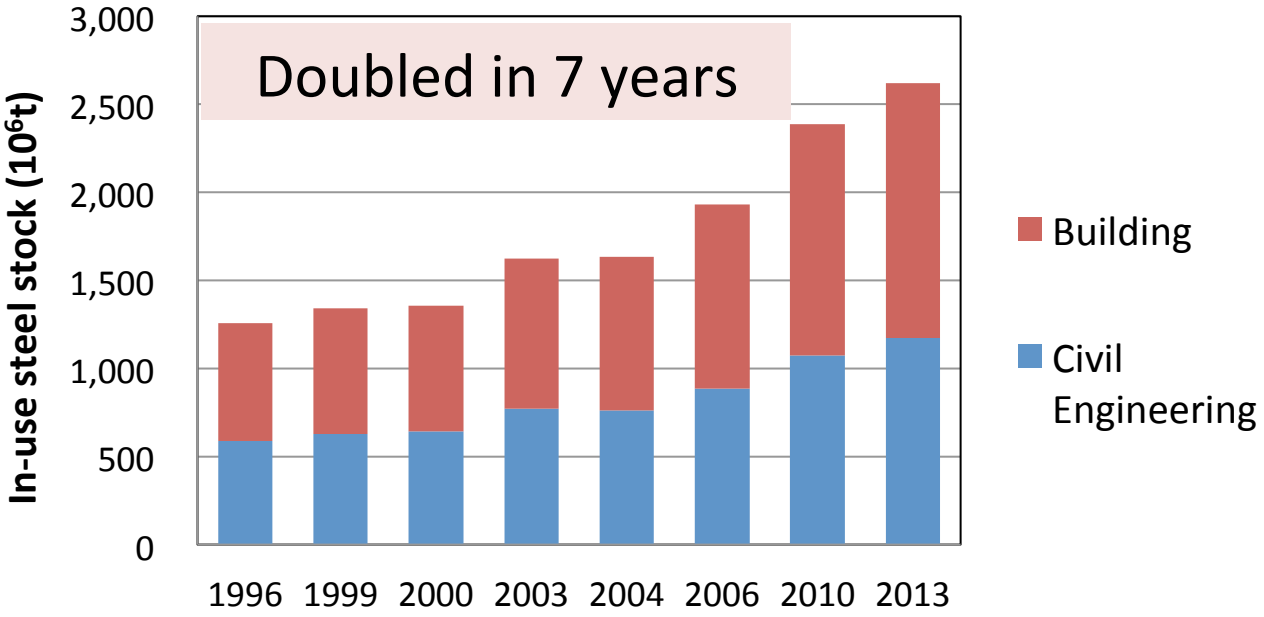
(Previous study) Stock in 2010
11.3 Gt

This study (2013)
13.4 Gt

Results 2: Time-series global steel stock

Conducted same analysis and estimation on Radiance Calibrated composite (1996 to 2010)

In-use steel stock in target countries from 1996 to 2013



Estimate future steel stock from these time-series data

Outline

1. Dynamic MFA of steel for 34 countries

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Outline

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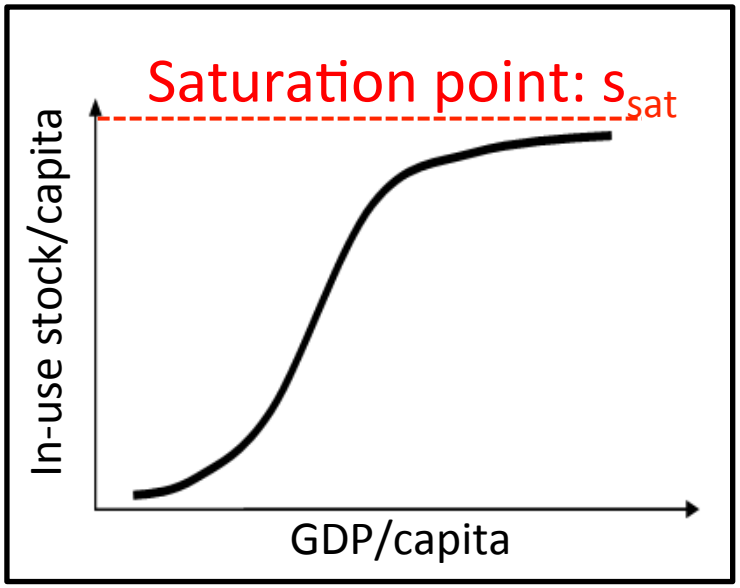
Method: Estimating Future Stock

S-shaped fitting by logistic curve



Stock will be saturated along the economic growth

$$s_t = \frac{s_{sat}}{1 + \exp(\alpha - \beta \times GDP_t)}$$

*α and β are parameters

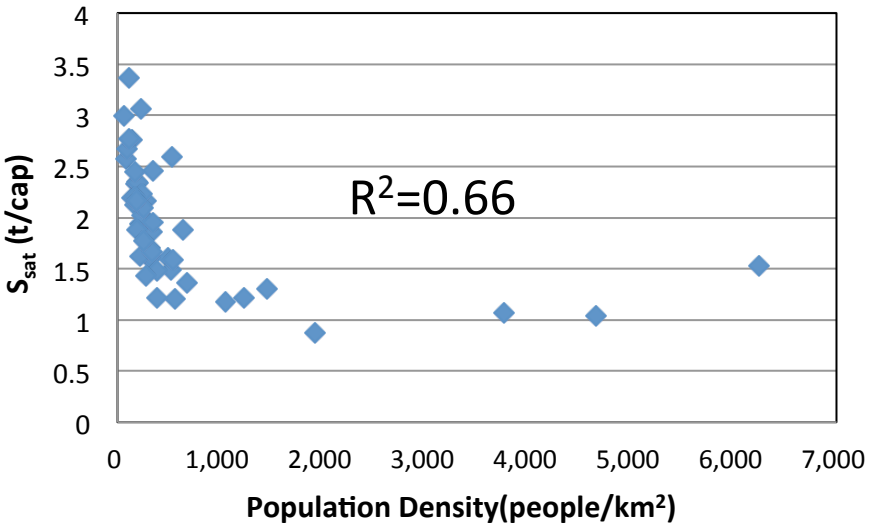
s_{sat} varies by country and end use

- Setting parameters by least squares method.
- Estimating stock from projected GDP.

Setting Saturation Value

Civil Eng. Civil Engineering stock in Japan has already saturated.

S_{sat} and population density in 47 prefectures



$$S_{sat} = 1.04 + \frac{339}{population\ \ density + 100}$$

Calculate S_{sat} in each country

Building Asia has high steel consumption rate.

Hsu et al., Tetsu-to-Hagane, 98, (2012)

Use values in developed countries

*Developed countries
(GDP/cap>20,000USD)

S_{sat} in developed countries

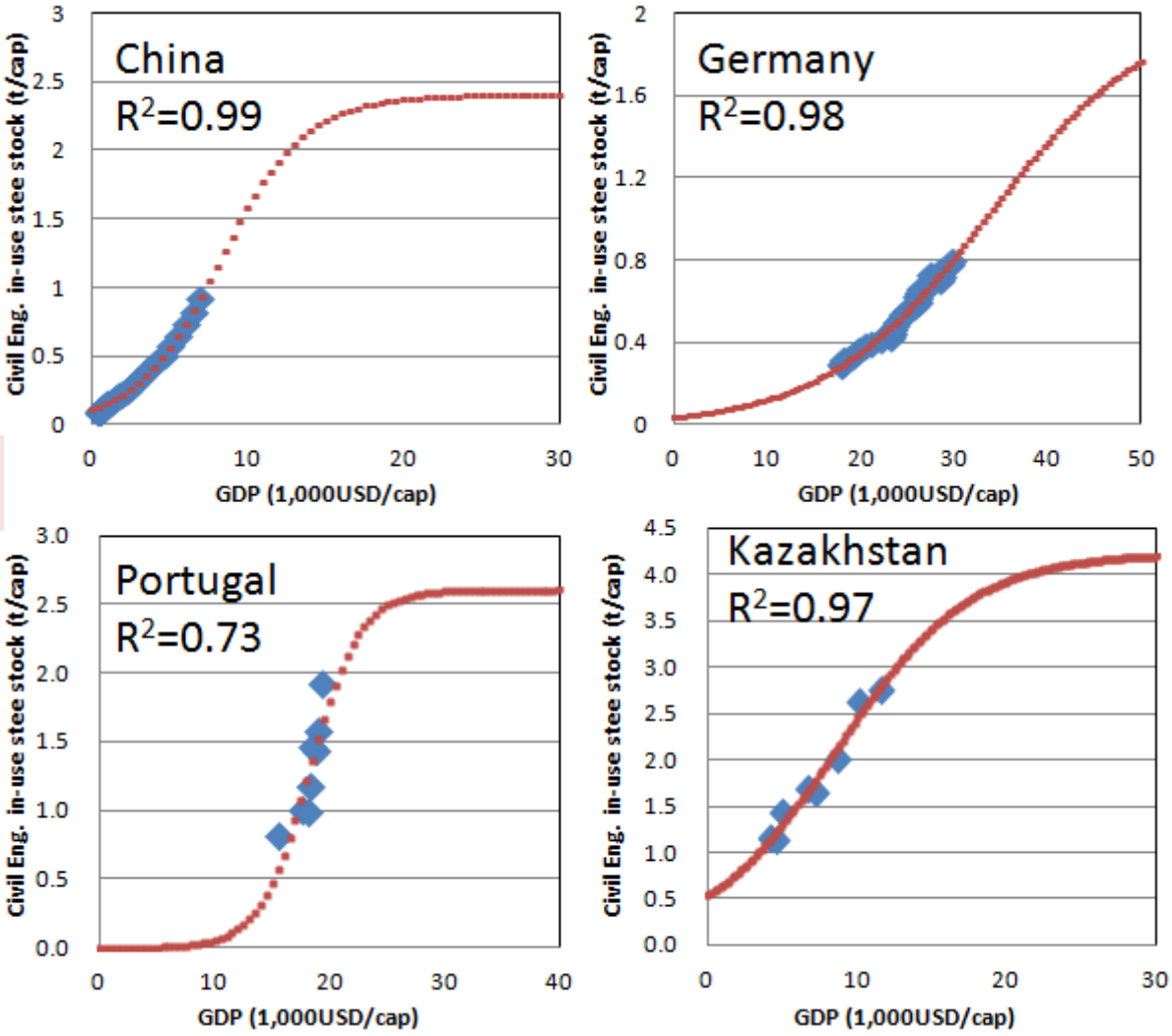
	Asia	The others
Average	7.19	2.50
Max	8.33	4.66

Results 3: Curve Fitting by Logistic Curve 1

Statistical data

Nighttime light

Example for Civil Engineering stock

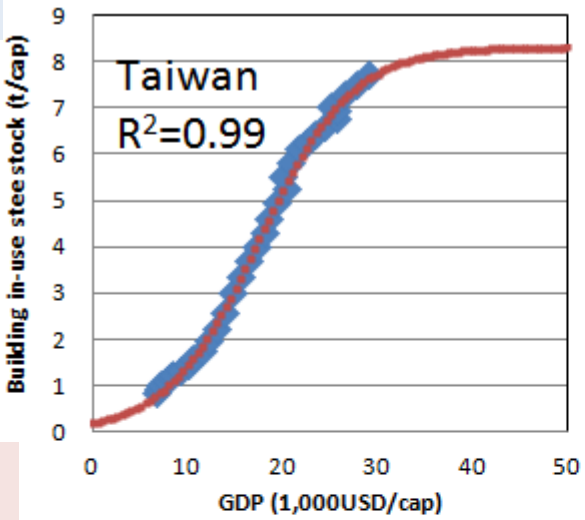


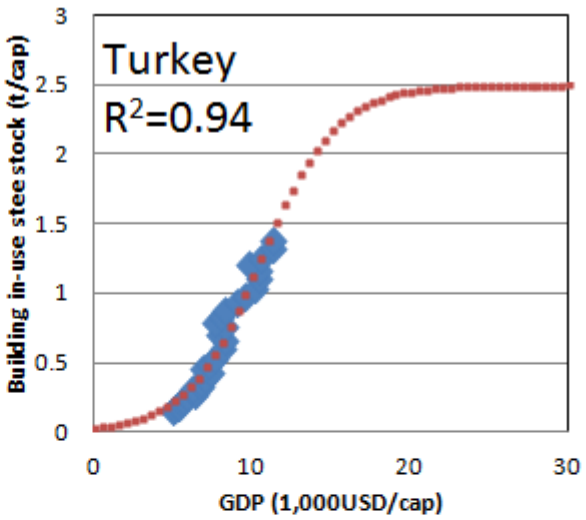
Results 3: Curve Fitting by Logistic Curve 2

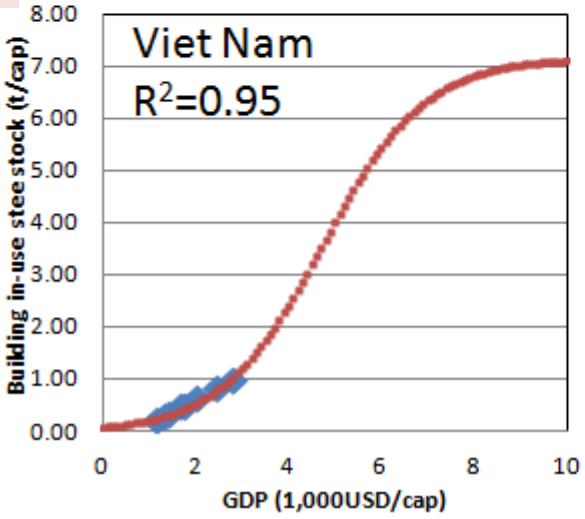
Examples for Building stock

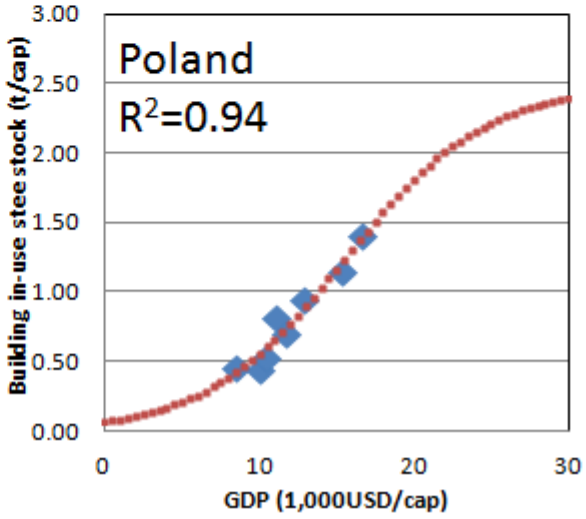
Statistical data

Nighttime light



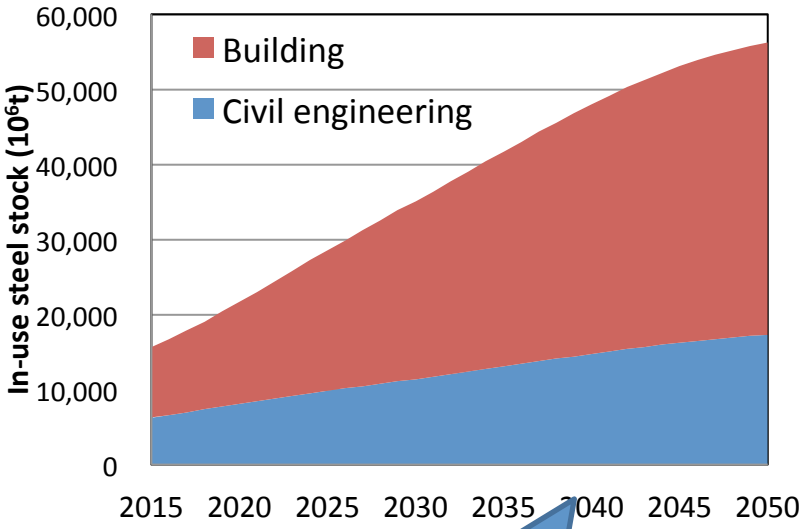




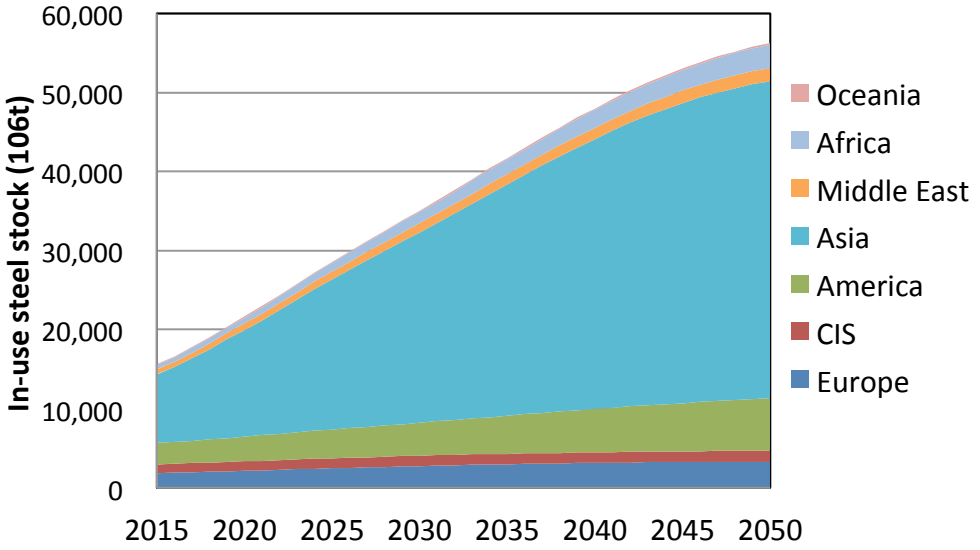


Results 3: Global Steel Stock to 2050

By end uses



By region



Equal to 40 years consumption

Asia covers about 70%

2012 Consumption: 1.43 billion ton

Recycling rate:90%

World Steel Association : The 3 Rs of sustainable steel

Global in-use steel stock:
56.3 billion ton

For Civil Eng. : 17.3 billion ton

For Building : 39.0 billion ton

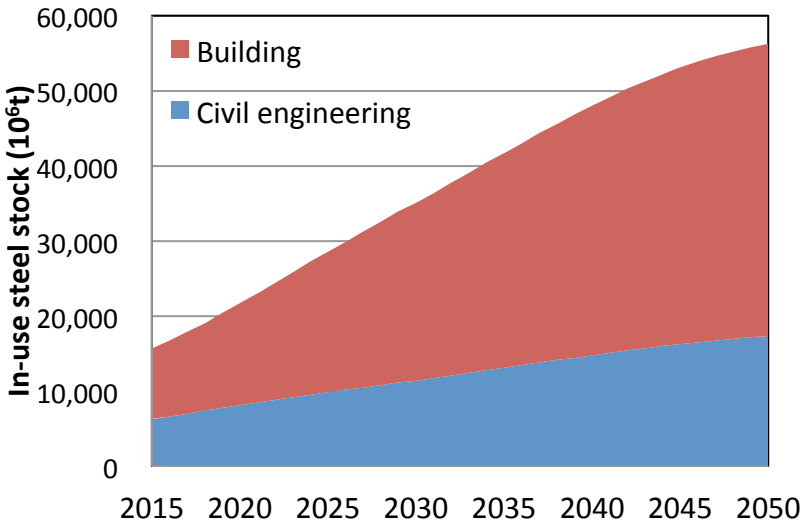
Vast amount resource

Conclusion

Outline of this study

- Dynamic MFA on 34 countries
- Nighttime light analysis
- Future forecast of steel stock to 2050

Global in-use steel stock to 2050



56.3 billion ton

This study proposed method of estimating future material stock using nighttime light
&
Estimated global in-use steel stock to 2050

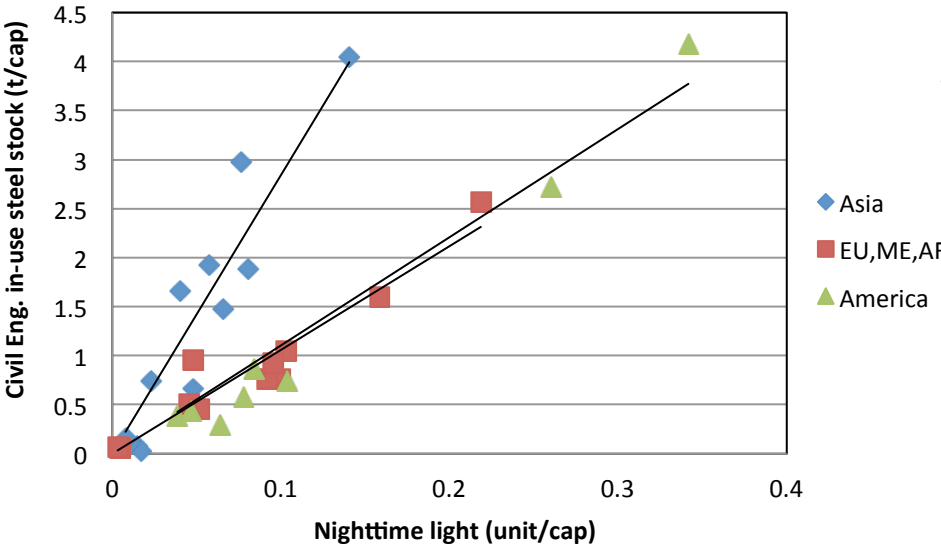
Thank you for listening

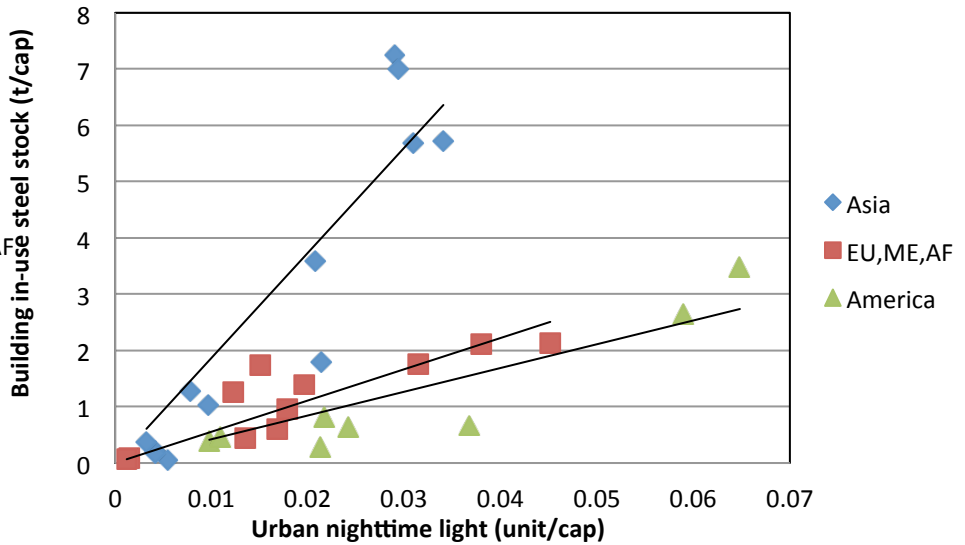
For further contacts:

hattori@gold.t.u-tokyo.ac.jp

2010 Nighttime light analysis

Using 2010 Radian Calibrated Composite





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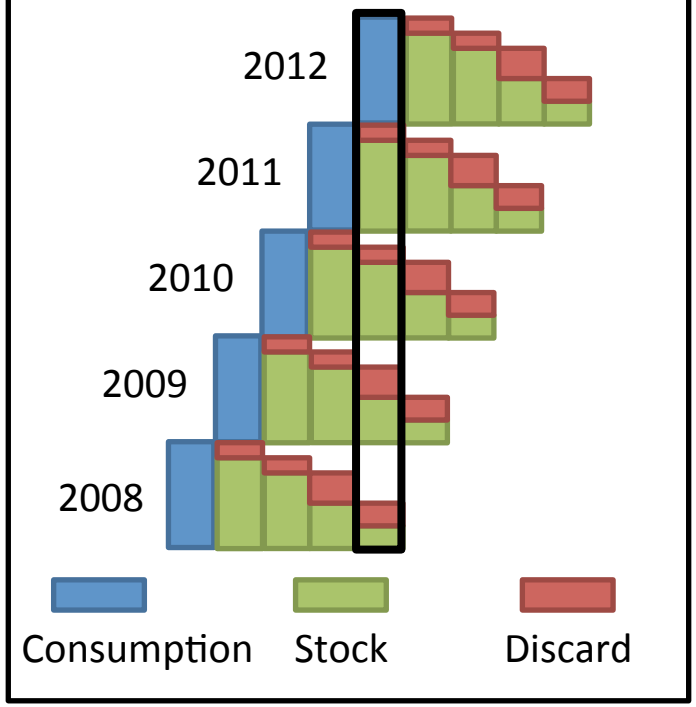
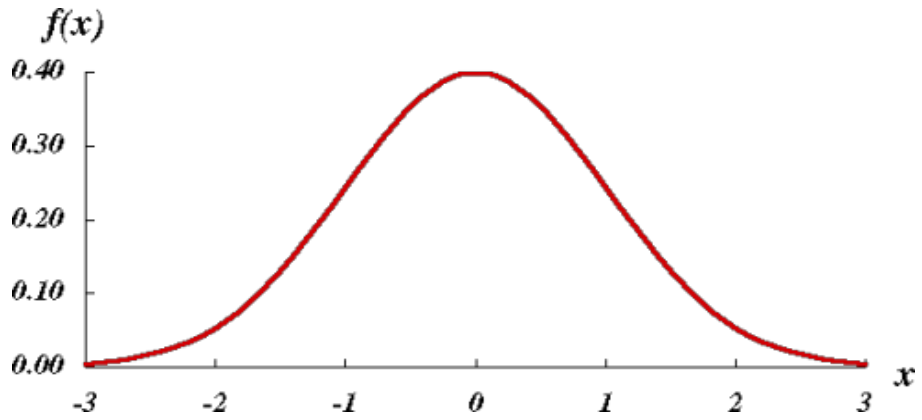
Asia	28.4	0.943	317	0.929
EU, ME, AF	10.6	0.969	73.0	0.922
America	11.0	0.977	45.4	0.908

Method: Population Balance Model (PBM)

Concept of PBM



Life time distribution



Distribution in each product and region is required.

Product is discarded along the life time distribution

- Steel consumption and distribution for each end use is necessary
- Estimating stock in 34 countries by PBM

S_{sat} for Building

Asia

Asia	S_{sat}	Note
Japan	5.65	value in 2012
Korea	6.84	Fitting
Taiwan	8.33	Fitting
Singapore	7.08	value in 2012
Hong-kong	8.04	value in 2012
average	7.19	
min	5.65	
Max	8.33	

Non-Asia

Non-Asia	S_{sat}	Note
Spain	2.18	value in 2012
UK	1.80	value in 2012
Greece	1.24	Fitting
Germany	4.66	Fitting
USA	2.69	value in 2012
Canada	3.65	value in 2012
New Zealand	1.58	value in 2012
Australia	1.87	value in 2012
average	2.50	
min	1.24	
Max	4.66	

Using average value in each region

Extracting population dense area

Threshold is value used in the previous study.
(GLCNMO ver.1)

Region	Threshold (people/ pixel)
Asia, Africa	800
The other region	500

Kasimu et al. (2008)