Tenth meeting of the Research Dialogue (RD 10) and preceding poster session
13:45 - 19:00, Dialogue Room Santiago de Chile, World Conference Centre Bonn, Bonn, Germany

De-carbonization Benefitting from Improving Renewable Energy's Economics and Better Knowledge on Co-benefits

Shobhakar Dhakal, Ph.D.
Associate Professor, and Head of Department
Department of Energy, Environment and Climate Change
Asian Institute of Technology

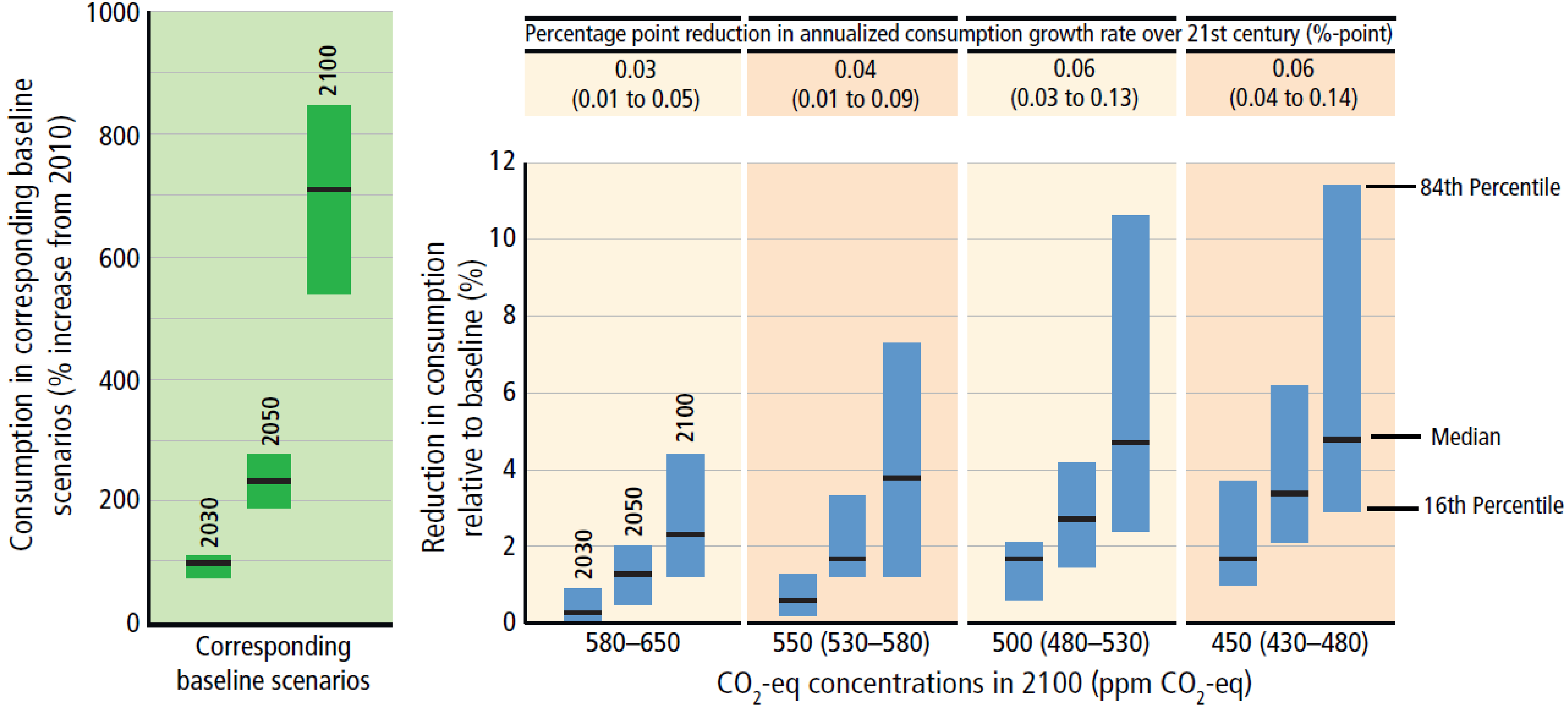
http://faculty.ait.asia/shobhakar/
shobhakar@ait.ac.th, shobhakar.dhakal@gmail.com

Co-benefits in mitigation assessments- IPCC AR5

- AR5 addresses co-benefits in “transformation pathways” as well as “various sectors” and “policies”
  - **Implications to climate stabilization costs**
  - Quantification of co-benefits themselves
  - Characterization (identification, nature/type) of co-benefits
  - Co-benefit as a key vehicle for climate policies
- *Summary for Policy Makers*, IPCC AR5 Mitigation

There is a wide range of possible co-benefits, adverse side-effects and spillovers from climate actions and policies that have not been well-quantified

Global mitigation costs and consumption growth in baseline scenarios



- Do not consider the benefits of reduced climate change or co-benefits and adverse side effects of mitigation
- The potential for co-benefits outweighs the potential for adverse side effects

IPCC AR5, 2014

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Quantification of co-benefits

- Mitigation scenarios of 450 or 500 ppm CO2-eq by 2100 show:
  - reduced costs for achieving air quality and energy security objectives
  - significant co-benefits for human health, ecosystem impacts and sufficiency of resources and resilience of the energy system
- These scenarios did not quantify other co-benefits or adverse side-effects

Co-Benefits of Climate Change Mitigation for Energy Security and Air Quality

Pp 62, main report, Technical Summary, IPCC AR5 Mitigation

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Identification and characterization (qualitative assessment) of co-benefits in various sectors

- Energy
- Transport
- Buildings
- Agriculture, forestry and other land uses
- Urban system

Buildings	Effect on additional objectives/concerns			
	Economic	Social	Environmental	Other
Fuel switching, RES incorporation, green roofs, and other measures reducing GHG emissions intensity	↑ Energy security **(m/h)** ↑ Employment impact **(m/m)** ↑ Lower need for energy subsidies **(l/l)** ↑ Asset values of buildings **(l/m)**	Fuel poverty (residential) via ↓ Energy demand **(m/h)** ↑ Energy cost **(l/m)** ↓ Energy access (for higher energy cost) **(l/m)** ↑ Productive time for women/ch replaced traditional cookstove	Health impact in residential buildings via ↓ Outdoor air pollution **(r/h)** ↓ Indoor air pollution (in developing countries) **(r/h)** ↓ Fuel poverty **(r/h)** ↓ Ecosystem impact (less outdoor	Reduced Urban Heat Island (UHI) effect **(l/m)**
Retrofits of existing buildings (e.g., cool roof, passive solar, etc.) **Exemplary new buildings** **Efficient equipment**	↑ Energy security **(m/h)** ↑ Employment impact **(m/m)** ↑ Productivity (for commercial buildings) **(m/h)** ↑ Lower need for energy subsidies **(l/l)** ↑ Asset values of buildings **(l/m)** ↑ Disaster resilience **(l/m)**	↓ Fuel poverty (for retrofits and efficient equipment) **(m/h)** ↓ Energy access (higher cost for due to the investments neede ↑ Thermal comfort (for retrofits a exemplary new buildings) **(m/** ↑ Productive time for women and children (for replaced traditional cookstoves) **(m/h)**		
Behavioural changes reducing energy demand	↑ Energy security **(m/h)** ↑ Lower need for energy subsidies **(l/l)**			

Social

Fuel poverty (residential) via
↓ Energy demand **(m/h)**
↑ Energy cost **(l/m)**

↓ Energy access (for higher energy cost) **(l/m)**

↑ Productive time for women/children (for replaced traditional cookstoves) **(m/h)**

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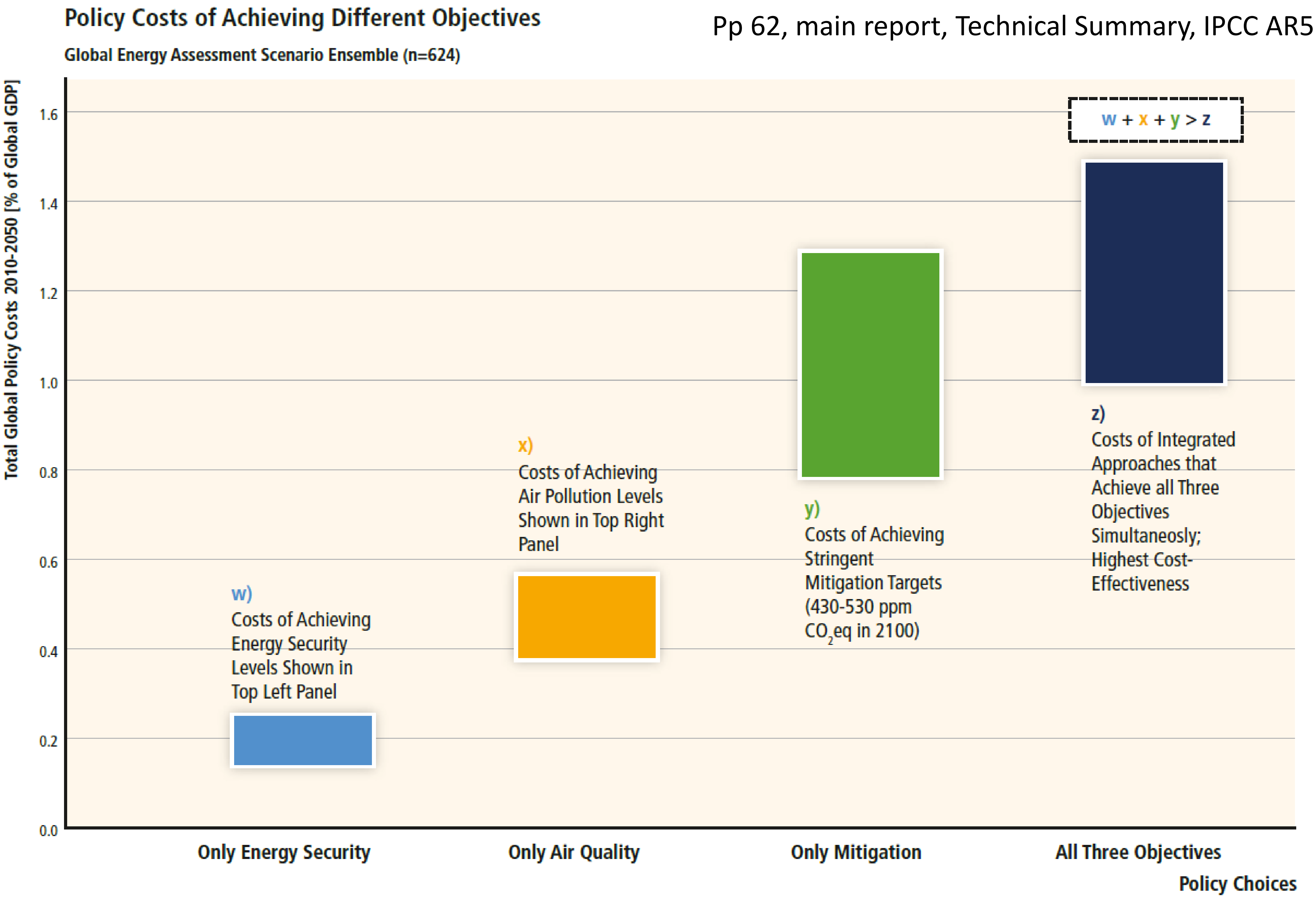


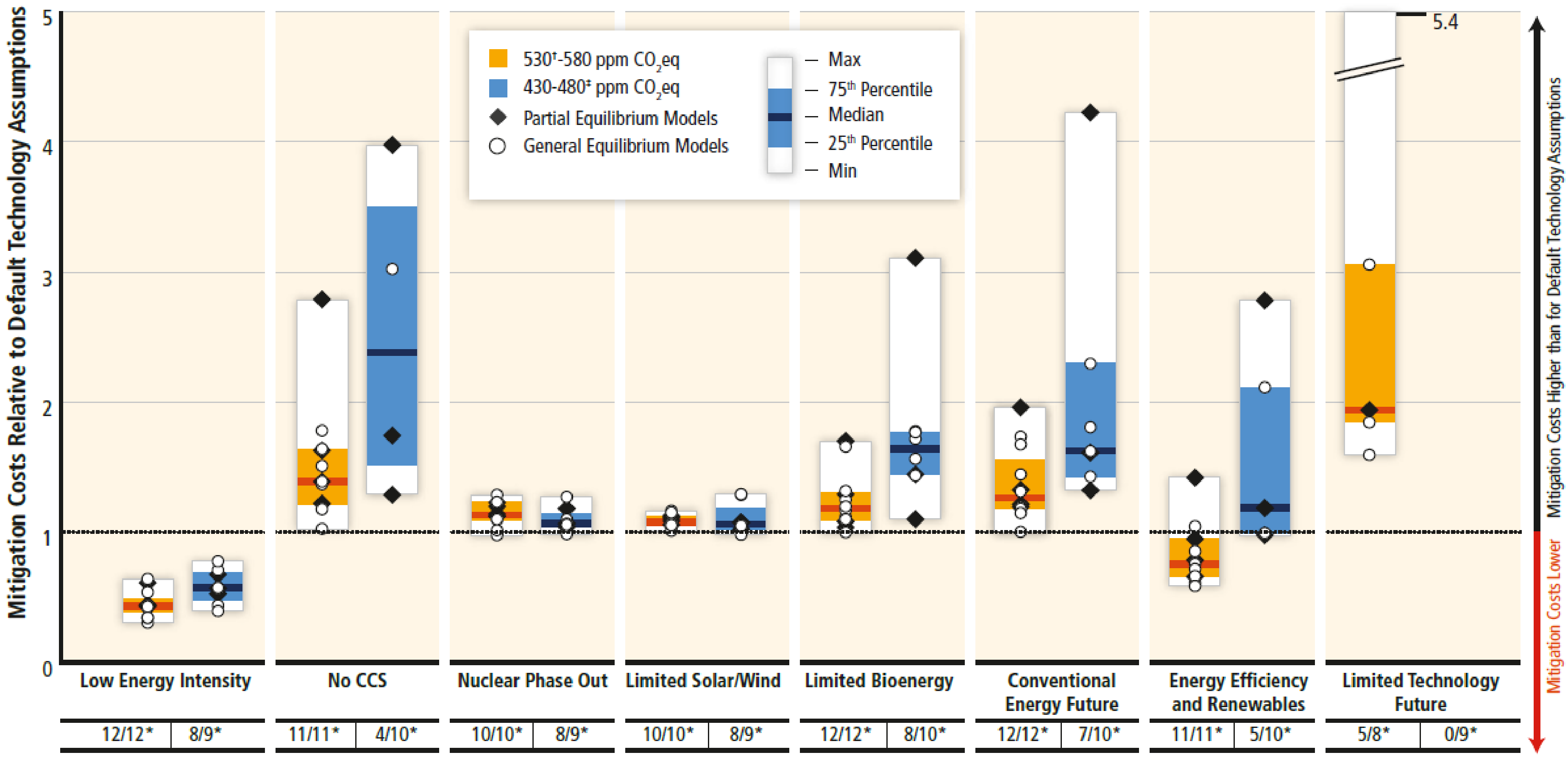
Summary on co-benefits

- The co-benefit are often well characterized – But, limitedly quantified→wide spectrum of co-benefits are yet unquantified
- Co-benefits, if incorporated to the cost of climate stabilization pathways, are expected to reduce overall cost → but yet to be comprehensively addressed in models
- In recent years the co-benefits quantification of climate actions has progressed → in areas such as air pollution, health, energy security and employment (e.g. through renewable energy)
- Supporting co-benefits are key → quantification, assisting research to understanding their implication in models, and using them for advancing climate policies

RE in IPCC AR5

- Decarbonizing electricity generation is a key cost-effective mitigation strategies for 430 – 530 ppm CO2eq scenarios
- In most integrated modelling scenarios, decarbonization happens more rapidly in electricity generation than in the industry, buildings, and transport sectors
- In the majority of low-stabilization scenarios, the share of low-carbon electricity supply (comprising renewable energy, nuclear and CCS) increases from the current approx. 30 % to > 80 % by 2050, and fossil fuel power generation without CCS is phased out almost entirely by 2100

IPCC AR5 does not identify solar energy as a strategically important technology option *(Creutzig et al., 2017, Nature Energy)*

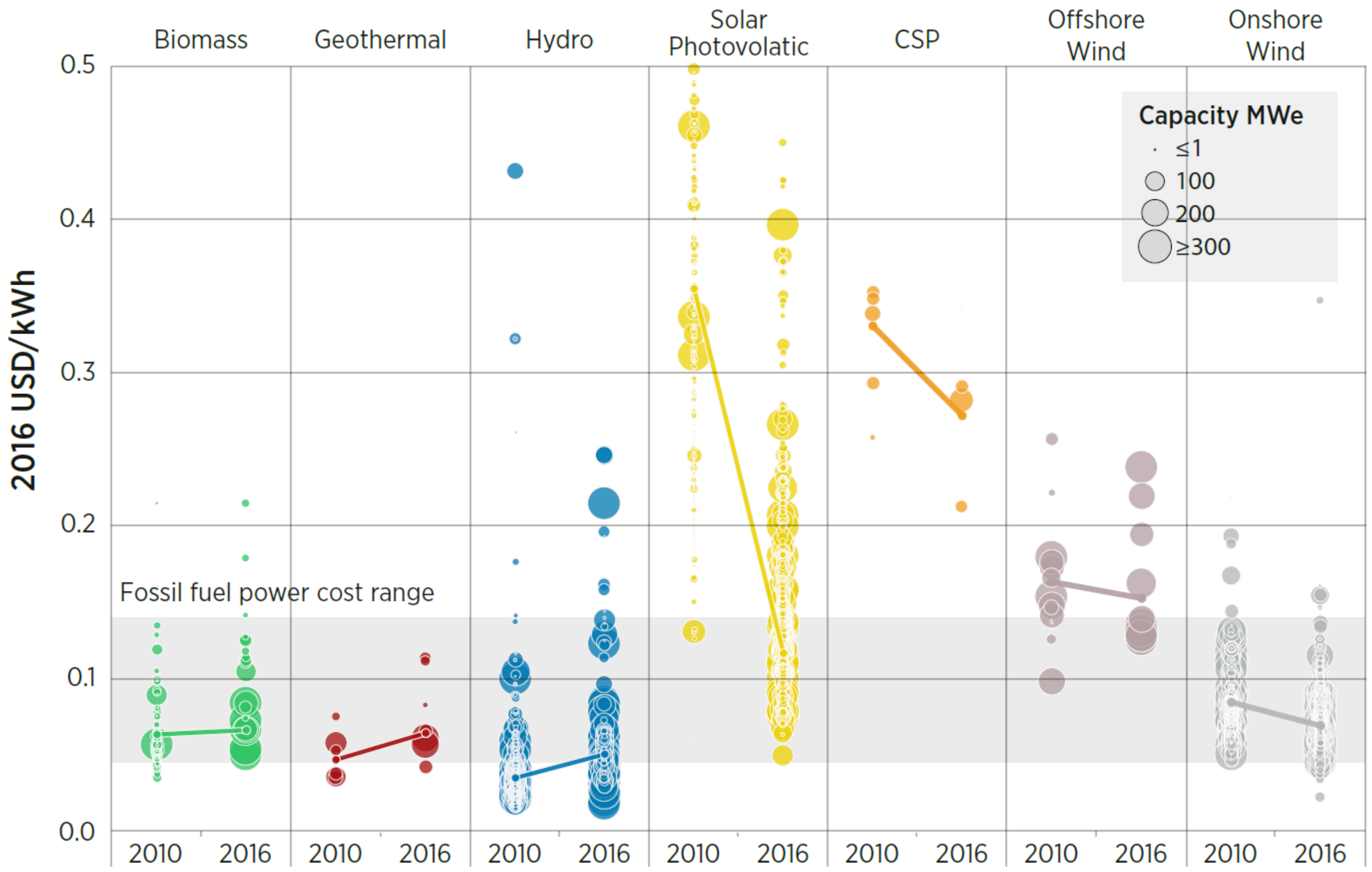


With coordinated advances in multiple components of the energy system, PV could supply 30–50% of electricity in competitive markets

(Creutzig et al., 2017, Nature Energy)

Relative increase of NPV mitigation costs (period 2015 – 2100 at 5 % discount rate) from technology portfolio variations compared to a scenario with default technology availability. (IPCC AR5 WGIII Report, pp 453)

Solar PV and onshore wind have seen very rapid cost reductions in recent years



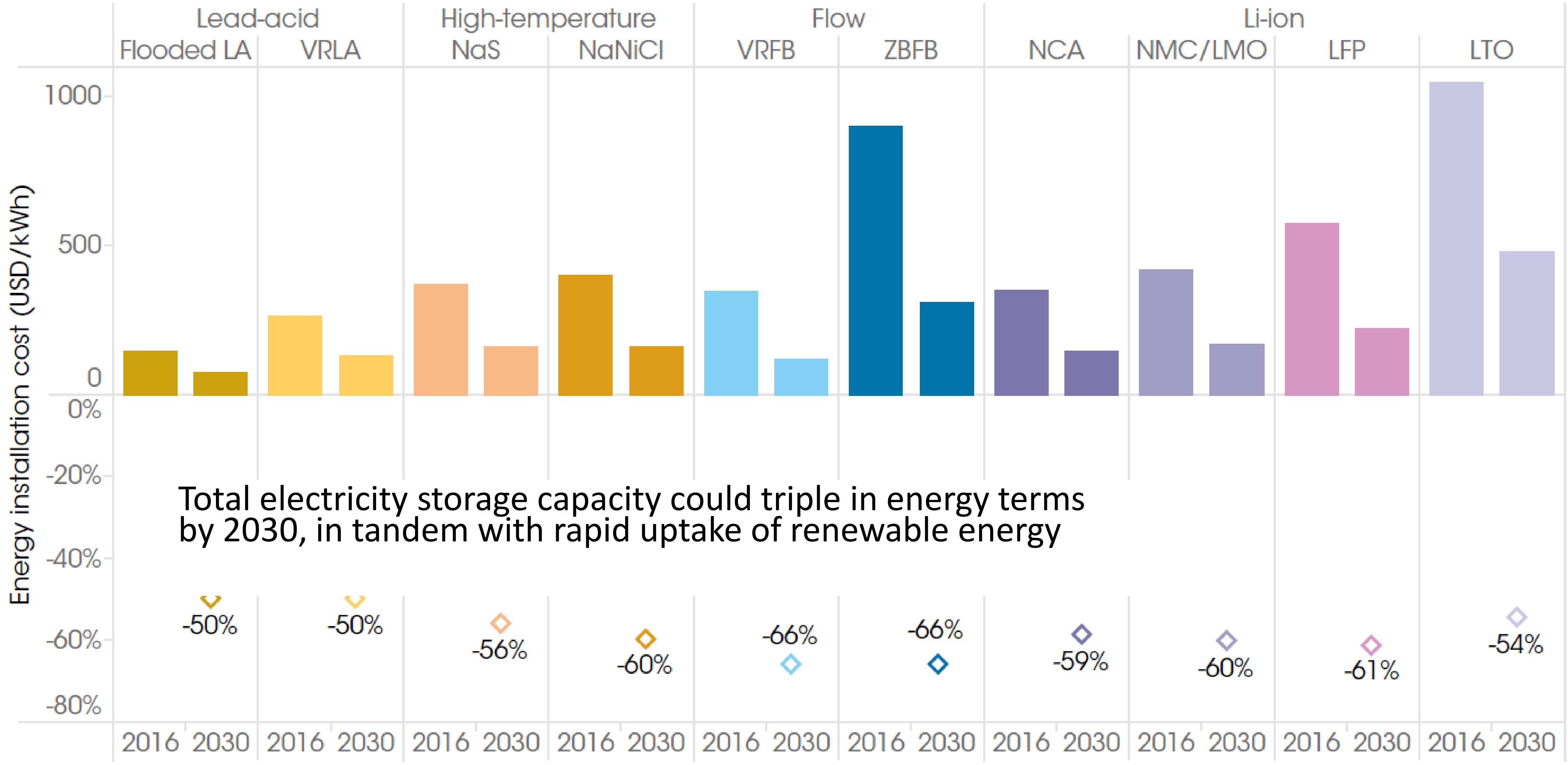
By 2025, the global weighted average cost of electricity from

- solar PV could fall by as much as 59%
- CSP by up to 43%
- Onshore and offshore wind could see cost declines of 26% and 35%, respectively

- *PV modules: learning rate 18% to 22%*
- *Module price fell 80% since 2010*
- *Onshore wind: Learning rate of 15% for the cost of electricity delivered*
- *Installed cost reductions (wind turbine prices fallen 38% on average since 2009)*

(IRENA, 2017)

Battery electricity storage systems: Installed energy cost reduction potential, 2016-2030



Total electricity storage capacity could triple in energy terms by 2030, in tandem with rapid uptake of renewable energy

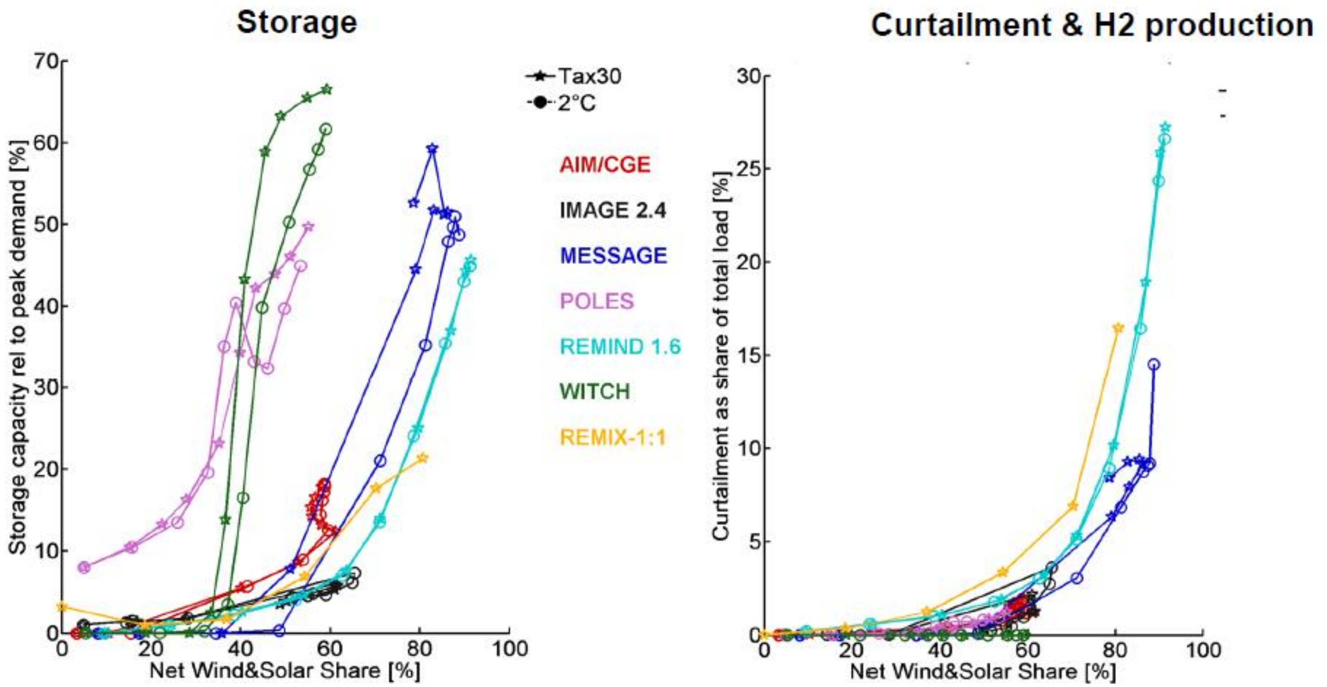
(IRENA, 2017)

IAMs

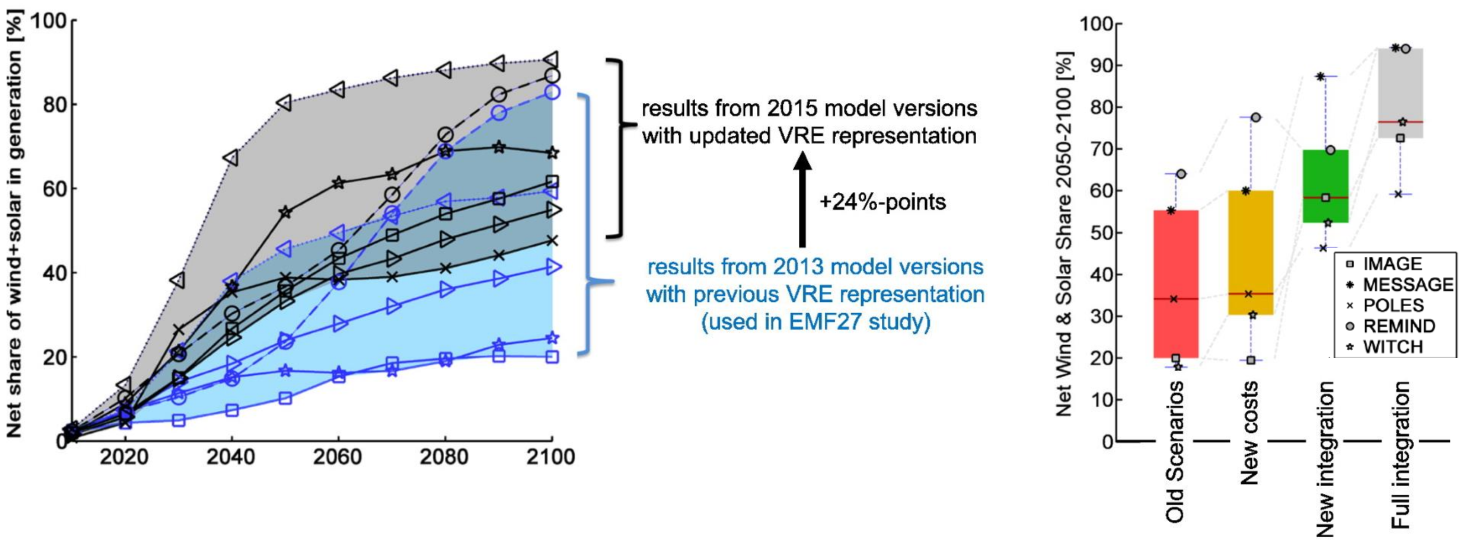
- Next generation IAM and sectoral studies must find a better way to integrate renewables electricity and co-benefits
  - declining cost of storage and cost of renewable, especially solar PV, storage, and onshore wind
  - variable nature of renewable electricity and their integration aspects
  - wide spectrum of co-benefits in evaluating costs of climate stabilization pathways

Improving IAMs?

- Incorporation of recent PV costs to REMIND Model of PIK *(Creutzig et al., 2017, Nature Energy)*
- Six IAM modelling teams → new approaches to improve the representation of power sector dynamics and variable renewable energy system (VRE) integration in IAMs *(Pietzcker et al., 2017, Energy Economics, 64:583-599)*
- Updating the power sector representation and the cost and resources of wind and solar → substantially increased wind and solar shares across models:
- Under a carbon price of 30$/tCO2 in 2020 (increasing by 5% per year), the model-average cost-minimizing VRE share over the period 2050-2100 is 62% of electricity generation, 24%-points *higher than with the old model version.*



Updating the wind and solar modeling increases their share in electricity generation in all six IAMs



Summary messages on RE

- **Cost of renewables, notably Solar and wind have reduced, storage technologies are evolving**
  - This has important implications to potential scale of renewable penetration and thus rate of decarbonization
  - IAM and past research have conservative assumptions in this regards → need to do more
  - Support for operationalization of renewable electricity integration is very important

Thank you

Rate of de-carbonization benefits from improving renewable energy economics and better knowledge on co-benefits

Declining cost of solar electricity, IRENA?

- Show declining cost of utility scale or hh scale solar electricity
- Show how installed capacity or global sell pf PV has increased
- Show how cost of battery storage has declined
- Check if anyone has done model simulation with faster rate of renewable penetration/storage spurred by cost reduction at large scale, any IAM model has published such results recently?

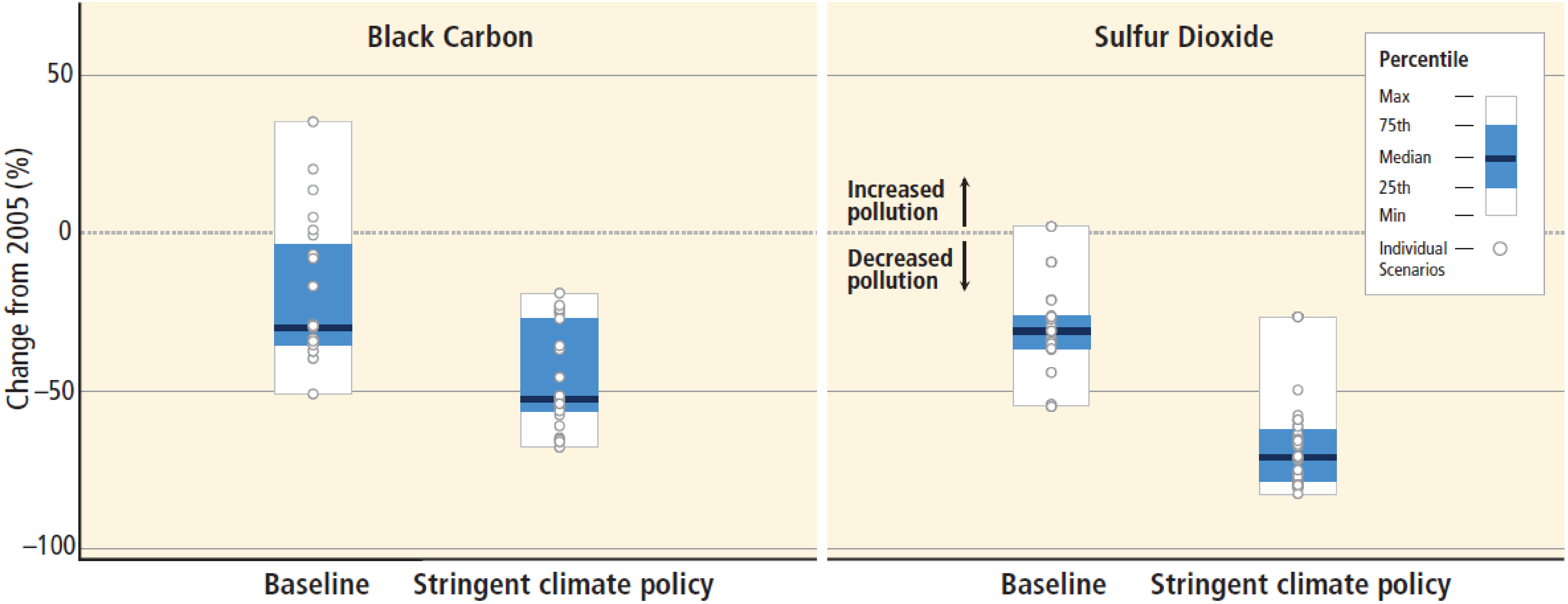
- Are there new studies with co-benefits better incorporated at global scale and estimated cost of climate change mitigation ?
- Are there studies which say that they found very high co-benefits OR considered new type of co-benefits OR found new methods of incorporating co-benefits

Quantification of co-benefits

- These mitigation scenarios show improvements in terms of:
  - sufficiency of resources to meet national energy demand
  - resilience of energy supply, resulting in energy systems that are less vulnerable to price volatility and supply disruptions
- The benefits from reduced impacts to health and ecosystems associated with major cuts in air pollutant emissions are particularly high
- Overall, the potential for co-benefits of energy end-use measures outweighs the potential for adverse side-effects, whereas the evidence suggests this may not be the case for all energy supply and AFOLU measures

Co-benefits of climate change mitigation for air quality

Impact of stringent climate policy on air pollutant emissions (Global, 2005–2050)



Air pollutant emission levels of black carbon (BC) and sulfur dioxide (SO2) by 2050, relative to 2005 (0 = 2005 levels). Baseline scenarios without additional efforts to reduce greenhouse gas (GHG) emissions beyond those in place today are compared to scenarios with stringent mitigation policies, which are consistent with reaching about 450 to about 500 (430 to 530) ppm CO2-eq concentration levels by 2100.

IPCC AR5 SYR, 2014

Energy Supply	Effect on additional objectives/concerns			
	Economic	Social	Environmental	Other
Nuclear replacing coal power	↑ Energy security (reduced exposure to fuel price volatility) (**m**/**m**) ↑ Local employment impact (but uncertain net effect) (**l**/**m**) ↑ Legacy cost of waste and abandoned reactors (**m**/**h**)	Health impact via ↓ Air pollution and coal mining accidents (**m**/**h**) ↑ Nuclear accidents and waste treatment, uranium mining and milling (**m**/**l**) ↑ Safety and waste concerns (**r**/**h**)	Ecosystem impact via ↓ Air pollution (**m**/**h**) and coal mining (**l**/**h**) ↑ Nuclear accidents (**m**/**m**)	Proliferation risk (**m**/**m**)
RE (wind, PV, concentrated solar power (CSP), hydro, geothermal, bioenergy) replacing coal	↑ Energy security (resource sufficiency, diversity in the near/medium term) (**r**/**m**) ↑ Local employment impact (but uncertain net effect) (**m**/**m**) ↑ Irrigation, flood control, navigation, water availability (for multipurpose use of reservoirs and regulated rivers) (**m**/**h**) ↑ Extra measures to match demand (for PV, wind and some CSP) (**r**/**h**)	Health impact via ↓ Air pollution (except bioenergy) (**r**/**h**) ↓ Coal mining accidents (**m**/**h**) ↑ Contribution to (off-grid) energy access (**m**/**l**) ? Project-specific public acceptance concerns (e.g., visibility of wind) (**l**/**m**) ↑ Threat of displacement (for large hydro) (**m**/**h**)	Ecosystem impact via ↓ Air pollution (except bioenergy) (**m**/**h**) ↓ Coal mining (**l**/**h**) ↑ Habitat impact (for some hydro) (**m**/**m**) ↑ Landscape and wildlife impact (for wind) **m**/**m**) ↓ Water use (for wind and PV) (**m**/**m**) ↑ Water use (for bioenergy, CSP, geothermal, and reservoir hydro) (**m**/**h**)	Higher use of critical metals for PV and direct drive wind turbines (**r**/**m**)
Fossil CCS replacing coal	↑↑ Preservation vs. lock-in of human and physical capital in the fossil industry (**m**/**m**)	Health impact via ↑ Risk of CO_2 leakage (**m**/**m**) ↑ Upstream supply-chain activities (**m**/**h**) ↑ Safety concerns (CO_2 storage and transport) (**m**/**h**)	↑ Ecosystem impact via upstream supply-chain activities (**m**/**m**) ↑ Water use (**m**/**h**)	Long-term monitoring of CO_2 storage (**m**/**h**)
BECCS replacing coal	*See fossil CCS where applicable. For possible upstream effect of biomass supply, see Table TS.8.*			
Methane leakage prevention, capture or treatment	↑ Energy security (potential to use gas in some cases) (**l**/**h**)	↓ Health impact via reduced air pollution (**m**/**m**) ↑ Occupational safety at coal mines (**m**/**m**)	↓ Ecosystem impact via reduced air pollution (**l**/**m**)	

Energy sector co-benefits or trade-offs

AR5 WGIII Report: pp 72

Transport	Effect on additional objectives/concerns		
	Economic	**Social**	**Environmental**
Reduction of fuel carbon intensity: electricity, hydrogen (H_2), compressed natural gas (CNG), biofuels, and other fuels	↑ Energy security (diversification, reduced oil dependence and exposure to oil price volatility) (**m/m**) ↑ Technological spillovers (e.g., battery technologies for consumer electronics) (**l/l**)	Health impact via urban air pollution by ? CNG, biofuels: net effect unclear (**m/l**) ↓ Electricity, H_2: reducing most pollutants (**r/h**) ↑ Shift to diesel: potentially increasing pollution (**l/m**) ↓ Health impact via reduced noise (electricity and fuel cell LDVs) (**l/m**) ↓ Road safety (silent electric LDVs at low speed) (**l/l**)	Ecosystem impact of electricity and hydrogen via ↓ Urban air pollution (**m/m**) ↑ Material use (unsustainable resource mining) (**l/l**) ? Ecosystem impact of biofuels: *see AFOLU*
Reduction of energy intensity	↑ Energy security (reduced oil dependence and exposure to oil price volatility) (**m/m**)	↓ Health impact via reduced urban air pollution (**r/h**) ↑ Road safety (via increased crash-worthiness) (**m/m**)	↓ Ecosystem and biodiversity impact via reduced urban air pollution (**m/h**)
Compact urban form and improved transport infrastructure **Modal shift**	↑ Energy security (reduced oil dependence and exposure to oil price volatility) (**m/m**) ↑ Productivity (reduced urban congestion and travel times, affordable and accessible transport) (**m/h**) ? Employment opportunities in the public transport sector vs. car manufacturing (**l/m**)	Health impact for non-motorized modes via ↓ Increased physical activity (**r/h**) ↑ Potentially higher exposure to air pollution (**r/h**) ↓ Noise (modal shift and travel reduction) (**r/h**) ↑ Equitable mobility access to employment opportunities, particularly in developing countries (**r/h**) ↑ Road safety (via modal shift and/or infrastructure for pedestrians and cyclists) (**r/h**)	Ecosystem impact via ↓ Urban air pollution (**r/h**) ↓ Land-use competition (**m/m**)
Journey distance reduction and avoidance	↑ Energy security (reduced oil dependence and exposure to oil price volatility) (**r/h**) ↑ Productivity (reduced urban congestion, travel times, walking) (**r/h**)	↓ Health impact (for non-motorized transport modes) (**r/h**)	Ecosystem impact via ↓ Urban air pollution (**r/h**) ↑ New/shorter shipping routes (**r/h**) ↓ Land-use competition from transport infrastructure (**r/h**)

Transport co-benefits, IPCC AR4 WGIII main report pp 77

Industry and co-benefits

- Co-benefits include enhanced competitiveness through cost-reductions, new business opportunities, better environmental compliance, health benefits through better local air and water quality and better work conditions, and reduced waste, all of which provide multiple indirect private and social benefits

Industry	Effect on additional objectives/concerns		
	Economic	Social	Environmental
CO_2 and non-CO_2 GHG emissions intensity reduction	↑ Competitiveness and productivity (**m/h**)	↓ Health impact via reduced local air pollution and better work conditions (for perfluorocarbons from aluminium) (**m/m**)	↓ Ecosystem impact via reduced local air pollution and reduced water pollution (**m/m**) ↑ Water conservation (**l/m**)
Technical energy efficiency improvements via new processes and technologies	↑ Energy security (via lower energy intensity) (**m/m**) ↑ Employment impact (**l/l**) ↑ Competitiveness and productivity (**m/h**) ↑ Technological spillovers in developing countries (due to supply chain linkages) (**l/l**)	↓ Health impact via reduced local pollution (**l/m**) ↑ New business opportunities (**m/m**) ↑ Water availability and quality (**l/l**) ↑ Safety, working conditions and job satisfaction (**m/m**)	Ecosystem impact via: ↓ Fossil fuel extraction (**l/l**) ↓ Local pollution and waste (**m/m**)
Material efficiency of goods, recycling	↓ National sales tax revenue in medium term (**l/l**) ↑ Employment impact in waste recycling market (**l/l**) ↑ Competitiveness in manufacturing (**l/l**) ↑ New infrastructure for industrial clusters (**l/l**)	↓ Health impacts and safety concerns (**l/m**) ↑ New business opportunities (**m/m**) ↓ Local conflicts (reduced resource extraction) (**l/m**)	↓ Ecosystem impact via reduced local air and water pollution and waste material disposal (**m/m**) ↓ Use of raw/virgin materials and natural resources implying reduced unsustainable resource mining (**l/l**)
Product demand reductions	↓ National sales tax revenue in medium term (**l/l**)	↑ Wellbeing via diverse lifestyle choices (**l/l**)	↓ Post-consumption waste (**l/l**)

(IPCC AR5 Mitigation Report, pp 85)

AFOLU	Effect on additional objectives/concerns			
	Economic	**Social**	**Environmental**	**Institutional**
Supply side: Forestry, land-based agriculture, livestock, integrated systems, and bioenergy (**marked by** *) **Demand side:** Reduced losses in the food supply chain, changes in human diets, changes in demand for wood and forestry products	* Employment impact via ↑ Entrepreneurship development (**m/h**) ↓ Use of less labour-intensive technologies in agriculture (**m/m**) ↑* Diversification of income sources and access to markets (**r/h**) ↑* Additional income to (sustainable) landscape management (**m/h**) ↑* Income concentration (**m/m**) ↑* Energy security (resource sufficiency) (**m/h**) ↑ Innovative financing mechanisms for sustainable resource management (**m/h**) ↑ Technology innovation and transfer (**m/m**)	↑* Food-crops production through integrated systems and sustainable agriculture intensification (**r/m**) ↓* Food production (locally) due to large-scale monocultures of non-food crops (**r/l**) ↑ Cultural habitats and recreational areas via (sustainable) forest management and conservation (**m/m**) ↑* Human health and animal welfare e.g., through less pesticides, reduced burning practices, and practices like agroforestry and silvo-pastoral systems (**m/h**) ↓* Human health when using burning practices (in agriculture or bioenergy) (**m/m**) * Gender, intra- and inter-generational equity via ↑ Participation and fair benefit sharing (**r/h**) ↑ Concentration of benefits (**m/m**)	Provision of ecosystem services via ↑ Ecosystem conservation and sustainable management as well as sustainable agriculture (**r/h**) ↓* Large scale monocultures (**r/h**) ↑* Land-use competition (**r/m**) ↑ Soil quality (**r/h**) ↓ Erosion (**r/h**) ↑ Ecosystem resilience (**m/h**) ↑ Albedo and evaporation (**r/h**)	↑↓* Tenure and use rights at the local level (for indigenous people and local communities) especially when implementing activities in natural forests (**r/h**) ↑↓ Access to participative mechanisms for land management decisions (**r/h**) ↑ Enforcement of existing policies for sustainable resource management (**r/h**)

AFOLU co-benefits, IPCC AR5 WGIII Report, pp 89

Urban-scale CC mitigation strategies and co-benefits

- Implementation of urban-scale climate change mitigation strategies can provide co-benefits
- Urban areas throughout the world continue to struggle with challenges, including ensuring access to energy, limiting air and water pollution, and maintaining employment opportunities and competitiveness.
- Action on urban-scale mitigation often depends on the ability to relate climate change mitigation efforts to local co-benefits

Co-benefits and policies

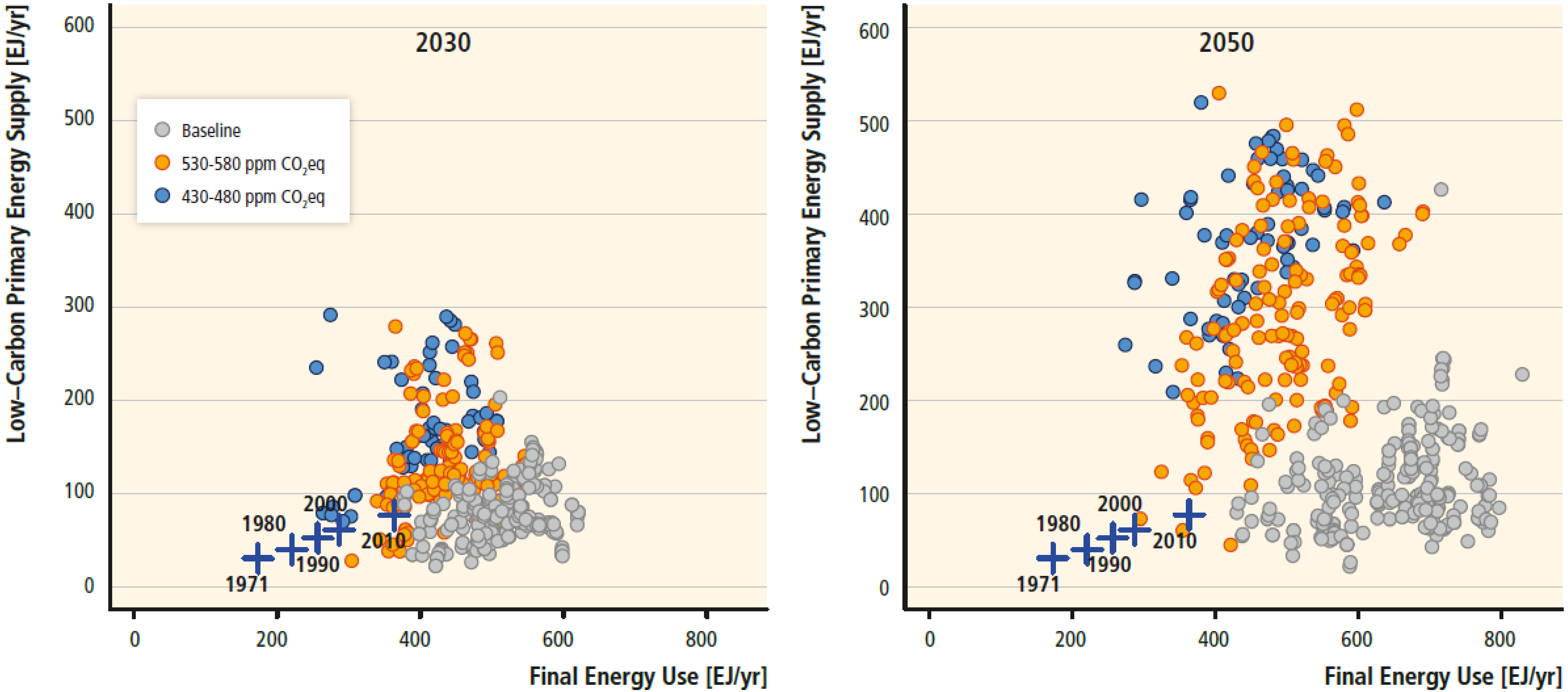
- There is growing political and analytical attention to co-benefits and adverse side-effects of climate policy on other objectives
- Increased focus on policies designed to integrate multiple objectives
- Co-benefits are often explicitly referenced in climate and sectoral plans and strategies and often enable enhanced political support
- The analytical and empirical underpinnings for many of these interactive effects, and particularly for the associated welfare impacts, are under-developed.
- The scope for co-benefits is greater in low-income countries, where complementary policies for other objectives, such as air quality, are often weak

Pp 96

RE and co-benefits

- The use of RE is often associated with co-benefits, examples
  - reduction of air pollution
  - local employment opportunities
  - few severe accidents compared to some other energy supply technologies
  - improved energy access and security

Global low-carbon primary energy supply vs. total final energy use for idealized implementation scenarios



Low carbon primary energy includes fossil energy with CCS, nuclear energy, bioenergy, and non-biomass renewable energy

IPCC AR5 WG III Report, pp 444