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CLIMATE CHANGE PROGRAMME

SOCIOECONOMIC SYSTEMS PUBLIC HEALTH BENEFITS OF GHG MITIGATION



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1. Introduction

Climate change is driven by global anthropogenic emissions of greenhouse gases, primarily carbon dioxide, which have been accelerating at rates that far exceed historical patterns. GHGs are emissions associated with modern-day human activities that involve the burning of fossil fuels, industrial processes, waste management, agricultural production, and land use change. There are strong linkages between greenhouse gas emissions that contribute to global climate change and air pollution that contributes to adverse local public health impacts. Air pollution is a byproduct of GHG emissions and is highly influenced by climatic factors.

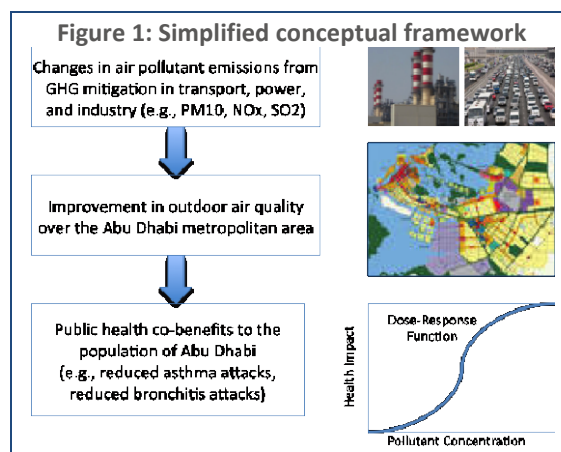
"Co-benefits" are collateral benefits associated with greenhouse gas mitigation policies additional to the direct emission reduction benefits from such policies. The Draft Abu Dhabi Climate Change Strategy proposes new policies in energy efficiency, renewable energy and nuclear power that, if implemented, will lead to sharp reductions in both greenhouse gas emissions and to air pollutants that harm human health. The magnitude of public health co-benefits from reduced outdoor air pollution, specifically avoided premature death and avoided hospital visits, has been quantified for seventeen (17) policies within the Draft Abu Dhabi Climate Change Strategy.

Much of the discussion of co-benefits from GHG mitigation has focused on the energy sector. Specifically, there are strong links between air quality and alternatives to the current way energy is produced, transmitted and consumed (e.g., energy efficiency, energy conservation, renewable energy, nuclear power). Notably, while reducing energy-related GHG emissions yields a global impact, air quality and public health co-benefits are experienced at the local and regional level. For most countries, GHG emissions from the energy represent the largest share of their annual GHG emissions. This is also true for the UAE where GHG emissions from energy-related activities typically account for almost 90% of all GHG emissions.

Epidemiological studies have reported strong associations between an increase in daily levels of ozone (O₃) and particulate matter (PM), and an increase in the rates of mortality and hospital admissions predominantly related to respiratory and cardiovascular diseases. The planning priorities and goals of the Health Authority of Abu Dhabi (HAAD) emphasize reducing air pollution to minimize long-term health risks to Abu Dhabi's population. Notably, pollution from power plants, motor vehicles, and industries is implicated as an underlying factor across several of HAAD's public health priorities. The annual public health impacts associated with outdoor air pollution was estimated in the Abu Dhabi Environmental Burden of Disease Assessment (EBDA). Led by the University of North Carolina, EAD, and HAAD, the research team used local population and local hospital data for the Abu Dhabi emirate to develop a set of relationships between local air pollution and public health (MacDonald Gibson, et al., 2013).

2. Approach

A “bottom-up” approach was used to estimate public health co-benefits of GHG mitigation activities in Abu Dhabi. The key elements of this approach are illustrated in Figure 1. It first involves characterizing the air pollutant emissions with and without the implementation of GHG mitigation policies. Changes in air quality are then calculated as the difference in ambient air pollutant concentrations with and without the GHG mitigation policies. Finally, these changes are translated into public health co-benefits through the application of a series of dose-response functions that have been developed in the Abu Dhabi Environmental Burden of Disease Assessment. Extensive data acquisition and numerical modeling has been carried out in order to offer a quantitative basis by which to understand the public health implications of GHG mitigation activities at both the metropolitan and individual precinct level.



The core research question was: are there significant public health co-benefits in the greater Abu Dhabi City metropolitan area associated with the Emirate's DRAFT Climate Change Strategy? That is, can a reliable estimate be developed regarding the number of avoided premature deaths and the number of avoided excess health-care facility visits due to the implementation the Abu Dhabi Climate Change strategy, in part or in whole? Addressing this question has involved extensive local data acquisition and focused on several interlinked issues such as regional climate change modeling, air pollutant emission inventory development, air quality modeling, demographic characterizations, and epidemiological research. It also involved a quantification of the public health response with and without GHG mitigation initiatives, as well as understanding the public health response under changing climatic conditions. A study period of 2007 to 2035 was assumed.

The greater Abu Dhabi Metropolitan Area was the spatial focus of the assessment. This is a region of approximately 3,800 square kilometers, and is shown in Figure 2. The area includes current high population density areas of about 1,030 people/km² within Abu Dhabi Island. It also includes surrounding areas where urban expansion plans call for significant future residential and industrial zones to the south and east. These are the very areas that are expected to bear the brunt of increased air pollution under a Business-as-usual scenario and would benefit the most from the implementation of Abu Dhabi's Climate Change Strategy. A total of 462 grid cells make up the metropolitan plus offshore area, each sized 4 km by 4 km and corresponding to outputs from the regional modeling study.

Certain elements of the Abu Dhabi DRAFT Climate Change Strategy were used as the policy framework for which public health co-benefits were estimated. These elements are focused on several key GHG-emitting sectors, namely power supply, transport, and industry. Specifically, 17 specific strategies were chosen for public health co-benefit analysis, as indicated in Table 1. Six pollutants were modeled: Particulate matter (PM₁₀ and PM_{2.5}), Volatile organic compounds (VOC), Nitrogen oxides (NO_x), Ground-level Ozone (O₃), Carbon monoxide (CO), and Sulfur dioxide (SO₂).

A scenario framework was developed to estimate the impact of GHG mitigation policies. A scenario is simply an assumed representation of a plausible future under certain conditions. It is not a prediction of the future, but rather a narrative concerning a potential future given certain assumptions. Specifically, two scenarios were considered; a “Baseline Scenario”, corresponding to a future where Abu Dhabi’s Climate Change Strategy is not implemented and a “Policy Scenario” corresponding to a future where Abu Dhabi’s

Figure 2: Gridded 4-km spatial domain of the study area

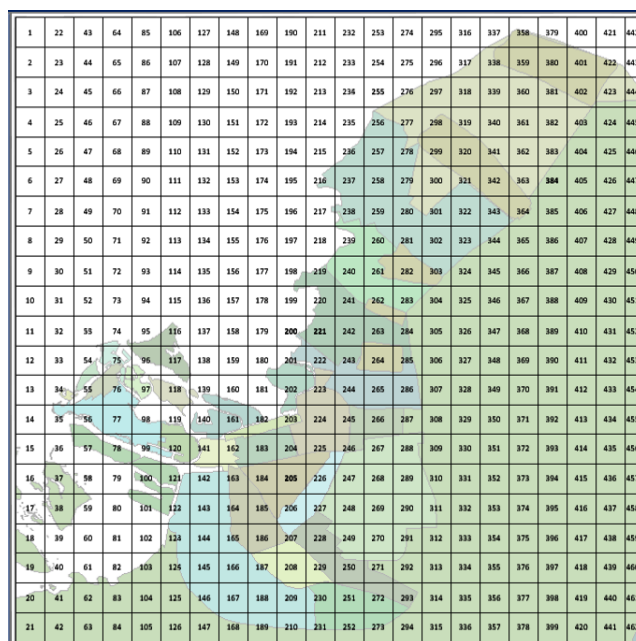
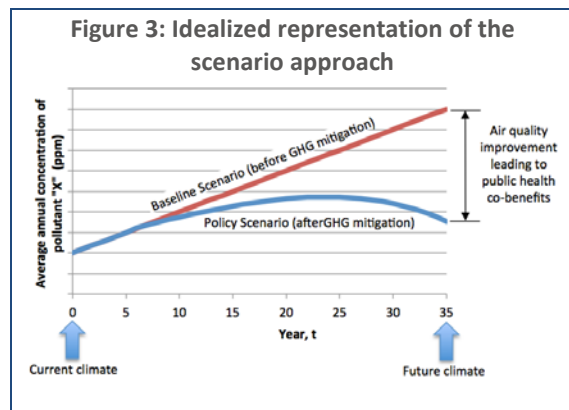


Table 1: Policies considered in assessing public health co-benefits in the Abu Dhabi Metropolitan Area

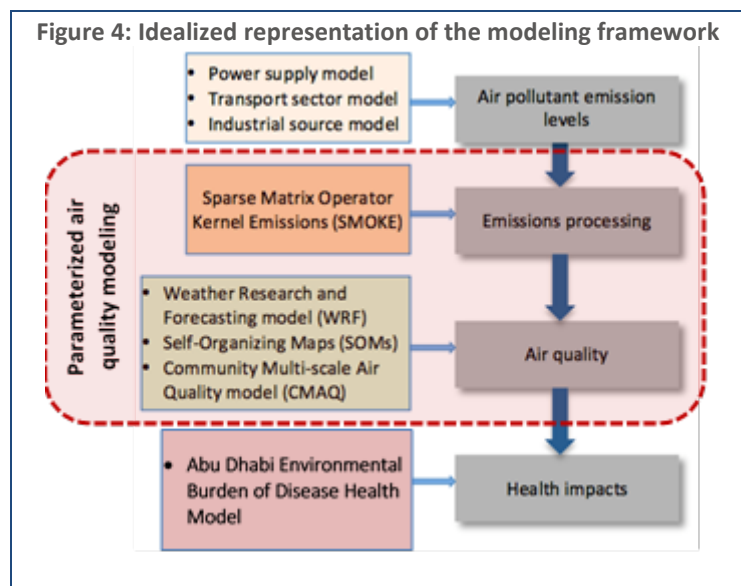
Priority	Sector	Programme	Policy No	Description
Clean Energy and Climate Action	Power and water supply	Peaceful nuclear power	1	Nuclear power generation
		Promote renewable energy electricity generation	2	Renewable energy power plants
			3	One renewable energy water desalination pilot project
			4	Renewable energy water desalination plants
			5	Waste-to-energy power plants
			6	Feed in tariff to sell power to the grid
			7	Solar roofs
Green Life Styles and Sustainable Use of Resources	Power and water demand	Increase power plant efficiency	8	Supply side energy efficiency strategy for electricity and water production
		Energy efficiency	9	Demand side management strategies for electricity and water production
		Green buildings	10	Current Estidama initiative
			11	More stringent building codes for energy conservation
			12	Energy efficiency standardization and labeling programme
	Transport	Sustainable transport	13	Transportation demand strategies
			14	Encourage purchase of high efficiency vehicles
	Industry	Energy and industrial efficiency	15	Gas flaring reduction in oil and gas industry
			16	Energy efficiency at industrial cogeneration facilities
			17	Energy efficiency in aluminum production

Climate Change Strategy is implemented, in part or in whole (see Figure 3). Absent any initiatives to reduce greenhouse gas or air pollutant emissions, the concentration of air pollutants in the Abu Dhabi Metropolitan Area are projected to increase over the planning period (red line in Figure 3). With the implementation of greenhouse gas mitigation initiatives, the concentration of air pollutants in the Abu Dhabi Metropolitan Area are projected to decrease over the planning period, a direct co-benefit of those initiatives (blue line in Figure 3).



The sequence of calculations from emissions to health co-benefits required the development of a comprehensive modeling framework. An idealized representation of the key components and analytical flow sequence appears in Figure 4. A brief description is offered in the bullets below.

- **Air pollutant emission levels:** Three source emission models for the power supply, transport, and industrial sectors were developed to estimate stationary and mobile air pollutant emissions (i.e., total annual pollutant emissions to the atmosphere in units of tonnes per year) over the period 2007 through 2035 for the Abu Dhabi Metropolitan Area.
- **Parameterized air quality modeling:** A parameterized approach was developed to process the source emissions and quantify the impact on air quality (i.e., concentrations of pollutants in the atmosphere in units of $\mu\text{g}/\text{m}^3$). This approach relies indirectly on a number of input models including the Weather Research and Forecasting (WRF) model, the Self Organizing Maps (SOM) model, and outputs from the the Sparse Matrix Operator Kernel Emissions (SMOKE) model and the Community Multi-scale Air Quality model (CMAQ) model.
- **Health impacts:** The Environmental Burden of Disease Model was used to evaluate premature avoided



deaths avoided and excess health-care visits avoided by the introduction on one or more of the policies in Abu Dhabi's Climate Change Strategy. This is the model developed for the UAE that translates air pollutant concentrations from the previous steps into public health impacts from the inhalation of outdoor particulate matter and ground-level ozone (Macdonald Gibson, et al., 2013).

3. Source emissions modeling

Annual air emissions in the Abu Dhabi Metropolitan Area were estimated through the application of power supply, transport, and industrial models. Each of these models were developed as independent analysis modules that can be run individually to analyze one or more sector-specific policies, or as part of an integrated modeling system to analyze one or more policies across one or more sectors. An idealized representation of the overall modeling system is shown in Figure 8. The modularity of this approach offers the flexibility for each emissions model to be capable of policy-specific analysis of air emission reductions.

The power supply model aims to represent the capacity planning and dispatching of electricity within the Abu Dhabi Emirate. It includes all capacity, generation, and electricity transmission components that together comprise ADWEA operations. Power generation takes place in high-efficiency cogeneration stations where desalinated water is co-produced. Power plant performance characteristics such as combustion efficiency, installed air pollution control equipment, and fuel type used for both existing and new generating technologies are used in combination with projected electricity demand to estimate annual emissions of air pollutants and GHGs. The model is able to capture changes in power supply system characteristics under Baseline (i.e., business-as-usual) conditions as well as under conditions of individual or collective implementation of GHG mitigation strategies

The transport model aims to represent current and future travel conditions within the Abu Dhabi Metropolitan Area. It codifies and integrates assumptions embedded in the travel demand model developed by the Department of Transportation for Abu Dhabi's Surface Transportation Master Plan (STMP; DoT, 2009, 2013 update). These assumptions apply to certain transport modes (i.e., on-road vehicles, metro), travel demand characteristics (e.g., trip patterns, growth in vehicle kilometers travelled), infrastructure conditions (e.g., public transport, roads, land use) and other parameters. Transport sector emissions associated with private, commercial and public on-road vehicles (i.e., cars, light trucks, heavy trucks, buses) or their displacement by electric-powered transport alternatives (i.e., metro) are accounted for in the model. All other modes - air, marine, recreational boating, military vehicles - are not addressed by the model. The model is able to capture changes in vehicle stock under Business-as-usual (i.e., the STMP) conditions as well as under conditions of individual or collective implementation of GHG mitigation strategies.

The industrial model aims to represent current and future productive activities within key

sub-sectors in the Abu Dhabi Metropolitan Area. Both onshore and offshore industrial facilities were considered. As a simplifying assumption, the focus of the industrial model is focused on four distinct activities at these facilities. For onshore facilities, the focus was on process heat and power generation aluminum production, and oil refining. For offshore facilities, the focus was on oil and gas operations. Together, these activities represent a large share of air emissions associated with industrial activities. The industrial model is the crudest of the three emission models in terms of its internal algorithms. This is primarily due to the nature of the data received which was relatively high-order (e.g., total annual emissions per facility) and generally sparse regarding activity (e.g., tonnes of steam per facility) or growth data (private sector growth plans).

4. Air quality modeling

Air quality modeling for the Abu Dhabi Metropolitan Area was carried out using a parameterized process. It is important to note that a parameterized approach was adopted after the original modeling-based approach turned out to be overly problematic. The original approach involved linking the outputs of the regional atmospheric model (i.e., WRF) and emissions models (i.e., for Power Supply, Transport, and Industry) to the pre-processing model (i.e., the Sparse Matrix Operator Kernel Emissions model, or SMOKE) and ultimately to the air quality model (i.e., CMAQ) to produce air pollutant concentrations. While the atmospheric and emission models were fully accessible, running SMOKE and CMAQ proved to be an intractable challenge due to extensive and detailed data requirements. This was the case despite consultations with other modelers and numerous attempts at numerical work-arounds. Therefore, a parameterized approach was developed and applied, as briefly discussed below.

The starting point for the air quality parameterization process was the previous CMAQ modeling for the UAE for 2007. This modeling effort was undertaken by researchers at the University of North Carolina as part of the Environmental Burden of Disease Assessment. The inputs and assumptions for CMAQ modeling in the UAE - including links with the SMOKE pre-processing model - were discussed in an internal report prepared by the UNC in 2009 and made available to the health co-benefits research team. In brief, previous CMAQ modeling used a grid resolution of 12 km and temporal resolution of one hour. Pollutant concentrations were modeled for two periods: 1 May 2007 – 30 July 2007 and 15 December 2007 – 28 March 2008. These two periods likely captured most of the annual variability and was assumed to provide a representative dataset for average annual pollutant concentrations.

The CMAQ pollutant concentrations dataset was post-processed to create pollutant concentrations centered over the Abu Dhabi Metropolitan Area for the 2007 Base Year. Broadly, this involved extracting CMAQ pollutant concentration outputs data at a 12 km resolution and interpolating these outputs to the 4 km spatial resolution. For 2035, pollutant

concentrations from stationary sources in 2035 involved several steps. These steps aimed at accounting for the lateral dispersion and vertical mixing of the projected pollutant emissions over the Abu Dhabi Metropolitan Area. Pollutant concentrations in 2035 were estimated for emissions from the 21 power plants and industrial facility sites that are operational across the Abu Dhabi emirate.

The development of pollutant concentrations from mobile sources in 2035 involved several steps. These steps also aimed at accounting for the lateral dispersion and vertical mixing of the projected pollutant emissions over the Abu Dhabi Metropolitan Area. Mobile sources refer to seven (7) types of on-road vehicles in the Abu Dhabi Metropolitan area. The steps involved 1) accessing mobile source emission inventories; 2) developing gridded pollutant dispersion estimates; 3) developing vertical pollutant dispersion estimates; and 4) developing pollutant concentration estimates.

One challenge in this analysis methodology is to estimate the distribution of ozone. The total concentration of ozone near the surface is dependent on the amount of emissions such as NO_x and to a lesser degree VOC observed in the boundary layer. CMAQ outputs provided estimates of the background ozone emissions. For the 2007 base year, ozone emissions were estimated using the observations from available air quality monitoring stations located around Abu Dhabi. The distribution of ozone was then estimated by using the spatial distribution pattern of the NO_x emissions and scaled to the distribution of ozone observed at the air quality monitoring stations for the 2007 Base Year. For 2035, the NO_x change fields for the Baseline and Policy Scenarios were used to adjust the level of ozone from the 2007-baseline. The spatial distribution of ozone was then mapped to the spatial distribution of NO_x for 2035.

5. Public health co-benefit modeling

Public health co-benefit modeling relied exclusively on the algorithms in the health model developed as part of the Environmental Burden of Disease Assessment for outdoor air pollution. This model was developed using UAE-specific health and population data for the year 2008. Such data were used in combination with a set of concentration-response coefficients obtained from a duly referenced set of epidemiological study references. No other concentration-response coefficients were used to derive estimates of public health co-benefits.

The structure of the EBDA health model consists of separate submodules devoted to PM₁₀, PM_{2.5} and O₃ within the “Outdoor Air Pollution Global Module”. Each of these submodules is comprised of the same structure consisting of individual nodes that represent entry points for the range of required data and assumptions. Within the EBDA, health endpoints are defined as the outcome of the impact of pollution on human health. Specifically, two health endpoints are modeled, premature deaths and excess health-care visits. The former refers to

mortality in adults over 30 years of age and children under 5 years of age that can be directly attributed to outdoor air pollutant after background pollution from natural and transboundary pollution have been netted out. The latter refers to morbidity effects that can be directly attributed to outdoor air pollutant after background pollution from natural and transboundary pollution sources have been netted out

The above assumptions were codified into algorithms in the Health Co-benefits Inspector to compute the magnitude of premature deaths avoided and excess health-care facility visits avoided. Co-benefits are generated as pollutant concentrations decrease throughout the Abu Dhabi Metropolitan Area due to the implementation of the GHG mitigation policies. For 2035, the difference in average annual pollutant concentrations is calculated directly on the basis of model-generated ambient air pollutant concentrations. For intervening years, linear scaling and interpolation techniques will be applied to determine the change in ambient air pollutant concentrations from the start year of policy implementation through to the end of the assessment period. Health Co-benefits of Abu Dhabi's Climate Change Strategy

The magnitude of health co-benefits is a function of the kinds of policies implemented and the nature of their implementation. That is, some policies affect emissions from point sources while other policies affect emissions from mobile sources. The kind of policy has a large impact on how pollution is dispersed (i.e., large quantities from a few tall stacks versus small quantities from many ground-level sources). In addition, some policies apply targets that can have a large impact on the particular sector while other policies apply targets that produce a more modest impact. The results presented below are based on an illustrative Health Co-benefits Inspector run assuming that all policies are implemented (see screen capture in Figure 14). It is important to emphasize that the results are illustrative as they are based on target assumptions in the DRAFT Strategy (GoAD, 2014) that may or may not be consistent with the actual FINAL Strategy. Nevertheless, the results offer insight into the order of magnitude regarding what the Climate Change Strategy might achieve relative to emission reductions, air quality benefits, and public health co-benefits

6. Policy Targets

As much as possible, targets were established consistent with information provided in the Climate Change Strategy, where such information was available. For those policies where targets are in the process of being developed and hence unavailable, placeholders assumptions were made. These assumptions were typically on the aggressive side, as a way of illustrating the public health potential. They should not be understood as a prediction of the eventual target, but simply a placeholder until such targets are finalized. The bullets below summarize the target assumptions.

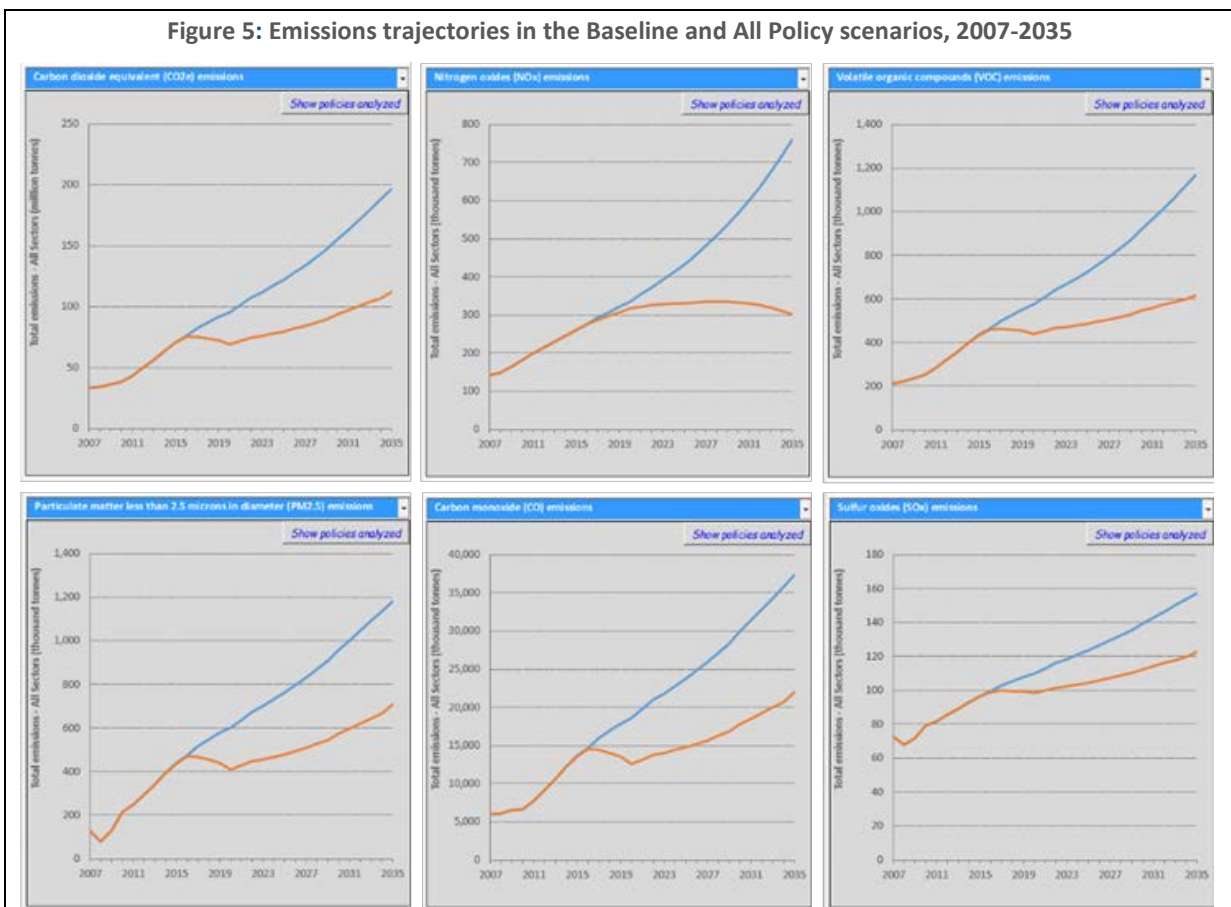
- *1: Nuclear power generation* – 4 units each with a net capacity of 1,345 MWe, coming only in 2017, 2018, 2019, and 2020.

- *2: Renewable energy power plants* – Start year for the policy in 2020, with 10% of all generation comes from non GHG-emitting renewable sources by 2035.
- *3: One renewable energy water desalination pilot project* - Start year for the policy is 2020 for a 100 MW solar PV station.
- *4: Renewable energy water desalination plants* - Start year for the policy is 2020 for a 100 MW concentrating solar power stations (Shams 1) and a 10 MW concentrating solar power stations (Masdar).
- *5: Waste-to-energy power plants*: Start year for the policy is 2020 for a 50 MW waste-to-energy plant.
- *6: Feed in tariff to sell power to the grid* - Start year for the policy in 2020, with the feed-in tariff leading to an incremental 10% of all generation comes from non GHG-emitting renewable sources by 2035.
- *7: Solar roofs* - Start year for the policy in 2020, resulting in 10% of all generation coming from distributed generation in solar roofs by 2035.
- *8: Supply side energy efficiency strategy for electricity and water production* - Start year for the policy in 2020, resulting in 1.0%/year improvement through 2035 in the heat rate (i.e., combustion efficiency) of the following power stations: Taweelah New Extension, Taweelah A2, Shuweih S1, and Sas Al Nakhi.
- *9: Demand side management strategies for electricity and water production* - Start year for the policy in 2020, resulting in 10% demand side savings in new residential construction by 2035.
- *10: Current Estidama initiative* - Start year for the policy in 2020, with 10% electricity savings of new commercial buildings by 2035.
- *11: More stringent building codes for energy conservation* - Start year for the policy in 2020, with 10% of new home floor space included in the Programme by 2035.
- *12: Energy efficiency standardization and labeling programme* - Start year for the policy in 2020, with 10% electricity savings in the residential sector by 2035.
- *13: Transportation demand strategies* - Start year for the policy in 2020, with passenger car and passenger light vehicle kilometer growth rates half of what they were in the Baseline Scenario.
- *14: Encourage purchase of high efficiency vehicles* - Start year for the policy in 2020, with all passenger vehicles a 50%-50% mix of plug-in hybrid and electric vehicles by 2035 and all other vehicle sales being 100% high efficient vehicles by 2035.

- *15: Gas flaring reduction in oil and gas industry* - Start year for the policy in 2020, with flaring growth rates half of what they were in the Baseline Scenario.
- *16: Energy efficiency at industrial cogeneration facilities* - Start year for the policy in 2020, resulting in 1.0%/year improvement through 2035 in the heat rate of the following facilities: Asab Agd II, Ruwais refinery, Habshan, Bu Hasa Adgas, Al Wagan, Sheikh Khalifa hospital, Mussafeah Industrial City.
- *17: Energy efficiency in aluminum production* - Start year for the policy in 2020, resulting in 1.0%/year improvement through 2035 in the heat rate of the Taweelah aluminum smelter.

7. GHG mitigation policies co-benefits

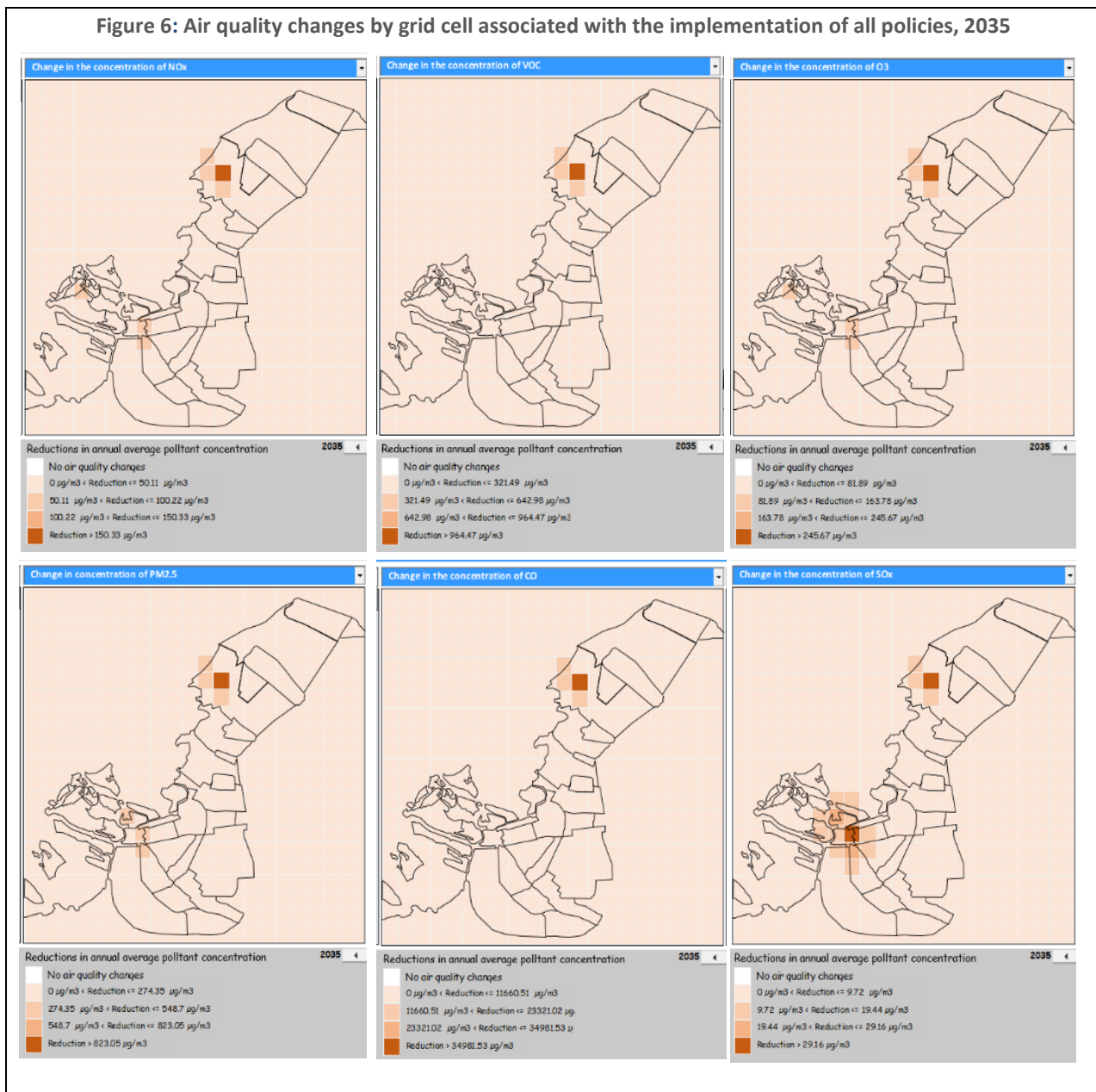
The emissions trajectories associated with the implementation of all policies in shown in **Figure 5**. As shown in the Figure, the collective impact of the Climate Change Strategy is significant, resulting in a sharp decrease in the average annual rate of growth in emissions. Relative to Baseline Scenario emissions in 2035, the reductions achieved by the policies range from 40% for PM2.5 to 60% for NOx. The sharp discontinuity in the charts for all but NOx



reflect the impact of the nuclear station coming online and the emission factor assumptions that were used to compute total emissions.

The air quality changes in 2035 associated with the implementation of all policies in shown in the maps in Figure 6. As shown in the Figure, the collective impact of the Climate Change Strategy is significant, resulting in improvements in air quality, especially around the location of stationary sources of pollution. Though not reported here, air quality changes are also estimated for the intervening years of 2020, 2025, and 2030. It is important to note that only changes in PM2.5 and O3 concentrations are used to estimate public health co-benefits. For fine particulate matter, most of the Abu Dhabi Metropolitan Area (i.e., 332 out of 462 grid

Figure 6: Air quality changes by grid cell associated with the implementation of all policies, 2035



cells, or 72%) experiences improvements in air quality less than $30 \mu\text{g}/\text{m}^3$. For those areas close to large stationary sources of pollution air quality changes can be many times higher. For ozone, the situation is similar. Most of the Abu Dhabi Metropolitan Area (i.e., 430 out of 462 grid cells, or 93%) experiences improvements in air quality less than $30 \mu\text{g}/\text{m}^3$.

The annual premature deaths avoided in 2035 and cumulative premature deaths avoided through 2035 due to the implementation of all policies in shown in the maps in Figure 7. As shown in the Figure, the collective benefits to public health

in the Abu Dhabi Metropolitan Area from the implementation of the Climate Change Strategy is significant, resulting in 2,896 cumulative avoided premature deaths from particulate matter and 313 cumulative avoided premature deaths from ground-level ozone. In total, 3,219 premature deaths are estimated to be avoided by the implementation of the Climate Change Strategy. For particulate matter, the areas showing the highest benefits from implementation of the policies are located near Abu Dhabi Island and the Capital District. For ozone, the areas showing the highest benefits from implementation of the policies are located near Abu Dhabi Island. Though not reported here, premature death avoided are also estimated for the intervening years of 2020, 2025, and 2030.

The annual excess health-care visits avoided in 2035 and cumulative excess health-care visits avoided through 2035 due to the implementation of all policies in shown in the maps in Figure 8. As shown in the Figure, the collective benefits to public health in the Abu Dhabi Metropolitan Area from the implementation of the Climate Change Strategy is significant, resulting in 40,769 cumulative avoided excess health-care facility visits due to exposure to particulate matter and another 42,084 cumulative avoided excess health-care facility visits due to

Figure 7: Avoided premature deaths by grid cell associated with the implementation of all policies, 2035

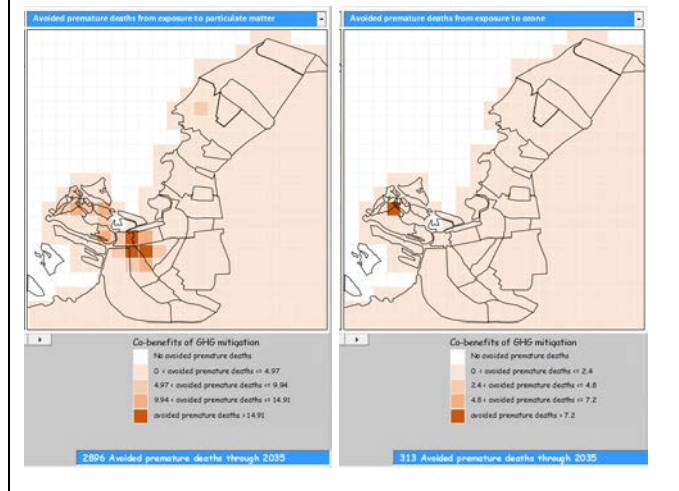
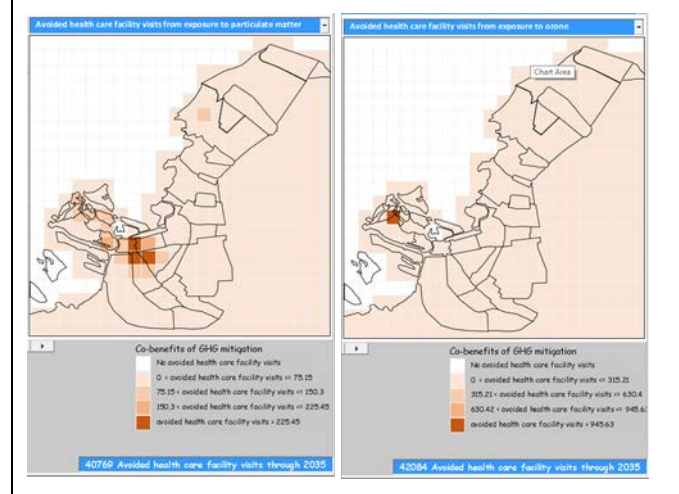


Figure 8: Avoided excess health-care facility visits by grid cell from implementation of all policies, 2035



exposure to ground-level ozone. In total, 82,853 avoided excess health-care facility visits are estimated to be avoided by the implementation of the Climate Change Strategy. For particulate matter, the areas showing the highest benefits from implementation of the policies are located near the Capital District. For ozone, the areas showing the highest benefits from implementation of the policies are located near Abu Dhabi Island. Though not reported here, excess health-care facility visits avoided are also estimated for the intervening years of 2020, 2025, and 2030.

8. List of References

- Bollen, J. Guay, B. Jamet S. and Corfee-Morlot, J. —Co-benefits of Climate Change Mitigation Policies. Economic Department Working Papers No. 693. Paris: Organisation for Economic Cooperation and Development (OECD), 2009. p. 5.
- Department of Transportation of Abu Dhabi (DoT), 2009. Surface Transportation Master Plan, All Volumes.
- DoT, 2013. Updates to the Surface Transportation Master Plan.
- Fajersztajn, L., Veras, M., Barrozo, L. and Saldiva, P., 2013. "Air pollution: a potentially modifiable risk factor for lung cancer", Nature Reviews Cancer 13, 674–678
- Government of Abu Dhabi (GoAD), 2014. "Climate Change Strategy for the Emirate of Abu Dhabi (2015-2019): A High Level Strategy and Action Plan to Mitigate Climate Change and Adapt to its Impacts, Final version for approval, July.
- Local, National, and Regional Climate Change Programme (LNRCCP), 2015. "Regional Atmospheric Modeling for the Arabian Gulf Region – Future Scenarios and Capacity Building", prepared by David Yates, Andrew Monaghan, and Daniel Steinhoff from the National Center for Atmospheric Research (NCAR), Abu Dhabi Global Environmental Data Initiative (AGEDI).
- MacDonald Gibson, J., Brammer, A., Davidson, C., Folley, T., Launay, F., and Thomsen, J., 2013. "Environmental Burden of Disease Assessment - A case study in the United Arab Emirates", Environmental Science and Technology Library, VOLUME 24, Springer.
- Miller, K., 2013. "ADWEC Winter 2012 / 2013 Electricity and Water Demand Forecasts", Abu Dhabi Water and Electricity Company.
- Ren, W., Yong Geng, Y., Xue, B., Fujita, T., Ma, Z. and Jiang, P., 2012. "Pursuing co-benefits in China's old industrial base: A case of Shenyang", Urban Climate, Volume 1, November 2012, Pages 55–64
- Smith, K. and Haigler, E., 2008. "Co-Benefits of Climate Mitigation and Health Protection in Energy Systems: Scoping Methods", Annual Review of Public Health, Vol. 29: 11-25
- Stern, G., Latzin, P., Rösli, M., Fuchs, O., Proietti, E., Kuehni, C. and Frey, U., 2013. "A Prospective Study of the Impact of Air Pollution on Respiratory Symptoms and Infections in Infants", American Journal of Respiratory and Critical Care Medicine, Vol. 187, No. 12, pp. 1341-1348.
- West, J., Smith, S., Silva, R., Naik, V., Zhang, Y., Adelman, Z., Fry, M., Anenberg, S., Horowitz, L. and Lamarque, J., 2013. "Co-benefits of mitigating global greenhouse gas emissions for future air quality and human health", Nature Climate Change 3, 885–889

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