清華大學环境学院
SCHOOL OF ENVIRONMENT, TSINGHUA UNIVERSITY

Roundtable on the Future of North-East Asia Clean Air Partnership

Integrated Assessment Modeling: approaches and applications in China

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Effective AQ management requires IAM

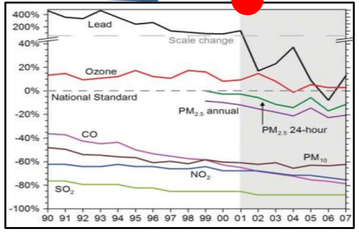
"Technology-Based" air pollution control strategy

Emission Target → ***Feasible control measures*** → ***Control planning*** → ?

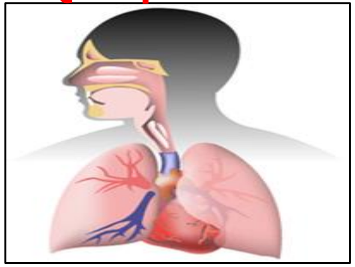
"Risk-Based" air pollution control strategy

Air Quality Target

Integrated Assessment Model



AQ Improvement



Health & Env.

control cost

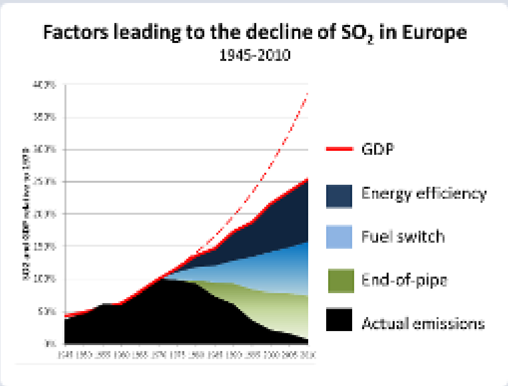
Air pollution control measures ↔ **Implement Emissions Control Plan**

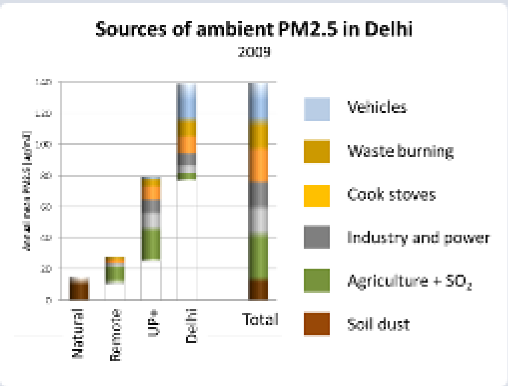
Examples of widely-used IAM: GAINS

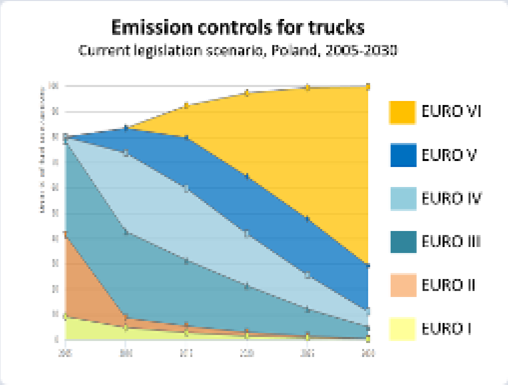
GAINS Online

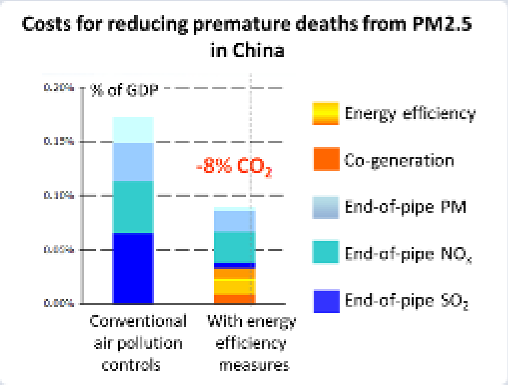
Greenhouse Gas - Air Pollution Interactions and Synergies

Reveal win-win policy interventions with GAINS-online









http://gains.iiasa.ac.at/

Many traditional air pollutants and greenhouse gases have common sources. Their emissions interact in the atmosphere, and—jointly and individually—cause a variety of harmful environmental effects at the local, regional, and global scales.

The GAINS model explores cost-effective emission control strategies that simultaneously tackle local air quality and greenhouse gases so as to maximize benefits at all scales.

This GAINS tool offers three ways to reveal policy interventions with multiple benefits:

- **Simulation** of the costs, health and ecosystems benefits of user-defined packages **of emission control measures**;
- **Cost-effectiveness analysis** to identify least-cost packages of measures that achieve user-defined policy targets; and
- **Cost-benefit assessments** that maximize (monetized) net benefits of policy interventions.

Examples of widely-used IAM: ABaCAS

Integrated Cost/Benefit & Attainment Assessment

Control & Cost Estimate	Real-time Air Quality Benefit	Air Quality Attainment Assessment	Health & Economic Benefit

http://www.abacas-dss.com/

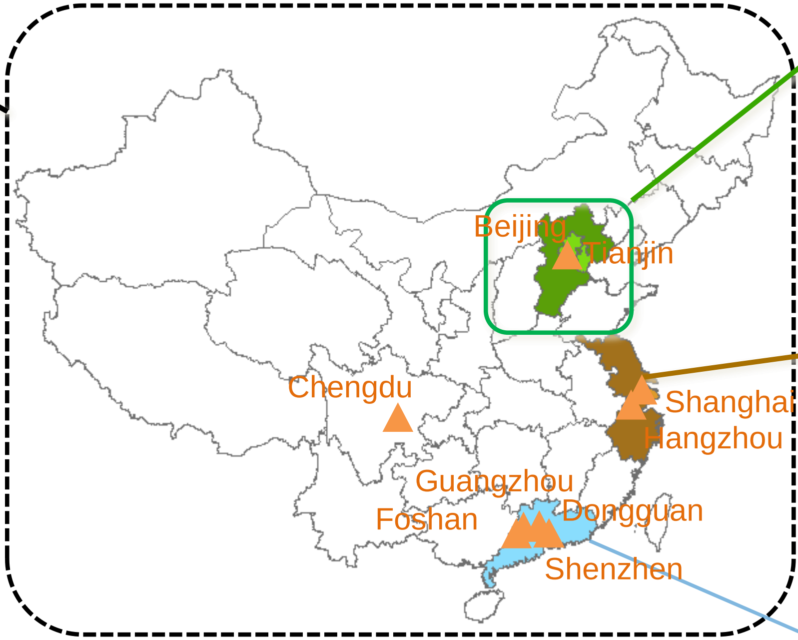
Applications of ABaCAS in China

China

2010- RSM

2016- BenMAP-CE, SMAT

2018- pf-ERSM, CoST, LECO



▲ City

Beijing-Tianjin-Hebei

2013- RSM, SMAT

2015- BenMAP-CE

2017- pf-ERSM, CoST, LECO

Yangtze-River-Delta

2012- CoST, RSM, SMAT, BenMAP-CE

2017- pf-ERSM, LECO

Pearl-River-Delta

2013-2015 SMAT

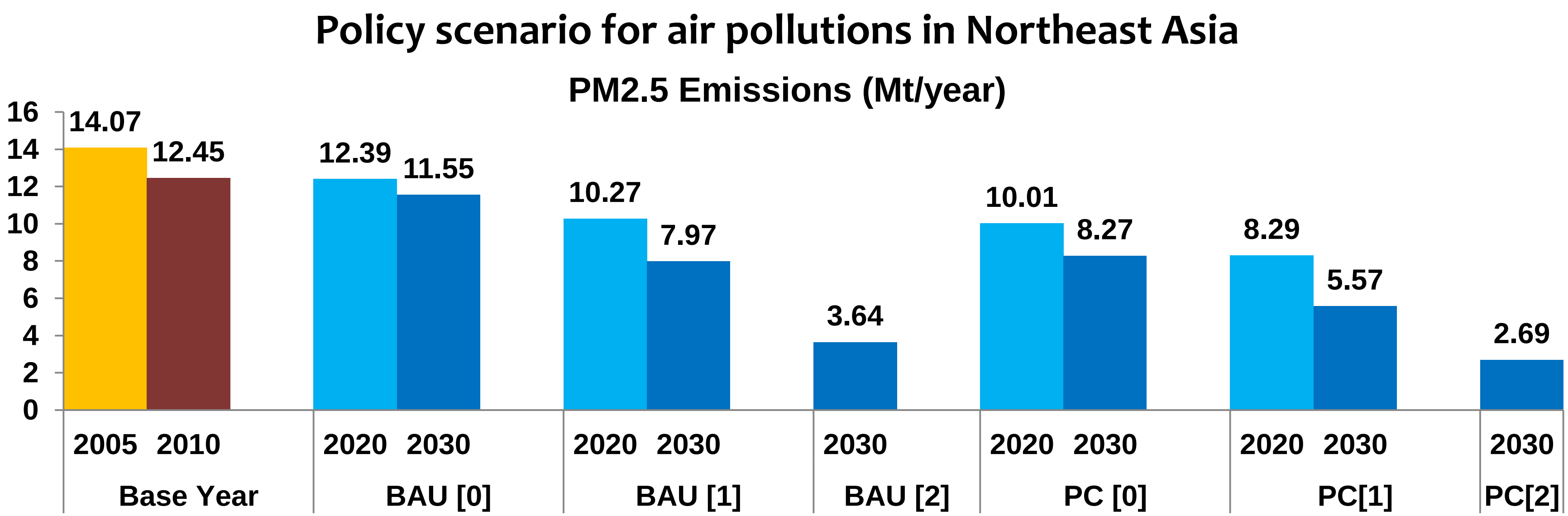
2016- CoST, RSM, BenMAP-CE

ABaCAS has served as a key decision support community tool for air pollution cost/benefit and attainment assessment in China

Key components of IAM: Scenario analysis

Integrated assessment modeling for policy scenario:

(a)Projections of emission scenarios by considering social-economic drivers, emission control options, and baseline emissions



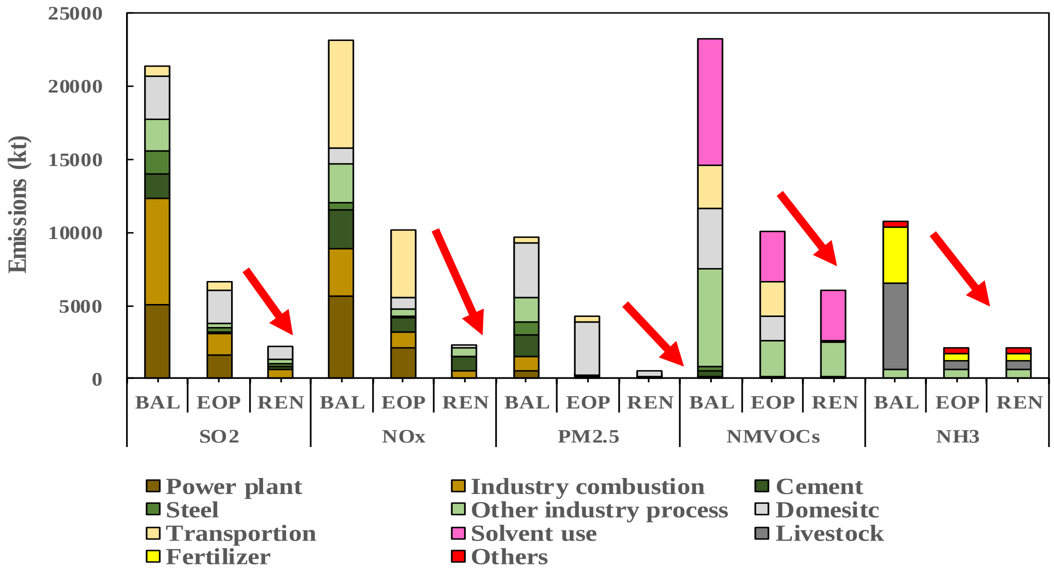
Countries include China, DPRK, Mongolia, Japan and ROK

Scenarios are based on the combination of end-of-pipe control measures and energy-saving policies

Wang et.al. 2014. Emission trends and mitigation options for air pollutants in East Asia, Atmos. Chem. Phys., 14, 6571–6603

Key components of IAM: Scenario analysis

- *BAL* - the baseline emissions of 2014
- *EOP* - with maximum application of end-of-pipe measures
- *REN* - with maximum application of both end-of-pipe and energy polices



	REN	
	Emission reduction /Mt	Total Cost /billion CNY
SO_2	19.2	92.5
NO_x	20.8	469.7
$PM_{2.5}$	9.1	75.7
NMVOCs	17.2	449.0
NH_3	8.6	361.8
Total Cost	-	1448.6

- **Under EOP scenario, the emission of SO_2, NO_x, primary $PM_{2.5}$, and NMVOCs will decrease by 69.2%, 56.1%, 53.8%, and 56.6%, respectively;**
- **Under REN scenario, the emission of SO_2, NO_x, primary $PM_{2.5}$, and NMVOCs will be reduced by 89.7%, 89.9%, 94.6%, and 74.0%, respectively**

Zhang et al., 2019, Estimation of the abatement potential and costs of air pollution emissions in China, submitted

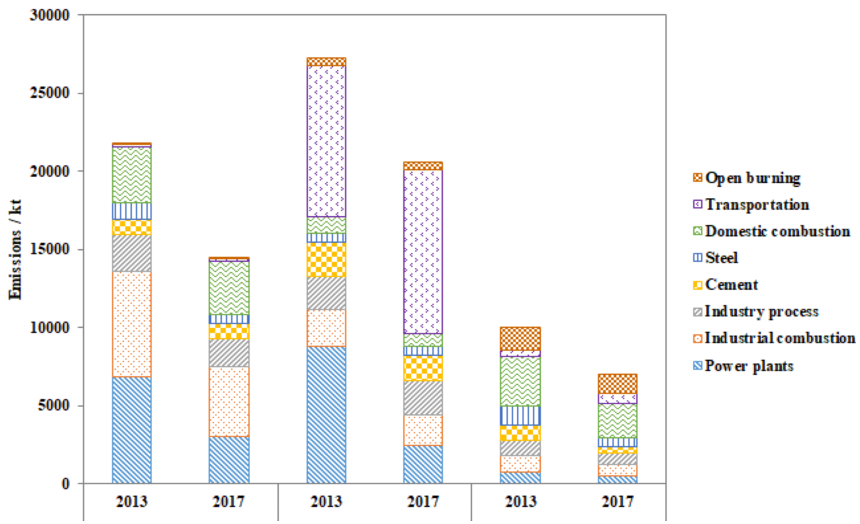
Key components of IAM: AQ assessment

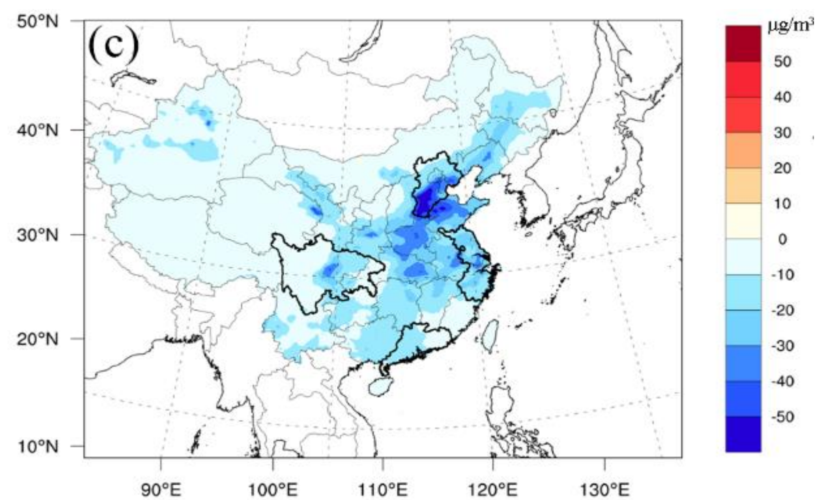
Integrated assessment modeling for policy scenario:

(a) **Projections of emissions** by considering social-economic drivers, air pollution control measures, and baseline emissions

(b) **Assessments of air quality improvements** under certain emission scenarios using CTMs or other source-receptor models

CAMx | NAQPMS | CMAQ | WRF-Chem | GOES-Chem | RSM



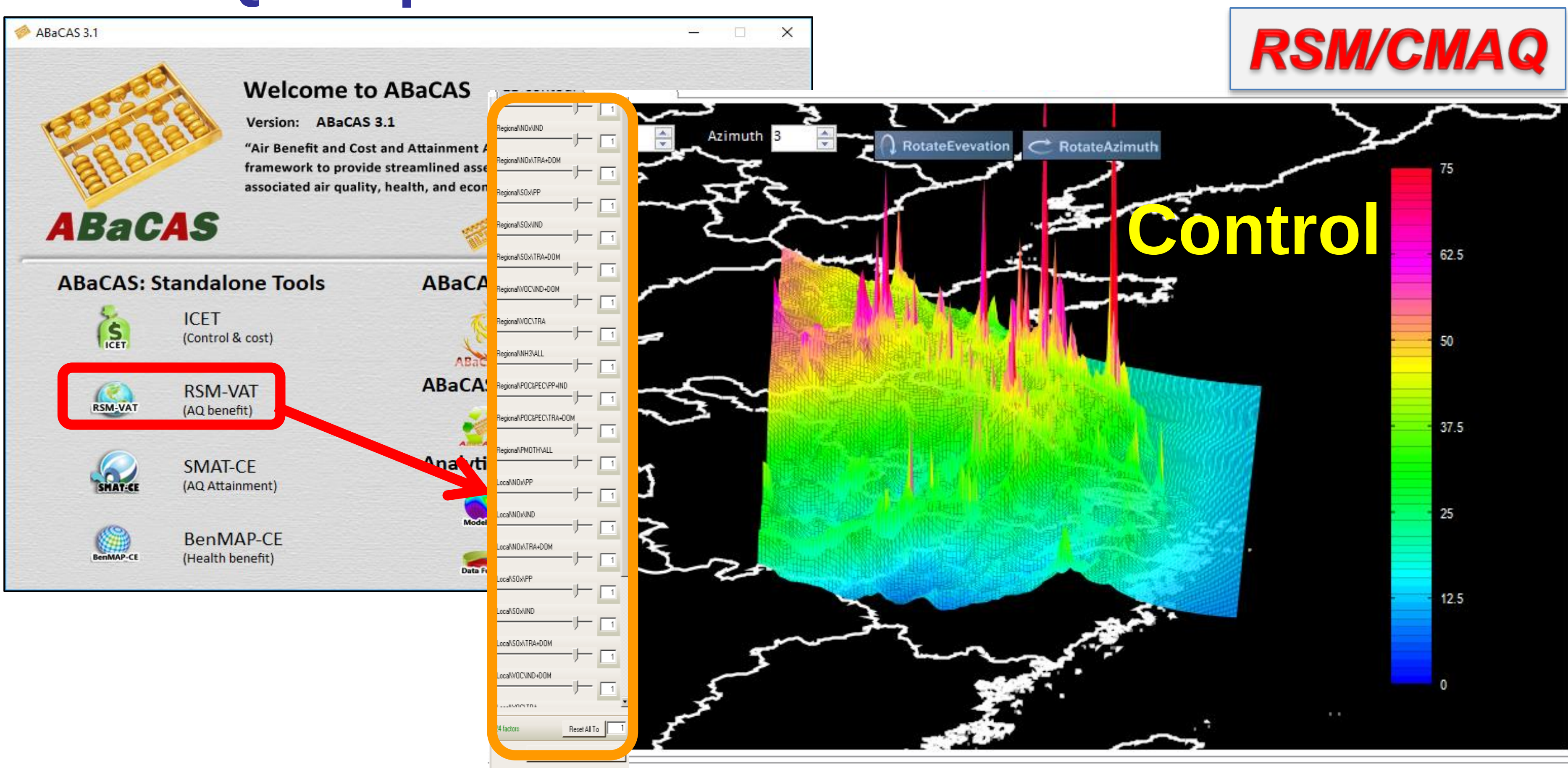


Change in China's emissions and annual average $PM_{2.5}$ concentration between 2013 and 2017

Ding et.al. 2019. Estimated contributions of emissions controls, meteorological factors, population growth, and changes in baseline mortality to reductions in ambient PM2.5 and PM2.5-related mortality in China, 2013–2017. Environ. Health. Persp.

Key components of IAM: AQ assessment

Response Surface Model (RSM): Provide Real-time AQ Response to Emissions Control



Zhao, et al., 2015, [Assessing the nonlinear response of fine particles to precursor emissions: development and application of an extended response surface modeling technique v1.0.]() Geoscientific Model Development, 8(1), 115-128

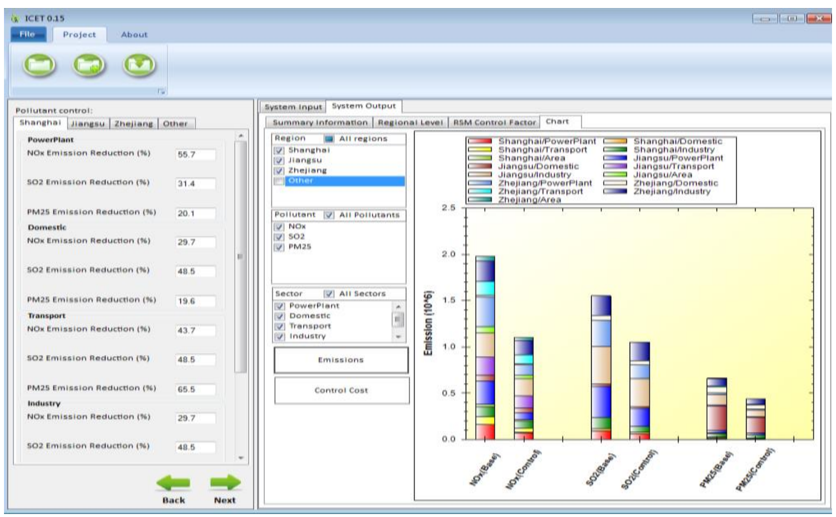
Key components of IAM: Cost/Benefit

Integrated assessment modeling for policy scenario:

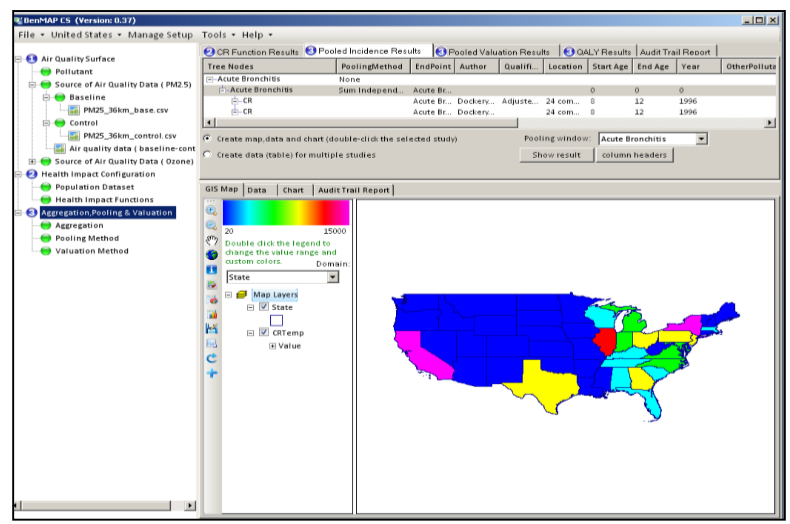
(a) **Projections of emissions** by considering social-economic drivers, air pollution control measures, and baseline emissions

(b) **Assessments of air quality improvements** under certain emission scenarios using CTMs or statistical models

(c) **Cost and/or benefits analysis** by estimating the control costs and the environmental/health benefits of emission reductions



ICET: Provide emission control cost analysis and estimate



BenMAP-CE: Evaluate health impacts & economic benefits estimate

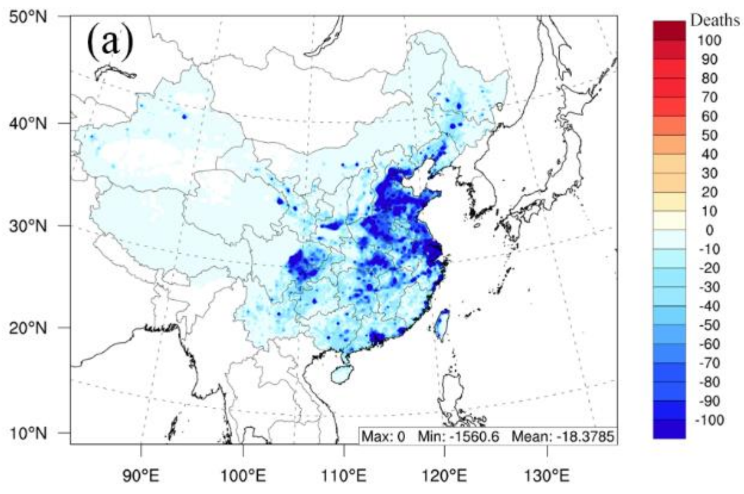
Key components of IAM: Cost/Benefit

Integrated assessment modeling for policy scenario:

(a) **Projections of emissions** by considering social-economic drivers, air pollution control measures, and baseline emissions

(b) **Assessments of air quality improvements** under certain emission scenarios using CTMs or statistical models

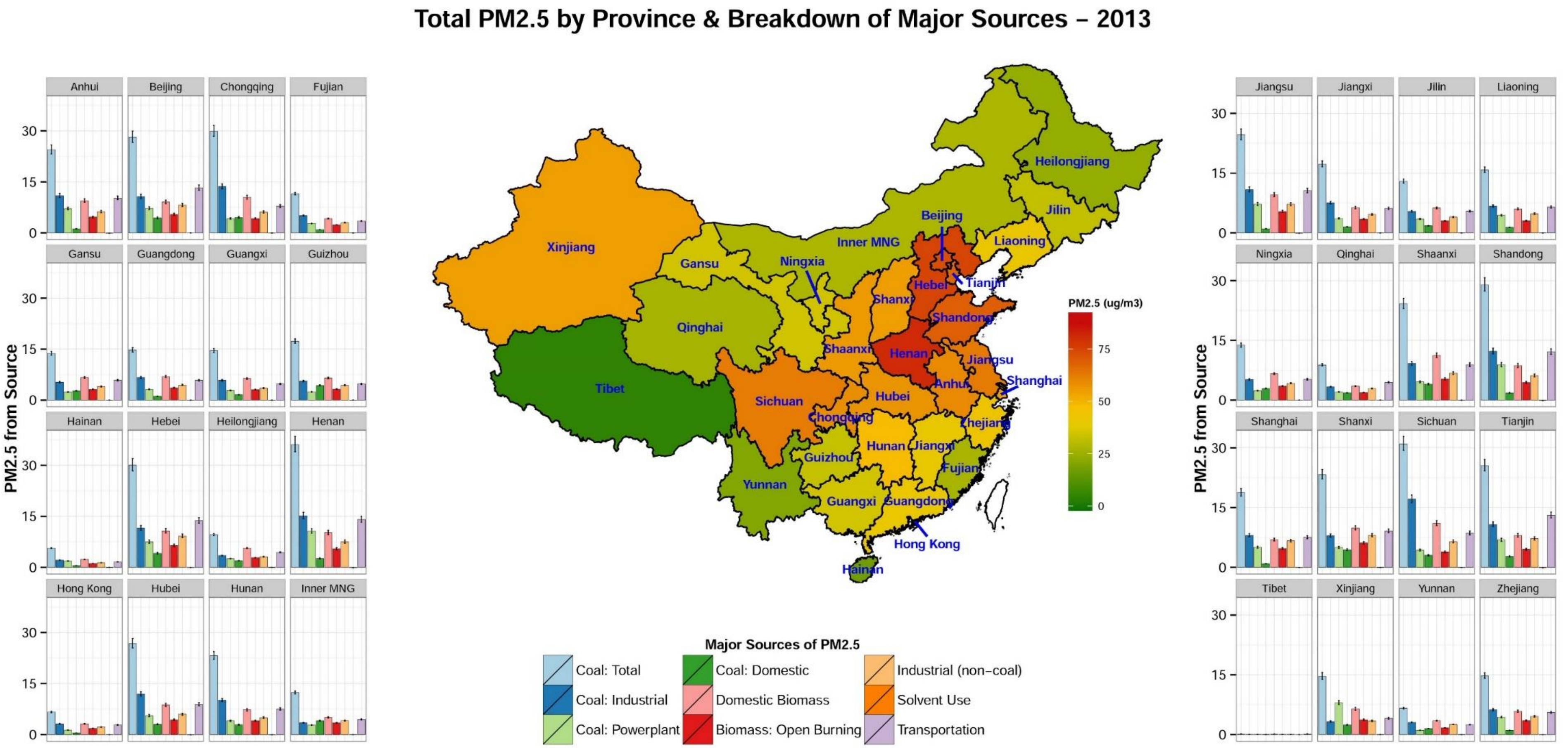
(c) **Cost and/or benefits analysis** by estimating the control costs and the environmental/health benefits of emission reductions



About 287,000 deaths per year in China were avoided between 2013 and 2017 due to the Action Plan, with an estimated benefits of 3,762 billion CNY during 2013-2017, which was much higher than the total investment in the Action Plan (1,840 billion CNY)

Ding et.al. 2019. Estimated contributions of emissions controls, meteorological factors, population growth, and changes in baseline mortality to reductions in ambient PM2.5 and PM2.5-related mortality in China, 2013–2017. Environ. Health. Persp.

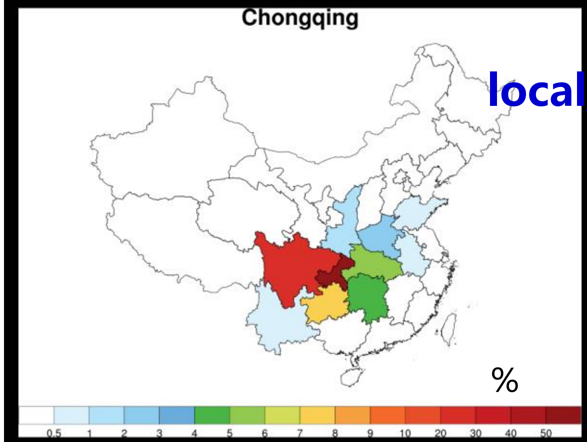
Using IAM for source apportionment



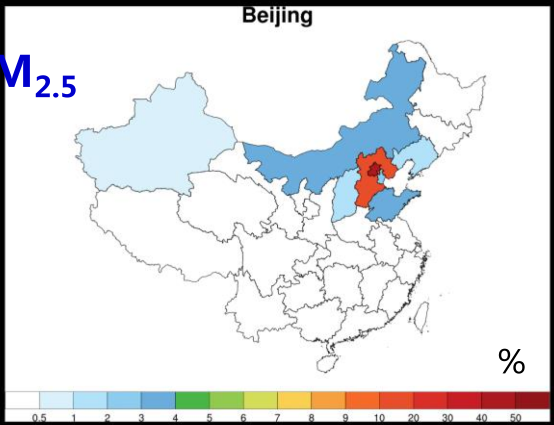
GBD MAPS China Report, 2016

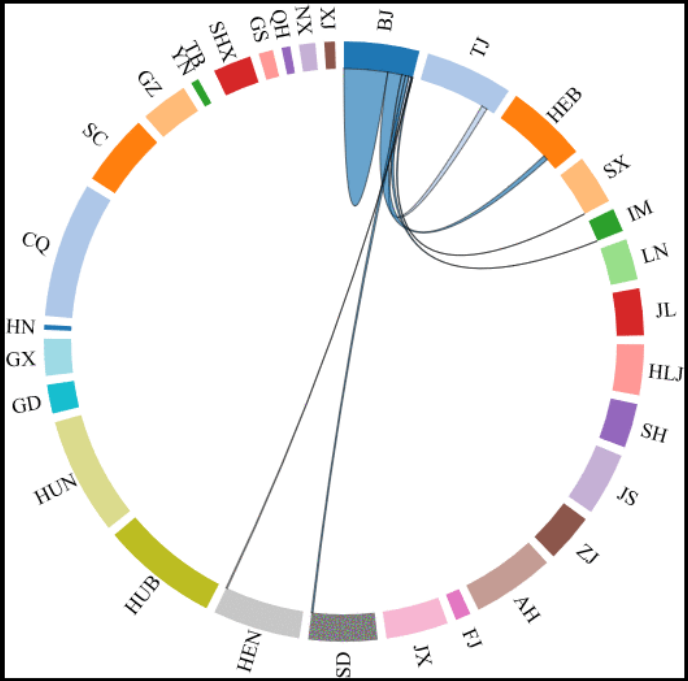
Ma et al, Atmos Chem and Phys, 2017, 17(7): 4477-4491

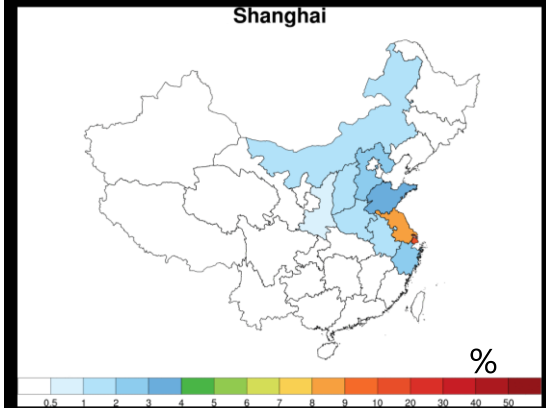
Using IAM for source apportionment



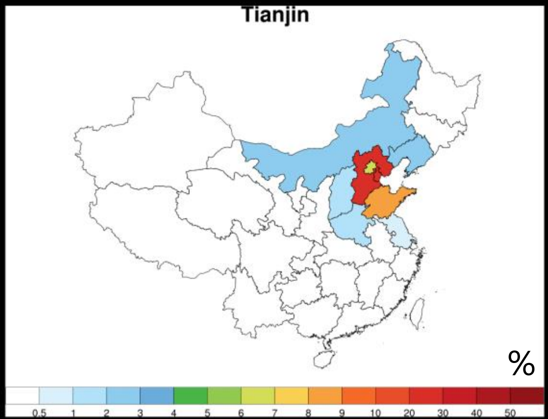
Spatial and seasonal variation of local/regional emission influences on $PM_{2.5}$



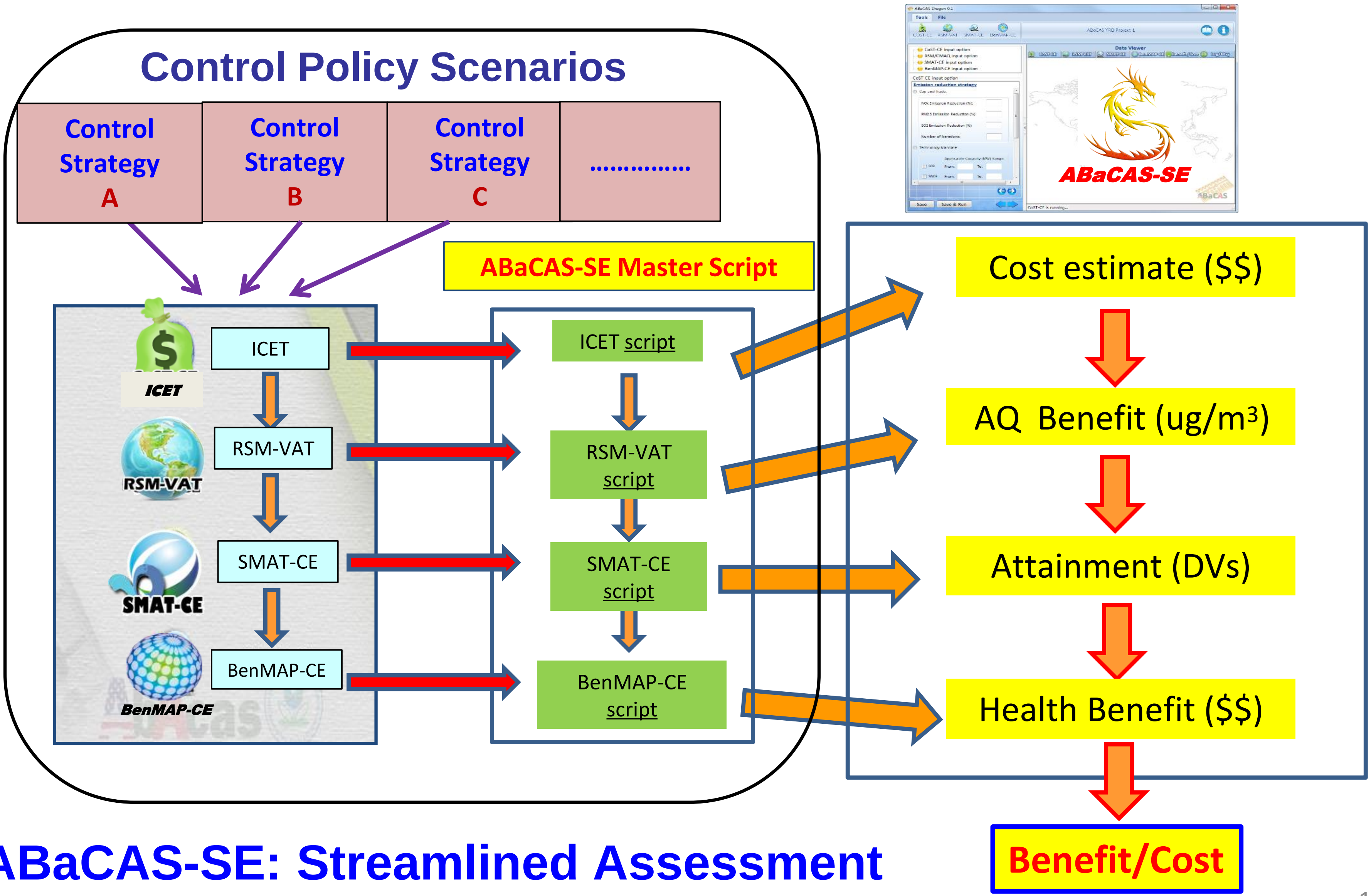




Transport of air pollutants among 31 provinces in China



Using IAM to evaluate control policies



ABaCAS-SE: Streamlined Assessment

Using IAM to evaluate control policies

Case study: which measure was more effective in reducing $PM_{2.5}$ and its related exposure in China during 2005-2015?

Integrated population-weighted exposure to $PM_{2.5}$ (IPWE): weighted sum of $PM_{2.5}$ concentrations in all microenvironments people spend time.

IPWE = $PM_{2.5}$ exposure due to AAP + Extra $PM_{2.5}$ exposure due to HAP

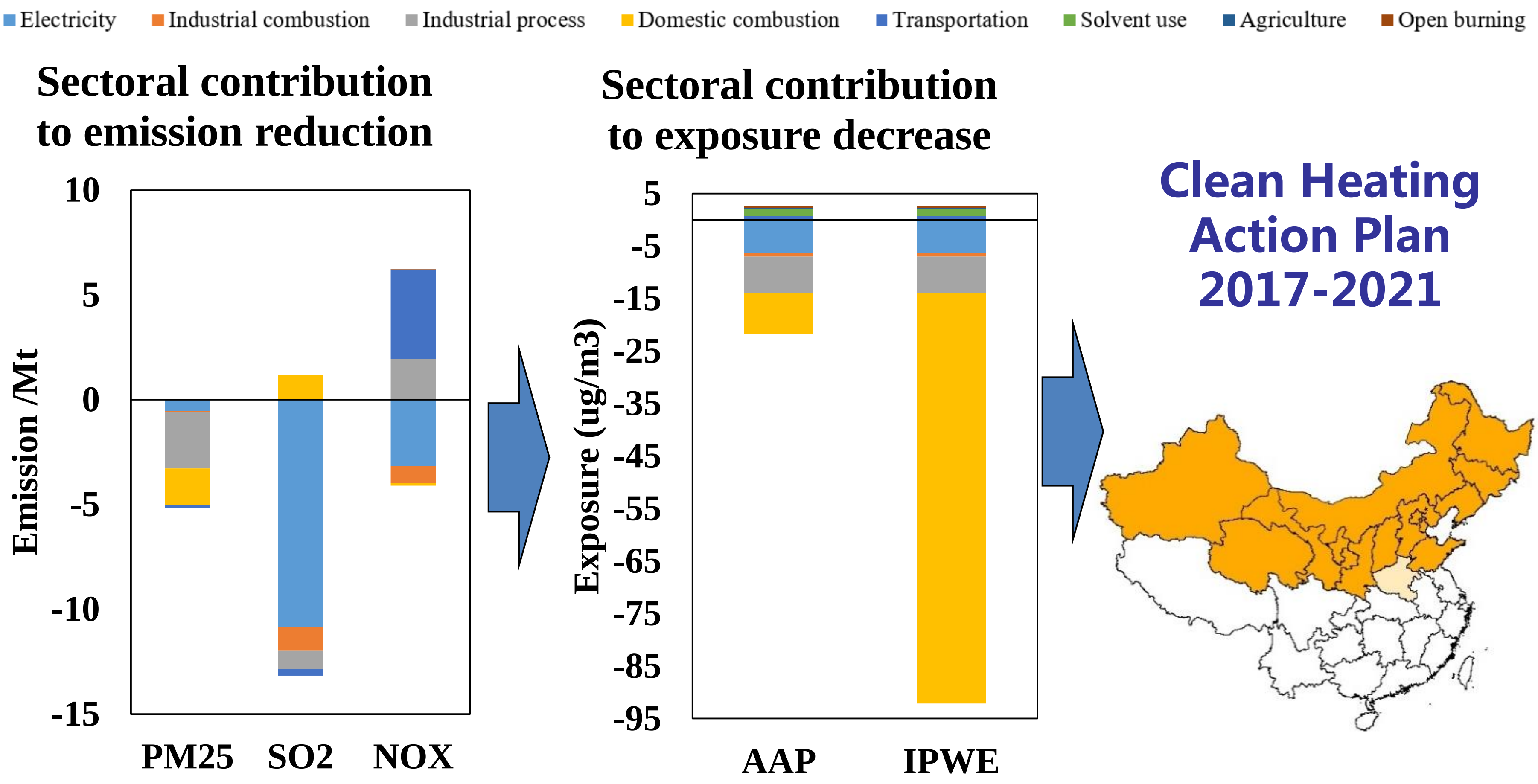
$$\mathrm{PWE}_{HAP} = \frac{1}{P}\sum_{i,j,k}\left(P_{i,j,k} \cdot HAP_{j,k}\right)$$

Populations using coal and biomass as main cooking fuels ($P_{i,j,k}$)

Extra $PM_{2.5}$ exposure levels of solid fuel users ($HAP_{j,k}$)

AAP: ambient air pollution. HAP: household air pollution

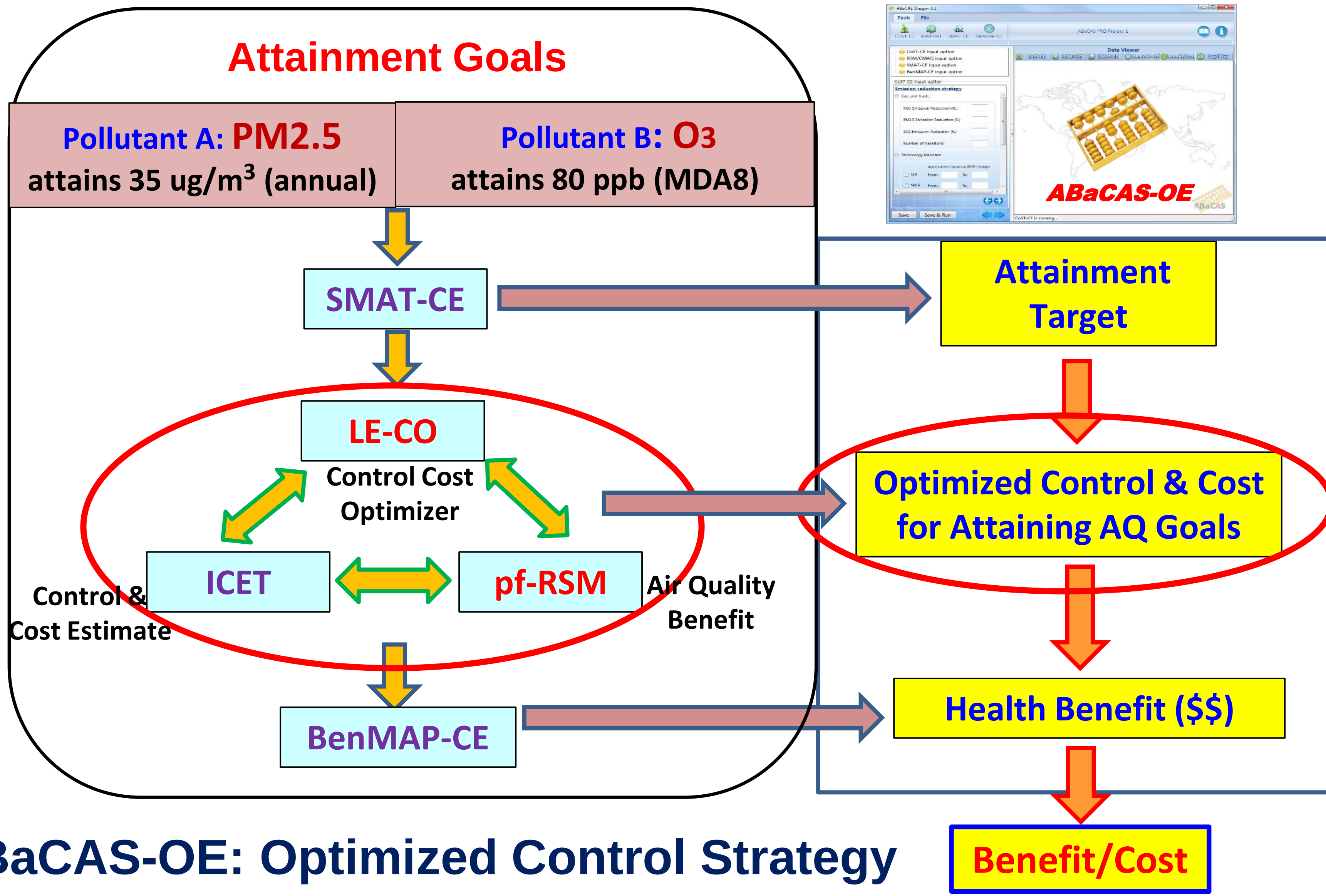
Using IAM to evaluate control policies



Household-fuel use shall be highly prioritized in air pollution control policies, considering its effects on $PM_{2.5}$ exposures.

Zhao et al., 2018，Proceedings of National Academy of Sciences

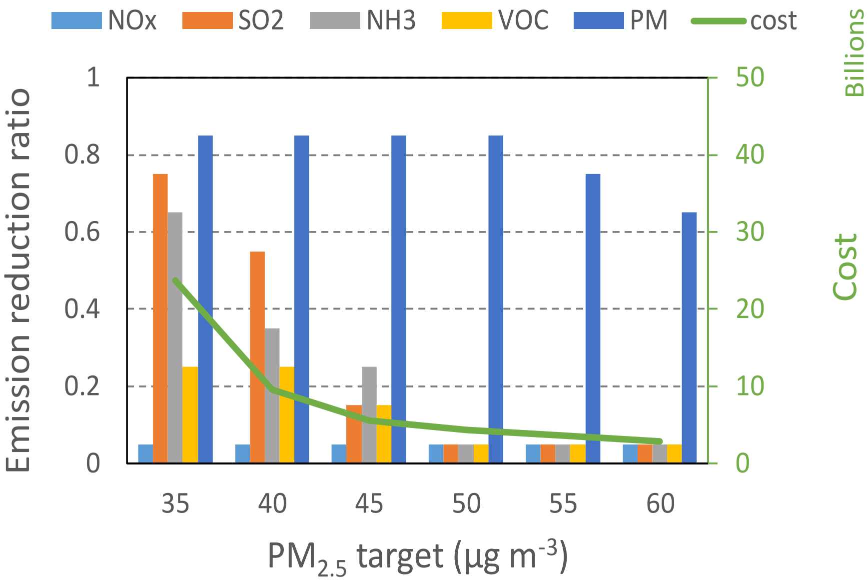
Using IAM to optimize control options



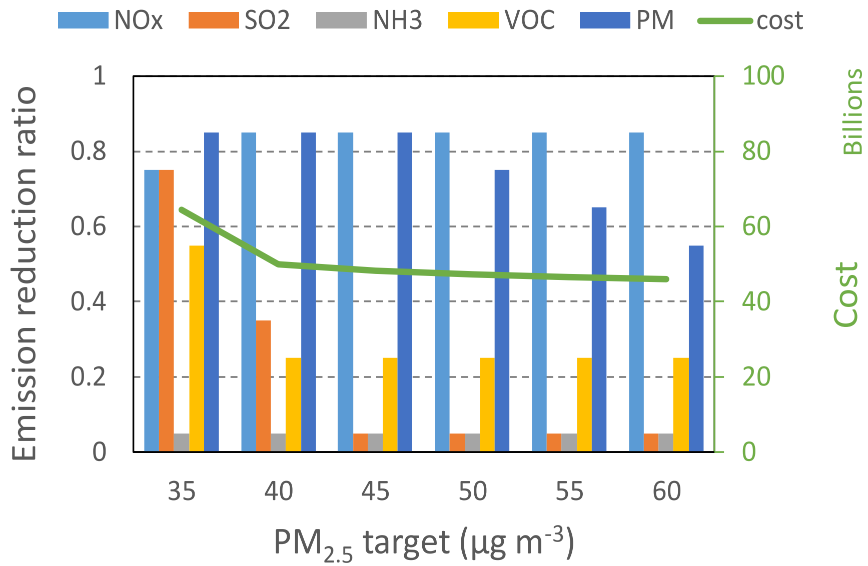
ABaCAS-OE: Optimized Control Strategy

Using IAM to optimize control options

S1: only control $PM_{2.5}$



S2: control both O_3 and $PM_{2.5}$



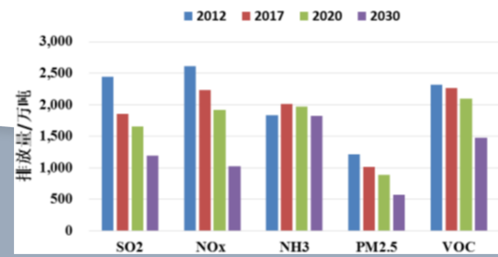
Optimal control pathway to achieve certain concentration:

- **S1: NOx(-5%), SO2(-75%), VOC(-25%), PM(-85%), NH3(-65%)**
- **S2: NOx(-75%), SO2(-75%), VOC(-55%), PM(-85%), NH3(-5%)**

Xing et al., 2019, Least-cost control strategy optimization for air quality attainment of Beijing–Tianjin–Hebei region in China, Journal of Environmental Management

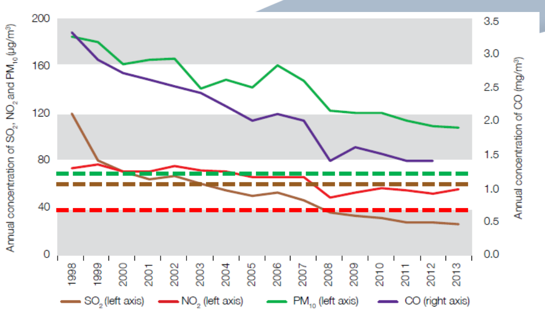
Using IAM results for policy development

Air Quality Target

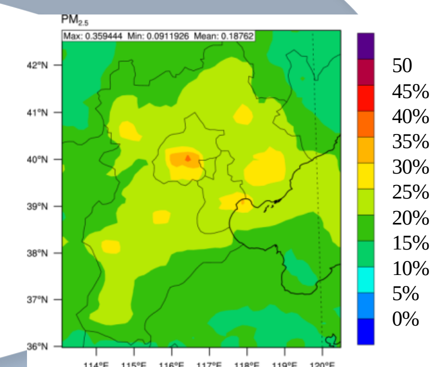


Emission Reduction Scenarios

Integrated Assessment Modeling



Post-evaluation of policy effectiveness



Pre-evaluation or optimization of control measures

Policy and implementations

Proposed IAM approaches under NEACAP

Aims:

- utilizing IAM as a practical tool to help partners identifying cost-effective emission reduction pathways and measures for air pollution issues of their nation and to assist the mitigation of air pollutants at both nations and sub-regions.

Proposed approach:

- Taking an "ensemble" approach that builds on model results from the combination of work by multi-models/multi-teams to extensively utilize model capacities from diverse groups.

Proposed IAM approaches under NEACAP

Synergies with existing efforts (MICS-Asia, CMAS-Asia, etc)

Linkage to national target and policies (periodic reporting and governmental consultation)

- **To establish a NEA technical center and/or an working group to facilitate the IAM research collaborations.**
- **To build up a platform to enhance the scientific exchange, capacity building and trainings among partners.**
- **To develop a database of emission control measures and evaluate the cost-benefit of applying these measures for NEA nations to serve as a reference for policy development.**
- **To provide science-based clean air solutions utilizing IAM approach considering the emission and modelling uncertainties and national social-economic circumstances**

Think Globally

Act locally

Thanks for your attention!