Climate policies can help resolve energy security and air pollution challenges

David L. McCollum*, Volker Krey, Keywan Riahi, Peter Kolp, and Marek Makowski
(IIASA – Laxenburg, Austria)

*corresponding author: mccollum@iiasa.ac.at

Abstract

This research assesses three key energy sustainability objectives: energy security improvement, climate change mitigation, and the reduction of air pollution and its human health impacts. We illustrate how the common practice of narrowly focusing on singular issues ignores potentially enormous synergies, highlighting the need for a paradigm shift toward more holistic policy approaches. Our analysis of a large ensemble of alternate energy-climate futures, developed using MESSAGE, an integrated assessment model, shows that climate change policy offers a strategic entry point along the path to energy sustainability in several dimensions. Decarbonization will lead to improved air quality, thereby reducing energy-related health impacts worldwide (22-32 million fewer disability-adjusted life years in 2030). At the same time, low-carbon technologies and energy-efficiency improvements can help to further the energy security goals of individual countries and regions by promoting a more dependable, resilient, and diversified energy portfolio. The cost savings of these climate policy synergies are potentially enormous: $100-600 billion annually by 2030 in reduced pollution control and energy security expenditures (0.1-0.7% of GDP). Novel aspects of this work include an explicit quantification of the health-related co-benefits of present and future air pollution control policies; an analysis of how future constraints on regional trade could influence energy security; a detailed assessment of energy expenditures showing where financing needs to flow in order to achieve the multiple energy sustainability objectives; and a quantification of the relationships between different fulfillment levels for energy security and air pollution goals and the probability of reaching the 2°C climate target.

Spanning the scenario space

- Using MESSAGE-MACRO (an integrated assessment model with considerable technological detail of the global energy system (Riahi et al. 2007)), the GAINS air pollution model (Amann, 2009), and the MAGICC climate model (Wigley, 2008), we developed an ensemble of several hundred alternate energy futures, each of which assumes a unique combination of policy priorities with respect to climate, energy security and air pollution.
- Hence, the scenarios stretch the potential development of the energy system in several dimensions by fulfilling the individual objectives to varying degrees of satisfaction: Weak, Intermediate, and Stringent (see Figure 1).

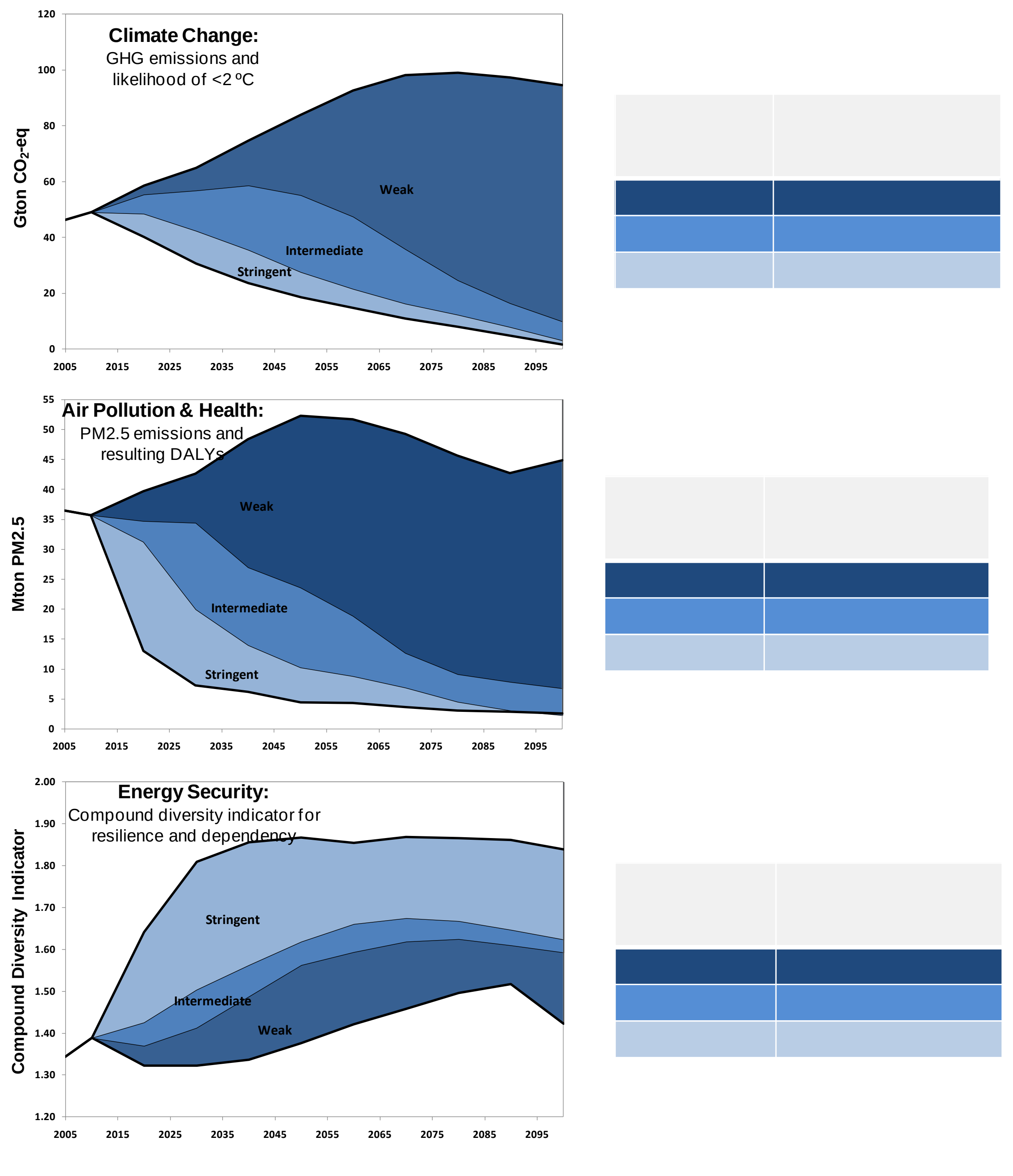

Figure 1. Trajectories for global greenhouse gas emissions, PM2.5 emissions, and the compound energy diversity indicator for the full scenario ensemble. Corresponding indicators for sustainability objective fulfillment within the Weak-Intermediate-Stringent framework are shown to the right.

Acknowledgments & References

- We thank Arnulf Grübler and Nebojsa Nakicenovic for their important contributions to this research. Shilpa Rao, Hongtao Ren, Wolfgang Schöpp and Charlie Wilson also provided critical assistance. The research was supported by the Global Environment Facility, United Nations Industrial Development Organization, Research Institute of Innovative Technology for the Earth and US National Academy of Sciences.
- Amann M, Bertok I, Borken-Kleefeld J, Cofala J, Heyes C, Hoeglund-Isaksson L, Klimont Z, Purohit P, Rafaj P, Schoepp W, Toth G, Wagner F, Winiwarter W (2009) Potentials and Costs for Greenhouse Gas Mitigation in Annex I Countries: Methodology, IIASA Interim Report IR-09-043. International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria.
- Jansen JC, Arkel WGv, Boots MG (2004) Designing indicators of long-term energy supply security. Energy Research Centre of the Netherlands (ECN), p. 35.
- McCollum D, Krey V, Riahi K (2011) An integrated approach to energy sustainability. Nature Climate Change 1:428-429.
- Riahi K, Grübler A, Nakicenovic N (2007) Scenarios of long-term socio-economic and environmental development under climate stabilization. Technological Forecasting and Social Change 74:887-935.
- Wigley TML (2008) MAGICC/SCENGEN 5.3: User Manual (version 2). National Center for Atmospheric Research, Boulder.

Synergies between multiple objectives

Key Finding: *climate change mitigation can be an important entry point for achieving society's pollution- and health-related goals*

- Because of the major cuts in PM2.5 that decarbonization brings about (left-hand panel of Figure 2), energy-related health impacts worldwide are reduced by up to 22 million DALYs in 2030 compared to our baseline scenario, which assumes that no new climate policies are implemented and that only currently legislated and planned air pollution policies are enacted (the CLE case).
- A significant portion of climate mitigation costs can be compensated for by reduced pollution control requirements (right-hand panel of Figure 2). Our scenarios indicate cost savings of up to US$500 billion per year by 2030, almost half the level of today's investments into the global energy system.

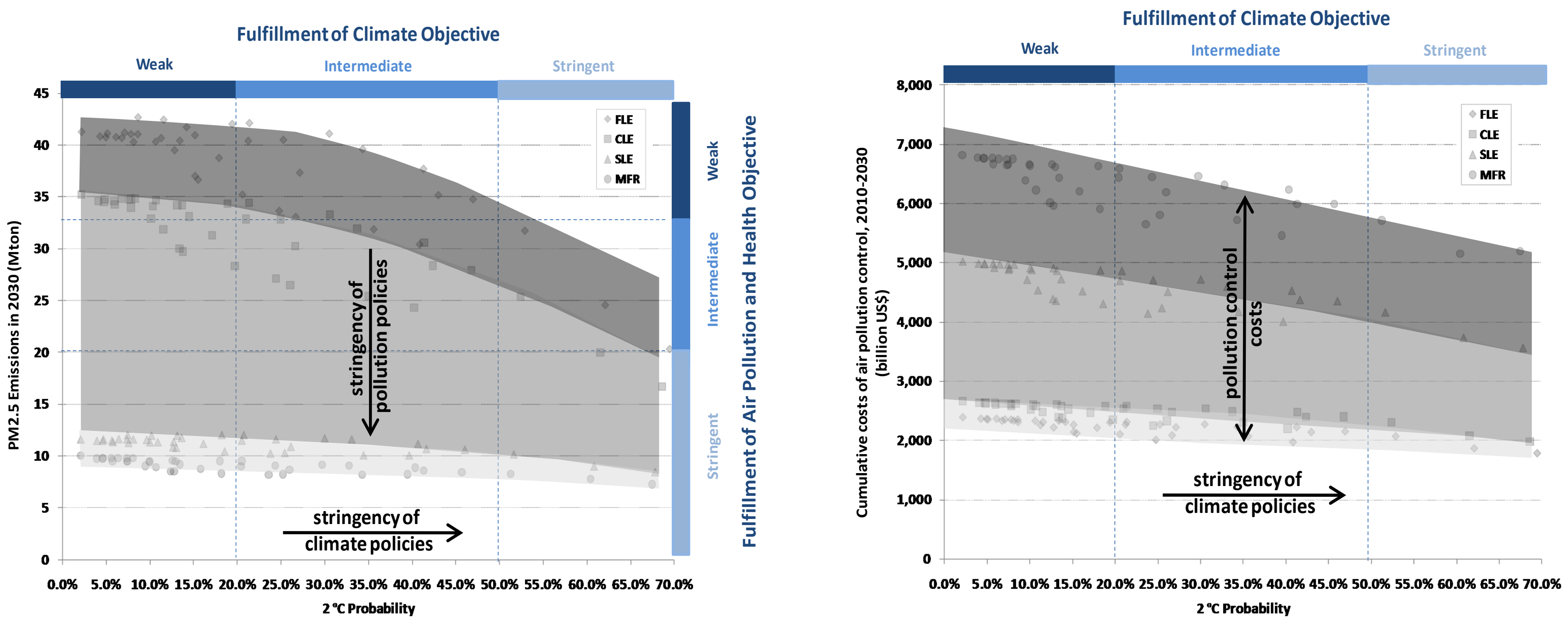

Figure 2. Synergies between climate change mitigation and near-term pollution controls. The left-hand panel shows the relationship between climate change mitigation (expressed in terms of the likelihood of staying below 2°C) and the reduction of PM2.5 emissions. The right-hand panel shows the corresponding relationship between climate change mitigation and resulting costs for pollution abatement technologies. Each dot in the panels represents a single scenario, and the style of each dot indicates the assumed stringency for air pollution control legislation (FLE = Frozen Legislation; CLE = Current and planned Legislation; SLE = Stringent Legislation; MFR = Maximum Feasible Reduction; see SM for details). Grey-shaded areas indicate the relative placement of scenarios with different pollution legislation. Vertical and horizontal blue bars indicate the range of outcomes for pollutant emissions (PM2.5) and climate (2°C probability) that correspond to the Weak, Intermediate, or Stringent Fulfillment levels (see also Figure 1).

Key Finding: *climate change mitigation can be an important entry point for achieving society's energy security goals*

- Decarbonization of the energy system can simultaneously reduce import dependence (improved sovereignty) and increase energy diversity (improved resilience), two key indicators of a more secure energy supply mix (left-hand panel of Figure 3).
- A significant portion of climate mitigation costs can be compensated for by the reduced need for extra security expenditures (right-hand panel of Figure 3), since climate policy promotes both energy efficiency and conservation and the increased utilization of domestically available, low-carbon energy sources. Investment cost savings of up to US$130 billion per year are possible by 2030.

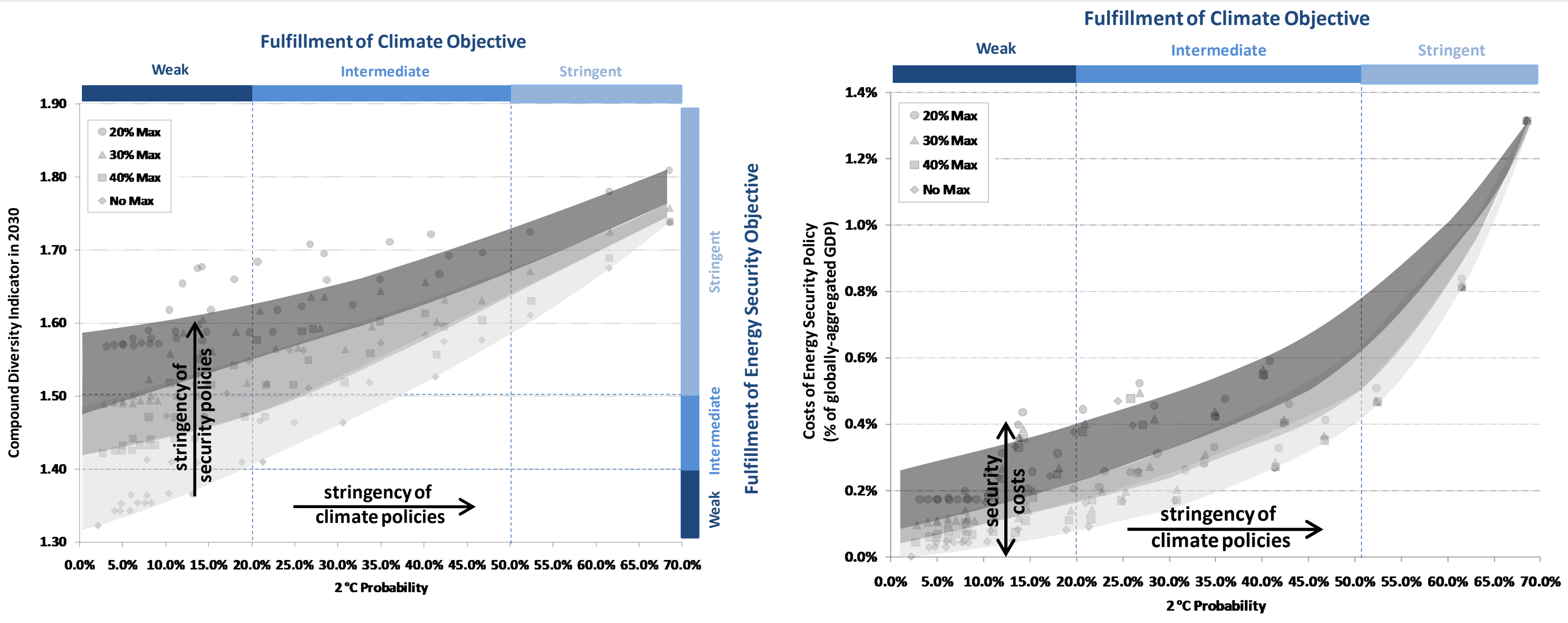

Figure 3. Synergies between climate change mitigation and near-term improvement of energy security. The left-hand panel shows the relationship between climate change mitigation (expressed in terms of the likelihood of staying below 2°C) and improvements in energy security with respect to both energy system resilience and sovereignty (expressed in terms of a compound diversity indicator, see Jansen (2004)). The right-hand panel shows the corresponding relationship between climate change mitigation and the reduced costs for energy security expenditures. Each dot in the panels represents a single scenario, and the style of each dot indicates the assumed stringency for the energy security constraint used in the model (formulated as an upper limit on the share of total primary energy that can be supplied by imports in a given region and year). Grey-shaded areas indicate the relative placement of scenarios with different energy security legislation. Vertical and horizontal blue bars indicate the range of outcomes for energy security (diversity indicator) and climate (2°C probability) that correspond to the Weak, Intermediate, or Stringent Fulfillment levels (see also Figure 1). Energy security policy costs are global, cumulative (2010-2030), discounted, and relative to a baseline scenario which contains no explicit energy security policies. The costs of end-of-pipe air pollution policies are also included here; they do vary somewhat even though the scenarios assume the same level of stringency for air pollution control legislation.

Key Finding: *a more integrated, holistic approach to our energy challenges is needed*

- Once stringent climate policies are in place, our calculations show the synergistic effects to be so strong that the added costs of any supplementary policies needed to ensure fulfillment of the air pollution and energy security objectives at their stringent levels are significantly reduced.
- A simple way of visualizing these synergies is to note how the sum of the three leftmost cost bars in Figure 4 (single-minded policy approaches) is much larger than the rightmost bar (integrated policy approach).

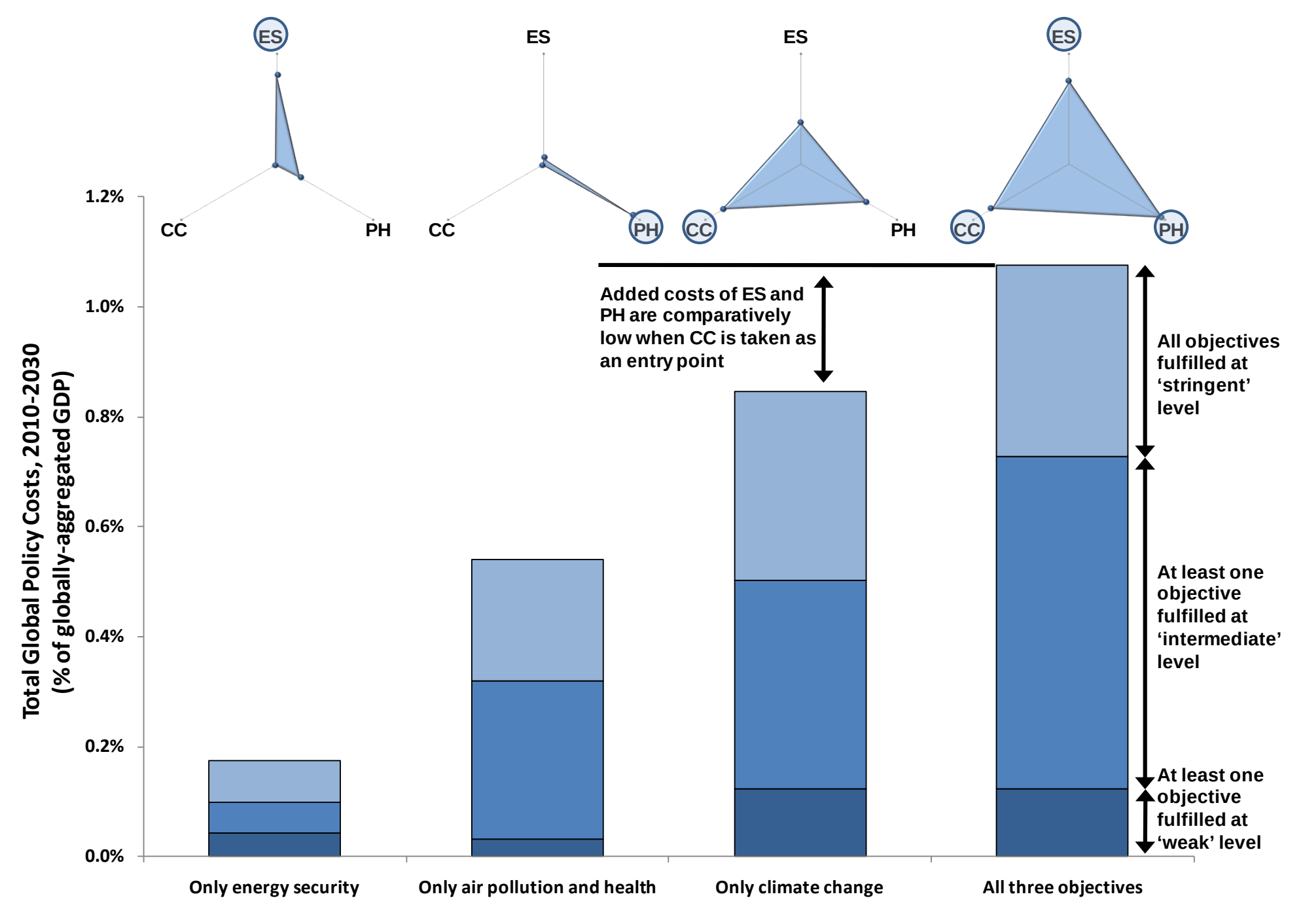

Figure 4. Costs of achieving societal objectives for energy sustainability under different policy prioritization frameworks. Global policy costs are cumulative (2010-2030), and represent the net financial requirements (energy-system and pollution-control investments, variable, and operations and maintenance costs) over and above baseline energy-system development, which is itself estimated at 2.1% of globally-aggregated GDP. Triangular schematics above the bars summarize the performance of scenarios that achieve 'stringent' fulfillment only for the objective(s) targeted under the corresponding policy frameworks (axis values normalized from 0 to 1 based on the full range of scenario ensemble outcomes; CC = Climate Change, ES = Energy Security, PH = Air Pollution and Health). [see also Fig. 1 in McCollum et al. (2011)].