Integrated Assessment Model in China: progress and prospect

Hancheng Dai[1], Yang Xie[2]

On behalf of AIM China team

[1] Laboratory of Energy & Environmental Economics and Policy (**LEEEP**), PKU

[2] School of Economics and Management, Beihang University

2024.8.29

Outline

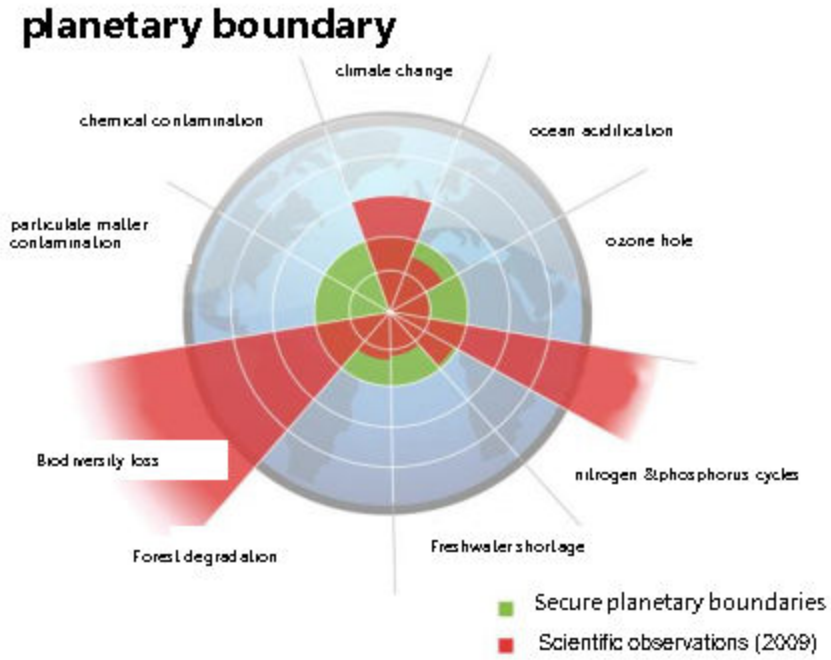
- IAM in China
- IAM at Peking University
- Some thoughts

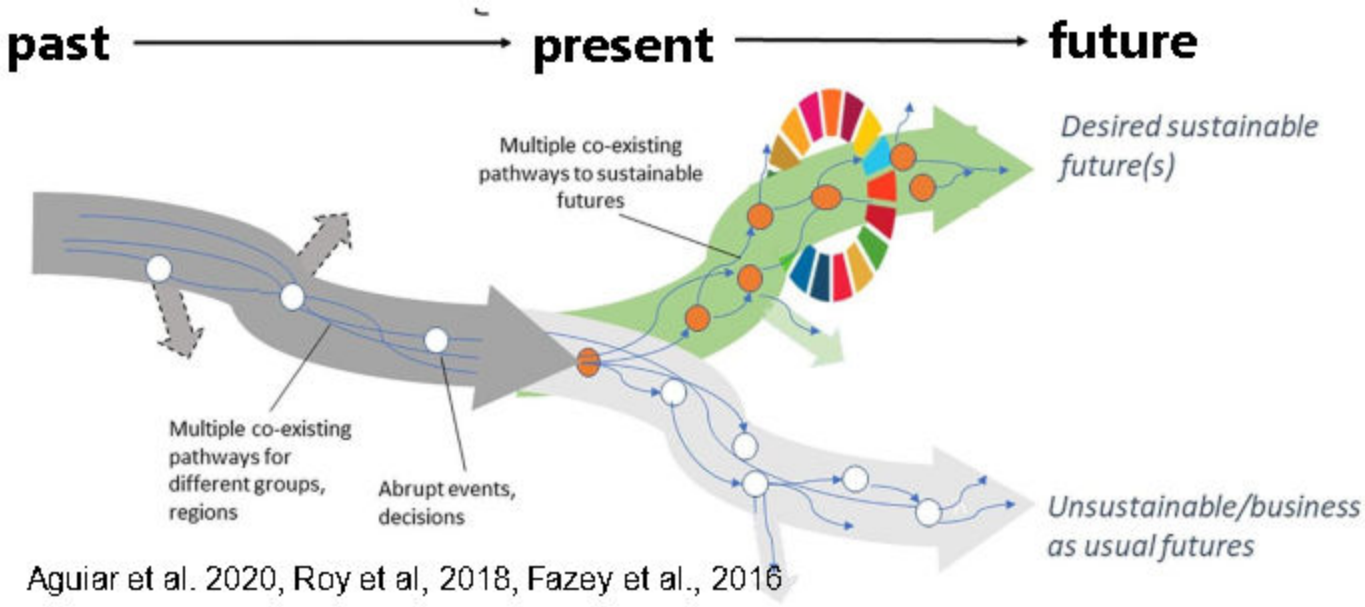
01 IAM in China

- A preliminary review

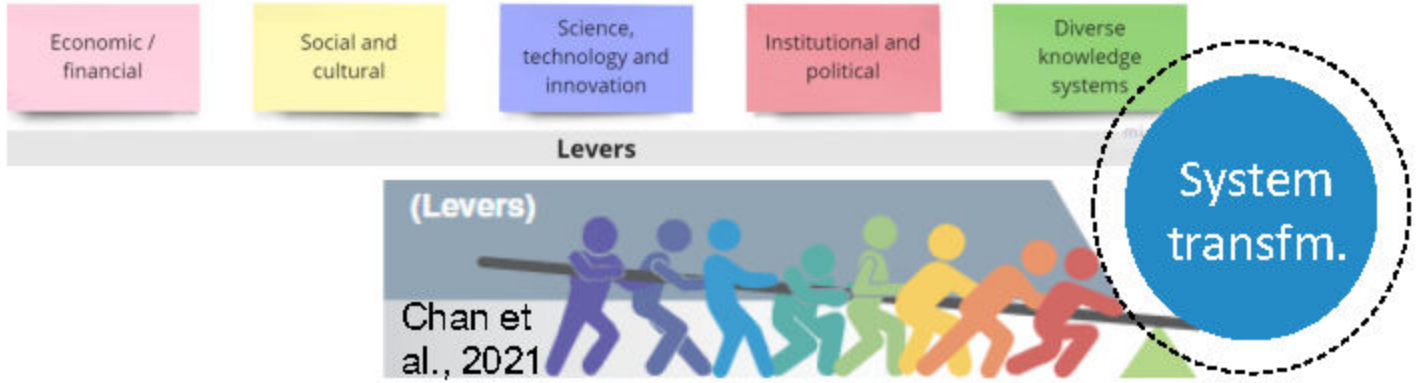
LEEEP

Addressing the planetary crisis via system transformation





Aguiar et al. 2020, Roy et al, 2018, Fazey et al., 2016



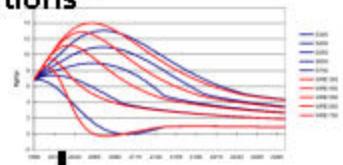
UNEP, GEO-7

Carbon and air pollution mitigation status and trends

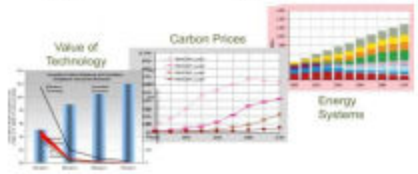
New constraints on "Dual-Carbon" policies: **transformative impacts** on the inter-feedbacks of the "energy-economy-environment-land" complex system, and the urgency to identify **multidimensional integrated impacts** and **spillover risks**

Global

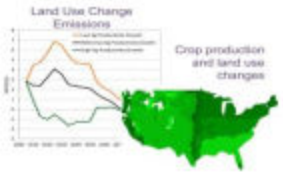
1980s
- The energy-economy-climate Nexus
- IPCC **projected emissions and concentrations**



1990-2000s
- **Energy-economy-climate** linkages
- Energy, **Technology** and mitigation

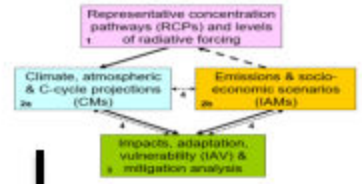


2000s
- **Land use** emissions and mitigation



Since 2015
- Mitigation and **sustainable development**

Trends
- **Two-way coupling of climate-economic models**

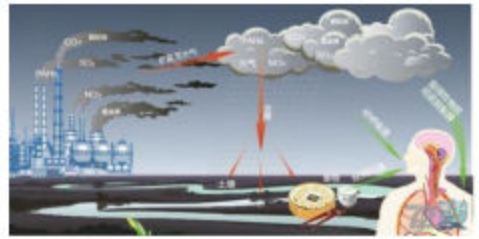


Trends

China

1980s
- Acid rain crisis leads to recognition of urgency and necessity of **air Pollution**
- SO2 and acid rain control

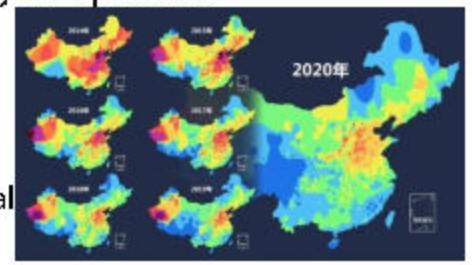
2000s
- Concentration on single-pollutant control
- Concentration on localized, single-sector control



2013
Air Pollution Prevention and Control Action Plan

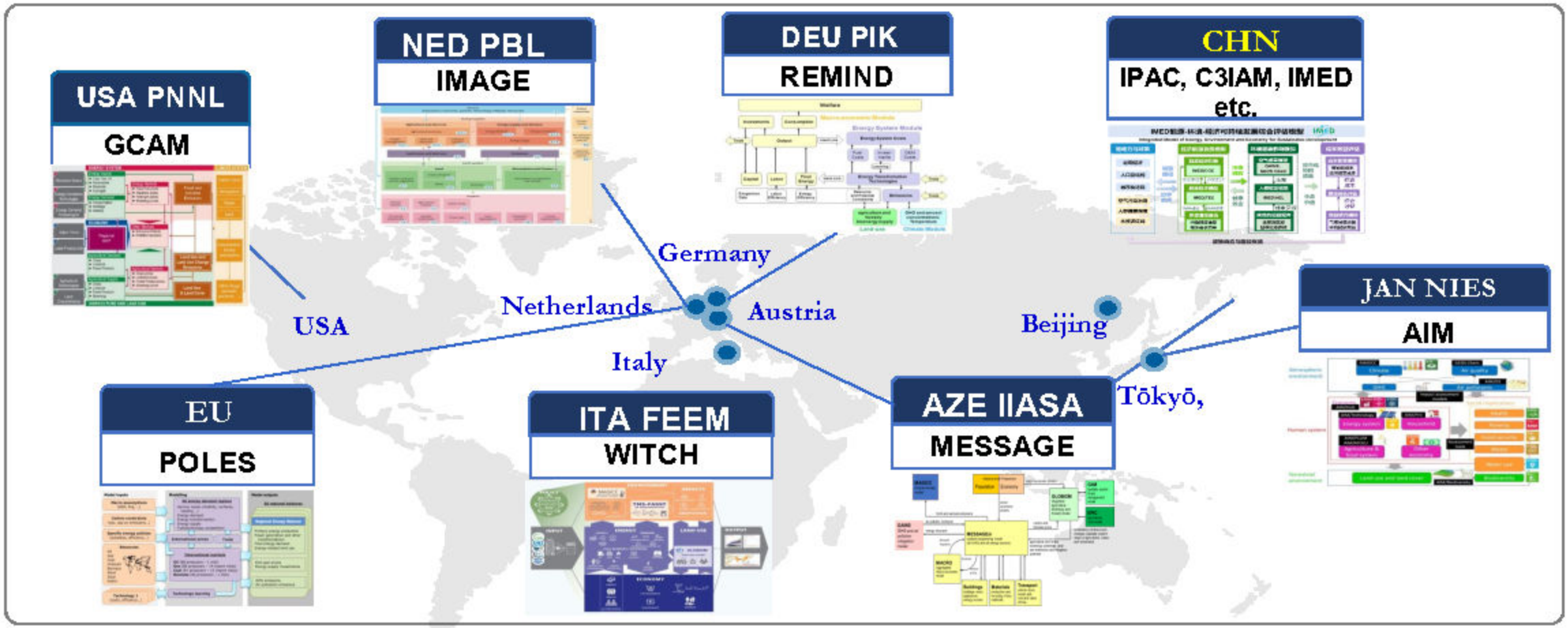
2018
Three-year action plan to fight air pollution

2010s
- Focus on multiple pollutants
- Multi-objective synergistic control
- Cross-regional - multi-sectoral
- End-of-pipe management



Integrated assessment models

- China has started to fund IAMs development in recent years.



Need for IAMs to explore “dual-carbon” transition pathways

国家自然科学基金委员会
National Natural Science Foundation of China

Carbon Neutrality Grand Project 2022

管理科学部

首页 » 管理科学部 » 通知公告

Project Guidelines for the 2022 National Natural Science Foundation of China (NSFC) Special Project “Preliminary Study on Key Theory and Technology of Multiscale Model Coupling of Natural-Social Systems for Carbon Neutral Realization Pathways

日期 2022-10-24 来源： 作者： 【大 中 小】 【打印】 【关闭】

(一) 自然-社会系统多尺度相互作用模式耦合和决策支撑研究的顶层设计（总课题）

(二) 以煤电转型为主的中国能源结构变化建模及预测研究（子课题1）

(三) 面向能源结构转型的中国储能布局预测研究（子课题2）

(四) 中国碳中和实现路径的预测研究（子课题3）

(五) 中国及全球能源转型风险、金融风险、资源风险和气候损失等建模和预测研究（子课题4）

(六) 碳中和产业转型与经济社会系统变革的政策驱动机制与异质性建模研究（子课题5）

Dual Carbon Special Project in 2022

Project Guidelines for the 2022 NSF Special Project “Research on Policy Modeling and Strategies to Support National Dual-Carbon Strategies

日期 2022-10-14 来源： 作者： 【大 中 小】 【打印】 【关闭】

Carbon emission reduction policy is a multi-dimensional policy system that requires **multi-system coupling** between industries, regions and sectors.

Policy models and management systems for promoting high-quality economic growth and ensuring national energy and climate security

The guide argues for a strong emphasis on modeling

Home-grown IAMs emerging in China: carbon policy assessment

International IAM helped a lot in earlier years, several **more localized and refined** home-grown IAM emerged in recent years.

Global

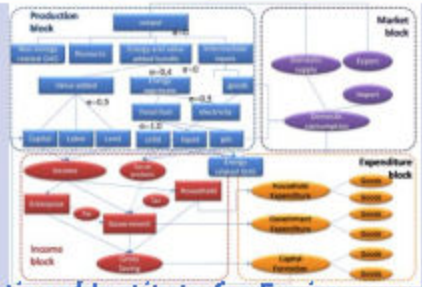
- **MESSAGE, IIASA**
- **GCAM, PNNL**
- **IMAGE, PBL**
- **AIM, NIES**
- **……**

Domestic

- **IPAC, ERI**
- **C3IAM，BIT**
- **IMED，PKU**

Retrieved from: He Kebin, 2022, Shuangqing Forum

AIM-CGE
Asia-Pacific Regional Assessment System (APRAS)

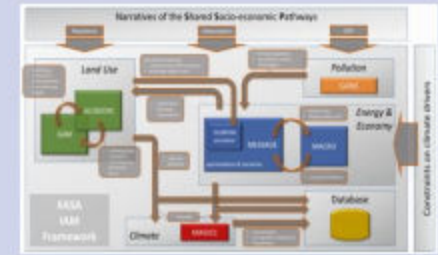


National Institute for Environmental Studies, Japan (NIES)

GCAM
Global Change Assessment Model (GCM)

Pacific Northwest National Laboratory, USA (PNNL)

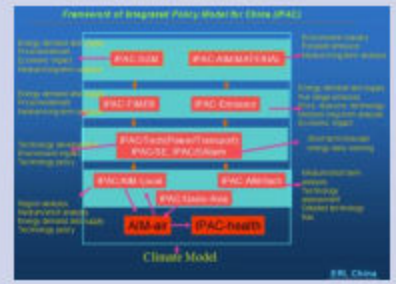
MESSAGE
Energy Supply Alternative Systems and Environmental Impact Model



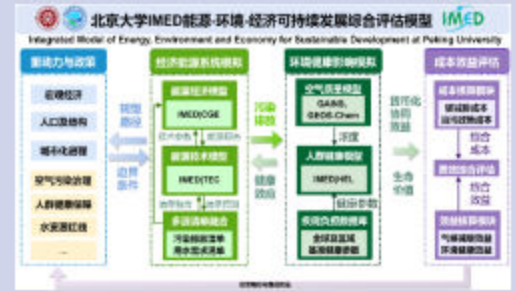
International Institute for Systems Analysis, Austria(IIASA)

NIT C3IAM
Integrated Model for Integrated Assessment of Climate Change

Energy Institute of NDRC IPAC
China Energy Environment Integrated Assessment Model



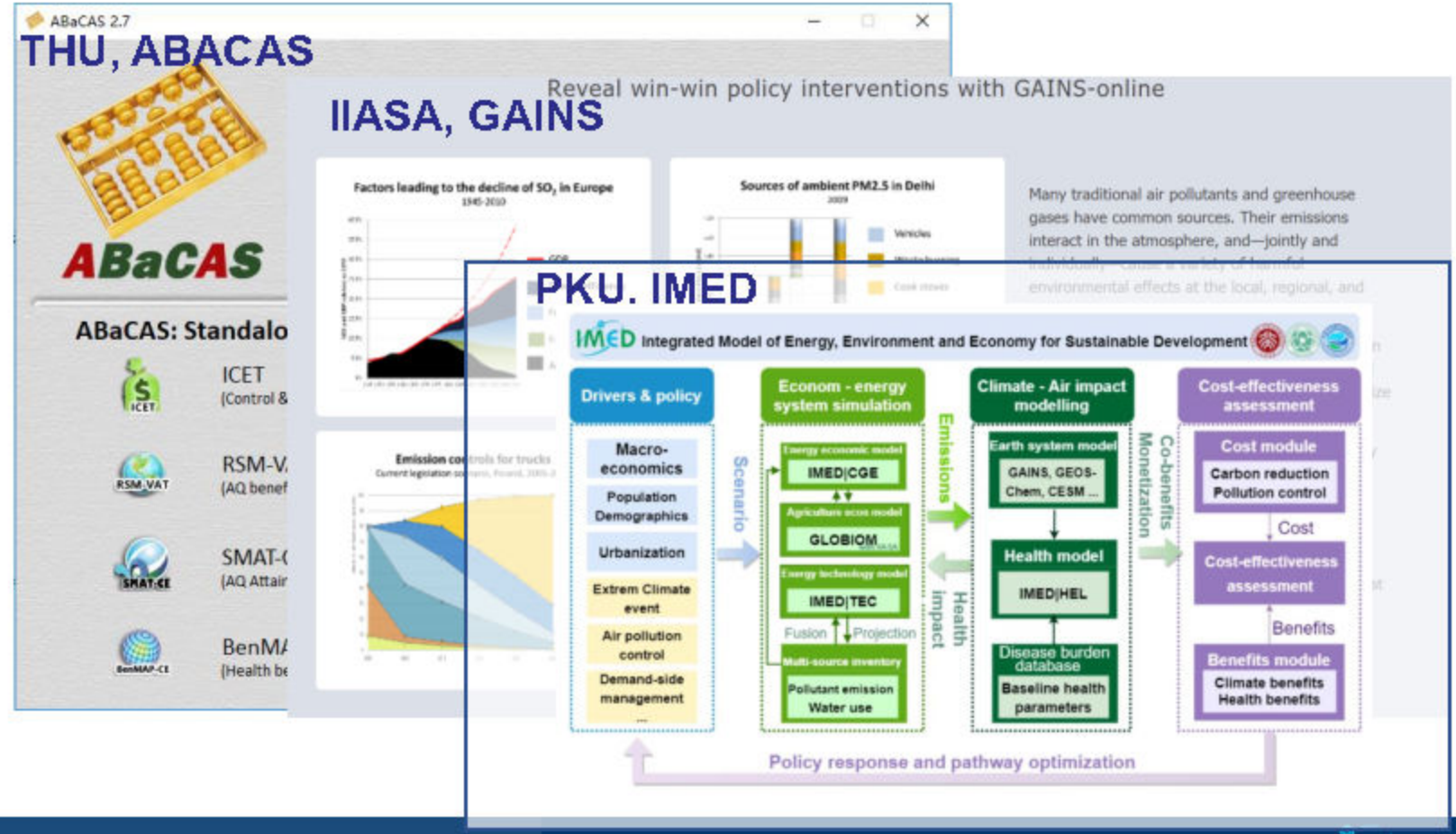
PKU IMED
Integrated Energy-Environment-Economic Sustainable Development Assessment Model



Home-grown IAMs emerging in China: air pollution control policy

IAM for cost-effectiveness such as ABACAS, GAINS and IMED, and **initially constructed a decision support platform for regional air pollution prevention and control**, which has been applied in national and local air pollution control practices.

- **THU ABACAS**
- **PKU IMED**
- **IIASA GAINS**
- **……**



Retrieved from: He Kebin, 2022, Shuangqing Forum

02 IAM at PKU

LEEEP

3-6-3 Framework in the Institute of Carbon Neutrality, Peking University

Steering committee
interdisciplinarity


Academician Jingyun Fang

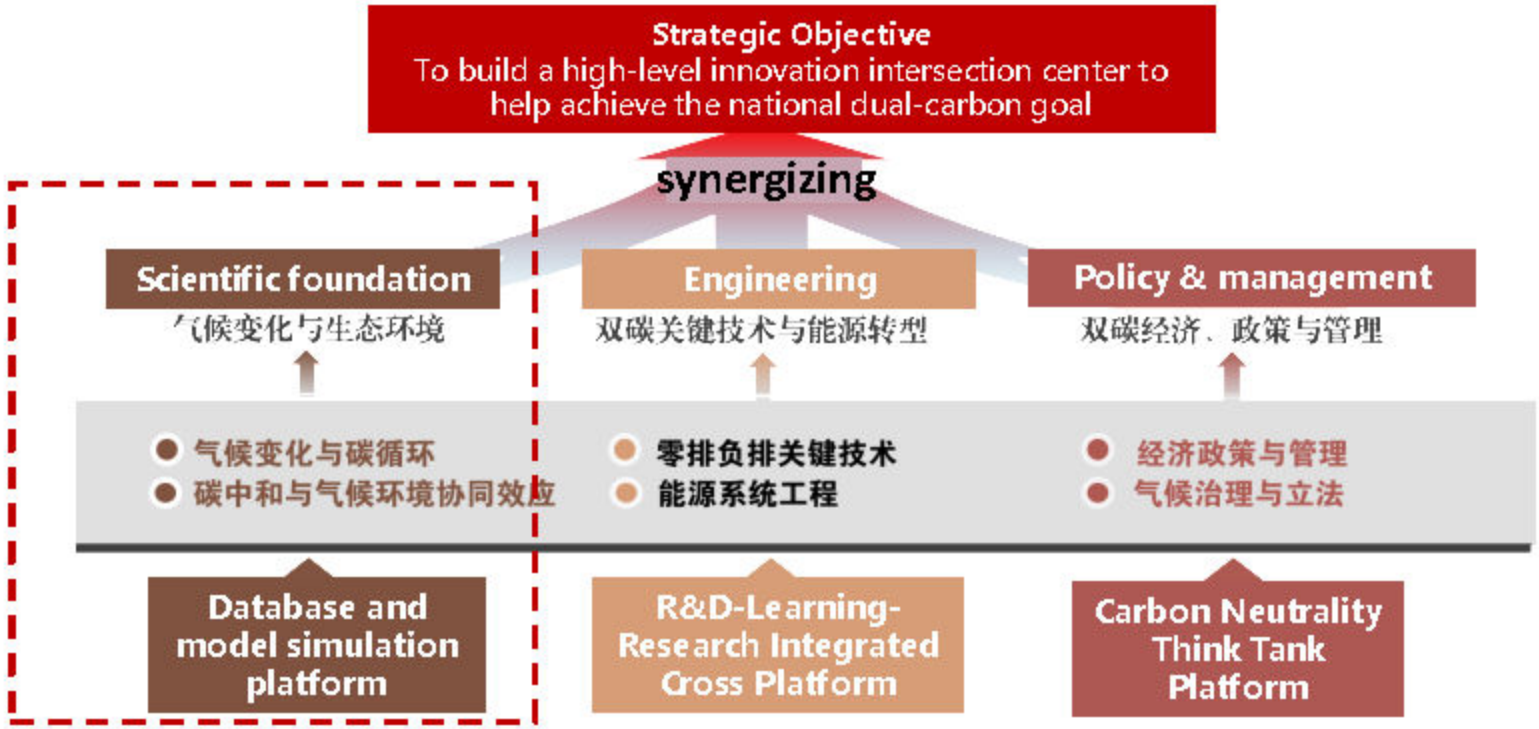

Academician Peng Tao


Academician Yuanhang Zhang


Academician Tong Zhu


Academician Zhijun JIn


Academician Shilong Piao

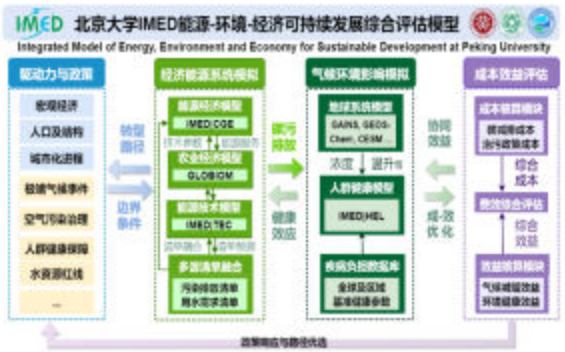


Current status of PKU Integrated Assessment Model for pollution and carbon reduction

By self-developed modeling and adopting international pioneer models, PKU has established initial modeling capacity such as **IMED**, **GCAM**, **GAINS**, **GLOBIOM**, etc.

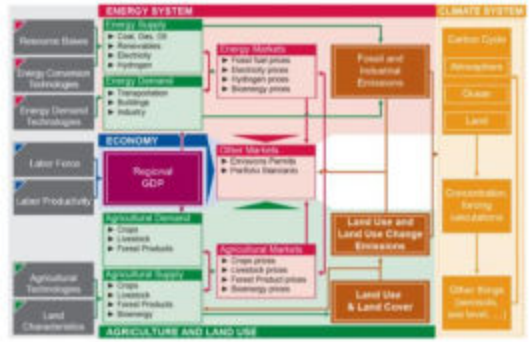
Integrating representative models for multidisciplinary cross-cutting research

IMED



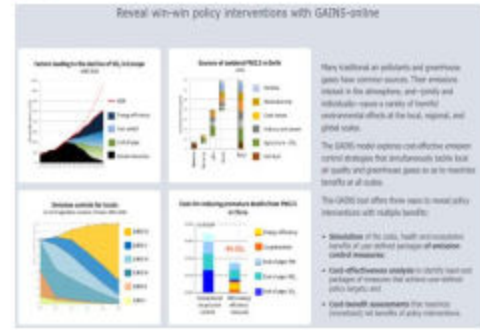
Listed by UNEP as a **representative IAM in China**

GCAM



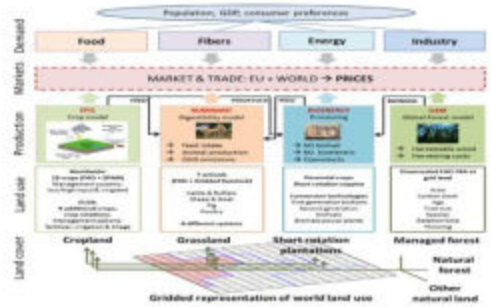
Adopted the **IPCC flagship model**——the GCAM model

GAINS



Assesses **GHG-air pollution** interactions and synergies.

GLOBIOM



Well-known model for land use simulation

Representative models at PKU

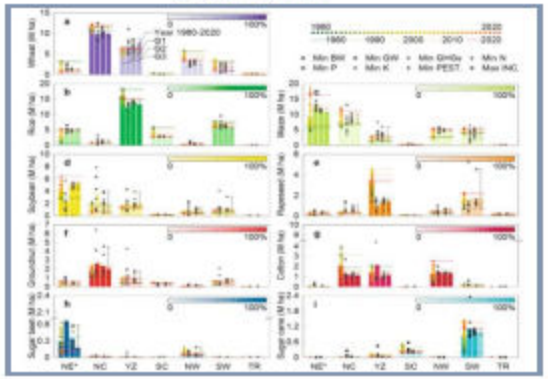
- PKU has established initial modeling capacity such as **CEEGE**, **CAPSiM**, **WILIAM**, etc.
- Energy economic & engineering models

Multidisciplinary representative models as a basis for cross-cutting studies and integrated assessment

College of Urban and Environmental Sciences
CEEGE

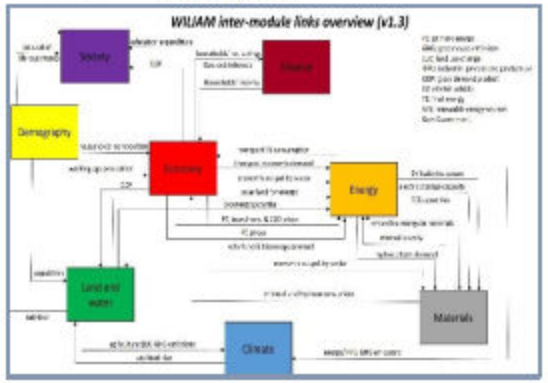
Interregional input-output and trade simulations, multi-scale policy analysis

School advanced agricultural sciences
CAPSiM



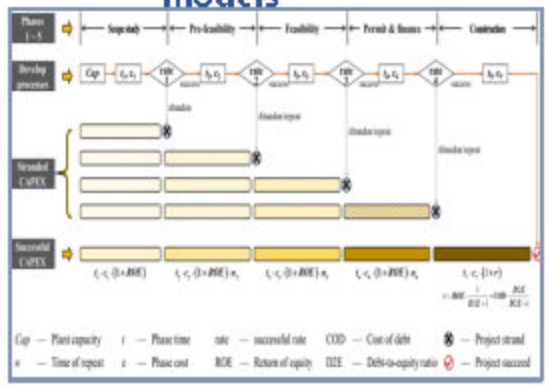
Supply, demand and price analysis of external shocks to China **agricultural products**

College of Urban and Environmental Sciences
WILIAM



High-precision emission accounting and integrated **climate-ecology-health** assessment

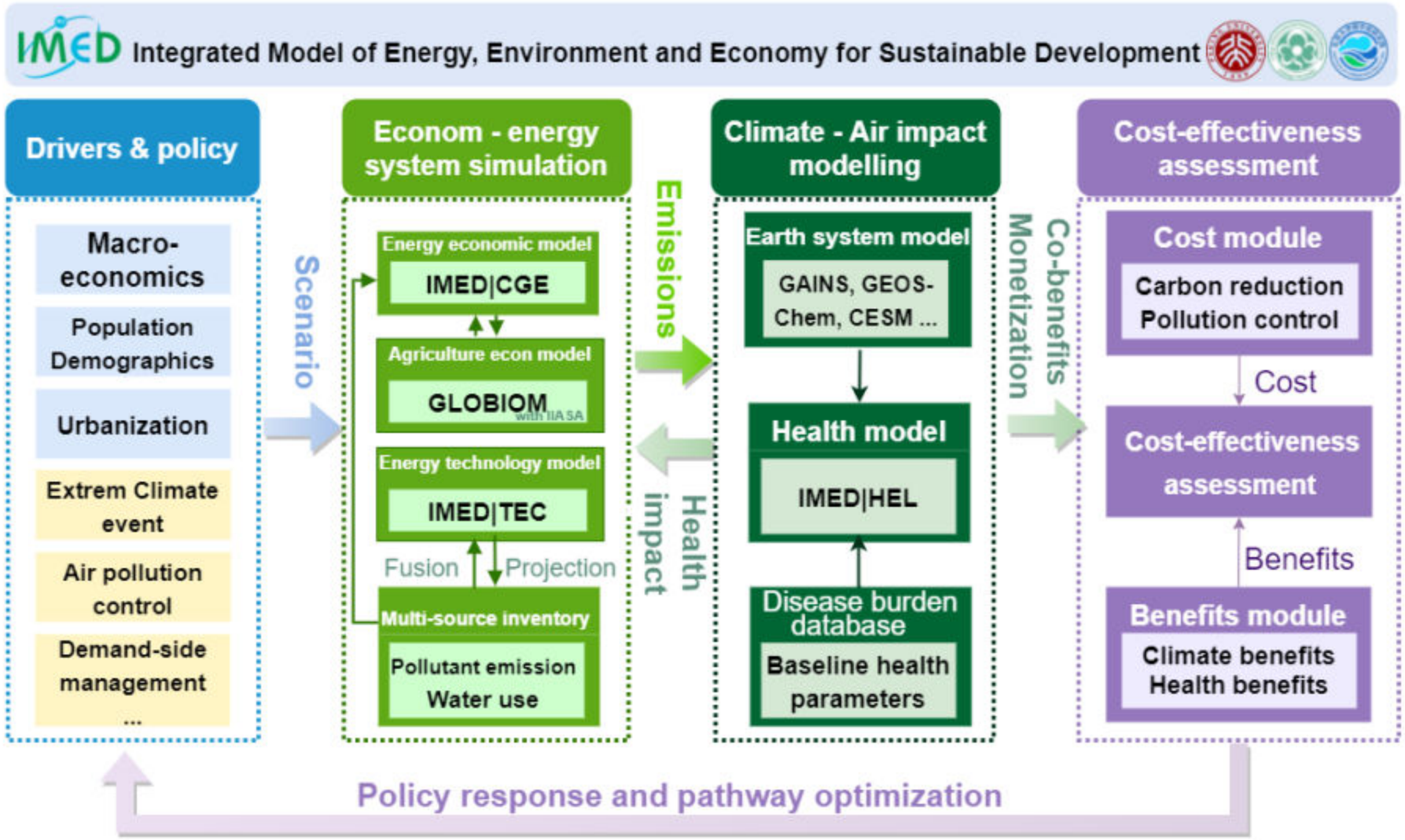
Institute of Energy
macro-energy system models



Analysis, control and optimization of **low-carbon energy systems**

The IMED model at PKU

- Developed by LEEEP group at PKU & BUAA, covering eight modules of energy economic system, air quality, and public health, etc.
- Integrated simulation and assessment of synergistic effects and cost-effectiveness of low-carbon policies.



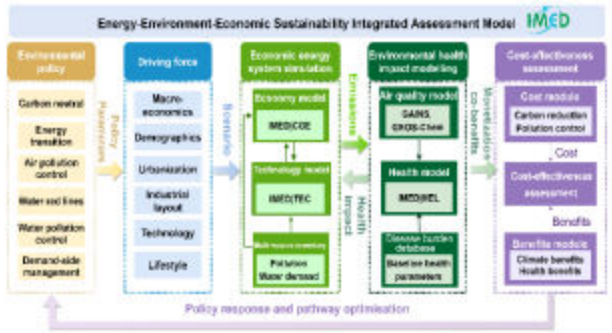
The IMED model for integrated decision support at PKU

- ◆Integrated simulation and assessment of synergistic effects and cost-effectiveness of low-carbon policies.
- ◆Widely applied in literature.

IMED Online Model

www.imedmodel.com

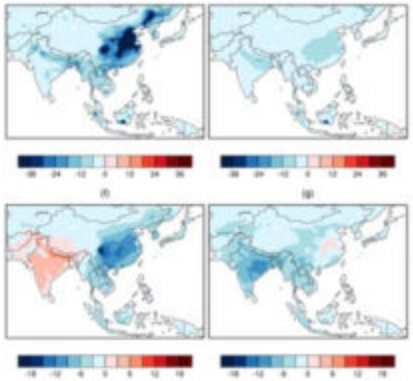
IMED offline model and Database



Decision support

Cost-benefit analysis

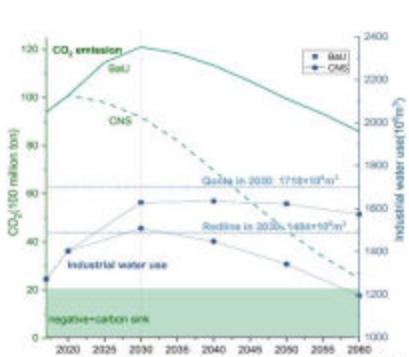
➢Low-carbon in Asia

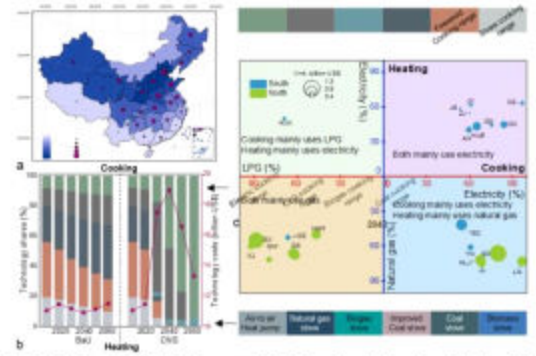


➢Bioenergy in China

Nature Food, 2023
Nature Comm, 2023
One Earth, 2022; 2024
iScience, 2023

Carbon reduction and water saving in China



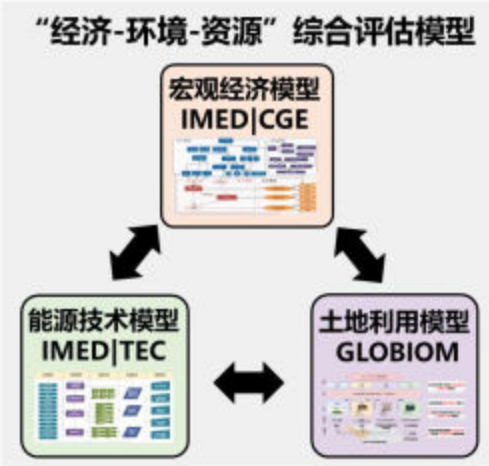


GEC, 2023; EST, 2016, 2019

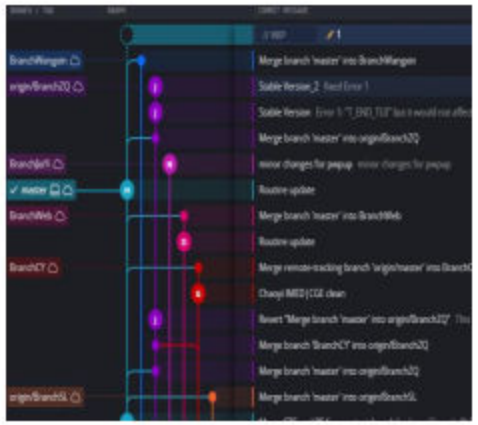
IMED underlying source code with version control

School of Environment

- Independent development and maintenance of 100,000+ lines of underlying source code
- Initially built an integrated energy-environment-economy modeling system (IMED)

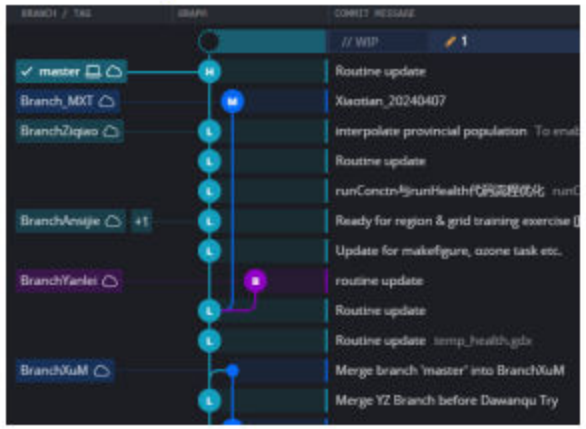


IMED/CGE economic model

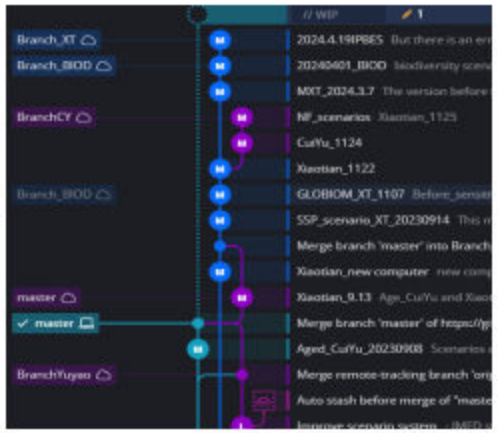


IMED/TEC technical model

IMED/HEL health model



GLOBIOM land use model



IMED reveals synergies or trade-offs of air & climate policies

50+ SCI papers

IMED model systematically used to assess the **cost-benefit** of **pollution and carbon reduction pathways** to global, national and provincial levels

Global

Global Asia Korea Japan

31 provinces

$PM_{2.5}$ and ozone in 31 provinces

Beijing, Tianjin and Hebei

Beijing Hebei Tianjin

Yangtze River Delta

Shanghai

Pearl River Delta

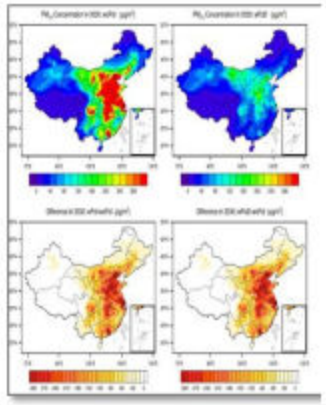
Guangdong 粤港澳

Chengdu-Chongqing /Southwest China

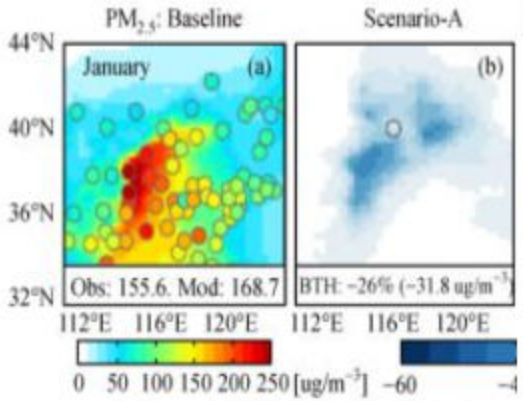
Sichuan Chongqing Guangxi

Northeast /Northwest China

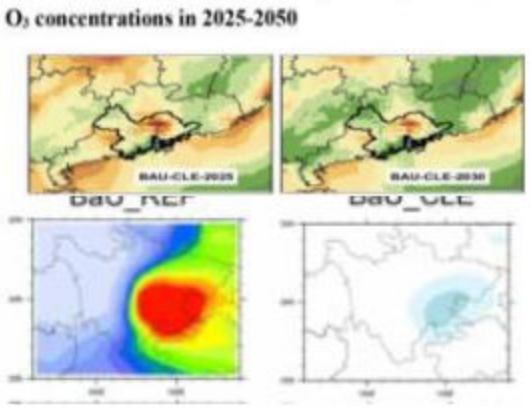
Liaoning Gansu Northwest 5 provinces



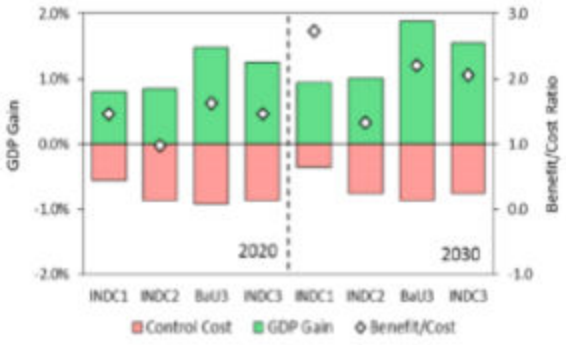
Xie, 2019, *EI*



Liu, 2019, *FESE*



Zhang, 2022, *ERL*; Xie, 2023, *UC*

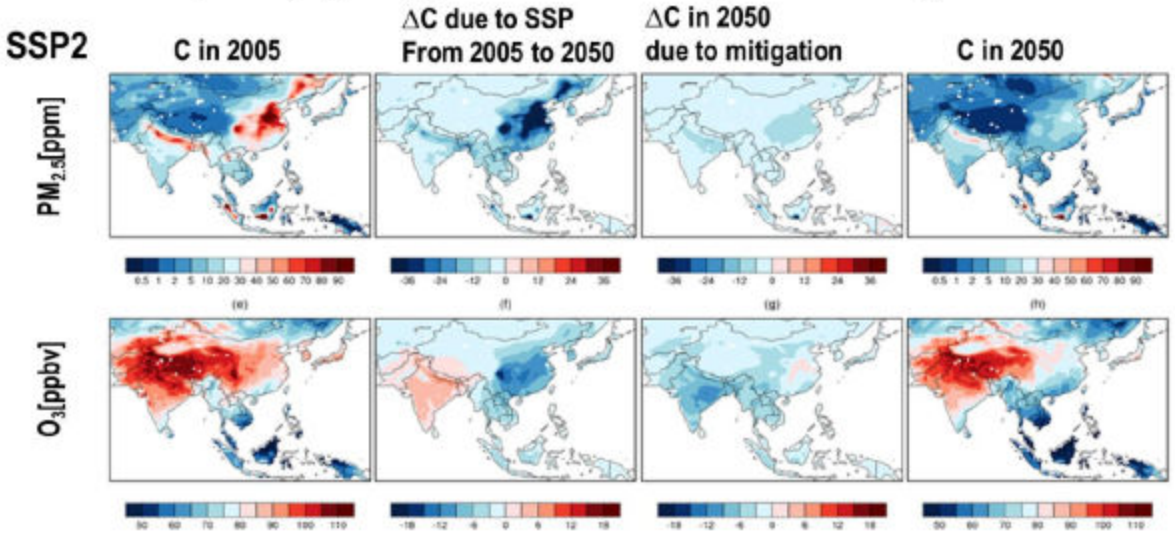


Wu, 2019, *ES&T*

Earlier research: health benefits of air and climate policies

- ✓**Model Application: IMED/CGE + IMED/HEL Health Models**
- ✓**Key Finding:** Asia will reduce premature deaths by 790,000 in 2050, 220,000 in China and 460,000 in India

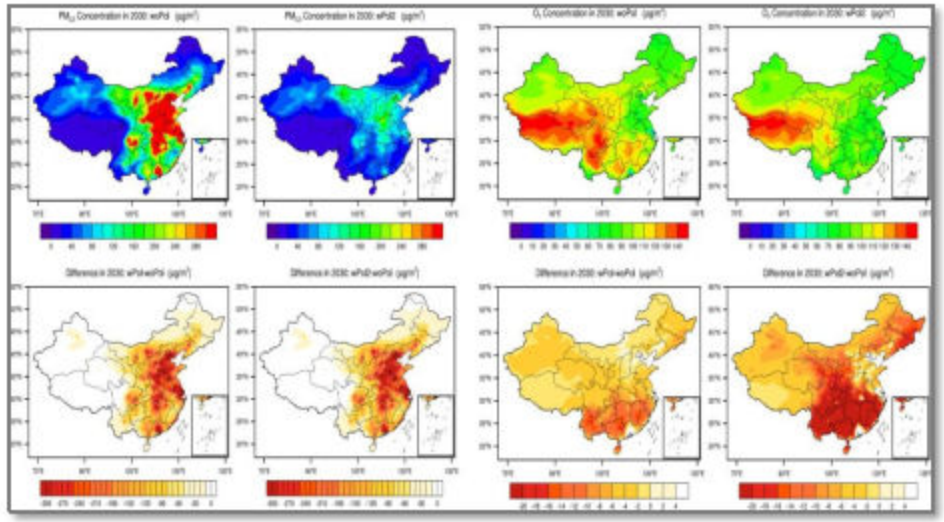
Air quality synergies for achieving the 2℃ objective in Asia



Xie, et al., ***Environment International***, 2018; 2019; Dong, 2015

- ✓**Model application: IMED|CGE + IMED|HEL models**
- ✓**Regional heterogeneity:** eastern provinces are more severely affected by PM2.5 pollution and health impacts, while O3 has a greater impact on western provinces

$PM_{2.5}$ and O_3 pollution and health burden, China, 2030



Xie et al.., ***EST, 2016; 2019***

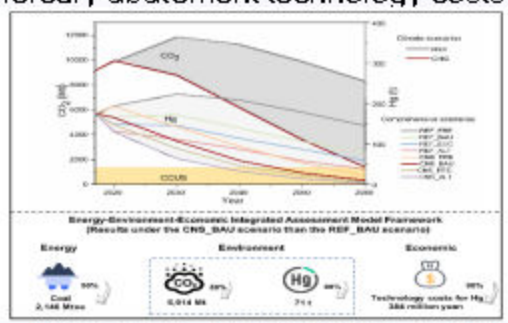
Recent research: synergies or trade-offs of low-carbon pathways

The IMED model has been applied to uncover cost-effectiveness and multi-dimensional effects of green and low-carbon policies aimed at pollution and carbon reduction.

Representative the IMED-based publications in recent years

Synergies between carbon and mercury reduction goals

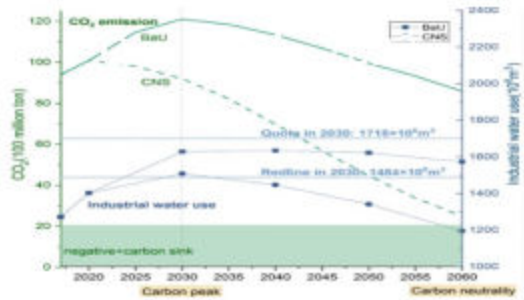
Carbon neutrality will reduce atmospheric mercury emissions by 88% and save $384 million in mercury abatement technology costs



Pan, et al, **One Earth**., 2024

Potential synergies between carbon reduction and water saving targets

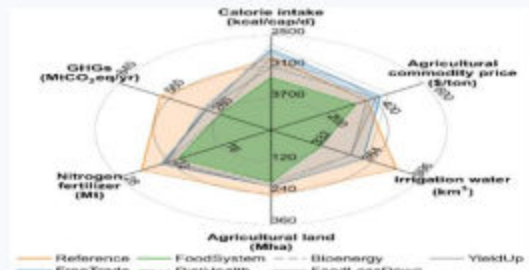
Carbon neutrality will save 38 billion m^3 of water and achieve the industrial water red line target



Liu#, Dai# et al, **One Earth**, 2022

Agri-food system protects food and enhances negative CO2 emission in a win-win situation

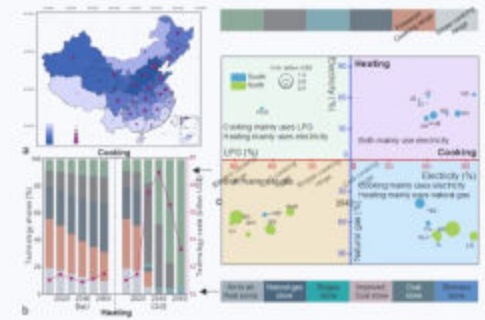
Rationalizing biomass energy supply choices for both carbon neutrality and sinks and mitigating negative impacts on agrifood systems



Ren, ..., Dai*, **Nature Food**. 2023

Rural energy transition contributes to carbon neutrality

Rural generation energy transition is critical for China to achieve multiple sustainable development goals



Ma, et al, **Nature Comm**. 2023

Participation in GEO-7 amd IAMC

- PKU IMED model is listed as one of the representative IAM models in China by UNEP to support GEO-7
- Institute for Carbon Neutrality of PKU officially becomes a member of the IAMC.

GEO-7 multimodel coupling framework

Model name	IMED: Integrated Model of Energy, Environment and Economy for Sustainable Development
Purpose of model	
The IMED integrated assessment model addresses key scientific challenges and policy imperatives crucial for facilitating green and low-carbon transitions in alignment with national and global sustainability objectives. Central to its investigations are questions surrounding the mitigation costs associated with ambitious climate targets and their co-benefits, particularly in terms of improvements in air pollution, human health, and resource efficiency.	

GEO 7 UN environment programme

Institute for Carbon Neutrality becomes a member of IAMC

IAMC
Integrated Assessment Modeling Consortium
Founded 2007

THE CONSORTIUM

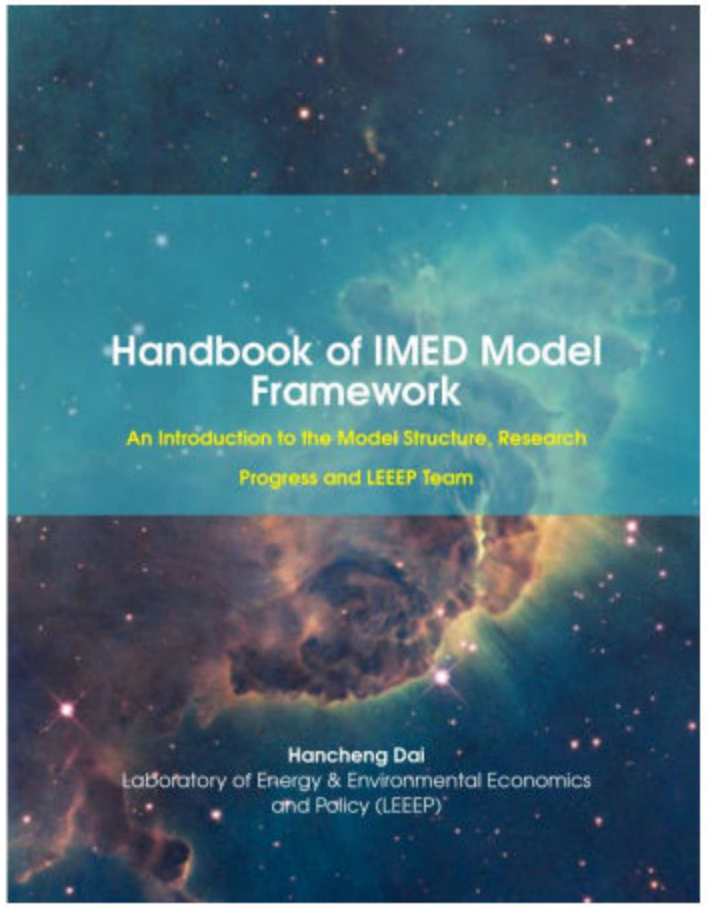
Institute of Carbon Neutrality, Peking University (ICN-PKU), China

Website: https://carbon.pku.edu.cn/en/index.htm

Contact: Hancheng Dai

LEEEP group with IMED model for more information

scan to download



https://www.jianguoyun.com/p/DZnI8a8QIL7CBhi913M

https://www.jianguoyun.com/p/DVrcIwsQIL7CBhjE13M

scan to download

PKU Workshop on IAM for Carbon Neutrality

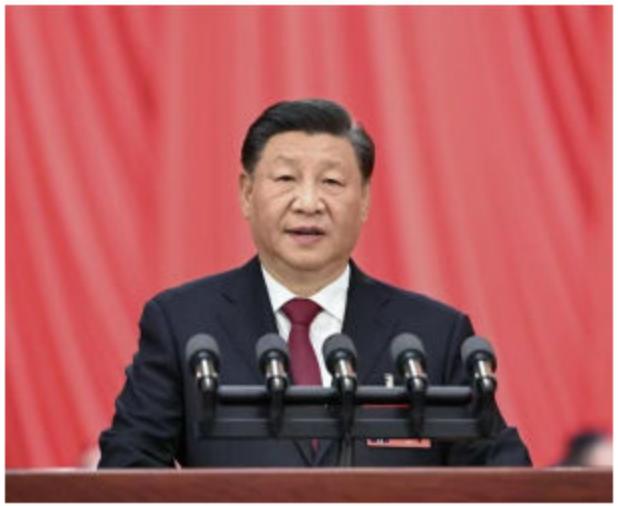
- ✓ A 5-day workshop for IMED and GCAM held by PKU in 2023 and 2024
- ✓ Over 50 participants from 30+ institutes, over 20,000 views online

03 Future trends

- Some thoughts

LEEEP

Opportunities for IAM to build a "Beautiful China"



20th National Congress: Synergizing carbon reduction, pollution reduction, greening and growth

- Accelerating the green transformation of development approaches
- Deeply promoting of environmental pollution prevention and control
- Enhancing ecosystem diversity, stability and sustainability
- Actively and steadily promoting carbon peak carbon neutrality

By 2035, a green production and lifestyle to be widely formed, carbon emissions to be decreased steadily after reaching the peak, the ecological environment to be fundamentally improved, and the **goal of a beautiful China** to be basically realized.

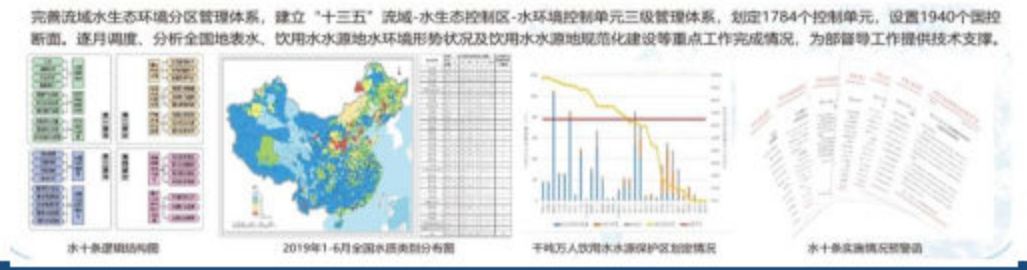
Decision support: major national strategies

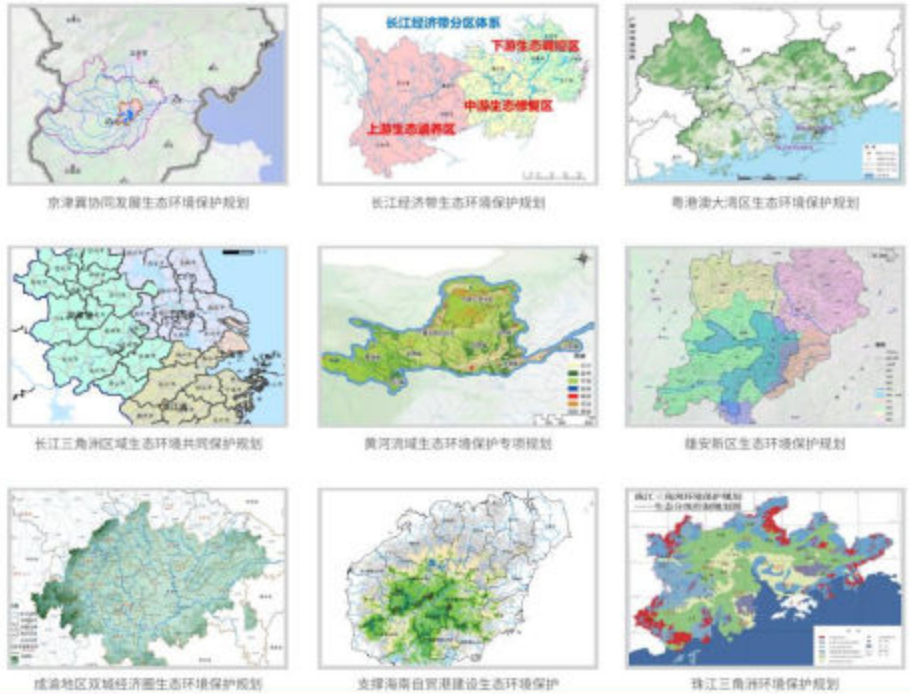
- **National level**: Scientific support for top-level design of national strategies such as the national five-year ecological and environmental protection plan, the "Beautiful China", "Ten Measures" of air, water and soil, and the blue sky defense campaign.
- **Regional level**: Scientific support for preparation of ecological and environmental protection plans for major national strategic areas such as Beijing-Tianjin-Hebei region, Yangtze River Economic Belt, Greater Bay Area, the Yellow River Basin, Yangtze River Delta, Chengdu-Chongqing region, and Belt and Road Initiative.

air pollution prevention action(2013)

soil pollution prevention action(2016)

water pollution prevention action(2015)





Decision support: compliance with intl. environmental conventions

- Deep involvement in national and international global environmental agreements, with research results contributing to technical reports for decision-making at the international level and supporting compliance with important national environmental conventions.
- Several members of Peking University have served as co-chairs or members of the expert groups of the Montreal Protocol on Science, Technology and Economics for the Protection of the Ozone Layer, as chair of the Multilateral Fund Replenishment Working Group, as members of the Climate and Clean Air Coalition's Scientific Advisory Group.

Lead preparation of national compliance program

unep award for the protection of the ozone layer, 2005

Special Gold Medal of the National Award for Contribution to the Protection of the Ozone Layer, 2004.

Capacity building in science-based policy making process

AIM experiences since 2009

- Strengthen the capacity building of China's provinces, cities & developing countries
- Integrate databases, case studies, and modeling toolboxes to support carbon neutrality policy formulation at national and sub-national levels

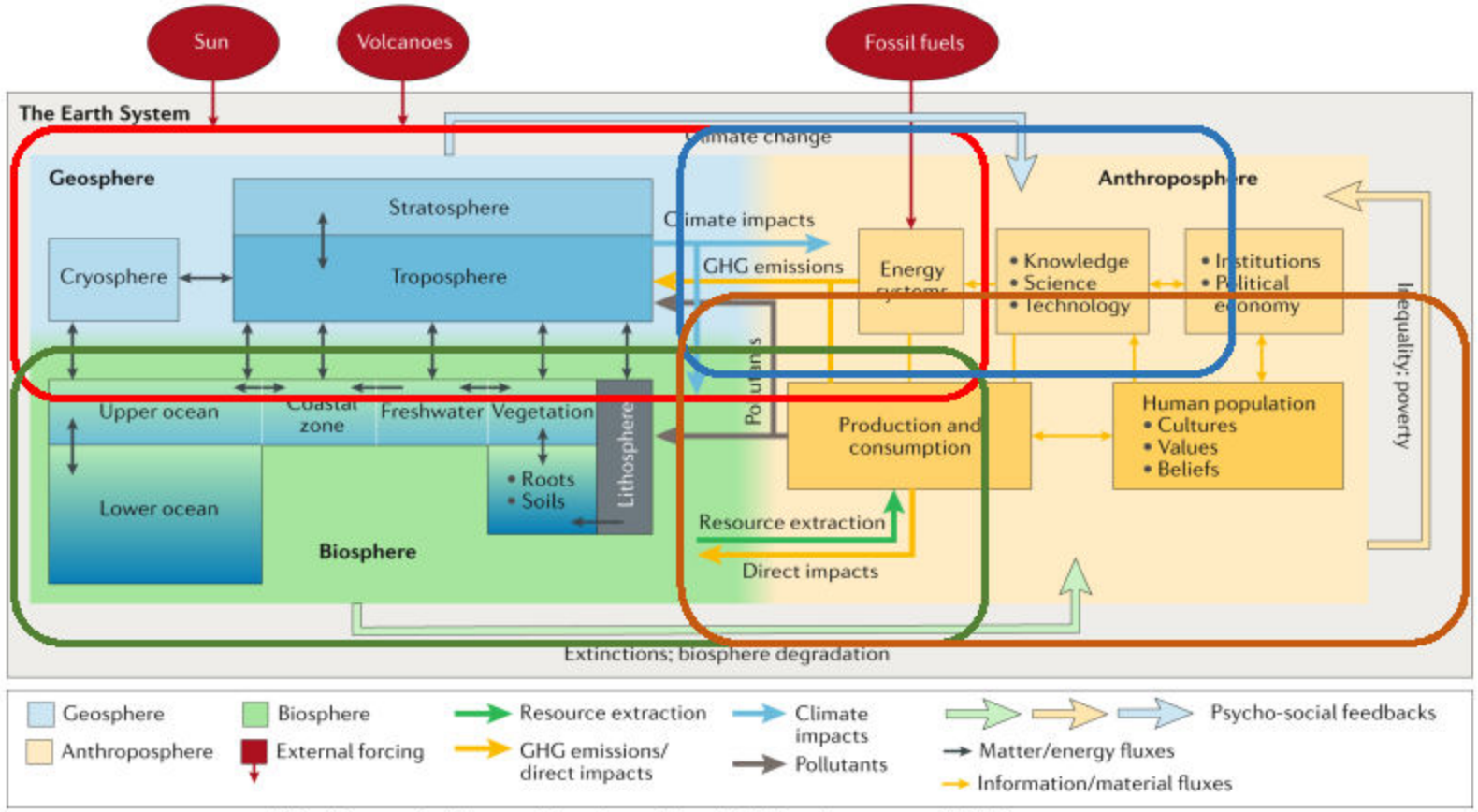
Knowledge gap from an educational perspective

Improve the interdisciplinary environmental curriculum system with systematic thinking, more focus on human system is needed.

Fig. 3: An updated conceptual model of the Earth System.

Env. Science

Env. Engineering



Env. health

Env. Management

(Steffen et al. Nature Reviews Earth & Environment 2020)

Concluding remarks

- IAM is increasingly regarded as a key tool in China to support domestic dual-carbon pathway optimization and international climate cooperation.
- An urgent need to learn from international experiences, while independently construct several sets of “domestic” IAMs, and carry out multi-model comparative studies.
- IAM has high learning cost and long development time, university plays a key role to overcome the challenges to train young talents in this field.

LEEEP at PKU is just one of the multiple teams on the way
AIM’s experience and support are invaluable highly needed in the next 30 years

LEEEP_Forum

LEEP IMED

环境科学与工程学院 北京大学碳中和研究院

北京大学能源环境经济与政策研究室

Laboratory of Energy & Environmental Economics and Policy, PKU

关于我们 · 科研拾贝 · 信息发布

THANK YOU! Q&A

Prof. Hancheng Dai

dai.hancheng@pku.edu.cn