Brief Overview of Recent (post Copenhagen) IAM Inter-Model Comparisons and the Questions They Have ~~Answered~~ Addressed

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For SESSION #5: Scenarios for Climate Research and Assessment

Snowmass Workshop in Climate Change Impacts and Integrated Assessment

August 2, 2013

Studies Included

- Asian Modeling Exercise (AME: PNNL/USEPA)
- AMPERE WPs 1, 2, 3, 4, 5 (EU)
- EMF 24, 27, 28, 28i, 29
- LIMITS (EU)
- Rose (PIK+Collaborators)
- LCS (NIES)
- ALPS (RITE)

Bottom Lines

- Past Contributions (pre-Copenhagen, end 2009):
  - Where flexibility (Aldy, Pershing, Boathouse Group, et al.)
  - When flexibility (Aldy, Pershing, Boathouse Group, et al.)
  - What flexibility (Aldy, Pershing, Boathouse Group, et al.)
  - How flexibility (Aldy, Pershing, Boathouse Group, et al.)
  - Rough feasibility of targets, inc. accessions and overshoots
- Emerging Contributions (post Copenhagen):
  - Highly relevant country/EU policy scenario ensembles (Fawcett, EIA, van Ierland, etc.)
  - Much richer set of technology and policy sensitivities (Pershing, et al.)
  - Overshoot scenarios
  - Impact of SR goals on LR targets
  - Feasibility/plausibility of various targets
  - Relative costs of various policies (Cap and trade, regulatory, etc.)
  - Links to sustainability/sustainable development
  - More emphasis on model diagnostics (AME, AMPERE, PIAMDDI, etc.)
- Let's keep clear distinction between simple and complex IAMs

Big Four Inter-Community Suggested Research Directions From IAM Community

- Land Use/Land Cover
- Non-Kyoto Forcing/Air Pollution
- Overshoots - BECCS, CDR , SRM, etc.
- Technology development/diffusion determinants

Goals of Asian Modeling Exercise (Calvin)

- ***Objective:*** **to better articulate the role of Asia in addressing climate change**.

- ***Goal:*** To **bring together global modelers** that commonly participate in efforts to explore international policy architectures **with regional modelers and experts** with Asia-specific knowledge, understanding, data, and analysis.

- ***Method:*** A **coordinated modeling exercise** that attempts to link these communities to provide more effective modeling and analysis of Asia within a global context.

AME Key Findings

- Base year data differs across models for a variety of explainable reasons. But, while differences in base year data do affect future growth projections, differences in assumed growth rates have a much larger impact on the future.
- Models differ in their projections of economic growth, energy intensity, and carbon intensity. Differences in underlying growth assumptions result in a factor of 2 difference in Chinese CO_2 emissions across models in 2020. Models with similar emissions levels may achieve them in very different ways.
- Models differ significantly in the amount of mitigation achieved for a particular carbon price. Differences in mitigation are due to a variety of factors, including baseline emissions levels, model flexibility, technology cost and availability
- Models show a wide variety of future energy systems across time and scenarios. While there is some variation across regions within a model due to resource constraints, many models tend to "favor" certain technologies.

Overview of the AMPERE project (Kriegler)

Assessment of Climate Change **M**itigation **P**athways and **E**valuation of the **R**obustness of Mitigation Cost **E**stimates.

AMPERE - Research Questions

How sensitive are mitigation scenarios and costs to model assumptions and structural differences, and why?

➔ Model transparency, validation, diagnostics, comparison (WP4)

Global Perspective:

How are mitigation scenarios and costs affected by

- Feedbacks in the climate response (WP1)
- Technology availability and planning horizons (WP2)
- Fragmented climate policy (WP3)

EU Perspective:

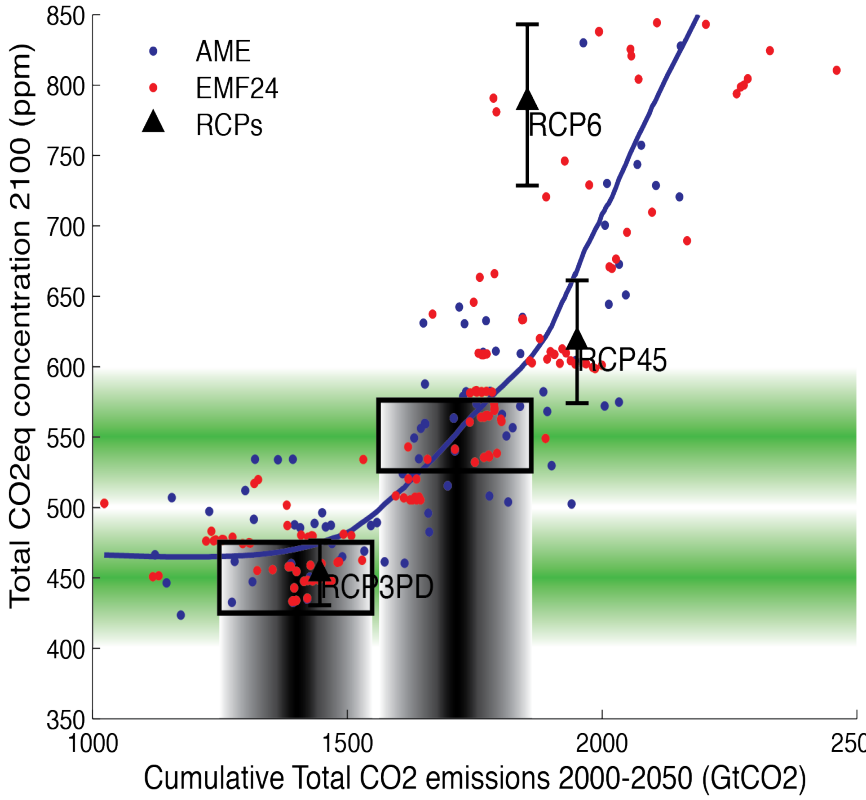
What are the implications for climate policy in the EU? (WP5)

AMPERE WP1 (van Vuuren)

- **Goal**:
  - Determine the importance of climate system representation in IAM for IAM outcomes.
  - Determine representative relationships between CO_2 budgets, forcing and temperature
  - Look at new insights from climate science on feedbacks for carbon budgets

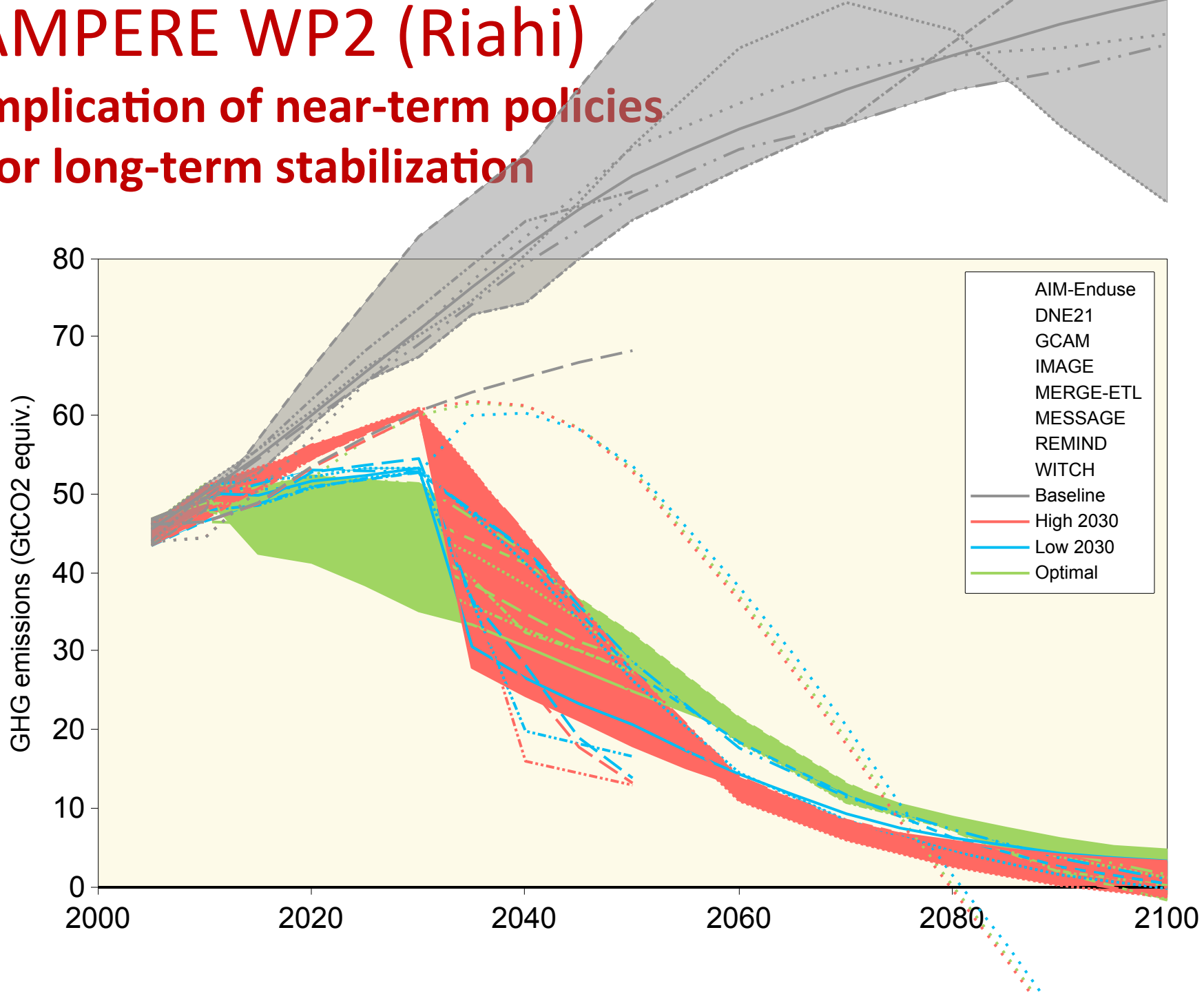
AMPERE WP1

- Findings/products so-far:
  - Comparison of climate cycle/climate system for AMPERE models
  - Establishment of carbon budget (more uncertainty!)
  - MAGICC model runs for AMPERE / LIMITS scenarios.
  - First insights into impacts of feedbacks



AMPERE WP2 (Riahi)

Implication of near-term policies for long-term stabilization



AMPERE WP 2 Key Findings

- **High 2030 emissions (~60 GtCO2e) pose a triple-challenge:**
  - Fossil fuel lock-in (+50% compared to today by 2030)
  - Stranded assets (100s of coal power plants globally)
  - Requires doubling the "upscaling pace" of low-carbon energy
- **Implications for the transformation:**
  - Increased risks that low stabilization targets become unattainable
  - Higher costs (particularly in the medium term)
  - "Overshoot" reduces chances to stay below 2C
- **<u>Energy Efficiency</u> critical for keeping options open**
- **Results are being published as a Special Issue of TFSC and open-access databases**

(https://secure.iiasa.ac.at/web-apps/ene/AMPEREDB)

AMPERE study on staged accession (WP3) (Kriegler)

Key results:

- Staged accession can still achieve stringent stabilization levels even if the target is relaxed.
- Early moving attractive for those countries that already have ambitious reference policy (e.g. EU)
- Leakage effects during a period of differentiated action is limited
- Latecomers benefit only in the near term, but have higher long term costs due to carbon lock-ins. In the aggregate, total 21st century costs are not significantly lower (at 5% discount rate).

AMPERE WP 4: Model Diagnostics – Key Results (Kriegler)

Many models exhibit distinct fingerprint:

- strong abatement response + strong reliance on CI + strong transformation of energy system
- limited abatement response + limited reliance on CI + limited transformation of energy system

Useful model classification to explain differences in model results (e.g. on mitigation costs) may be established

Solidifying and testing the preliminary model classification in applications needed

Aim: Standardized diagnostic experiments that can be run by a large class of energy-economy and integrated assessment models (could be a community activity)

LIMITS in a nutshell (Tavoni)

Low climate IMpact scenarios and the requirements for Tight emission control Strategies

LIMITS is a research programme funded by the European Commissions whose main objective is to provide an assessment of the emissions reductions strategies at the level of the world and the major global economies, and to assess their implementation in terms of:

1. Defining the **feasibility space of 2C scenarios** and the associated emission reduction pathways according to different policy architectures (**Durban Action Scenarios**) in 2020 and 2030 and different **burden sharing schemes**.

2. Assessing the **investment** requirements to implement these transformation pathways **and the financing** mechanisms such that these resources can be best raised and allocated.

3. Quantifying the changes in the **energy infrastructure and land use** which major economies would need to implement to attain stringent climate policies, and assessing the feasibility and risks of such changes.

4. Evaluating the linkages of climate policies with other pressing social and environmental issues such as **energy security, air pollution and economic development**.

Team: FEEM (coordinator), PIK, IIASA, Univ. Utrecht, ERI-NDRC, LSE, JRC-IES, CEU, IIM, PNNL, NIES

LIMITS main insights (WP 1-2)

- Global time-averaged economic costs of the Durban Action scenarios are limited across models, and are largely unaffected by the stringency of 2020 pledges. By contrast, the economic impact of delaying action beyond 2030 is much stronger on transitional costs.
- The main significance of short term action in the period 2010-2030 lies in preparing the ground for steep emissions reductions thereafter by inducing global emissions to peak and decline.
- The biggest challenge for achieving 2C policies will the distributional impacts on the major economies. Without transfers across regions, OECD will have costs lower than average, DCs higher, and Energy exporters significantly higher.
- Allocation of emissions allowances according to a per capita scheme from 2050 onwards would only partly alleviate the distributional tensions. All burden sharing schemes would require large carbon markets and significant financial flows.
- A considerable upscaling of investments into low-carbon energy and energy efficiency is needed, reaching approximately $45 trillion (range: $30-75 trillion) cumulative between 2010 and 2050, or about $1.1 trillion annually.
- The annual additional capacity deployment intensity (expressed in GW/yr) for solar and wind energy until 2030 needs to be around that recently observed for coal-based power plants, and will have to be several times higher in the period 2030-2050.
- Climate policies are likely to lead to significantly lower global energy trade and reduce energy imports of major economies, decrease the rate of resource depletion, and increase the diversity of energy systems, particularly in the especially vulnerable transportation sector. China, India and the EU will derive particularly strong benefits from climate policies, whereas the US may forego some opportunities to export fossil fuels in the 2nd half of the century

Common Frame for EMF 24-29

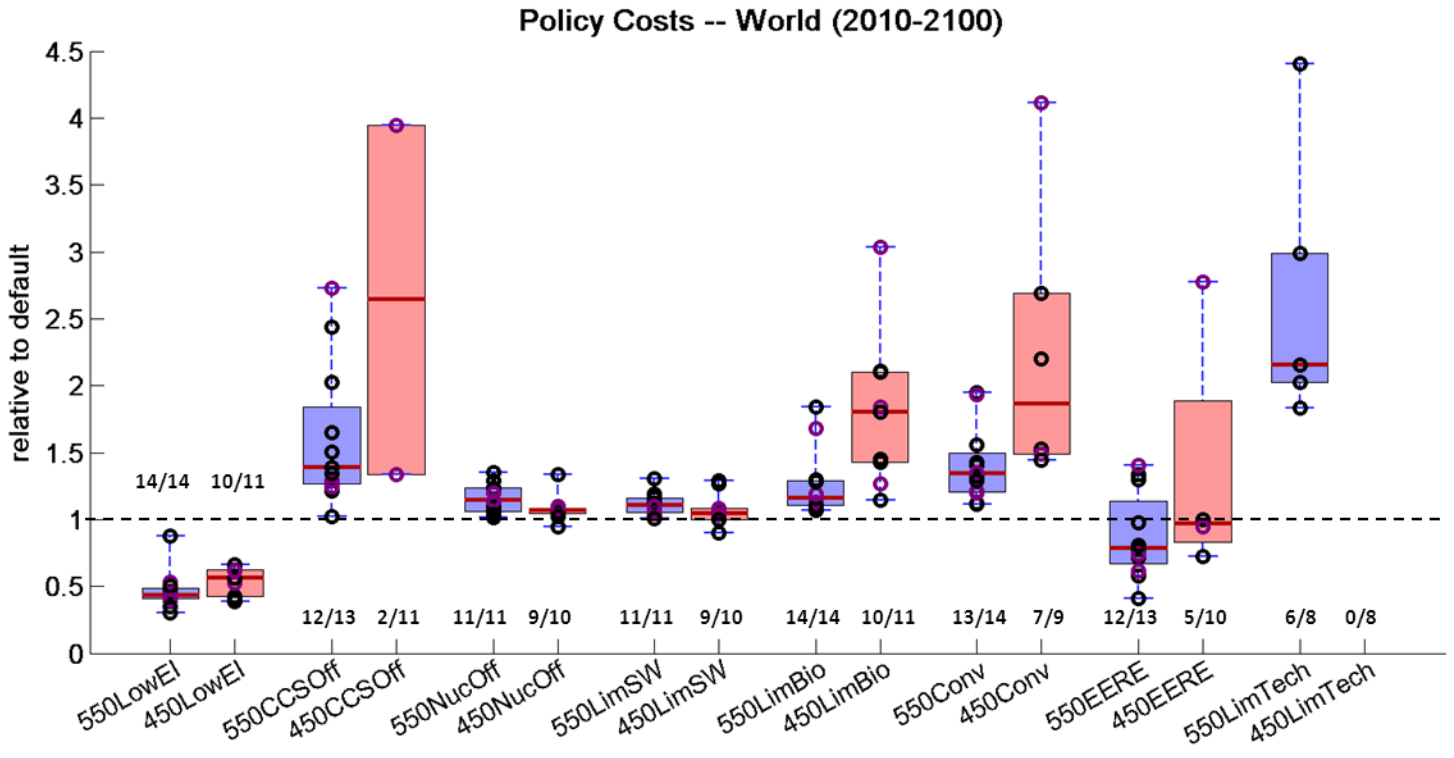
- Impacts of advanced technology assumptions on efficacy of policies
- Impacts of alternative policy architectures on value of advanced energy technologies
- Five Parallel Studies
  - EMF 24: US (Heavy Focus on RPS, CES, etc.)
  - EMF 27: Global
  - EMF 28: EU (Built around EU Road Map)
  - EMF 28i: EU Infrastucture
  - EMF 29: International Trade

Scenario Space of the EMF27 Study (Kriegler, et al.)

Policy Dimension	Technology Dimension								
Baseline	Base FullTech	Base LowEI		Base NucOff	Base LimSW	Base LimBio	Base Conv	Base EERE	**Base LimTech**
450 CO_2e	450 FullTech	450 LowEI	450 NoCCS	450 NucOff	450 LimSW	450 LimBio	450 Conv	450 EERE	**450 LimTech**
550 CO_2e	550 FullTech	550 LowEI	550 NoCCS	550 NucOff	550 LimSW	550 LimBio	550 Conv	550 EERE	**550 LimTech**
Modified G8 scenario	G8 FullTech							G8 EERE	
Fragmented Policy	FP FullTech							FP EERE	

Definition of technology variations	
FullTech	include all technologies represented in models, reference energy intensity improvements
LowEI	low energy intensity: 20-30% lower final energy demand in 2050 and 35-45% in 2100 compared to the reference case
NoCCS	carbon capture and storage excluded from technology portfolio in all sectors
NucOff	phase out of nuclear energy with no new nuclear power plants built beyond those under construction; existing plants operated until end of their technical lifetime
LimSW	share of electricity production from intermittent solar and wind technologies (wind, solar PV and CSP) limited to 20%
LimBio	global primary bio-energy supply – including purpose grown crops, residues and municipal solid waste, but excluding traditional biomass –limited to 100 EJ/yr
Conv	Combined LimSW & LimBio
EERE	Combined LowEI & NoCCS & NucOff
LimTech	Combined LowEI & NoCCS & NucOff & LimSW & LimBio

Technology values measured in terms of mitigation costs relative to the default technologies (AllTech) case



Structure of EMF 27 Special Issue (in Climatic Change)

<table>
<tr><td colspan="4">Overview of Overviews
(Kriegler, Weyant)</td></tr>
<tr><td colspan="2">Policy
Overview
(Kriegler, Blanford, Tavoni)</td><td colspan="2">Technology
Overview
(Krey, Luderer, Clarke)</td></tr>
<tr><td><u>Resources</u>
(McCollum, Kitous, Riahi, Calvin, Henri, Bauer, Kurosawa)</td><td><u>Renewables</u>
(Krey, Luderer Calvin, Masui, Merrick, Pietzcker, van Vliet, van Vliet)</td><td><u>Bioenergy (2)</u>
(Rose, Popp, Kriegler)
<u>Nuclear Energy</u>
(Kim, Wada, Kurosawa, Roberts)</td><td><u>Energy Efficiency</u>
(Sugiyama, Kanudia, Wada, Akashi, Lin, Weyant, Davidian)</td></tr>
<tr><td colspan="4">Non-CO2 Forcing
(Richels, Smith, Rose)</td></tr>
<tr><td colspan="4">Individual Modeling Team Papers (18)</td></tr>
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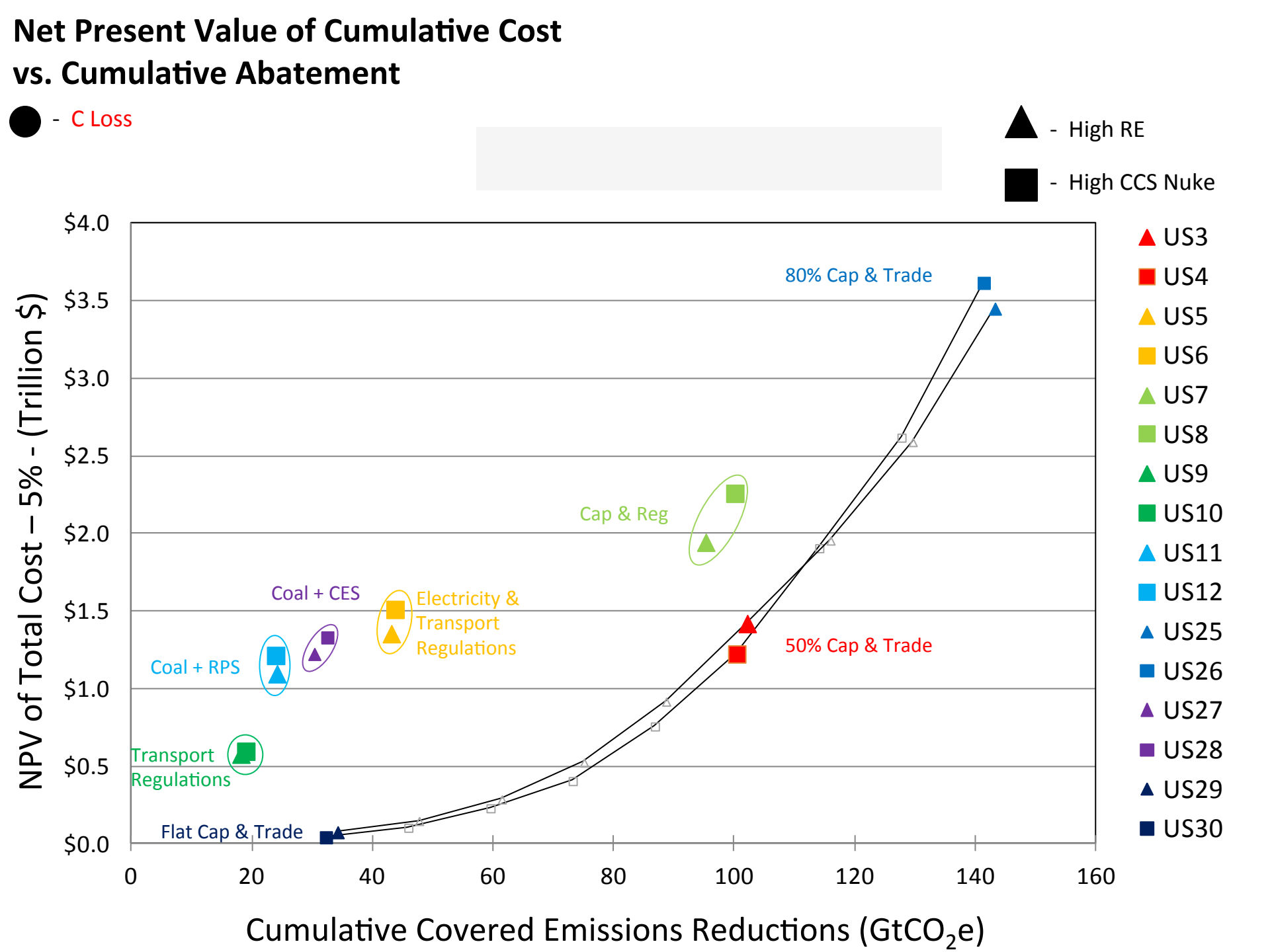
Overview of EMF 24 US Scenarios (Clarke, Fawcett)

Technology Dimension								
	High (Default)	**Single Technology Sensitivities**				**Combined Sensitivities**		**Low**
End Use Technology	High	Low	High	High	High	High	Low	Low
CCS	High	High	Low	High	High	Low	High	Low
Nuclear energy	High	High	High	Low	High	Low	High	Low
Wind & Solar	High	High	High	High	Low	High	Low	Low
Bioenergy	High	High	High	High	Low	High	Low	Low
Policy Dimension								
Baseline	US13F	US15F	US17F	US19F	US02F	US01F	US21F	US23F
Cap & Trade 50%	US14F	US16F	US18F	US20F	US04F	US03F	US22F	US24F
Electricity (Coal + RPS) + Transport					US06F	US05F		
Elecricity (Coal + RPS) + Transport + 50% Cap & Trade					US08F	US07F		
Transport					US10F	US09F		
Electricity (Coal + RPS)					US12F	US11F		
Electricity (Coal + CES)					US28F	US27F		
Cap & Trade 0%					US30F	US29F		
Cap & Trade 10%					US32F	US31F		
Cap & Trade 20%					US34F	US33F		
Cap & Trade 30%					US36F	US35F		
Cap & Trade 40%					US38F	US37F		
Cap & Trade 60%					US40F	US39F		
Cap & Trade 70%					US42F	US41F		
Cap & Trade 80%					US26F	US25F		

LEGEND

- Required Common Scenarios
- Required Policy Scenarios
- Rquired Technology Scenarios
- Optional Scenarios

Net Present Value of Cumulative Cost vs. Cumulative Abatement



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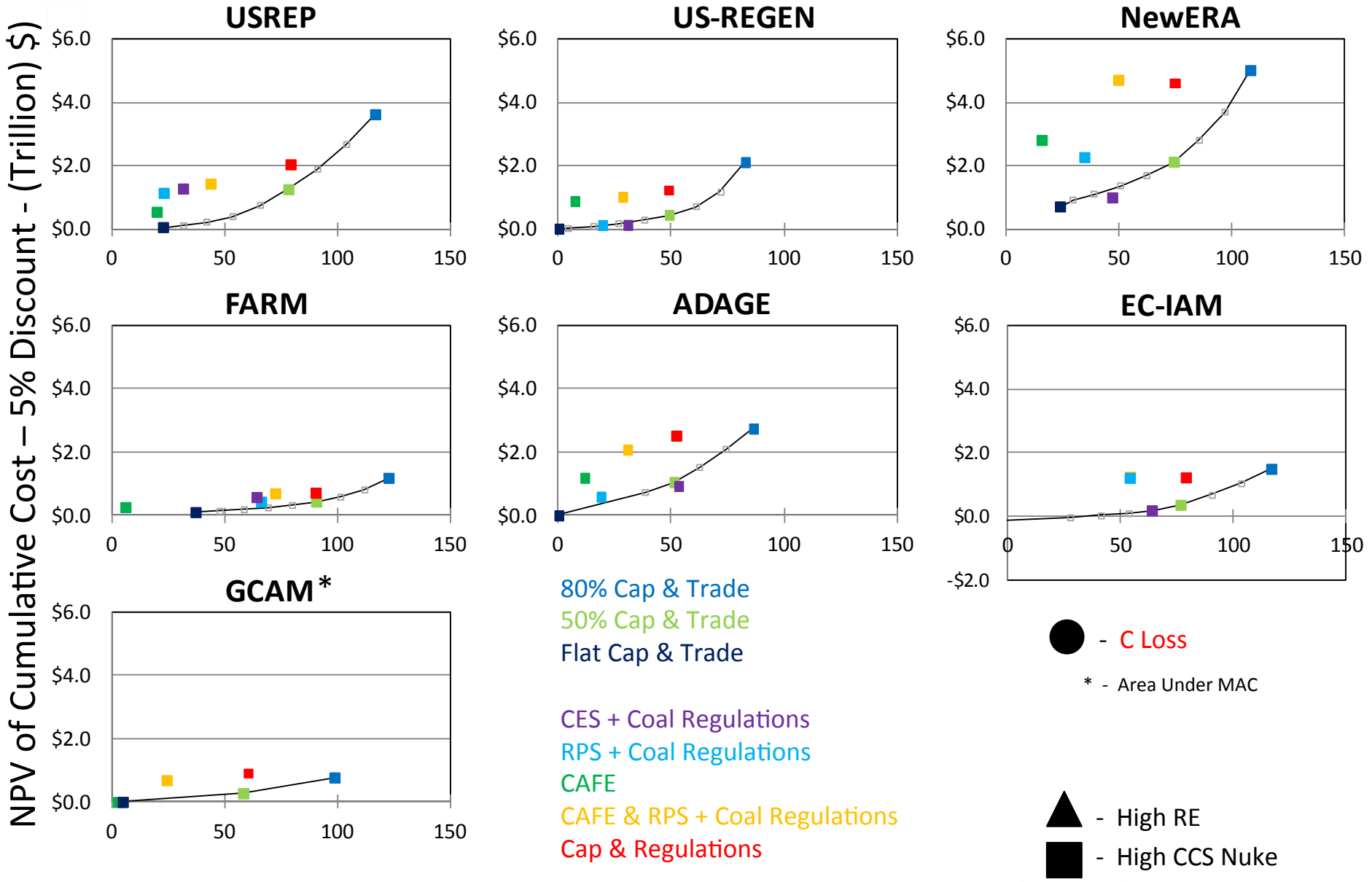


Roadmaps towards Sustainable Energy futures (RoSE) Project (Kriegler)

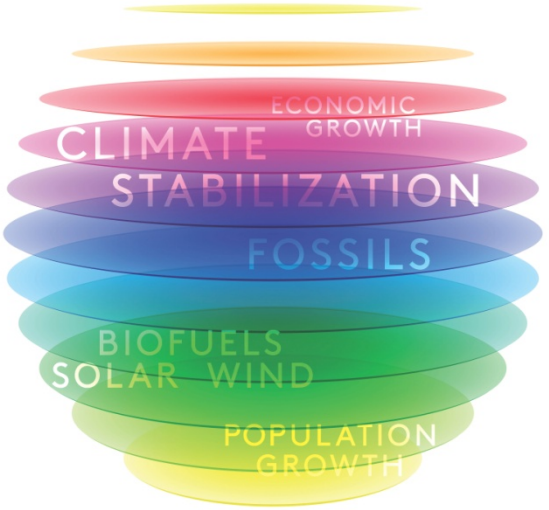
- A collaborative research project with modeling teams from **the EU (PIK & FEEM), the USA (PNNL), and China (ERI, Tsinghua)**. Coordinated by PIK.
- First MIP to systematically explore the implications of **economic growth, population and fossil fuel scarcity** for climate policy

For more information: www.rose-project.org

Funded by Stiftung Mercator

RoSE

Roadmaps towards Sustainable Energy futures and climate protection: A synthesis of results from the RoSE project

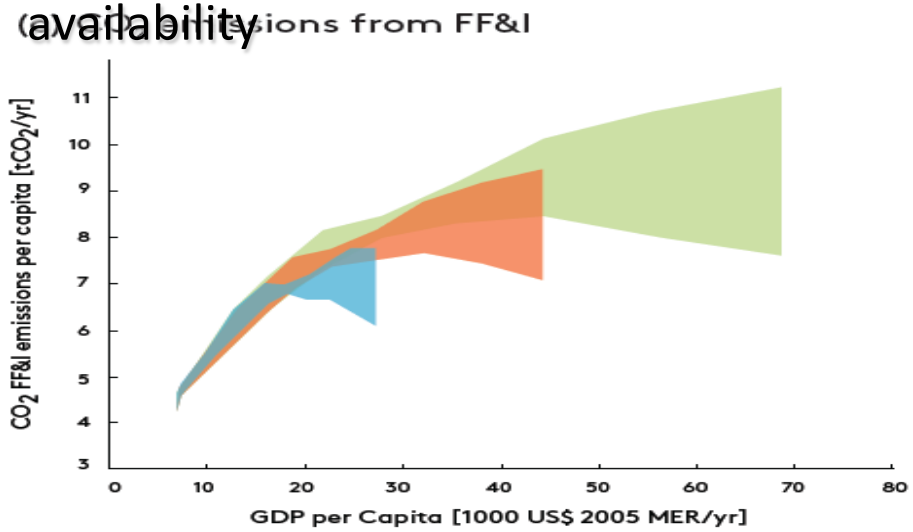


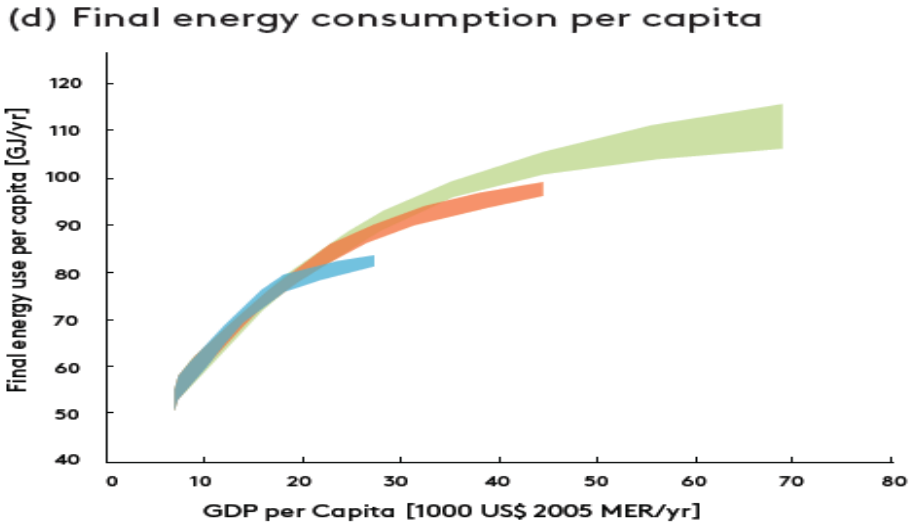
Elmar Kriegler, Ioanna Mouratiadou, Gunnar Luderer, Nico Bauer, Katherine Calvin, Enrica DeCian, Robert Brecha, Wenying Chen, Aleh Cherp, Jae Edmonds, Kejun Jiang, Shonali Pachauri, Fabio Sferra, Massimo Tavoni, Ottmar Edenhofer

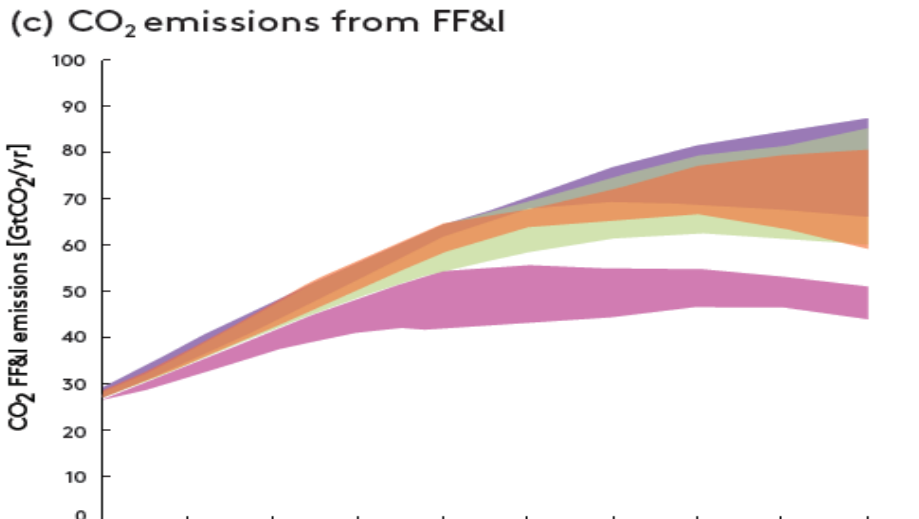
RoSE Roadmaps towards Sustainable Energy futures

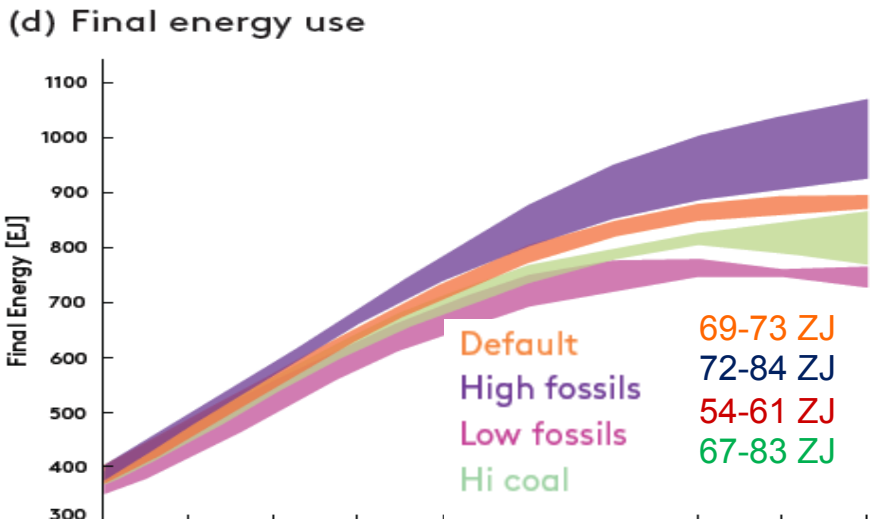
RoSE Study Design & Key Results (1)

In the absence of climate policy, atmospheric GHG concentrations continue to rise for a wide range of assumptions about economic growth and fossil fuel availability









Low-Carbon Asia Research Project

- **Objective**: Develop a methodology to evaluate mid to long term environmental policy options and analyze strategies and roadmaps by applying it toward low-carbon society in Asia
- **Two approaches:** One is based on a global target with assumptions of society in 2050, and the other is based on the country's target based on the country's situation
- **Common/different features**: There are several common features among the scenarios, whereas some other features vary across scenarios. The variations are either due to region or country specific characteristics (for example, domestic energy resource base and present level of technological advancement) or due to certain scenario specific assumptions made by the modeling team.

Messages from the LCS Scenario Analysis (Kainuma-NIES)

- In order to achieve the 2 degrees C target, it is an urgent task to develop low carbon societies in Asia, as Asian countries account for almost half the global population and GHG emissions by 2050 in the business as usual (BAU) scenarios. It is thus necessary to identify leapfrog development pathways to enable a shift to low carbon emissions and low-resource consumption while simultaneously improves daily life through economic growth.
- The following two points are the necessary and specific characteristics of this region's scenarios. They are: i) diversity in Asia, ii) multiple transitions (e.g. demographic, income, technological, infrastructures, institutional) which Asian countries will have to go through. Based on these view points, the link of sustainable development and low carbon transition is feasible and essential.
- Considered from the size of the anticipated emissions reductions, this problem is not a matter of perturbing existing society which has been the assumption of most environmental plans to date. Rather it is an issue where no solution will be found unless we endogenize the entire social and economic frame and set a planning horizon of several decades or more. This issue is a good chance to reexamine and re-enhance earlier environment research methods and to contribute to realize low carbon societies.

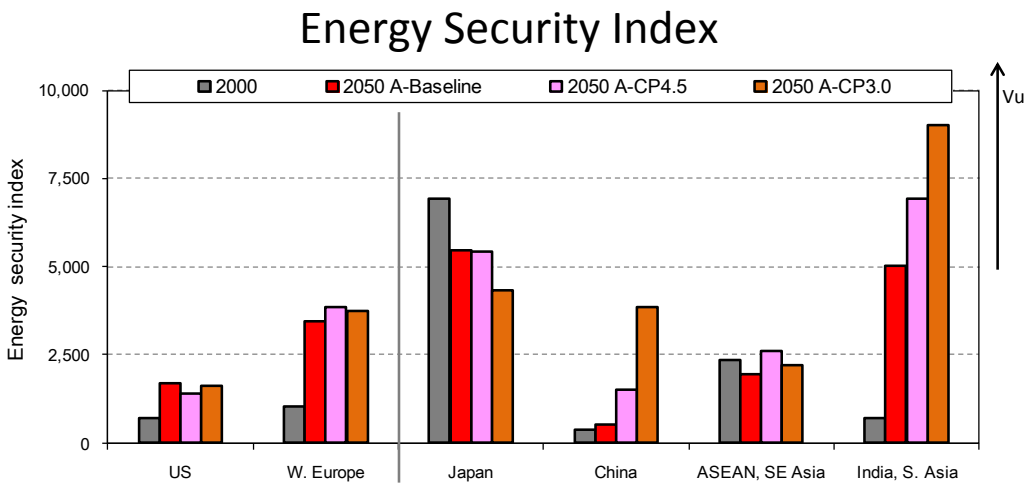
ALPS Research Questions (Wada – RITE)

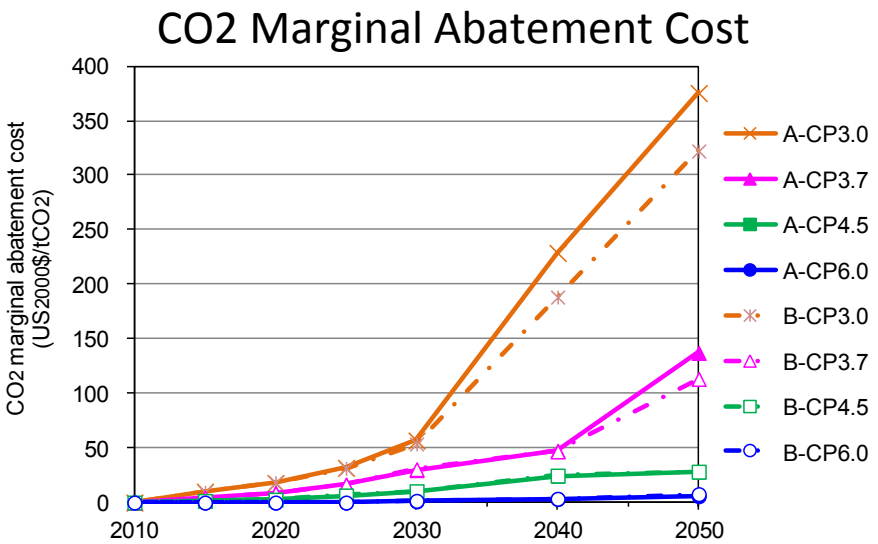
- ALPS project: The ALPS (**AL**ternative **P**athways toward **S**ustainable development and climate stabilization) was 5 year project from 2007 to 2012, carried out by RITE with more than 80 experts are involved from a wide variety of areas.
- The main objectives of this project are;
  1. to propose mitigation measures in line with sustainable development for stabilizing GHG concentrations, based on our original emission scenarios
  2. to provide indicators of sustainable development regarding water resource, food access, poverty, energy security and biodiversity for quantitative assessment
  3. to explore policy implications for a better balance among sustainable development, mitigation and adaptation

Reference: K. Akimoto, K. Wada, F. Sano, A. Hayashi, T. Homma, J. Oda, M. Nagashima, K. Tokushige, T. Tomoda, Consistent assessments of pathways toward sustainable development and climate stabilization Natural Resources Forum, Vol.36, No.4, pp.231-244, November 2012.

ALPS - Key Messages

- We need to tackle climate challenges by mitigating GHG emissions. Imposing excessive emission-reduction requirements, however, may make matters worse from sustainable development standpoint.
- Some indicators, such as poverty and food security, are strongly affected by socioeconomic changes rather than climate change impacts, although impacts vary widely among regions and countries.
- Not only putting prices on carbon but also removing technology diffusion barriers is a key to make climate policy feasible.
- Balancing between climate target and many other sustainable development is necessary.





Simple Snowmass Rules & Regulations

1. No whining
2. No BS
3. No grand standing
4. Admit your discipline is impotent
5. This is NOT all about you

Thank You

Questions & Comments?

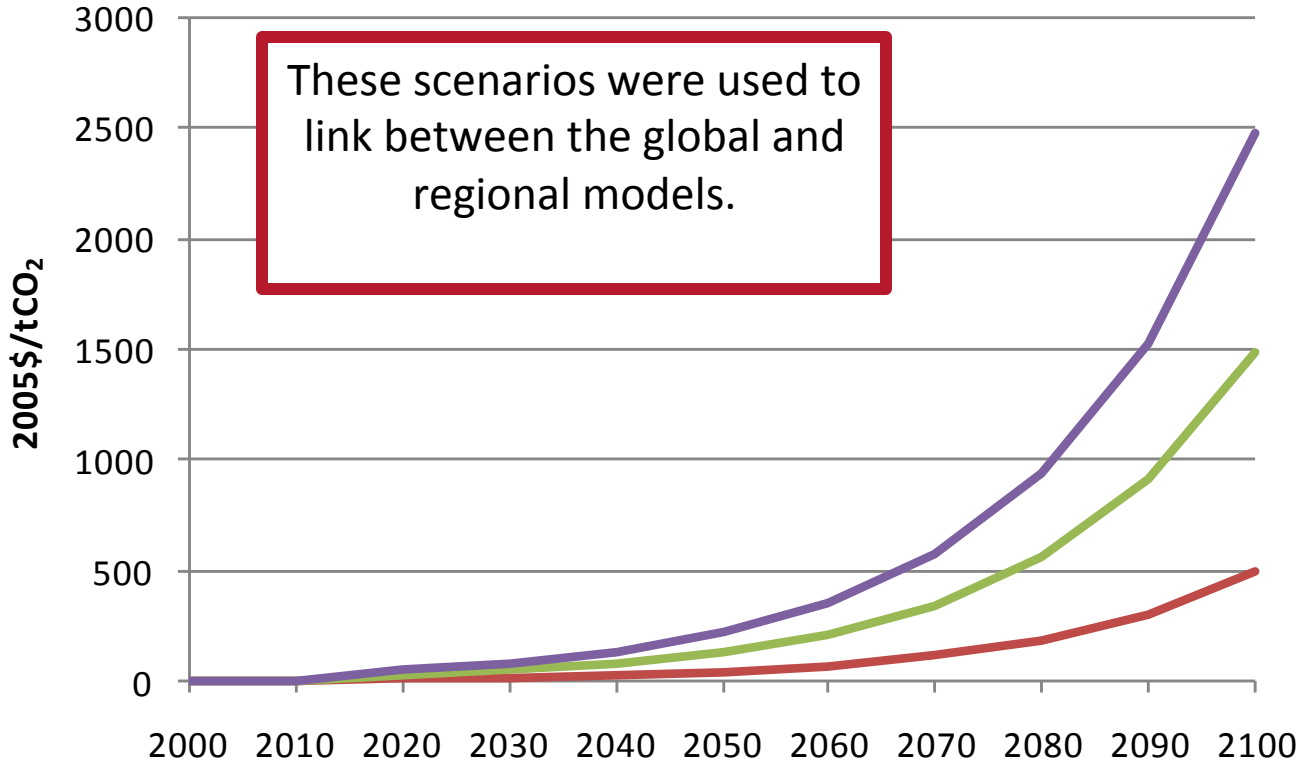
The Asia Modeling Exercise

Participants

- **26 Participating Models**
  - Australia (GTEM)
  - Canada (TIAM-World)
  - China (China MARKAL, IAMC, IPAC, PECE),
  - EU (GEM-E3, IMAGE, MESSAGE, POLES-IPTS, REMIND, TIMES-VTT, WITCH)
  - India (GCAM-IIM)
  - Japan (AIM-CGE, AIM-Enduse, DNE21+, GRAPE, MARIA-23)
  - Korea (KEI-Linkages)
  - Nepal (Nepal MARKAL)
  - United States (EPPA, GCAM, iPETS, MERGE, Phoenix)

Exercise Design

- Six Core Scenarios:
  - Baseline
  - 3 CO_2 price paths



Exercise Design

- Six Core Scenarios:
  - Baseline
  - 3 CO_2 price paths
  - 2 Stabilization paths (global models only)
    - 550 CO_2-e stabilization (total forcing)
    - 450 CO_2-e overshoot (total forcing)
  - For models without all forcing agents, we provided exogenous paths that they could use.

Overview of the AMPERE project (Kriegler)

Assessment of Climate Change **M**itigation **P**athways and **E**valuation of the **R**obustness of Mitigation Cost **E**stimates.

The research leading to these results has received funding from the European Community's Seventh Framework Programme FP7/2007-2013 under grant agreement n° 265139 (AMPERE)

AMPERE is a unique European modeling platform

- Bringing together European groups with 10 global and 6 EU27 energy-economy / integrated assessment models

  PIK (PI, WP3&4), IIASA (WP2), U Utrecht (WP1), FEEM (WP6), ICCS (WP5), CIRED, PSI, IPTS, LEPII U Grenoble, Enerdata, IPTS, IER Stuttgart, TU Wien, ERASME

- Plus 5 groups from China (ERI), India (IIM), Japan (NIES, RITE), USA (PNNL)
- Plus 2 climate modeling groups (ClimateAnalytics, Hadley Centre)

	Inter-temporal GE model	CGE	Partial equilibrium energy system model		Other (Bottom-up / econometric models)
Global	REMIND	IMACLIM	IMAGE / TIMER	DNE21+	
Global	WITCH	WorldScan (EU detail)	TIAM-IER	IPAC	
Global	MESSAGE-MACRO	GEM-E3	POLES	GCAM	
Global	MERGE-ETL			**AIM**	
EU27		GEM-E3	PRIMES, Green-X TIMES-PanEU		GAINS, NEMESIS

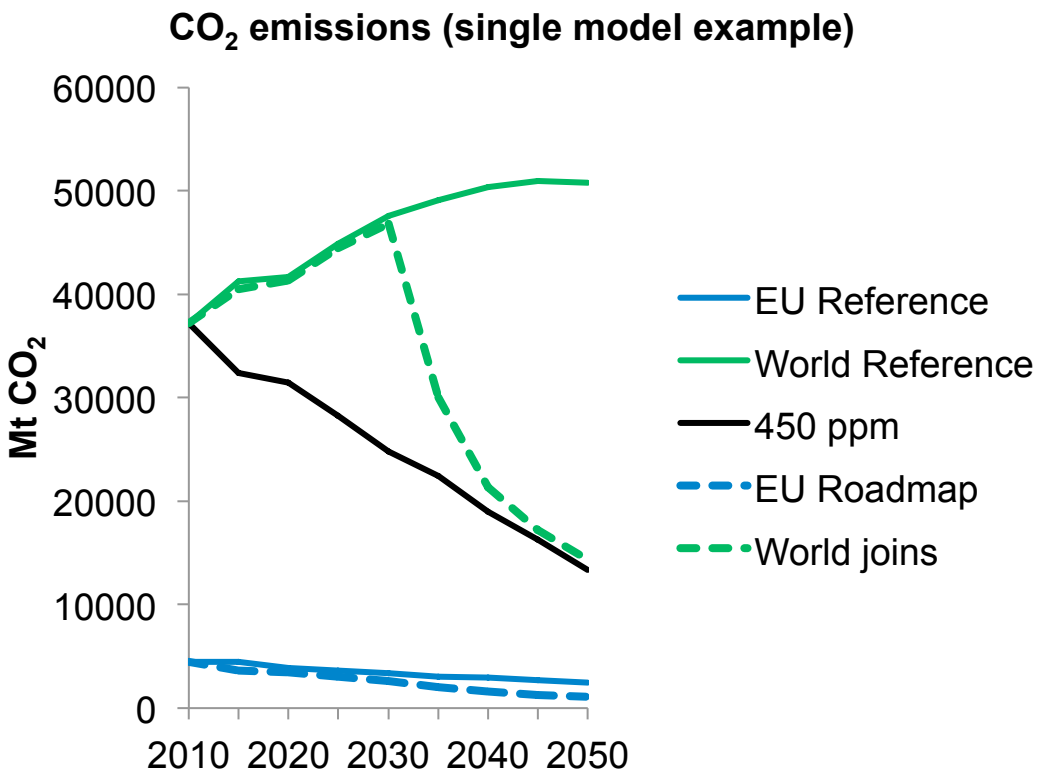
AMPERE - Achievements

AMPERE

- Establishment of a European energy-economy-climate modelling platform
- Large progress on model validation and diagnostics (together with US DOE funded project PIAMDDI)
- Multi-model analysis of policy relevant questions
  - Achievability of long term targets for various short term commitments until 2030
  - The consequences for Europe if implementing the roadmap and acting as first mover towards a global climate regime
- Preparation of a Special Issue in the Journal Technological Forecasting and Social Change
- Contribution to the IPCC 5th Assessment Report of Working Group III (in particular Chapters 6 & 7)

AMPERE study on staged accession (WP3)

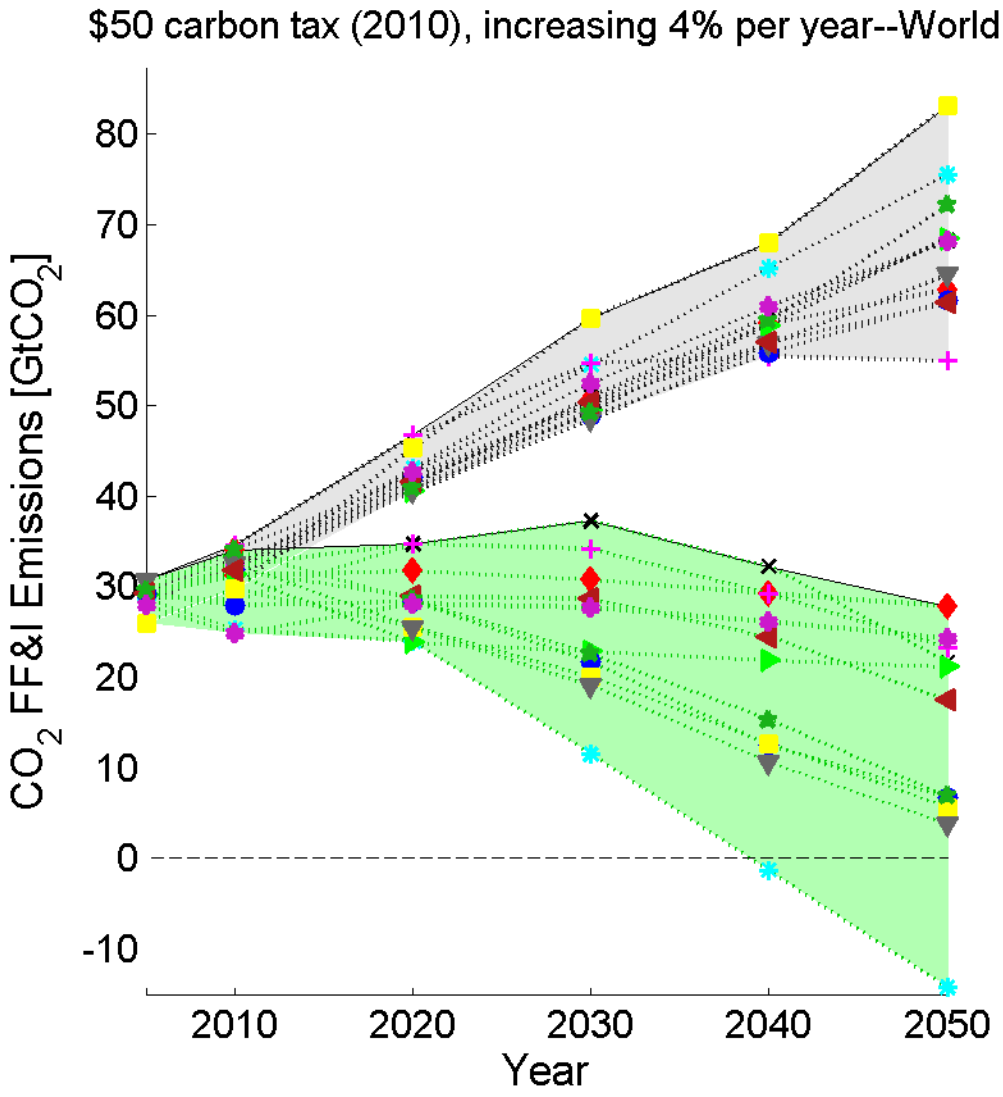
Study design



Excess emissions until 2050 are not compensated in the 2nd half of the century

Scenario Type	Global Target	Regions	Carbon Price Until 2030	Carbon Price After 2030-50 Transition
Reference policy	None	All	Derived from regional targets (where existing)	
No-policy baseline	None	All	None	
Climate policy benchmark scenarios	450 ppm	All	Globally harmonized to meet 450 ppm target	
	550 ppm	All	Globally harmonized to meet 550 ppm target	
Staged accession scenarios	None	EU (front runner)	EU Roadmap	Globally harmonized price from *450* or *550* ppm scenario
		Other regions	Regional prices from *RefPol*	
	None	EU + China (front runners)	Price from scenario *450*	Globally harmonized price from *450* scenario
		Other regions	Regional prices from *RefPol*	
Reconsideration scenarios	None	EU (front runner)	EU Roadmap	Regional prices from *RefPol*
		Other regions	Regional prices from *RefPol*	
	None	EU + China (front runners)	Price from scenario *450*	Regional prices from *RefPol*
		Other regions	Regional prices from *RefPol*	

Model Diagnostics – Response to carbon pricing



Diagnosing integrated assessment models of climate policy

Elmar Kriegler, Nils Petermann, Volker Krey, Jana Schwanitz, Gunnar Luderer, Shuichi Ashina, Valentina Bosetti, Jiyong Eom, Alban Kitous, Aurélie Méjean, Leonidas Paroussos, Fuminori Sano, Hal Turton, Charlie Wilson,Detlef Van Vuuren

submitted to Technological Forecasting and Social Change (AMPERE Special Issue)

PRELIMINARY RESULTS

Technology Dimension									
		Default	**Single technologies changed**					**Conventional vs. renewable**	
Energy intensity (energy demand)		Ref	Low	Ref	Ref	Ref	Ref	Ref	Low
CCS		On	On	Off	On	On	On	On	Off
Nuclear energy		On	On	On	Off	On	On	On	Off
Wind & solar		Adv	Adv	Adv	Adv	Cons	Adv	Cons	Adv
Bioenergy potential		High	High	High	High	High	Low	Low	High
Policy Dimension									
Long term scenarios:									
Baseline		*AM2S1*	AM2S4		AM2S5	AM2S6	AM2S7	AM2S8	AM2S9
450 CO2e		*AM2S2*	AM2S28	AM2S40	AM2S29	AM2S30	AM2S31	AM2S32	AM2S33
550 CO2e		*AM2S3*	AM2S34	AM2S41	AM2S35	AM2S36	AM2S37	AM2S38	AM2S39
Myopic scenarios:									
Short term target	Long term target								
High/2030	450 CO2e	AM2S10	AM2S11	AM2S12	AM2S13	AM2S14	AM2S15	AM2S16	AM2S17
Low/2030	450 CO2e	AM2S18	AM2S19	AM2S20	AM2S21	AM2S22	AM2S23	AM2S24	AM2S25
High/2030	550 CO2e	AM2S26							
Low/2030	550 CO2e	AM2S27							

LIMITS

Project description

Low climate IMpact scenarios and the Implications of required Tight emission control Strategies

The research leading to these results has received funding from the European Community's Seventh Framework Programme FP7/2007-2013 under grant agreement n° 282846 (LIMITS)

LIMITS scenario protocol (WP 1-2)

Scenario class	Scenario Name	Scenario Type	Near-term Target / Fragmented Action	Fragmented Action until	Long-term Target	Burden sharing
No policy baseline	Base	Baseline	None	N/A	None	none
Fragmented action	RefPol	Reference	Lenient	2100	None	none
	StrPol	Reference	Stringent	2100	None	none
Immediate action	450	Benchmark	None	N/A	450 ppm	Tax
	500	Benchmark	None	N/A	500 ppm	Tax
Delayed action	RefPol-450	Climate Policy	Lenient	2020	450 ppm	Tax
	StrPol-450	Climate Policy	Stringent	2020	450 ppm	Tax
	RefPol-500	Climate Policy	Lenient	2020	500 ppm	Tax
	StrPol-500	Climate Policy	Stringent	2020	500 ppm	Tax
	RefPol2030-500	Climate Policy	Lenient	2030	500 ppm	Tax
Delayed action, burden sharing	RefPol-450-PC	Climate Policy	Lenient	2020	450 ppm	Per capita convergence
	RefPol-450-EE	Climate Policy	Lenient	2020	450 ppm	Equal effort

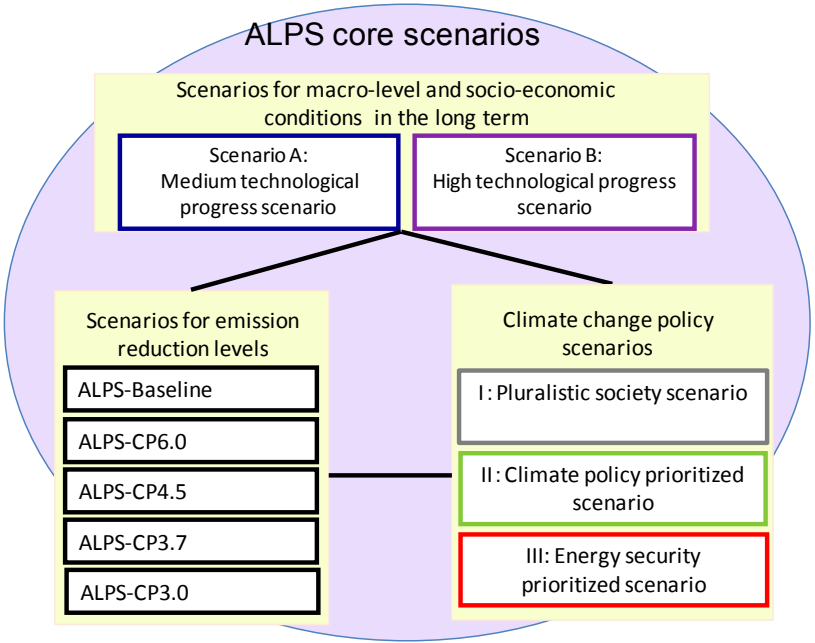
LIMITS scenario protocol (WP 4)

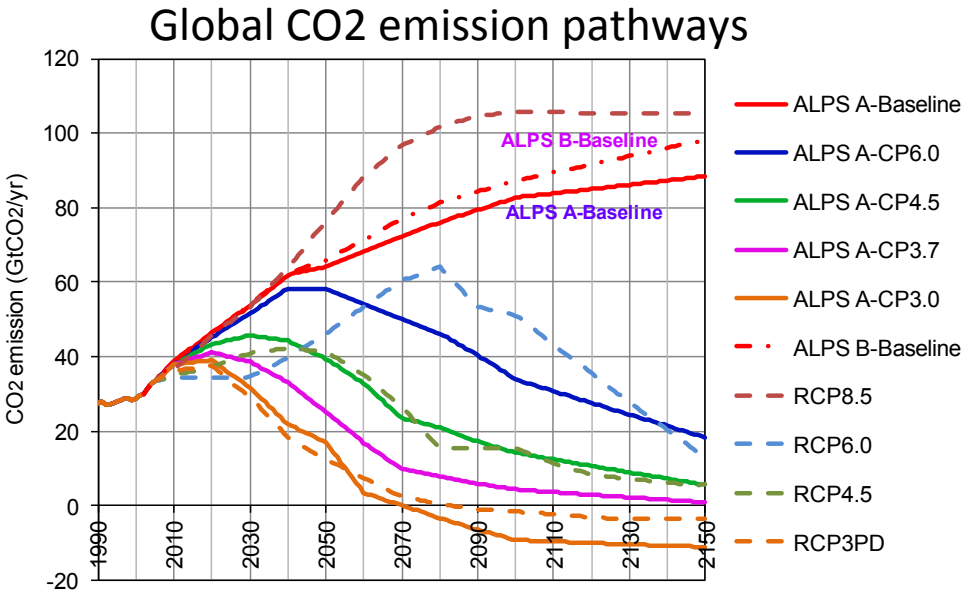
Scenario group		Baseline, no carbon constraints	Mitigation scenario, 2.8 W/m^2 in 2100
WP1 (existing scenarios)		LIMITS1	LIMITS6
Energy security scenarios (limits on imports)		LIMITS1_ES	LIMITS6_ES
Air pollution Scenarios	CLE (current legislation)	LIMITS1_APCLE	LIMITS6_APCLE
	FLE (Fixed legislation)	LIMITS1_APFLE	LIMITS6_APFLE
	SLE (stringent legislation)	LIMITS1_APSLE	LIMITS6_APSLE

Scenario design

Combination of three main scenario dimensions; 1) Socio-economic development, 2) Social objectives, and 3) Concentration Pathways with 4) sub-scenarios focus on technological progress.

1. Socio-economic development covers GDP and Population
2. Scenarios on social objectives describe the degree of emphasis placed on climate challenge. If climate change is highly prioritized, people behavior rationally in a way that mitigation measures are taken cost effectively. In the current real world, however, people have diverse values in nature, and there exist various barriers to technology diffusion from climate change standpoint . Another scenario focuses on energy security, putting high priority on securing domestic energy resources.
3. Concentration Pathways range from Baseline to CP 3.0
4. Technological progress scenarios assume two patterns – one is medium technological progress in consistent with historical trends and the other assumes accelerated technological progress.





Assumptions of society in 2050 in long-term LCS scenarios

Global, Asia, China and India scenarios have been developed

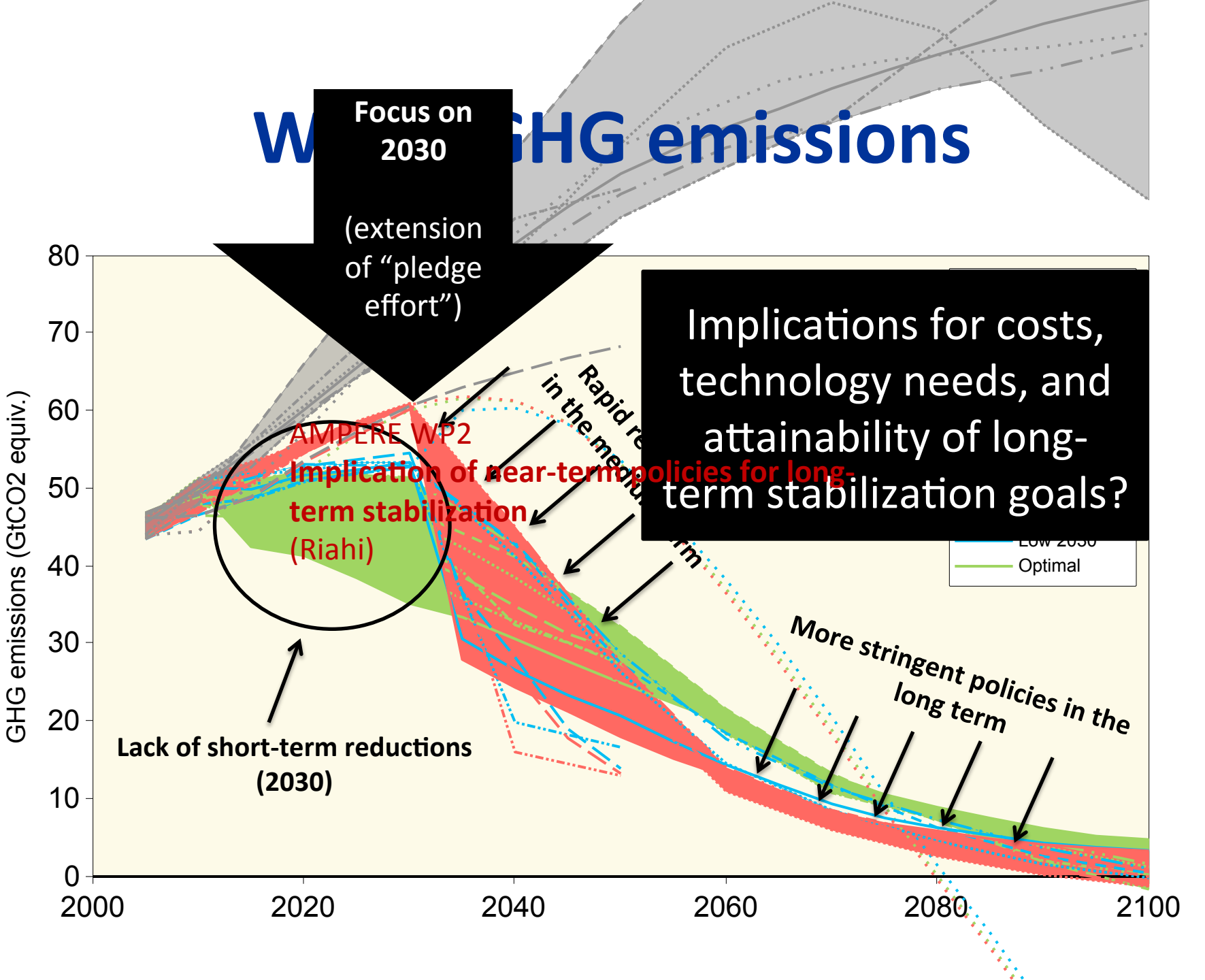
	Advanced Society Scenario (ADV)	Conventional Society Scenario (CNV)
Summary	Accept the new social system, institution, technologies etc. positively and proactively.	Discreet about the new social system, institution, technologies etc., and worry about their transition cost.
Economy	Annual growth rate from 2005-2050: 3.27%/year (Global) and 4.16%/year (Asia)	Annual growth rate from 2005-2050: 2.24%/year (Global) and 2.98%/year (Asia)
Population	Total population in 2050: 9.3 billion persons in the World, and 4.6 billion persons in Asia	
Education	Education system will be improved positively. Education period: from 4-12 years in 2005 to 11-14 years in 2050	Education system will be improved normally. Education period: from 4-12 years in 2005 to 8-13 years in 2050
How to use time	Time for working and improving career will be longer.	Time for staying with family or friends will be linger.
Labor	0% of unemployment rate in 2075	Fixed unemployment rate to 2009 level
Government	Efficiency will Improved immediately.	Efficiency will be improved gradually.
International Cooperation	Reduction of trade barriers and FDI risks	Gradual improvement in collaborative relationships among Asian countries.
Innovation	High	Medium
Transportation	Increase of demand sue to high economic growth	Gradual increase of demand
Land use	More speedy and more efficient land use	Moderate and careful land use change

Summary of LCS scenarios

Global, Asia, China, India, Thailand, Indonesia, Malaysia, Vietnam, Cambodia and Korea scenarios have been developed

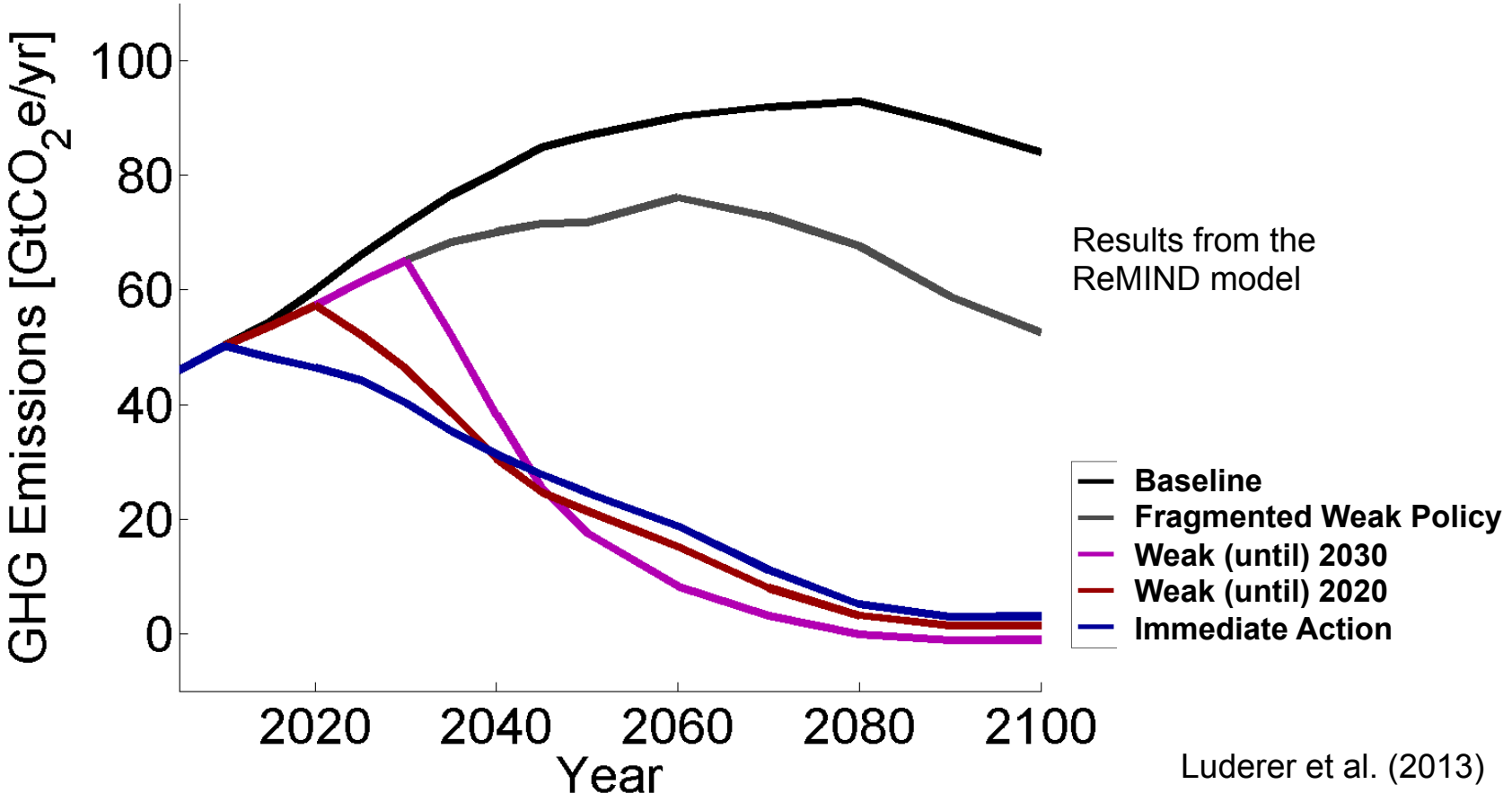
LCS scenario type	Measure type	Energy supply side	Energy demand side
Global and country scenarios	Common features	• Renewable energies – solar, wind, biomass • Conversion efficiency improvement	• Energy efficient technologies and other measures in end-use sectors
	Features varying across regions and scenarios	• Extent of nuclear power • Extent of CCS deployment • Extent of biomass and biofuels	• Relative potential of demand side measures to total carbon reduction • Behavioural changes
Local and city level scenarios	Common features	• Renewable energies – both centralized and de-centralized options	• Energy efficient technologies in residential, commercial industry and transport sectors • Urban public transport systems • Behavioural changes toward eco-friendly lifestyle
	Features varying across regions and scenarios	• Mix of renewable energy sources • Extent of biomass and biofuels	• Urban design/ compact city • Mode-mix for urban transportation • Reforestation

W GHG emissions



RoSE – Key Results (2)

- The later strong global action is enacted, the steeper midterm emissions reductions requirements for reaching the 2°C target



Luderer et al. (2013)

RoSE Roadmaps towards Sustainable Energy futures