An Alternative Co-Benefit Framework Prioritizing Health Impacts: Potential Air Pollution and Climate Change Mitigation Pathways through Energy Sector Fuel Substitution in South Korea

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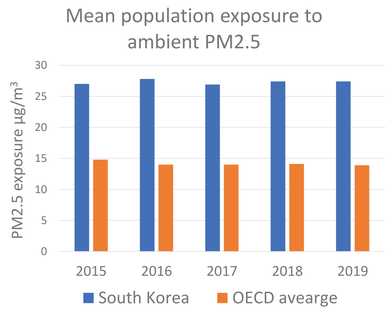
Background

- Exposure to PM2.5 causes various adverse health impacts including increasing the relative risk for ischemic heart disease, stroke, lung cancer, chronic obstructive pulmonary disease (COPD), and acute lower respiratory infections (ALRI).
- Ambient PM2.5 exposure attributable premature deaths from these five diseases were 4.2 million globally in 2015, and 11,523 in South Korea in 2012.
- As South Korea is a rapidly aging society, the negative impacts of ambient PM2.5 are becoming more severe.



Alternative co-benefit framework

This study utilizes an alternative co-benefit framework, which views air pollution reduction as the primary goal and climate change mitigation as a secondary objective, for three primary reasons:

- Air pollution is the top environmental concern of Korean citizens.
- The negative impacts of air pollution are more near-term than climate change.
- Policies framed with focus on local benefits are more likely to be supported and implemented.

Methodology

2022-2050 scenario analysis utilizing the Low Emissions Analysis Platform (LEAP) and its Integrated Benefits Calculator (IBC).

- The benefits of replacing coal electricity generation with liquefied natural gas (LNG) and nuclear power are estimated using electricity demand and energy capacities from South Korea's 9th Basic Plan for Power Supply and Demand.
- Health benefits are calculated in avoided premature deaths and avoided years of life lost, and climate benefits are calculated in avoided million tons of CO_2 equivalent ($MTCO_2e$).
- National PM2.5 and GHGs emissions are estimated from this research's created model, with rest of world emissions taken from the IIASA GAINS ECLIPSE scenario.
- Total emissions are translated into population-weighted concentrations in the target country based on GEOS-Chem adjoint model [see Kuylenstierna et al. for full detailed methodology: doi.org/10.1016/j.envint.2020.106155].
- Annual premature mortality and years of life lost are calculated using integrated exposure-response functions (IERs) from Cohen et al. analysis of 2015 Global Burden of Disease study data [doi.org/10.1016/S0140-6736(17)30505-6].
- The IERs have the mathematical form:

$$IER(\beta,z)=1+\alpha\times(1-e^{-\beta(z-z_{cf})_+^{\gamma}})$$

where z is the level of PM2.5 and z_{cf} is the theoretical minimum risk exposure level (assigned a uniform distribution of 2.4–5.9 µg/m³ of PM2.5) below which no additional risk is assumed, with

$$(z-z_{cf})_+=(z-z_{cf})$$

if z is greater than z_{cf} and zero otherwise. $1+\alpha$ is the maximum risk, β is the ratio of the IER at low to high concentrations, and γ is the power of PM2.5 concentration.

- Diseases rates by gender and five year age category for ischemic heart disease, stroke, lung cancer, COPD and ALRI from base year 2019, with change in mortality calculated:

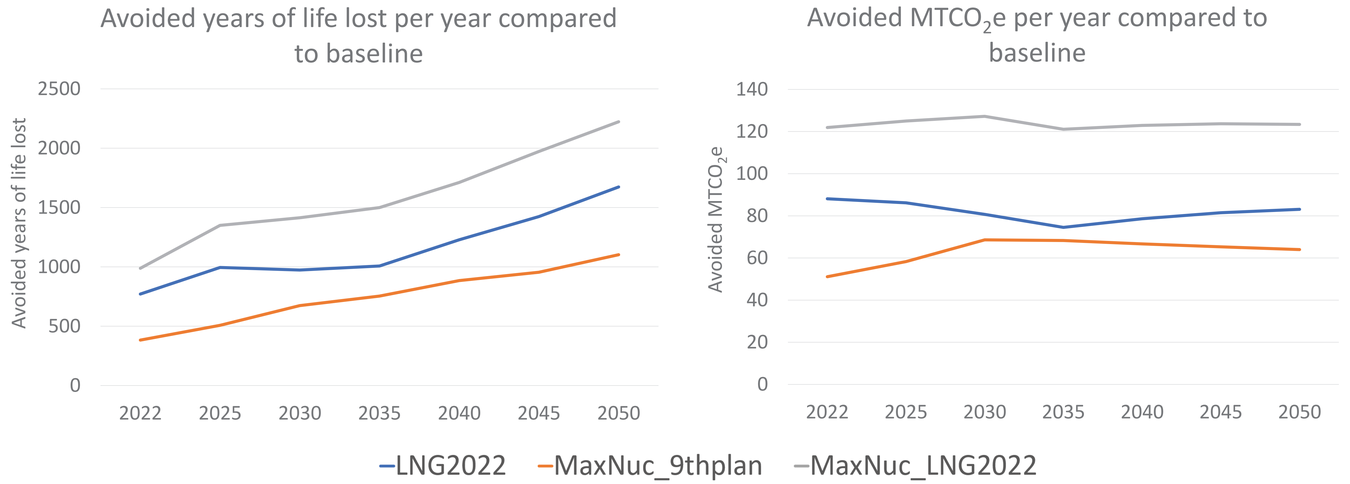
$$\Delta\text{Mort}=y_0\left(\frac{RR_{IER}-1}{RR_{IER}}\right)Pop$$

Here y_0 is the baseline mortality rate for each disease category, and Pop is the exposed population for each age category.

Scenarios

Scenario Name	Description
Baseline	○ Coal and LNG dispatch proportionally to effective capacities of the 9th Basic Plan. ○ Renewable energy dispatches according to full effective capacity of the 9th Basic Plan. ○ Nuclear power capacity and electricity generation decrease from 2022 in accordance with 9th Basic Plan.
LNG2022	○ From 2022 all coal electricity generation ceases and is replaced by LNG.
MaxNuc_9thplan	○ 2022 nuclear capacity is maintained, and its use maximized. ○ Coal and LNG dispatch proportionally to effective capacities of the 9th Basic Plan.
MaxNuc_LNG2022	○ 2022 nuclear capacity is maintained, and its use maximized. ○ From 2022 all coal electricity generation ceases and is replaced by LNG.

Results



Policy implications

- There are major health and climate benefits of using LNG and nuclear power as alternatives to coal.
- Traditional co-benefit frameworks, which view climate change as the main goal and other goals as secondary, have been ineffective in inducing large scale mitigation policy implementation.
- By focusing on reducing air pollution, South Korea can also reduce its greenhouse emissions.
- As nuclear power is currently the cheapest energy source in South Korea, increased use of nuclear energy has the largest benefits to cost ratio.
- Given the health and climate benefits of nuclear energy, the South Korean government should reconsider it plan to phase out nuclear energy.
- LNG is currently a more expensive fuel for electricity generation than coal, but the health and climate benefits of LNG use should be considered when calculating overall cost.

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