INSTITUTE of ENERGY, ENVIRONMENT and ECONOMY
TSINGHUA UNIVERSITY

Carbon Emission Scenarios for Future China

Wenying Chen

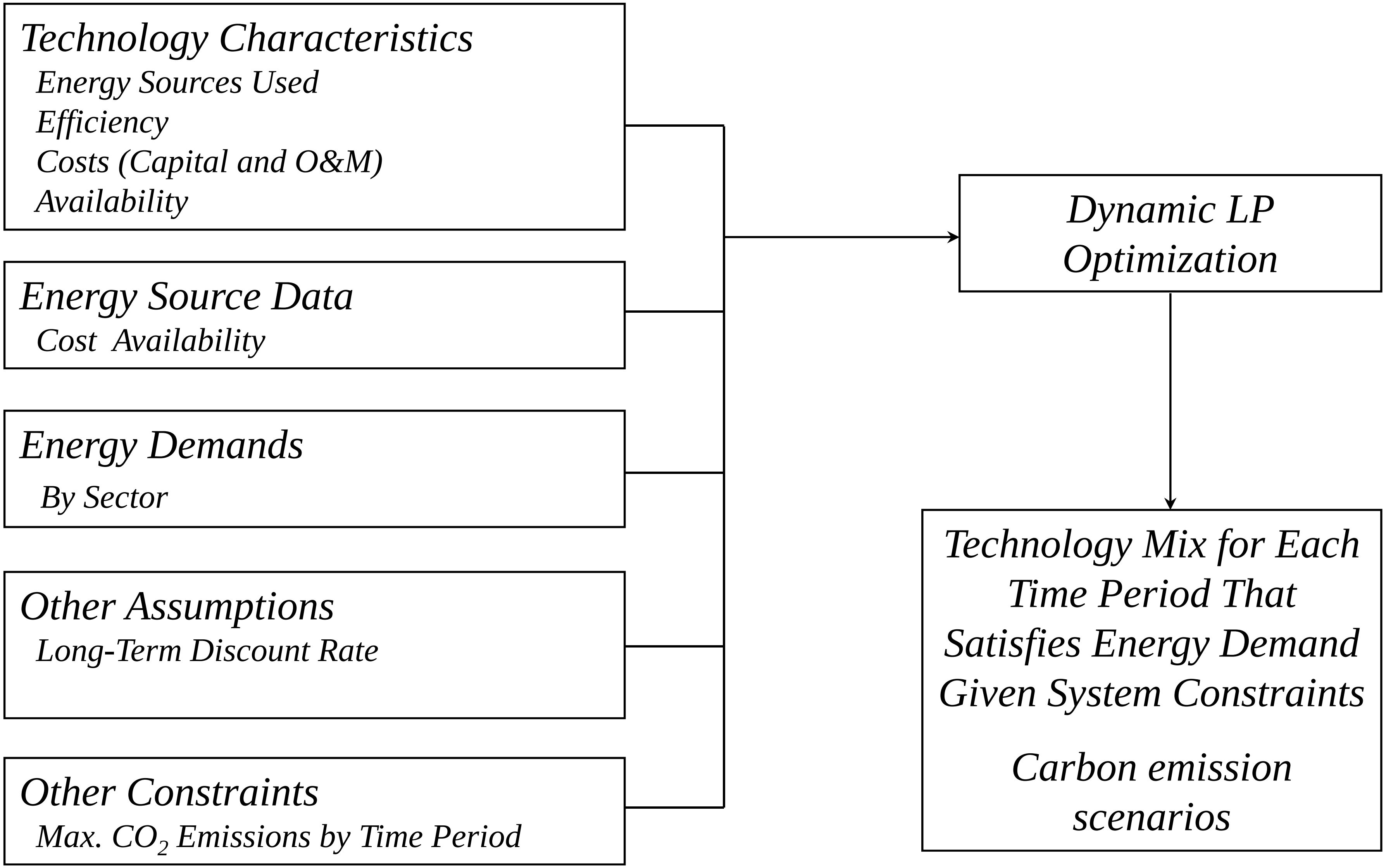
Institute of Energy Environment and Economy (3E)
Tsinghua University

Nov. 15, 2014

Energy system optimization model: China MARKAL/TIMES

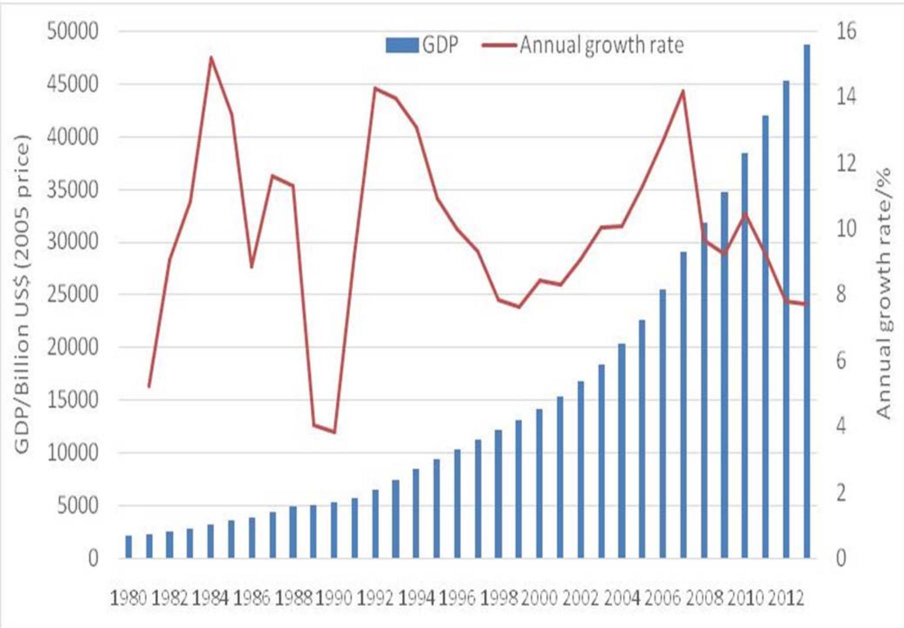
- **Dynamic linear programming model based on Reference Energy System(RES).**
- **Incorporate the full range of energy processes e.g. exploitation, conversion, transmission, distribution and end-use.**
- **Consider existing technologies as well as advanced technologies which may be deployed in future.**
- **Searche for a least-cost combination of technologies and fuels dynamically over the planning period to meet user-specified energy service demands.**

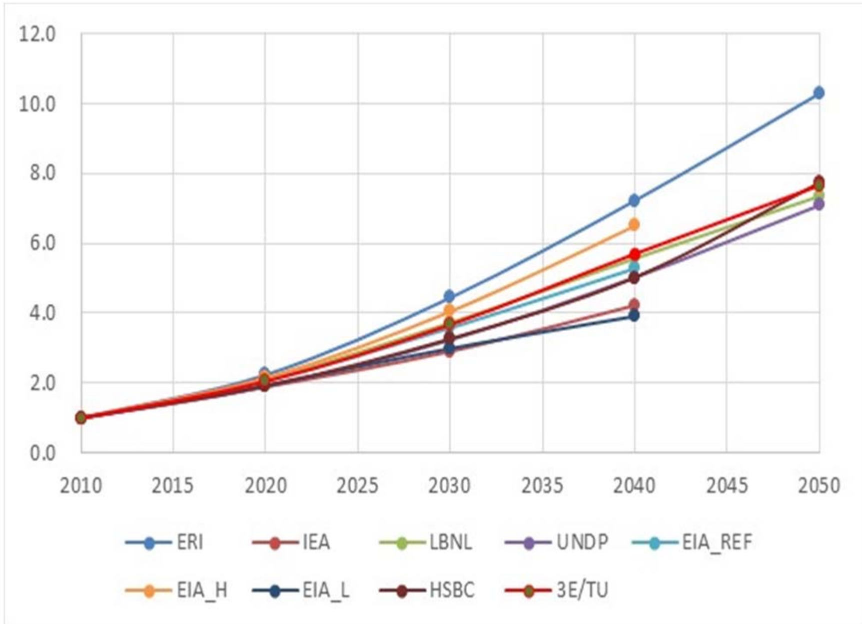
Main inputs and outputs



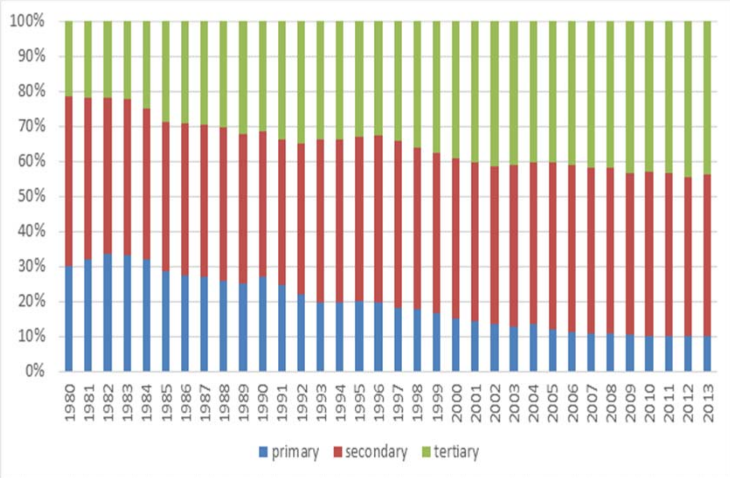
Key social-economic drivers for future carbon emission growth: GDP

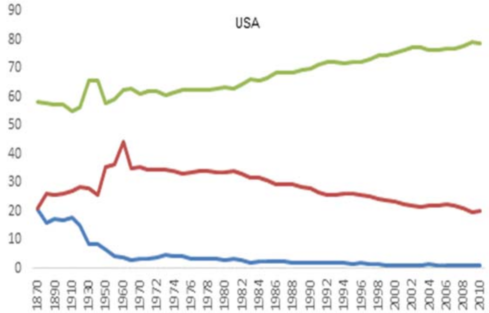
	ERI	IEA	LBNL	UNDP	EIA_REF	EIA_H	EIA_L	HSBC	3E/TU
2010-2020	8.4	6.6	7.8	6.6	7.5	7.9	6.9	6.7	7.4
2020-2030	7.1	4.4	5.9	5.5	5.7	6.6	4.4	5.5	6.0
2030-2040	5.0	3.8	4.1	4.5	4.0	4.8	2.7	4.4	4.5
2040-2050	3.6	na	2.8	3.5	na	na	na	4.4	3.0

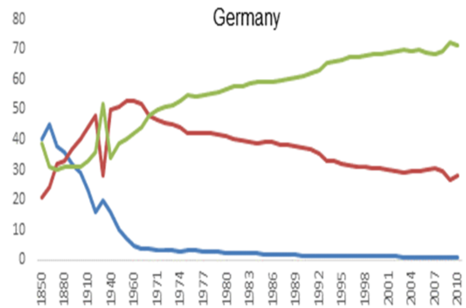


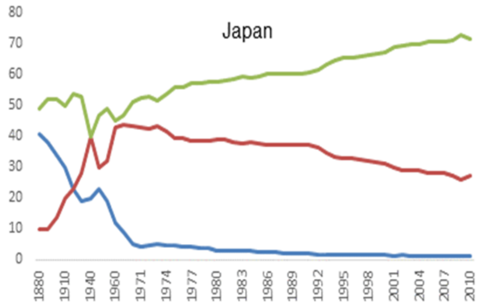


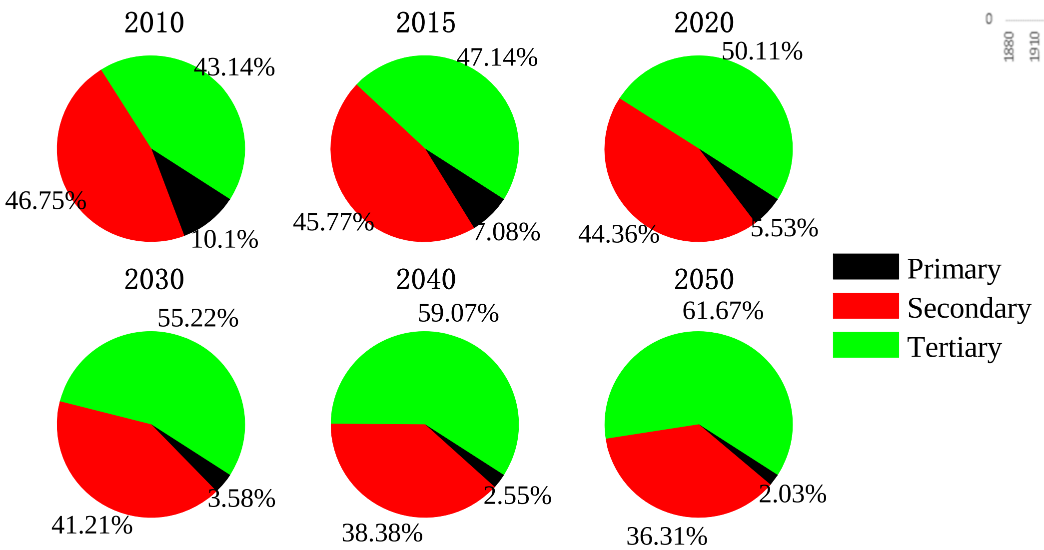
Key social-economic drivers for future carbon emission growth: industrial structure



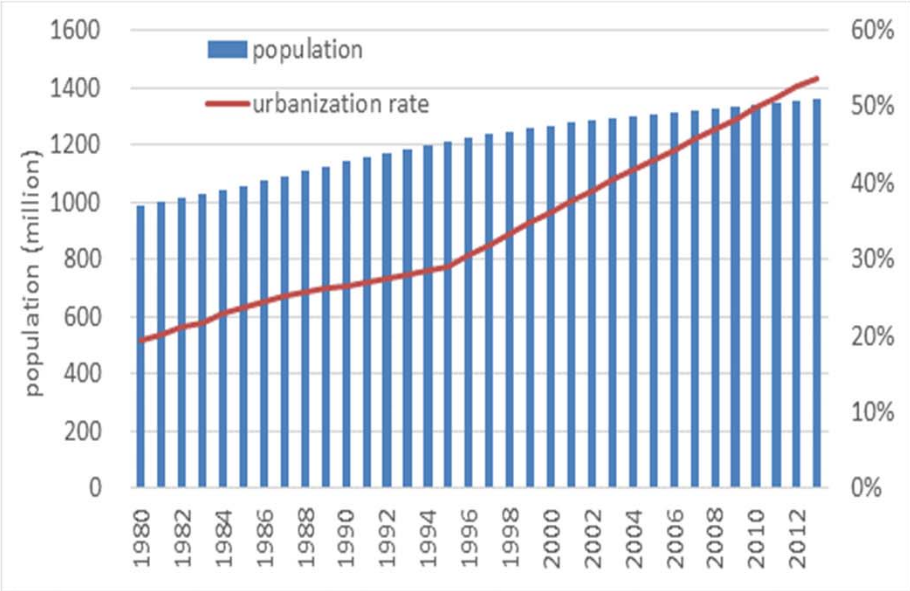


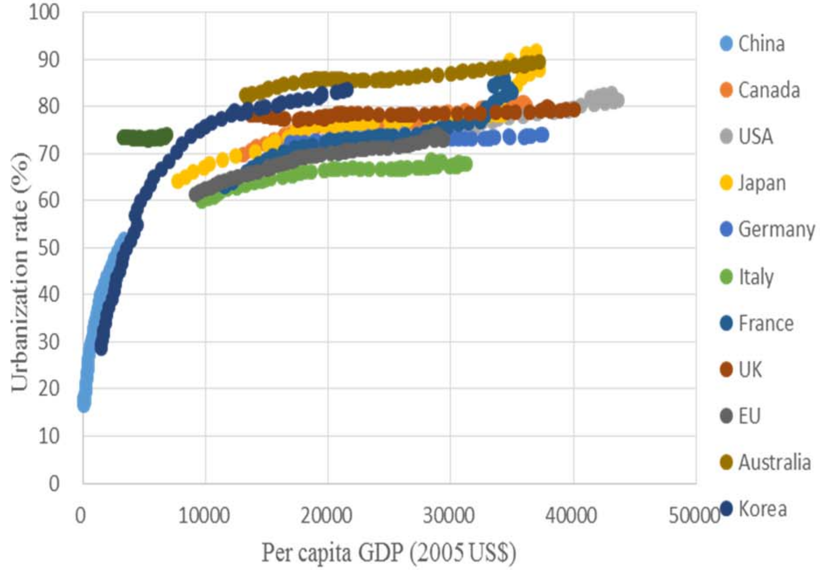


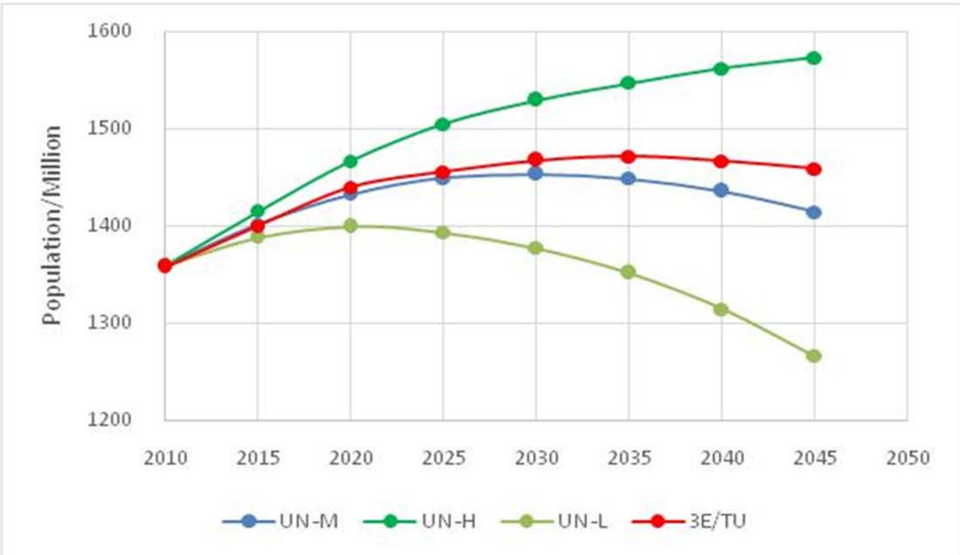


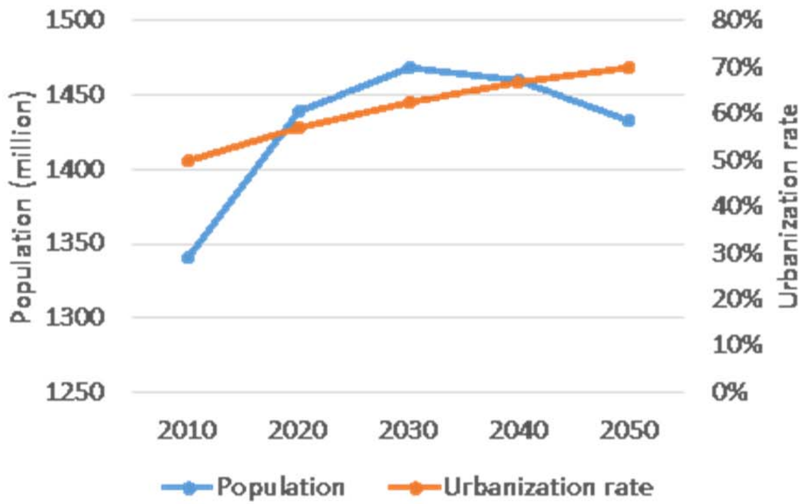


Key social-economic drivers for future carbon emission growth: Population and urbanization





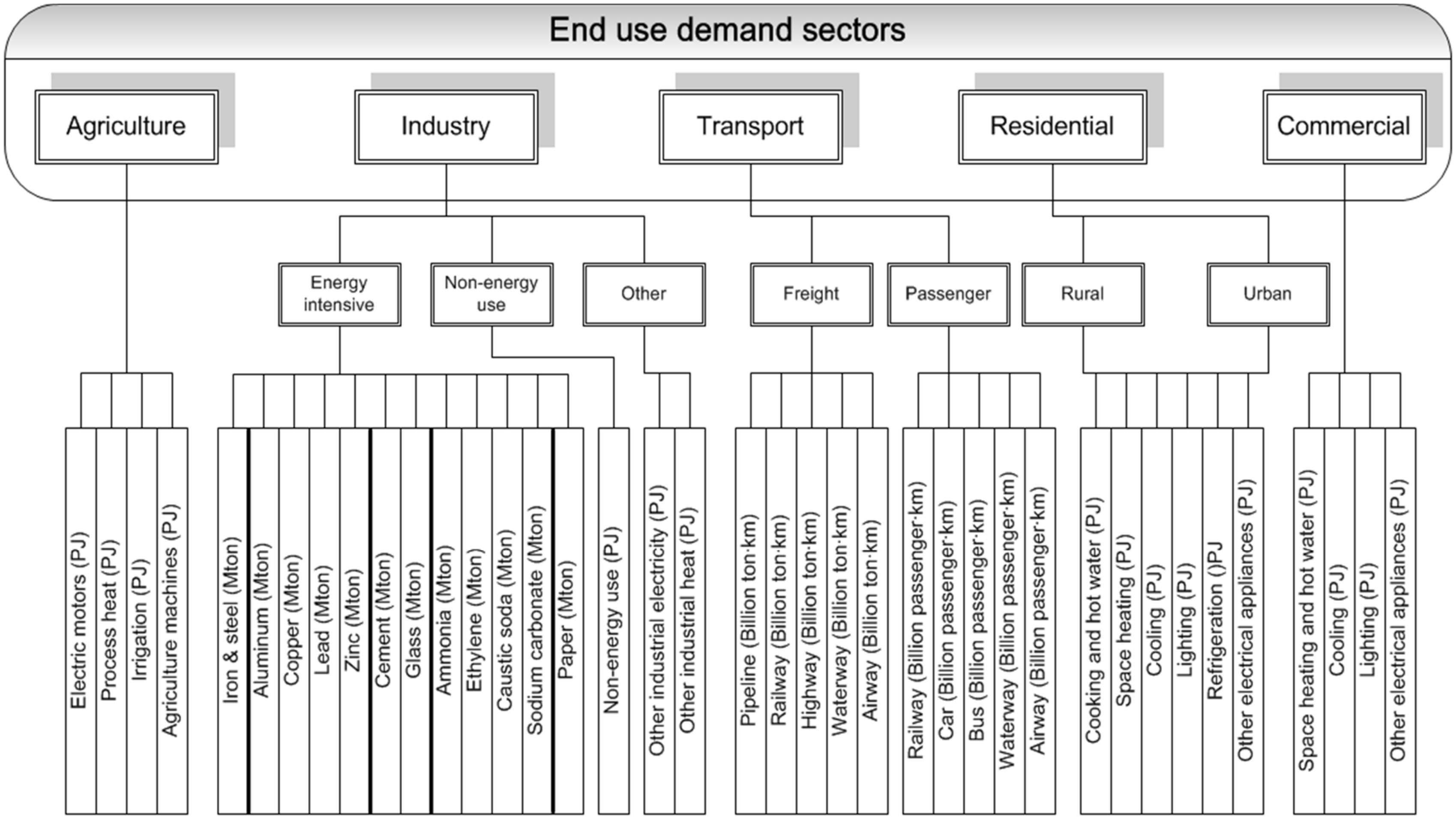




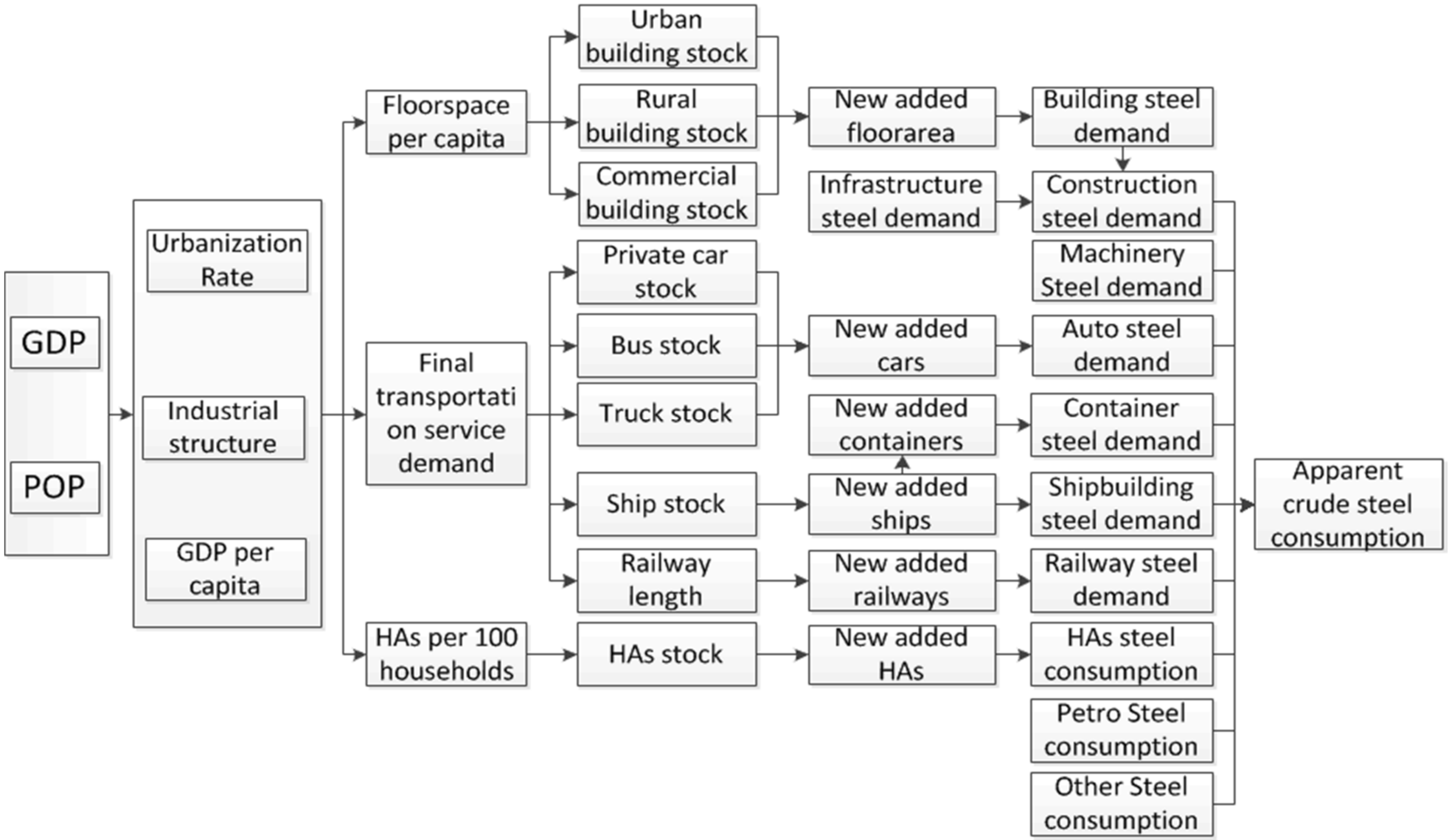
How social economic drivers to impact energy service demand

- Industry
  - Energy-intensive products
  - Others
- Transport
  - Freight transport (Air, railway, highway, waterway, pipeline)
  - Passport transport (Air, railway, highway, waterway)
- Building
  - Space heating
  - Cooking and water heating
  - Cooling
  - Lighting and electric appliances

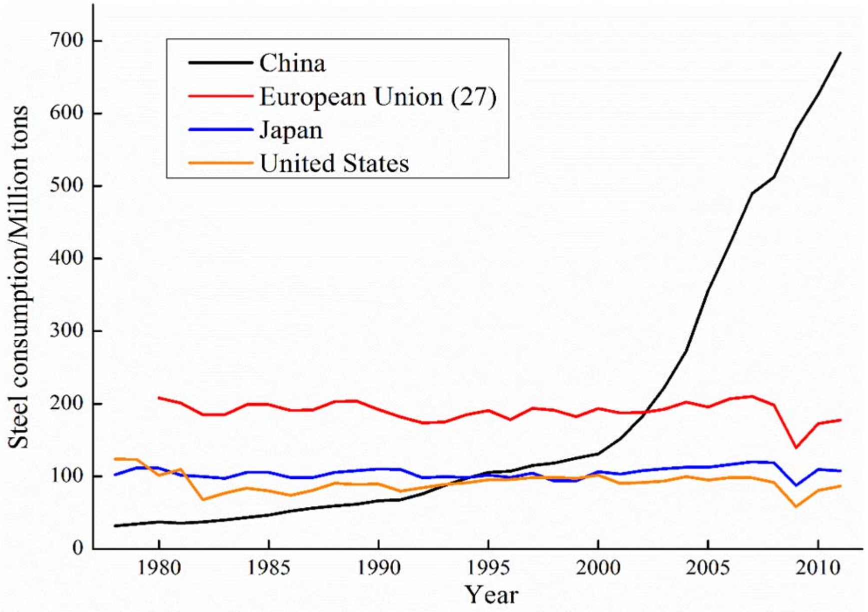
Energy service demand projection model

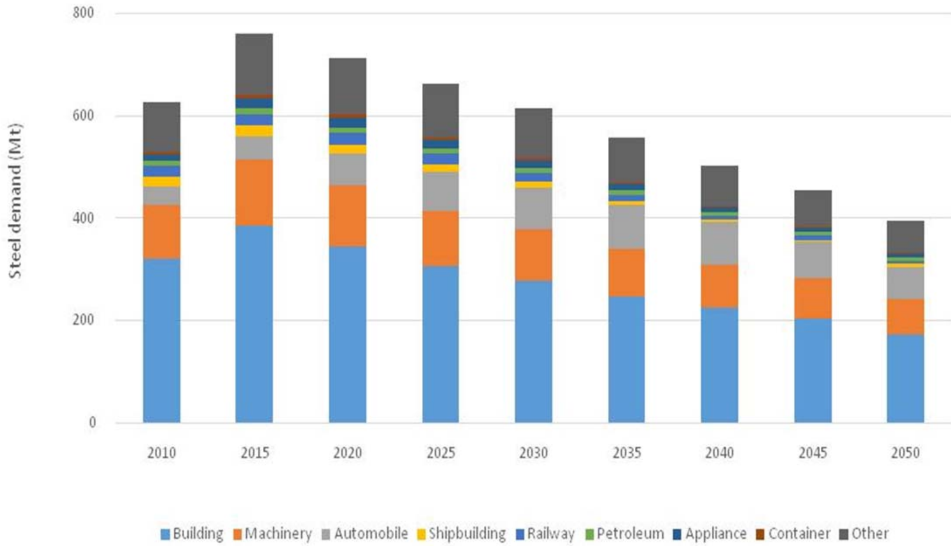


Steel demand projection approach

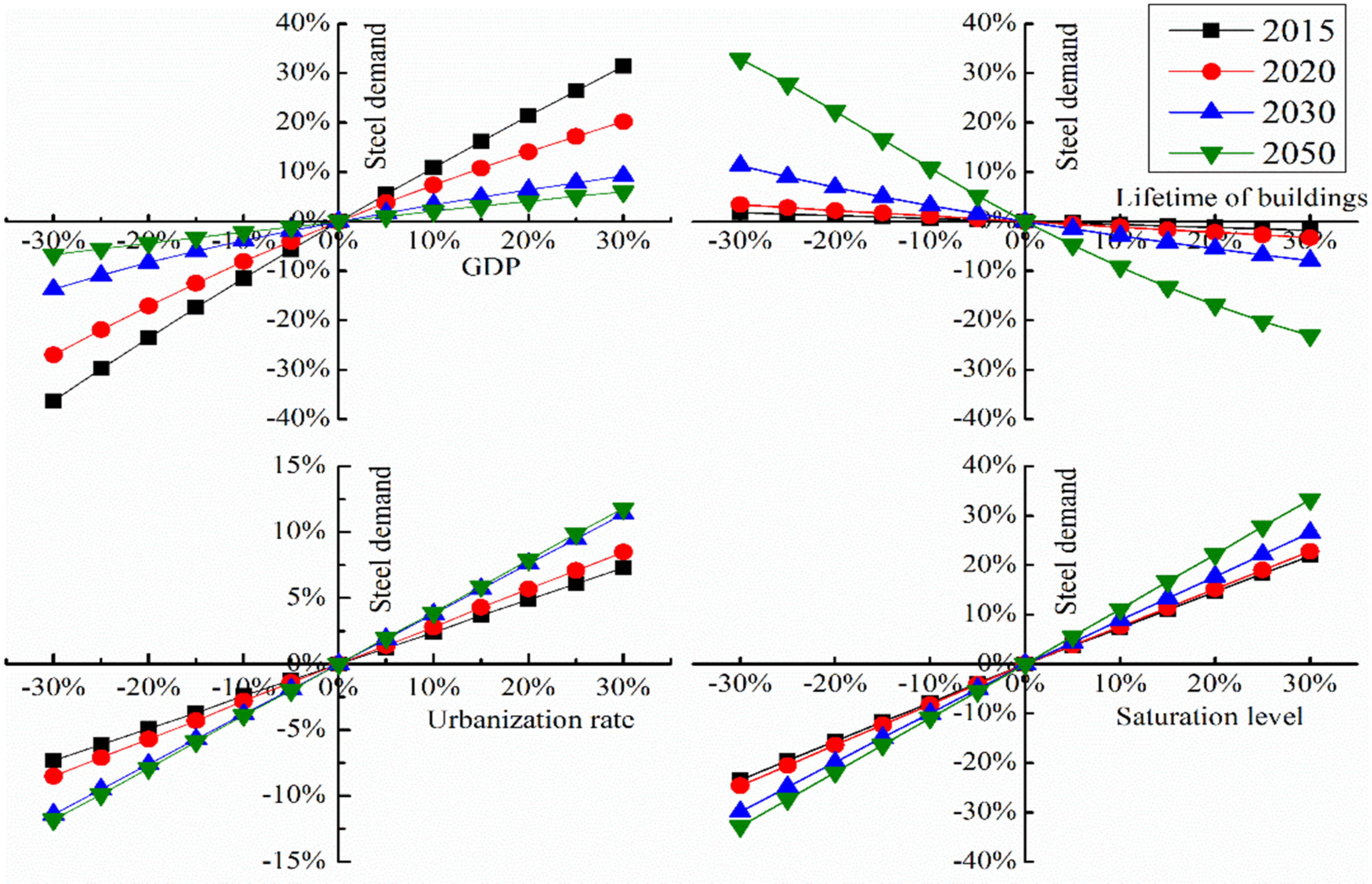


Steel demand projection

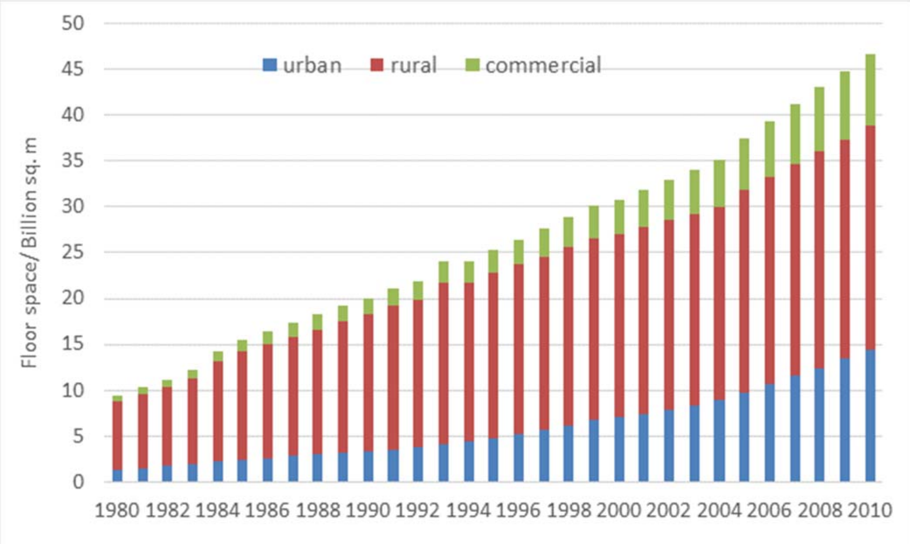


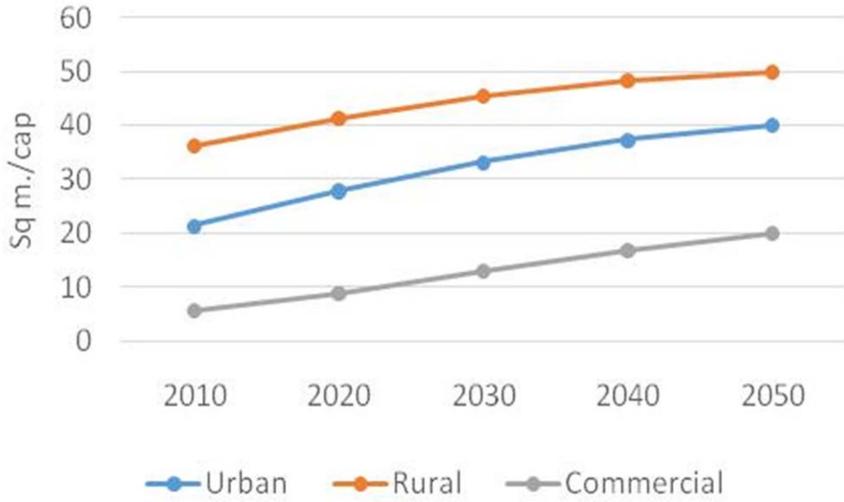


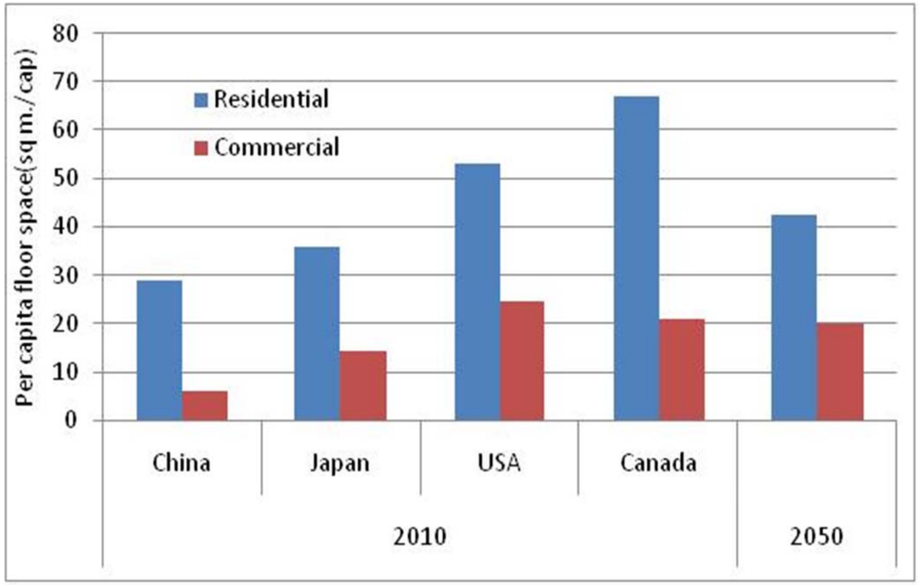
Sensitivity analysis of future steel demand

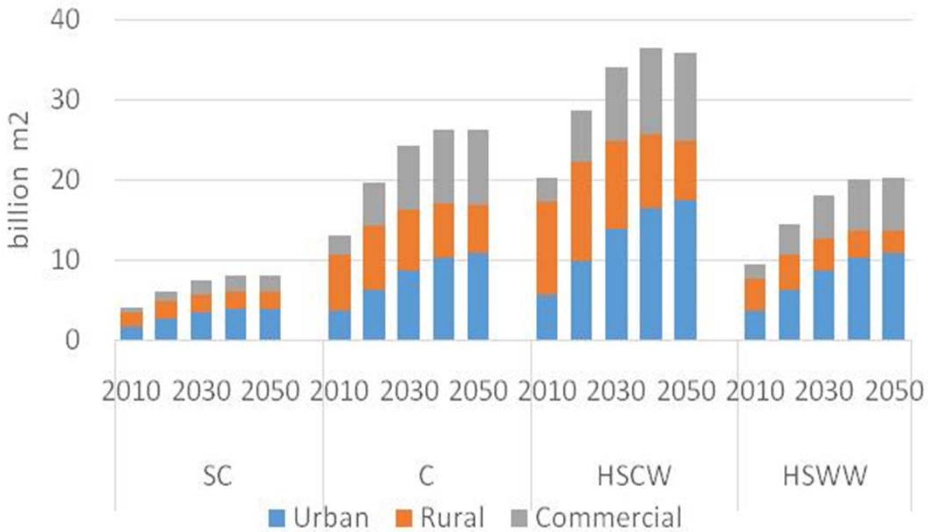


Building floor space projection

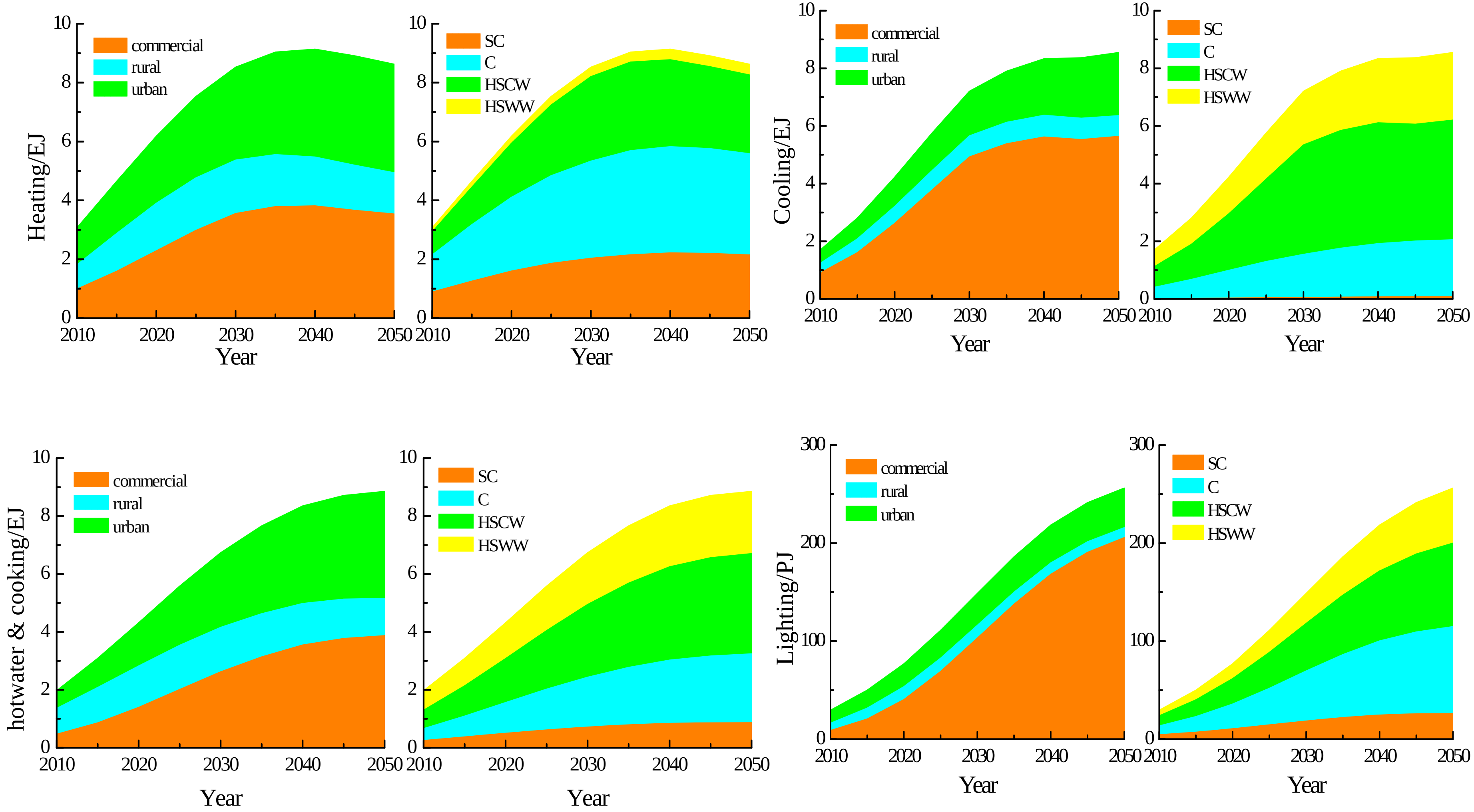




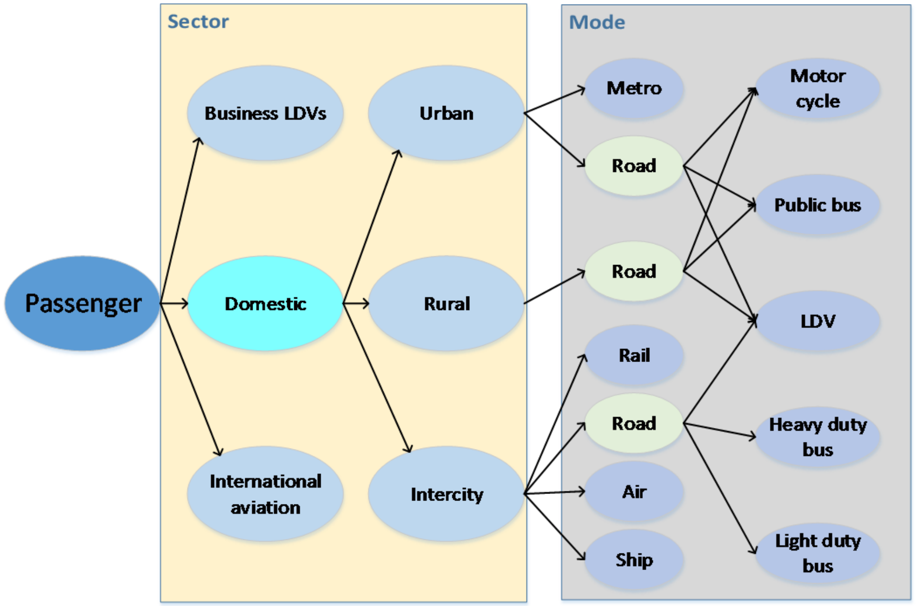


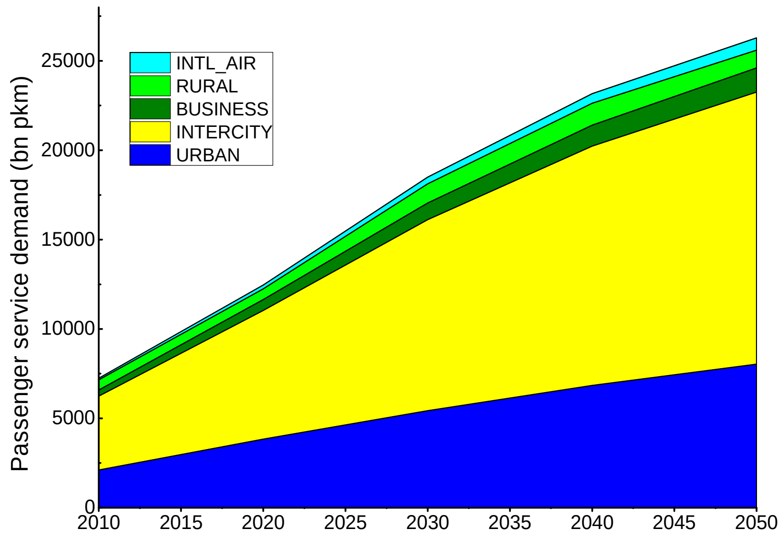


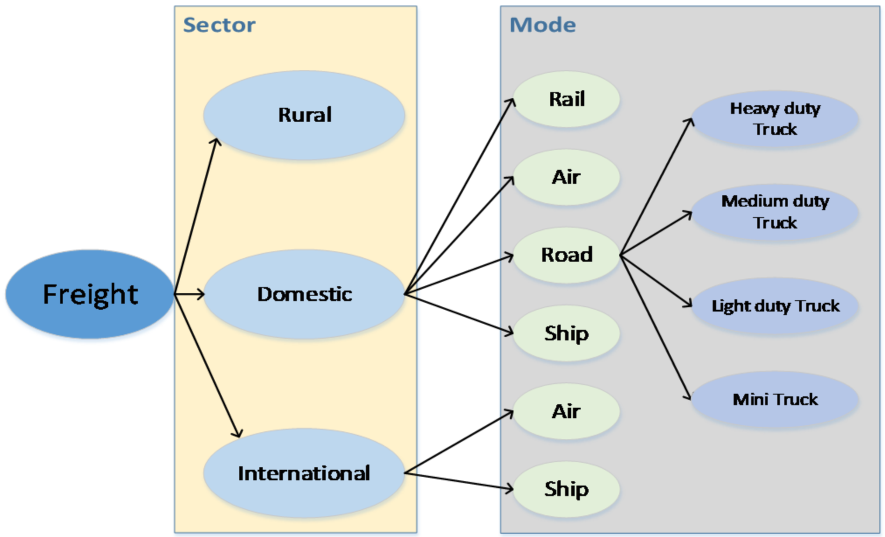
Building ESD projection

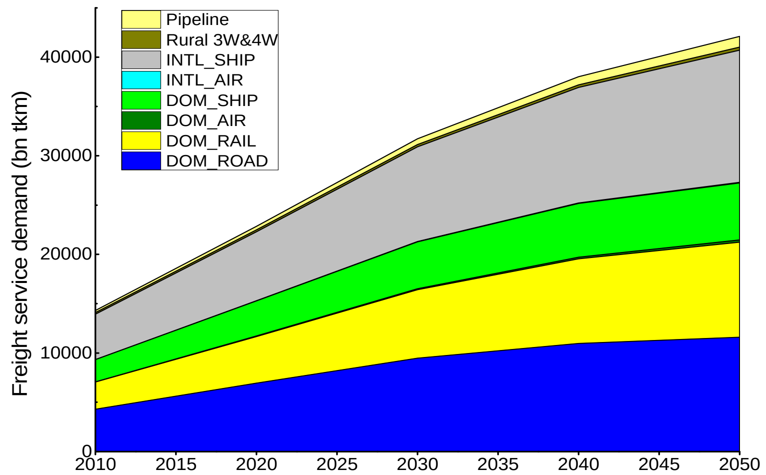


Transportation ESD projection

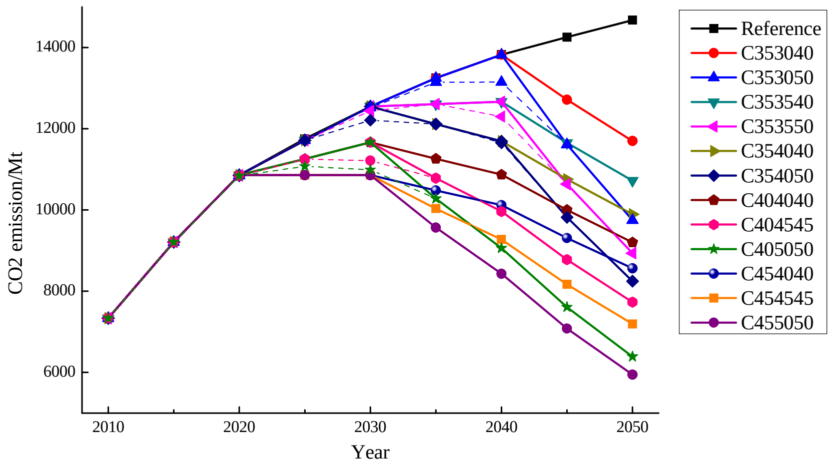


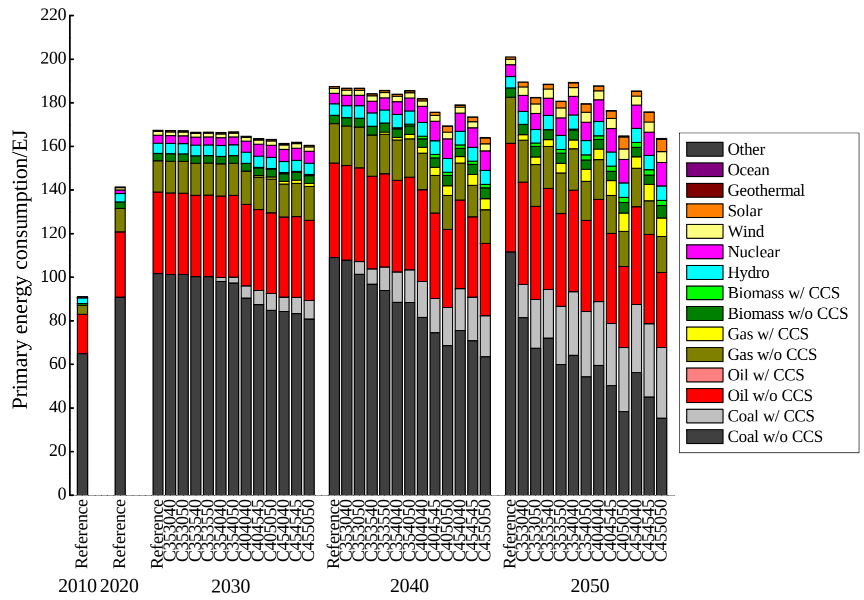


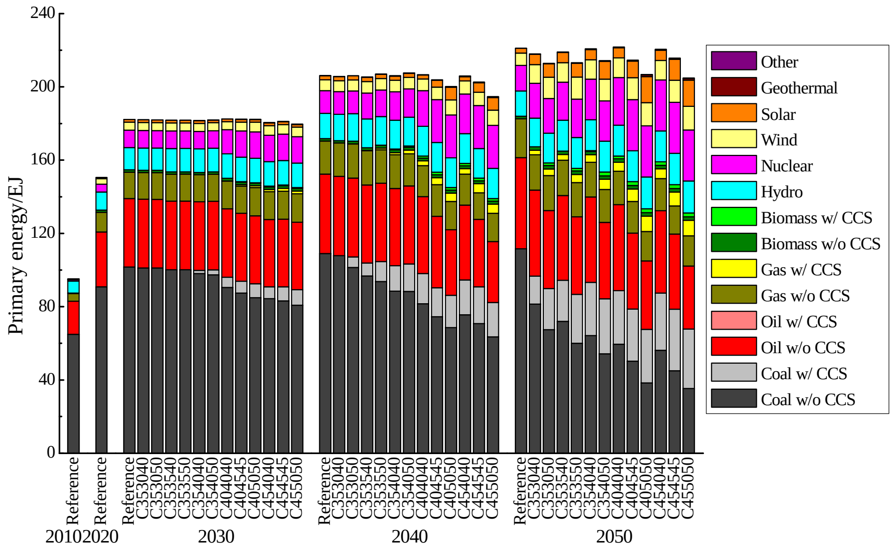


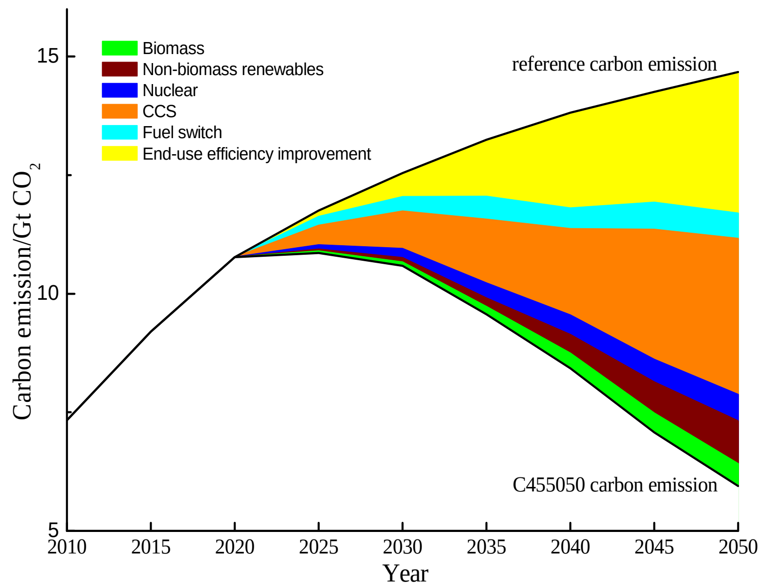


Scenarios (without elastic demand)

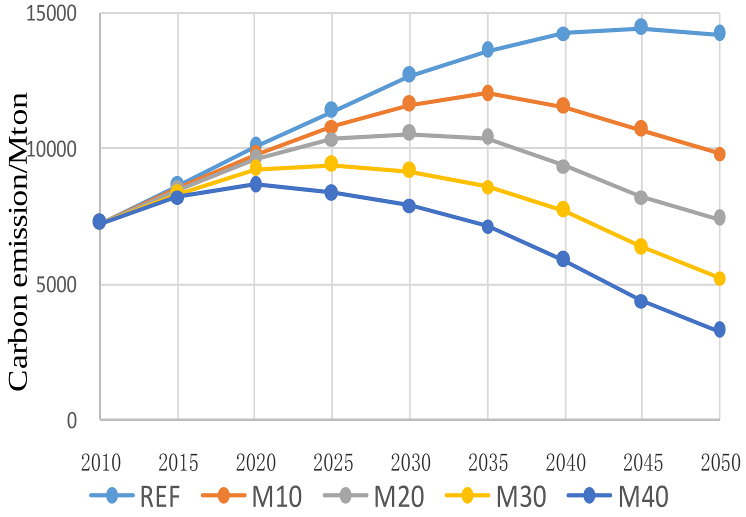


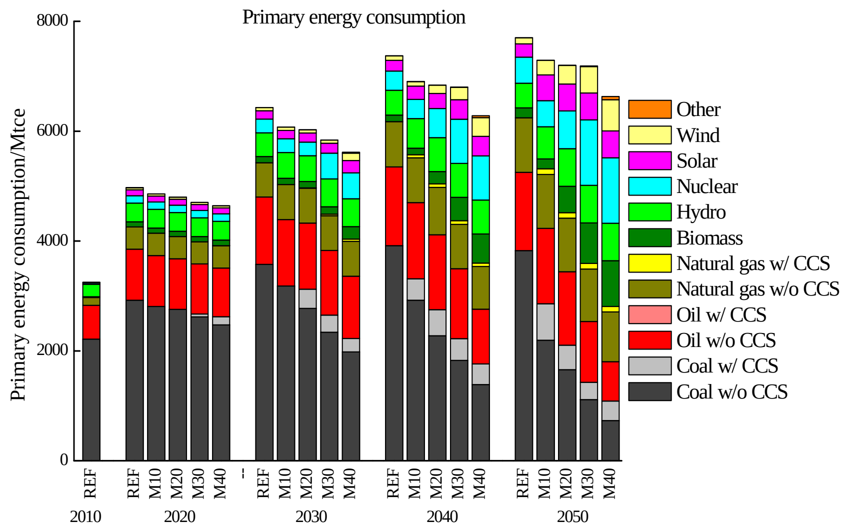


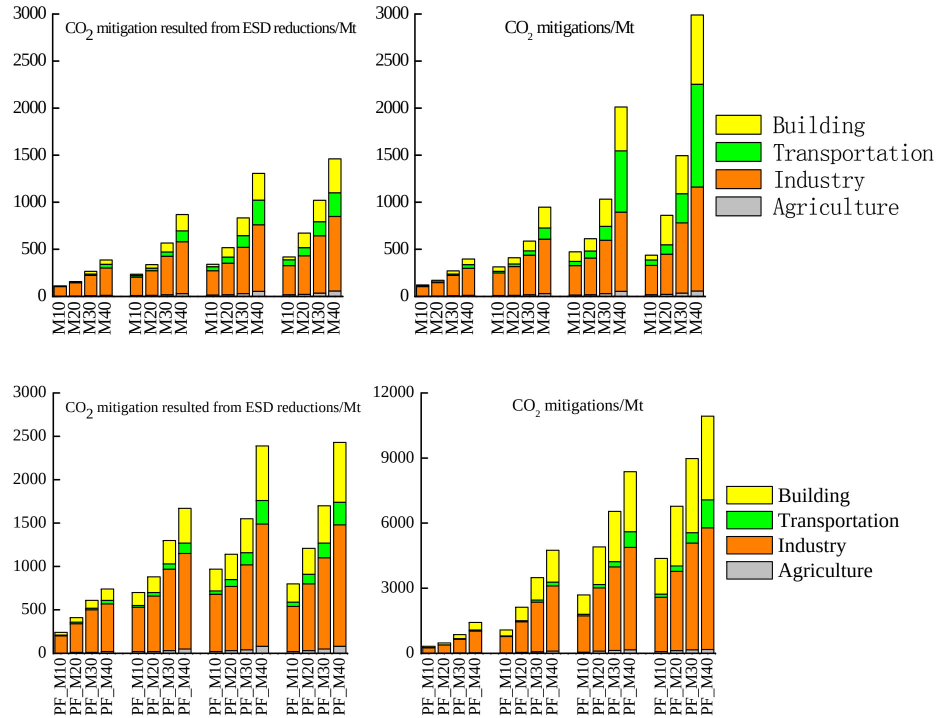




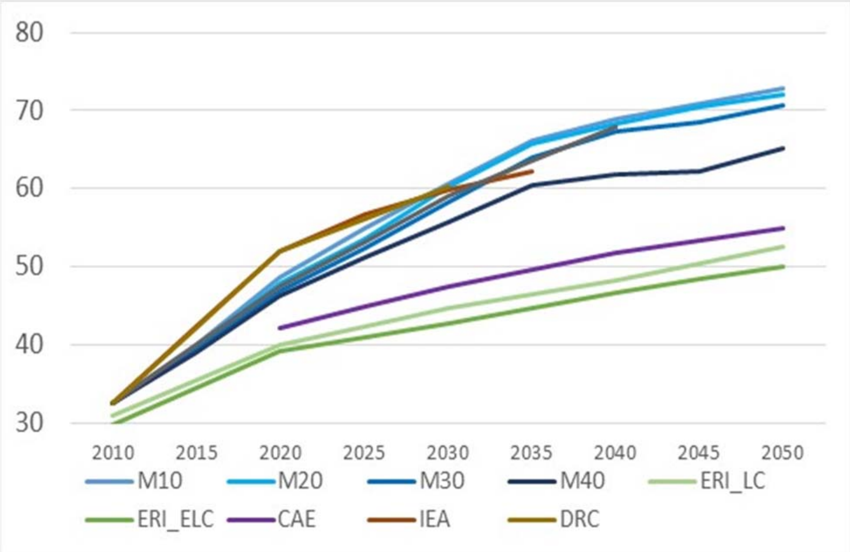
Scenarios (with elastic demand)

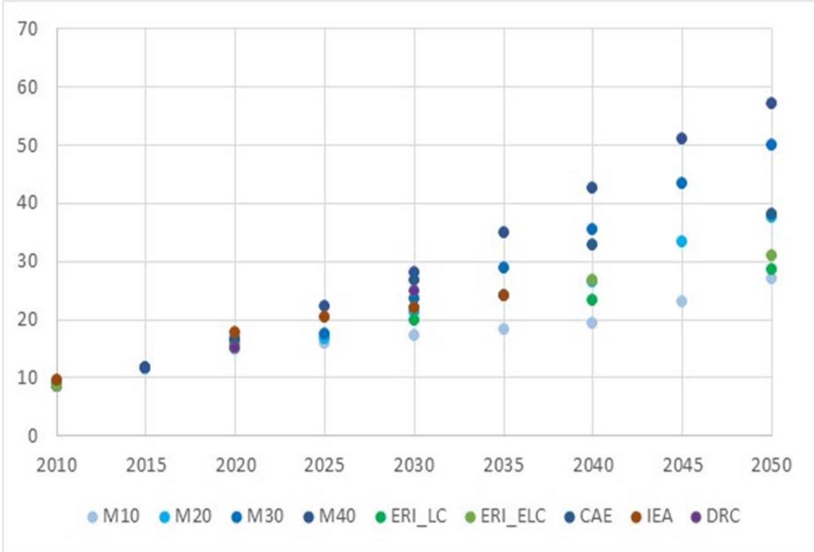


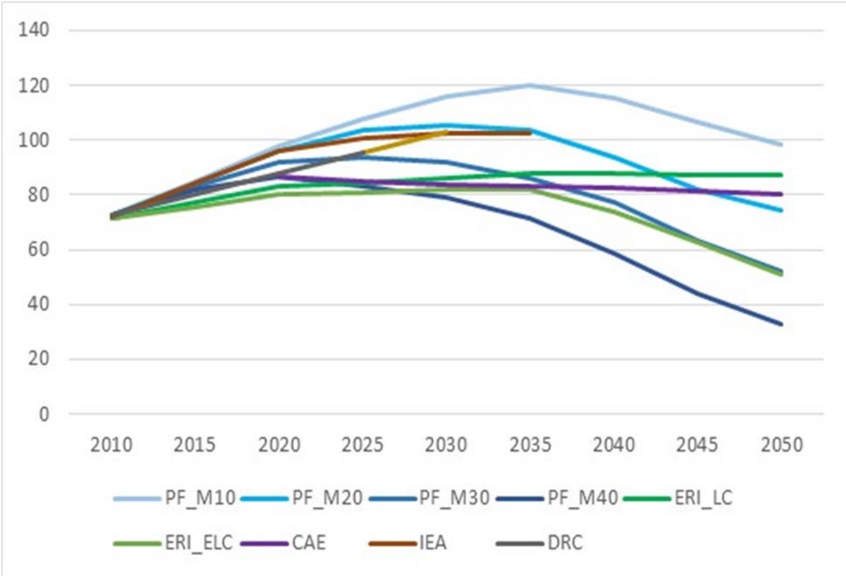




Comparison with other domestic studies







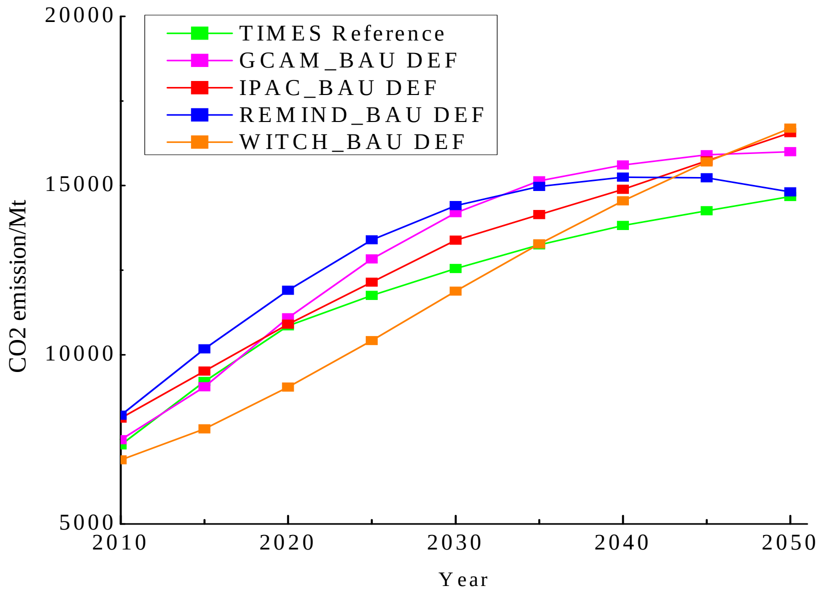
Model comparisons

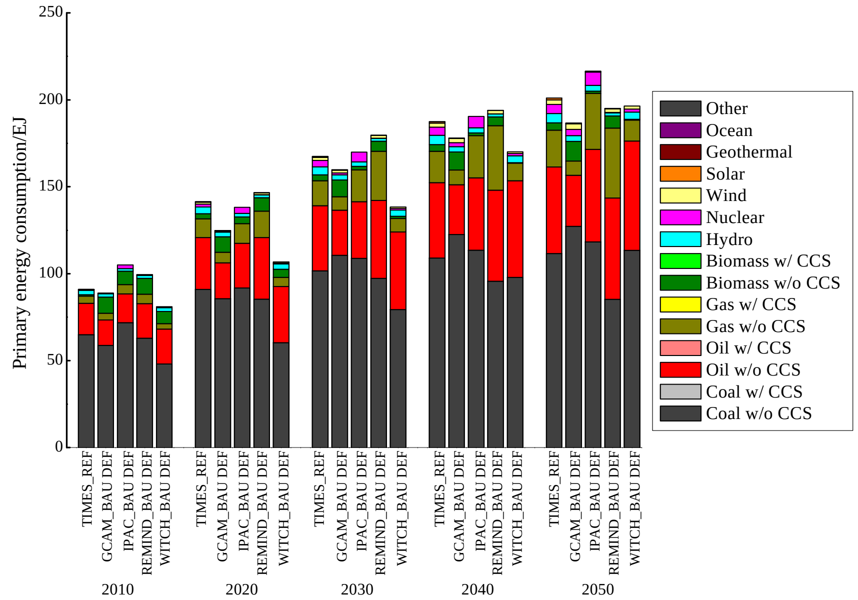
- **GCAM (Global Change Assessment Model) developed by the Joint Global Change Research Institute, USA**
- **IPAC (Integrated Policy Assessment Model for China) developed by the Energy Research Institute, China**
- **REMIND (Refined Model of Investments and Technological Development) developed by the Potsdam Institute for Climate Impact Research, Germany**
- **WITCH (World Induced Technical Change Hybrid) developed by the Centro Euro-Mediterranean Centre on Climate Change, Italy**

Model comparisons

Model	China TIMES	GCAM	IPAC	REMIND	WITCH
Region coverage	China	Global (14 regions)	Global (9 regions)	Global (11 regions)	Global (13 regions)
Time Horizon	2010-2050	2005-2100	2005-2100	2005-2100	2005-2100
Model class	Energy system optimization, partial equilibrium	Recursive dynamic, partial equilibrium	Recursive dynamic, partial equilibrium	Inter-temporal optimization, general equilibrium	Inter-temporal optimization, general equilibrium
End-use sectors	6 (agriculture, industry, transportation, commercial, urban, rural), further divided into 43 subsectors	3 (industry, transportation, building)	3 (industry, transportation, building)	2(transportation, other)	1 aggregated
Demands	Exogenous energy service demands	Endogenous energy service demand driven by income and price	Endogenous energy service demand driven by income and price	Endogenous CES production function	Endogenous CES production function
Technology choice by	Linear least-cost	Logit-shares based on cost	Logit-shares based on cost	Inter-temporal cost minimization	Inter-temporal cost minimization
Endogenous learning	No	No	No	Yes	Yes
Endogenous R&D	No	No	No	No	Yes

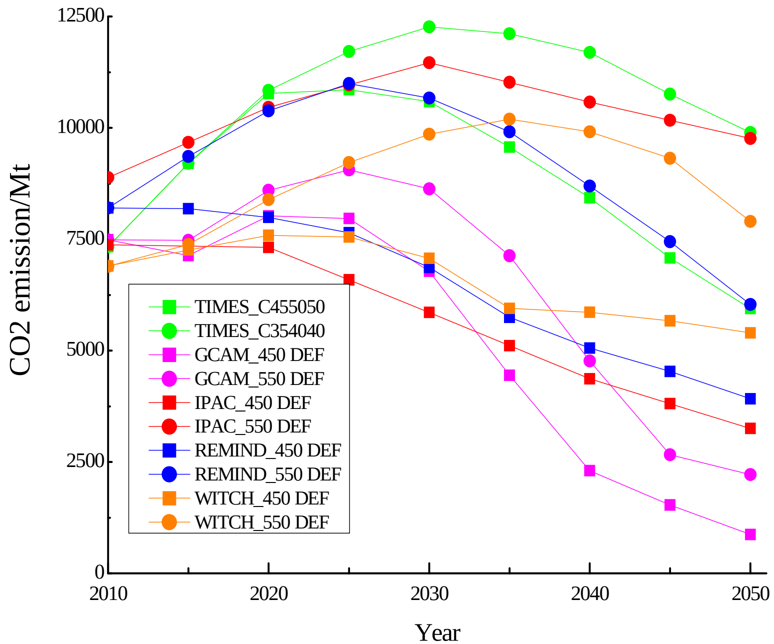
Model comparisons for reference scenarios

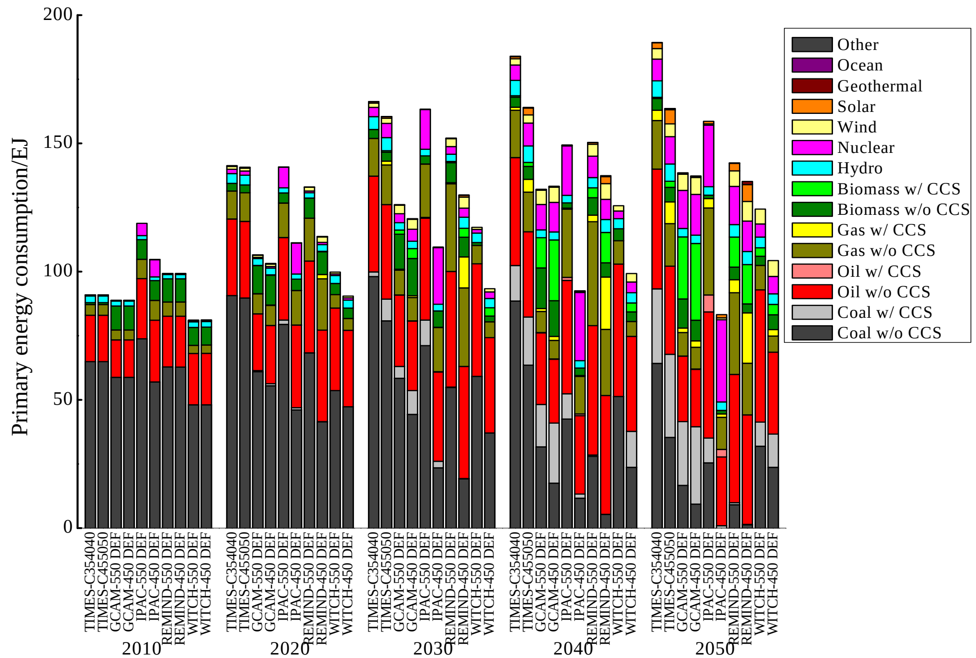


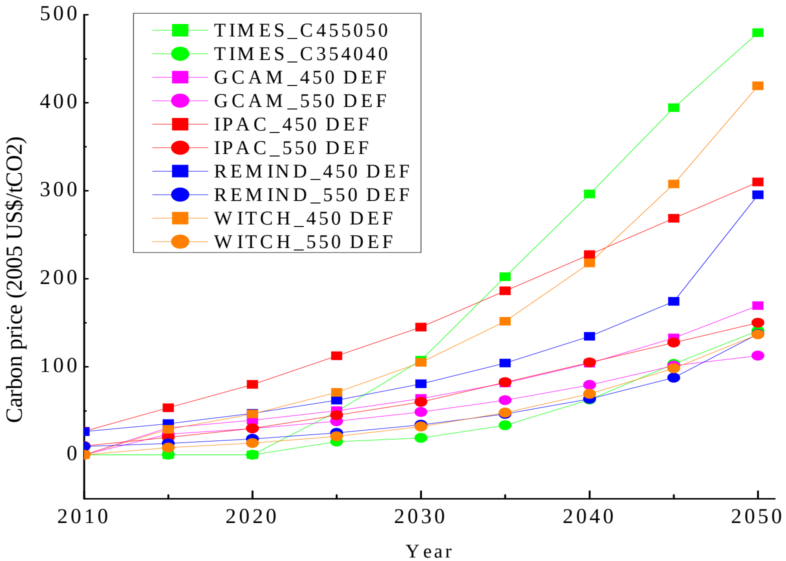


- **The models use similar assumptions for the economic and population growth, and project that the carbon emissions will reach 14.7-16.7 Gt CO2 by 2050 in the reference scenario, about twice their level in 2010.**
- **The differences in the various models are mainly attributed to:**
  - **1) slightly different regional definitions for China,**
  - **2) different base years and different data sources used for calibration,**
  - **3) different definitions of the reference scenario with different levels of policies and actions related to carbon mitigation in the reference.**

Model comparisons for mitigation scenarios







- **All the models illustrate the importance of renewable energy sources excluding biomass (mainly hydro, wind and solar) for carbon mitigation, which will have continuously increasing shares in the primary energy consumption, reaching to 7%-15% in the 450 CO2eq stabilization scenario in the global models and 11% in the C455050 scenario in China TIMES by 2050.**

Model comparisons for mitigation scenarios

- Despite the similarities, there are larger differences in the climate policy scenarios than in the reference scenario across models.
- The differences are mainly due to:
  - different targets,;
  - different model structures and modeling approaches;
  - different model assumptions on technology availability and techno-economic characteristics of the technologies (in particular, biomass power generation with CCS and biomass liquefaction with CCS;
- The sharp reductions of the energy demand together with large scale deployment of biomass liquefaction and power generation in combination with CCS (15%-30% in the primary energy consumption in 2050 in GCAM and REMIND), make it possible to reduce carbon emissions in 2050 below 5GtCO2.

Model comparisons for mitigation scenarios

- **The sharp reductions of the energy demand (more than 80% reduction of the energy intensity per unit of GDP compared to the year 2010 by 2050), together with large scale deployment of biomass liquefaction and power generation in combination with CCS (15%-30% in the primary energy consumption in 2050 in GCAM and REMIND) or large deployment of nuclear power, make it possible to phase out coal fast (less than 10% in the primary energy consumption in 2050) to reduce carbon emissions in 2050 below the level in 2005 (around 5 GtCO2).**

Summary

- **With economic growth, China's energy consumption and carbon emissions are expected to increase steadily if without considerable mitigation efforts.**
- **Stringent carbon mitigation scenarios not only require substantive deployment of low- and non- carbon technologies but also significant change of both production mode and consumer behavior.**
- **However, whether it is realistic for the large scale development of nuclear, wind, solar and CCS technologies (in particular biomass with CCS) needs further investigation.**
- **The impact of sharp reductions in energy service demands on the GDP, industrialization, urbanization, living standards, employment and other social-economic aspects also need to be further investigated.**

Thank you for your attention

chenwy@tsinghua.edu.cn