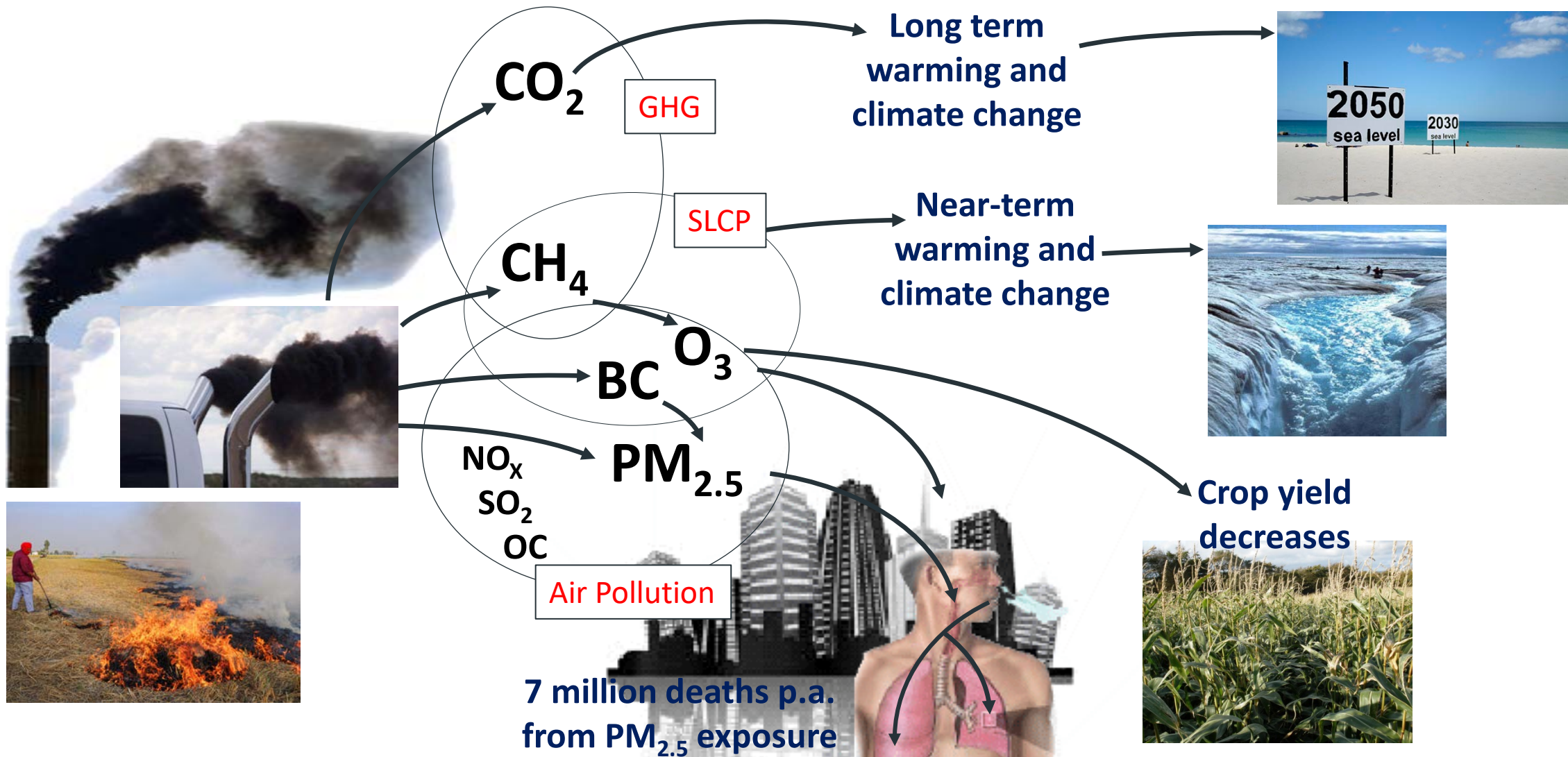# Climate change interactions with air pollution
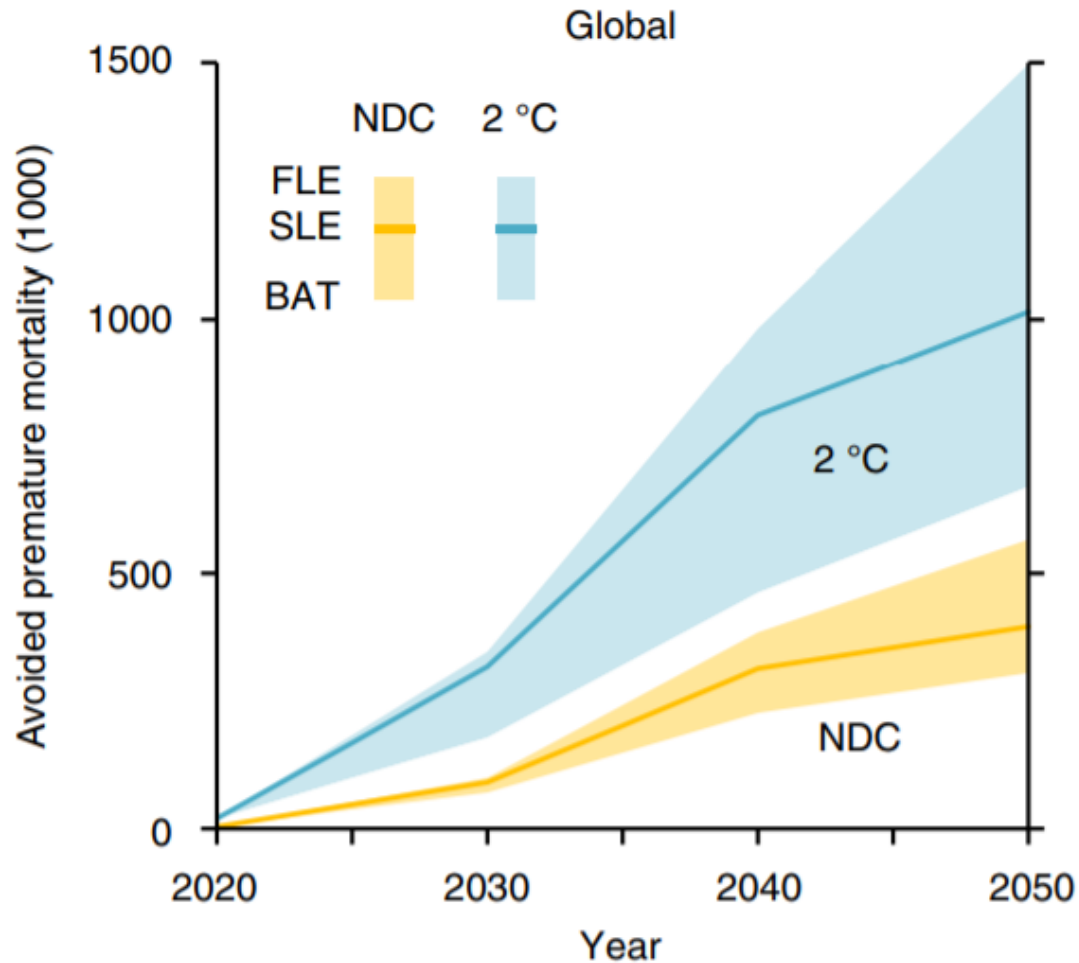
Johan Kuylenstierna
SEI Research Leader

The strong linkage between air quality, SLCP and climate planning

CO_2

GHG

Long term warming and climate change

2050 sea level   2030 sea level

CH_4

SLCP

Near-term warming and climate change

O_3

BC

$PM_{2.5}$

NO_X
SO_2
OC

Air Pollution

Crop yield decreases

7 million deaths p.a. from $PM_{2.5}$ exposure

AIR POLLUTANT REDUCTIONS DUE TO CO2 MITIGATION

Over 1 million premature deaths avoided in 2050 if Paris target is achieved

Vandyck et al. 2018

ccacoalition.org

Health and climate at COP26

- Massive interest in health at COP26

- WHO representative:

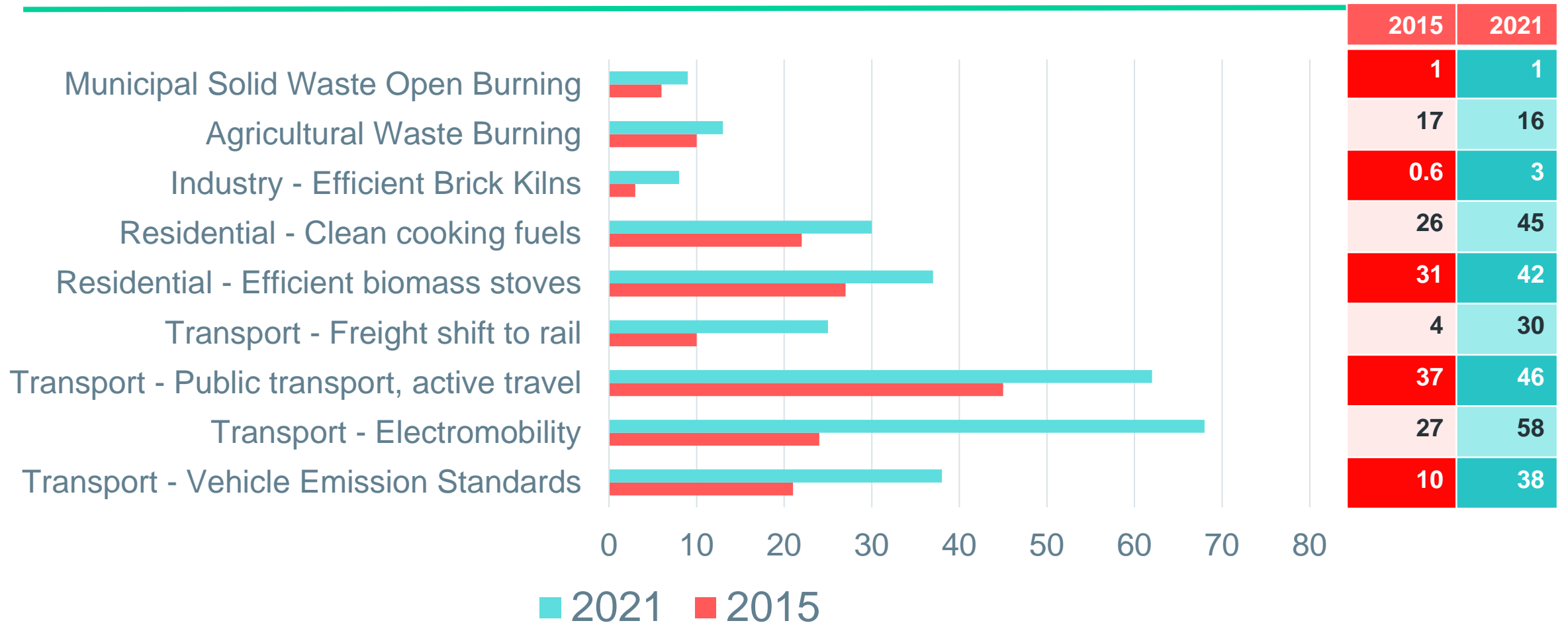*'previously we were chasing people to put the health argument into climate; now they are chasing us'*

WHO 'Health pavilion' at COP26

There are double the number of countries highlighting benefits for air quality and health in their NDCs, between 2015 and 2021, and many are CCAC partners
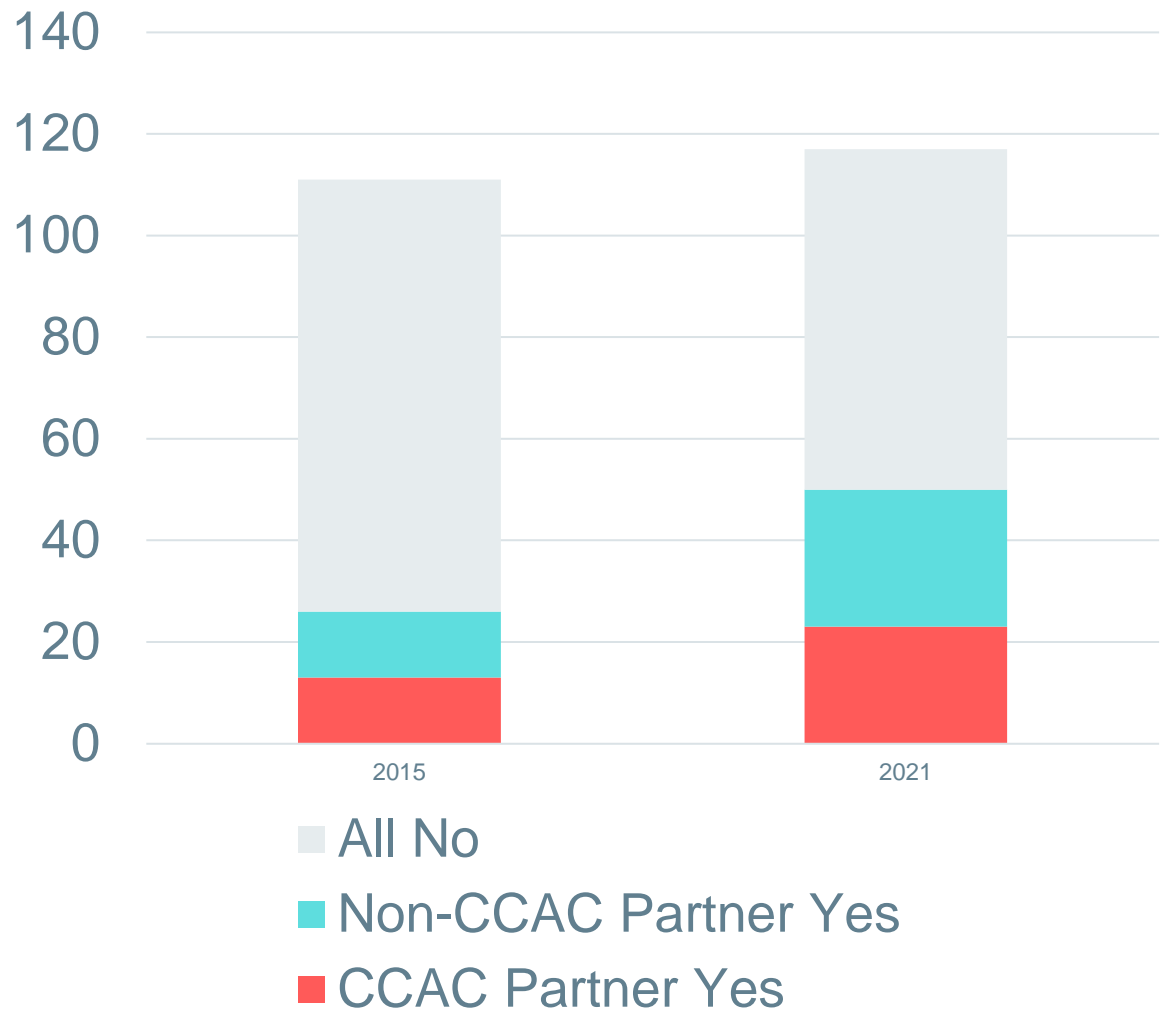
Legend:
- All No
- Non-CCAC Partner Yes
- CCAC Partner Yes

Number of NDCs submitted in 2015 and 2020/2021 that included mitigation measures targeting major Black Carbon sources

	2015	2021
Municipal Solid Waste Open Burning	1	1
Agricultural Waste Burning	17	16
Industry - Efficient Brick Kilns	0.6	3
Residential - Clean cooking fuels	26	45
Residential - Efficient biomass stoves	31	42
Transport - Freight shift to rail	4	30
Transport - Public transport, active travel	37	46
Transport - Electromobility	27	58
Transport - Vehicle Emission Standards	10	38

Legend: ■ 2021 ■ 2015

X-axis: 0 10 20 30 40 50 60 70 80

UK NDC recognises air pollution – climate link

'The UK recognises the potential for carbon emission reduction policies to improve air quality'

'The UK's support decarbonisation approaches that strive to improve air quality and minimise adverse impacts on human health, balanced with action to achieve reductions in carbon emissions'

UK Government

TOGETHER FOR OUR PLANET

SLCP Strategies can slow warming and avoid millions of premature deaths each year
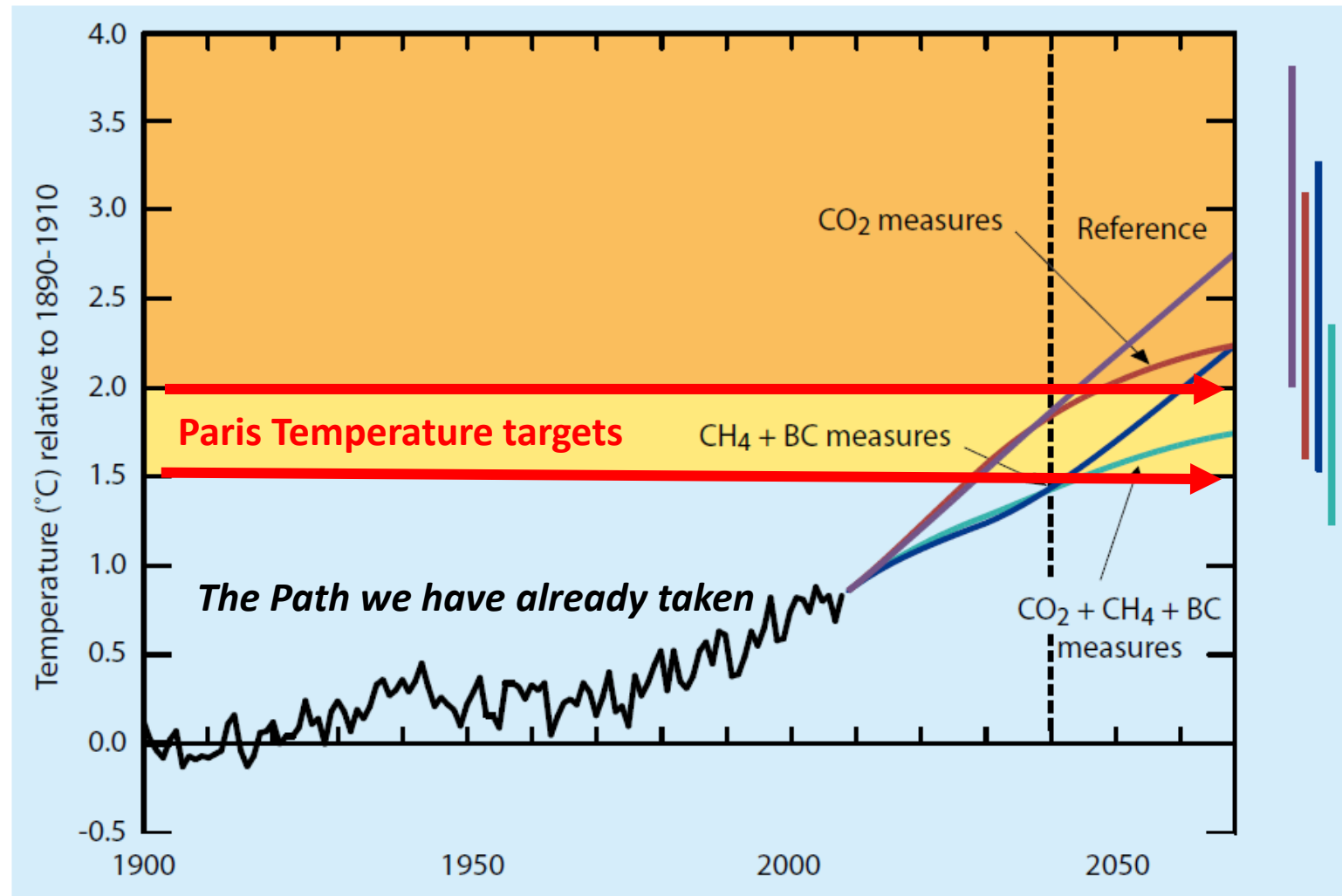
Source: UNEP/WMO (2011). *Integrated Assessment of Black Carbon and Tropospheric Ozone.* UNEP, Nairobi

The measures aiming at reducing methane emissions

Intermittent aeration -paddy
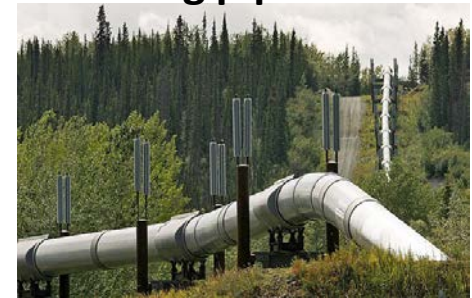
Recovery from wastewater

Recovery from oil and gas

Recovery from landfill

Recovery from livestock manure / feed

Reducing pipeline leakage

Coal mine methane capture

The measures aiming to reduce black carbon emissions

Improved biomass stoves

Modern coke ovens

Remove big smokers / DPF

Cooking with clean fuel

Pellet biomass heating stoves

Improved brick kilns

Coal briquettes replacing coal

Reduce agricultural burning
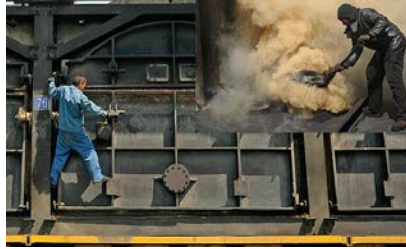
Reduce flaring

The measures aiming to reduce black carbon emissions

Improved biomass stoves

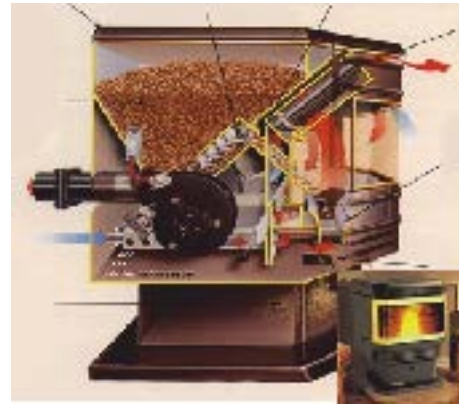**Modern coke ovens**

Remove big smokers / DPF

Cooking with clean fuel

Pellet biomass heating stoves

Improved brick kilns

Coal briquettes replacing coal

Reduce agricultural burning

Reduce flaring

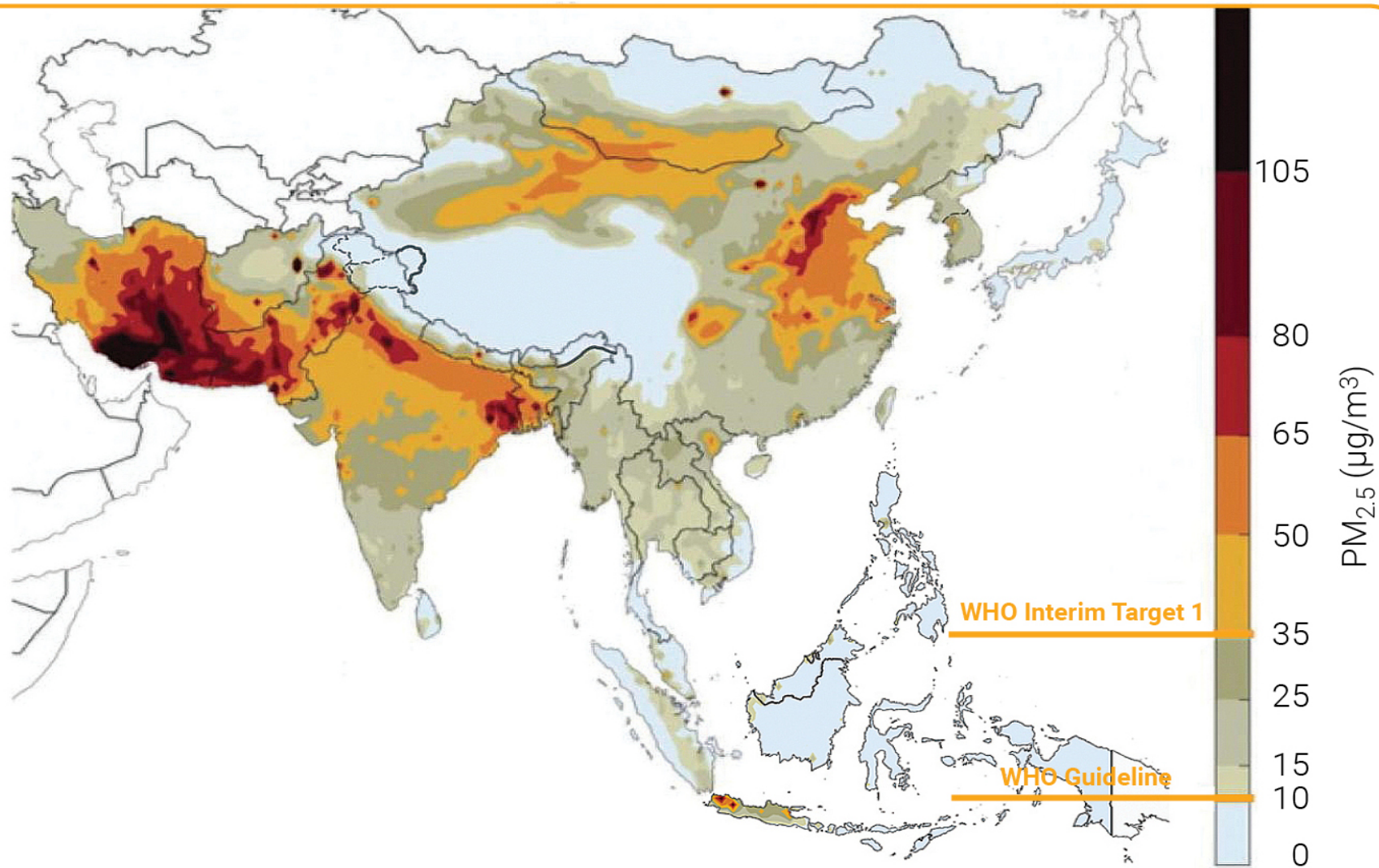# Why do we need a near term goal and worry about the pathways to the Paris Agreement target?
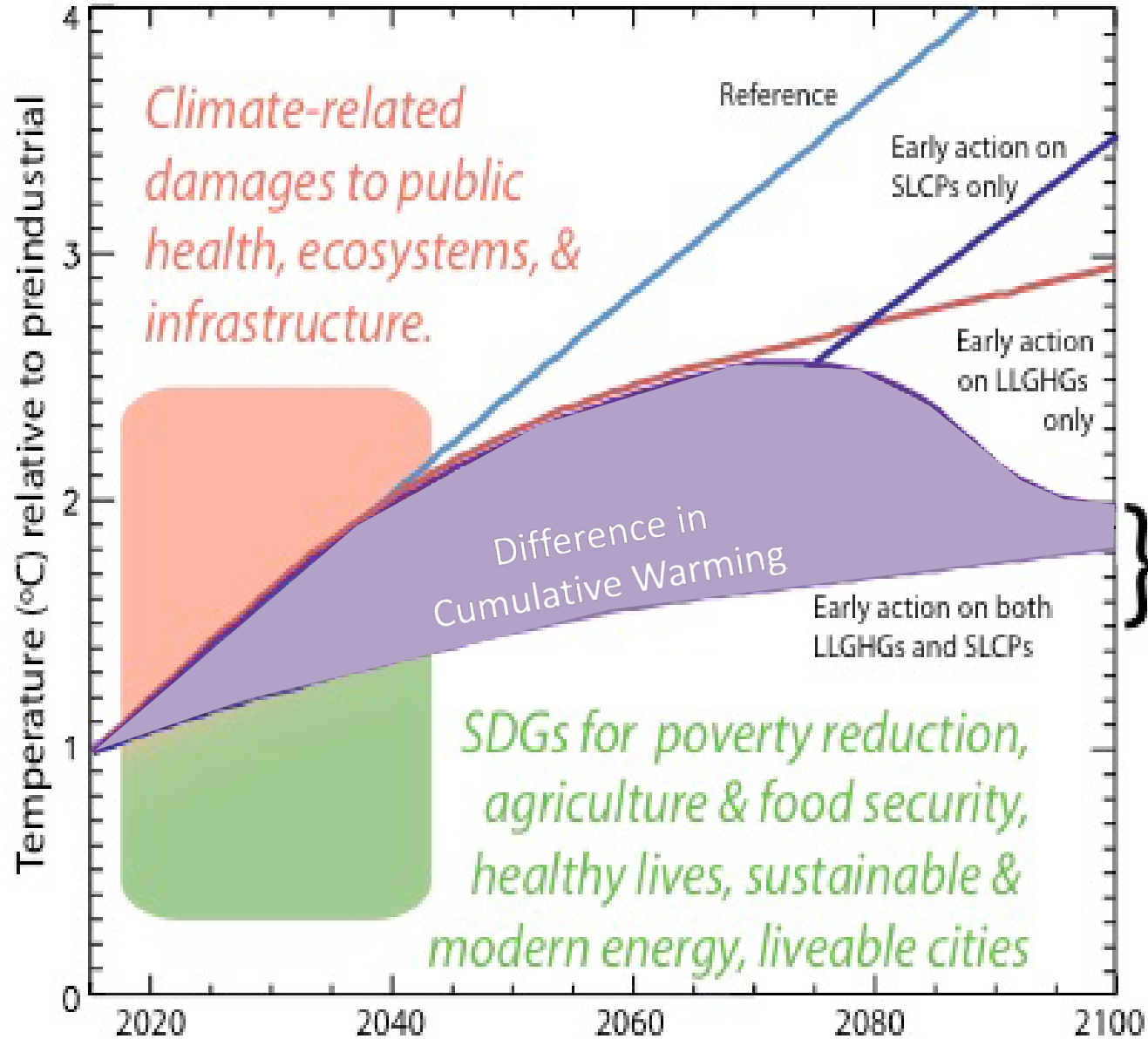
Consider the path to the target!

Results from the CCAC/UNEP Asian assessment

IIASA GAINS model results

WHO Interim Target 1

WHO Guideline

PM$_{2.5}$ (µg/m^3)

105

80

65

50

35

25

15

10

0

FIGURE 2.2: AMBIENT LEVELS OF PM$_{2.5}$ IN 2030 COMPUTED FOR THE CURRENT LEGISLATION BASELINE SCENARIO
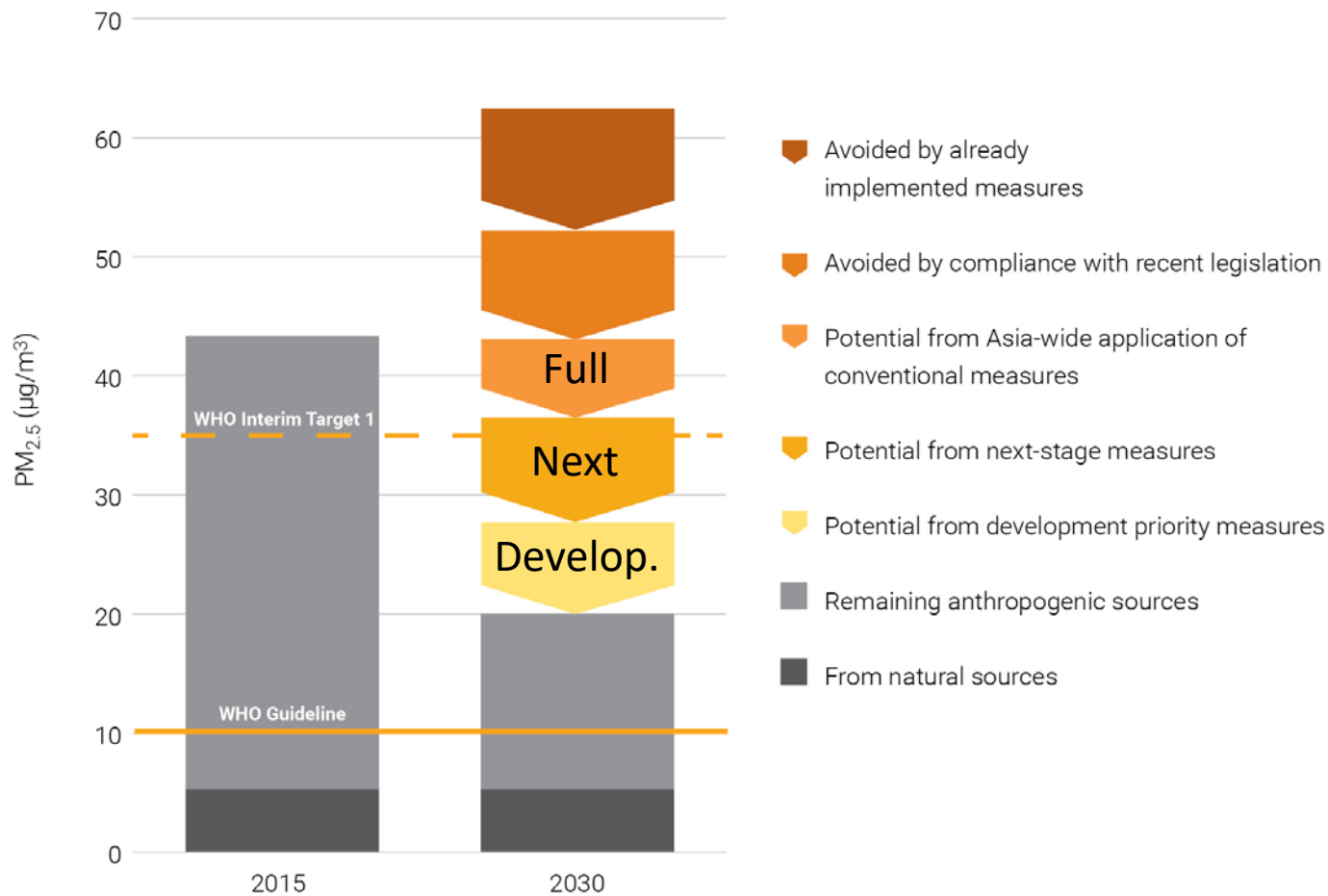
FIGURE 2.3: POTENTIAL CONTRIBUTIONS OF THE THREE PORTFOLIOS OF MEASURES TO POPULATION-WEIGHTED MEAN EXPOSURE TO PM$_{2.5}$

The Top 25 measures will provide clean air [<10µg m^{-3}] to 1 billion people in 2030

And reduce the number of people facing the highest WHO Interim Target (35µg m^{-3}) by 80%
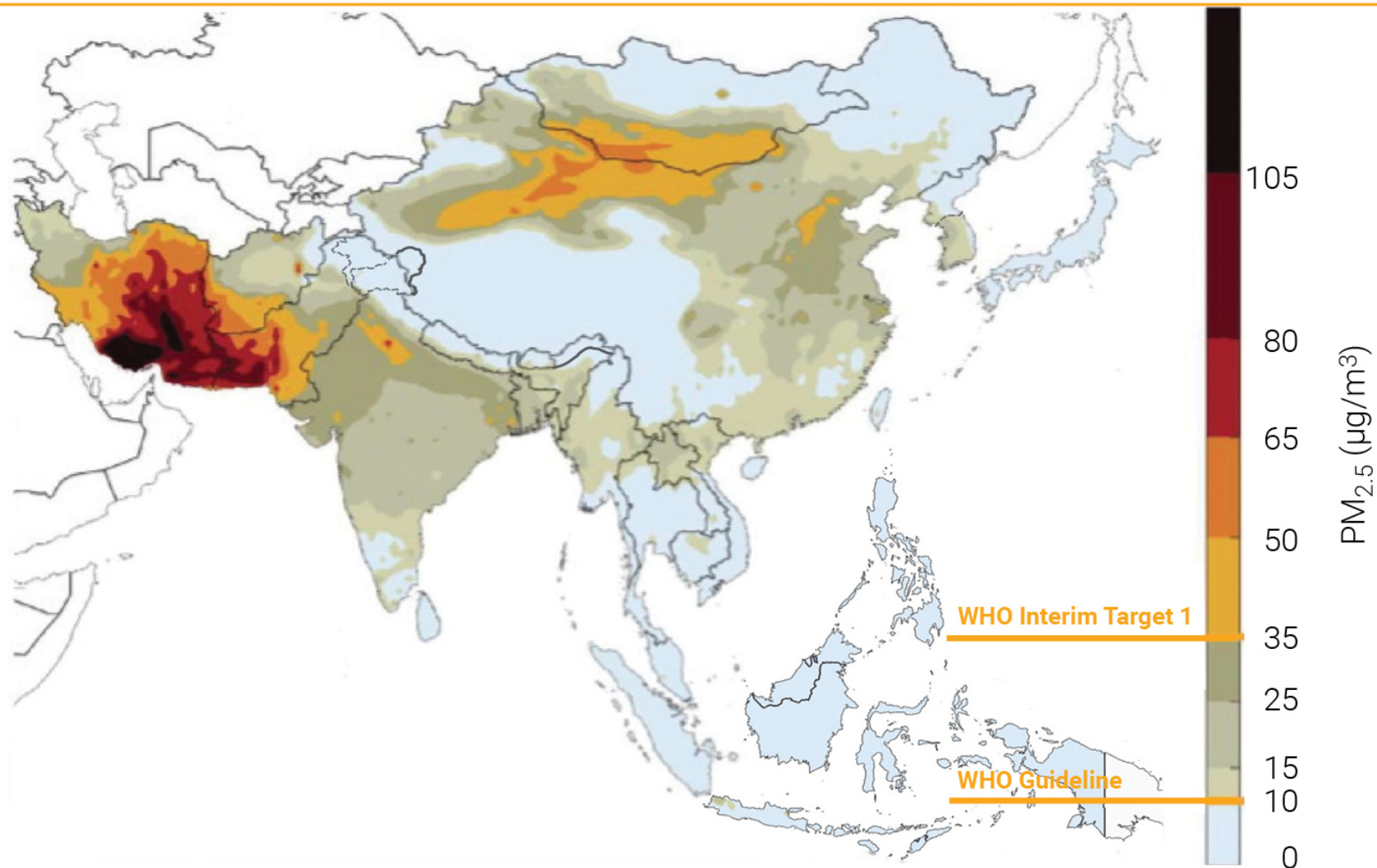
Map showing PM$_{2.5}$ after implementation of the Top 25 Measures

WHO Interim Target 1

WHO Guideline

PM$_{2.5}$ (μg/m³)

105

80

65

50

35

25

15

10

0

FIGURE 2.5: PM$_{2.5}$ CONCENTRATIONS IN 2030 AFTER IMPLEMENTATION OF THE TOP 25 CLEAN AIR MEASURES
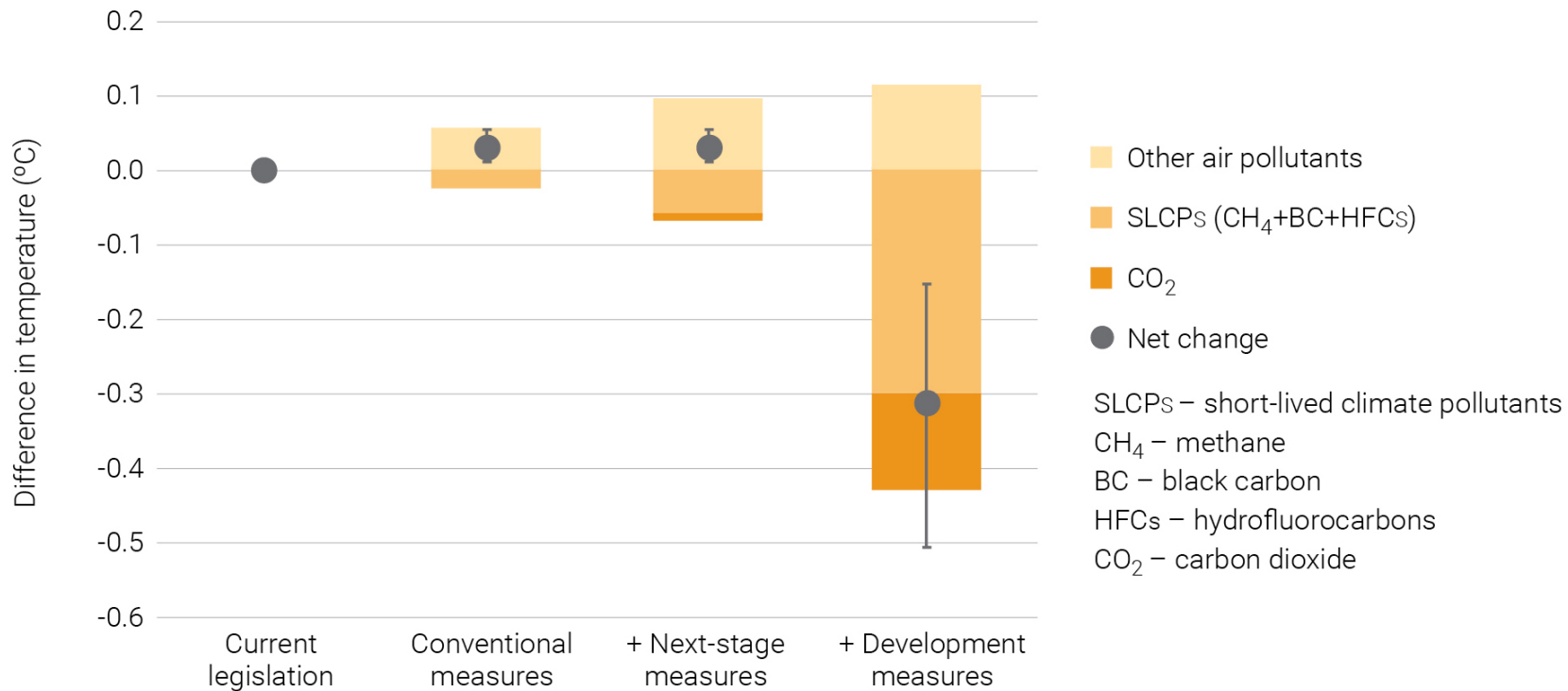
FIGURE 2.11: CHANGES IN GLOBAL MEAN TEMPERATURE FROM THE THREE PORTFOLIOS OF MEASURES, IN 2050 RELATIVE TO THE 2030 BASELINE PROJECTION

The Top 25 clean air measures could avoid 0.3˚C of warming by 2050

Climate and Clean Air Coalition: Enhancing Capacity to undertake Integrated National Planning

CAPACITY ENHANCEMENT: Countries SEI is working with in SNAP using LEAP-IBC for integrated air quality and climate planning
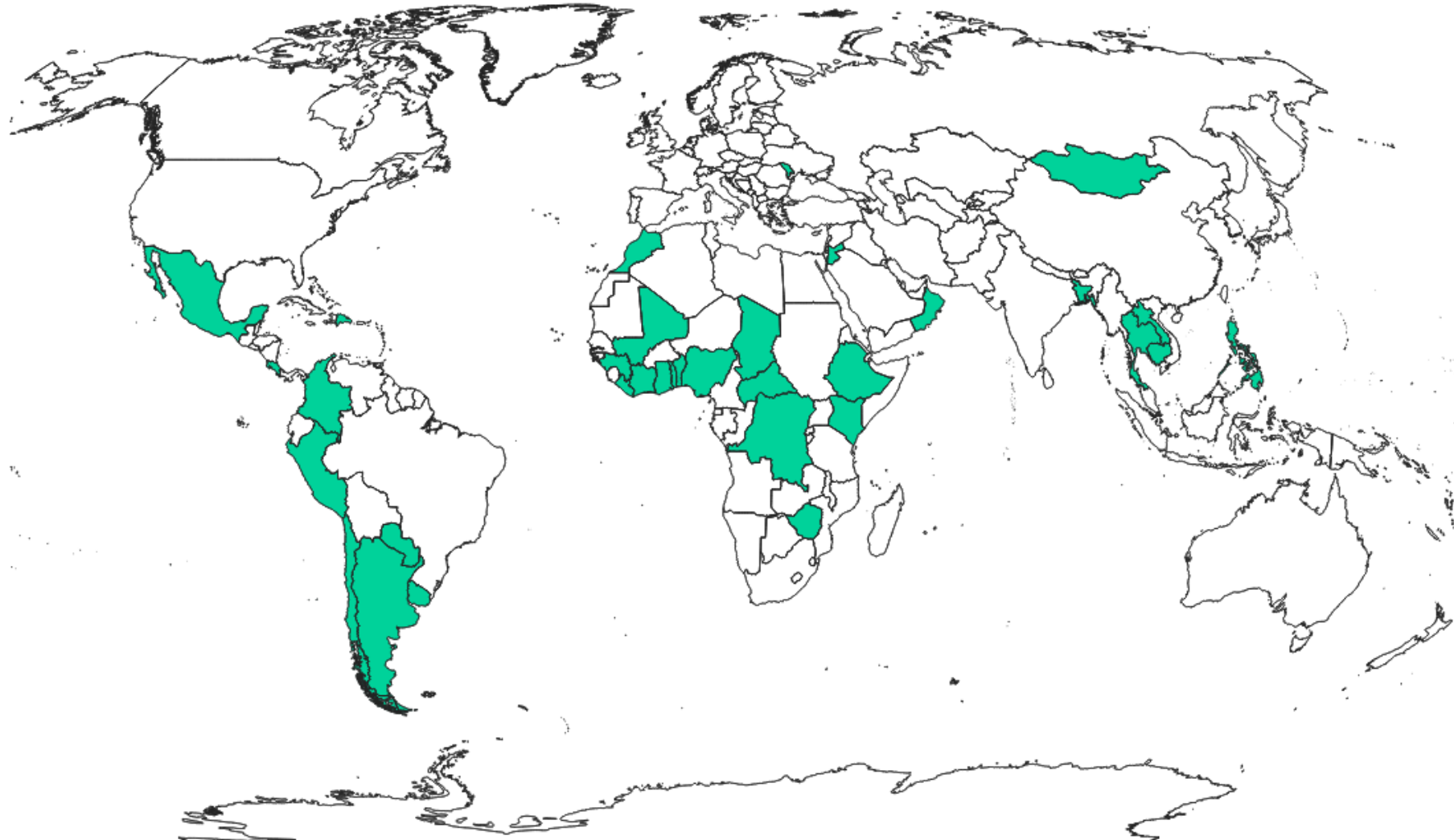
National Plans and Strategies endorsed by national Governments

Providing quantitative assessments

Emissions

Transport

Exposure

Impacts: Climate

Impacts: Health and vegetation

LEAP

Use in climate planning

At Least 37 Countries Used LEAP for INDC Preparation		
Armenia	Ghana	Myanmar
Albania	Haiti	Niger
Antigua & Barbuda	Iraq	Nigeria
Azerbaijan	Israel	Palau
Bahamas	Jamaica	Palestine
Bangladesh	Lebanon	Philippines
Belarus	Liberia	Serbia
Bosnia and Herzegovina	Mauritania	Uganda
Botswana	Mongolia	Vietnam
Cambodia	Montenegro	Yemen
Chile	Morocco	Zambia
Ecuador	Mozambique	Zimbabwe
Micronesia		

Many others using LEAP to help develop National Communications (TNCs), Biennial Update Reports (BURs), Low Emission Development Strategies (LEDS), Nationally Appropriate Mitigation Actions (NAMAs), etc.

GHG Mitigation Potential from Scenarios in Nigeria

- Emissions progressively reduced by:

- - including the **INDC measures**

- - **'Enhanced Ambition'** scenario measures

- - **'Maximum Ambition'** scenario measures

- Second highest GHG source is the AFOLU sector (predominantly agriculture)
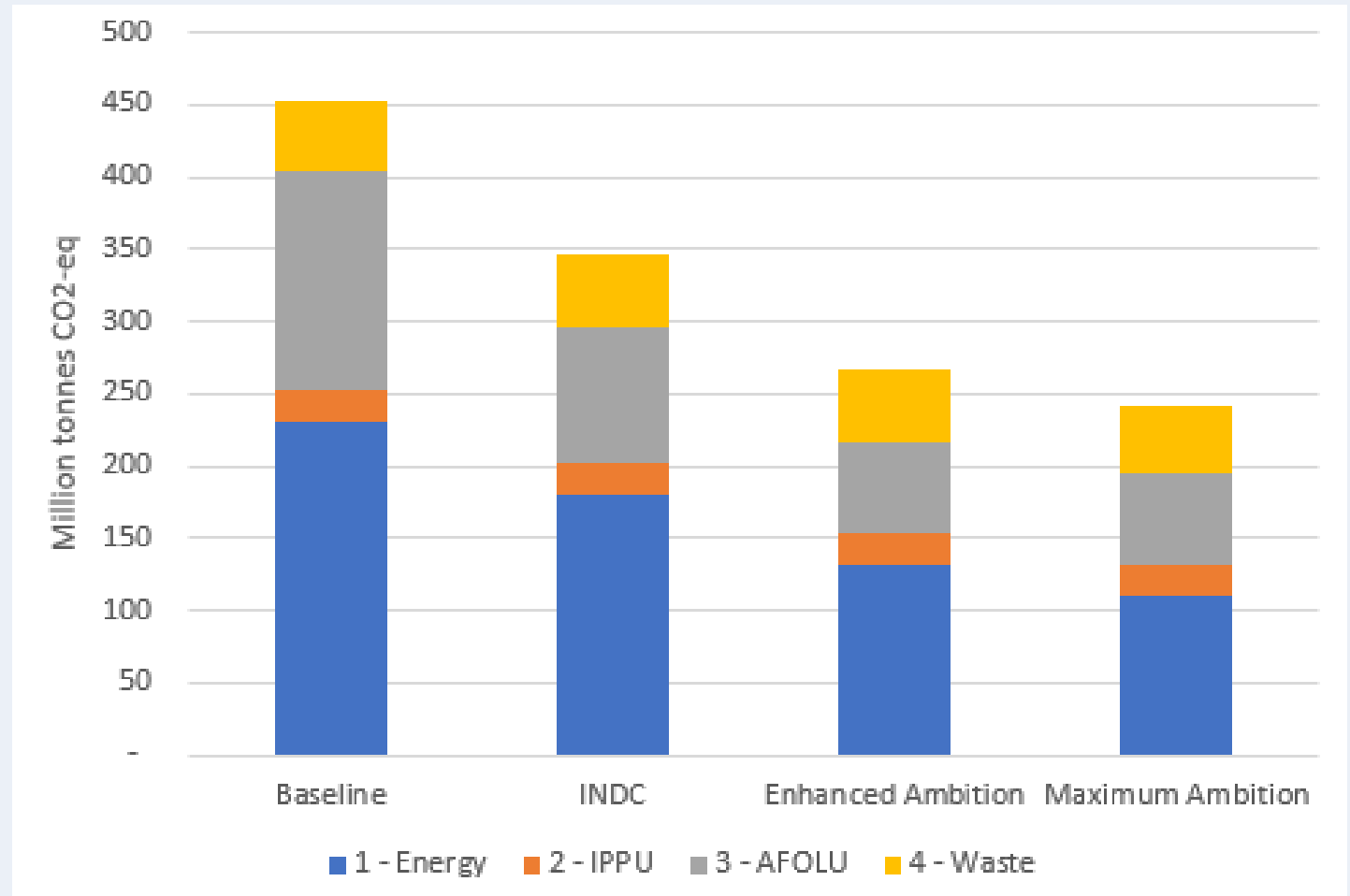
Short-Lived Climate Pollutant mitigation

- measures outlined reduce emissions of key air pollutants and short-lived climate pollutants (SLCP's) like black carbon

- This further reduces Nigeria's contribution to climate change, and achieves local benefits for human health

- Black carbon emissions can be more than halved through implementation of NDC measures

- Reducing emissions resulting in reduced $PM_{2.5}$ will have massive health benefits for Nigerian people

- In 2019, almost 198,000 premature deaths in Nigeria were associated with exposure to air pollution)
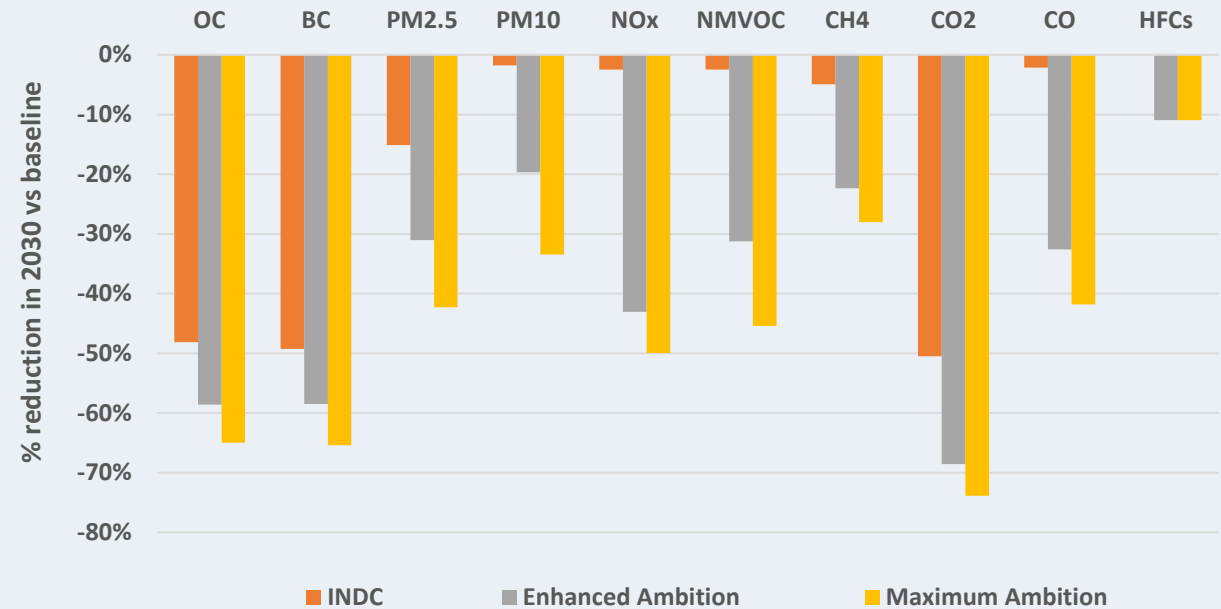
Maximum Ambition Scenario Measures

Sector	Mitigation measure
Residential	48 % of population (26.8 million households) using LPG and 13 % (7.3 million households) using improved cookstoves by 2030
Economy Wide	2.5% per year increase in energy efficiency across all sectors
Electricity Generation	Elimination of diesel generators by 2030
Oil and Gas	60% reduction in fugitive methane emissions

Additional Co-benefits of Measures

- In 2030, 97 thousand premature deaths are attributable to household air pollution in the baseline scenario.

- The 'enhanced ambition scenario' clean cooking measure results in 11 thousand avoided premature deaths in 2030 compared to the baseline scenario.

- The maximum ambition scenario, results in 30 thousand avoided premature deaths in 2030, from avoided indoor exposure.
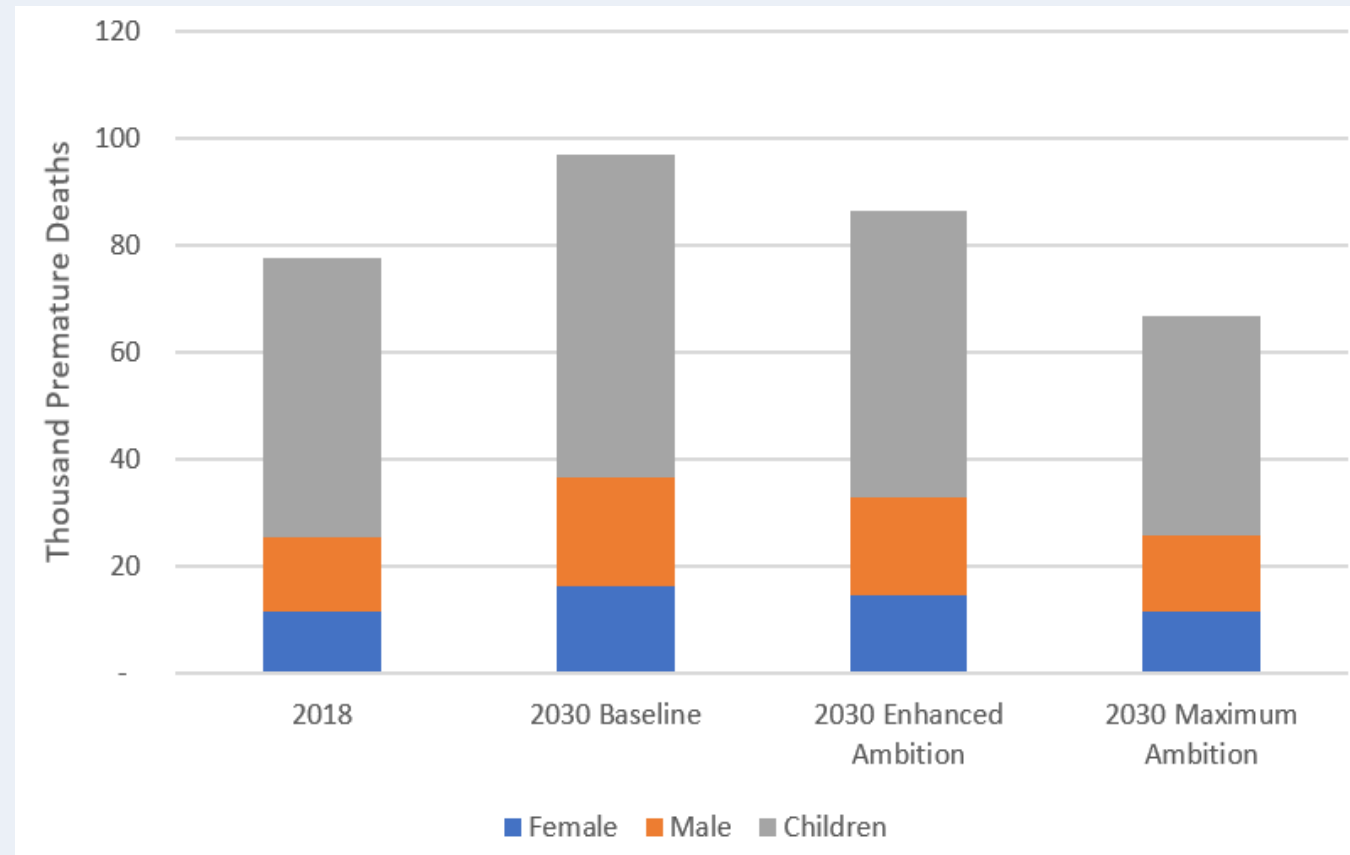
Identifying air quality benefits of climate change planning: The Maldives
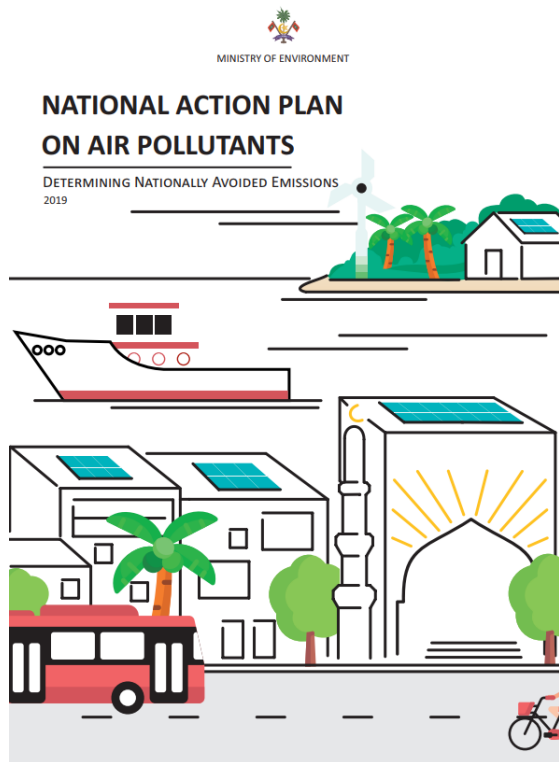
Reduction of PM2.5 in MT: Mitigation Measures

Legend:
- Air Quality Strategy measures
- All measures
- Baseline
- NDC measures
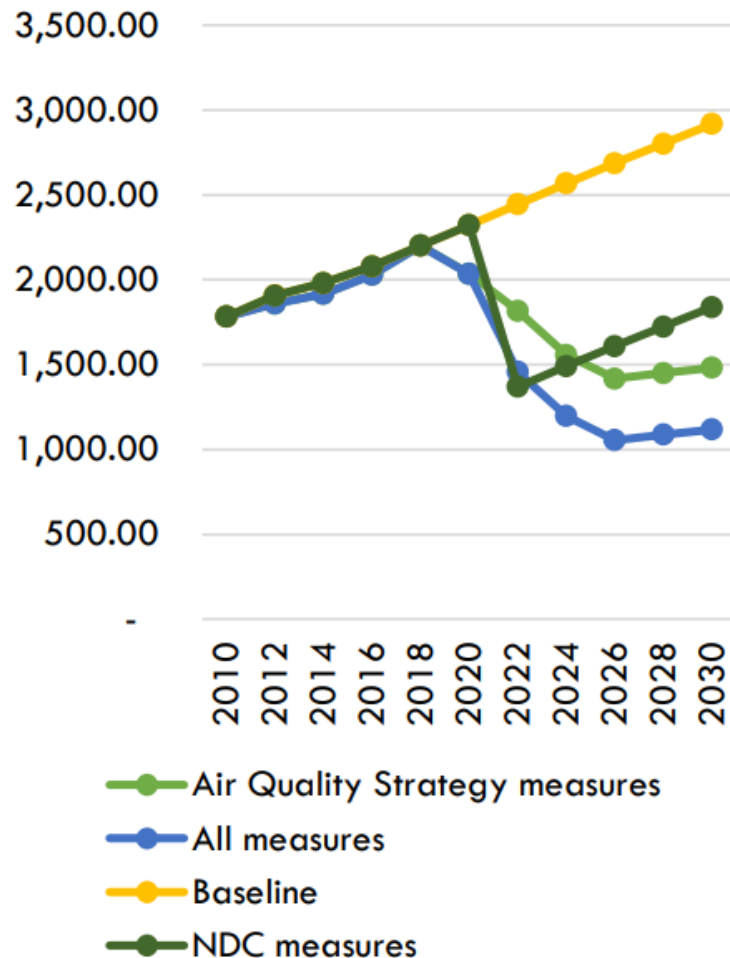
- National Action Plan on Air Pollutants

- Aligned with climate change planning

- Includes 22 measures from Maldives NDC, which reduce $PM_{2.5}$ emissions by 35% in 2030

- 6 additional air pollution actions reduce $PM_{2.5}$ emissions by further 25%

- Additional actions include emission standards for land and marine vehicles

Key perspectives from work with countries

The existence of quantified health benefits of NDCs emphasise local benefits from climate action and motivate action and promote ambition. E.g. following statistics on health benefits included in NDCs:

- In Nigeria's NDC, the plans would avoid 30,000 deaths in 2030;
- in Ghana's NDC 2900 avoided deaths by 2030 are quoted in the NDC;
- In Togo the number of avoided deaths from the NDC implementation is 1000 by 2030

Can't keep going from consultancy to consultancy to develop low emission plans – need a sustained capacity in countries to be able to do this.

C.f. UN Secretary Generals call – submit new NDCs every year – need consistency using capacity in national institutions to regularly update plans – cannot be a piecemeal process

Guidance for NDCs

o SEI and CCAC secretariat produced guidance under SNAP Initiative to enhance NDCs, especially by integrating air pollution into plans

Opportunities for Increasing Ambition of Nationally Determined Contributions through Integrated Air Pollution and Climate Change Planning:

A Practical Guidance document

Supporting National Action & Planning on short-lived climate pollutants (SNAP) Initiative

CLIMATE & CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

Assessing business contributions to air pollution

Sulfur dioxide — >99% energy
Nitrogen oxides — >99% energy
Particulate matter$_{2.5}$ — 85% energy
Carbon monoxide — 92% energy
Volatile organic compounds — 66% energy
Ammonia — 3% energy

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

Industry — Fuel combustion, process emissions

Transport — Exhaust, brake and tyre and road wear, fuel evaporation

Buildings — Cooking, heating and lighting

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

Non-energy — Agriculture, solvents and waste

What role can they play in reducing air pollutant emissions down their value chains?

IEA 2016

Sources within value chain

Project between CCAC, IKEA and SEI

Six sources of air pollutant emissions within generic value chain identified

Methods to quantify air pollution down these being developed and trialled with IKEA and other companies

Ready mid-2022

Value Chain

- Raw material extraction/ cultivation
- Manufacturing/ Processing/Assembly
- Distribution, Storage and Transport
- Retail
- In use
- End of Life

Sources of Pollution

Raw material extraction/ cultivation:
- Electricity
- Fuel Combustion
- Transport
- Industrial Processes
- Agriculture

Manufacturing/Processing/Assembly:
- Electricity
- Fuel Combustion
- Transport
- Industrial Processes

Distribution, Storage and Transport:
- Electricity
- Fuel Combustion
- Transport

Retail:
- Electricity
- Fuel Combustion
- Transport
- Waste

In use:
- Electricity
- Fuel Combustion

End of Life:
- Electricity
- Fuel Combustion
- Transport
- Waste

Methodology for Quantifying Emissions

Raw material extraction/ cultivation:
- Section 4.1
- Section 4.2
- Section 4.3
- Section 4.4
- Section 4.5

Manufacturing/Processing/Assembly:
- Section 4.1
- Section 4.2
- Section 4.3
- Section 4.4

Distribution, Storage and Transport:
- Section 4.1
- Section 4.2
- Section 4.3

Retail:
- Section 4.1
- Section 4.2
- Section 4.3
- Section 4.6

In use:
- Section 4.1
- Section 4.2

End of Life:
- Section 4.1
- Section 4.2
- Section 4.3
- Section 4.6

Air Pollution Emissions

Associated with:

i. processes along value chain

ii. Electricity use; transport or fuel combustion associated with steps along value chain

Emissions of:

A. Primary Particles
$PM_{2.5}$
Black Carbon (BC)
Organic Carbon (OC)
Mineral dust

B. Gases
Sulphur dioxide (SO_2)
Nitrogen oxides (NO_X)
Ammonia (NH_3)
Non-methane Volatile Organic Compounds (NMVOCs)
Carbon monoxide (CO)

GLOBAL METHANE ASSESSMENT

Benefits and Costs of Mitigating Methane Emissions

22 Authors

11 Institutions
Chair: Drew Shindell of Duke University

5 state-of-the art global composition-climate models

Web-based decision support tool
http://shindellgroup.rc.duke.edu/apps/methane/

Publicly available archive of ozone modelling results
https://doi. org/10.7924/r4qn65b0z

CLIMATE &
CLEAN AIR
COALITION

GLOBAL METHANE ASSESSMENT

The atmospheric concentration of methane is increasing faster now than at any time in the observational record.

- Methane emissions are projected to continue rising through at least 2040.

- Current concentrations are well above levels in the 2° C scenarios used in the IPCC's 2013 Assessment.

- The Paris Agreement's 1.5° C target cannot be achieved at a reasonable cost without reducing methane emissions by 40–45 per cent by 2030.

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CLIMATE &
CLEAN AIR
COALITION
TO REDUCE SHORT–LIVED
CLIMATE POLLUTANTS

GLOBAL METHANE ASSESSMENT

The atmospheric concentration of methane is increasing faster now than at any time in the observational record.

- Likely in part due to fossil fuels - surge in gas extraction
- Likely in part due to tropical biogenic flux (perhaps climate driven)
- Regardless of exact fraction of total or growth from specific sectors, we know the big ones and can reduce them!
- Rapid changes are needed to limit temperature rise to 1.5°C

Global average methane concentrations
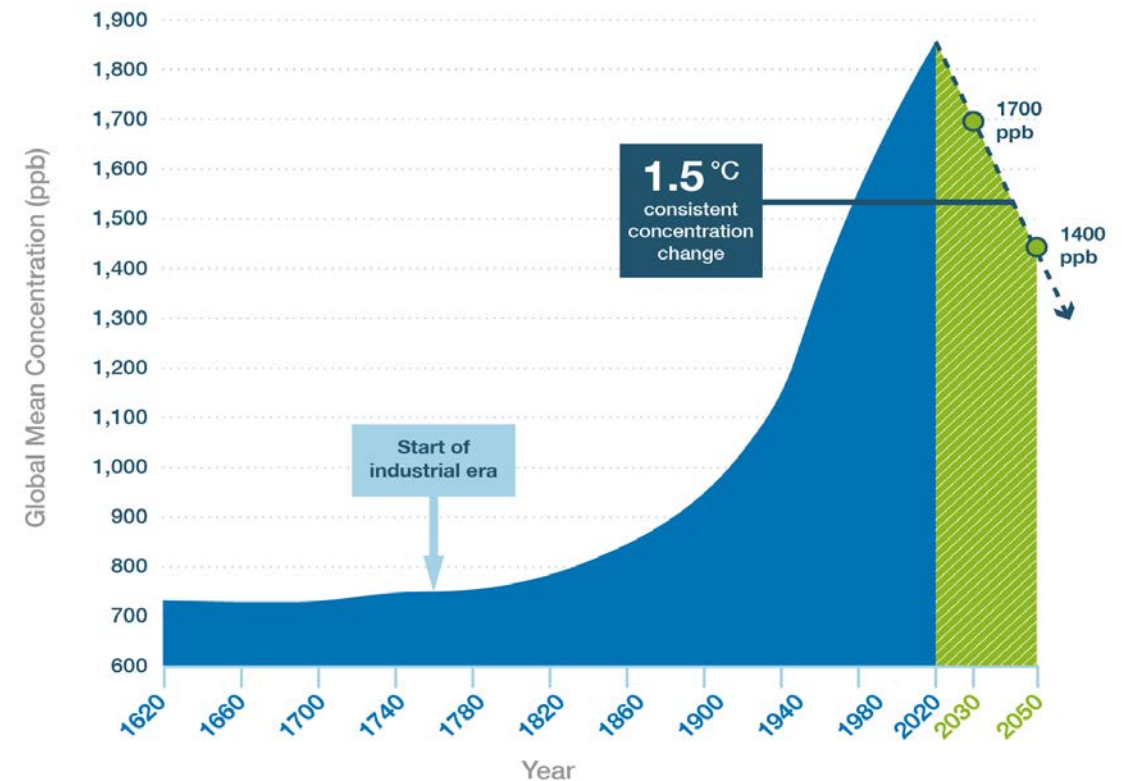
Source: Ed Dlugokencky, NOAA/ESRL

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TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

Limiting Warming to 1.5°C at the Lowest Cost

By **2030**

methane emissions need to be reduced in each of the three main emitting sectors:

Fossil Fuels	Waste	Agriculture
60%	30% - 35%	20% - 25%

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CLIMATE & CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

	Avoided warming (C) 2040-2070	Avoided deaths ozone (per year)	Avoided asthma-related ER visits (per year)	Avoided crop losses (Mt/yr)	Lost work hours avoided (billion hrs/yr)
AGRICULTURE	0.04	40 000	120 000	4	11
WASTE	0.05	45 000	135 000	5	13
FOSSIL FUELS	0.09	80 000	250 000	8	24
ADDITIONAL	0.10	90 000	270 000	9	25
TOTAL	0.28	255 000	775 000	26	73

Remaining global anthropogenic methane emissions

Range of methane mitigation consistent with the IPCC 1.5°C pathways

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CLIMATE & CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

	Avoided warming (C) 2040-2070	Avoided deaths ozone (per year)	Avoided asthma-related ER visits (per year)	Avoided crop losses (Mt/yr)	Lost work hours avoided (billion hrs/yr)
NEGATIVE COST	0.06	55 000	170 000	6	16
LOW COST	0.05	45 000	145 000	4	14
ALL COST	0.07	65 000	190 000	7	18
ADDITIONAL	0.10	90 000	270 000	9	25
TOTAL	0.28	255 000	775 000	26	73

Remaining global anthropogenic methane emissions

Range of methane mitigation consistent with the IPCC 1.5°C pathways

1.5 °C consistent mitigation

Anthropogenic methane emissions (Mt/yr)

Year

2020   2030

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CLIMATE & CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

Global Methane Pledge – an important concrete step to address SLCPs

Countries have committed to collectively reduce human-caused methane emissions by at least 30% by 2030

A total of over 107 countries representing 70% of the global economy and nearly half of anthropogenic methane emissions have now signed onto the pledge

Conclusions

Progress on SLCPs and integrating air pollution and climate change planning:

- Penny has dropped that need to consider the mitigation of these together
- Now the planning needs to be institutionalised and made easy to update
- Health benefits of action now increasingly part of climate discourse
- **BC mitigation** – countries are very interested due to local benefits – some need support, and it can increase climate ambition. Emissions decreasing in most places – but needs more focus
- **HFCs** – covered by Kigali – should reduce – could do with it going faster
- **Methane** – emissions increasing rapidly – but opportunities are huge to reduce this rapidly – methane pledge is great first step

Thank you for listening

johan.kuylenstierna@york.ac.uk
chris.malley@york.ac.uk

METHANE (CH$_4$)

Methane emissions caused by human activities are one of the most significant drivers of climate change. Methane is also the main precursor of tropospheric ozone, a powerful greenhouse gas and air pollutant.

SOURCES

Methane is one of the fastest growing greenhouse gases in the atmosphere. Human activity causes ⅔ of emissions.

42%
AGRICULTURE

36%
FOSSIL FUEL OPERATIONS

18%
WASTE

**3%**
OTHER

% = global emissions

IMPACTS

CLIMATE
Responsible for **40% of warming** since the industrial revolution

84x
times more powerful than carbon dioxide over a **20-year period**

HEALTH
Increasing emissions are driving a rise in tropospheric ozone air pollution, **causing 1+ million premature deaths annually**

- Respiratory diseases
- Heart disease
- Damages airways and lung tissue
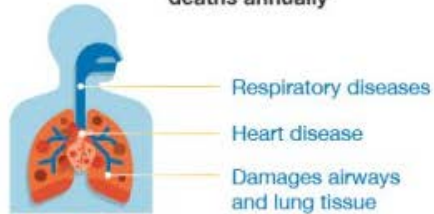
AGRICULTURE & ECOSYSTEMS

Up to **15%** annual yield losses of soy, wheat, rice and maize
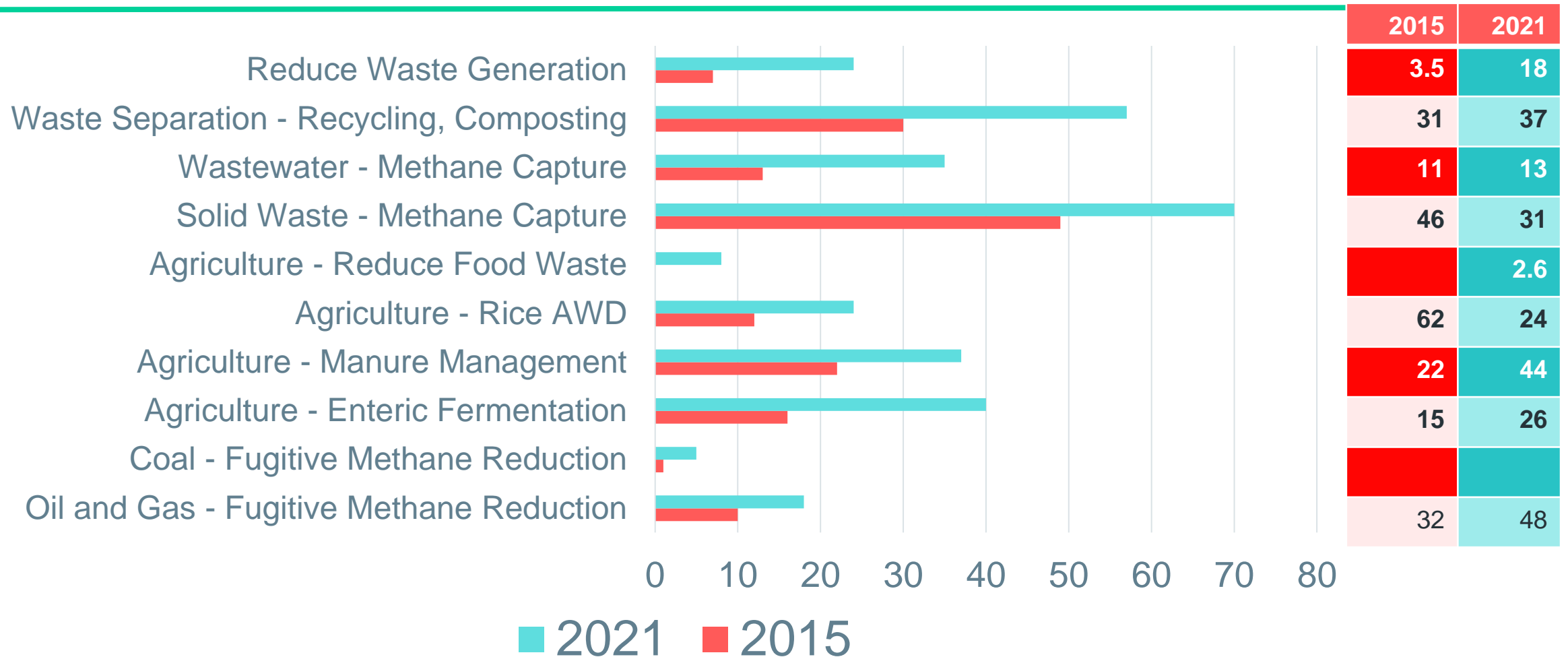
LIFETIME IN ATMOSPHERE:
12 YEARS

Since methane does not last long in the atmosphere, efforts to reduce it will bring immediate benefits for the climate and human health.

ccacoalition.org

Number of NDCs submitted in 2015 and 2020/2021 that included mitigation measures targeting major methane sources

	2015	2021
Reduce Waste Generation	3.5	18
Waste Separation - Recycling, Composting	31	37
Wastewater - Methane Capture	11	13
Solid Waste - Methane Capture	46	31
Agriculture - Reduce Food Waste		2.6
Agriculture - Rice AWD	62	24
Agriculture - Manure Management	22	44
Agriculture - Enteric Fermentation	15	26
Coal - Fugitive Methane Reduction		
Oil and Gas - Fugitive Methane Reduction	32	48

■ 2021 ■ 2015

Note: the amount of methane reduced is compared to unabated emissions for 2018 in both cases. China did not include AWD or solid waste methane recovery in 2021 – perhaps as these actions were already taken… so the decrease may be an anomaly

TARGETED MEASURES

FOSSIL FUEL SECTOR (oil, gas, and coal)

- **Upstream and downstream leak detection and repair**

- **Recovery and utilization of vented gas**: capture of associated gas from oil wells; blowdown capture; recovery and utilization of vented gas with vapor recovery units and well plungers; installation of flares.

- **Improved control of unintended fugitive emissions from the production of oil and natural gas**: regular inspections (and repair) of sites using instruments to detect leaks and emissions due to improper operations; replace pressurized gas pumps and controllers with electric or air systems; replace gas-powered pneumatic devices and gasoline or diesel engines with electric motors; early replacement of devices with lower-release versions; replace compressor seals or rods; cap unused wells.

- **Coal mine methane management:** pre-mining degasification and recovery and oxidation of ventilation air methane; flooding abandoned coal mines

WASTE SECTOR

- **Solid waste management**:
(residential) source separation with recycling/reuse; no landfill of organic waste; treatment with energy recovery or collection and flaring of landfill gas;
(industrial) recycling or treatment with energy recovery; no landfill of organic waste.

- **Wastewater treatment:**
(residential) upgrade to secondary/tertiary anaerobic treatment with biogas recovery and utilization; wastewater treatment plants instead of latrines and disposal;
(industrial) upgrade to two-stage treatment, i.e., anaerobic treatment with biogas recovery followed by aerobic treatment.

AGRICULTURE SECTOR

- **Improve animal health and husbandry**: reduce enteric fermentation in cattle, sheep and other ruminants through feed changes and supplements; selective breeding to improve productivity and animal health/fertility
- **Livestock manure management:** treatment in biogas digesters; decreased manure storage time; improve manure storage covering; improve housing systems and bedding; manure acidification.
- **Rice paddies:** improved water management or alternate flooding/drainage wetland rice; direct wet seeding; phosphogypsum and sulphate addition to inhibit methanogenesis; composting rice straw; use of alternative hybrids species.
- **Agricultural crop residues**: prevent burning of agricultural crop residues.

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TO REDUCE SHORT–LIVED
CLIMATE POLLUTANTS

ADDITIONAL BENEFICIAL MEASURES

FOSSIL FUEL SECTOR (oil, gas, and coal)

- **Renewables for power generation:** use incentives to foster expanded use of wind, solar, and hydro power for electricity generation.

- **Improved energy efficiency and energy demand management:**
(residential) use incentives to improve the energy efficiency of household appliances, buildings, lighting, heating and cooling, encourage rooftop solar installations;
(industrial) introduce ambitious energy efficiency standards for industry; improve consumer awareness of cleaner energy options.

WASTE SECTOR

- **Reduced consumer waste** and improved waste separation and recycling, improved sustainable consumption.

AGRICULTURE SECTOR

- **Reduced food waste and loss:** strengthen and expand food cold chains; consumer education campaigns; facilitate donation of unsold or excess food.

- **Adoption of healthier diets:** decrease intake where consumption of ruminant products is above recommended guidelines.

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CLIMATE & CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

Providing quantitative assessments

LEAP

Emissions

Transport

Exposure

Impacts: Climate

Impacts: Health and vegetation

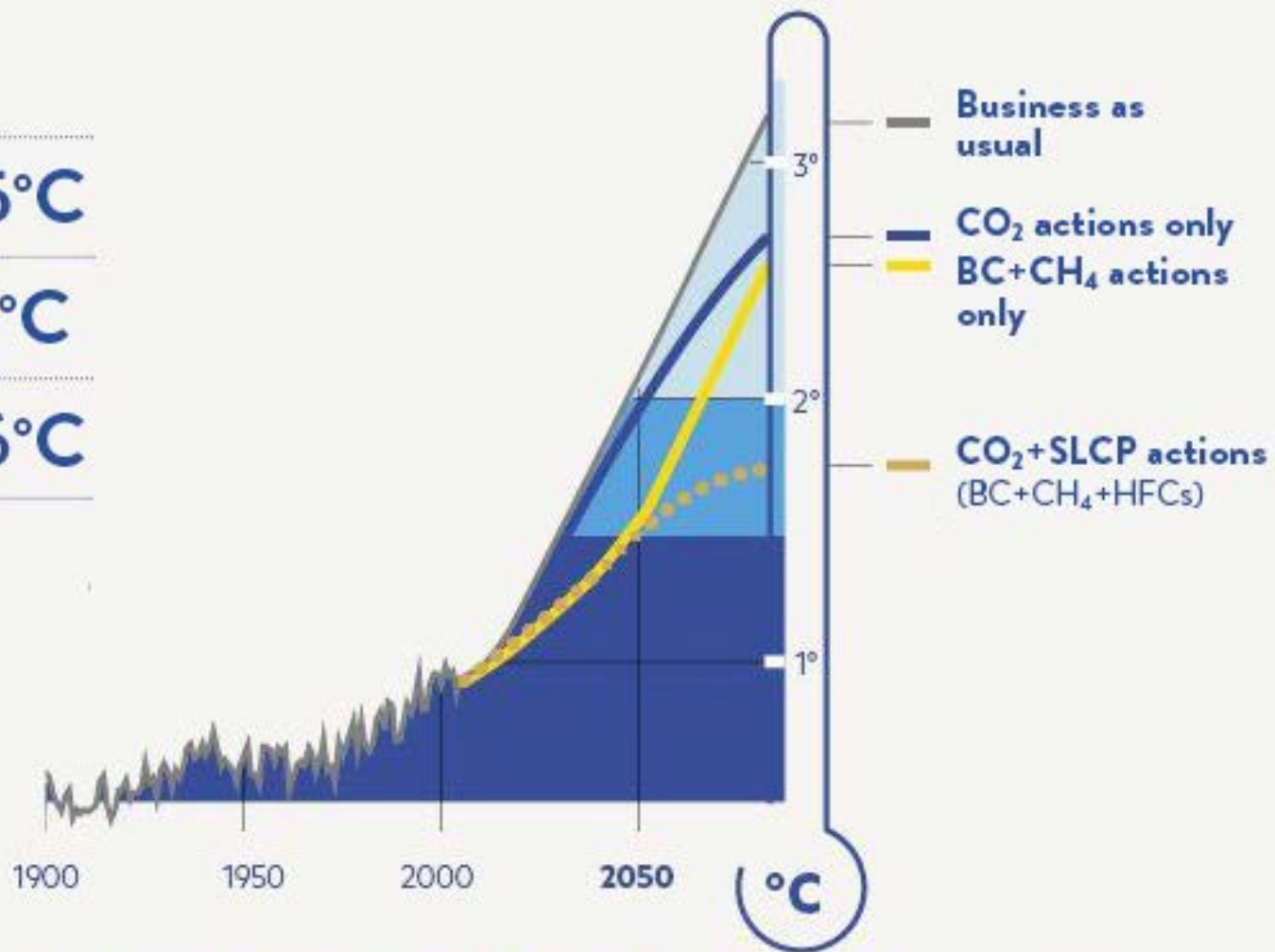# CLIMATE MITIGATION PATHWAYS
Avoided global warming by 2050

Black Carbon (BC) + Methane (CH₄)	0.5°C
Hydrofluorocarbons (HFCs)	0.1°C
All Short-Lived Climate Pollutants	0.6°C

Business as usual

CO₂ actions only

BC+CH₄ actions only

CO₂+SLCP actions (BC+CH₄+HFCs)

3°
2°
1°

1900 1950 2000 **2050** °C

SIMULATED TEMPERATURE CHANGE UNDER VARIOUS MITIGATION SCENARIOS

www.ccacoalition.org/science

CLIMATE & CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS