Global Trade Analysis Project

Global Fossil-fuel Subsidies and Emission Externalities: Inclusive Approaches to Welfare Assessment

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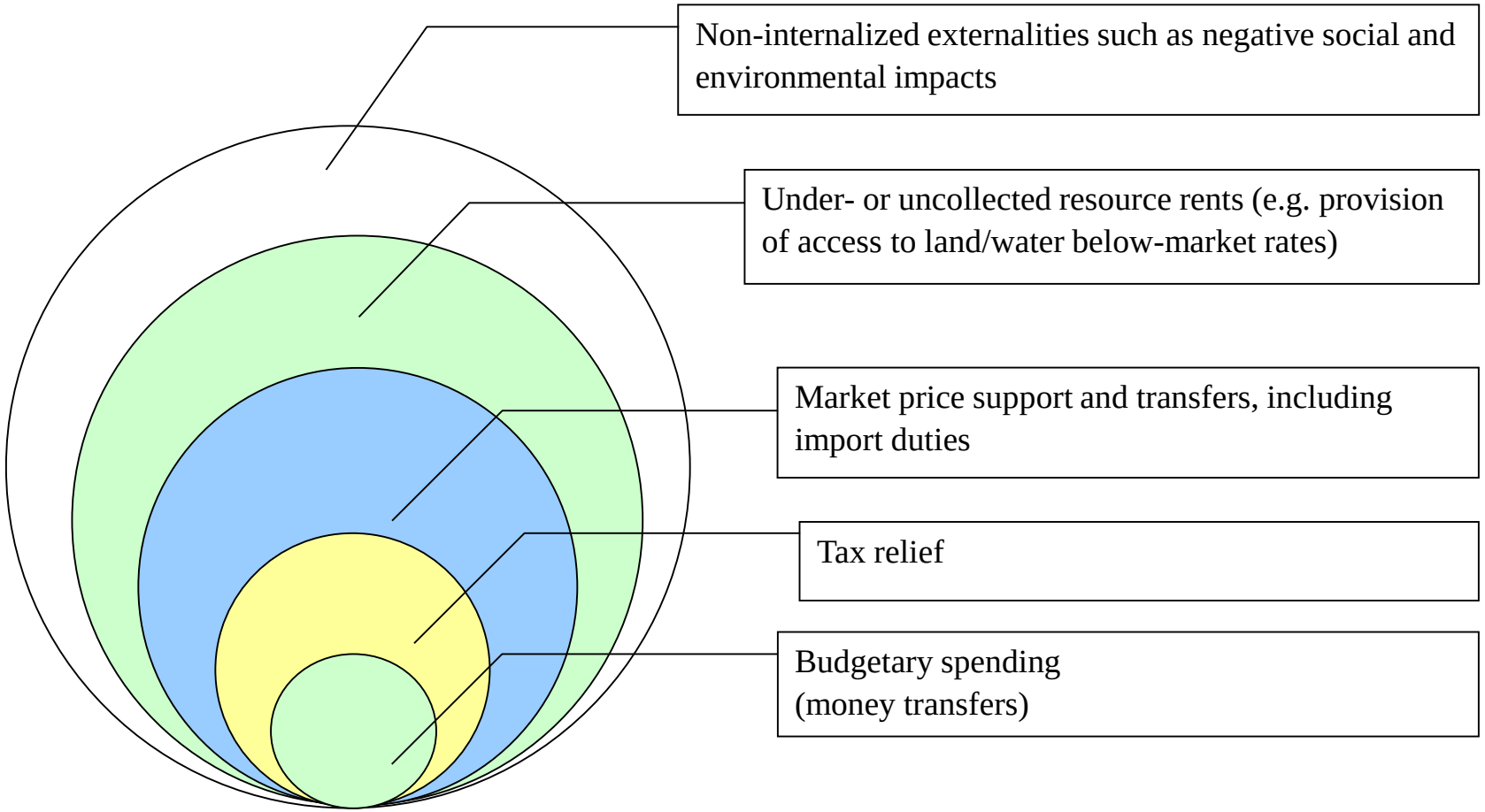
Outline

1. Motivation
2. Measurement of energy subsidies
3. Environmental co-benefits assessment approaches
4. Theoretical framework and methods
5. Scenarios and results
6. Concluding remarks

1. Motivation

- **Global *fossil-fuel consumption subsidies* (cases with domestic energy prices lower than international market price) are estimated to be around $500 billion in 2014.**
  - For many countries these subsidies can represent between 2 and 10 percent of GDP and for a handful even between 10 and 20 percent.
- **Air pollution externalities (costs associated with negative health impacts of air pollution – *post-tax subsidies*) are even larger and amount to over 3 trillion USD worldwide.**
- **Energy subsidies are not represented in most global modelling databases, including Global Trade Analysis Project (GTAP) Database.**
- **These subsidies are mostly associated with fossil fuels and have a significant impact on GHGs emissions and air pollution.**
- **Welfare assessment of subsidization policies usually does not take into account environmental co-benefits and often results in regressive economic outcomes.**

2.1. Subsidies definition



Source: Adopted from (Gerasimchuk, 2012)

2.2. Energy subsidies estimation approaches

Approach	Description	Strengths	Limitations
Producer support estimate (PSE)	Cash value of transfers to energy producers	Includes different types of support	Data intensive. Does not capture market price support measures
Consumer support estimate (CSE)	Cash value of transfers to energy consumers		
General Services Support Estimate (GSSE)	Cash value of transfers that support general services		
Program-specific approach (PSA)/ Program-aggregation	Estimates cash transfers associated with various government programs; aggregates programs into overall support level	Captures transfers regardless of their influence on prices	Sensitive to the program selection. Requires highly disaggregated data
Price-gap approach (PGA)	Compares actual end-user prices with reference prices, defined as those prices that would prevail in undistorted markets in the absence of subsidies	Relatively low data requirements; useful for international comparisons	Ignores support that does not influence end-user price; sensitive to reference price estimates

Source: compiled from (UNEP, 2003; Honkatukia, 2002; Jones, 2010)

2.3. Comparison of fossil fuel subsidy estimates

	OECD	IEA	IMF
Estimates (bn, $2014) *	170	493	Pre-tax: 481 Post-tax: 5175
Country coverage	34 OECD members + 6 partner economies	41, mostly developing	188
Product coverage	Petroleum products, coal, natural gas	Gasoline, diesel, kerosene, LPG, heavy fuel oil, coal, natural gas, electricity	Gasoline, diesel, kerosene, coal, natural gas, electricity
Consumer coverage	Consumers and producers	Consumers	Consumers and producers
Definition	Budgetary transfers and tax expenditures that provide benefits to fossil-fuel consumption/production	Government actions that result in end-user prices being lower than full cost of supply	Pre-tax: price paid by consumers below supply cost + budgetary transfers that provide benefits to producers Post-tax: pre-tax + taxes below efficient level (consumption and corrective "Pigouvian" taxes)
Estimation approaches	PSE, CSE, GSSE	PGA	PGA (consumer subsidies), PSE+CSE+GSSE (producer subsidies)

*For comparison reasons estimates are provided for the latest mutually available year.

Source: based on (IISD, 2014; OECD, 2015; IEA, 2017; IEA, 2015; Coady, 2016)

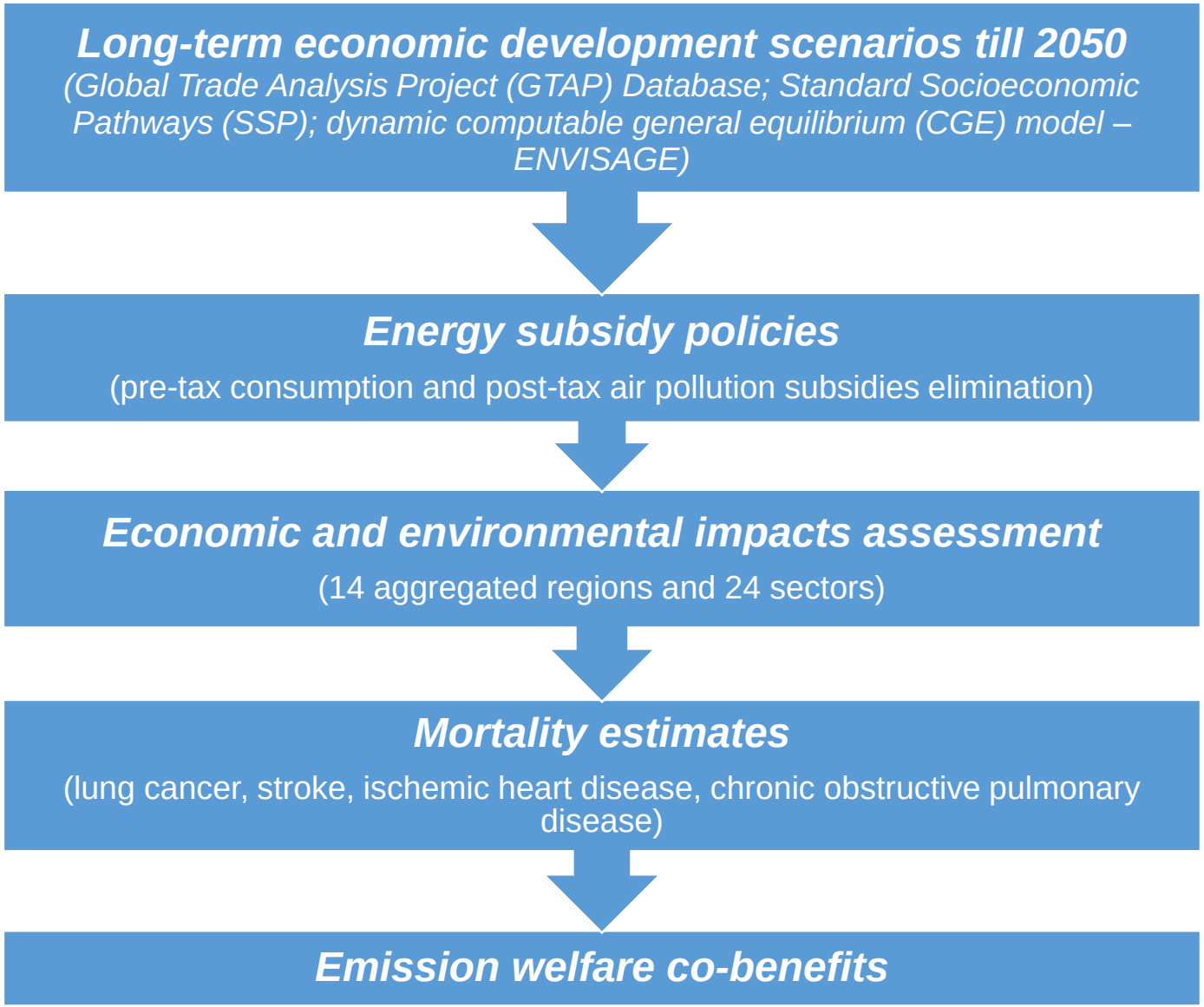
2.4. Subsidy assessment studies comparison

Study/ feature	Experiment description	Regional coverage	Removal timeframe	Reported year	Assessment approach	Effects estimates (global), % from BaU		
						GDP	CO_2 emissions	Households income
IMF, 2015	Post-tax energy subsidies removal	188 countries	2013	2013	Static partial equilibrium	2.0	-20.8	-
IEA, 2015b	Gradual phase-out of fossil-fuel consumption subsidies	40 OECD and non-OECD countries	2014-2030	2030	IEA's World Energy Model (partial equilibrium)	-	-10 (energy related GHGs)	-
Magne, 2014	Multilateral fossil-fuel subsidies removal	35 non-OECD countries, Mexico and South Korea	2013-2020	2035	ENV-Linkages model (dynamic CGE)	+0.5	-6.5	+0.3
OECD, 2009	Multilateral fossil-fuel demand-related subsidies removal	Non-OECD countries	2013-2020	2050		+0.1	-10	+0.0
Saunders and Schneider, 2000	Consumption subsidies removal	10 non-OECD regions	2001-2005	2010	ABARE GTEM model (dynamic CGE)	+0.1 (developed economies) +0.45 (10 non-OECD)	-1.1 (all GHG)	-
IEA, 1999	Removal of consumer energy subsidies	8 non-OECD countries	1997-1998	1997-1998	Static Partial-Equilibrium	+0.73 (8 non-OECD countries)	-4.6	-

3. Environmental co-benefits assessment approaches

- ***Climate change:***
  - policies towards temperature increase bounds (IPCC, etc.);
  - impact functions and damage costs (Tol, 2002; Roson and van der Mensbrugghe; WHO, 2014; Roson and Sartori, 2016).
- ***Biodiversity and ecosystems:***
  - human-related influence on biodiversity and ecosystems (Lovett et al., 2009; Stevens et al., 2004; Phelps, 2012);
  - planetary boundaries estimates (Rockstrom et al., 2009; Steffen et al., 2015).
- ***Human health:***
  - human-related benefits/costs of air pollution (EPA, 1999; Kunzli et al, 2000; Bell et al., 2011 (for studies review); OECD, 2012);
  - assessment of economic consequences of air pollution (OECD, 2016a; IMF, 2015; Saari et al., 2015; Matus et al., 2012).

4.1. Energy subsidies reform assessment framework



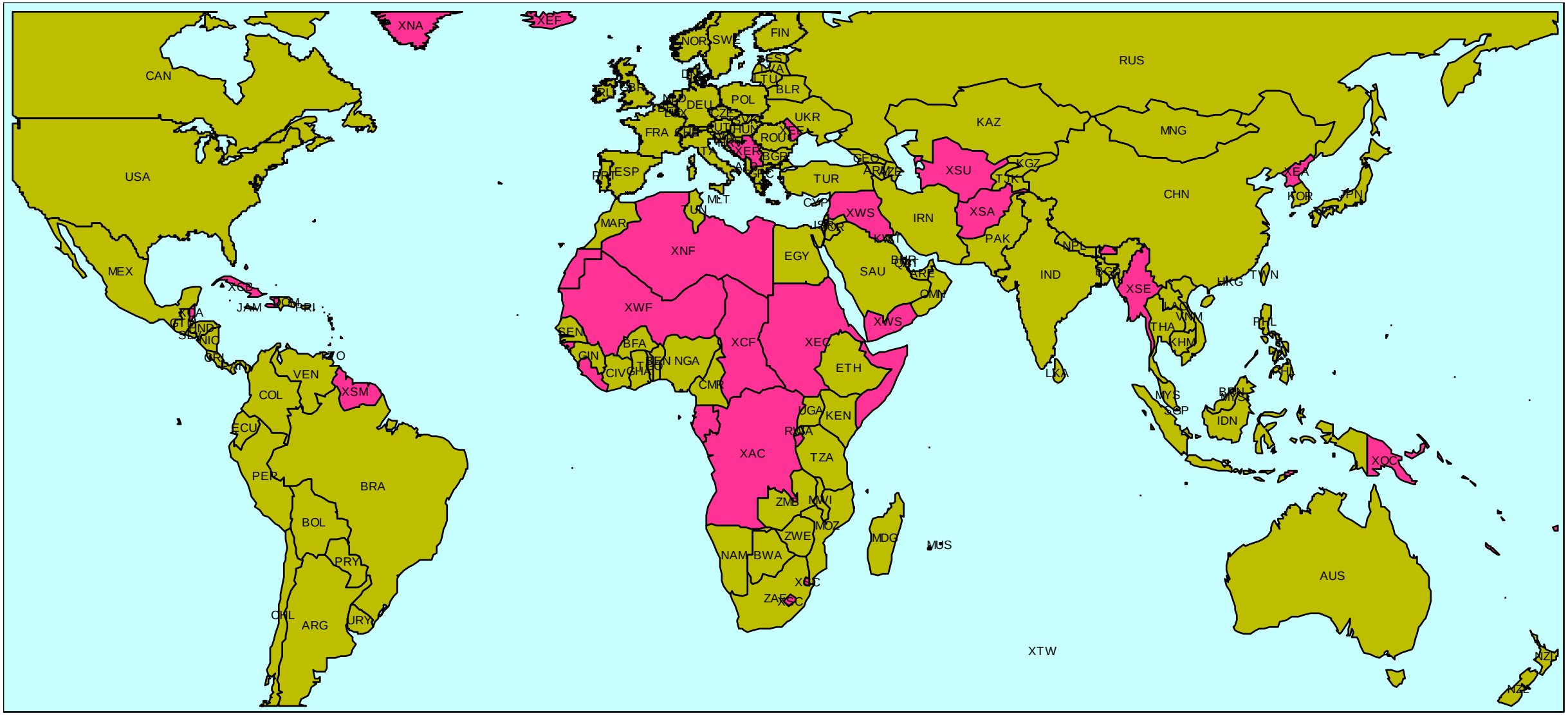
4.2. Modelling framework – GTAP database

- **Global Trade Analysis Project**
- **Based at Purdue University**
- **Consortium of international and government agencies, research institutes and universities, private sector (currently 30 members)**
- **International database for analysis of policy issues**
  - Harmonized national input/output tables with satellite accounts
  - Trade, migration, development, energy & the environment, etc.
- **Global GE model also available**
  - Model is known as the GTAP model and is coded using GEMPACK, see Hertel, Thomas, ed. (1997), *Global Trade Analysis: Modeling and Applications*, Cambridge University Press.

4.3. GTAP database – Release 9.2

- **Base year: 2011 (plus 2007 & 2004)**
- **141 regions, of which 121 are countries**
- **57 sectors**
  - 14 agriculture, 8 processed foods, 6 energy
- **8 factors or production**
  - Labor (professionals, technicians, clerks, service workers, unskilled workers)
  - Capital, land (agriculture), natural resources

4.4. Spatial coverage—GTAP V 9.2



Country (121) Composite region (20)

4.5. Commodity coverage

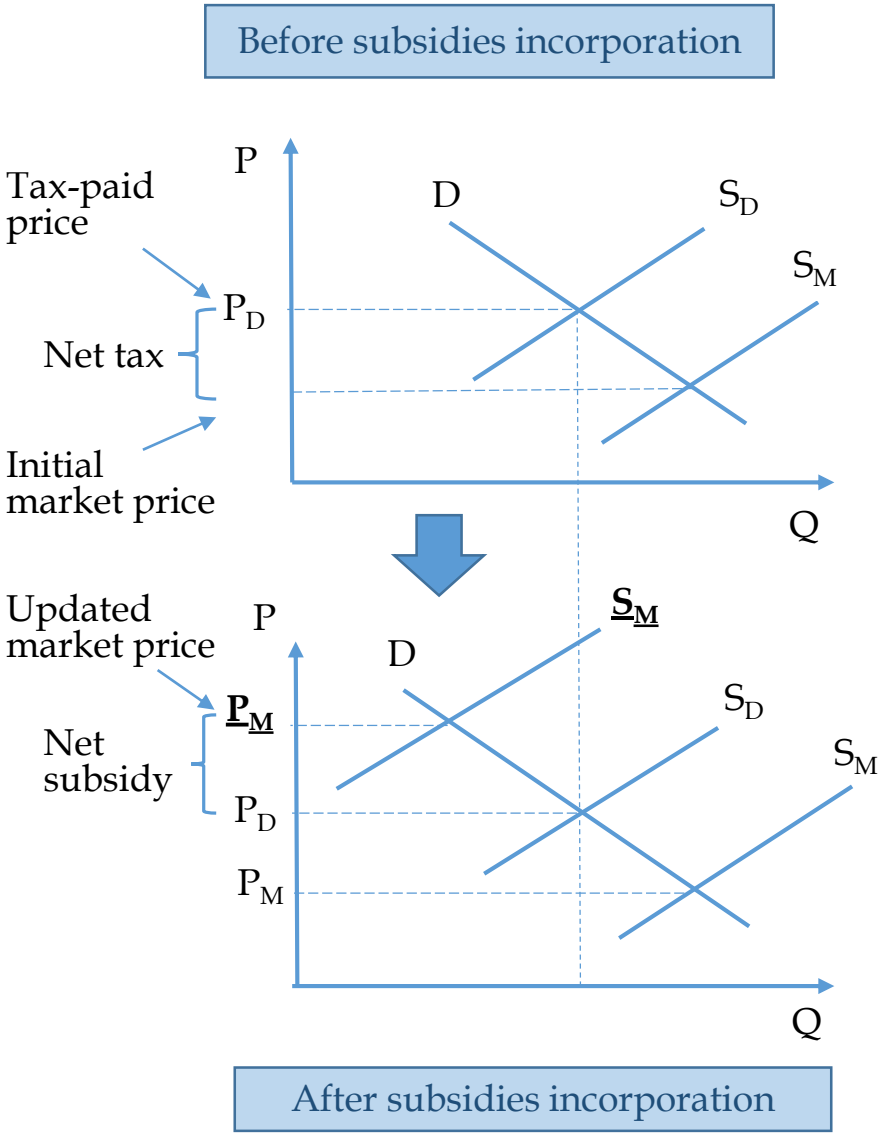
Agriculture etc.	Processed food	Oth. Manufacturing	Energy intensive	Services
Paddy rice	Coal	Wood products	Electricity	
Wheat	Oil	Pulp, paper etc.	Gas distribution	
Other cereals	Gas	Refined oil etc.	Water	
Vegetables & fruits	Other minerals	Chemicals etc.	Construction	
Oil seeds	Red meat	Other mineral prod.	Trade	
Sugar cane & beet	White meat	Ferrous metals	Land transportation	
Plant-based fibers	Vegetable oils	Other metals	Sea transportation	
Other crops	Dairy products	Metal products	Air transportation	
Beef etc.	Processed rice	Mot. vehicles & parts	Communication	
Poultry, pork, etc.	Refined sugar	Oth. trp. eqpt.	Financial services	
Raw milk	Other food	Electronic eqpt.	Insurance	
Wool etc.	Beverages & tobacco	Other mach. & eqpt.	Other bus. services	
Forestry	Textiles	Other manu.	Recr. & other serv.	
Fishing	Clothing		Public services	
	Leather products		Dwellings	

4.6. GTAP Database – satellite accounts

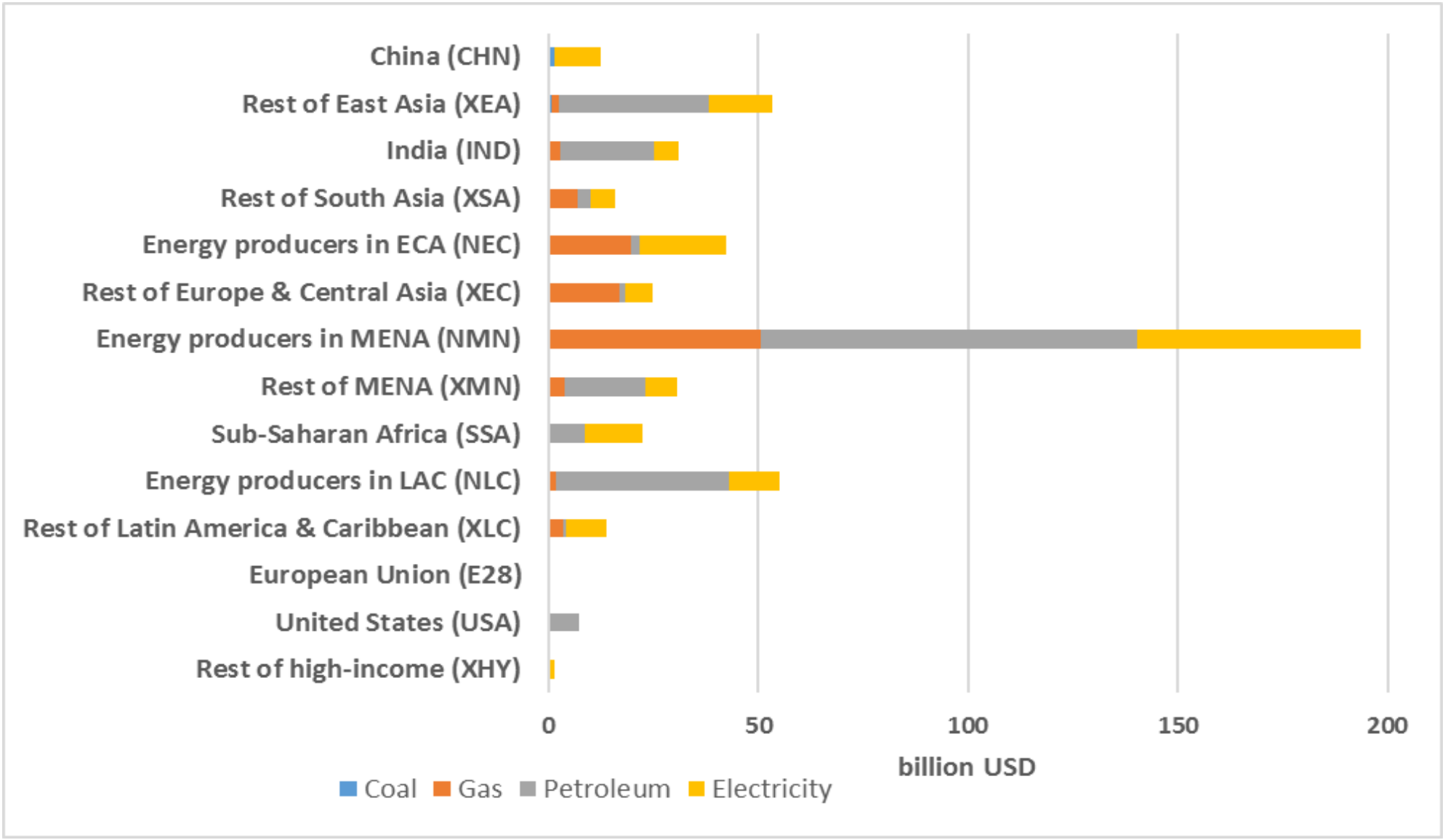
- ***Standard***
  - Times series of bilateral merchandise trade flow (199x-201x)
  - Energy consumption in MTOE
  - CO_2 emissions related to fossil fuel consumption
- **Additional**
  - Bilateral stock of foreign-born population and workers (by skill)
  - Cross-border flows of capital income
  - ***Emissions of other greenhouse gases*** (N_2O, CH_4, F-gases)
  - ***Air pollution*** (10 types – BC, CO, NH_3, NMVB, NMVF, NO_x, OC, PM10, PM2.5, SO_2)
  - Land use (18 agro-ecological zones—AEZs)
  - Forestry coverage and sequestered carbon
- **Special databases**
  - ***Power database – 67 sectors*** (electricity production split into 11 sources (thermal, nuclear, hydro, renewables, etc.) + transmission & distribution)
  - Water database (rain-fed and irrigated crops, aggregate water use for livestock, municipal and industrial)

4.7. Fossil-fuel consumption subsidies incorporation in GTAP

(1) Input data preprocessing	• ***Data:*** fossil-fuel supply costs, consumer prices and consumption (IMF, 2015): 188 countries, 6 energy commodities. • Elimination of discrepancies, conversion to uniform units.
(2) Subsidy estimates	• ***Data:*** GTAP-based energy volumes, prices, IMF-based subsidy values and volumes • subsidy estimates and mapping to GTAP regions
(3) Domestic energy prices and taxes update	• ***Data:*** GTAP-based energy quantities, IMF-based subsidy values. • Coal, petroleum products, natural gas and electricity subsidy rates estimates (per unit consumed), commodity tax rates and price updates.
(4) Data Base build	• Updated GTAP 9.2 Data Base distribution with incorporated pre-tax fossil-fuel consumption subsidies



4.8. Fossil-fuel consumption subsidies distribution in 2011



4.9. Development of the GTAP air pollution database

Input data:
EDGAR database (JRC, 2016).

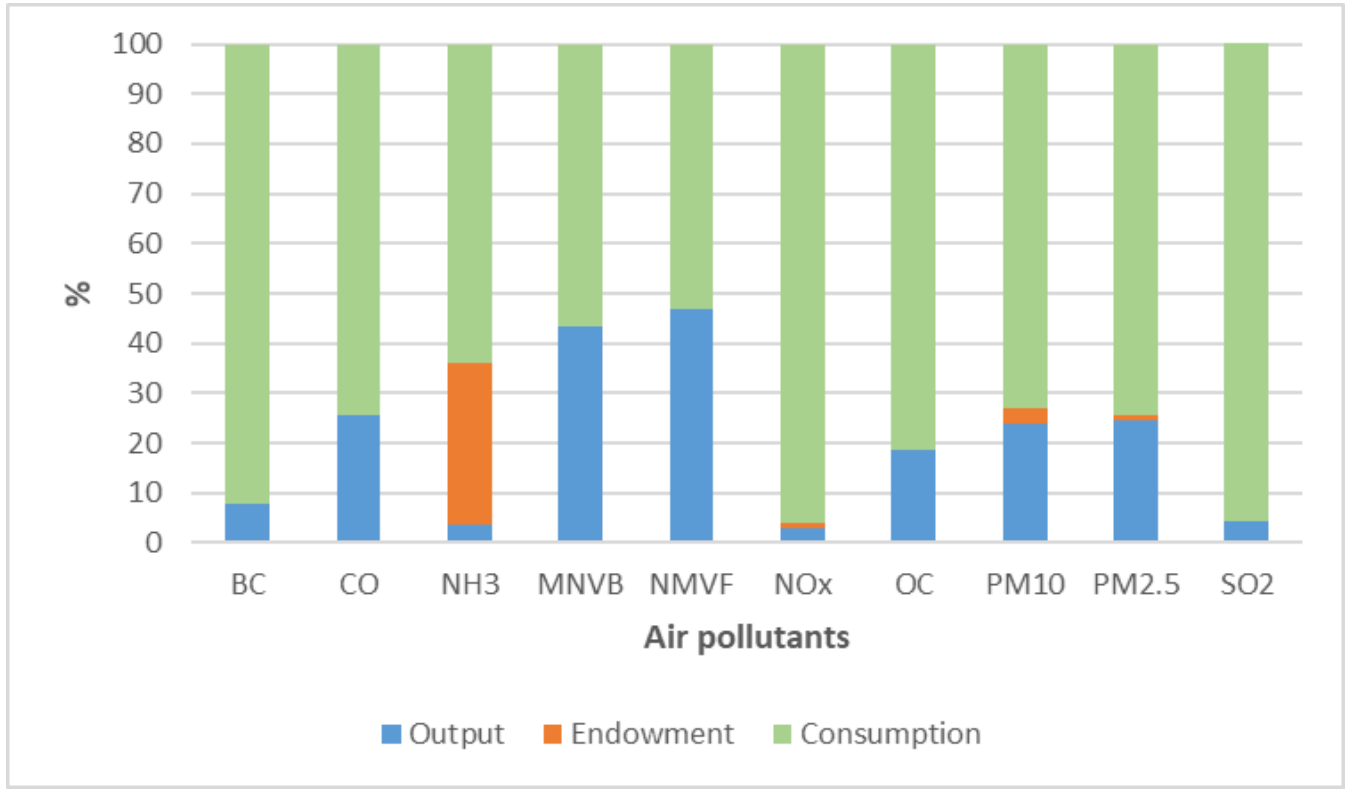
Processing steps:
- data gap filling (emission growth approach);
- mapping to GTAP regions.

Output data:
- 2004, 2007 and 2011 emissions;
- 10 pollutants, 141 regions, 36 emission sources.

Consumption-linked emissions

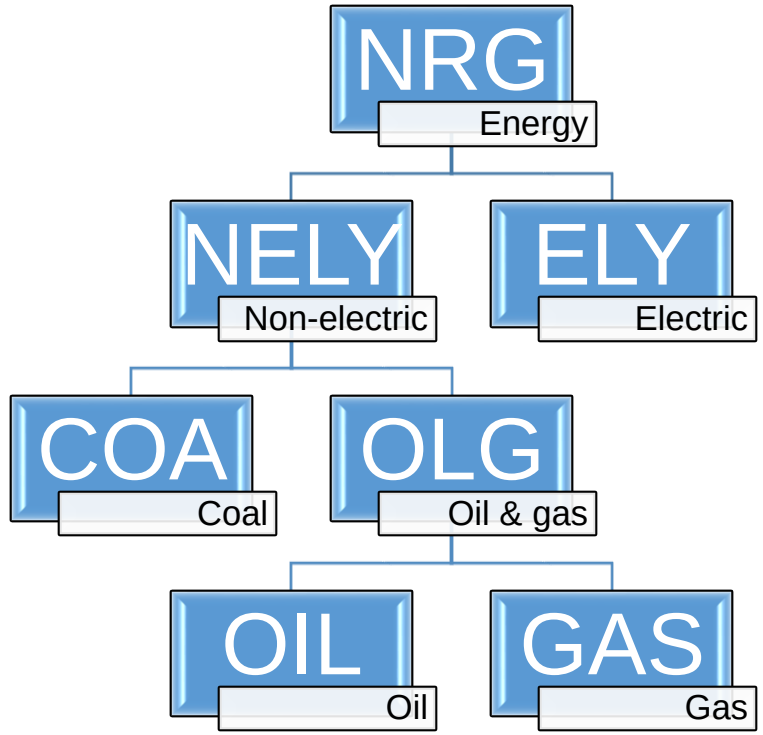
Output-linked emissions

Endowment-linked emissions



4.10. Modelling framework – ENVISAGE (1)

- **Global recursive-dynamic CGE model**
  - 2011-2100
- **Calibrated to GTAP-Power v9.2** (2011 base year)
- **Nested energy demand:**
  - energy preferences are agent-specific; substitution elasticities are vintage specific; autonomous energy efficiency improvement
- **Flexible incorporation of carbon pricing**
  - carbon tax, caps with and without trade, exemptions
- **Dynamics:**
  - exogenous labor growth; capital growth a function of savings; exogenous land, energy and trade productivity
- **Current mapping:** 24 sectors and 14 regions



4.11. Modelling framework – ENVISAGE (2)

- **Representative household**
  - 5 utility functions (CD, LES, ELES, AIDADS, CDE)
- **Armington trade**
  - Top level sourcing (domestic v. importer) either agent specific or national
  - Second level sourcing (across exporting regions) is national
- **Preference shift parameters**
  - Change the preference for one set of commodities in a demand system relative to other commodities, but without changing the aggregate cost
- **Bilateral trade prices**
  - Producer
  - Border (FOB) – Producer plus export tax/subsidy
  - Border (CIF) – FOB + international trade and transport margin
  - Domestic – CIF + import tariff

4.12. Modelling framework – ENVISAGE (3)

- **Cost of fossil fuels driven in part by supply elasticities**
- **Model incorporates Kyoto greenhouse gases (GHGs)**
  - CO_2 (fossil fuel combustion), N_2O, CH_4 and F-gases
- **Air pollution representation**
  - 10 air pollutants - BC, CO, NH_3, NMVB, NMVF, NO_x, OC, PM10, PM2.5, SO_2
- **Flexible incorporation of carbon pricing**
  - Carbon tax
  - Caps with and without trade
  - Exemptions (partial or full and agent specific)

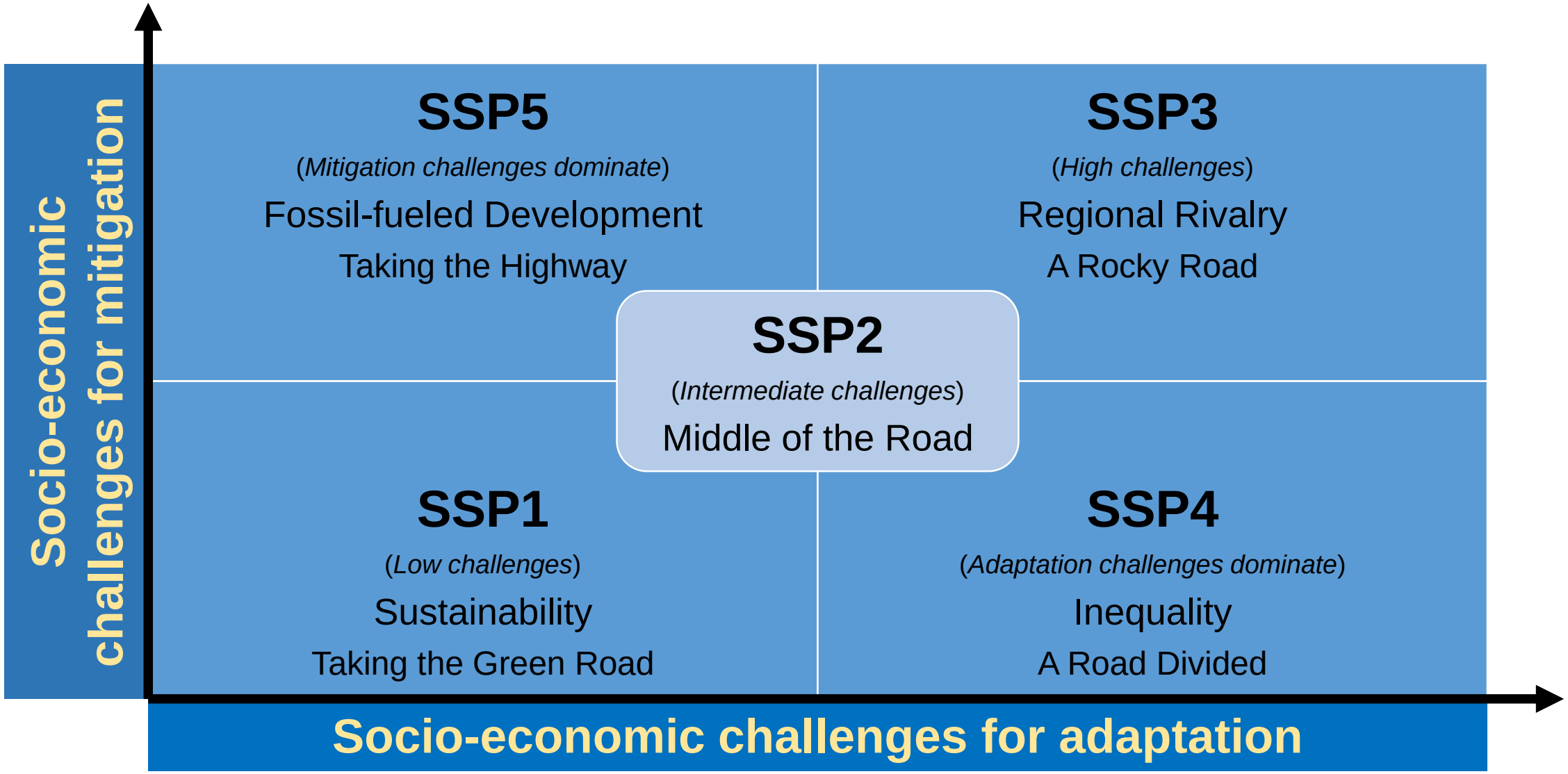
4.13. Dynamics in ENVISAGE

- **Labor/population**
  - UN Population Division
  - IIASA/Shared Socio-economic Pathways (SSPs)
  - Labor growth = growth of working age population (15-64), constant LFPR
- **Capital growth a function of savings**
  - $K_t=(1-\delta)K_{t-1} + I_{t-1}$ $I=S^h+S^g+S^f$
- **Productivity**
  - Labor productivity, differentiated across activities
  - Land productivity, calibrated to external assumptions
  - Energy efficiency, calibrated to external assumptions
  - Trade and transport margins efficiency improvement

4.14.

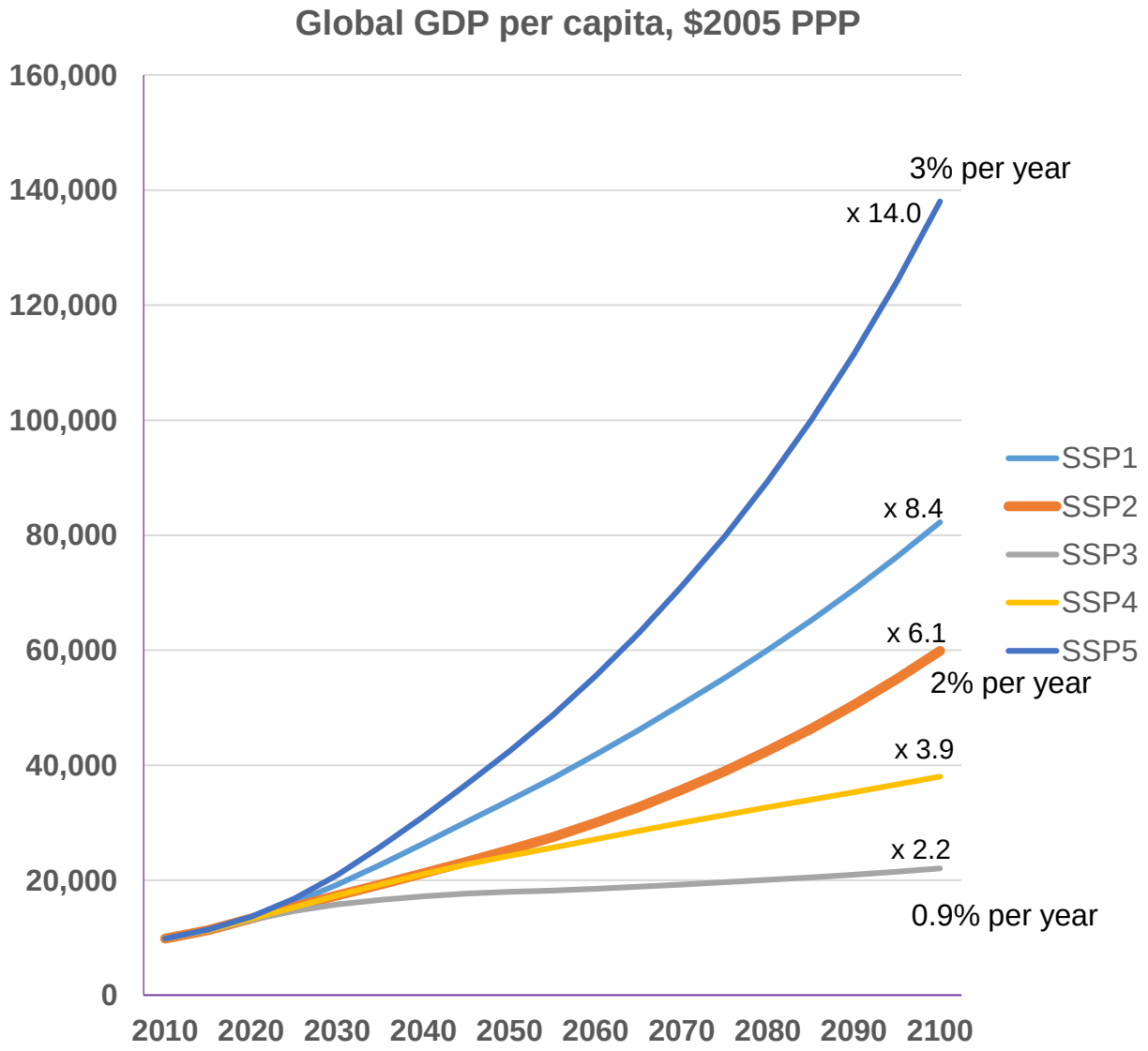
- **Evolution of the economics of climate change community**
  - Since 2007, Integrated Assessment Modeling Consortium (IAMC)
  - Coordinates international research on climate change
  - Provides key contributions to IPCC Assessment Reports
- **Key drivers available**
  - Demographics, education, GDP and urbanization
- **Require additional assumptions on:**
  - Evolution of energy sector, environmental indicators, consumption behavior

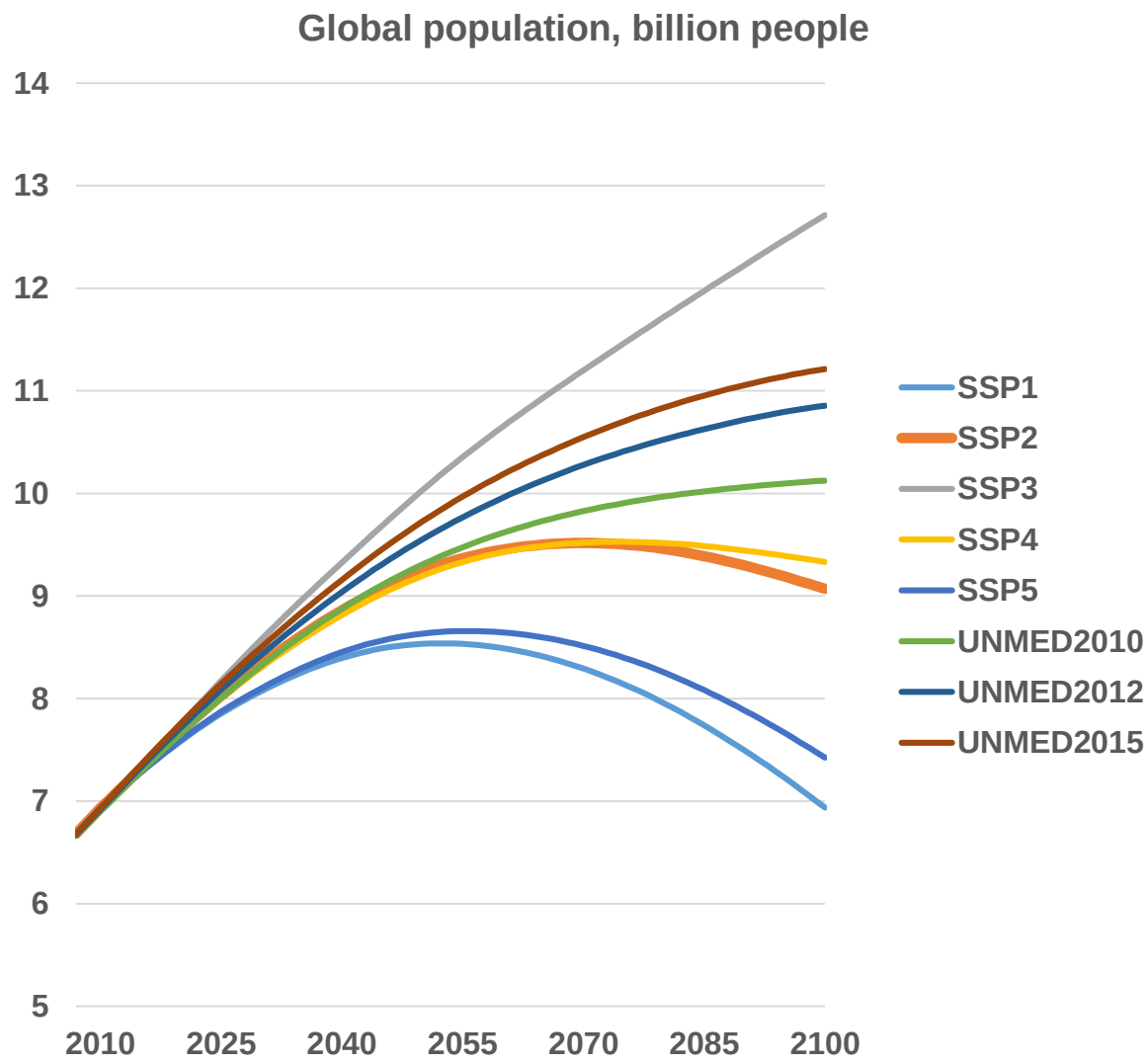
4.15. Two-axes: adaptation & mitigation challenges



Source: O'Neill et al. 2015

4.16. SPP's macroeconomic and demographic assumptions



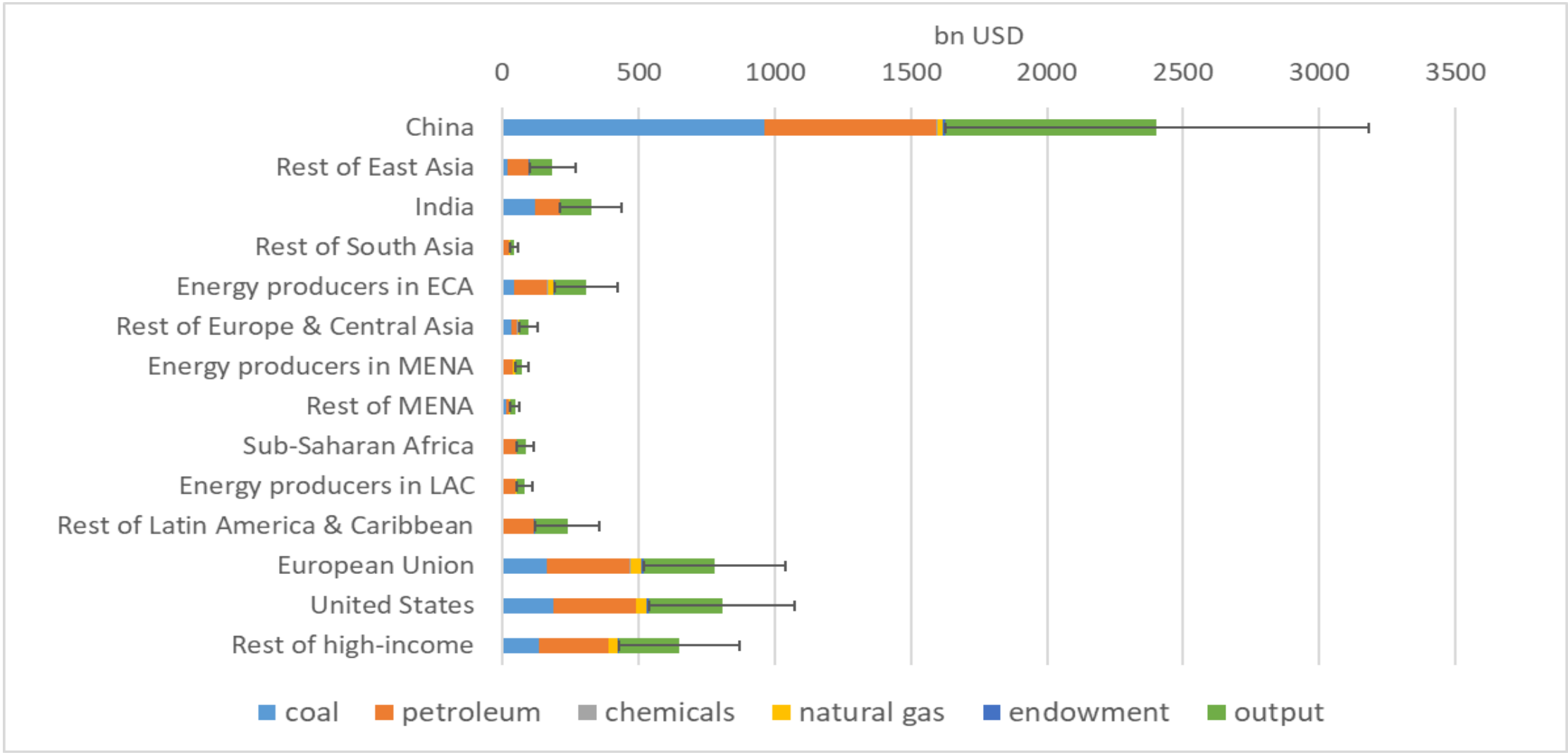


Source: IIASA/OECD 2013, UN Population Division (2010, 2012, 2015)..

4.17. Emission co-benefits assessment

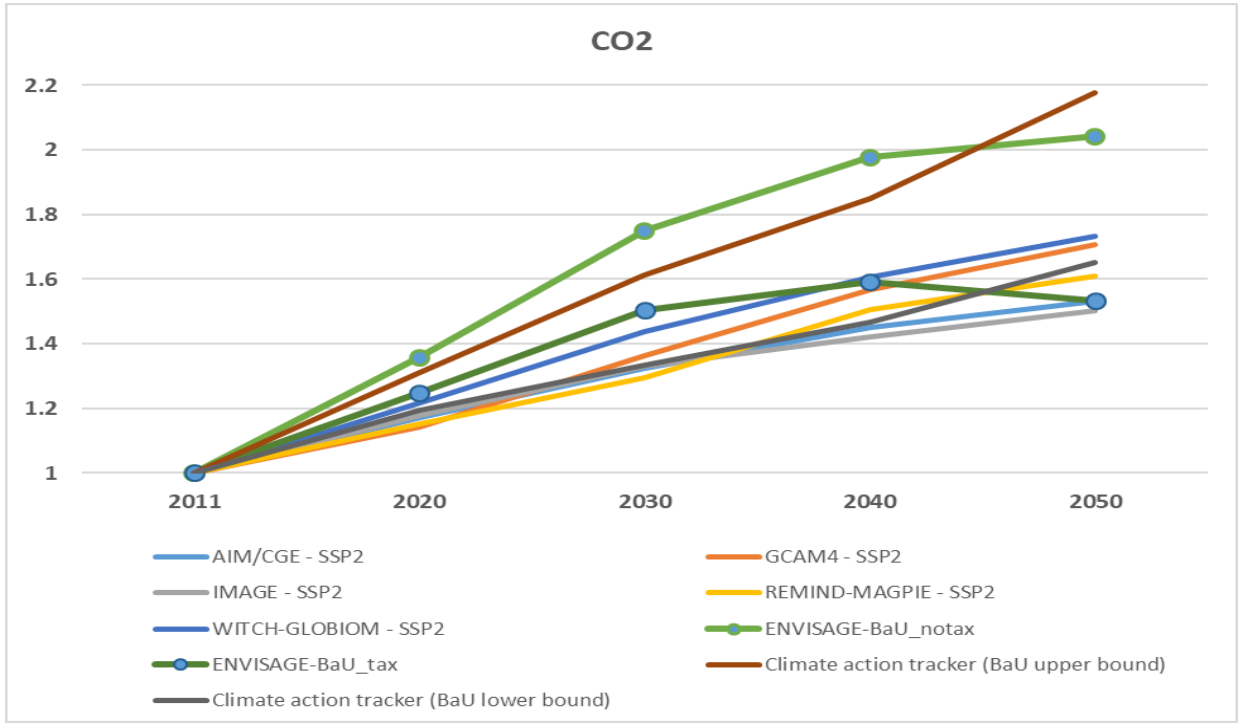
- ***Changes in GHGs emissions*** *(CO_2,* N_2O, CH_4 and F-gases*)* ***and air pollution*** *(SO_2, NOx, PM2.5)* due to environmental policy application within ENVISAGE modelling framework.
- ***Deaths per ton*** for each emitter, energy product and four diseases (chronic obstructive pulmonary disease, lung cancer, ischemic heart disease and stroke) (IMF, 2015; WHO). Premature deaths of population under 25 are excluded.
- ***Value of statistical life*** (VSL) estimates based on willingness to pay (WTP) approach adopted from OECD (2016a) study (3 million, $2005) and country-adjusted based on per capita GDP PPP values (IMF, 2015) and income elasticity of VSL (0.8). Is assumed to grow region-specific at per capita GDP growth rate.
- ***Systematic Sensitivity Analysis*** (SSA) approach based on meta-analysis studies - lower and upped bounds for OECD VSL equal to $1.5 million and $4.5 million ($2005 PPP) respectively; income elasticity varies between 0.7 and 0.9. Social cost of carbon (SCC) varies between $15/ton CO_2 and $55/ton CO_2 with central value $35 (is assumed to grow 3% annually).
- ***ENVISAGE-based co-benefits assessment*** monetary valuation of changes in pre mature deaths level and GHGs emissions.

4.18. Mortality-associated air pollution costs in 2011, bn USD

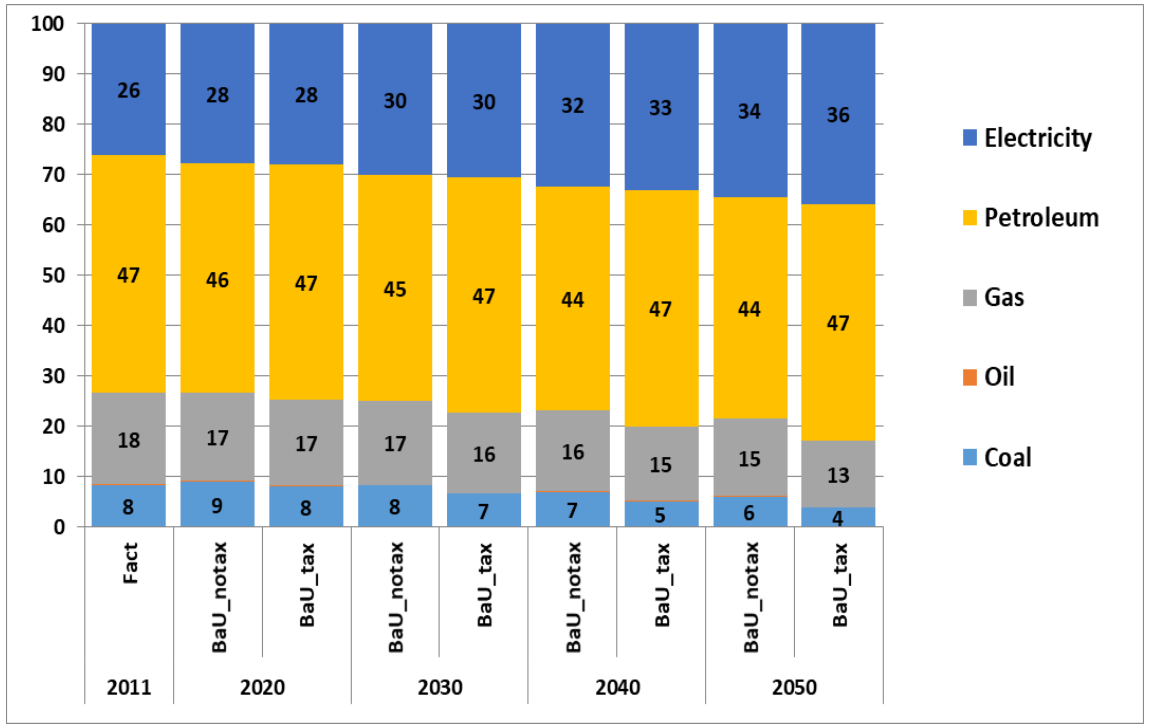


5.1. Baseline scenarios

- ***Macroeconomic and demographic assumptions:*** SSP2 scenario
- ***Energy assumptions:*** target increase in electricity share, cost reduction for renewables, preference twist for renewables;
- ***Carbon taxation:*** no carbon taxes in ***"BaU_notax"*** scenario, slight carbon tax ($7/ton in 2020 with 5% annual increase) in ***"BaU_tax"*** scenario.

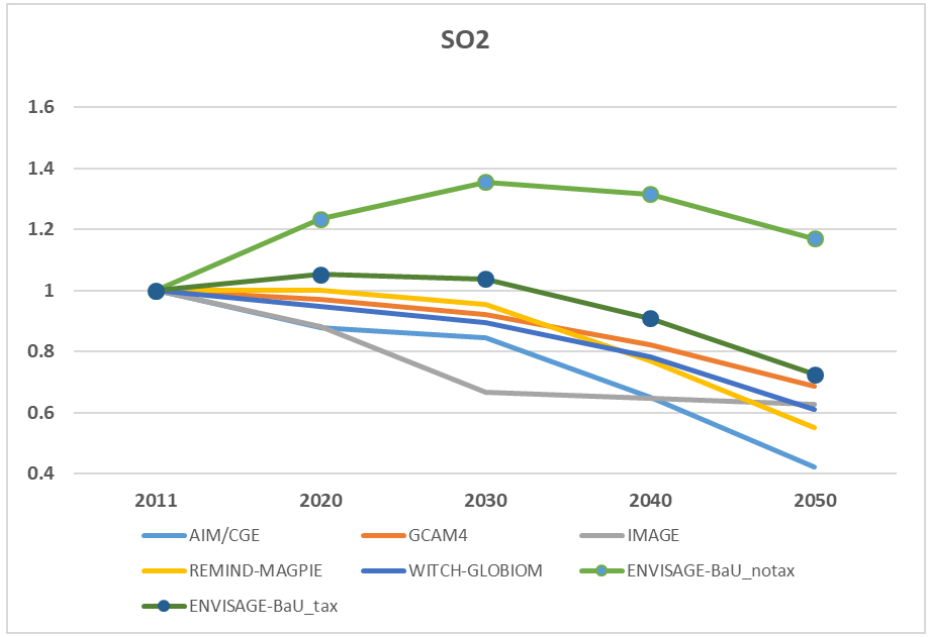


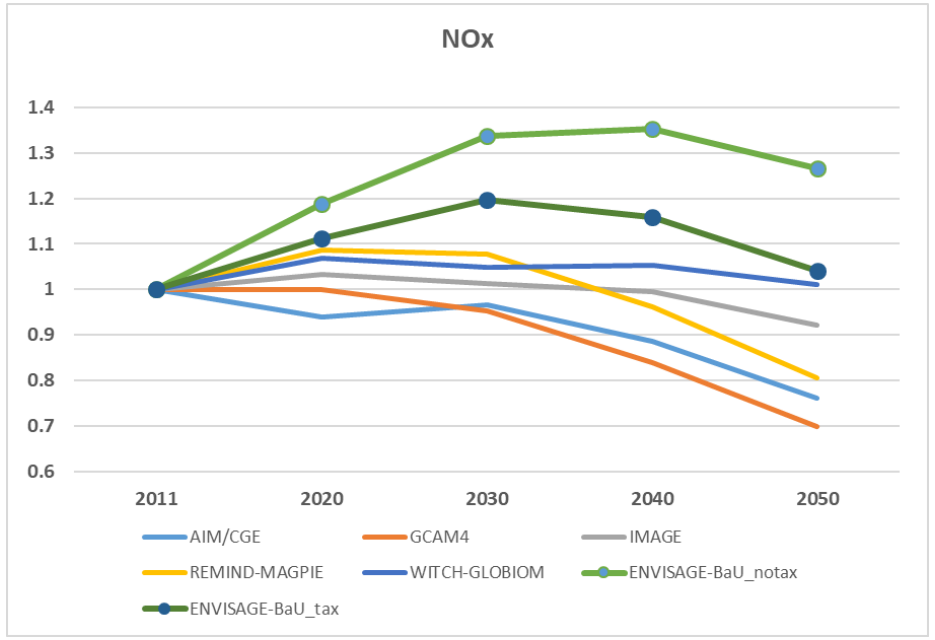
Comparison of baseline CO_2 emissions (2011=1)

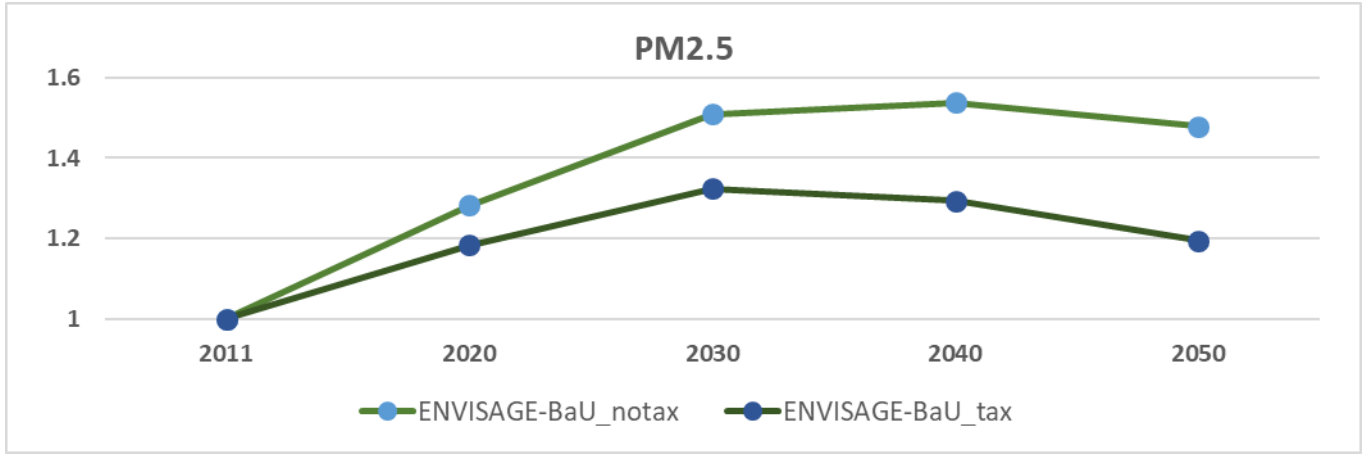


Global shares of final energy consumption by sources and BaU scenarios

5.2. Baseline scenarios – air pollution (2011 = 1)





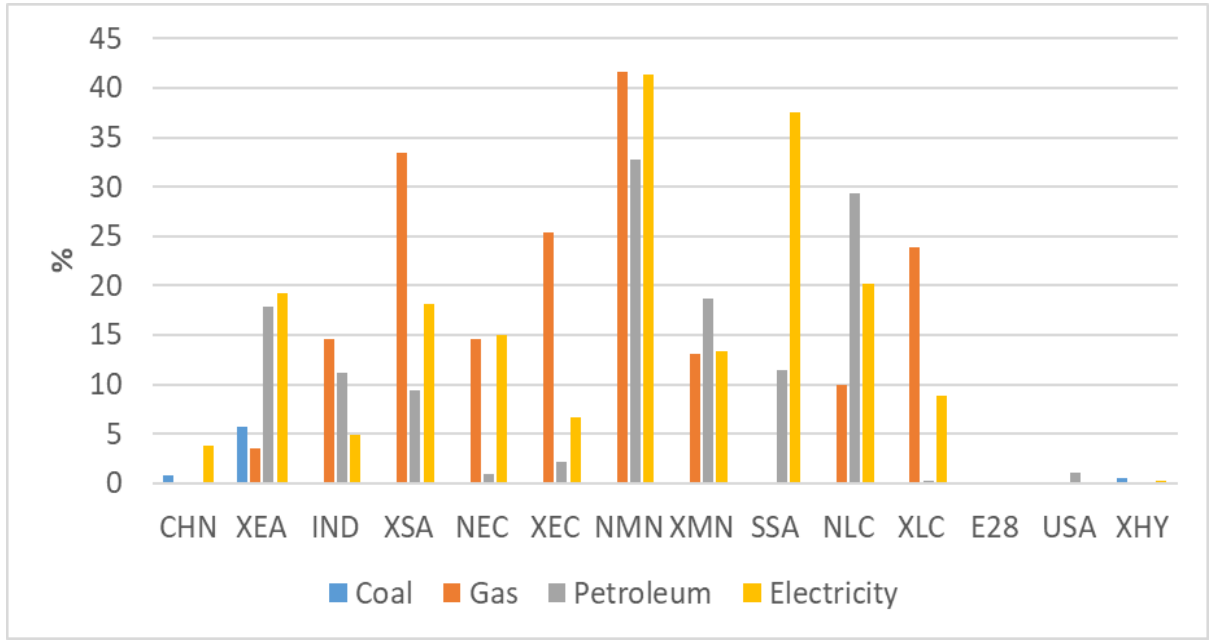


"BaU_tax" air pollution profiles are close to OECD 2016 study on the "The economic consequences of outdoor air pollution".

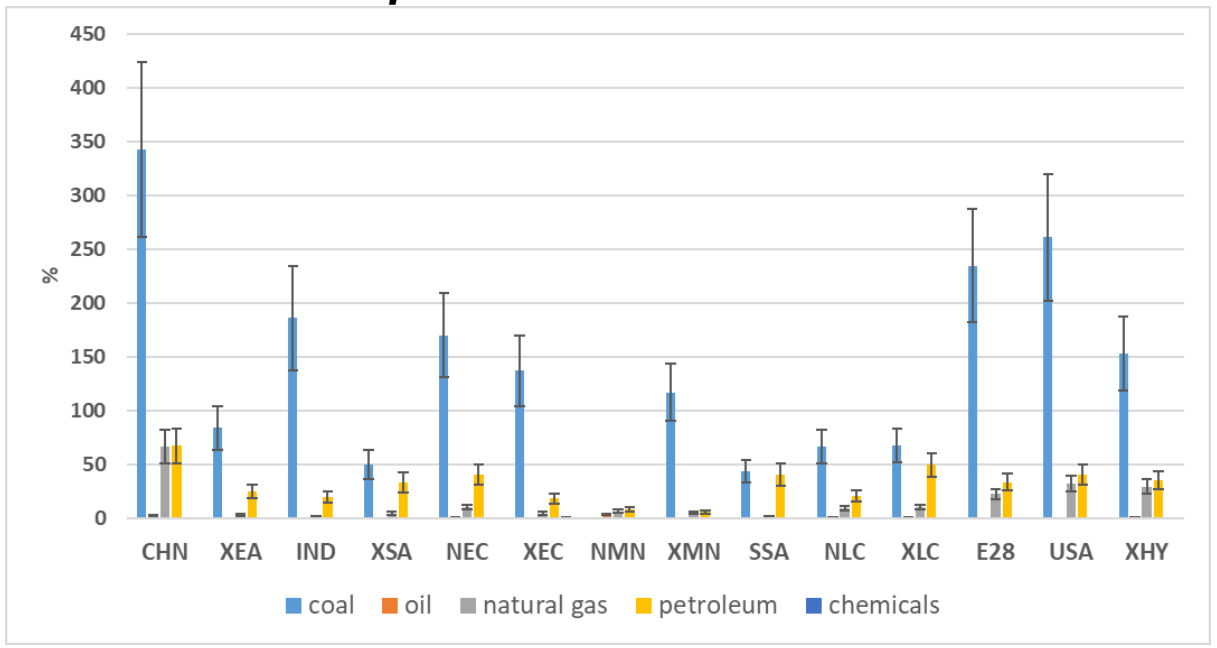
5.3. Energy subsidy elimination scenarios

Elimination of energy subsidies through corresponding energy commodity taxes increase relative to the 2011 benchmark. 2020-2030 elimination timeframe for pre-tax subsidies; 2020-2050 elimination for post-tax

Pre-tax consumption energy subsidies elimination



Air pollution taxation



Weighted average energy consumption tax rate changes, %

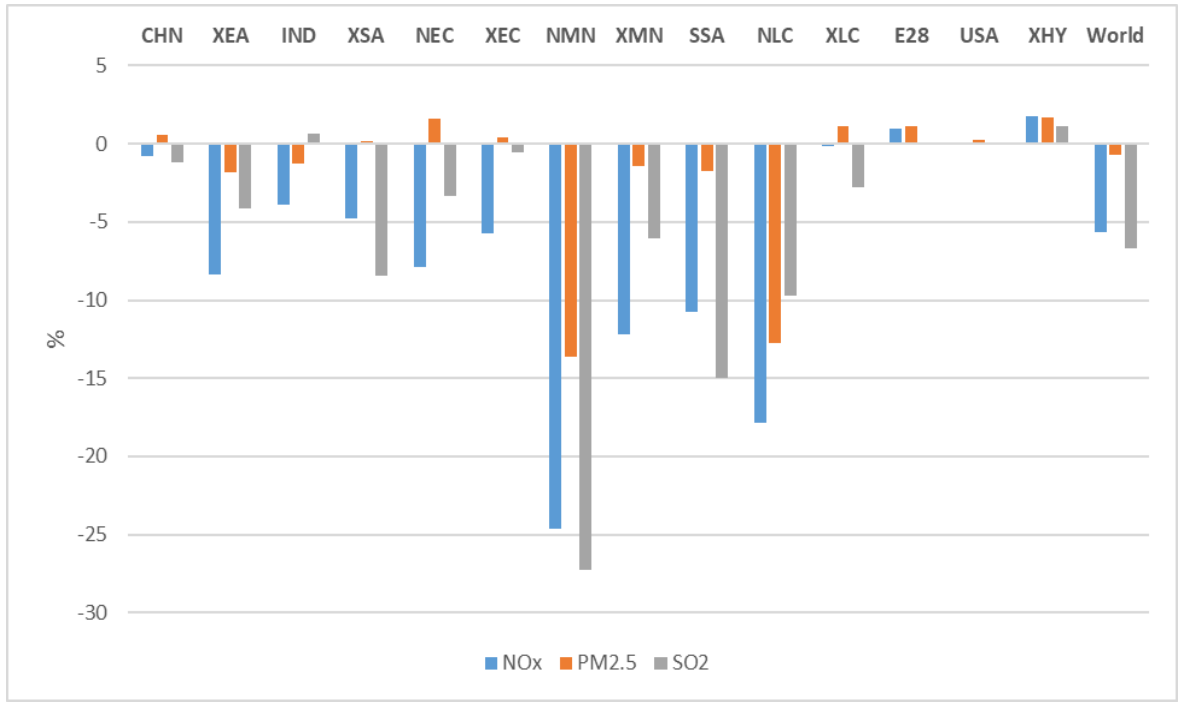
Scenario 1 = pre-tax subsidies elimination;
Scenario 2 = Scenario 1 + pollution taxation -> ***post-tax subsidies***

X 2 BaU paths X SSA analysis

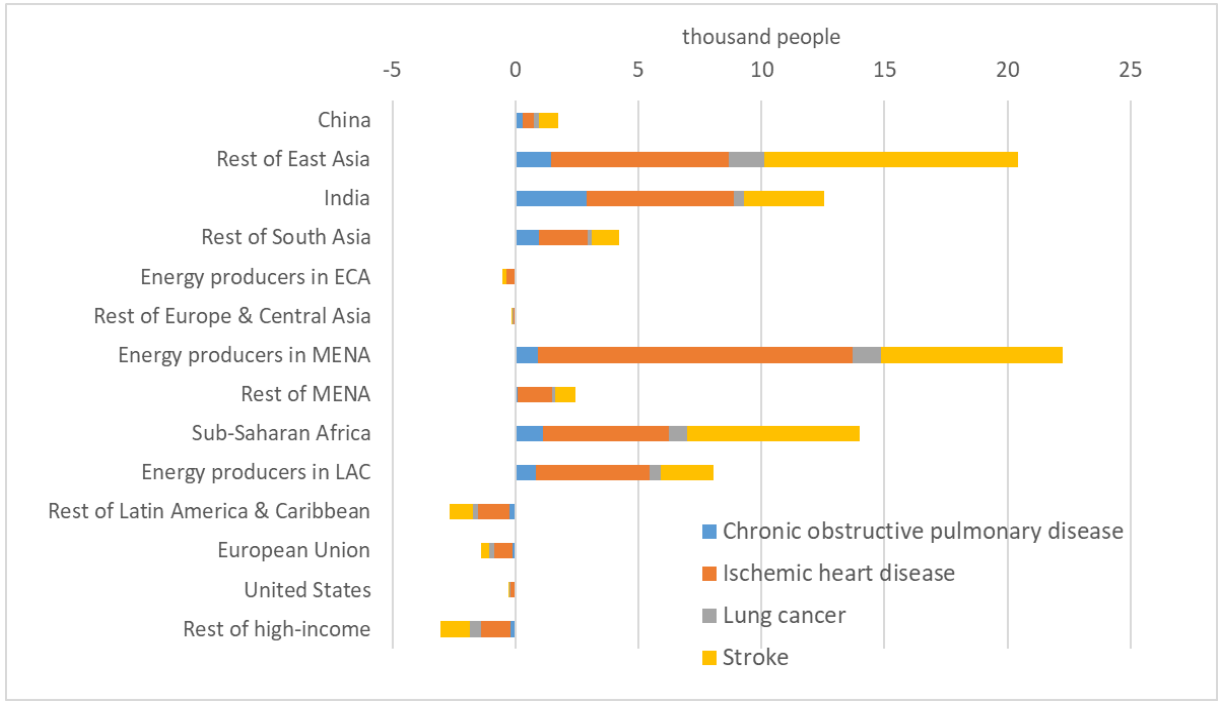
5.4. Pre-tax subsidies elimination: aggregate results (w.r.t. “ENVISAGE-BaU_notax” in 2050)

Region	GDP		HHs real income		GHG emissions, %	Emission welfare co-benefits, bn $2011	Net welfare changes, bn $2011
	bn $2011	%	bn $2011	%			
China	6.8	0.0	-15.8	-0.1	-2.0	42.7 (24.3; 61.1)	26.9 (8.5; 45.3)
Rest of East Asia	-5.8	-0.1	-2.3	0.0	-6.1	71.7 (45.2; 98.1)	69.4 (42.9; 95.8)
India	-44.7	-0.3	-24.9	-0.3	-2.7	38.9 (24.6; 53.2)	14 (-0.3; 28.3)
Rest of South Asia	-4.2	-0.2	-5.5	-0.3	-7.9	12.8 (8.1; 17.5)	7.3 (2.6; 12)
Energy producers in ECA	-36.3	-0.6	-34.6	-1.0	-8.8	21.8 (9.8; 33.8)	-12.8 (-24.8; -0.8)
Rest of Europe & Central Asia	-24.0	-1.4	-6.0	**-0.6**	-9.9	10 (4.9; 15.2)	**4.1 (-1.1; 9.2)**
Energy producers in MENA	92.6	1.0	5.5	0.1	-27.3	172.5 (115; 229.9)	177.9 (120.5; 235.4)
Rest of MENA	-20.3	-0.4	-20.0	**-0.6**	-10.8	21.6 (13.8; 29.4)	**1.6 (-6.2; 9.4)**
Sub-Saharan Africa	-22.1	-0.2	-39.7	**-0.6**	-10.8	68.2 (43.6; 92.8)	**28.5 (3.9; 53.1)**
Energy producers in LAC	-12.3	-0.2	-19.0	**-0.5**	-13.0	42.5 (28; 56.9)	**23.5 (9; 37.9)**
Rest of Latin America & Caribbean	-0.9	0.0	-3.2	0.0	-2.4	-5.2 (-10.1; -0.3)	-8.4 (-13.3; -3.5)
European Union	33.8	0.1	-23.0	-0.1	0.9	-12.1 (-16.2; -8)	-35.1 (-39.2; -31)
United States	12.5	0.0	-13.7	-0.1	0.1	-2.9 (-4; -1.8)	-16.6 (-17.8; -15.5)
Rest of high-income	25.6	0.1	-0.6	0.0	1.1	-26.2 (-36.2; -16.3)	-26.9 (-36.8; -16.9)
World	**0.7**	**0**	**-203.0**	**-0.1**	**-5.1**	**456.3 (296; 616.6)**	**253.3 (93.0; 413.6)**

5.5. Pre-tax subsidies elimination: pollution impacts (w.r.t. “ENVISAGE-BaU_notax” in 2050)

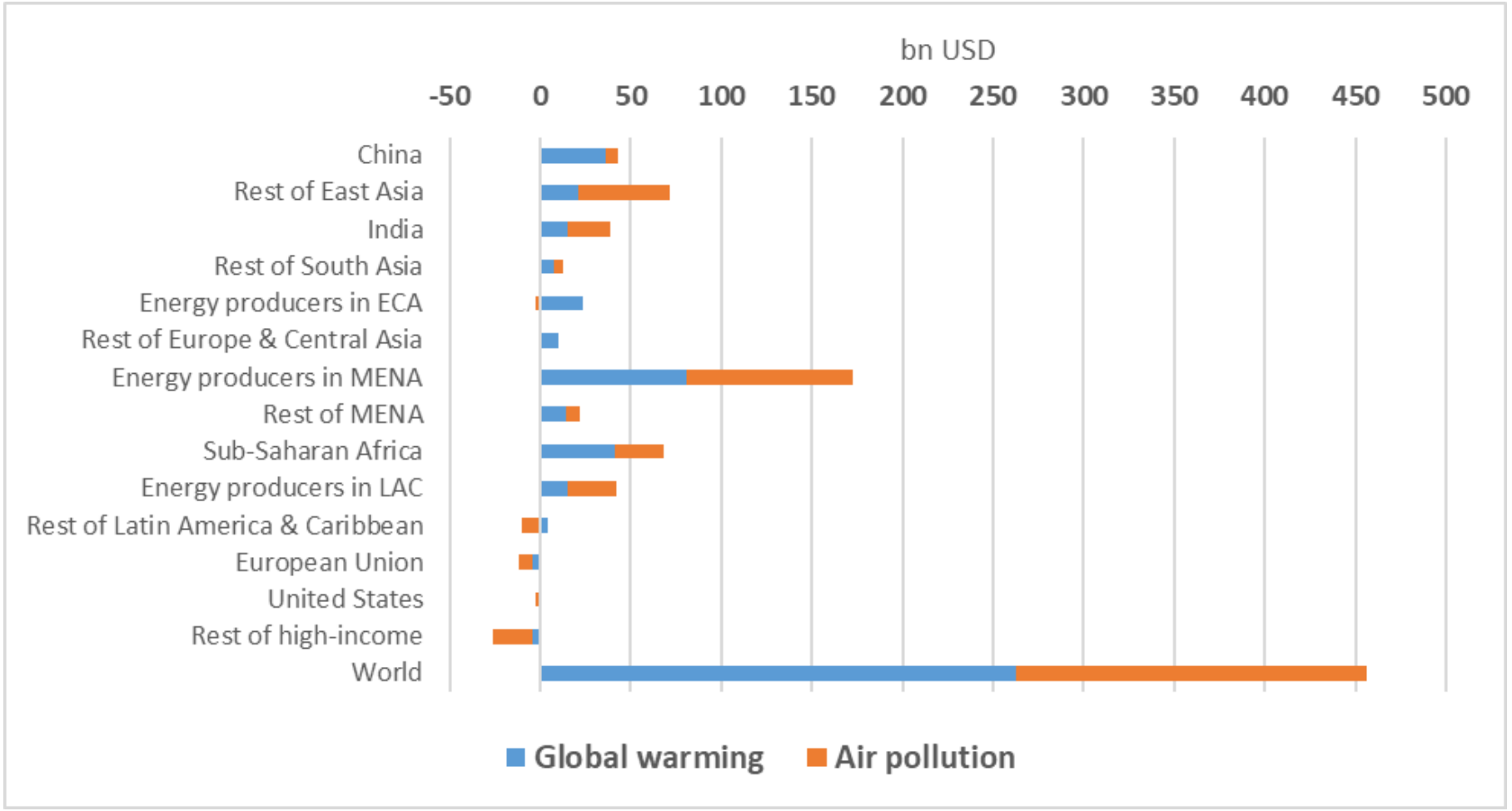


Air pollutants emission changes, %



Mortality reduction, thousand people

5.6. Decomposition of fossil-fuel consumption subsidies elimination co-benefits (bn USD in 2050)

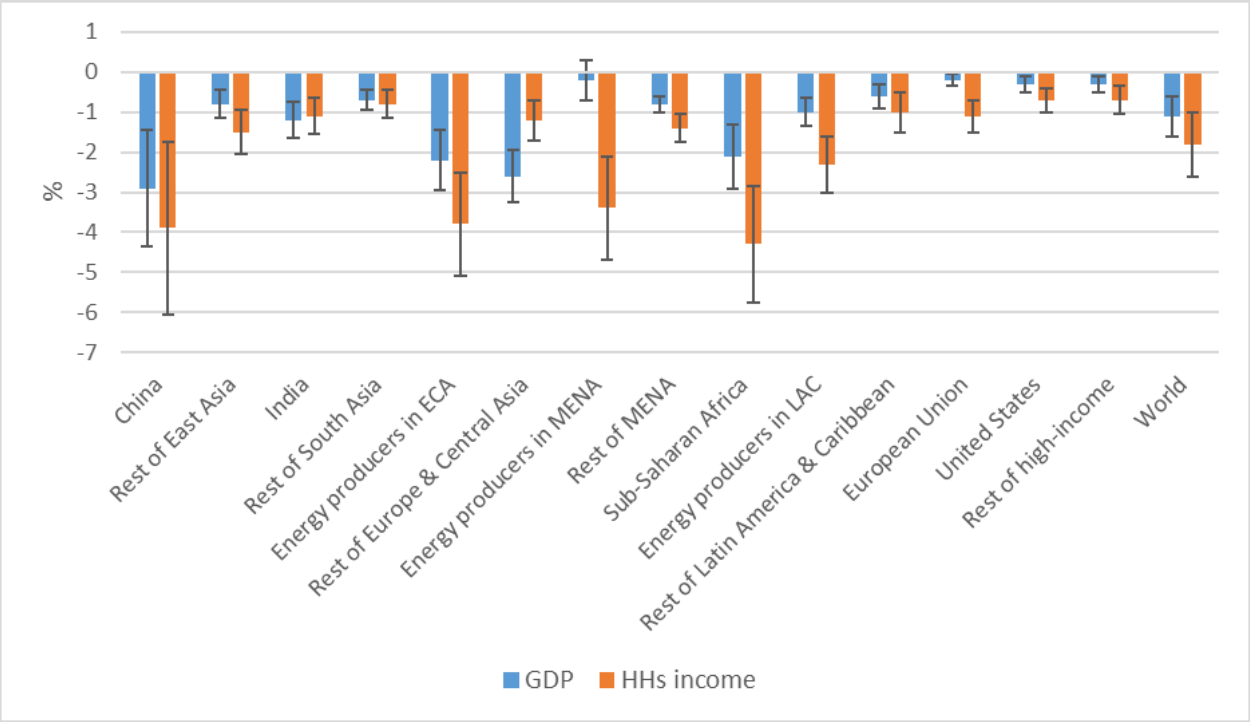


Consumption fossil-fuel subsidies elimination (w.r.t. "ENVISAGE-BaU_notax" in 2050)

5.7. Pre-tax subsidies elimination (w.r.t. "ENVISAGE-BaU_tax" in 2050)

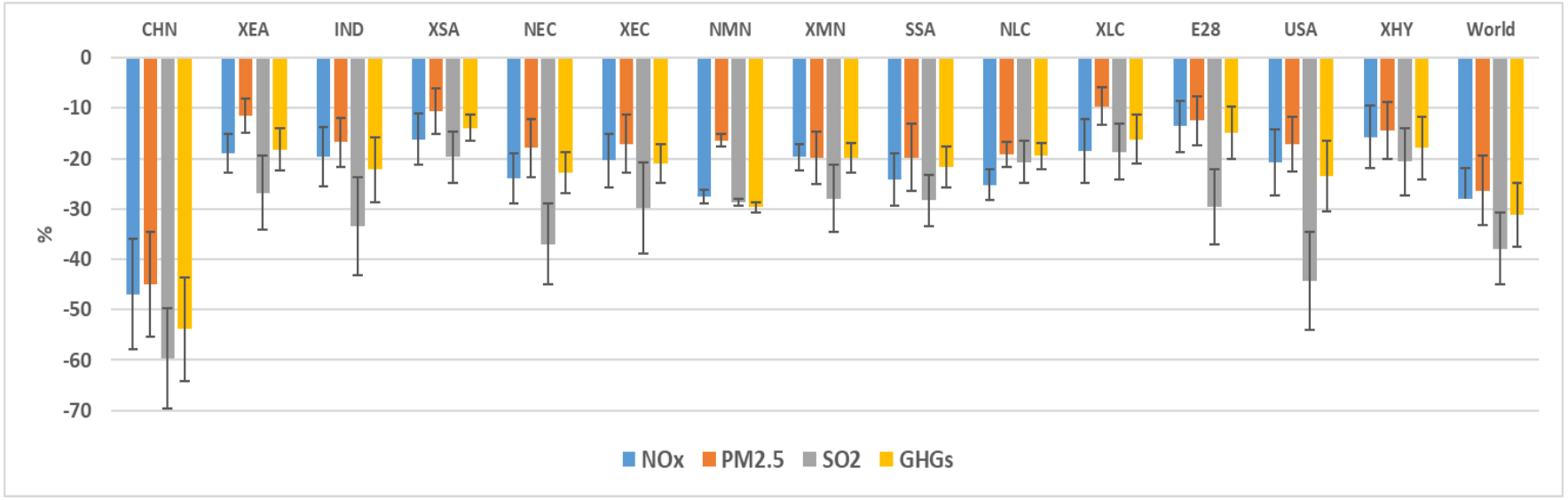
Region	GDP		HHs real income		GHGs emissions, %	Emission welfare co-benefits, bn $2011	Net welfare changes, bn $2011
	bn $2011	%	bn $2011	%			
China	4.4	0.0	-15.8	-0.1	-0.8	**-46.9 (-73.6; -20.3)**	**-62.7 (-89.4; -36.1)**
Rest of East Asia	-17.4	-0.2	-15.1	-0.2	-6.2	63.5 (40.1; 86.9)	48.4 (25; 71.8)
India	-50.3	-0.4	-31.3	-0.3	-3.6	40.2 (24.8; 55.5)	8.9 (-6.5; 24.2)
Rest of South Asia	-6.6	-0.2	-7.9	-0.4	-6.7	10.7 (6.8; 14.6)	2.8 (-1.1; 6.7)
Energy producers in ECA	-44.8	-0.7	-43.2	-1.2	-8.7	18.7 (8.3; 29)	-24.5 (-34.9; -14.2)
Rest of Europe & Central Asia	-24.7	-1.5	-8.7	**-0.9**	-9.4	9.6 (5.1; 14.2)	**0.9 (-3.6; 5.5)**
Energy producers in MENA	37.3	0.4	-44.8	**-0.8**	-25.5	154.7 (103.2; 206.2)	**109.9 (58.4; 161.4)**
Rest of MENA	-25.8	-0.5	-24.3	-0.7	-10.0	18.6 (12.1; 25.1)	-5.7 (-12.2; 0.8)
Sub-Saharan Africa	-30.3	-0.3	-45.2	-0.7	-7.1	31.2 (19.5; 43)	-14 (-25.8; -2.2)
Energy producers in LAC	-18.3	-0.3	-24.3	**-0.6**	-12.2	35.3 (23.3; 47.4)	**11 (-1.1; 23.1)**
Rest of Latin America & Caribbean	-1.7	0.0	-3.8	-0.1	-1.1	-6.7 (-10.7; -2.8)	-10.6 (-14.5; -6.6)
European Union	32.5	0.1	-22.5	-0.1	0.8	-11 (-14.8; -7.3)	-33.5 (-37.2; -29.8)
United States	12.0	0.0	-14.0	-0.1	0.0	-2.3 (-3.2; -1.3)	-16.3 (-17.2; -15.3)
Rest of high-income	25.4	0.1	-0.6	0.0	1.1	-23.2 (-32.1; -14.4)	-23.8 (-32.6; -15)
World	**-108.2**	**-0.1**	**-301.4**	**-0.2**	**-4.7**	**292.2 (185.8; 398.6)**	**-9.2 (-115.6; 97.2)**

5.8. Post-tax subsidies elimination: aggregate results (w.r.t. “ENVISAGE-BaU_notax” in 2050)

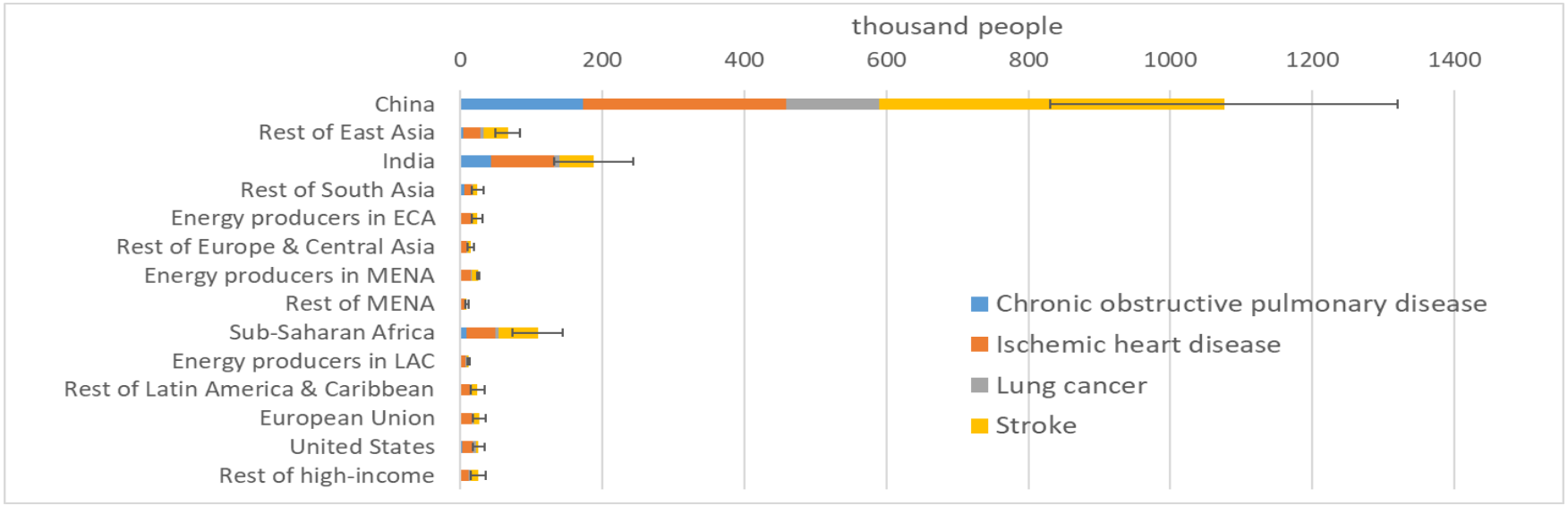


Region	Emission co-benefits,	Net welfare changes,
	bn $2011	
China	4554.8 (1793.7; 7315.9)	***3639.2 (1382.5; 5895.9)***
Rest of East Asia	227 (90.7; 363.3)	***119.8 (23.1; 216.5)***
India	462.8 (151.5; 774.1)	***362.2 (92.1; 632.4)***
Rest of South Asia	44.2 (14.5; 73.8)	***27.3 (3.7; 50.8)***
Energy producers in ECA	145 (65.1; 224.8)	***6 (-31.8; 43.8)***
Rest of Europe & Central Asia	46.6 (21.2; 72)	***34.5 (13.6; 55.3)***
Energy producers in MENA	190.4 (121.6; 259.2)	-7 (-55.1; 41.1)
Rest of MENA	53.5 (27.8; 79.2)	***4.5 (-11.4; 20.4)***
Sub-Saharan Africa	290.9 (103; 478.8)	-6.9 (-102.4; 88.5)
Energy producers in LAC	61.6 (34.3; 88.9)	-34.1 (-45.9; -22.3)
Rest of LAC	117.9 (37; 198.7)	***42 (-4.2; 88.2)***
European Union	220.1 (78.1; 362.1)	-24.4 (-77; 28.3)
United States	342.4 (144.2; 540.6)	***184.1 (53.3; 314.9)***
Rest of high-income	247.7 (74.3; 421.1)	***130.7 (14.2; 247.2)***
World	7004.7 (2830.7; 11178.7)	***4477.9 (1409.5; 7546.3)***

5.9. Post-tax subsidies elimination: pollution impacts (w.r.t. “ENVISAGE-BaU_notax” in 2050)

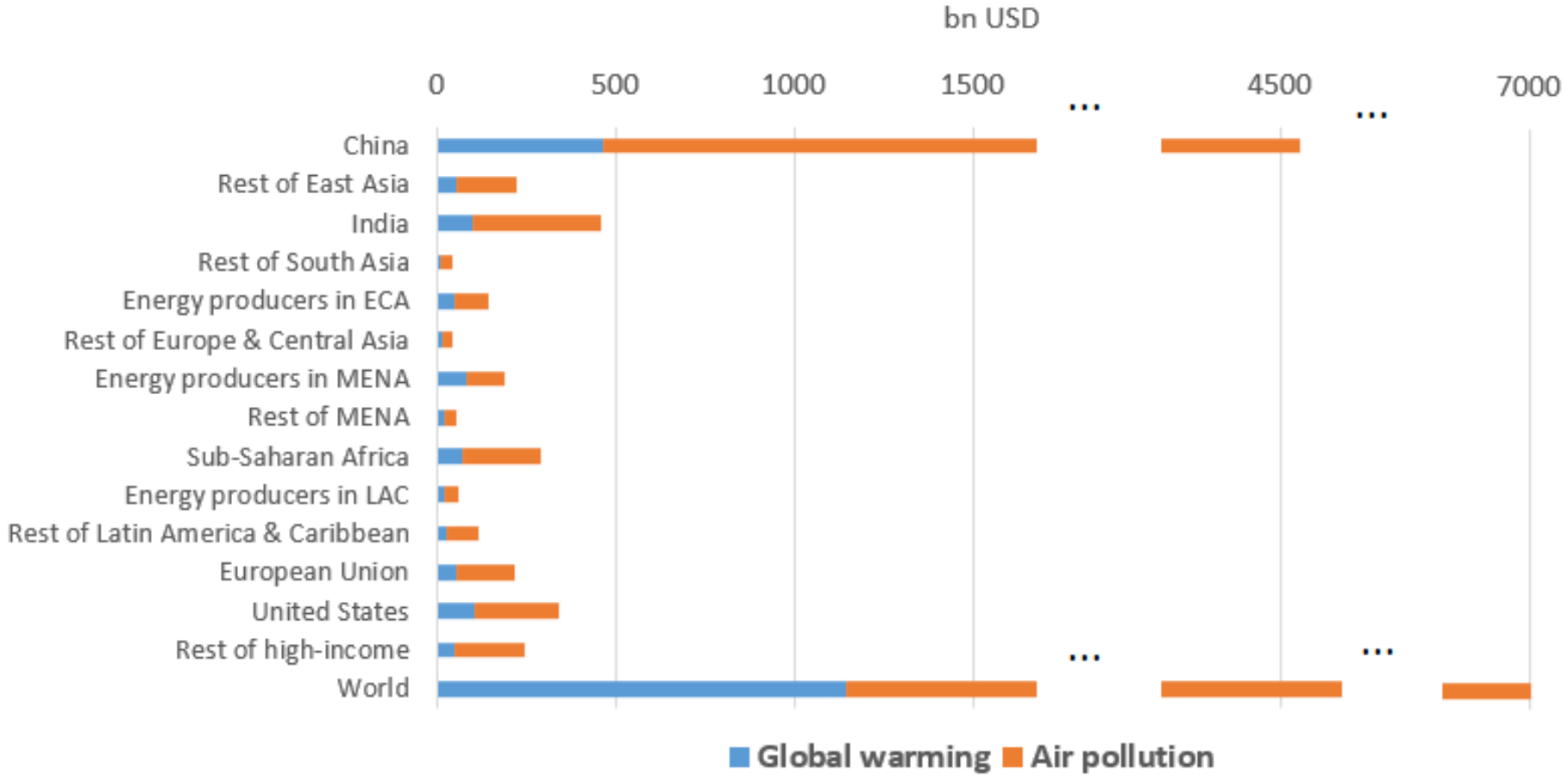


Emission changes, %



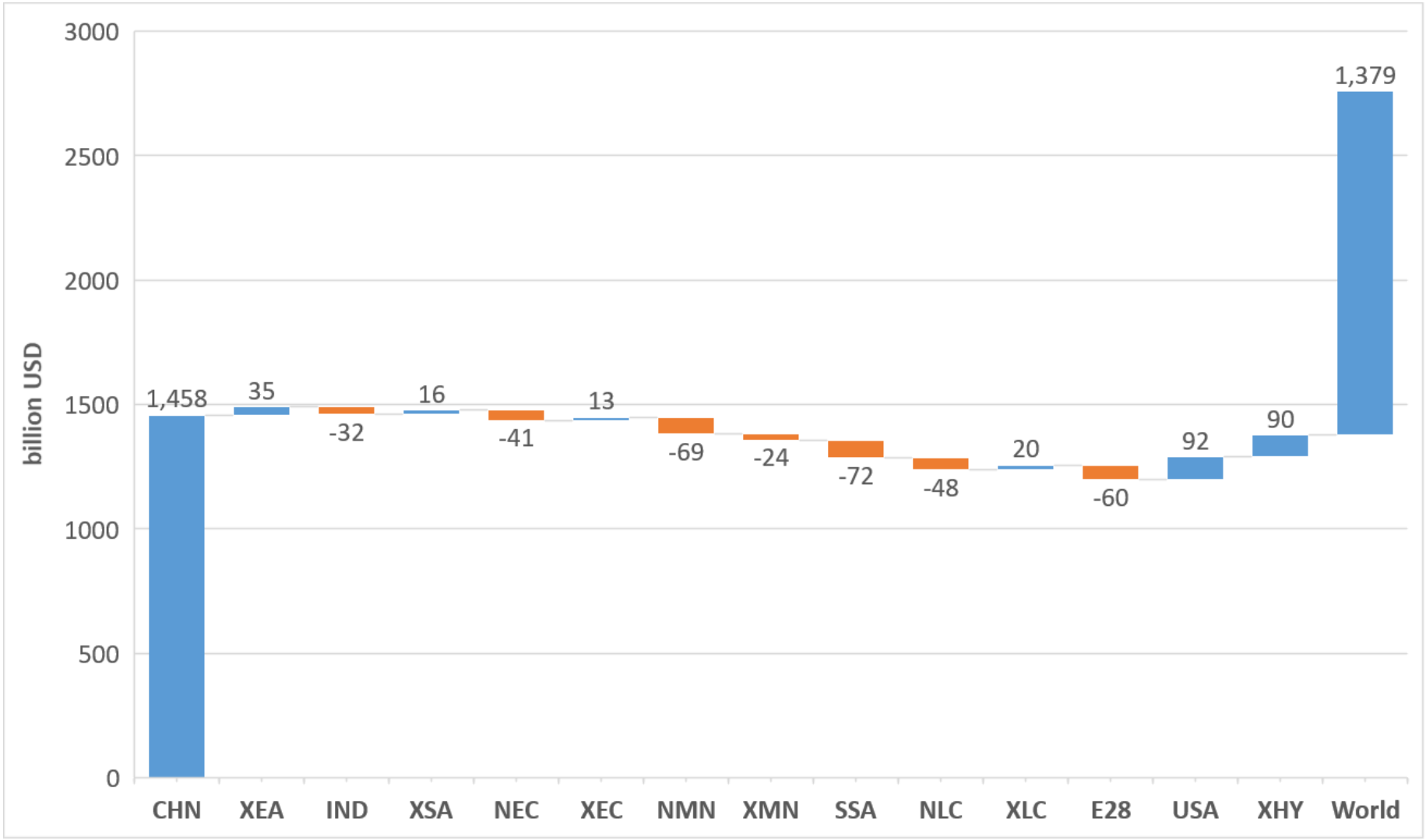
Mortality reduction, thousand people

5.10. Decomposition of post-tax subsidies elimination co-benefits (bn USD in 2050)



Post-tax subsidies elimination (w.r.t. "ENVISAGE-BaU_notax" in 2050)

5.11. Post-tax subsidies elimination: net welfare change (w.r.t. “ENVISAGE-BaU_tax” in 2050)



Conclusion

- Energy subsidies have large fiscal and distortive impacts.
- Shift towards renewables.
- Global GHG emissions reduction by 4.7-5.1% in 2050 for pre-tax subsidies elimination; 22.1-31.2 for post-tax subsidies reform.
- Global air pollution (SO2, NOx, PM2.5) reduction up to 25%-40% due to pollution taxation.
- Avoidance of 49 (pre-tax) – 1654 (post-tax) thousand deaths per year in a long run.
- Significant influence of air pollution-related mortality co-benefits (many regions becoming net winners).

Caveats

- Only mortality impacts are considered (for population over 25)
- Provide more focus on equivalent variation (EV) change over time and explore alternative policies of pollution taxes redistribution
- Explore in a consistent way policies towards reducing endowment- and output-linked pollution
- Sensitivity analysis with additional set of variables (substitution and transformation elasticities, concentration-response functions, etc.)
- Direct integration of environmental feedback to the production framework (impact on labor productivity, health expenditures, etc.)

Global Trade Analysis Project

Questions/Comments?

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Regional mapping for policy experiment

Aggregate region	GTAP region
China, P.R. (CHN)	China (CHN)
Rest of East Asia (XEA)	Rest of Oceania (XOC), Mongolia (MNG), Rest of East Asia (XEA), Brunei Darussalam (BRN), Cambodia (KHM), Indonesia (IDN), Laos (LAO), Malaysia (MYS), Philippines (PHL), Thailand (THA), Viet Nam (VNM), Rest of Southeast Asia (XSE)
India (IND)	India (IND)
Rest of South Asia (XSA)	Bangladesh (BGD), Nepal (NPL), Pakistan (PAK), Sri Lanka (LKA), Rest of South Asia (XSA)
Energy producers in ECA (NEC)	Russian Federation (RUS), Kazakhstan (KAZ), Tajikistan (TJK), Azerbaijan (AZE)
Rest of Europe & Central Asia (XEC)	Albania (ALB), Belarus (BLR), Croatia (HRV), Ukraine (UKR), Rest of Eastern Europe (XEE), Rest of Europe (XER), Kyrgyzstan (KGZ), Rest of Former Soviet Union (XSU), Armenia (ARM), Georgia (GEO)
Energy producers in MENA (NMN)	Bahrain (BHR), Iran (IRN), Kuwait (KWT), Oman (OMN), Qatar (QAT), Saudi Arabia (SAU), United Arab Emirates (ARE), Rest of Western Asia (XWS), Rest of North Africa (XNF)
Rest of MENA (XMN)	Jordan (JOR), Turkey (TUR), Egypt (EGY), Morocco (MAR), Tunisia (TUN)
Sub-Saharan Africa (SSA)	Benin (BEN), Burkina Faso (BFA), Cameroon (CMR), Côte d'Ivoire (CIV), Ghana (GHA), Guinea (GIN), Nigeria (NGA), Senegal (SEN), Togo (TGO), Rest of Western Africa (XWF), Central Africa (XCF), South-Central Africa (XAC), Ethiopia (ETH), Kenya (KEN), Madagascar (MDG), Malawi (MWI), Mauritius (MUS), Mozambique (MOZ), Rwanda (RWA), Tanzania (TZA), Uganda (UGA), Zambia (ZMB), Zimbabwe (ZWE), Rest of Eastern Africa (XEC), Botswana (BWA), Namibia (NAM), South Africa (ZAF), Rest of South African Customs Union (XSC), Rest of the World (XTW)
Energy producers in LAC (NLC)	México (MEX), Bolivia (BOL), Colombia (COL), Ecuador (ECU), Venezuela (VEN)
Rest of Latin America & Caribbean (XLC)	Argentina (ARG), Brazil (BRA), Chile (CHL), Paraguay (PRY), Peru (PER), Uruguay (URY), Rest of South America (XSM), Costa Rica (CRI), Guatemala (GTM), Honduras (HND), Nicaragua (NIC), Panama (PAN), El Salvador (SLV), Rest of Central America (XCA), Dominican Republic (DOM), Jamaica (JAM), Puerto Rico (PRI), Trinidad and Tobago (TTO), Rest of Caribbean (XCB)
European Union (E28)	Austria (AUT), Belgium (BEL), Cyprus (CYP), Czech Republic (CZE), Denmark (DNK), Estonia (EST), Finland (FIN), France (FRA), Germany (DEU), Greece (GRC), Hungary (HUN), Ireland (IRL), Italy (ITA), Latvia (LVA), Lithuania (LTU), Luxembourg (LUX), Malta (MLT), Netherlands (NLD), Poland (POL), Portugal (PRT), Slovakia (SVK), Slovenia (SVN), Spain (ESP), Sweden (SWE), United Kingdom (GBR), Bulgaria (BGR), Romania (ROU)
United States (USA)	United States of America (USA)
Rest of high-income (XHY)	Australia (AUS), New Zealand (NZL), Hong Kong (HKG), Japan (JPN), Korea (KOR), Taiwan (TWN), Singapore (SGP), Canada (CAN), Rest of North America (XNA), Switzerland (CHE), Norway (NOR), Rest of EFTA (XEF), Israel (ISR)

Sectoral mapping for policy experiment

Sector code	Sector description	GTAP-E-Power sector
Crp	Crops	pdr wht gro v_f osd c_b pfb ocr
Lvs	Livestock	ctl oap rmk wol frs fsh
Coa	Coal	coa
Oil	Oil	oil
Gas	Gas	gas gdt
omn	Minerals nec	omn
Pfd	Processed food	cmt omt vol mil pcr sgr ofd b_t
xma	Other manufacturing	tex wap lea lum ppp mvh otn ele ome omf
p_c	Petroleum and coal products	p_c
chm	Chemical, rubber, plastic products	crp
ke5	Energy intensive industries	nmm i_s nfm fmp
Etd	Electricity transmission	TnD
Nuc	Nuclear power	NuclearBL
Clp	Coal-fired power	CoalBL
Gsp	Gas-fired power in base load	GasBL GasP
wnd	Wind power	WindBL
Hyd	Hydro power in base load	HydroBL HydroP
Olp	Oil-fired power in base load	OilBL OilP
Xel	Other power	OtherBL
Sol	Solar power	SolarP
Wtr	Water	wtr
Cns	Construction	cns
Ttp	Transportation	trd otp wtp atp
Xsv	Other services	cmn ofi isr obs ros osg dwe