SSPs and industrial water by AIM modeling team

Shinichiro Fujimori
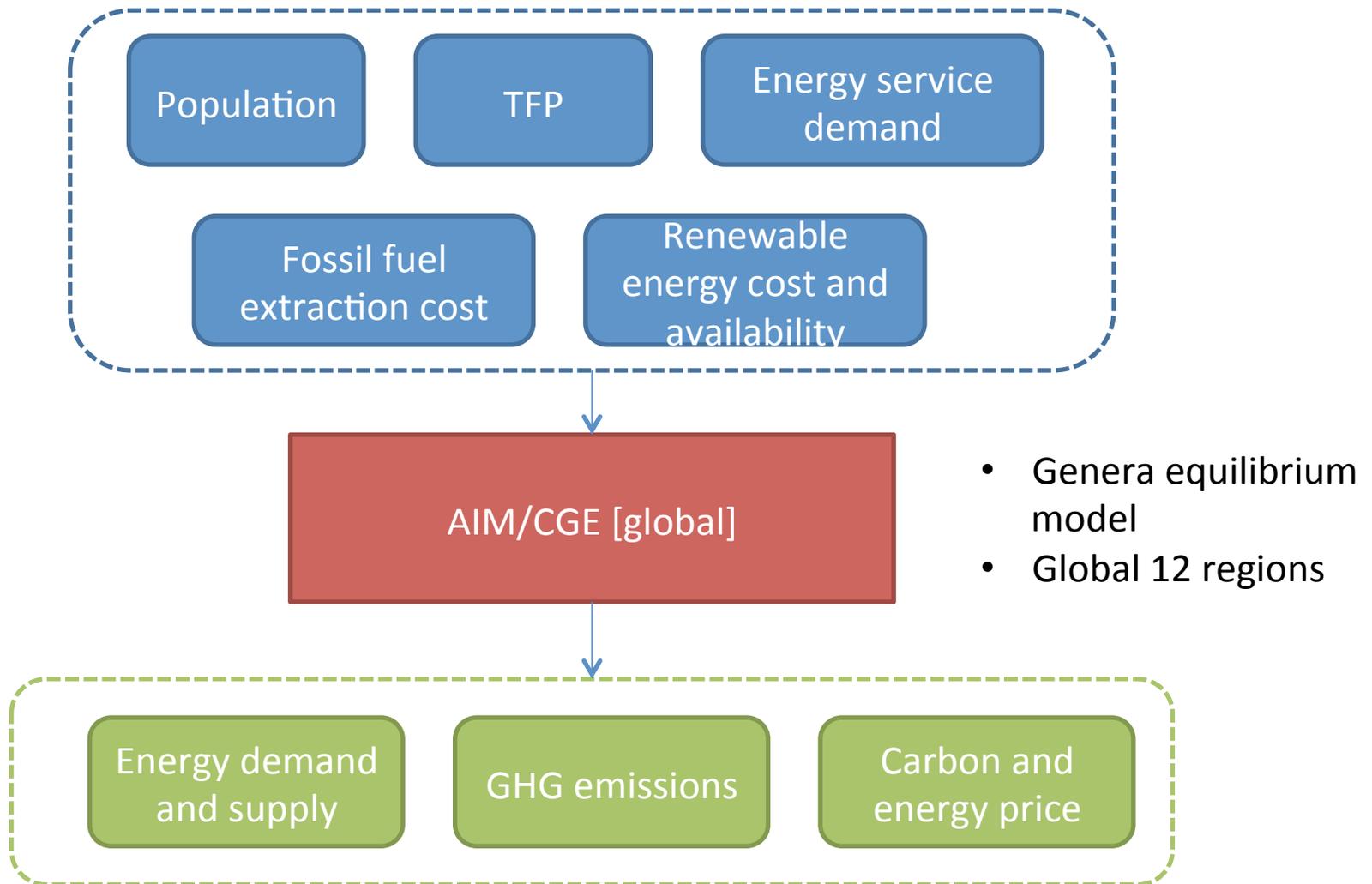
with T. Masui, N. Hanasaki, T. Hasegawa, M. Kainuma, K. Takahashi, Y. Hijioka

CCI/IA, Snowmass Colorado, 25, Jul., 2012

Contents

- SSP quantification
  - AIM modeling framework
  - SSPs quantification process
  - Energy and agriculture

- Bridging IAM and IAV
  - Water assessment
  - Industrial water withdrawal estimation

AIM modeling framework

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┌ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ┐
│   [Population]   [TFP]   [Energy service demand]   │
│                                         │
│     [Fossil fuel extraction cost]   [Renewable energy cost and availability]   │
└ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ┘
                    ↓
          [AIM/CGE [global]]          • Genera equilibrium model
                                       • Global 12 regions
                    ↓
┌ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ┐
│  [Energy demand and supply]  [GHG emissions]  [Carbon and energy price]  │
└ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ─ ┘
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SSP quantification for energy and GHG emissions

- Interpret SSP characteristics
  - Service demand
  - Energy intensity
  - Fuel dependency
  - Cost of the energy sources
- We have an consensus across modeling team in terms of narrative storyline
 - Quantification is modeling team dependent assumptions

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Energy related characteristics

	SSP1	SSP2	SSP3	SSP4	SSP5
Energy intensity	low	medium	high	High/ low	medium
Energy service demand	modest	medium	Medium (material intensive)	Medium/ low	high
Environmental awareness	High	medium	low	High/low	medium

GDP – provided by OECD

World total

Industrialized countries

Middle income countries
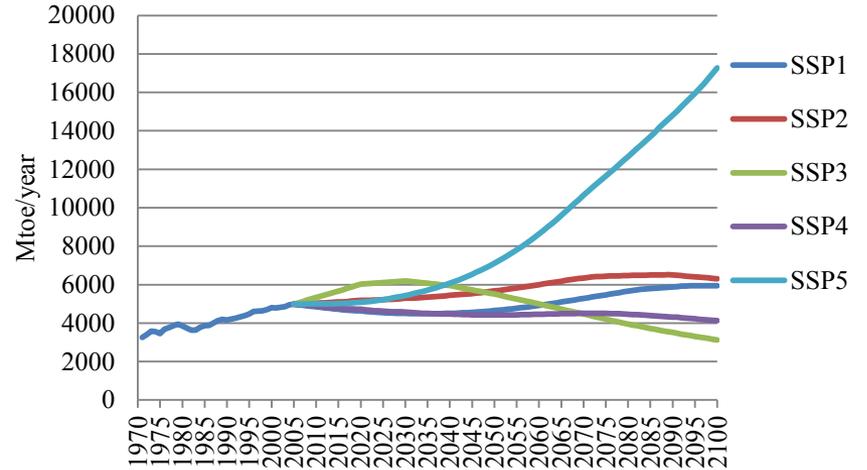
Other countries

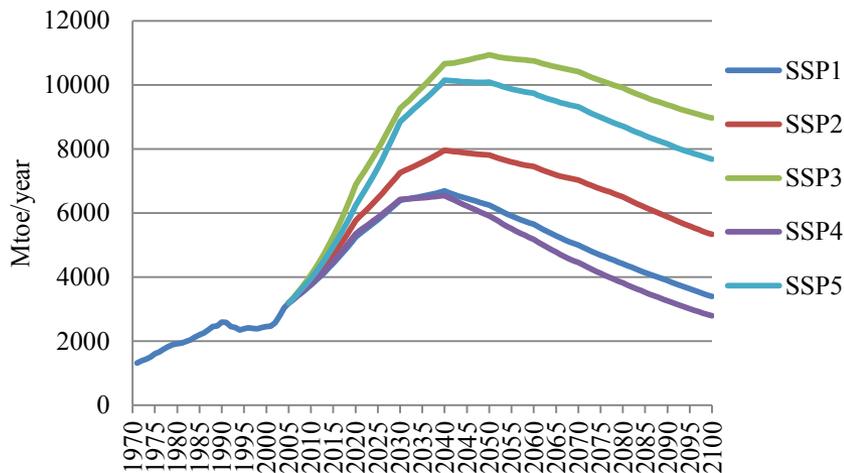SSP1
SSP2
SSP3
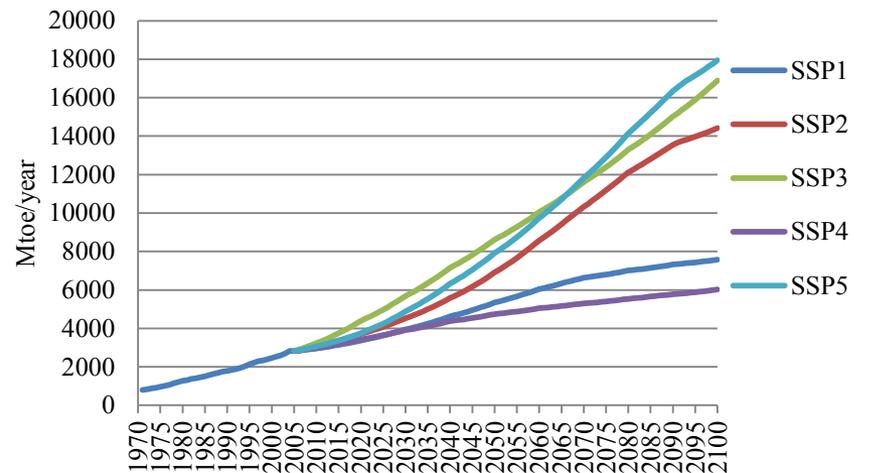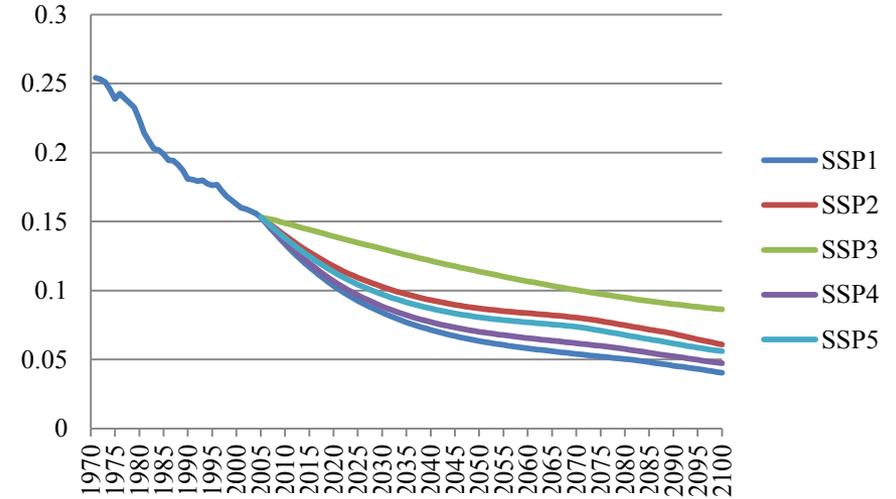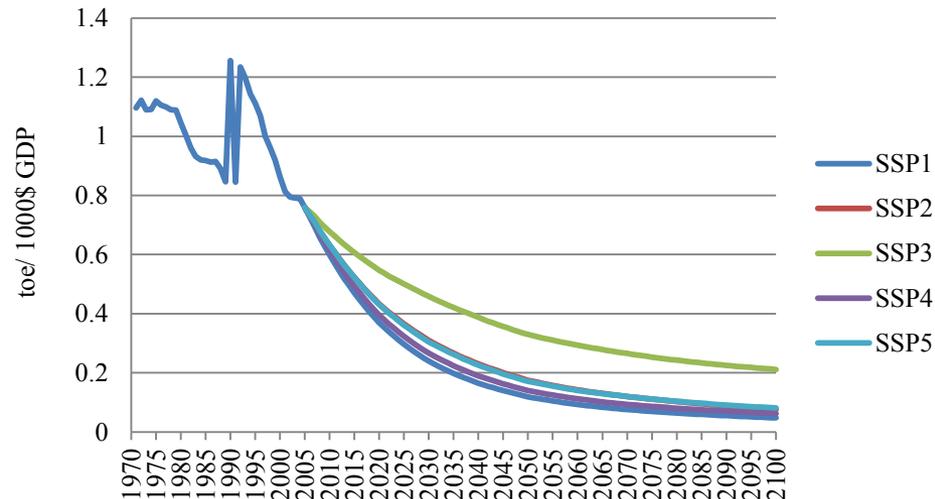SSP4
SSP5
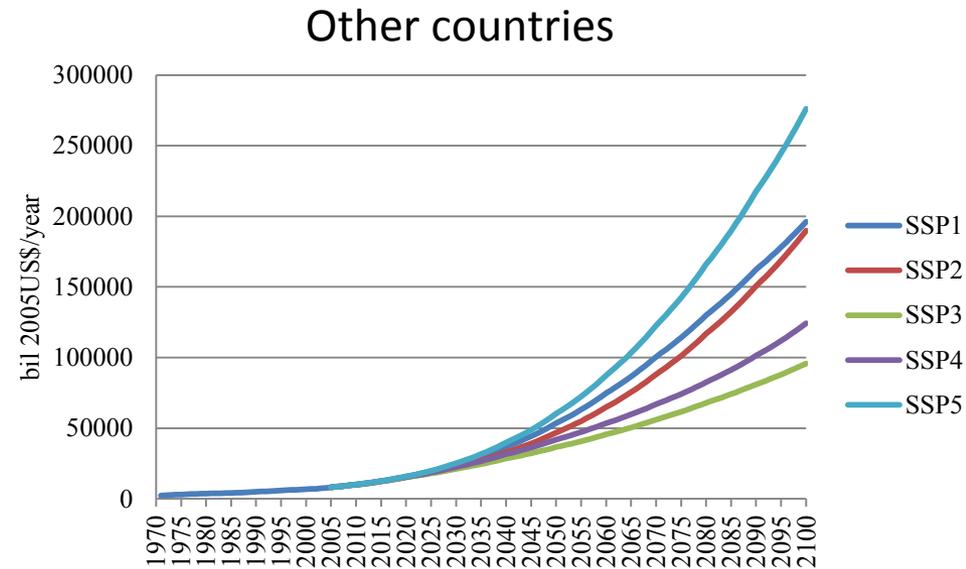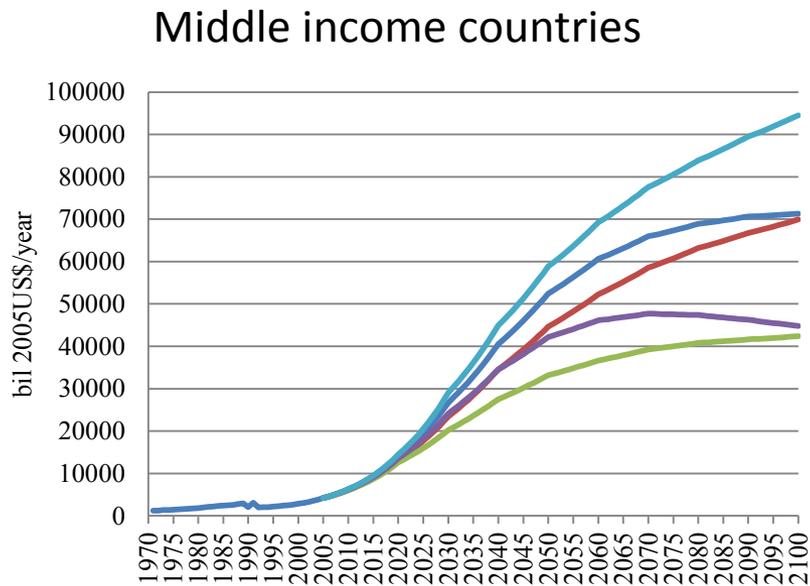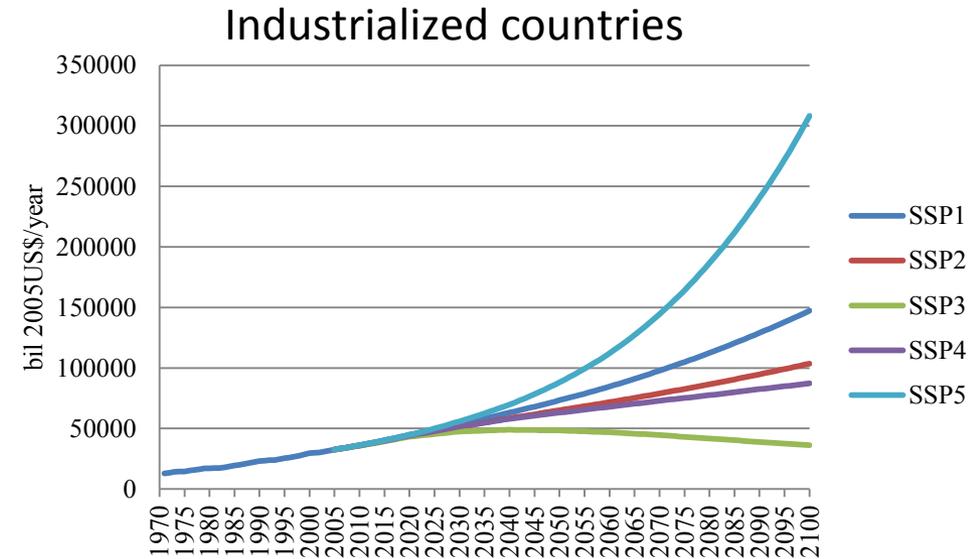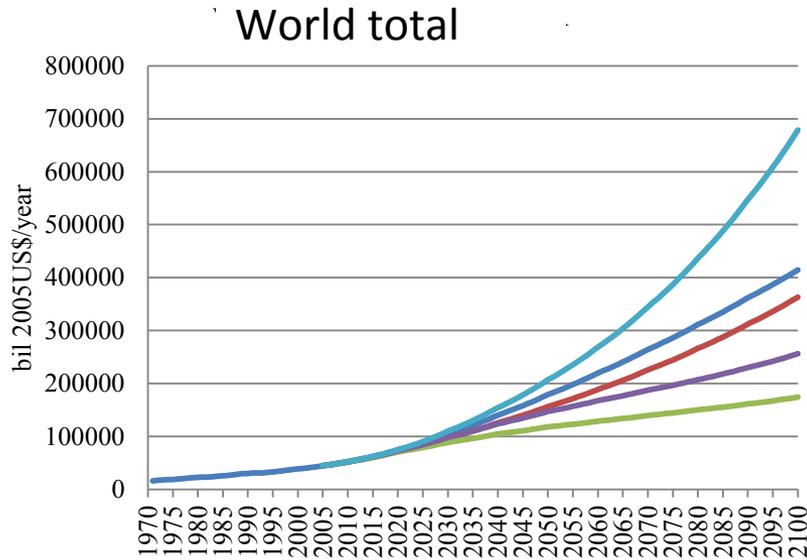
Energy Supply

World total
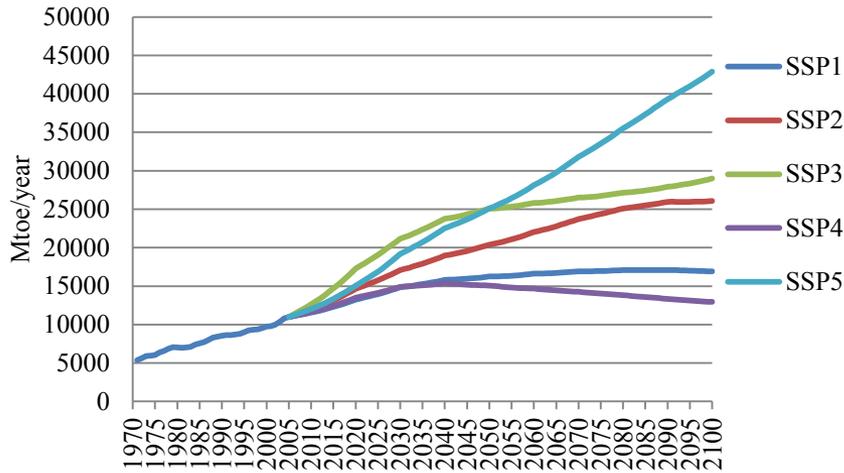
Industrialized countries

Middle income countries

WLD _TPES

Energy intensity
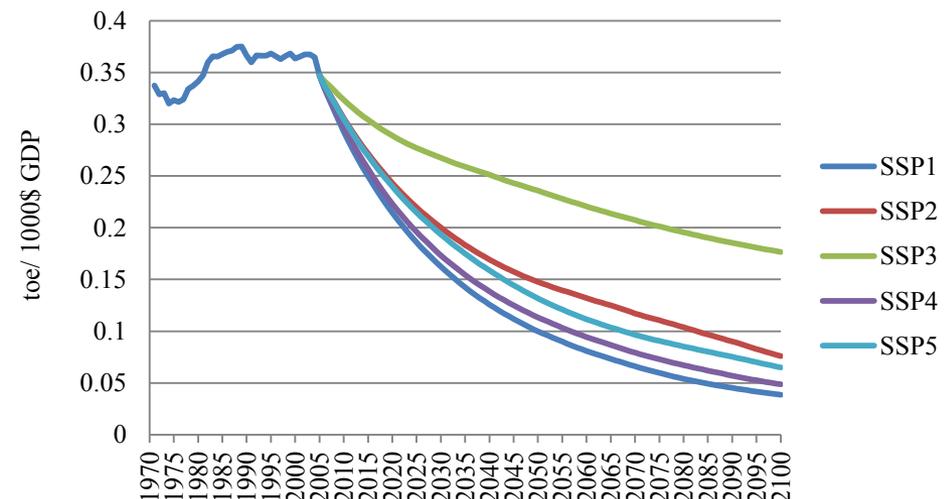
GHG emissions with RCP
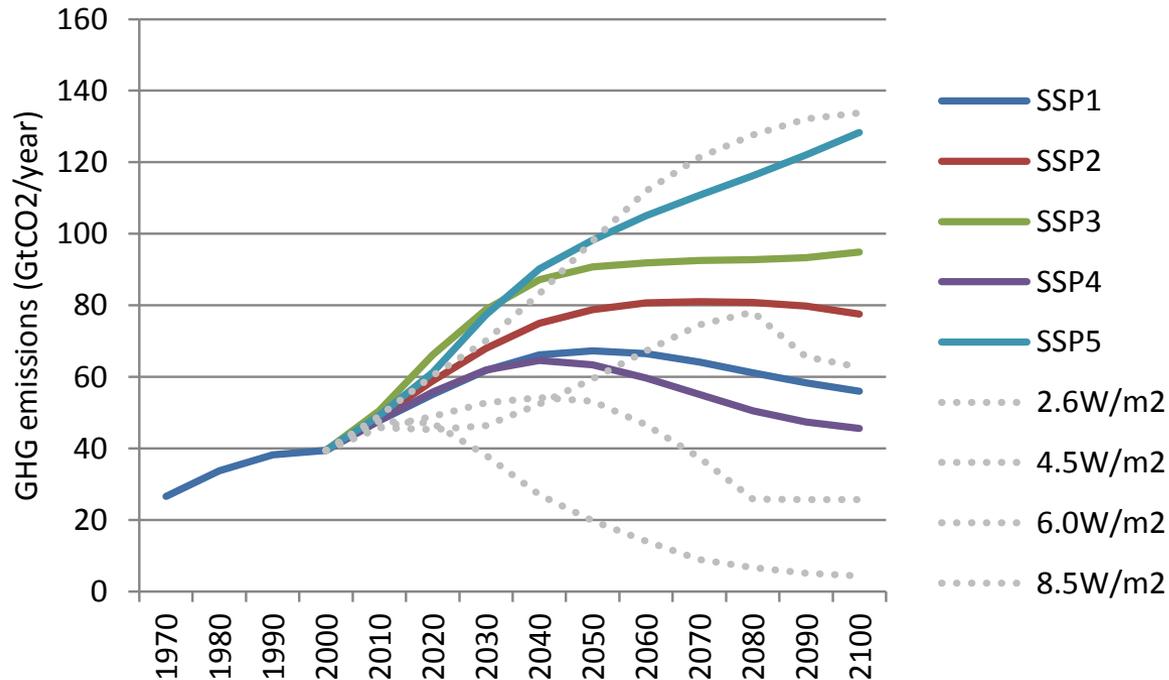
- Some are below RCP 6.0.
- SSP1-4 are surrounding RCP 6.0 and SSP5 is the exception.

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Agricultural aspect –average daily calories per capita-
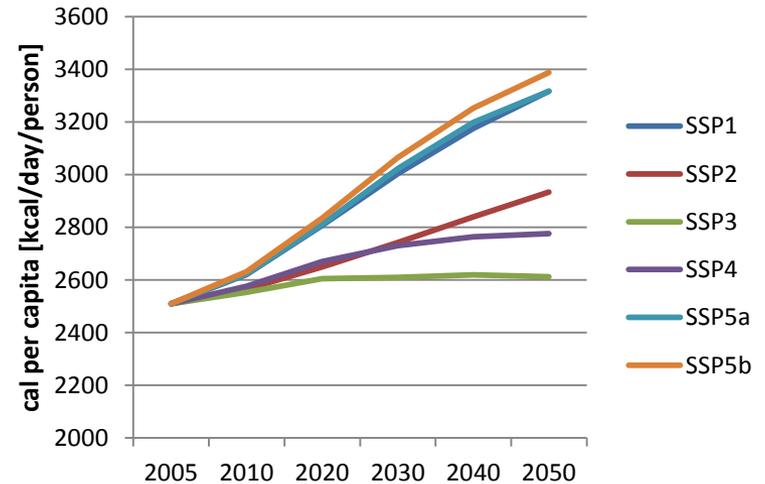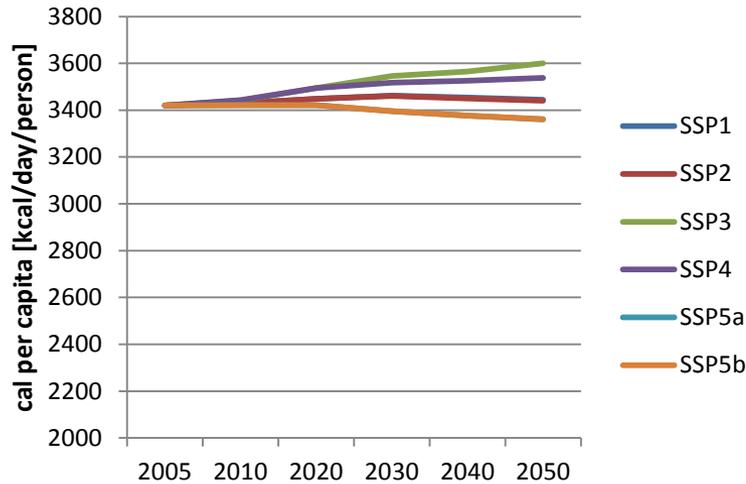
Industrial countries

Developing countries
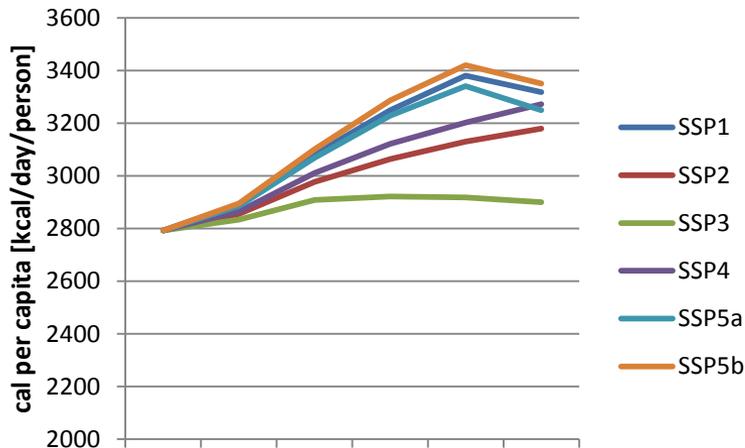
Middle income countries

- Developing and middle income regions have large variety
- Particularly in SSP3, SSP5 show pessimistic world
- Income and productivity differences

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SSP with Impact assessment

- SSP is stylized to be used for not only mitigation but also adaptation assessment.
  - IAM modeling teams know well how to use SSP
  - but might not be as well for IAV community.
- We would like to show how to do with.
  - AIM team collaborate with IAV modeling
  - Water assessment

Water assessment model H08

Rivers in Asia on TRIP in 1°x1° mesh

Reservoirs larger than 1000 MCM in The World

452 reservoirs, 4140 km^3

Hanasaki et al., 2006, J. of Hydrol.
Hanasaki et al. ,2008a,b, Hydrol. Earth Sys. Sci.
Hanasaki et al., 2010, J. of Hydrol

- Characteristics
1. Simulate at 0.5°×0.5°spatial resolution
2. Simulate both water availability (streamflow) and water use at daily-basis
3. Deal with interaction between natural hydrological cycle and anthropogenic activities

Reservoir Operation Model
(Hanasaki et al., 2006)

Crop Growth Model
(Krysanova et al., 2000)

non-irrigated

S L H E G

irrigated

Land Surface Model
(Manabe, 1969)

snow

P E

Withdrawal Model
(Hanasaki et al., 2006)

Rs

Rb

River Model
(Oki et al., 1999)

Environmental Flow Model
(Shirakawa et al., 2005)

12
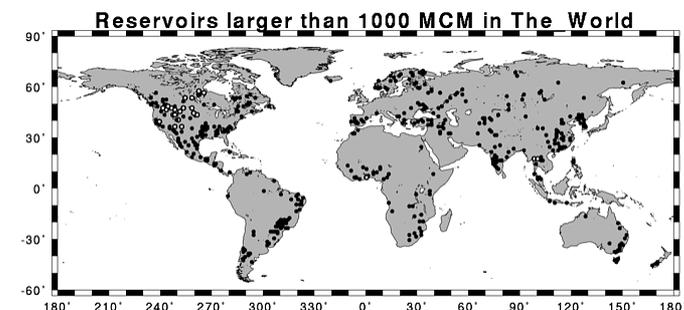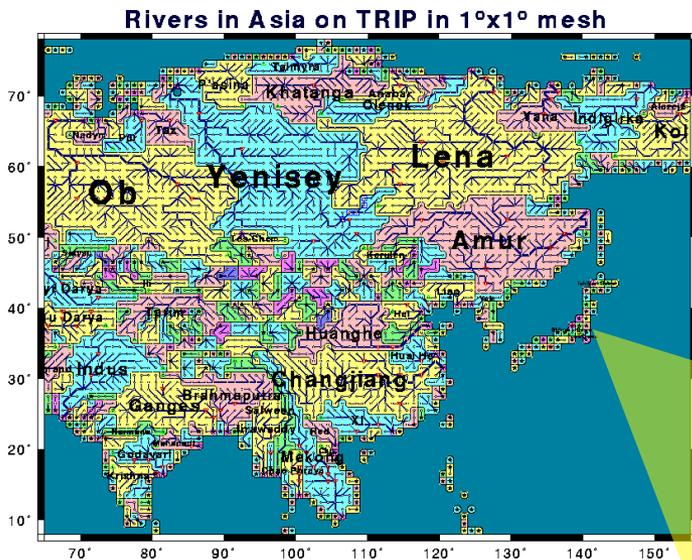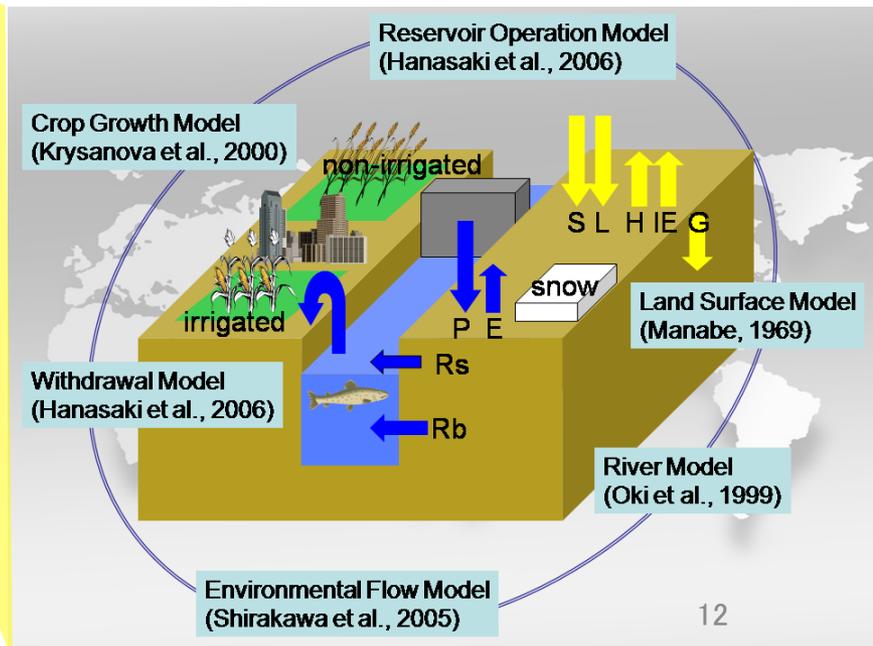
Water usage
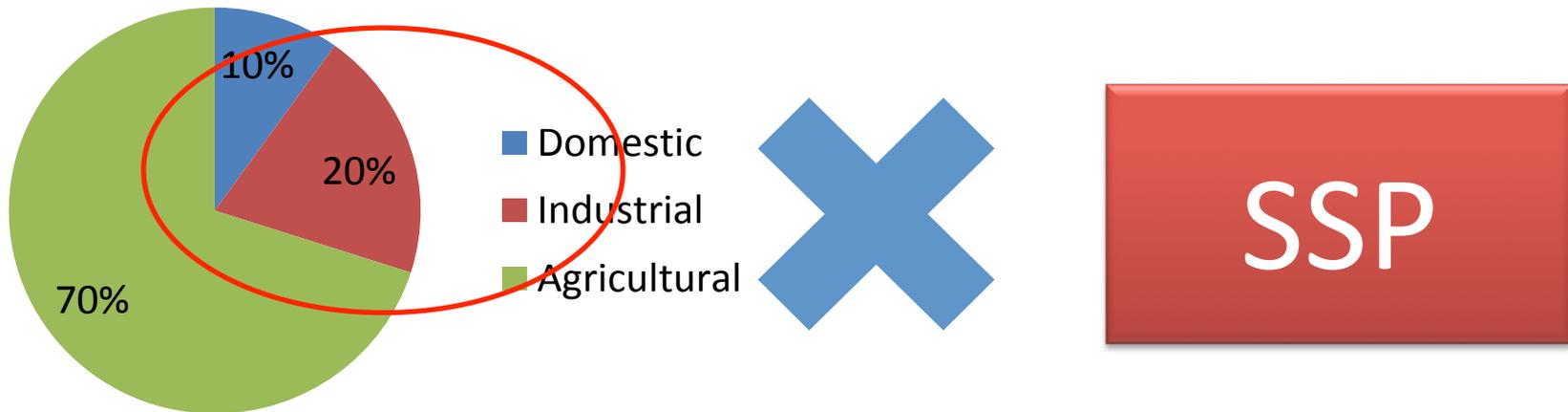
(Shiklomanov, 1996)

- Industrial water demand has relatively high relationship with aggregated IAM.
- What happen to the industrial water use?

How to explore the future industrial water withdrawal

Future assumptions

Current industrial withdrawal

Driving forces

Water technological assumptions

Industrial water withdrawal scenarios
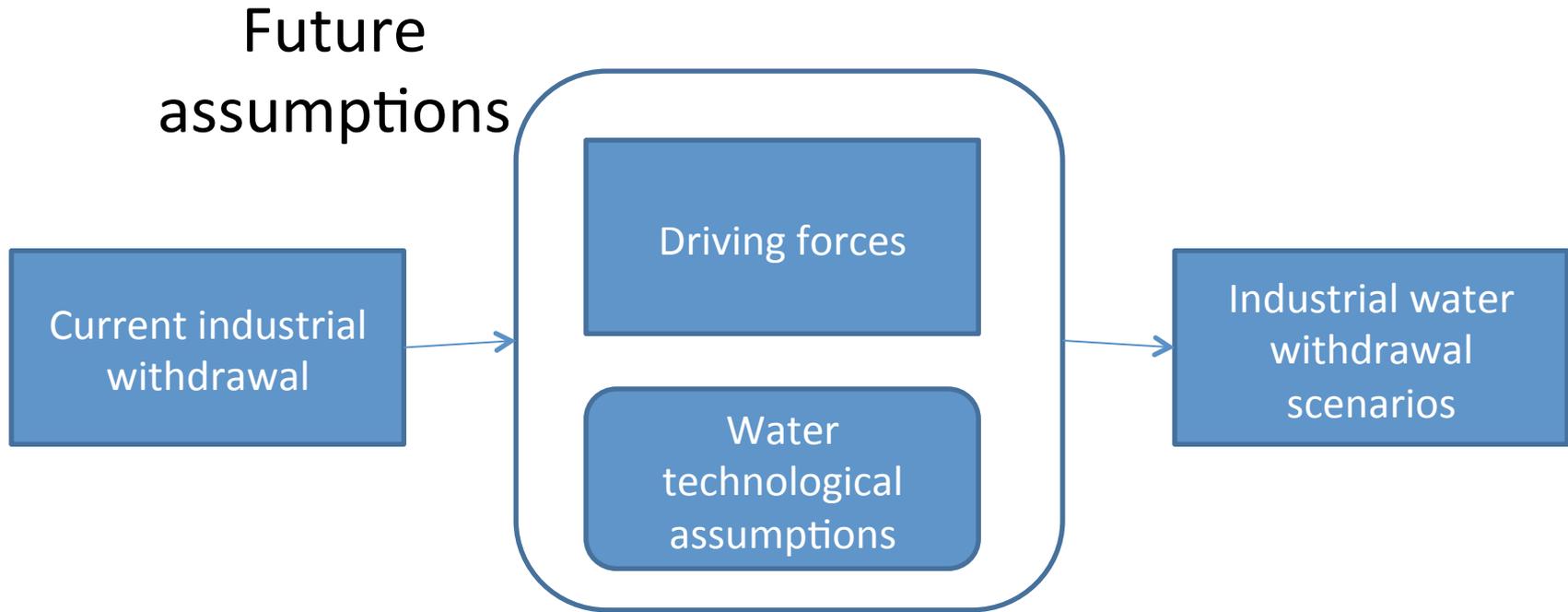
- Shen et al (2008)

$$WD_r^t = \left(1 - \theta_r\right)^t \cdot \frac{WD_r^0}{ele_r^0} \cdot ele_r^t$$

technology — Intensity of base year — Driving force (electricity)

Previous study's methodology

- Shen et al (2008) $$WD_r^t = \left(1 - \theta_r\right)^t \cdot \frac{WD_r^0}{ele_r^0} \cdot ele_r^t$$

  technology | Intensity of base year | electricity

- Industry is aggregated. Is it OK?
  - Due to the data limitation (AQUASTAT just show us the total industry demand)
  - Industrial structure change could make different scenarios.
  - Only single driving force may have systematic bias.

- Consider disaggregated sector estimation
- Future driving forces can be prepared by AIM/CGE but how can we prepare the base year and technology scenario?

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Past industrial water usage and technology

- We have limited country base statistics.

- They are valuable to estimate global situation
  - Country statistics
  - Eurostat

	Number of countries
Industry total	83
Basic metal	13
Chemical	15
Electricity	13
food proccessing	15
Mining	11
Non-metal and mineral	4
Paper and pulp	15
Textile	14
Other manufacturing	14
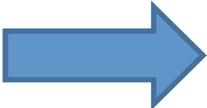
- Panel data regression is made!!
- Estimate the technological progress and water intensity by sectors

Past regression analysis

$$WD_{r,j}^{t} = \gamma_{r,j}^{t} \cdot D_{r,j}^{t}$$

- Value added (constant price)
- Fired and nuclear power

| Water withdrawal | Water intensity | Driving forces |

$$\ln \gamma_{r,j}^{t} = \alpha_{j} t + \beta_{r,j} + C_{j} + \varepsilon_{r,j}^{t}$$

| Technological coefficient | Country specific technology level | Global standard intensity |
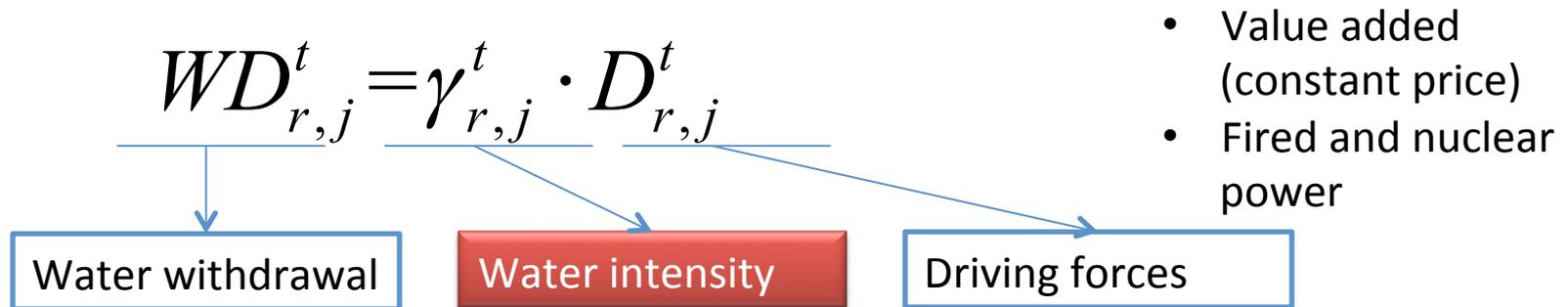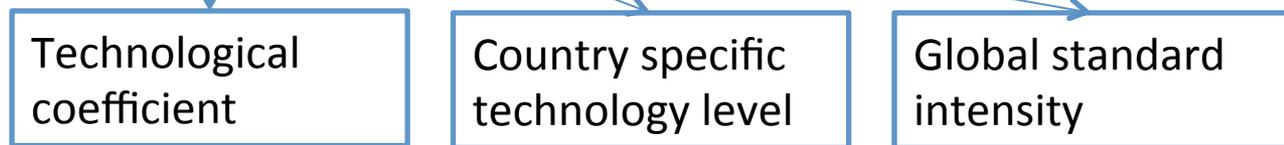
- These are applied to each sector

Application

- Sectors
- statistics
- Period

Industry total	Japan
Basic metal	China
Chemical	Canada
Electricity	USA
Food proccessing	UK
Mining	Eurostat country (37)
Non-metal and mineral	Aquastat (Total industry only)
Paper and pulp	
Textile	
Other manufacturing	

1971-2005

(mostly after 1990)

Main results of the regression

$$\ln \gamma^t_{r,j} = \alpha_j t + \beta_{r,j} + C_j + \varepsilon^t_{r,j}$$

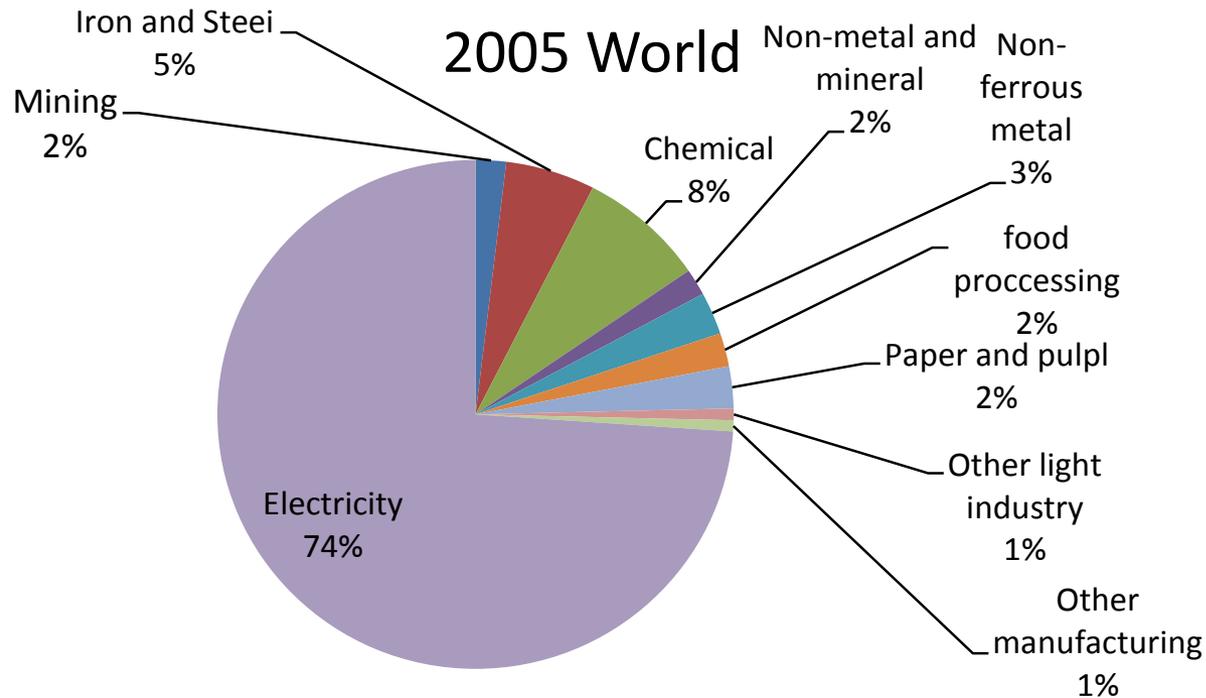| Technological coefficient | Country specific technology level | Global standard intensity |

	Industry total	Basic metal	Chemical	Electricity	Food proccessing	Mining	Non-metal and mineral	Paper and pulp	Textile	Other manufacturing
α	-0.006	-0.013	-0.045	-0.032	-0.021	-0.06	-0.037	-0.016	-0.033	-0.093
t-value	-9.76	-51.3	-146.22	-192.02	-94.52	-213.93	-144.2	-49.33	-98.89	-272.07
Data counts	225	101	104	56	105	56	38	106	100	69
Coefficient of determinant	0.81	0.71	0.88	0.79	0.74	0.90	0.87	0.84	0.92	0.70

- Technology coefficient
  - All are negative → technological improvement
  - The numbers vary across sectors

Base year situation by sectors

2005 World

- Iron and Steel 5%
- Mining 2%
- Chemical 8%
- Non-metal and mineral 2%
- Non-ferrous metal 3%
- food proccessing 2%
- Paper and pulpl 2%
- Other light industry 1%
- Other manufacturing 1%
- Electricity 74%

- Electricity sector dominates
- Basic metals and chemistry follow

Base year situation by regions

2005 World

Pie chart data:
- Africa 2%
- Middle East 0%
- Former USSR 11%
- Other europe 4%
- Western Europe 16%
- Latine America 4%
- North America 34%
- Oceania 1%
- Japan 2%
- China 18%
- India 1%
- Other Asia 7%
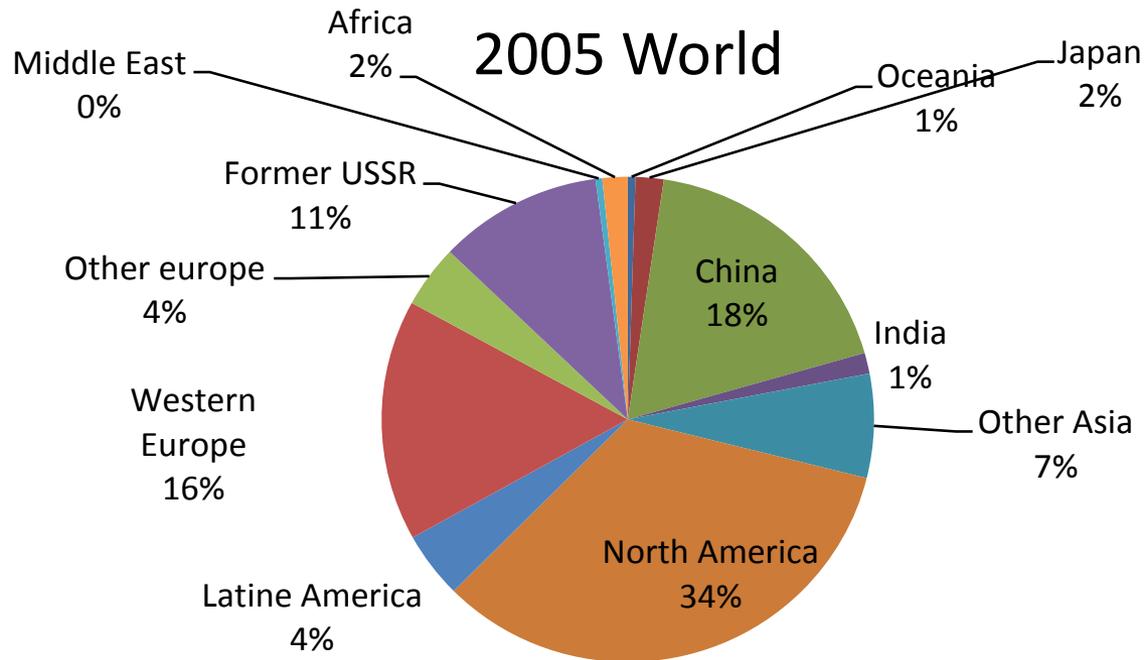
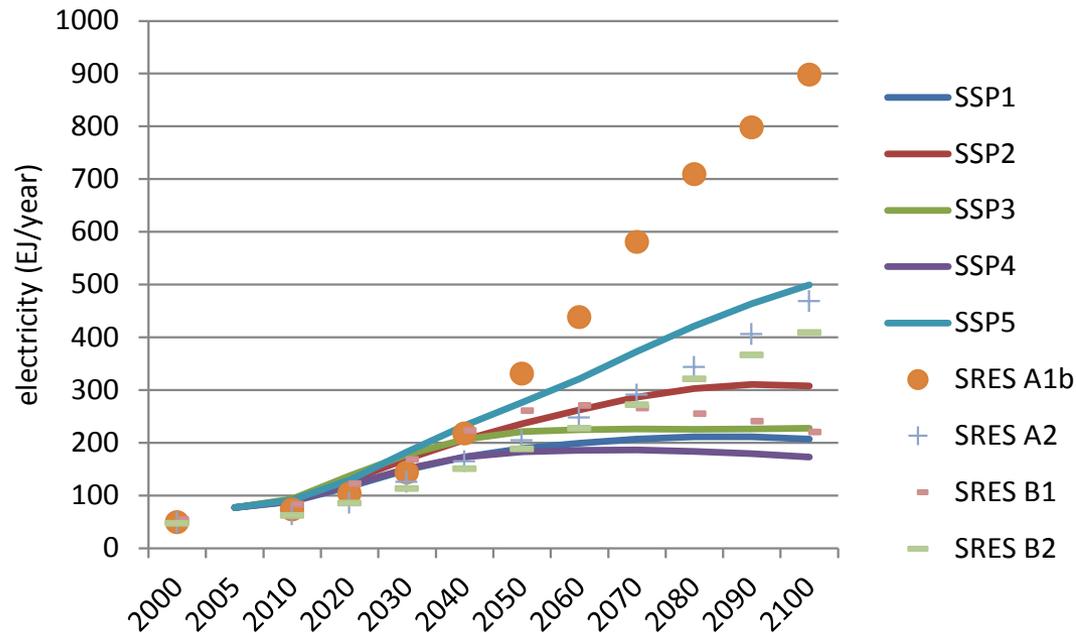- North America, Western Europe and China
  - Scale of the economy reflects
- Japan may be one of the exception.
  - High water technology

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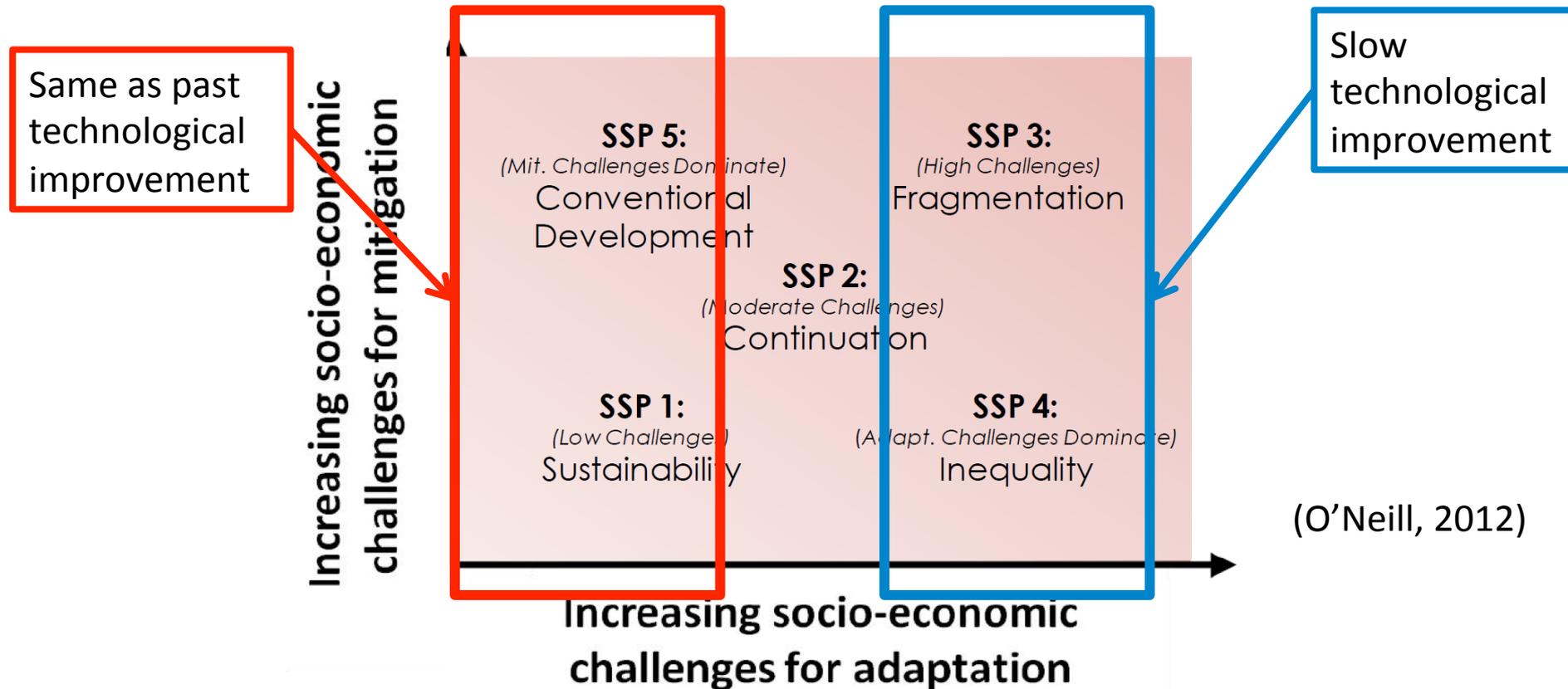# Key drivers - Industrial production -
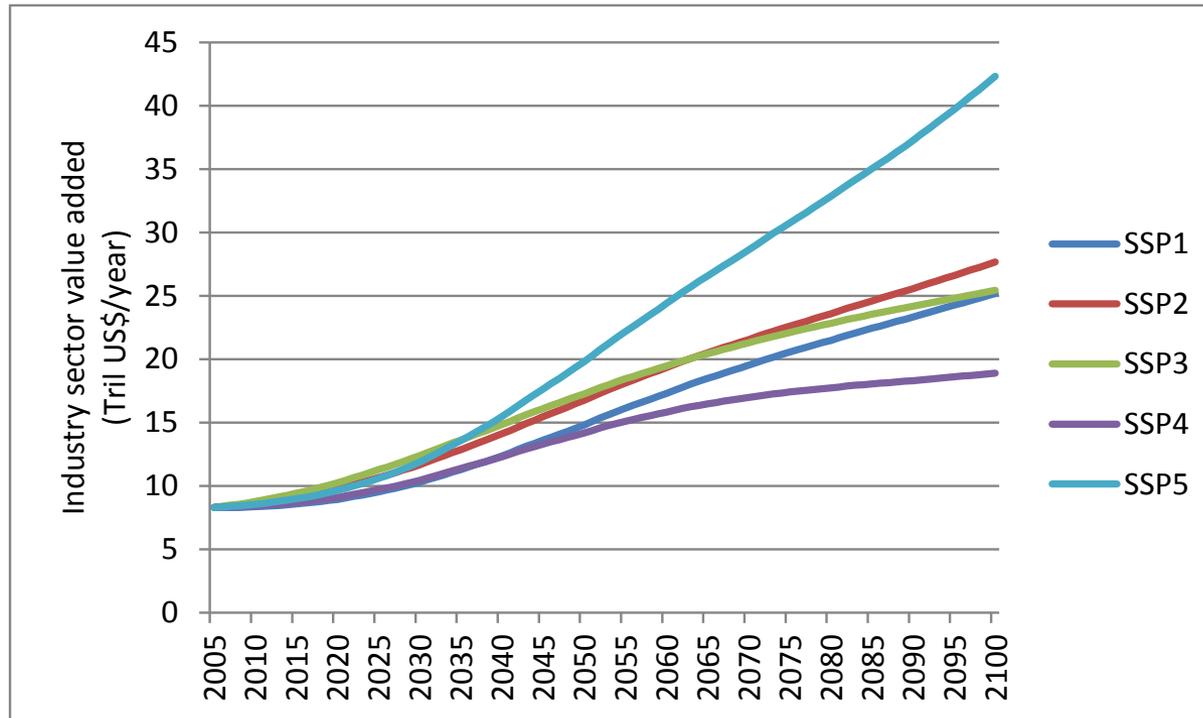
- Industrial production is high in SSP5
- The others are not so different globally.

Key drivers - Power supply -

- SSP5 is high, SSP2 is middle and the others are low.
- SRES show a little bit higher trends

# Key assumptions for water technological improvement

Same as past technological improvement

Slow technological improvement

Increasing socio-economic challenges for mitigation

SSP 5:
(Mit. Challenges Dominate)
Conventional Development

SSP 3:
(High Challenges)
Fragmentation

SSP 2:
(Moderate Challenges)
Continuation

SSP 1:
(Low Challenges)
Sustainability

SSP 4:
(Adapt. Challenges Dominate)
Inequality

(O'Neill, 2012)

Increasing socio-economic challenges for adaptation

- SSP1 and SSP5; same as past
- SSP3 and SSP4; slow (1/4 of historical improvement rate)
- SSP2; half of historical improvement rate

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Explore world industrial withdrawal
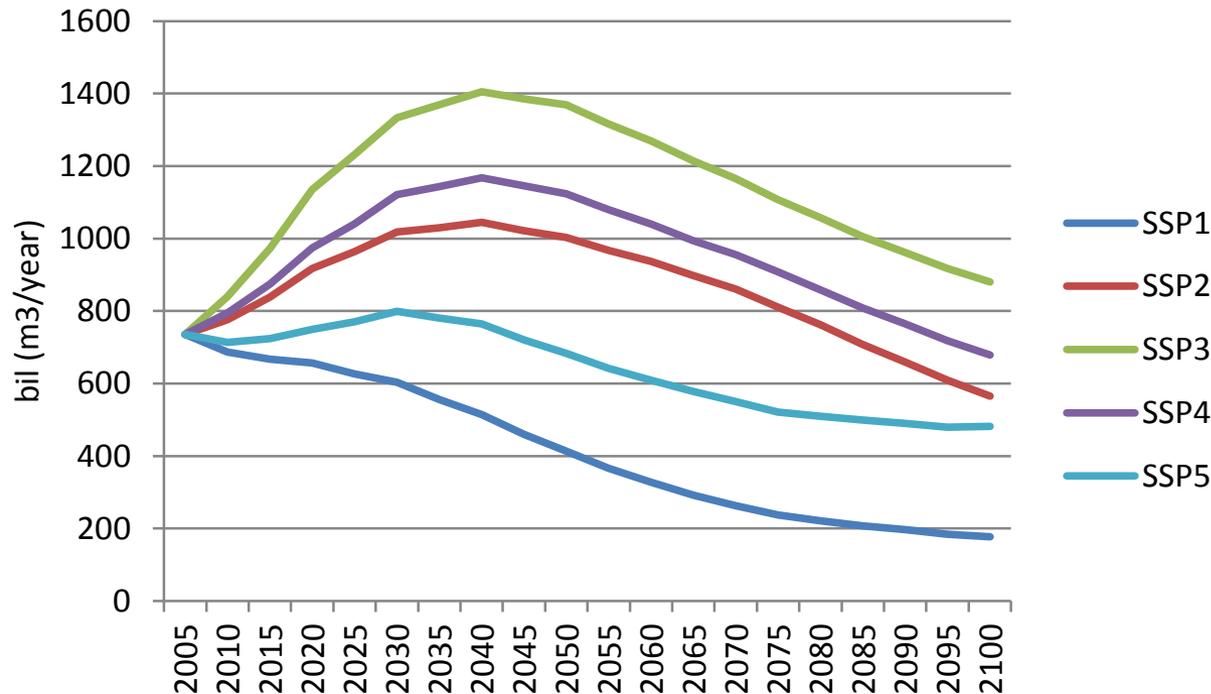
- SSP3 and SSP4 are higher trajectory
  - Technological assumption induces
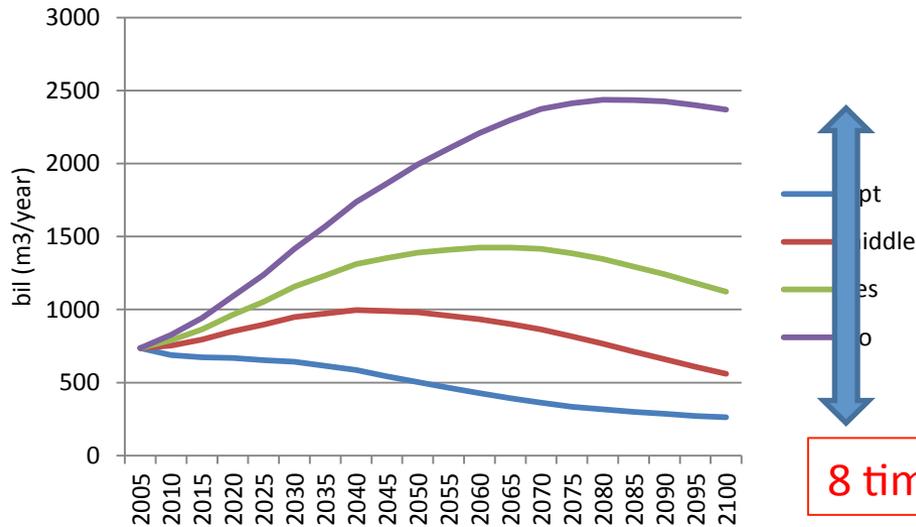- Mostly declined in the end of 21st century
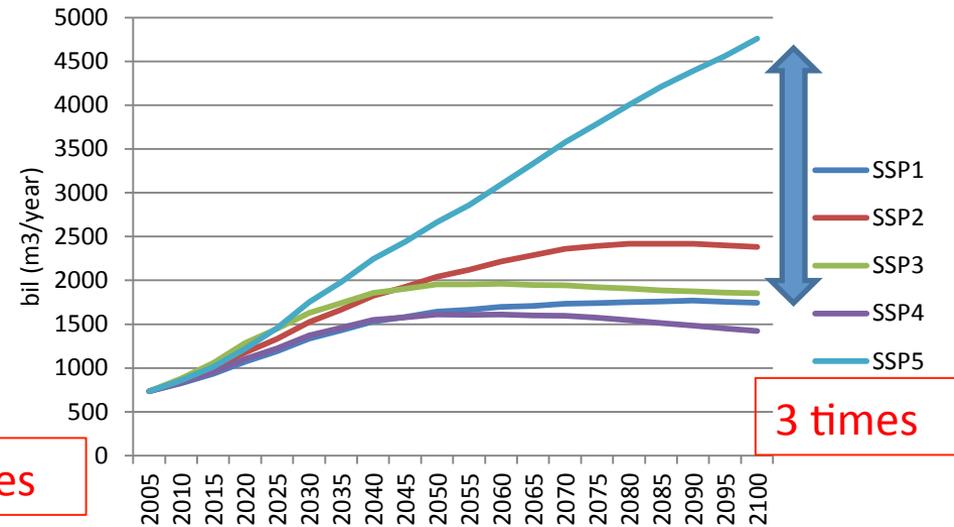
Comparison with previous studies
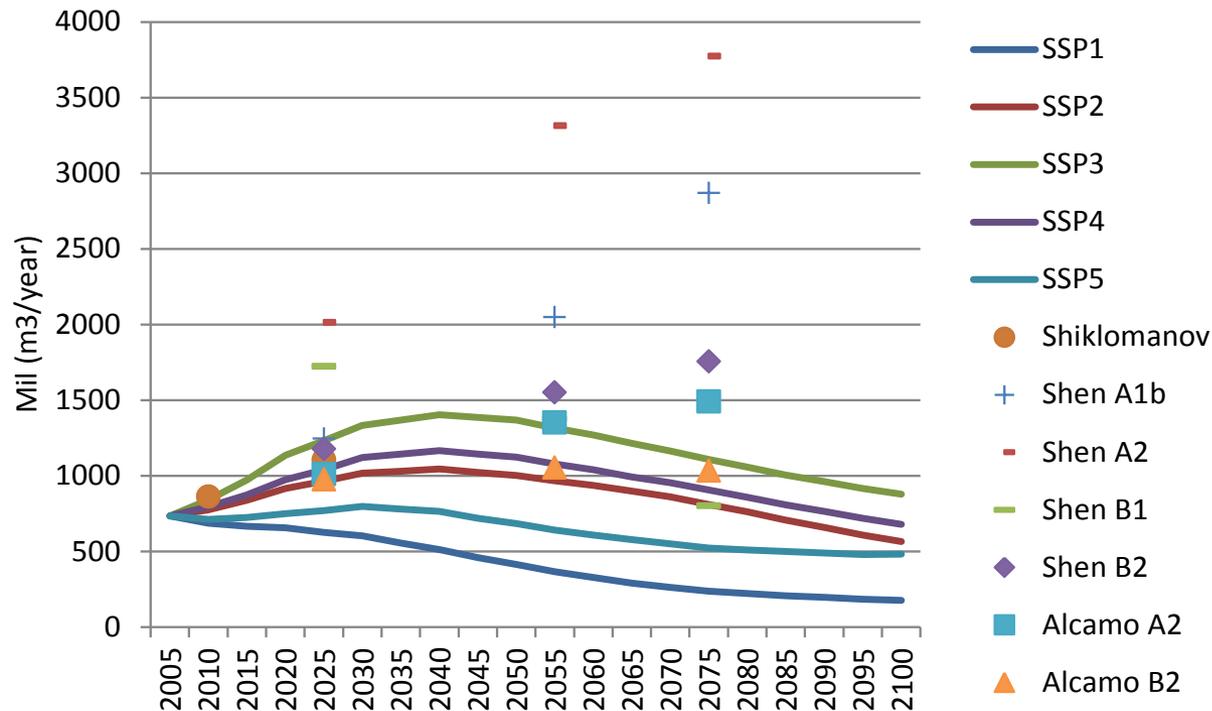
Shen et al. 2008
Alcamo et al. 2007

- SRES based estimation are higher than this estimation
  - Technological assumptions and driving forces

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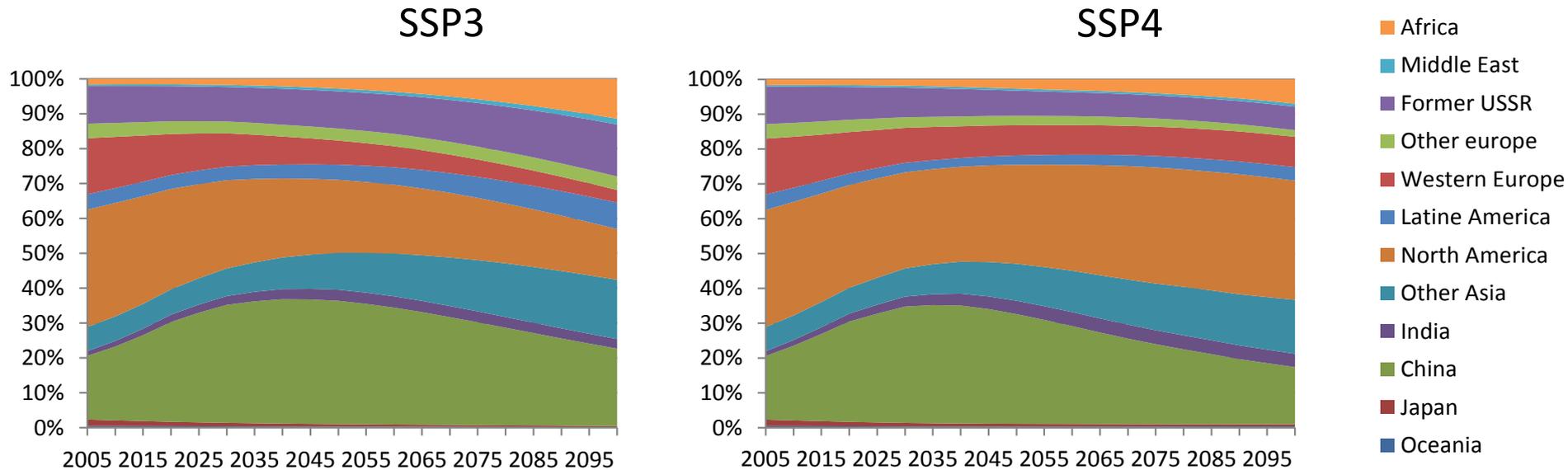# How do the driving forces and technological assumptions matter?

SSP2 with different technology assumption
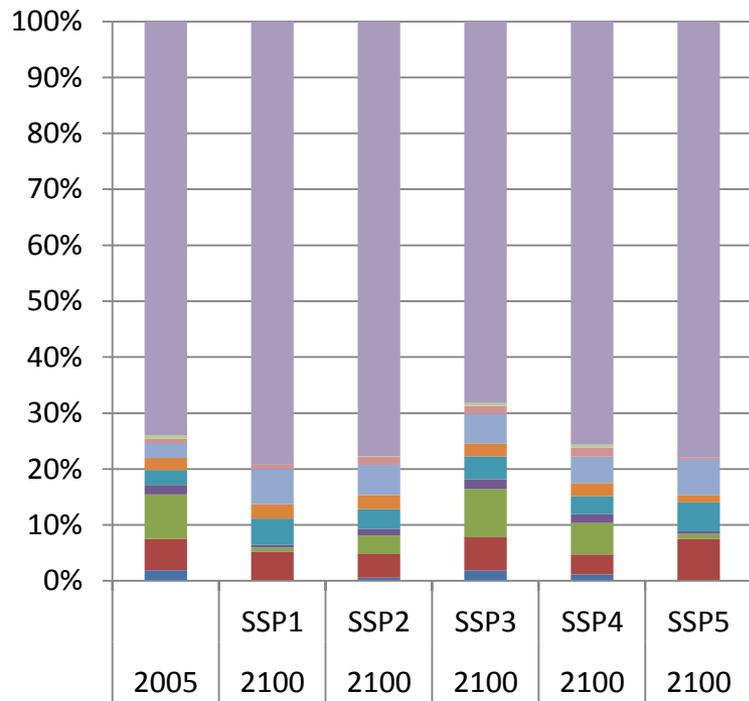
No technological improvement for all SSPs

- Both sensitivity analysis show wide range.
- In terms of ratio of bottom to top in 2100, technological assumption make larger range.
- Absolute volume is depending on the scale of SSPs driving forces

The share of regions

SSP3

SSP4

Legend:
- Africa
- Middle East
- Former USSR
- Other europe
- Western Europe
- Latine America
- North America
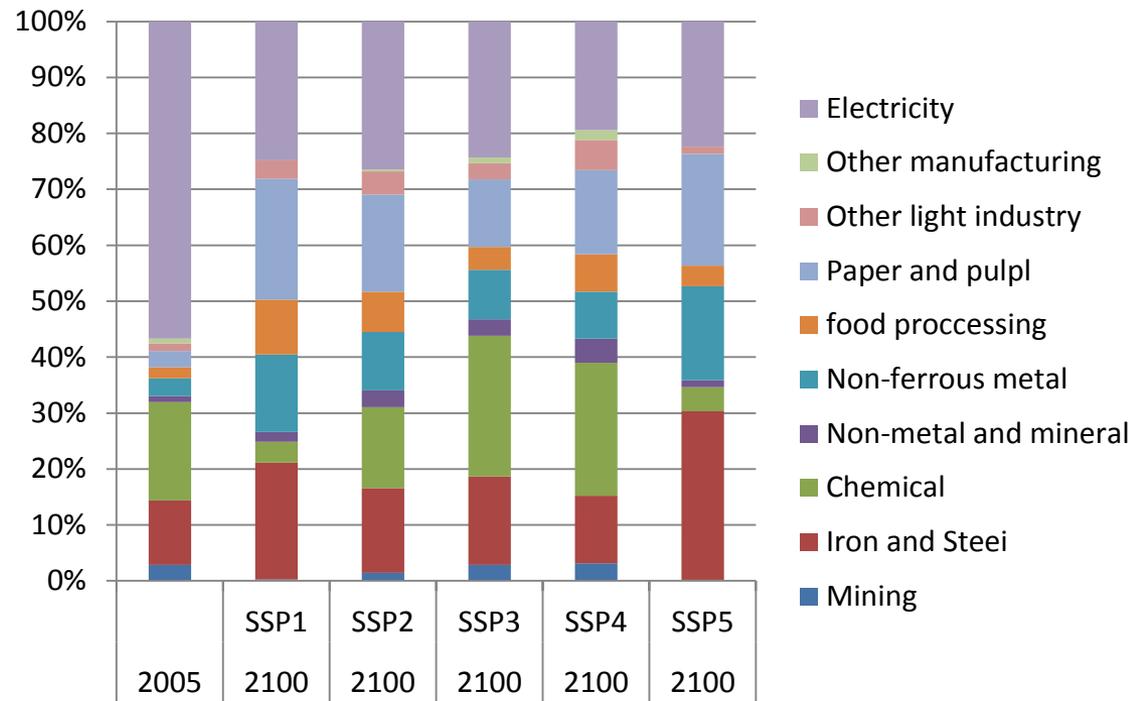- Other Asia
- India
- China
- Japan
- Oceania

- SSP4 is characterized as divided world
  - Developed regions keep their share
- SSP3 is fragmented.
  - Developed region's GDP are declined due to the population decrease and slow economic growth .
  - Developing regions population expand a lot and it drives the demand of industrial water.

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The share of sectors

Global sector share

China's sector share

Legend:
- Electricity
- Other manufacturing
- Other light industry
- Paper and pulpl
- food proccessing
- Non-ferrous metal
- Non-metal and mineral
- Chemical
- Iron and Steei
- Mining

- The share of electricity could be changed from current share
- Different regions have different share changes

Key findings

- We explore the future industrial water withdrawal based on SSPs.

- The driving forces and technological assumption make characteristics of the scenarios.
  - Both assumptions are key determinants.
  - The demand of industrial water are declined in the end of this century.
  - The share of the sectors would be changed but depending on the regions.
  - The regional breakdowns are different among the scenarios in the end of 21st century.

Limitations

- Is time trend term able to represent technological improvement?

- Is it possible to expand the developed region's limited information to developing countries?

- Technological assumption for each SSP is totally depending on my assumption.

- Water supply has not been taken into account.

Summary

- SSP quantification by AIM modeling team
  - GDP and population is provided
  - Interpret energy technology and service demand

- Industrial water withdrawal scenario
  - Regression analysis provides disaggregated sector's base year and historical technology improvement
  - Combined with SSPs
  - Different pattern from previous study is shown

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Input and Output

Meteorological (0.5°×0.5°, 6hourly, 1971-2000)
Ai...
Sp...
A...
W...
Sh...
Lo...
Prec...

Geographical/other (0.5°×0.5°, circa 2000)	
Cropland area	Ramankutty et al. 2008
Irrigated area	Siebert et al., 2005
Crop intensity	Döll and Siebert, 2002
Irrigation efficiency	Döll and Siebert, 2002
River map	Döll et al., 2003
Reservoir map	Hanasaki et al. 2006
Industrial water dem.	FAO, 2011
Domestic water dem.	FAO, 2011

Output (0.5°×0.5°, daily, 1971-2000)
La...

Climate information

Water assessment

H08

Socioeconomic scenario

Irrigated area, crop intensity, irrigation efficiency scenarios

Reference	Population	GDP	Irrigated area (10^6ha)			Irrigated area growth rate (%/yr)	Crop intensity growth rate (%/yr)	Irrigation efficiency growth rate (%/yr)
			2000	2030	2050			
Rosegrant et al. 2002	UN 1998 med	IFPRI	*375 (1995)*	*441 (2025)*				
Bruinsma , 2003 (Faures et al., 2002)	UN 2001 med	WB 2001	271 202 <u>257</u>	324 242 <u>341</u>	(365)	0.60	0.4	0.3
Alcamo et al., 2005 MA-Techno Garden	MA-TG	MA-TG	239		252	0.11		
de Fraiture, 2007 CA-Irrig area expansion	MA-TG	MA-TG			<u>450</u>	0.60		
CA-Comprehensive	MA-TG	MA-TG			<u>394</u>	0.30	0.2	0.15
CA-Irrig yield improve	MA-TG	MA-TG	<u>340</u>		<u>370</u>	0.15		
CA-rain area expansion	MA-TG	MA-TG			<u>340</u>	0		
CA-rain yield improve	MA-TG	MA-TG			<u>340</u>	0		
CA- trade	MA-TG	MA-TG			<u>340</u>	0		
Rosegrant et al., 2009	UN 2005 med	MA-TG	*433*	*478 (2025)*	*473*	0.06	0.15	0

High variant

Medium variant

Low variant

Revisiting concept of SSP
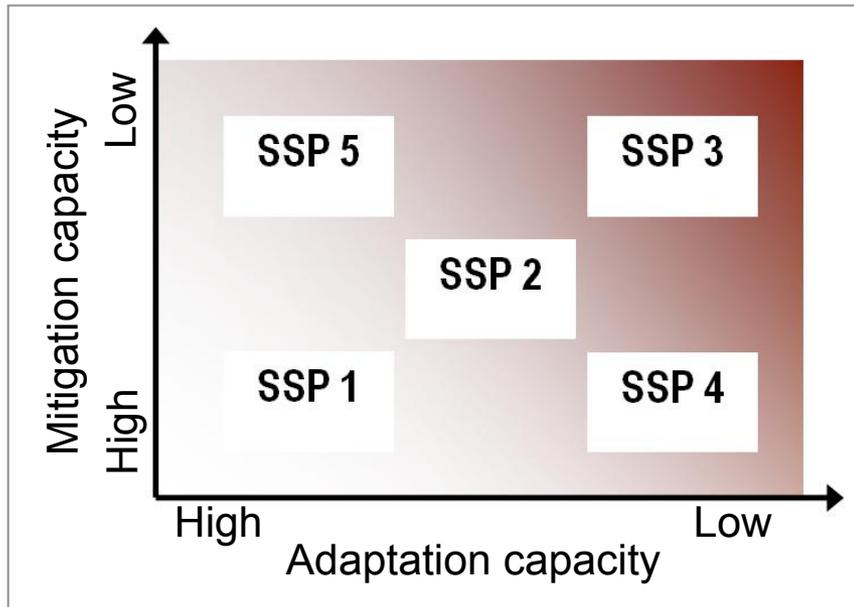
Narrative scenario of SSP

SSP1	Sustainable world High international cooperation High technological improvement High environmental awareness
SSP2	Middle of the road in between SSP1 and SSP3
SSP3	Fragmented world Low international cooperation Low technological improvement
SSP4	Divided in rich & poor Low international cooperation High technological improvement
SSP5	Coal gas powered growth High international cooperation High technological improvement Low environmental awareness?

SSP interpretation
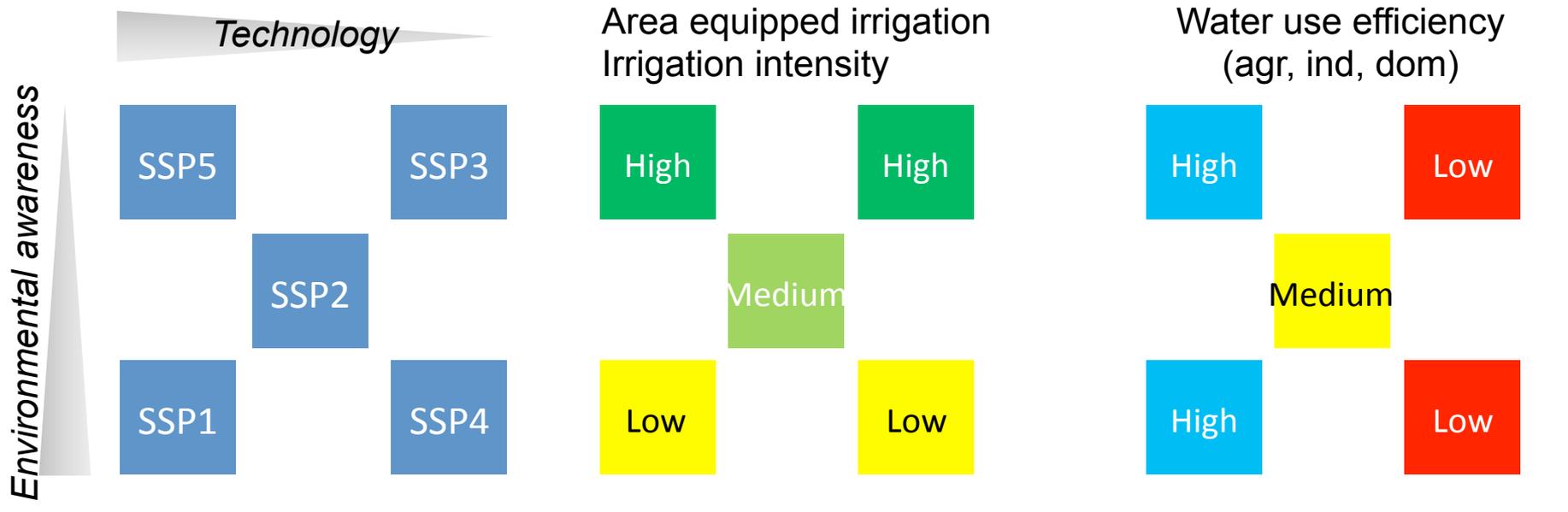
	in a word	Area	intensity	A eff.	I eff.	D eff.
SSP1	Sustainable world	0.06	0.15	0.3	HE	HE
SSP2	middle of the road	0.3	0.2	0.15	ME	ME
SSP3	Fragmented world	0.6	0.4	0	LE	LE
SSP4	Divided in rich & poor	0.06	0.15	0	LE	LE
SSP5	Fossil fuel dependent	0.6	0.4	0.3	HE	HE

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ASIA-PACIFIC INTEGRATED MODEL
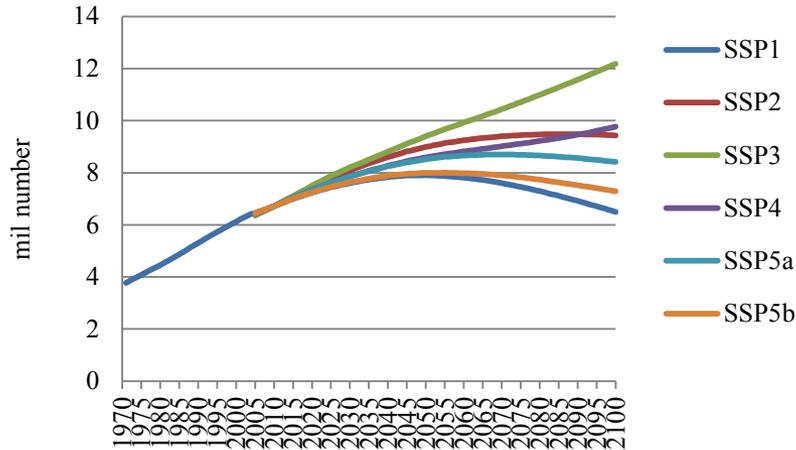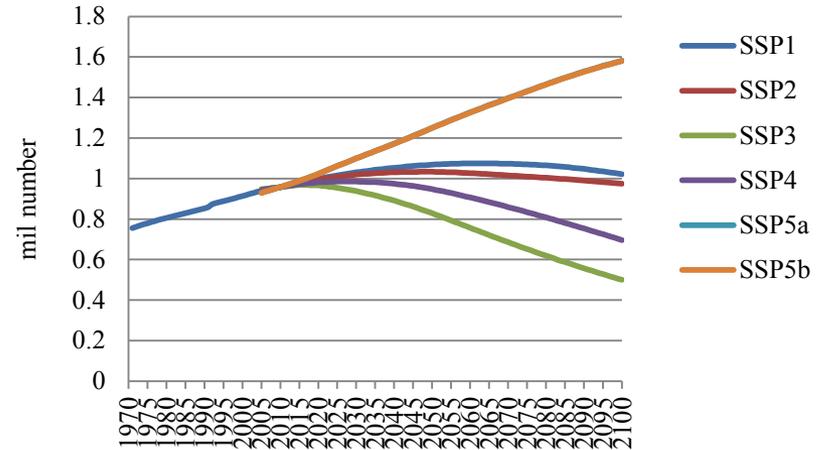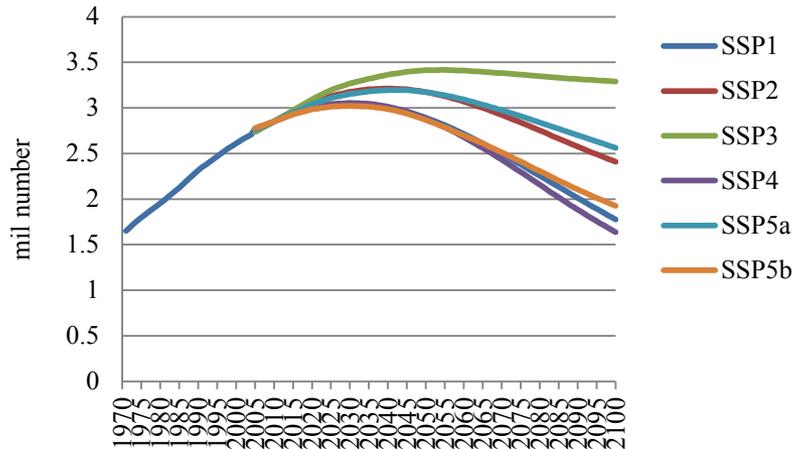
Population
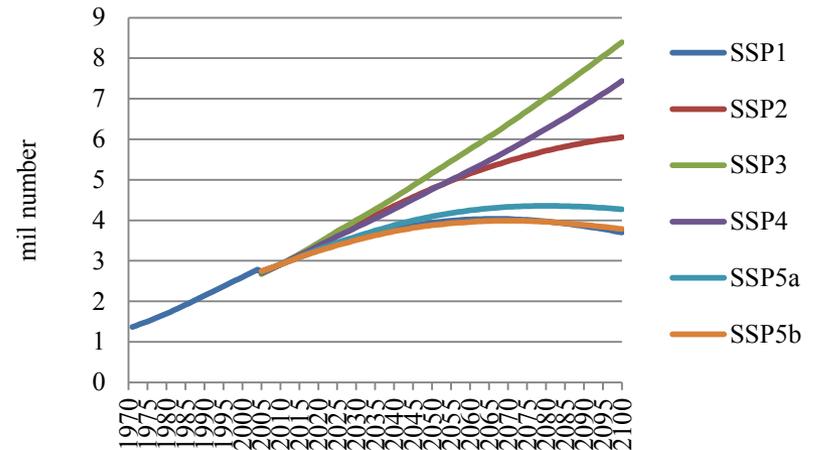
GDP

WLD _Total GDP_ MER
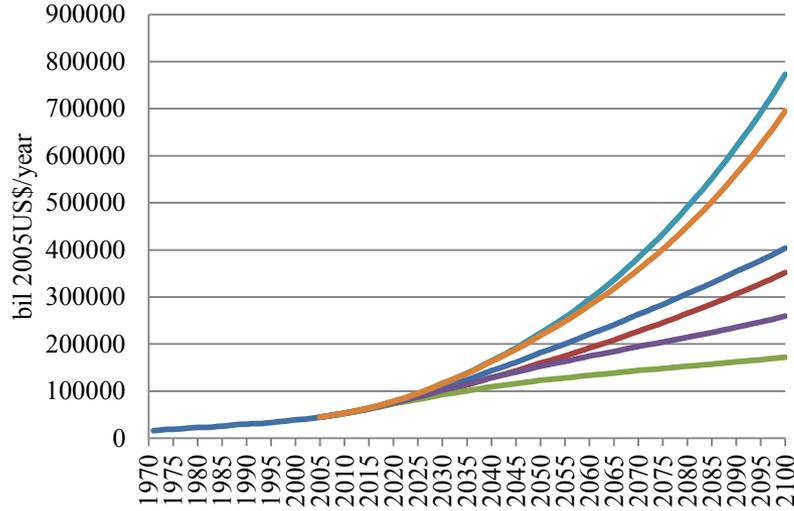
OEC _Total GDP_ MER
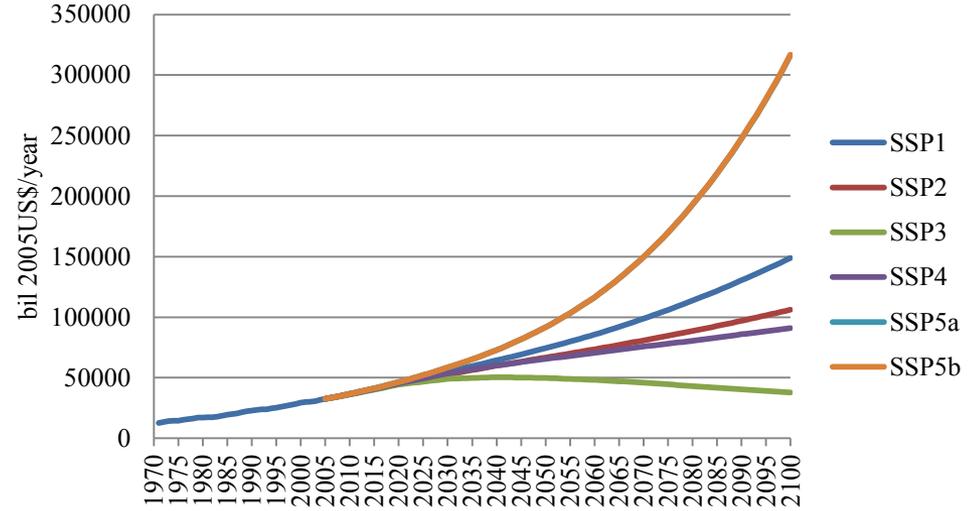
Tra _Total GDP_ MER
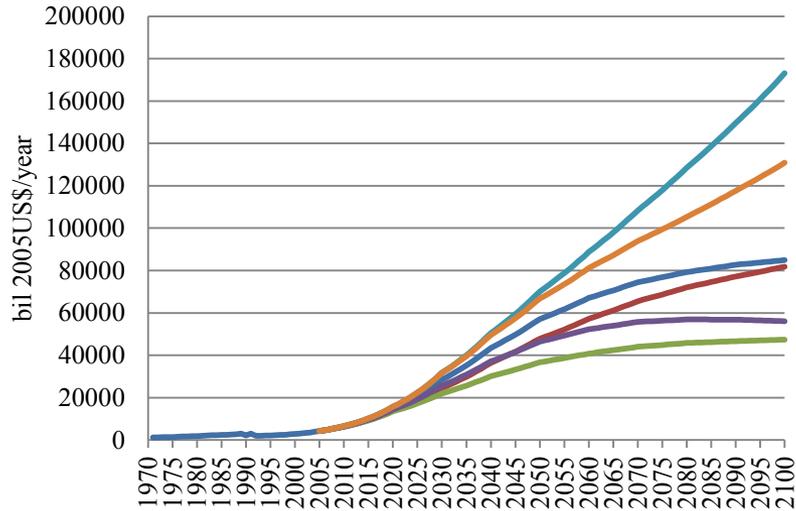
Other_Total GDP_ MER

GDP/cap
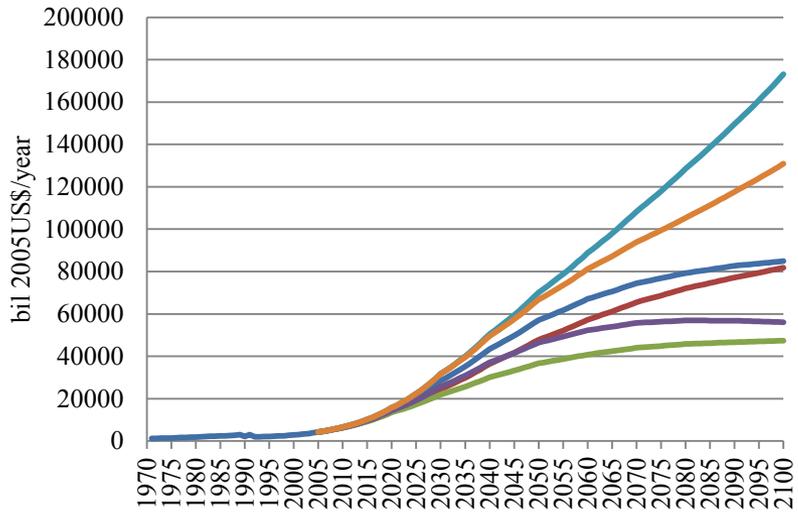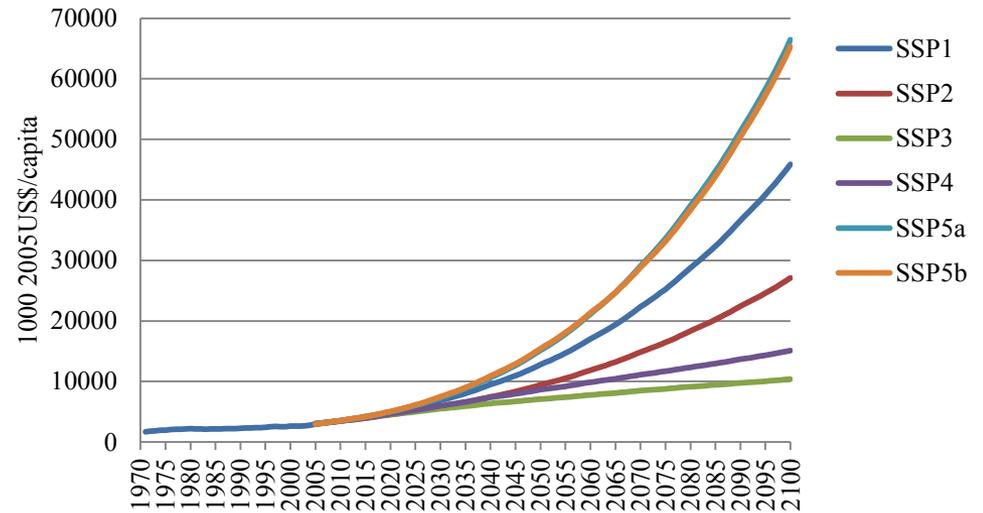
Energy supply

: Biomass
: Nuclear
: Gas
: Oil
: Coal

NIES *JAPAN*

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