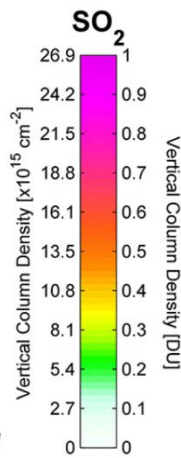
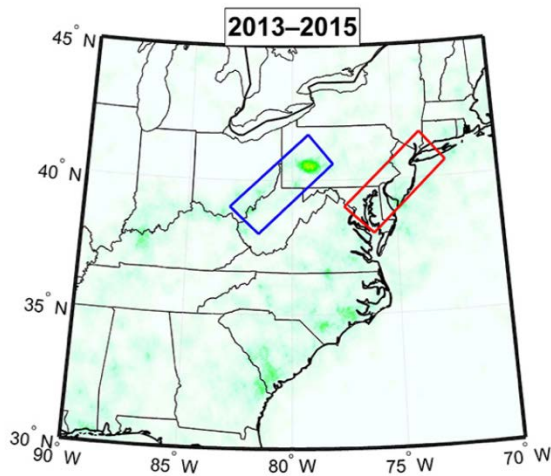


EVS341

Air Quality Standards and Objectives



Recap of Last Week's Lecture

Sources of air pollution:

- Type and origin
- Primary (directly emitted)
- Secondary (chemical processing)

Processing of air pollution:

- Physical (transport)
- Chemical (oxidation, condense to aerosols)

Sinks of air pollution:

- Dry deposition
- Wet deposition

Examples of air pollution:

- Fine particles ($\text{PM}_{2.5}$)
- Ozone (O_3)
- Acid Rain
- Eutrophication
- Persistent Organic Pollutants (POPs)
- Heavy Metals
- Chlorofluorocarbons (CFCs)

Today's Lecture Outline

AIR QUALITY STRATEGY

- General legislative framework
- Air quality strategy
- Air quality standards
- Local air quality management (LAQM)

INSPECTION and ENFORCEMENT

- Monitoring compliance
- Cheating compliance (VW Emissions Scandal)

ASSESSING SUCCESS OF AIR QUALITY POLICY

- From space
- From the ground

PUTTING ALL 3 LECTURES TOGETHER

Generic Air Quality Strategy



Establish Environmental Act



Establish government agency: protect environment



Develop targets and standards



Measure, assess and review local air quality

Regulatory Agencies by Country/Region

United Kingdom



Department
for Environment
Food & Rural Affairs

China



中华人民共和国
环境保护部

Ministry of Environmental Protection
The People's Republic of China

United States



Europe



European
Environment
Agency

Japan



環境省

Ministry of the Environment

South Africa



environmental affairs

Department:
Environmental Affairs
REPUBLIC OF SOUTH AFRICA

UK Air Quality Strategy

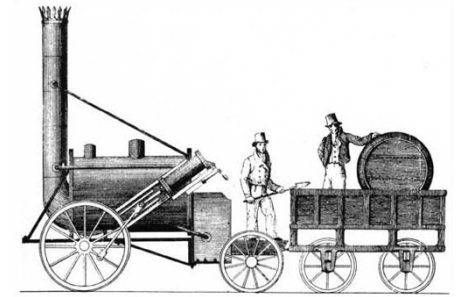
Historical Perspective (Snapshots)



1273: Prohibit coal (coke) use in London



1306: Ban use of sea coal in furnaces



1845: Locomotives made to consume own smoke



1980s: Controls on power plants



1970s: Directives and Controls on vehicles



1956: Clean Air Act (controls on chimneys)

Full timeline here: <http://www.air-quality.org.uk/02.php>

UK Air Quality Strategy

Recent History

1990: Environmental Protection Act

Small emissions sources under control of local authorities

1995: The Environment Act

Regulatory framework for local air quality management
(**LAQM**)



The Environment Act of 1995:

Requires that National Air Quality Strategies be published

AQ Strategy documents:

- Define air quality standards and targets for priority pollutants
- Published in 1997, 2000, and 2007.
- Develop with a panel of experts (**Air Quality Expert Group, AQEG**)
- Rigorous review before comes into effect

Air Quality Standards

Definition: Threshold concentration of an air pollutant above which it negatively impacts human and environmental health

Developed in consultation with an **advisory board**

UK advisory board: **Expert Panel on Air Quality Standards (EPAQS)**

AQ Standard Features

Concentration:

ppb for gases

$\mu\text{g}/\text{m}^3$ for aerosols and gases

Averaging period:

Short (acute) or long (chronic) term

Season (vegetation or ecosystem)

Cumulative (vegetation or ecosystem)

Examples: 1-hour mean (acute), 24-hour mean (acute), annual mean (chronic), maximum daily 8-hour average or MDA8 (ozone).

Number of exceedances:

Area out of compliance if standard exceeded a certain number of times

Air Quality Standards

Running mean practice example

Hourly average ozone measured in central Birmingham:

| Hour | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 |
|----------------------|------|------|------|------|------|------|------|------|------|------|------|
| O ₃ (ppb) | 44.2 | 46.2 | 40.8 | 43.0 | 40.9 | 33.5 | 30.4 | 32.8 | 36.4 | 36.4 | 38.2 |

What is the 8-hour running mean ozone concentration at this site at 8pm?

A Look at the AQ Standards for the UK

Sample of standards for the protection of human health

| National air quality objectives and European Directive limit and target values for the protection of human health | | | | | | | |
|---|----------------------|---|---|--|--|--|--|
| Pollutant | Applies | Objective | Concentration measured as ¹⁰ | Date to be achieved by and maintained thereafter | European obligations | Date to be achieved by and maintained thereafter | New or existing |
| Particles (PM _{2.5}) Exposure Reduction | UK (except Scotland) | 25µg.m ⁻³ | annual mean | 2020 | Target value 25µg.m ⁻³ ¹² | 2010 | New (European obligations still under negotiation) |
| | Scotland | 12µg.m ⁻³ | | 2020 | Limit value 25µg.m ⁻³ | 2015 | |
| | UK urban areas | Target of 15% reduction in concentrations at urban background ¹¹ | | Between 2010 and 2020 | Target of 20% reduction in concentrations at urban background | Between 2010 and 2020 | |
| Nitrogen dioxide | UK | 200µg.m ⁻³ not to be exceeded more than 18 times a year | 1 hour mean | 31 December 2005 | 200µg.m ⁻³ not to be exceeded more than 18 times a year | 1 January 2010 | Retain existing |
| | UK | 40µg.m ⁻³ | annual mean | 31 December 2005 | 40µg.m ⁻³ | 1 January 2010 | |
| Ozone | UK | 100µg.m ⁻³ not to be exceeded more than 10 times a year | 8 hour mean | 31 December 2005 | Target of 120µg.m ⁻³ not to be exceeded more than 25 times a year averaged over 3 years | 31 December 2010 | Retain existing |

Concentration & Exceedances

Averaging period

Target date

EU equivalent standards, exceedances, and targets

Other pollutants monitored: **PM₁₀**, sulphur dioxide (**SO₂**), Polycyclic aromatic hydrocarbons (**PAHs**), **benzene**, **1,3-butadiene**, **lead**

A Look at the AQ Standards for the UK

Standards for the protection of vegetation and ecosystems

| Pollutant | Applies | Objective | Concentration measured as | Date to be achieved by and maintained thereafter | European obligations | Date to be achieved by and maintained thereafter | New or existing |
|--|---------|---|---------------------------|--|---|--|---|
| National air quality objectives and European Directive limit and target values for the protection of vegetation and ecosystems | | | | | | | |
| Nitrogen oxides | UK | 30µg.m ⁻³ | annual mean | 31 December 2000 | 30µg.m ⁻³ | 19 July 2001 | Retain existing in accordance with 1 st Daughter Directive |
| Sulphur dioxide | UK | 20µg.m ⁻³ | annual mean | 31 December 2000 | 20µg.m ⁻³ | 19 July 2001 | Retain existing in accordance with 1 st Daughter Directive |
| | UK | 20µg.m ⁻³ | winter average | 31 December 2000 | 20µg.m ⁻³ | 19 July 2001 | |
| Ozone: protection of vegetation & ecosystems | UK | Target value of 18,000µg m ⁻³ based on AOT40 to be calculated from 1 hour values from May to July, and to be achieved, so far as possible, by 2010 | Average over 5 years | 1 January 2010 | Target value of 18,000µg m ⁻³ based on AOT40 to be calculated from 1 hour values from May to July, and to be achieved, so far as possible, by 2010 | 1 January 2010 | New EU target |

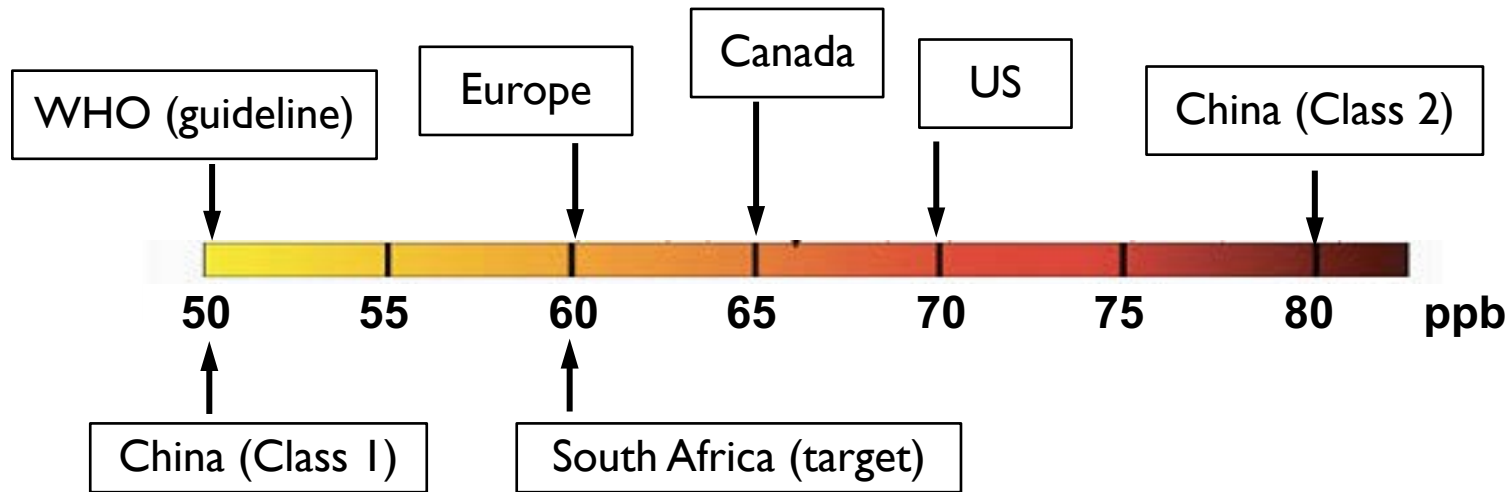
NO_x: Excessive addition of nutrients (eutrophication)
Precursor of ozone (oxidant harmful to plants)

SO₂: Contributes to acid rain
Precursor of sulfate, a component of PM_{2.5} (changes light availability for plants)

Ozone: Powerful oxidant harmful to crops (food security) and other vegetation

Air Quality Standards by Country/Region

Comparison of current MDA8 ozone standards, guidelines and targets



Class 1: special locations (national parks)

Class 2: other areas (industrial and urban)

Reminder: **MDA8** is maximum daily average 8-hour

Ozone is often reported in $\mu\text{g m}^{-3}$.

Conversion: $1 \mu\text{g m}^{-3} = 0.5 \text{ ppb}$

Health Thresholds

Toxicology Tests

Test toxicity in cells or animals

Response ranges from subtle changes to death

Conduct exposure or dose experiments

Limitation: issues scaling from laboratory animal to human



Clinical Cases

Individual experiments of air pollution exposure

Limitation: narrow exposure range



Health Thresholds

Epidemiological Studies

Human population exposed to a chemical is compared to a non-exposed group
Identify statically significant association between health and exposure.

Harvard Six Cities Study

Mortality amongst 8111 adults in 6 cities in the US with different levels of pollution from 1974 to 1991.

Letters are different cities:

W: Watertown, Massachusetts

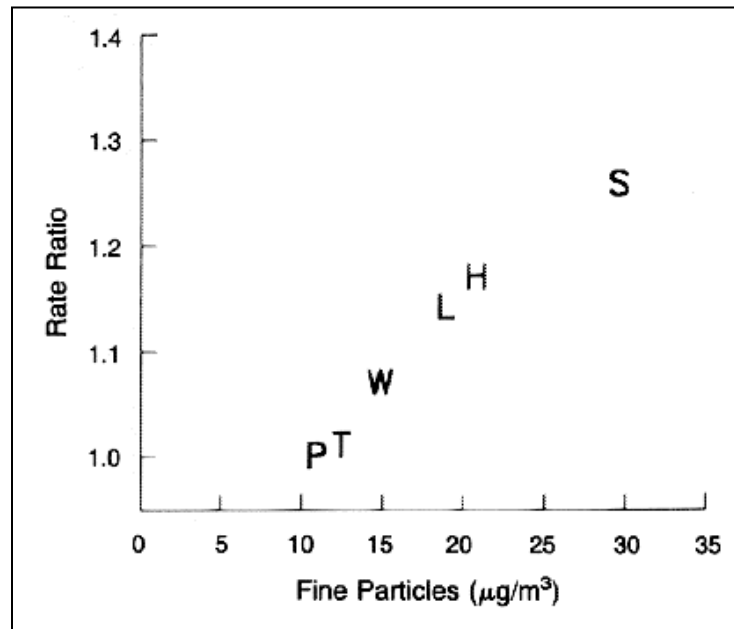
H: Harriman, Tennessee

S: Steubenville, Ohio

P: Portage, Wisconsin

T: Topeka, Kansas

L: St. Louis, Ohio.



Source: Dockery et al., 1993

Linear relationship between fine particles and adverse health
(**does not prove causation**)!

UK Local Air Quality Management (LAQM)

Role of Local Authorities

Review current and future local air quality

Assess against standards and objectives

Local authorities designate infringement areas as **air quality management areas (AQMAs)** and take action.

Environmental consultants contracted to measure and assess pollution and provide recommendations.



Responsibilities of Birmingham City Council:

- Monitor and report on levels of NO₂, PM₁₀, PM_{2.5}, and SO₂.
- Develop action plans where air quality is poor

Latest annual report by BCC shows that PM₁₀, PM_{2.5} and SO₂ are in compliance, but NO₂ is exceeded (<https://www.birmingham.gov.uk/info/20076/pollution>).

AQMA and Action Plans

Action plan not done in isolation: involves multiple sectors (e.g. transport, energy)

Examples:

Controls on pollution sources

Smart city planning

Demarcate Clean Air Zones

Recent Birmingham City Council Action Plan:

Clean Air Zone



A Clean Air Zone is an area where targeted action is taken to improve air quality. Clean Air Zones aim to reduce all types of air pollution, including nitrogen dioxide and particulate matter, so that people breathe in less of all these pollutants.

Within a Clean Air Zone, there is also a focus on reducing carbon emissions and making sure that improvements in air quality are long lasting. Pollution should not be increased by growth in population, new buildings or changes in land use.

There are two types of Clean Air Zone:

- non-charging Clean Air Zones – these will have a focus for action to improve air quality but do not include charging money for any type of vehicle to enter the zone.
- charging Clean Air Zones – drivers must pay to enter these zones if their vehicle is of a type which emits too much pollution.



Source: <https://www.birmingham.gov.uk/>

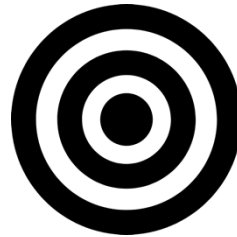
UK Air Quality Strategy



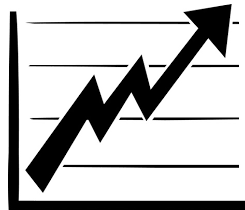
The Environmental Act of 1995



Department for Environment Food and Rural Affairs



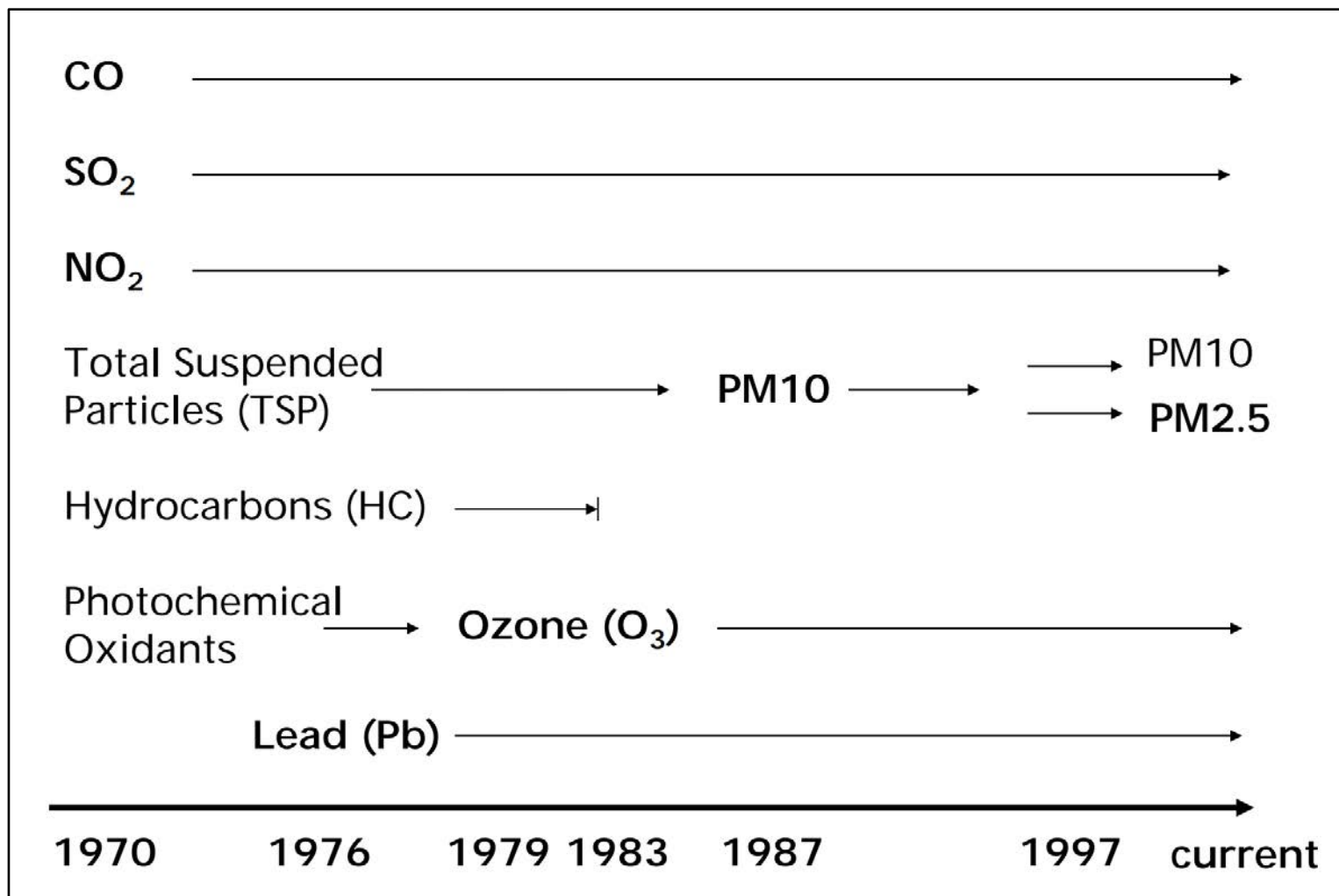
Air Quality Strategy documents



Local Air Quality Management & Air Quality Management Areas

Evolution of AQ regulation in the US

Timeline of regulating priority pollutants in the US



Air Quality Policy in China

Structure:

Ministry of Environmental Protection (MEP) is tasked with protecting the environment
Central government issues strict regulations
Local governments monitor and enforce

Timeline:

1978: Third Chinese Constitution issued included an environmental commission.
1979: Trial Environmental Protection Law issued
1989: Environmental Protection Law issued
1989-present: 30 laws issued related to the environment
2006: China gets serious about emissions controls in its 11th Five-Year Plan

Issue:

Regulatory system is comprehensive
Implementation and enforcement are weak

Further Reading:

Highlights of the 13th 5-Year Plan:

http://news.xinhuanet.com/english/photo/2015-11/04/c_134783513.htm

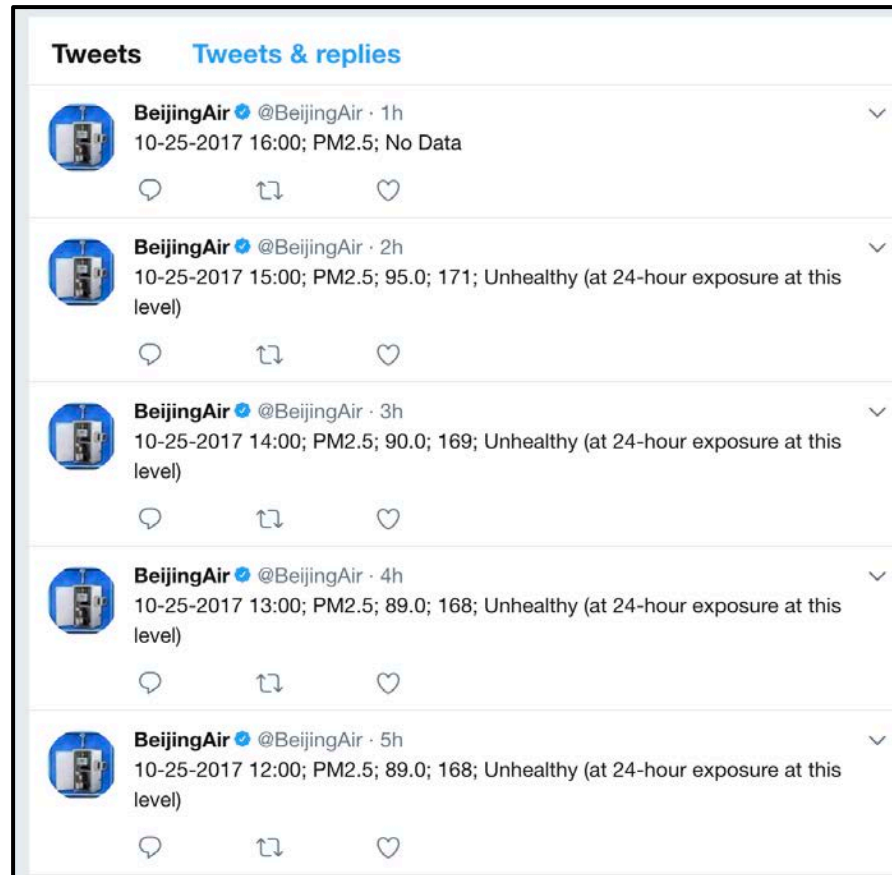
AQ standards: <http://www.transportpolicy.net/standard/china-air-quality-standards/>

Air Quality and Diplomacy

US Embassy tweets out that Beijing has “crazy bad” air quality (2010)

US Embassy results contradict measurements from local authorities (2012/13)

US Embassy BeijingAir twitter page



Link to video: <https://www.youtube.com/watch?v=0-u2bt36qaQ>

Inspection and Enforcement

Air Quality Policy is nothing without clear strategy to monitor compliance

Monitoring Compliance

Do emissions from pollution source meet emissions standards?
Is Clean Air Zone at target concentrations?

Logistics: needs to be as convenient and cost-effective as possible.

Incentive to comply (fined if caught).

Examples:

SO₂ from coal-fired power plants (smokestack measurements)

NO_x (NO + NO₂) from motor vehicles (exhaust measurements)

PM_{2.5} from a Clean Air Zone monitoring station

Inspection and Enforcement

UK (and EU) Vehicles

Vehicles in the UK need to meet Euro 6 standards (implemented 2014)

Euro 6 Emissions Standards

| Pollutant | Emission Standard (grams per km) | |
|-----------------|----------------------------------|--------|
| | Petrol | Diesel |
| CO | 1.0 | 0.50 |
| NO _x | 0.06 | 0.08 |
| Particles | 0.005 | 0.005 |



| Description | Limits | Actual Value | |
|--------------------------|-----------------|------------------------|---------------|
| Fast Idle Test | | | Pass |
| RPM | 2500 - 3000 RPM | Manual Check | Pass |
| CO | <= 0.2 % | 0.06 % | Pass |
| HC | <= 200 PPM | 68 PPM | Pass |
| Lambda | 0.97 - 1.03 | 1.00 | Pass |
| Natural Idle Test | | | |
| RPM | 450 - 1500 RPM | Manual Check | Pass |
| CO | <= 0.3 % | 0.05 % | Pass |
| Overall Result: | | Exhaust Emissions Test | Passed |



Cheating Compliance

The VW Emissions Scandal

How A Little Lab In West Virginia Caught Volkswagen's Big Cheat

September 24, 2015 · 5:04 AM ET

Heard on [Morning Edition](#)



SONARI GLINTON



Diesel car engines like this one in a 2012 Volkswagen Golf are among those that [include software that circumvents EPA emissions standards](#) for certain air pollutants.

Patrick Pleul/DPA/Landov

Source: <http://www.npr.org/>

Cheating Compliance

The VW Emissions Scandal

Video (The Verge): <https://www.youtube.com/watch?v=CQ4irwe3ZDk>

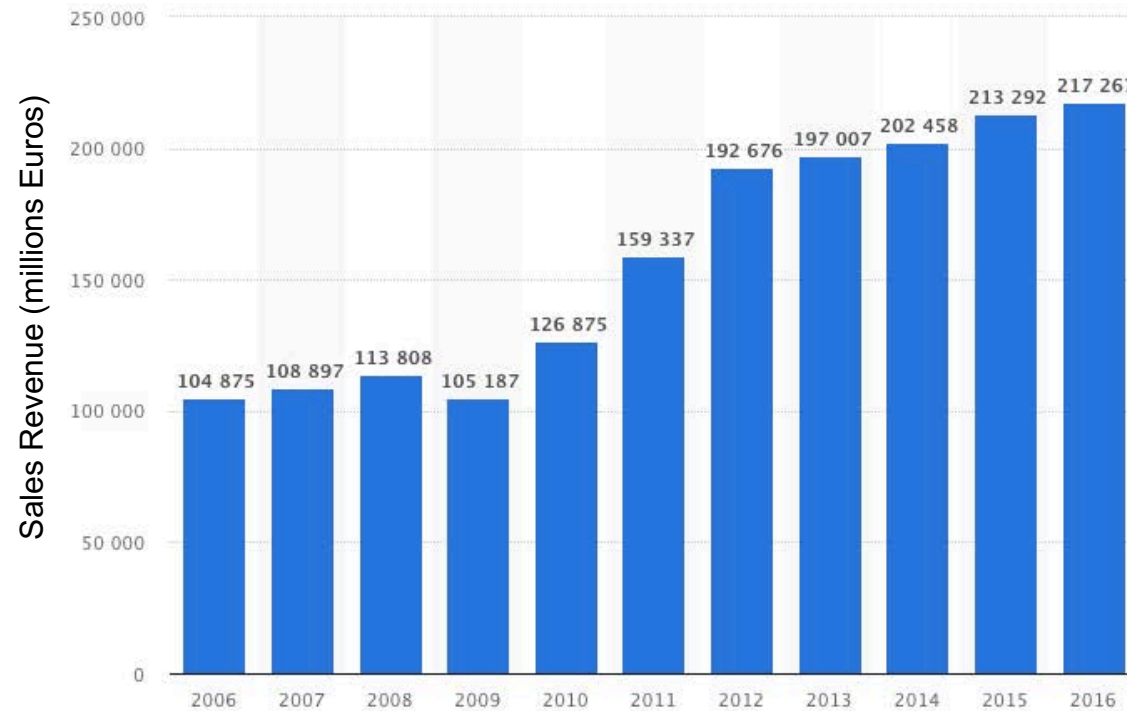
Video (Timeline): <https://www.youtube.com/watch?v=Y5TvFY7xRDM>

Cheating Compliance

The VW Emissions Scandal

Impact on VW Sales Revenue?

Volkswagen AG's sales revenue from FY 2006 to FY 2016 (in million euros)



Cheating revealed

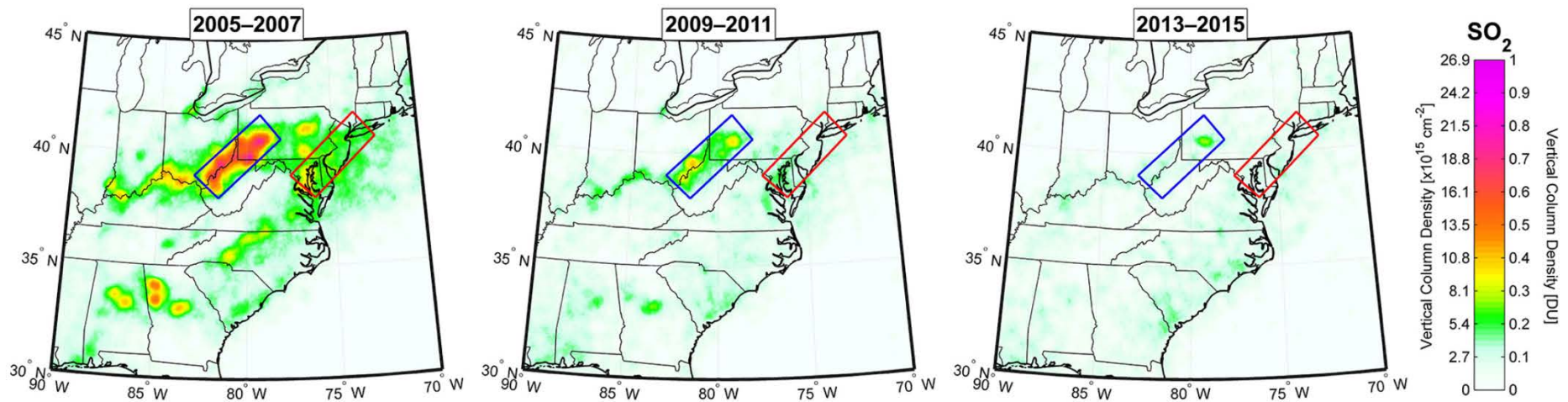
Evidence of Air Quality Improvements

Tracking air quality improvements from space

NASA Video:

<https://www.nasa.gov/press-release/new-nasa-satellite-maps-show-human-fingerprint-on-global-air-quality>

Decrease in SO₂ over the eastern US from 2005 to 2015



Source: Krotkov et al., 2016

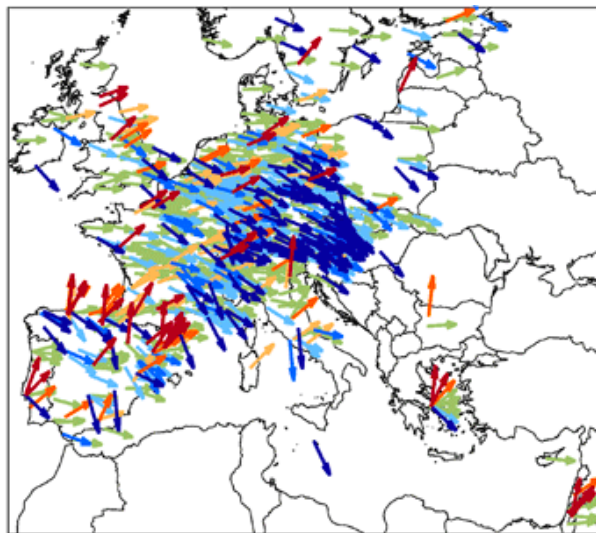
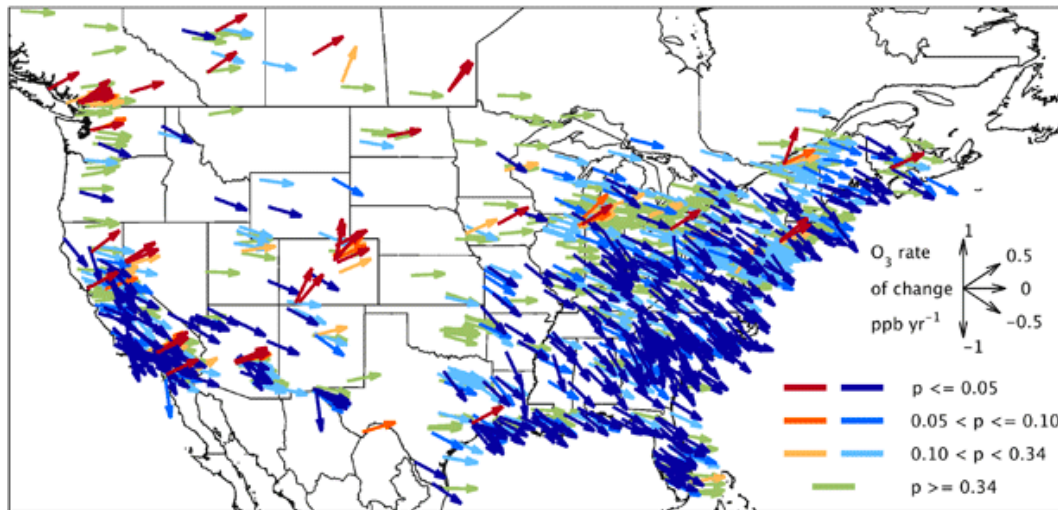
Many feared economy would suffer due to environmental regulation

US GDP grew by 38% from 2005 to 2015

Evidence of Air Quality Improvements

Tracking air quality improvements from the ground

Trends in summer daytime average surface ozone from 2000 to 2014



How to interpret the plot:

Arrow angle: size of change

Arrow colour: direction of change

Blue: decrease

Red: increase

Arrow shade: statistical significance

Dark : Significant

Light : Not significant

Source: Chang et al., 2017

Putting It All Together

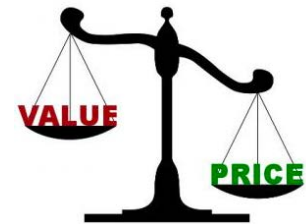
Identify problem



Quantify air pollution



Assess impact



Control strategies cost-benefit analysis



**Develop and Implement
Action Plan**



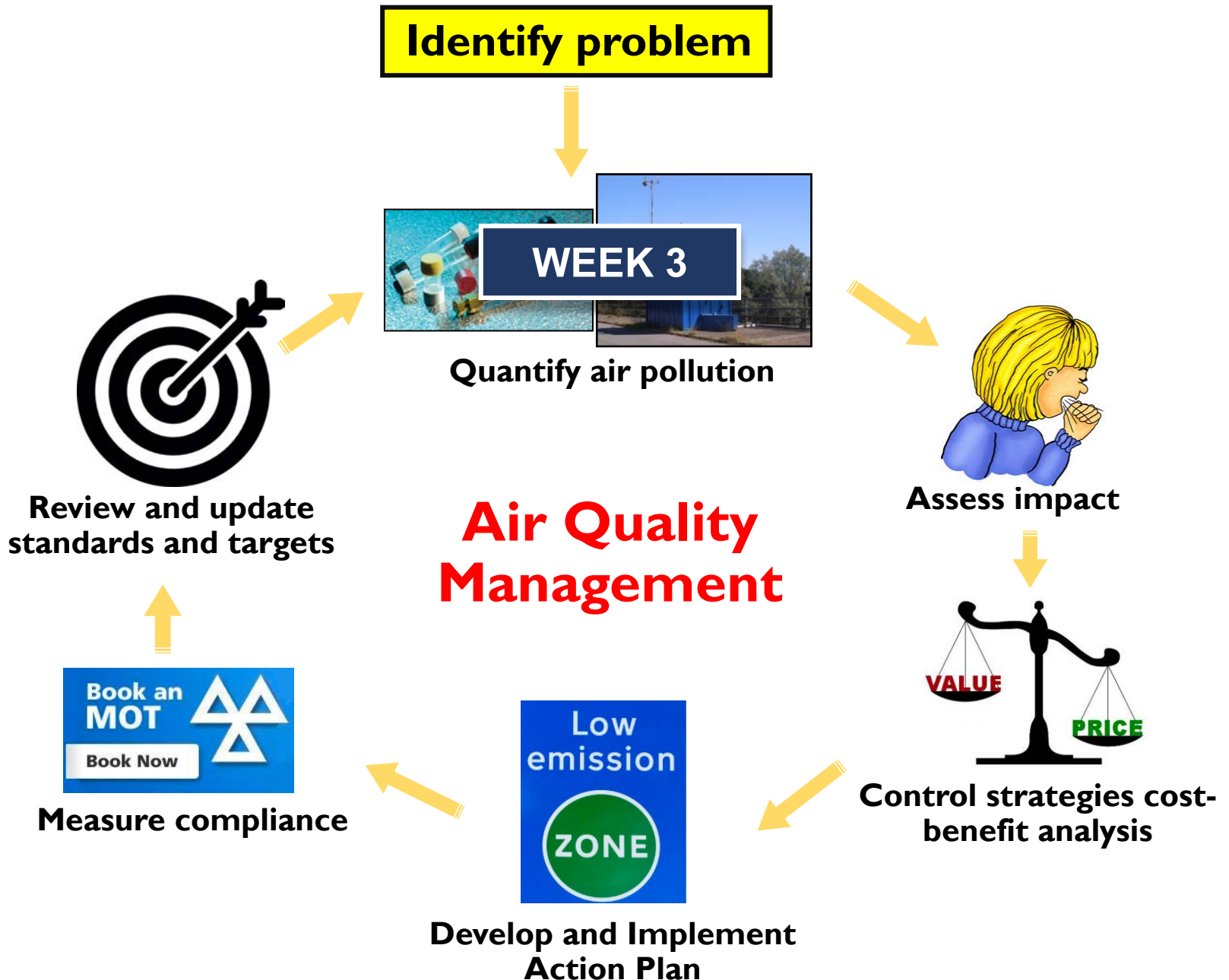
**Review and update
standards and targets**



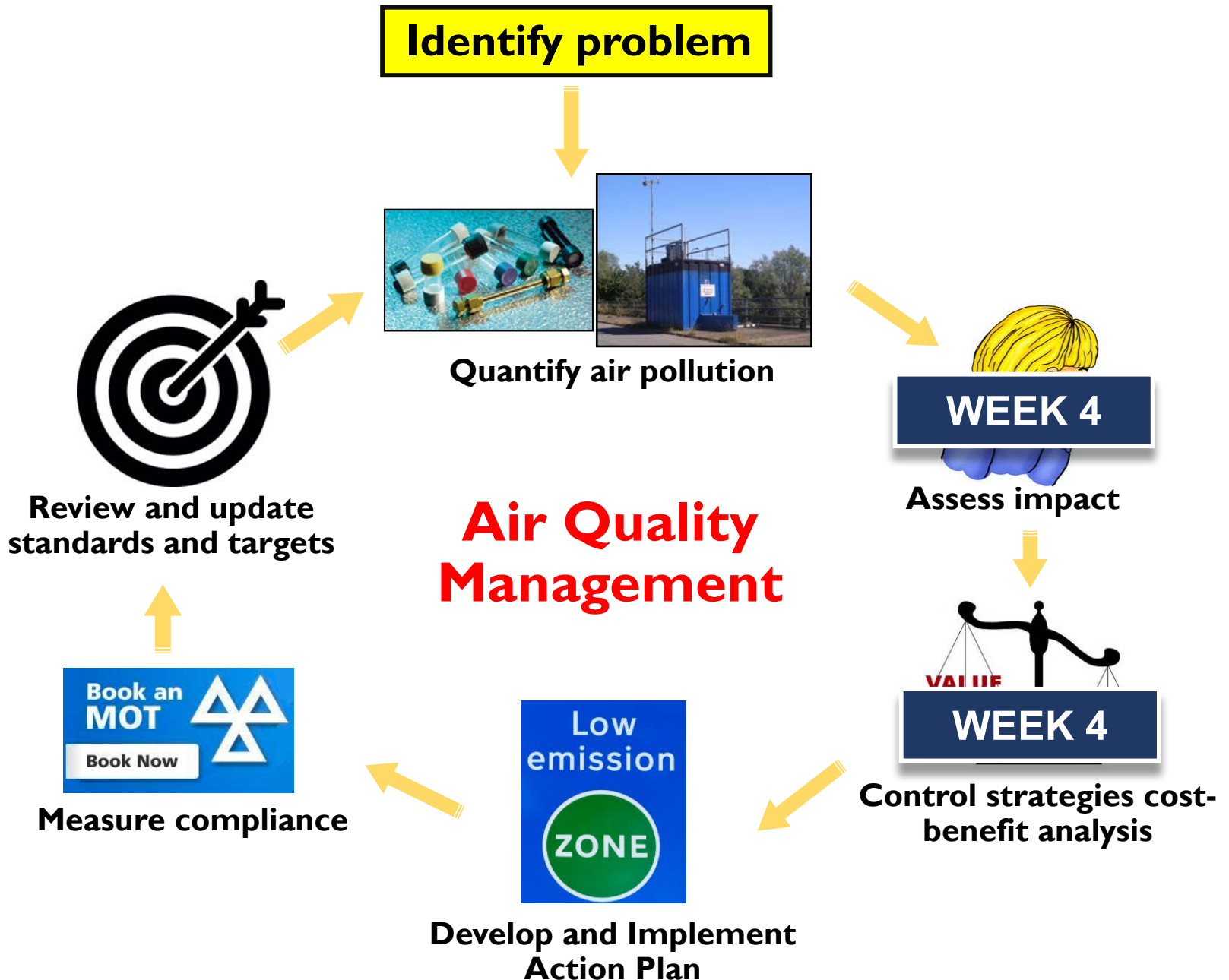
Measure compliance

**Air Quality
Management**

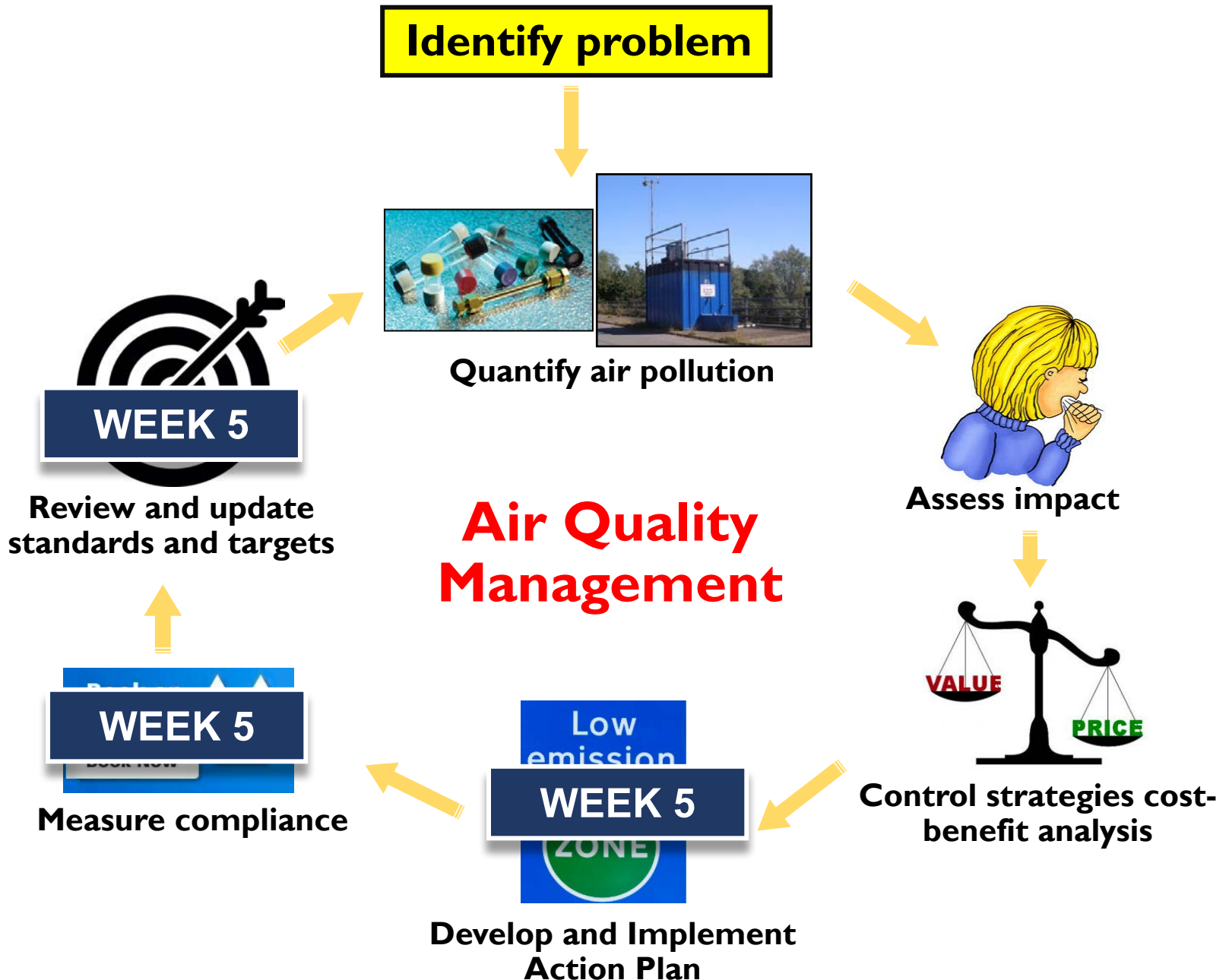
Putting It All Together



Putting It All Together



Putting It All Together



Worked Example

Thought Experiment

Task: The Birmingham City Council seeks the services of your Consultancy company to determine personal exposure to roadside pollution at a bus stop along the A4040.

Questions following Week 4:

What monitors would you use? (Week 3)

What pollutants would you measure? (Week 4)

What are the AQ standards? (Week 5)

Form groups of 4-5 individuals and discuss a potential air pollution assessment and monitoring strategy to propose to the Birmingham City Council. Provide justification for your approach and the advantages and potential limitations (25 min).

Choose a member from the group who might be selected to provide feedback from the group discussion (15 min).