

# Public Health Co-benefits of GHG Mitigation Strategies in Abu Dhabi

Bill Dougherty  
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Regional Climate Change Symposium  
March 15, 2017



# OUTLINE

- **Background**
- **Approach**
- **Emissions, air quality, & climate modeling**
- **Conclusions**
- **Recommendations**

# BACKGROUND

# RESEARCH TEAM



- Bill Dougherty. Climate Change Research Group, Principal Investigator



- Patrick Keys. Keys Consulting, Inc; research assistance



- Paul Kucera, National Center for Atmospheric Research; air quality modeling



- David Yates, National Center for Atmospheric Research; regional climate modeling

# REPORTS

## Preliminary Findings

LNRCC Programme  
RESEARCH REPORT

### Public Health Co-benefits of Greenhouse Gas Mitigation

Preliminary Findings Report from AGEDI's Local, National, and Regional Climate Change Programme

September 2014



Health co-benefits of climate change mitigation policies in the transport sector

Caroline Shaw, Simon Hales, Philipp Haurin-Chapman and Richard Edwards

AGEDI | NCAR | Climate Change Research Group

## Visualizations report

LNRCC Programme  
RESEARCH REPORT

### Public Health Co-benefits of Greenhouse Gas Mitigation

Visualizations Report from AGEDI's Local, National, and Regional Climate Change Programme

January 2015



Health co-benefits of climate change mitigation policies in the transport sector

Caroline Shaw, Simon Hales, Philipp Haurin-Chapman and Richard Edwards

AGEDI | NCAR | Climate Change Research Group

## Technical report

LNRCC Programme  
RESEARCH REPORT

### Public Health Co-benefits of Greenhouse Gas Mitigation

Technical Report from AGEDI's Local, National, and Regional Climate Change Programme

October 2015



Health co-benefits of climate change mitigation policies in the transport sector

Caroline Shaw, Simon Hales, Philipp Haurin-Chapman and Richard Edwards

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## Executive briefing

LNRCC Programme  
RESEARCH REPORT

### Public Health Co-benefits of Greenhouse Gas Mitigation

Executive Briefing from AGEDI's Local, National, and Regional Climate Change Programme

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# HEALTH CO-BENEFITS INSPECTOR

- One of 12 Inspectors
- Background; links to online resources
- Explore the Inspector
  - Inspector tools
  - Discussion forum



# APPROACH

# PUBLIC HEALTH CO-BENEFITS PROJECT

## Motivation

- Some benefits of greenhouse gas (GHG) mitigation strategies in Abu Dhabi are potentially significant but unknown

## Aim

- Quantify public health benefits in the Abu Dhabi City region from investments in GHG mitigation

## Approach

- Apply local emissions, air quality & health data to estimate health benefits of GHG mitigation

# GHG MITIGATION STRATEGIES

- Electricity/water supply
- Electricity demand
- Transportation
- Industrial activities



## 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

July 2014, Final version for approval

# GHG MITIGATION STRATEGIES CONSIDERED

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
		Increase power plant efficiency	8	Supply side energy efficiency strategy for electricity and water production
Green Life Styles and Sustainable Use of Resources	Power and water demand	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

# EMISSION REDUCTIONS

## Air pollutants

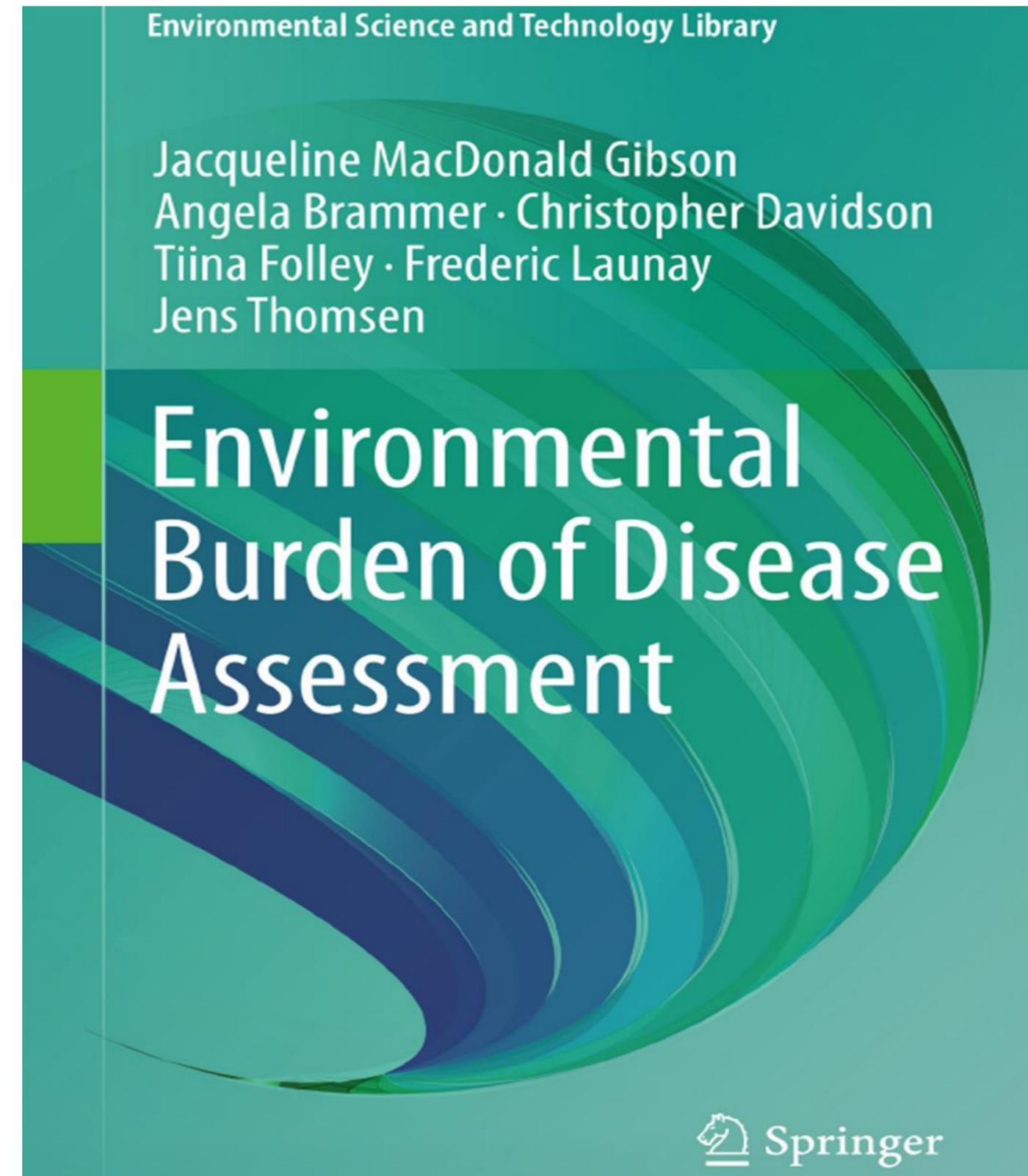
- Particulate matter (PM<sub>2.5</sub> and PM-10)
- Nitrogen oxides (NO<sub>x</sub>)
- Volatile Organic Compounds (VOC)
- Carbon monoxide (CO)
- Sulfur oxides (SO<sub>x</sub>)

## Greenhouse gases

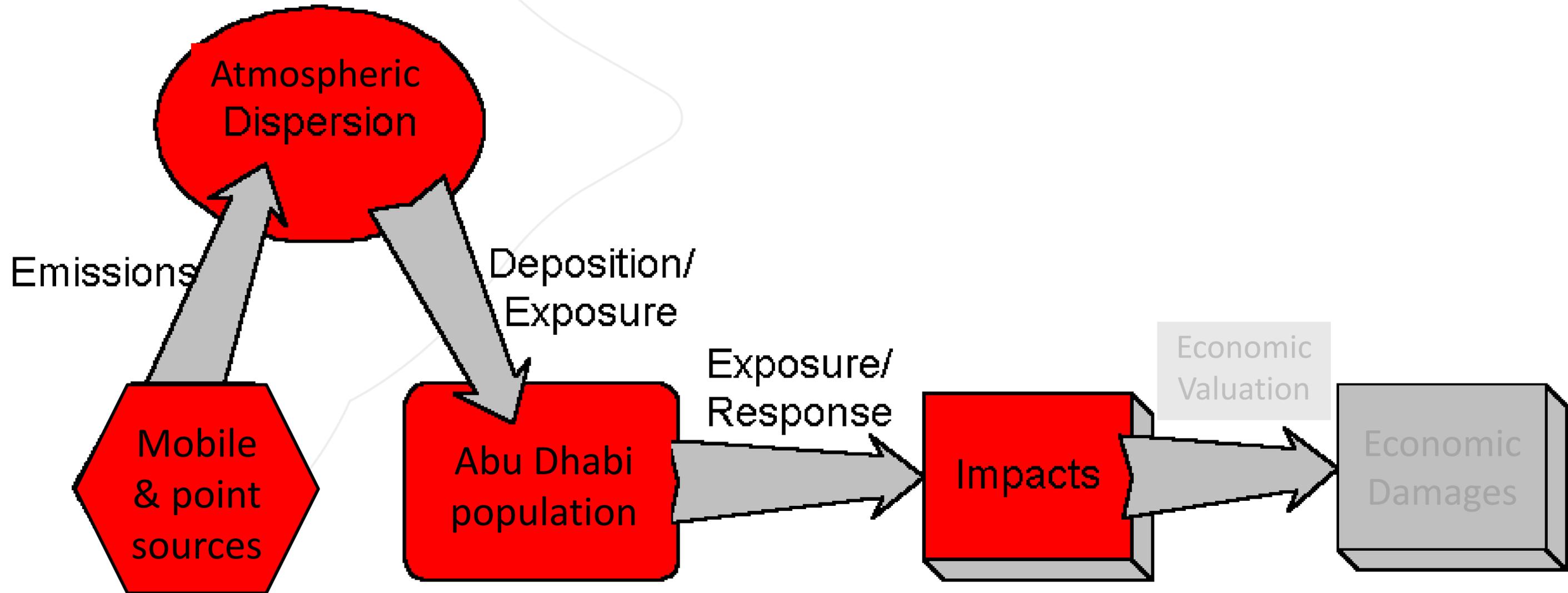
- Carbon dioxide-equivalent (CO<sub>2</sub>e)

# PUBLIC HEALTH IMPACTS IN UAE

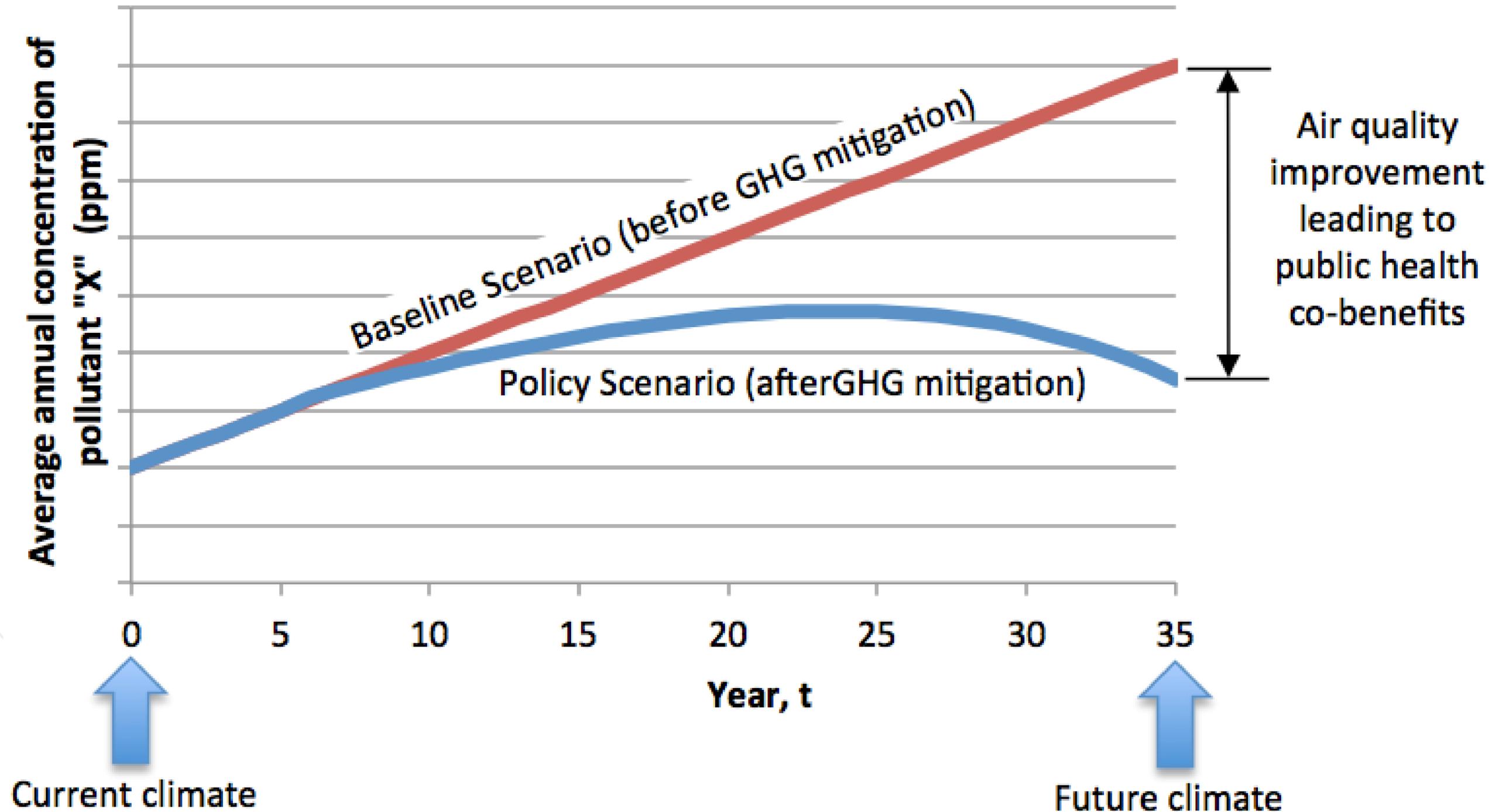
- **All-cause premature mortality caused by short-term exposure to outdoor air pollution**
- **Respiratory health-care facility visits caused by short-term exposure to outdoor air pollution**



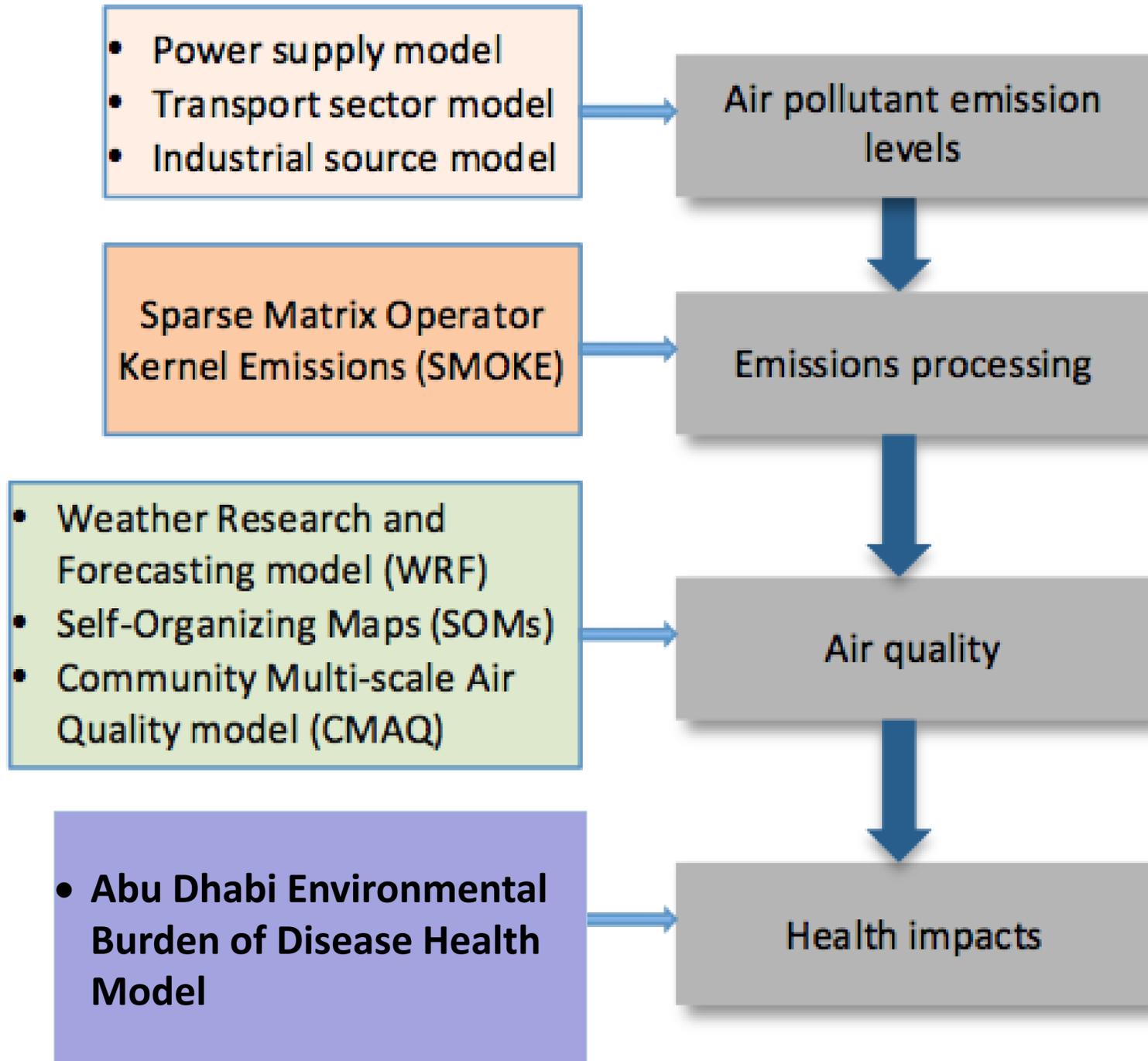
# CO-BENEFITS ANALYSIS SEQUENCE



# CO-BENEFITS ANALYSIS FRAMEWORK



# CO-BENEFITS MODELING FRAMEWORK



1	22	43	64	85	106	127	148	169	190	211	232	253	274	295	316	337	358	379	400	421	442
2	23	44	65	86	107	128	149	170	191	212	233	254	275	296	317	338	359	380	401	422	443
3	24	45	66	87	108	129	150	171	192	213	234	255	276	297	318	339	360	381	402	423	444
4	25	46	67	88	109	130	151	172	193	214	235	256	277	298	319	340	361	382	403	424	445
5	26	47	68	89	110	131	152	173	194	215	236	257	278	299	320	341	362	383	404	425	446
6	27	48	69	90	111	132	153	174	195	216	237	258	279	300	321	342	363	384	405	426	447
7	28	49	70	91	112	133	154	175	196	217	238	259	280	301	322	343	364	385	406	427	448
8	29	50	71	92	113	134	155	176	197	218	239	260	281	302	323	344	365	386	407	428	449
9	30	51	72	93	114	135	156	177	198	219	240	261	282	303	324	345	366	387	408	429	450
10	31	52	73	94	115	136	157	178	199	220	241	262	283	304	325	346	367	388	409	430	451
11	32	53	74	95	116	137	158	179	200	221	242	263	284	305	326	347	368	389	410	431	452
12	33	54	75	96	117	138	159	180	201	222	243	264	285	306	327	348	369	390	411	432	453
13	34	55	76	97	118	139	160	181	202	223	244	265	286	307	328	349	370	391	412	433	454
14	35	56	77	98	119	140	161	182	203	224	245	266	287	308	329	350	371	392	413	434	455
15	36	57	78	99	120	141	162	183	204	225	246	267	288	309	330	351	372	393	414	435	456
16	37	58	79	100	121	142	163	184	205	226	247	268	289	310	331	352	373	394	415	436	457
17	38	59	80	101	122	143	164	185	206	227	248	269	290	311	332	353	374	395	416	437	458
18	39	60	81	102	123	144	165	186	207	228	249	270	291	312	333	354	375	396	417	438	459
19	40	61	82	103	124	145	166	187	208	229	250	271	292	313	334	355	376	397	418	439	460
20	41	62	83	104	125	146	167	188	209	230	251	272	293	314	335	356	377	398	419	440	461
21	42	63	84	105	126	147	168	189	210	231	252	273	294	315	336	357	378	399	420	441	462

# EMISSIONS, AIR QUALITY, & CLIMATE MODELING



# Emissions Methodology

- A simple plume dispersion model was used to estimate the spatial distribution of annual emissions from point and mobile inventories around Abu Dhabi
- Weather Research and Forecast (WRF) model derived wind fields were used to transport the pollutants from sources
- Emissions were estimated for Abu Dhabi for the base year of 2007 and for two future scenarios in year 2035:
  - Business as Usual (BAU): No reduction in emissions
  - Policy Scenario: Integration of 18 planned policies to reduce emissions
- Background emissions estimated from a previous study using hourly 12-km Community Multiscale Air Quality (CMAQ) model output from a University of North Carolina (UNC) study for two periods in 2007-2008 (see Table)

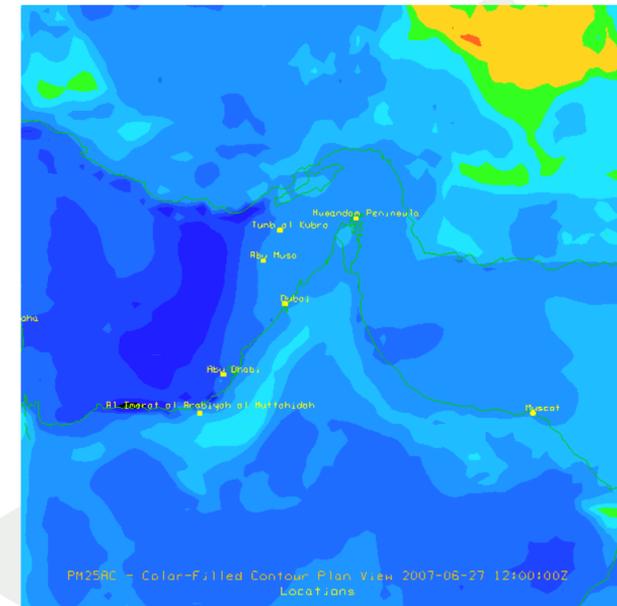
Period	Start Date	End Date
1	01-May-2007	30-July-2007
2	15-December-2007	28-March-2008

# Emissions Methodology (continued)

- The study estimated the annual average concentrations for the following emissions:
  - Carbon monoxide (CO)
  - Sulfur oxides (SOX)
  - Nitrogen oxides (NOX)
  - Volatile organic compounds (VOC)
  - Particulate matter for sizes  $< 2.5 \mu\text{m}$  (PM25)
  - Particulate matter  $< 10 \mu\text{m}$  (PM10)
  - ozone (O3)
- A 240 x 240 km domain was extracted over Abu Dhabi to compute the area averaged base emissions. The area averaged base emissions for each pollutant (see Table) were used for ambient pollutant for all grids

Pollutant	Value ( $\mu\text{g}/\text{m}^3$ )
CO	127.8
NOX	4.3
SOX	4.5
O3	105.5
PM25	14.8
PM10	16.0
VOC	2.0

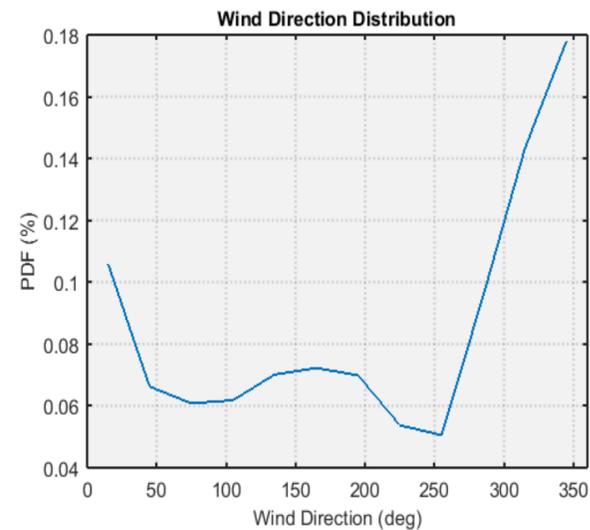
Example Base Emissions for PM25



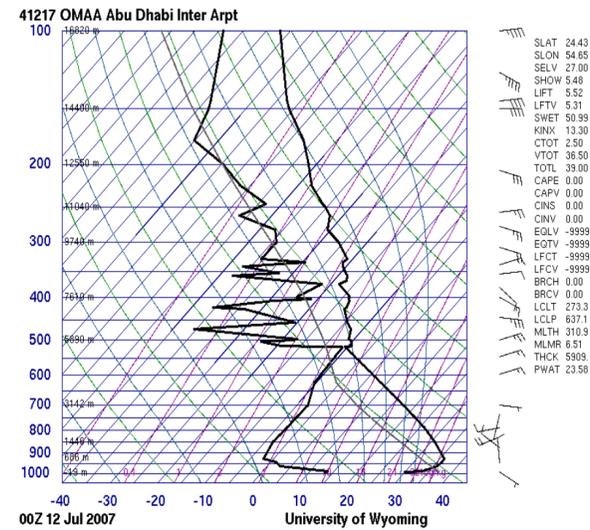
# Emissions Methodology (continued)

- Point source emission inventories from water, power, and industry were distributed horizontally and vertically using the climatological horizontal and vertical wind, temperature, and humidity conditions observed over Abu Dhabi
- The point source processing was conducted for the 2007-baseline, 2035 BAU, and 2035 Policy using the future climate change atmospheric fields scenarios generated by the Weather Research and Forecasting (WRF) modeling system

Climate Wind Distribution

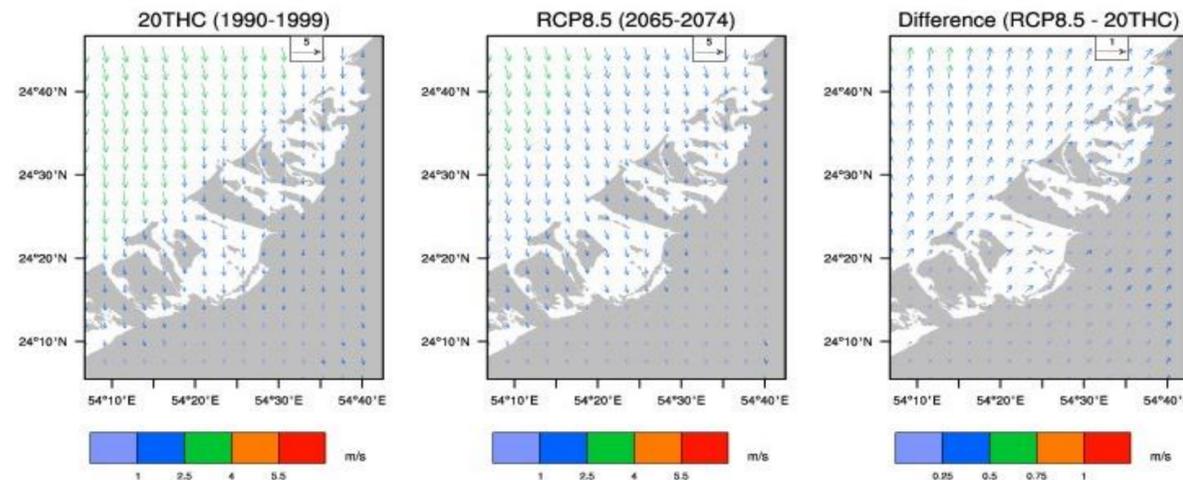


Vertical Atmosphere Profile



Climate Change Wind Field

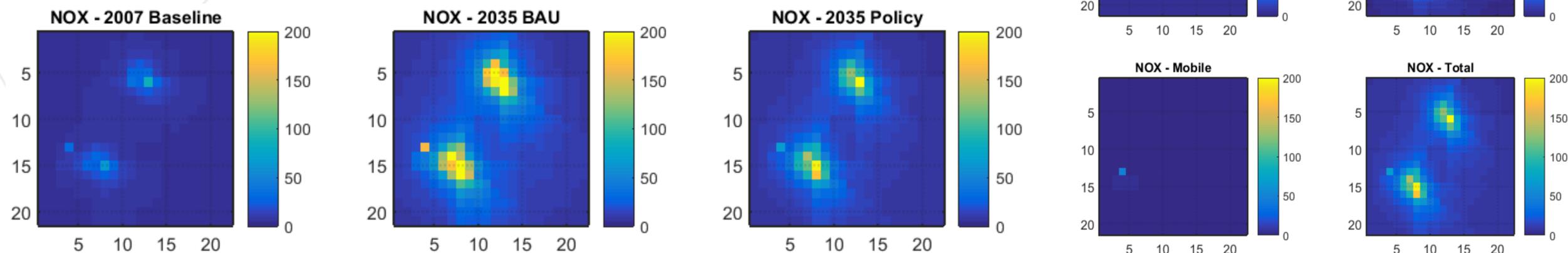
Abu Dhabi 10-m Winds JJA 0000



# Emissions Methodology (continued)

- Mobile emission sources were composed of seven categories of motorized vehicles, each vehicle type were accumulated to obtain the total mobile emissions at each grid point
- Mobile emissions were distributed based distribution residents living in each precinct
- All the emissions were combined for the background, point, and mobile sources for each pollutant at each grid cell the 2007-Baseline and 2035-BAU and 2035-Policy scenarios

Example: gridded NOX source distribution (right) and final gridded emission products for 2007-Baseline, 2035-BAU, and 2035-Policy (below)



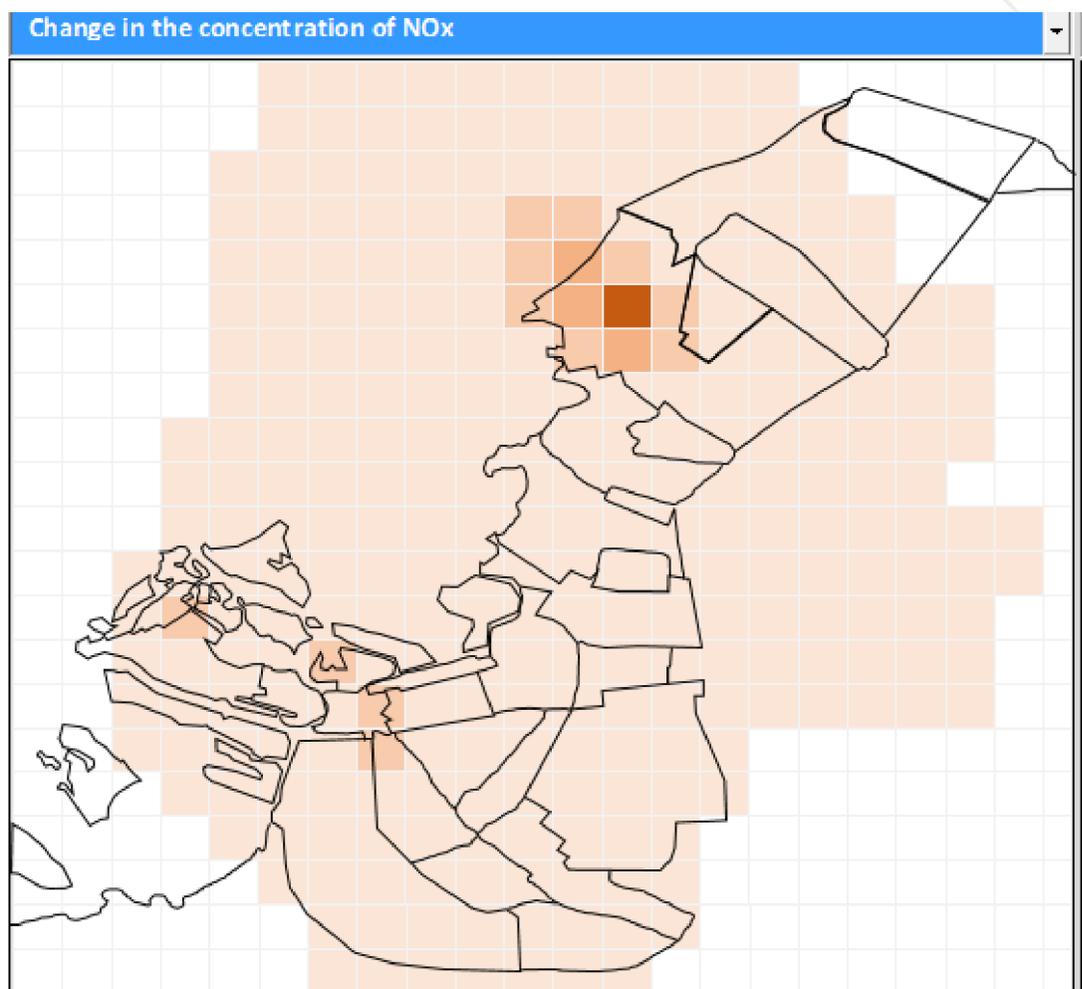
# RESULTS

# SUMMARY OF INDIVIDUAL POLICY ANALYSIS RESULTS:

# EMISSION REDUCTIONS

No.	Policy Type	Policy Name	Cumulative emission reductions by 2035 (thousand tonnes, except for CO2e million tonnes)					
			CO2e	NOX	VOC	PM2.5	CO	SOx
1	Electricity & Water supply	Nuclear power generation	400	298	2,037	2,798	91,715	167
2		Renewable energy power plants	117	87	597	820	26,875	49
3		One renewable energy water desalination pilot project	3	2	14	11	644	0
4		Renewable energy water desalination plants	0	0	2	4	69	0
5		Waste-to-energy power plants	3	-10	13	10	603	-9
6		Feed in tariff to sell power to the grid	38	29	195	268	8,787	16
7		Solar roofs	87	66	448	616	20,078	38
8		Supply side energy efficiency strategy for electricity and water production	142	114	733	1,128	32,681	73
9	Electricity demand	Demand side management strategies for electricity and water production	34	25	172	237	7,762	14
10		Current Estidama initiative	13	10	68	93	3,051	6
11		More stringent building codes for energy conservation	34	25	172	237	7,762	14
12		Energy efficiency standardization and labeling programme	34	25	172	237	7,762	14
13	Transport	Transportation demand strategies	5	110	79	0	148	0
14		Encourage purchase of high efficiency vehicles	19	377	223	1	417	0
15	Industry	Gas flaring reduction in oil and gas industry	12	5	29	0	5	53
16		Energy efficiency at industrial cogeneration facilities	0	0	0	0	0	0
17		Energy efficiency in aluminum production	0	0	0	0	0	0

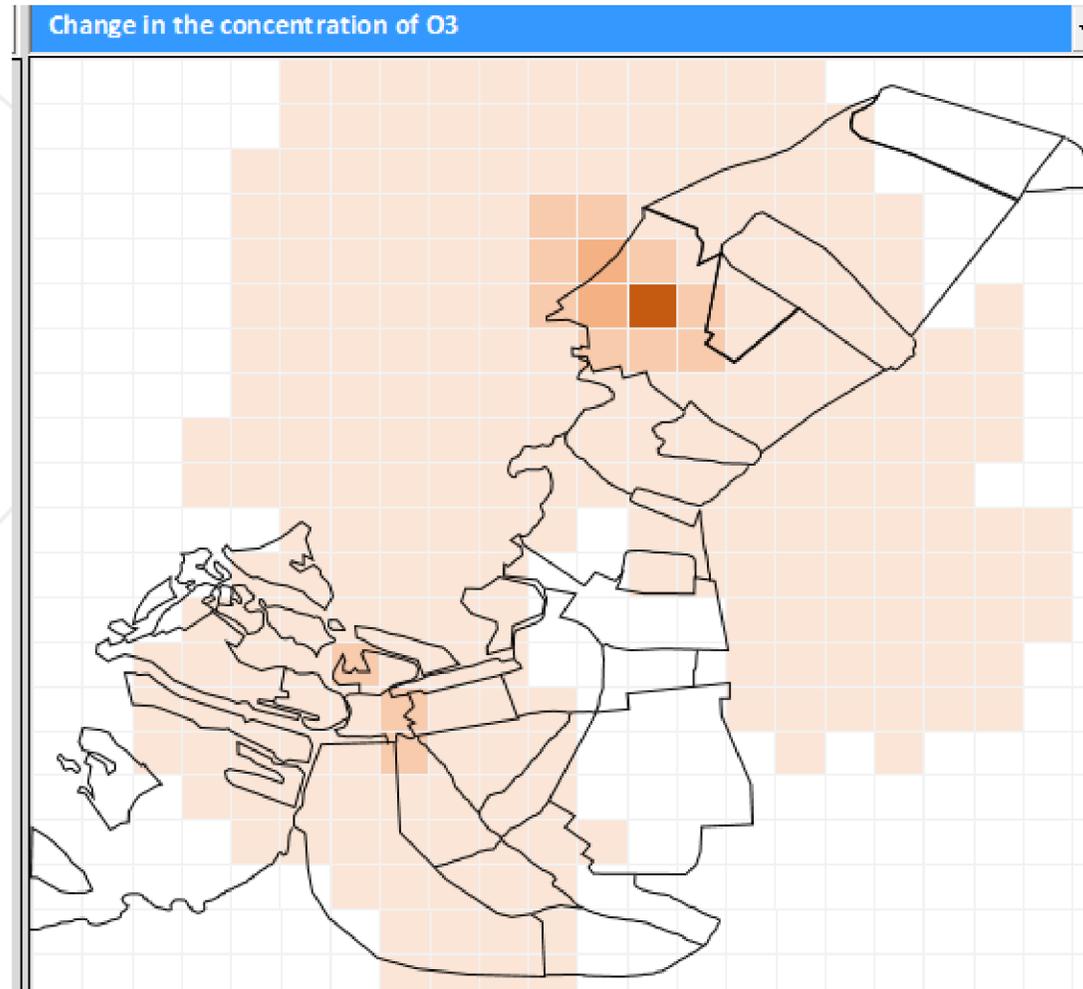
# SUMMARY OF RESULTS – AIR QUALITY CHANGES (EXAMPLE)



2035

Reductions in annual average pollutant concentration

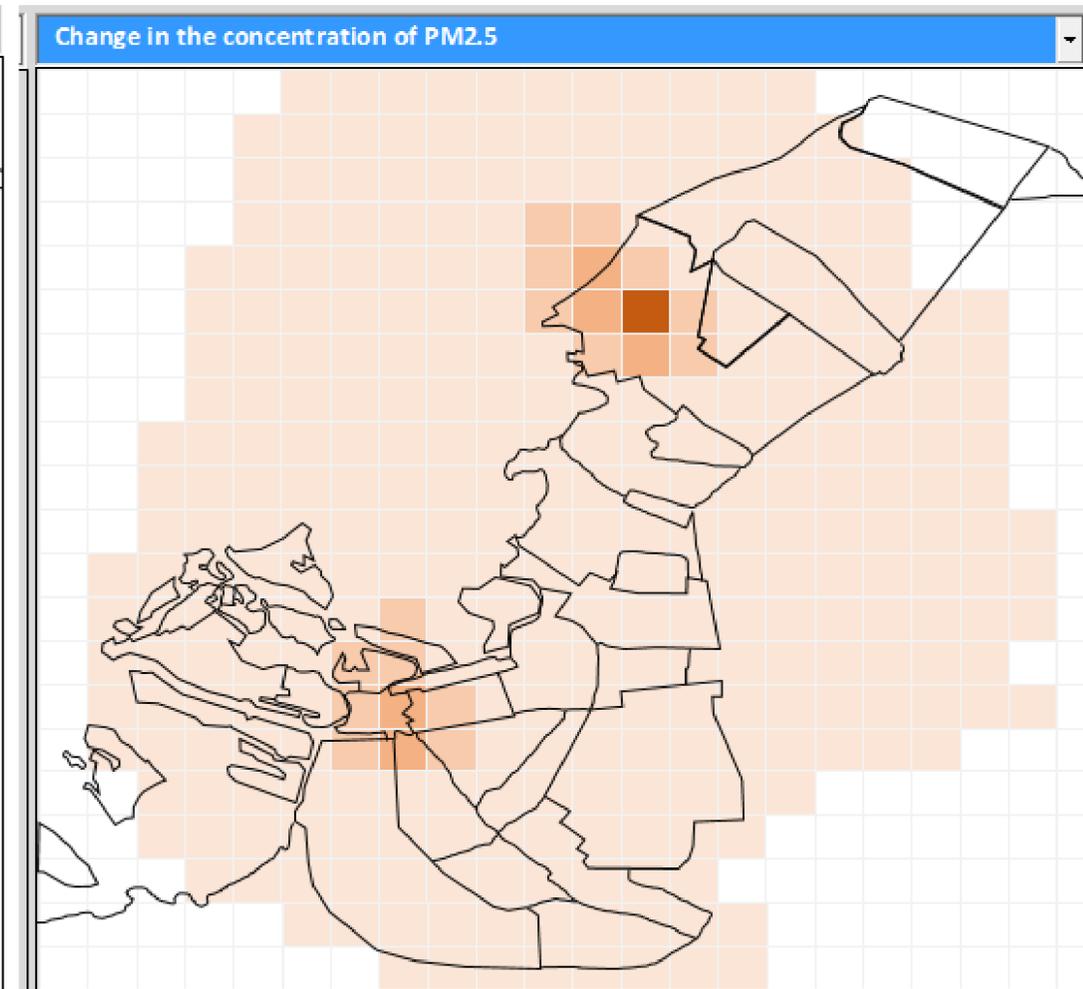
- Virtually no air quality change
- 0.1082554  $\mu\text{g}/\text{m}^3$  < Reduction  $\leq$  1.6238305
- 1.6238305  $\mu\text{g}/\text{m}^3$  < Reduction  $\leq$  3.247661  $\mu\text{g}/\text{m}^3$
- 3.247661  $\mu\text{g}/\text{m}^3$  < Reduction  $\leq$  6.495322  $\mu\text{g}/\text{m}^3$
- Reduction > 6.49532  $\mu\text{g}/\text{m}^3$



2035

Reductions in annual average pollutant concentration

- Virtually no air quality change
- 0.1758826  $\mu\text{g}/\text{m}^3$  < Reduction  $\leq$  2.6382389
- 2.6382389  $\mu\text{g}/\text{m}^3$  < Reduction  $\leq$  5.2764779  $\mu\text{g}/\text{m}^3$
- 5.2764779  $\mu\text{g}/\text{m}^3$  < Reduction  $\leq$  10.5529557  $\mu\text{g}/\text{m}^3$
- Reduction > 10.55296  $\mu\text{g}/\text{m}^3$



2035

Reductions in annual average pollutant concentration

- Virtually no air quality change
- 5.2696221  $\mu\text{g}/\text{m}^3$  < Reduction  $\leq$  79.0443301
- 79.0443308  $\mu\text{g}/\text{m}^3$  < Reduction  $\leq$  158.0886616  $\mu\text{g}/\text{m}^3$
- 158.0886616  $\mu\text{g}/\text{m}^3$  < Reduction  $\leq$  316.1773232  $\mu\text{g}/\text{m}^3$
- Reduction > 316.17732  $\mu\text{g}/\text{m}^3$

# SUMMARY OF INDIVIDUAL POLICY ANALYSIS RESULTS: HEALTH CO-BENEFITS

No.	Policy Type	Policy Name	Health co-benefits by 2035					
			Avoided premature deaths			Avoided health facility visits		
			PM	Ozone	Total	PM	Ozone	Total
1	Electricity & Water supply	Nuclear power generation	1,221	90	1,311	16,460	1,225	17,685
2		Renewable energy power plants	640	47	687	8,583	636	9,219
3		One renewable energy water desalination pilot project	0	0	0	0	0	0
4		Renewable energy water desalination plants	4	0	4	50	3	53
5		Waste-to-energy power plants	0	7	8	5	97	102
6		Feed in tariff to sell power to the grid	211	15	226	2,814	208	3,022
7		Solar roofs	445	32	477	5,955	439	6,394
8		Supply side energy efficiency strategy for electricity and water production	1,080	77	1,156	14,494	1,039	15,533
9	Electricity demand	Demand side management strategies for electricity and water production	191	14	204	2,541	188	2,728
10		Current Estidama initiative	75	5	80	999	74	1,073
11		More stringent building codes for energy conservation	191	14	204	2,541	188	2,728
12		Energy efficiency standardization and labeling programme	191	14	204	2,541	188	2,728
13	Transport	Transportation demand strategies	0	133	133	0	1,810	1,810
14		Encourage purchase of high efficiency vehicles	0	564	564	0	7,710	7,710
15	Industry	Gas flaring reduction in oil and gas industry	0	0	0	0	0	0
16		Energy efficiency at industrial cogeneration facilities	0	0	0	0	0	0
17		Energy efficiency in aluminum production	0	0	0	0	0	0

# SUMMARY OF INTEGRATED POLICY ANALYSIS RESULTS: EMISSION REDUCTIONS FOR ALL POLICIES

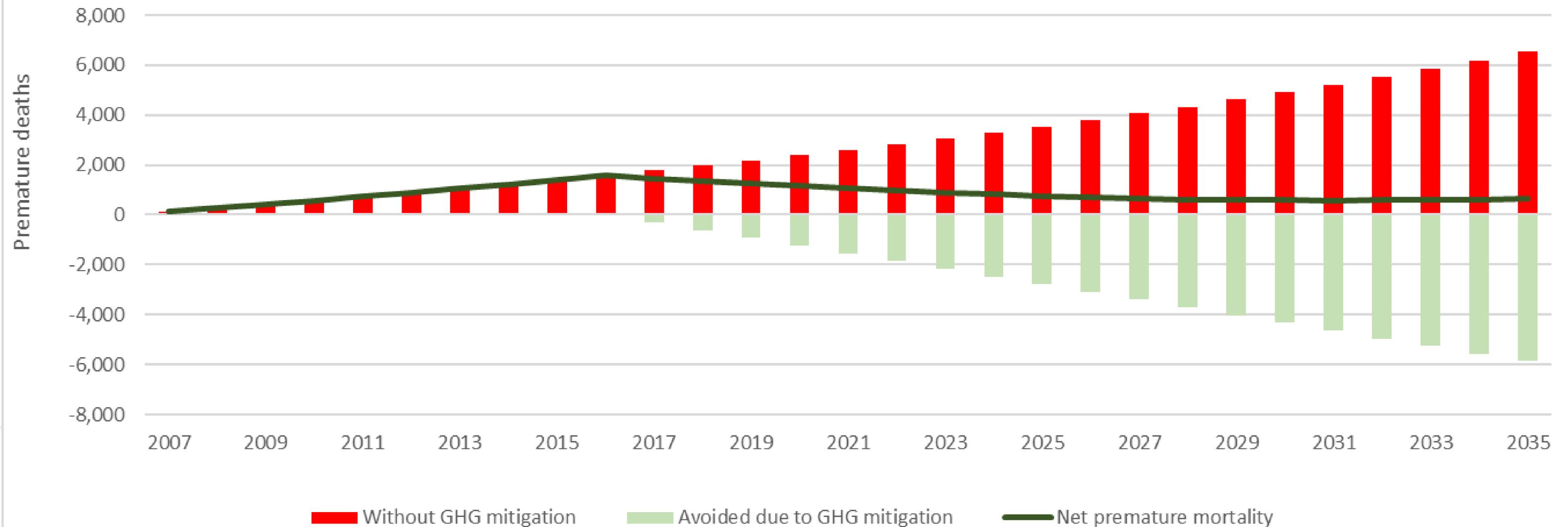
No.	Policy Type	Policy Name	Cumulative emission reductions by 2035 (thousand tonnes, except for CO2e million tonnes)					
			CO2e	NOX	VOC	PM2.5	CO	SOx
NA	Integrated analysis	All GHG mitigation strategies	912	1,012	4,795	6,502	205,427	438

# SUMMARY OF INTEGRATED POLICY ANALYSIS RESULTS: HEALTH CO-BENEFITS FOR ALL POLICIES

No.	Policy Type	Policy Name	Health co-benefits by 2035					
			Avoided premature deaths			Avoided health facility visits		
			PM	Ozone	Total	PM	Ozone	Total
NA	Integrated analysis	All GHG mitigation strategies	4,661	1,210	5,872	65,020	16,861	81,881

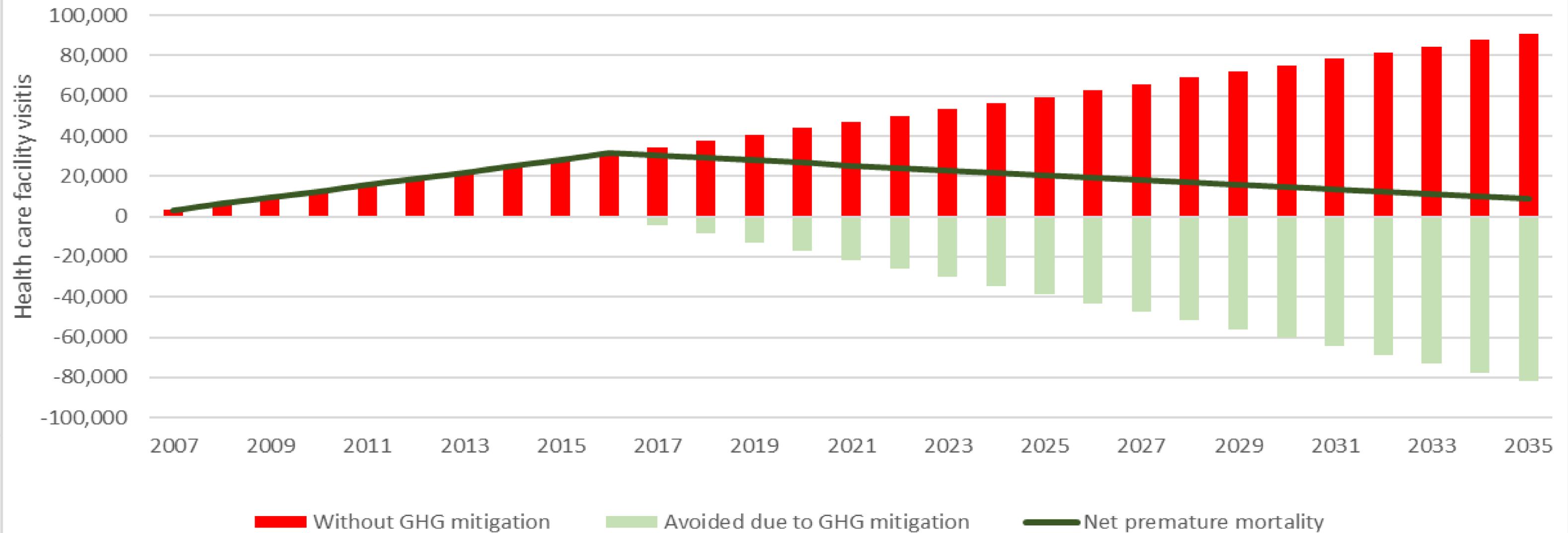
# SUMMARY OF INTEGRATED POLICY ANALYSIS RESULTS: AVOIDED PREMATURE MORTALITY

Cumulative premature mortality co-benefits of GHG mitigation in Abu Dhabi Metro area



# SUMMARY OF INTEGRATED POLICY ANALYSIS RESULTS: AVOIDED HEALTH CARE FACILITY VISITS

Cumulative morbidity co-benefits of GHG mitigation in Abu Dhabi Metro area



# RECOMMENDATIONS

# NEXT STEPS

- Expand Inspector to account for future greenhouse gas mitigation policies
- Adapt Inspector to other urban areas in the UAE
- Enhance air quality modeling aspects
- Introduce additional health endpoints
- Introduce sensitivity analysis of future climatic conditions



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