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Synergies in the Asian energy system: Climate change, energy security, energy access and air pollution

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A B S T R A C T

We use the MESSAGE model to examine multiple dimensions of sustainable development for three Asian regions in a set of scenarios developed for the Asian Modelling Exercise. Using climate change mitigation as a starting point for the analysis, we focus on the interaction of climate and energy with technology choice, energy security, energy access, and air pollution, which often have higher policy priority than climate change. Stringent climate policies drive the future energy supply in Asia from being dominated by coal and oil to a more diversified system based mostly on natural gas, coal with CCS, nuclear and renewable energy. The increase in diversity helps to improve the energy security of individual countries and regions. Combining air pollution control policies and universal energy access policies with climate policy can further help to reduce both outdoor and indoor air pollution related health impacts.

Investments into the energy system must double by 2030 to achieve stringent climate goals, but are largely offset by lower costs for O&M and air pollution abatement. Strong focus on end-use efficiency also helps lowering overall total costs and allows for limiting or excluding supply side technologies from the mitigation portfolio. Costs of additional energy access policies and measures are a small fraction of total energy system costs.

1. Introduction

The story of Asia over the past several decades is a story of dramatic change. The sheer size and speed of development in the countries of the region is striking. Their populations, for example, have grown so large that, collectively, Asia now accounts for about half of the global total, with a large share of its people now living in urban areas (United Nations, 2009). Rapid and sustained economic growth has made massive infrastructure projects possible and at the same time has lifted millions of poorer Asians out of poverty (ADB, 2011).

Yet, increased Asian prosperity has brought with it a number of challenges (United Nations, 2010a). Surging demands in the industrial, agricultural, transportation, and residential and commercial sectors have necessitated huge investments in energy supply infrastructure: more power plants, more oil refineries, more coal mines, and in general more of everything (IEA, 2010). This has led to large increases in emissions of greenhouse gases (GHG), that contribute to global climate change, and other air pollutants , that contribute to ecosystem eutrophication, acidification and a variety of human health impacts (Parry et al., 2007). Rapidly growing energy demands have also raised energy security concerns in certain Asian countries (Sovacool and Brown, 2010): with domestic production frequently unable to meet local demand, imports from foreign sources are on the rise. Moreover, even though many have benefited from the recent economic success in Asia, there are still far too many people who lack access to modern forms of energy (IEA/UNEP/UNIDO, 2010).

This article highlights findings of scenario analyses conducted using the MESSAGE model as part of the Asian Modelling Exercise (AME, see Calvin et al., 2012–this issue). The first goal is to better understand the implications of climate policy in Asia: which technologies might be used, how demand could develop, and what the costs are. However, in light of all the other energy challenges faced by Asian countries, this article goes one step further by presenting the interactions of climate policy with energy security, air pollution and energy access. In particular, we focus on the enormous synergies between climate change mitigation and these other energy-related objectives for sustainable development.

Section 2 briefly describes the MESSAGE model and scenarios examined. Section 3 starts out with a description of the resulting GHG emissions with Section 4 discussing the corresponding developments in the energy system, and the technologies used. Section 5 then discusses

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Table 1
Scenarios definitions used in this article.

Scenario name	Description
Reference	No GHG emissions reduction measures, baseline energy system development assuming conventional transportation and stringent air quality legislation (SLE, see Section 5.2).
CO_2 price \$10 (5% p.a.) CO_2 price \$30 (5% p.a.) CO_2 price \$50 (5% p.a.)	CO_2 price in 2020 at 10, 30 and 50 US\$$_{2005}$[a]/tonne CO_2 equivalent, respectively, with the CO_2 price increasing by 5% per year. Included in the Asian Modelling Exercise to facilitate comparison with models that do not feature emissions limits based on climate indicators (see Calvin et al., 2012–this issue).
3.7 W/m^2 NTE	Radiative forcing is not to exceed (NTE) 3.7 W/m^2 at any time, which is approximately equivalent to a maximum GHG concentration of 550 ppm CO_2 equivalent.
2.6 W/m^2 OS	Radiative forcing by the end of the century is below 2.6 W/m^2, but may overshoot (OS) this level in the intervening years, which is approximately equivalent to a GHG concentration of 450 ppm CO_2 equivalent at the end of the century.
No nuclear	Variant of the 2.6 W/m^2 OS scenario, included because of environmental and proliferation risks, and uncertain social acceptability. No new nuclear power plants are built after 2020, leading to full phase-out around 2060.
Lim. renewables	Variant of the 2.6 W/m^2 OS scenario, included to account for possible limits to systems integration and institutional barriers to expansion of intermittent renewables (wind, solar), which are restricted to 20% of final electricity use (see, e.g., Benjamin, 2007; Gross et al., 2007; Holttinen et al., 2009; Milligan et al., 2009; Smith et al., 2007; Swider et al., 2008; Vajjhala and Fischbeck, 2007).
High efficiency	Variant of the 2.6 W/m^2 OS scenario, included to examine how stronger focus on end-use efficiency might affect cost of the energy system. Improves final energy intensity of GDP in Asia with an additional 0.3% per year on average from 2010 to 2100 and 0.4% worldwide.
Current legislation for air pollution	Variants of the Reference and 2.6 W/m^2 OS scenarios, included to provide a baseline for calculating the effect of air pollution control technologies on energy system costs.
Universal access to modern energy	Variants of the 2.6 W/m^2 OS scenario using the MESSAGE-Access model, included to assess impacts of policies to attain universal access to modern cooking fuels and electricity.

[a] All currency values in this article are in real market exchange rate (MER) 2005 US dollars. All future and cumulative costs and investments are undiscounted unless otherwise noted.

synergies with other targets for sustainable development. Section 6 details the investments and economic effects of the previously discussed policies and Section 7 presents conclusions from these analyses.

2. Scenarios and model description

We use scenario analysis as a framework to facilitate the consistent integration of diverse energy issues, and for examining policies for a transition towards an energy system that supports sustainable development. For this analysis we explored nine scenarios, as described in Table 1.

The first six scenarios are mandatory in the AME and examine different strategies for climate change mitigation, ranging from baseline pathway without climate policy to CO_2 pricing scenarios that enable a comparison between regional and global model results, to radiative forcing targets of various stringency (see Calvin et al., 2012–this issue). Three other scenarios explore variations of the availability of technological mitigation options, such as nuclear energy, intermittent renewable energy sources and advanced energy efficiency for the costs of achieving the 2.6 W/m^2 OS climate change mitigation scenario. This scenario is compatible with reducing global temperature rise to below 2 °C target, a target often quoted at political levels (Fisher et al., 2007). Two additional scenarios look into effects of specific policies for air pollution control and promoting energy access in developing countries.

The scenarios presented in this article use the GEA Mix pathways (Riahi et al., 2012), developed for the Global Energy Assessment (GEA), as a starting point and therefore share the majority of underlying assumptions. As a result, the 2.6 W/m^2 scenario presented here is very similar to the illustrative GEA Mix pathway. We do not present a full set of permutations of all scenario variants for lack of space, but a wider analysis including many similar scenario permutations can be found in Riahi et al. (2012).

Two important assumptions in the scenario design that will be revisited during this analysis are:

- Conventional transportation sector, largely relying on liquid and gaseous fuels with electricity supplying a maximum of 25% of final energy for transport (e.g., introduction of plug-in hybrids possible, but no full electrification of passenger road transport allowed).
- Exogenous energy intensity, in final energy per GDP, improvement in the Reference scenario of 1.1% per year overall between 2010 and 2100 globally which is consistent with the historical rate for the period 1971–2008. In Asia, final energy intensity is currently higher than the global average, but improves faster at 1.9% overall between 2010 and 2100, peaking between 2020 and 2030 at 3.1%. Both final energy intensity of GDP and per capita demand for final energy in Asian regions converge towards OECD levels in the long term.

We explore these scenarios using the MESSAGE integrated assessment modelling framework. MESSAGE is a global systems engineering optimization model used for medium- to long-term (1990–2100) energy system planning, energy policy analysis, and scenario development (Messner and Strubegger, 1995). The model divides the world up into eleven regions in an attempt to represent the global energy system in a simplified way, yet with many of its complex interdependencies, from resource extraction, imports and exports, conversion, transport, and distribution, to the provision of energy end-use services such as light, space conditioning, industrial production processes, and transportation. The agriculture and forestry sectors are also included. MESSAGE tracks a full basket of greenhouse gases and other radiatively active gases.

End-use sectoral demands are derived from a scenario generator (Riahi et al., 2007); these are driven largely by regional projections for gross domestic product (GDP) and population. Energy prices are calculated endogenously and CO_2 prices are added to fuel prices via their emission factors. Price-induced changes in energy demand (i.e., elastic demands) are captured by coupling MESSAGE to a macro-economic model of the global economy. This combined set-up is known as MESSAGE-MACRO (Messner and Schrattenholzer, 2000). The climate system impacts of the scenarios generated by MESSAGE are estimated using MAGICC v5.3, a global climate model of intermediate complexity (Wigley, 2008).

Spatially, MESSAGE model resolves 11 regions, but this article focuses on only three of the eleven regions in MESSAGE: Centrally Planned Asia (CPA), South Asia (SAS) and Other Pacific Asia (PAS). In terms of energy, CPA is dominated by China; SAS is dominated by India; and PAS represents a collection of the remaining Asian countries excluding Japan (e.g., Indonesia, Malaysia, South Korea). Together, these three regions will be referred to as 'emerging Asia' in this article. For further and more detailed information about the MESSAGE integrated assessment modelling framework, see the supplementary online material (SOM).