OVERVIEW

Air Pollution Impact Model for Electricity Supply

AIRPOLIM-ES

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**Before we start...**

Who we are and project context

**NewClimate Institute:**
Germany-based research institute/think tank active in international climate policy

**Ambition to Action:**
3-year project funded under the German International Climate Initiative (IKI) implemented by NewClimate Institute and ECN, part of TNO

**Objectives:**
Support and accelerate further development and implementation of NDCs in four partner countries
MEASURING THE HEALTHS IMPACTS OF AIR POLLUTION

Methodology and data inputs
Introduction
From air pollutants to health effects
Sources of air pollutants

Energy and air pollution

Non-energy
Agriculture; solvents; and waste

Fuel supply
 Extraction, storage, transport, and transformation of fossil fuels

Buildings
Cooking, heating, and lighting

Power
Combustion of coal, oil, gas, bioenergy, and waste

Industry
Fuel combustion; process emissions

Transport
Exhaust fumes; brake, tyre and road wear; and fuel evaporation

Source: Own creation based on 'World Energy Outlook Special Report: Energy and Air Pollution', 2016
Impact Pathway Approach
Methodological framework

- Emissions (PM$_{2.5}$, SO$_2$, NO$_x$)
  - Dispersion and concentration change
  - Population exposure
  - Health impacts
  - Valuation of health impacts
Impact Pathway Approach

Methodological framework

- Emissions (PM$_{2.5}$, SO$_2$, NO$_x$)
- Coal–fired power plants
- Emission factors/rates
- Dispersion and concentration change
- Intake fraction coefficients (Zhou et al. 2006)
- GIS mapping & population statistics
- Population exposure
- Concentration-response functions
- Base cases, mortality rates and life expectancy
- Health impacts
- Valuation of health impacts

Intake Fraction = \[ \frac{\sum_i^N P_i \times \Delta C_i \times BR}{Q} \]

- $i$ = location
- $P_i$ = population at this location
- $\Delta C_i$ = change in the concentration of PM$_{2.5}$ caused by emissions from specific source
- BR = population average breathing rate
- $Q$ = total emission rate of the pollutant

**Zhou et al. 2006 coefficients**

Intake fraction coefficients for population residing within bands of 0–100 km, 100–500 km, 500–1,000 km, and 1,000–3,300 km from emission source

→ interpretation of coefficients: if population increases by 1 million, the intake fraction increases by $x$

*(Zhou et al. methodology: Step 1: Estimation of intake fractions through dispersion modelling for 29 Chinese coal power plants and population mapping; Step 2: Regression with estimated intake fraction as dependent and population within distance bands as independent variable)*

Widely used approach, e.g. in the following studies: IMF (2014) Getting Energy Prices Right, Greenpeace International (2014) South Africa Study, Cropper et al. (2012) The Health Effects of Coal Electricity Generation in India
Key data inputs required in the model

**Plant data**
- Lifetime
- Installed capacity
- Capacity factor
- Heat rate (efficiency)
- Emissions control
- Location

**Population mapping**
- Gridded population data
- GIS Mapping

**Population data**
- Country-specific mortality rates
- Share of population per age category
- Life expectancy at specific age
- Population growth estimates
## Input data

### Inside the Excel tool

### Plant data

Source: Global Coal Plant Tracker (2020), WorldPop, GIS mapping results

<table>
<thead>
<tr>
<th>Plant ID</th>
<th>Plant Type</th>
<th>Country</th>
<th>Status</th>
<th>Fuel</th>
<th>Type</th>
<th>Capacity</th>
<th>Actual start of operations</th>
<th>Actual end of operations</th>
<th>Start of operations</th>
<th>End of operations</th>
<th>Remaining lifetime</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN1</td>
<td>Aluminum Smelter power station</td>
<td>Indonesia</td>
<td>Operating</td>
<td>Coal</td>
<td>1</td>
<td>100.00 MW</td>
<td>2020</td>
<td>2045</td>
<td>2020</td>
<td>2045</td>
<td>40 years</td>
</tr>
<tr>
<td>EN2</td>
<td>East Kalimantan power station Unit 1</td>
<td>Indonesia</td>
<td>Operating</td>
<td>Coal</td>
<td>1</td>
<td>100.00 MW</td>
<td>2020</td>
<td>2045</td>
<td>2020</td>
<td>2045</td>
<td>40 years</td>
</tr>
<tr>
<td>EN3</td>
<td>East Kalimantan power station Unit 2</td>
<td>Indonesia</td>
<td>Operating</td>
<td>Coal</td>
<td>1</td>
<td>100.00 MW</td>
<td>2020</td>
<td>2045</td>
<td>2020</td>
<td>2045</td>
<td>40 years</td>
</tr>
<tr>
<td>EN4</td>
<td>Adarga power station Unit 1</td>
<td>Indonesia</td>
<td>Operating</td>
<td>Coal</td>
<td>1</td>
<td>100.00 MW</td>
<td>2020</td>
<td>2045</td>
<td>2020</td>
<td>2045</td>
<td>40 years</td>
</tr>
<tr>
<td>EN5</td>
<td>Amatapura Port power station Unit 1</td>
<td>Indonesia</td>
<td>Operating</td>
<td>Coal</td>
<td>1</td>
<td>100.00 MW</td>
<td>2020</td>
<td>2045</td>
<td>2020</td>
<td>2045</td>
<td>40 years</td>
</tr>
<tr>
<td>EN6</td>
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<td>Operating</td>
<td>Coal</td>
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<td>100.00 MW</td>
<td>2020</td>
<td>2045</td>
<td>2020</td>
<td>2045</td>
<td>40 years</td>
</tr>
</tbody>
</table>

### Population input

<table>
<thead>
<tr>
<th>Plant/Lat</th>
<th>Country</th>
<th>Plant ID</th>
<th>In-country population within radius</th>
<th>In-country population within radius</th>
<th>In-country population within radius</th>
<th>In-country population within radius</th>
<th>All countries</th>
<th>All countries</th>
<th>All countries</th>
<th>All countries</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>199 km</td>
<td>169 - 500 km</td>
<td>500 - 1000 km</td>
<td>1000 - 3300 km</td>
<td>199 km</td>
<td>169 - 500 km</td>
<td>500 - 1000 km</td>
<td>1000 - 3300 km</td>
</tr>
<tr>
<td>EN1</td>
<td>Indonesia</td>
<td>EN1</td>
<td>956</td>
<td>5.02</td>
<td>29.23</td>
<td>174.41</td>
<td>0.56</td>
<td>13.29</td>
<td>47.06</td>
<td>1.2109</td>
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<td>EN2</td>
<td>Indonesia</td>
<td>EN2</td>
<td>961</td>
<td>14.04</td>
<td>59.11</td>
<td>210.45</td>
<td>0.61</td>
<td>14.32</td>
<td>67.69</td>
<td>1.6254</td>
</tr>
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<td>59.11</td>
<td>210.45</td>
<td>0.61</td>
<td>14.32</td>
<td>67.69</td>
<td>1.6254</td>
</tr>
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<td>0.61</td>
<td>14.32</td>
<td>67.69</td>
<td>1.6254</td>
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<td>0.61</td>
<td>14.32</td>
<td>67.69</td>
<td>1.6254</td>
</tr>
</tbody>
</table>

Exposed population over 25 years: 78, 78, 78, 78, 78.
### Data Sources: Plant data

<table>
<thead>
<tr>
<th>Data Type</th>
<th>Description</th>
<th>Sources/Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plant data</td>
<td>Lifetime</td>
<td>Using individual data or the Global Coal Plant Tracker database.</td>
</tr>
<tr>
<td></td>
<td>Installed capacity</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Capacity factor</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Heat rate (efficiency)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Emissions control</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Location</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Using individual data or country-specific emission factors (GAINS).</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>GLOBAL COAL PLANT TRACKER</strong></td>
</tr>
<tr>
<td></td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td><strong>GAINS Online</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Greenhouse Gas - Air Pollution Interactions and Synergies</strong></td>
</tr>
</tbody>
</table>
Data sources: Population mapping

Open source population data set and GIS software

Population mapping
Gridded population data
GIS Mapping

GIS mapping visual results
Data sources: Population data

Population data
Country- and age-specific mortality rates
Share of population per age category
Life expectancy at specific age
Population growth estimates

World Population Prospects
UNDESA / POPULATION DIVISION

WDI DataFinder
Global Health Data Exchange | GHDx
Institute for Health Metrics and Evaluation

IHME
AIR POLLUTION HEALTH IMPACT INDICATORS

Illustrative results
Outputs

Emissions
Annual and lifetime emissions for:
- $PM_{2.5}$
- $NO_x$
- $SO_2$

Health Impacts
Annual and lifetime premature deaths and years of life lost for:
- Lung cancer
- Chronic obstructive pulmonary disease
- Ischemic heart disease
- Stroke

Available on plant, scenario and country level & restricted to country population or for all affected population
Number of premature deaths

Illustrative results
Number of years of life lost

Illustrative results

Cumulative years of life lost

Years of life lost (by cause)

Number of years of life lost per year

Cumulative number of years of life lost per year
Emissions

Illustrative results

Annual emissions (t/year)

<table>
<thead>
<tr>
<th>Type</th>
<th>Emissions (t/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM2.5</td>
<td>39,808</td>
</tr>
<tr>
<td>NOx</td>
<td>39,707</td>
</tr>
<tr>
<td>SO2</td>
<td>104,009</td>
</tr>
</tbody>
</table>

Total emissions (t/lifetime)

<table>
<thead>
<tr>
<th>Type</th>
<th>Emissions (t/lifetime)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM2.5</td>
<td>1,682,537</td>
</tr>
<tr>
<td>NOx</td>
<td>2,201,183</td>
</tr>
<tr>
<td>SO2</td>
<td>11,638,966</td>
</tr>
</tbody>
</table>
APPLICATIONS OF AIRPOLIM-ES
Published and ongoing application of AIRPOLIM-ES

+ analysis of coal plants in 24 countries, covering 90% of global fleet

Air pollution health impact assessment in Kenya

Illustrative results

Cumulated number of premature deaths

<table>
<thead>
<tr>
<th>Year</th>
<th>Stroke</th>
<th>Ischemic heart disease</th>
<th>Lung cancer</th>
<th>COPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2035</td>
<td>131</td>
<td>43</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>2045</td>
<td>132</td>
<td>43</td>
<td>3</td>
<td>8</td>
</tr>
<tr>
<td>2050</td>
<td>936</td>
<td>309</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2060</td>
<td>1,664</td>
<td>550</td>
<td>39</td>
<td>15</td>
</tr>
<tr>
<td>2070</td>
<td>2,750</td>
<td>777</td>
<td>150</td>
<td>60</td>
</tr>
</tbody>
</table>

Years of Life Lost

- Reference case: Lamu power station: 981 MW (start: 2024), Kitui power station: 960 MW (start: 2034)
- Alternative case: Lamu power station: 450 MW (start: 2034); assumed lifetime of all coal-fired power plants is 30 years
OVERVIEW OF AVOIDED PREMATURE DEATHS FROM EARLY COAL PHASE-OUT
DISCUSSION
Limitations and challenges
Considerations for the accuracy and interpretation of results

ZHOU ET AL. (2006) COEFFICIENTS
Limitations: Not taking into account stack height, meteorological conditions and other location specific factors

EMISSION FACTORS
Limitations: Only provide approximate emission estimations, however plant-specific factors can be entered if available

LINEAR CONCENTRATION RESPONSE FUNCTIONS FROM GLOBAL BURDEN OF DISEASE STUDY
Limitations: Concentration response functions are assumed to be linear in a way that health effects are independent from the initial level of pollution. This is a simplified approach used in many other studies.

HEALTH IMPACT ESTIMATES FOR POPULATION OUTSIDE OF ANALYSIS COUNTRY
Limitations: Those estimates do not take into account country-specific characteristics (including population growth, mortality rates and age shares) but assume those of the country where the power plant is located.

GIS KNOWLEDGE
Estimating population exposure requires at least basic knowledge of geographic information system software

EXCEL KNOWLEDGE
Using the model requires intermediate Excel knowledge / experience