Ozono, vegetazione e adattamento al cambiamento climatico

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Presentation’s structure

- Ozone: the present status
- Ozone present impacts on crops, forests and biodiversity
- Interactions between ozone and climate change
- Ozone levels: future projections
- Ozone exposure and risk: future projections
- International policies
- Climate change adaptation strategies
- Examples of sectoral adaptation measures and tools
- Conclusions
2016 - a bloom of reports
Ozone: the present status
Tropospheric ozone worldwide

Source: NASA 2015
Worldwide ozone distribution and trend

Europe: ozone rural AOT40 for crops in 2013
Europe: ozone rural AOT40 for forests in 2013
Europe: ozone exposure trend for crops 1996-2013

Source: EEA 2016, Air Quality Report
Ozone trends: background and peak levels

Source: EMEP-TFMM 2016_Air pollution trends in the EMEP region
Ozone trend in remote rural sites

Source: EMEP-TFMM 2016_Air pollution trends in the EMEP region
NO$_2$ trend in the EMEP region

Source: EMEP-TFMM 2016_Air pollution trends in the EMEP region
VOCs trend in the EMEP region

Source: EMEP-TFMM 2016_Air pollution trends in the EMEP region
Ozone present impacts on crops, forests and biodiversity
Metric for ozone impact on vegetation

\[
M12 \text{ (ppbv)} = \frac{1}{n} \sum_{i=1}^{n} [Co_3]_i
\]

\[
AOT40 \text{ (ppm h)} = \sum_{i=1}^{n} ([Co_3]_i - 0.04) \text{ for } Co_3 \geq 0.04 \text{ ppmv}
\]

\[
POD_Y = \int \max(F_{st} - Y, 0) \, dt
\]
Crops exposure to ozone worldwide in 2000

Source: Avnery et. al., 2011, Atm. Env. 45, 2284-2296
Yield loss (soybean, maize, wheat) in 2000

Source: Avnery et. al., 2011, Atm. Env. 45, 2284-2296

<table>
<thead>
<tr>
<th>Crop</th>
<th>No. of datapoints</th>
<th>% yield reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean(^1,^2)</td>
<td>3</td>
<td>22.5</td>
</tr>
<tr>
<td>Rice(^1,^2,^4)</td>
<td>11</td>
<td>13.7</td>
</tr>
<tr>
<td>Wheat(^1,^2)</td>
<td>10</td>
<td>7.4</td>
</tr>
<tr>
<td>Durum wheat(^2)</td>
<td>2</td>
<td>14.2</td>
</tr>
<tr>
<td>Peas / beans(^3)</td>
<td>2</td>
<td>3.2</td>
</tr>
</tbody>
</table>

Source: WGE 2016, Field evidence of ozone impacts on vegetation

Crop yield reductions, using data from
\(^1\)China, \(^2\)India, \(^3\)Japan and \(^4\)Pakistan
## OTC validation experiments

<table>
<thead>
<tr>
<th>Country</th>
<th>Ozone (24h mean, ppb)</th>
<th>Species</th>
<th>Biomass reduction</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Italy</td>
<td>37</td>
<td><em>Quercus ilex</em></td>
<td>17%</td>
<td>Gerosa et al., 2015, Atmospheric Environment 113: 41-49.</td>
</tr>
<tr>
<td>Spain</td>
<td>35</td>
<td><em>Quercus ilex</em></td>
<td>1%</td>
<td>Alonso et al., 2014, Plant Biology 16: 375-384.</td>
</tr>
<tr>
<td>Spain</td>
<td>32</td>
<td><em>Briza maxima</em></td>
<td>3%</td>
<td>Sanz et al., 2011, Environmental Pollution 159: 423-430.</td>
</tr>
<tr>
<td>Japan</td>
<td>19</td>
<td><em>Betula ermanii</em></td>
<td>4%</td>
<td>Hoshika et al., 2013, Environmental and Experimental Botany 90: 12-16.</td>
</tr>
</tbody>
</table>

Examples of responses to ozone shown in non-filtered compared to filtered air experiments

Source: WGE 2016, Field evidence of ozone impacts on vegetation

Ozone exposure experiments using open-top chambers in Spain and Italy
Risk maps for ozone exposure of crops in Europe 1990-2006

Source: Mills et. al. 2011, Global Change Biology 17, 592-613
Ozone exposure for forests (AOT40 vs POD1)

Source: EMEP 2016, Status Report
Ozone exposure for forests
POD1.6 vs AOT40

Ozone impacts on biodiversity

Source: WGE 2016, Report on biodiversity
Grassland exposure to ozone

Source: WGE 2016, Report on biodiversity
Risk assessment for grassland

Matrix for calculating the risk of ozone impact on grasslands, based on the phytotoxic ozone dose ($POD_1$) for grass* and the grassland area (%) per grid cell (0.5° (longitude) by 0.25° (latitude)). $POD_1$ was calculated over a six months period (April – September).

<table>
<thead>
<tr>
<th>Grassland area in grid cell (%)</th>
<th>POD$_1$ grass (mmol m$^{-2}$)*</th>
<th>&lt;5</th>
<th>5 - 15</th>
<th>15 - 20</th>
<th>20 - 25</th>
<th>25 - 30</th>
<th>&gt;30</th>
</tr>
</thead>
<tbody>
<tr>
<td>RISK</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>0.5 – 5</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>5 - 10</td>
<td>2</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>&gt;10</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>9</td>
<td>12</td>
<td>15</td>
<td>18</td>
</tr>
</tbody>
</table>


Source: WGE 2016, Report on biodiversity
Risk map for grassland

Source: WGE 2016, Report on biodiversity
Crossed interactions between ozone and climate change
Ozone, climate and ecosystem interaction

Ozone as a driver of climate change

Source: Sitch et al. 2007, Nature 448, 791-795
Impacts of climate change on ground ozone levels

• **Emission fluxes of ozone precursors**
  (e.g. VOC from vegetation, NO\textsubscript{X} from soil and lightning, CH\textsubscript{4} from wetlands and NO\textsubscript{X}, CO and VOC from wild fires);

• **Atmospheric chemistry**
  (e.g. via changes in temperature and atmospheric water vapour content);

• **Atmospheric dynamics**
  (e.g. boundary layer ventilation, convective mixing, prevalence of anticyclonic blocking highs, precipitation, and stratosphere-troposphere exchange);

• **Loss of ozone by dry deposition to vegetation**
  depending on soil moisture content and CO\textsubscript{2} concentrations.
Factors influencing biogenic VOCs emission

<table>
<thead>
<tr>
<th>Factor</th>
<th>Effects included in latest emissions estimates for natural nmVOC for this study (Lathiere et al. (unpublished data)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light</td>
<td>Yes</td>
</tr>
<tr>
<td>Temperature (current and previous)</td>
<td>Yes</td>
</tr>
<tr>
<td>Ambient CO₂ concentration</td>
<td>Yes</td>
</tr>
<tr>
<td>Losses within the canopy by reaction and/or deposition</td>
<td>Yes</td>
</tr>
<tr>
<td>Leaf age</td>
<td>Yes</td>
</tr>
<tr>
<td>Biomass</td>
<td>Yes</td>
</tr>
<tr>
<td>Plant species (usually by functional type)</td>
<td>Yes</td>
</tr>
<tr>
<td>Drought</td>
<td>Yes</td>
</tr>
<tr>
<td>O₃</td>
<td>No</td>
</tr>
<tr>
<td>Herbivory</td>
<td>No</td>
</tr>
<tr>
<td>Wind damage</td>
<td>No</td>
</tr>
<tr>
<td>Fire</td>
<td>No</td>
</tr>
<tr>
<td>Logging</td>
<td>No</td>
</tr>
<tr>
<td>Nutrient status</td>
<td>No</td>
</tr>
<tr>
<td>Circadian control</td>
<td>No</td>
</tr>
</tbody>
</table>
The puzzle of isoprene emissions

Ozone sources and sinks affected by climate change

Deposition parameters are in turn affected by CC

Stomatal opening vs temperature

Source: Mills et al. 2016, Env. Poll. 208, 898-908
Role of stomatal sluggishness

Source: Hoshika and Paoletti 2015, Nature Scientific Reports 5:09871
Drought and ozone in the stomatal opening regulation

Interference of ozone + ethylene in the ABA-induced stomatal opening regulation

Nitrogen effect on the response of shoot and root biomass to ozone

Source: Mills et al. 2016, Env. Poll. 208, 898-908
Ozone and CC extreme events: heat waves

Forests effects on climate change

Source: Bonan 2008, Science 320, 1444-1449
Ozone future projections
Ozone, methane and NOx

NO$_2$ anthropogenic predicted emissions

CH$_4$ predicted emissions

Expected changes in surface ozone due to increase of isoprene and soil-NOx emissions

Source: Zeng, Pyle, Young 2008, Atmos. Chem. Phys. 8, 369-387
Ground ozone concentration projections under RCP and SRES scenarios

Ozone projections by 2030

Changes in surface ozone due to CC only

Fig. 10. Changes in surface O₃ (ppbv) between 2000 and 2100 due to climate change, for January, April, July and October.

Source: Zeng, Pyle, Young 2008, Atmos. Chem. Phys. 8, 369-387
Changes in surface ozone due to emission changes only

Source: Zeng, Pyle, Young 2008, Atmos. Chem. Phys. 8, 369-387
Changes in surface ozone due to CC only

Changes in emissions under CLE and MFR scenarios

Changes in surface ozone due to emission changes only

Lurking uncertainties

- Changes in temperature
- Changes in atmospheric humidity and SWC
- Anthropogenic GHGs emissions (N$_2$O and CH$_4$)
- Anthropogenic high-ox NOx emissions
- Natural soil & vegetation emissions
- Hemispheric transport patterns
- Feedback (-) by increased water vapour
- Feedback (+) by increased stratosphere-troposphere exchange
Ozone exposure and risk: projections
Predicted wheat yield reduction in Europe

Source: WGE 2016, Trends in ecosystem response to ozone
Global ozone exposure by 2030 under the B1 scenario

Source: Avnery et. al., 2011, Atm. Env. 45, 2297-2309
Yield loss (soybean, maize, wheat) under the 2030 B1 scenario

Source: Avnery et al., 2011, Atm. Env. 45, 2297-2309
Present and predicted (2100) GPP due to ozone effect at fixed CO2

Source: Sitch et al. 2007, Nature 448, 791-795
Critical yield losses:
world cereal demand by 2050

Source: Tester and Langridge 2010, Science 327, 818-822
International policy

Article 2: Objective

1. The objective of the present Protocol is to control and reduce emissions of sulphur, nitrogen oxides, ammonia, volatile organic compounds and particulate matter that are caused by anthropogenic activities and are likely to cause adverse effects on human health and the environment, natural ecosystems, materials, crops and the climate in the short and long term, due to acidification, eutrophication, particulate matter or ground-level ozone as a result of long-range transboundary atmospheric transport, and to ensure, as far as possible, that in the long term and in a stepwise approach, taking into account advances in scientific knowledge, atmospheric depositions or concentrations do not exceed:

(a) For Parties within the geographical scope of EMEP and Canada, the critical loads of acidity, as described in annex I, that allow ecosystem recovery;

(b) For Parties within the geographical scope of EMEP, the critical loads of nutrient nitrogen, as described in annex I, that allow ecosystem recovery;

(c) For ozone:

(i) For Parties within the geographical scope of EMEP, the critical levels of ozone, as given in annex I;
III. Critical levels of ozone

A. For Parties within the geographical scope of EMEP

6. Critical levels (as defined in article 1) of ozone are determined to protect plants in accordance with the Convention's Manual on Methodologies and Criteria for Modelling and Mapping Critical Loads and Levels and Air Pollution Effects, Risks and Trends. They are expressed in terms of the cumulative value of either stomatal fluxes or concentrations at the top of the canopy. Critical levels are preferably based on stomatal fluxes, as these are considered more biologically relevant since they take into account the modifying effect of climate, soil and plant factors on the uptake of ozone by vegetation.

7. Critical levels of ozone have been derived for a number of species of crops, (semi-)natural vegetation and forest trees. The critical levels selected are related to the most important environmental effects, e.g., loss of security of food supplies, loss of carbon storage in the living biomass of trees and additional adverse effects on forest and (semi-)natural ecosystems.
Il protocollo di Gothenburg: determinazione dei livelli critici
Il protocollo di Gothenburg: livelli critici per l’ozono

<table>
<thead>
<tr>
<th>Approach</th>
<th>CLE&lt;sub&gt;t&lt;/sub&gt;</th>
<th>Crops</th>
<th>(Semi-) Natural vegetation</th>
<th>Forest trees</th>
</tr>
</thead>
</table>
| Stomatal flux-based critical level            |                 | *Wheat:* An AF<sub>6</sub> of 1 mmol m<sup>-2</sup> PLA  
*Potato:* An AF<sub>6</sub> of 5 mmol m<sup>-2</sup> PLA | Not available                       | *Birch and beech:* Provisionally AF<sub>6</sub>1.6 of 4 mmol m<sup>-2</sup> PLA |
| Time period                                   |                 | *Wheat:* Either 970°C days, starting 270°C days before mid-anthesis (flowering) or 55 days starting 15 days before mid-anthesis  
*Potato:* Either 1130°C days starting at plant emergence or 70 days starting at plant emergence |                              | One growing season               |
| Effect                                        |                 | Yield reduction                  | Growth reduction            |                             |

| Concentration-based critical level            | CLE<sub>c</sub> | *Agricultural crops:* An AOT40 of 3 ppm h  
*Horticultural crops:* An AOT40 of 6 ppm h | An AOT40 of 3 ppm h  
An AOT40 of 5 ppm h | Growth reduction                                      |
| Time period                                   |                 | *Agricultural crops:* 3 months  
*Horticultural crops:* 3.5 months | 3 months (or growing season, if shorter) | Growing season               |
| Effect                                        |                 | Yield reduction for both agricultural and horticultural crops | Growth reduction in perennial species and growth reduction and/or seed production in annual species | Growth reduction |

| VPD-modified concentration-based critical level | CLE<sub>c</sub> | An AOT30<sub>VPD</sub> of 0.16 ppm h | Not available | Not available |
| Time period                                   |                 | Preceding 8 days                   |                |               |
| Effect                                        |                 | Visible injury to leaves           |                |               |
Il protocollo di Gothenburg: ruolo della ricerca scientifica

Article 8: RESEARCH, DEVELOPMENT AND MONITORING

1. The Parties shall encourage research, development, monitoring and cooperation related to:

   (a) The international harmonization of methods for the calculation and assessment of the adverse effects associated with the substances addressed by the present Protocol for use in establishing critical loads and critical levels and, as appropriate, the elaboration of procedures for such harmonization;

   (b) The improvement of emission databases, in particular those on particulate matter, including black carbon, ammonia and volatile organic compounds;

   (c) The improvement of monitoring techniques and systems and of the modelling of transport, concentrations and depositions of sulphur, nitrogen compounds, volatile organic compounds and particulate matter, including black carbon, as well as of the formation of ozone and secondary particulate matter;

   (d) The improvement of the scientific understanding of the long-term fate of emissions and their impact on the hemispheric background concentrations of sulphur, nitrogen, volatile organic compounds, ozone and particulate matter, focusing, in particular, on the chemistry of the free troposphere and the potential for intercontinental flow of pollutants;

   (d bis) The improvement of the scientific understanding of the potential co-benefits for climate change mitigation associated with potential reduction scenarios for air pollutants (such as methane, carbon monoxide and black carbon) which have near-term radiative forcing and other climate effects;

   (e) The further elaboration of an overall strategy to reduce the adverse effects of acidification, eutrophication, photochemical pollution and particulate matter, including synergisms and combined effects;
The UN-ECE Convention on Long-Range Transboundary Air Pollution
Climate change adaptation strategies
Requested emission reduction under RCP ≤ 4.5 scenarios

Source: Rogelj et al. 2015, Nature Climate Change, 5, 519-528
Adaptation is based on risk assessment.
Local climatic pressure

Source: Espon 2013, Climate Project
Impacts, vulnerability and resilience factors

Source: Espon 2013, Climate Project
The adaptation process

1. Set up
   - High level support
   - Team for adaptation
   - Relevant authorities

2. Risks and Vulnerability
   - Estimate human and financial resources
   - Identify funding sources

3. Identifying Adaptation Options
   - PAST and FUTURE climate impacts
   - Existing adaptive capacity
   - Good practices abroad
   - BARRIERS to, OPPORTUNITIES for adaptation

4. Choosing Adaptation Options
   - Political approval
   - Secure political approval for the NASA
   - Prioritise
   - Priority criteria and select preferred options
   - Cost-Benefit Analysis
   - Assess costs & benefits for options

5. Implementation

6. Monitoring and Evaluation
   - On Policy objectives & Adaptation options

M&E
   - Define a clear BASELINE:
     - Unintended and Unexpected impacts
     - Trade-offs
     - Type and scale
     - Challenging assumptions

   - Develop indicators:
     - Exploit existing processes
     - Use process and outcome indicators
     - Clear and relevant purpose
     - Collect data efficiently

Action Plan
   - STRATEGIC APPROACH
     - What do you want to achieve?

1. Collect all possible adaptation options:
   - Existing measures
   - Types of options: technical, legal, informative...

2. Describe options in detail

3. Choose the best options...

4. Prepare a Strategy document and get political approval

5. Cross-cutting issues
   - trade-offs and synergies among options

Communicate and Agree on M&E at National Level

Engage stakeholders

Communications

Stakeholders
Two examples of sectoral adaptation at global level
Adaptation and forests

Source: Millar and Stephenson 2015, Science 349, 823-826
Adaptation practices in agriculture

Two examples of adaptation strategies

• The UK National Adaptation Plan (UK-NAP)
• The Regional Adaptation Strategy of the Lombardy Region (RL-SRACC)
The UK National Adaptation Plan

<table>
<thead>
<tr>
<th>CCRA Risk</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>FO1a</td>
<td>Forest extent affected by red band needle blight\textsuperscript{54}</td>
</tr>
<tr>
<td>WA7</td>
<td>Insufficient summer river flows to meet environmental targets</td>
</tr>
<tr>
<td>FL4a/b</td>
<td>Agricultural land at risk of flooding/regular flooding</td>
</tr>
<tr>
<td>FO4a</td>
<td>Decline in potential yield of beech trees in England</td>
</tr>
<tr>
<td>AG5</td>
<td>Increases in water demand for irrigation of crops</td>
</tr>
<tr>
<td>FO1b</td>
<td>Forest extent affected by green spruce aphid</td>
</tr>
<tr>
<td>FO2</td>
<td>Loss of forest productivity due to drought</td>
</tr>
</tbody>
</table>

Objective 18: To embed climate change adaptation into agriculture, horticulture and forestry research programmes, in order to improve knowledge of likely climate impacts and contribute to the development and uptake of climate resilient crops, tree and livestock species as well as relevant technologies.
The Lombardy Region adaptation strategy

Climate change evidences and projections


Spatial distribution of the projected thermometric anomalies for the period 2071-2100 compared to mean temperature of the reference period 1971-2000. Source: with data from Gobiet et al. 2013
Projected impact of climate change on the winter tourism sector in Lombardy: projected percentage of skiing areas below the snow line (Snow Reliability Line) by provinces under two different future scenarios of global warming. Source: with data from Kyoto Lombardia Project. 2008
Adaptation objectives priority and specific adaptation options

<table>
<thead>
<tr>
<th>Relevant impacts per sector</th>
<th>Adaptation objectives</th>
<th>Proposed adaptation measures</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Adaptation objectives**

1. **Relevance of each impact from a sectoral point of view** (1=very low importance; 5=very high importance)
2. **Need for actions to fulfill each adaptation objective** (1=very low priority; 5=very high priority)

**Weighting process (2 parameters)**

1. Relevance of each impact from a sectoral point of view
2. Need for actions to fulfill each adaptation objective

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**Proposta di misure di adattamento**

<table>
<thead>
<tr>
<th>Impatti</th>
<th>Proposta</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

**1. Alterazione delle caratteristiche fisico- chimiche e biologiche delle acque superficiali e sotterranee (Qualità)**

- 1.1 Ampliare e rinforzare i mezzi di misurazione, monitoraggio e sorveglianza delle risorse idriche superficiali e sotterranee
- 1.2 Incrementare la resilienza dei corpi idrici alle implicazioni dei mutamenti climatici e dell'assenza di servizi e fornimenti
- 1.3 Garantire e ampliare la disponibilità delle risorse idriche regionali e considerate in termini di manutenzione e gestione
- 1.4 Applicare conoscenze e tecniche di gestione dei rischi idrici nelle aree di pianificazione e gestione del territorio

**Proposta di misure di adattamento**

1. Potenziare ed estendere gli attuali strumenti e reti di monitoraggio e il controllo della qualità delle risorse idriche lombarde (identificare i gap esiistenti nell'attuale rete di monitoraggio costituita da 260 punti di prelievo e misura, relativi a 175 corpi idrici superficiali e 100 corpi idrici sotterranee)
2. Intensificare il controllo dell'evoluzione del grado di diluizione degli inquinanti nelle acque sotterranee durante i periodi a maggiore rischio (es: periodi siciliosi prolungati)
3. Rinforzare la prevenzione dei casi di penuria, fluttuazioni e peggioramento eccessivo della qualità dei corpi idrici in considerazione all'aumento dell'incidenza di eventi climatici estremi (es: intensificare il monitoraggio dell'influenza degli scarichi terremotati nelle acque superficiali)
4. Intensificare la gestione del ciclo idrico nel sistema di monitoraggio attuali: Introdurre i codici sintetici di invaso per i corsi d'acqua Montani e il rilievo della captazione del territorio in collaborazione con il territorio
5. Ampliare la caratterizzazione dettagliata delle acque del territorio e specificamente del territorio della Lombardia nell'ambito della politica comunitaria in rapporto alla tutela e alla realizzazione delle acque rispetto alle attività antropiche in particolare a partire dalla Val di Susa e della Val di Lanzo

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**Note:**

1. I superindici localizzati angolari indicano che la misura in questione si prevede di eseguire con la partecipazione attiva e azione di tutti gli attori interessati alla gestione delle acque.
Objective and measures prioritization

Simple additive weighting algorithm to determine objective priorities...

Relevance of each impact (from 1 to 5) + Need of adaptation actions in each adaptation objective (from 1 to 5) = Priority of Adaptation objectives (from 1 to 5)

\[
\frac{(W_1 + W_2 + W_3 + W_n)}{n} + \frac{(W_1 + W_2 + W_3 + W_n)}{n} / 2 = P
\]
Conclusion and wishes
The life on earth and its fight against the oxygen revolution(s)

Source: T. Lenton and A. Watson, 2013, Revolutions that made the Earth, Oxford
The United Nations’ Sustainable Development Goals (2016-2030)
Sustainable Development Goals (SDGs) and links to air pollution

In September 2015, countries adopted a set of goals to end poverty, protect the planet, and ensure prosperity for all as part of a new sustainable development agenda. Each goal has specific targets to be achieved over the next 15 years.

2. Zero hunger
Abating nitrogen emissions and managing nitrogen more sustainably has direct impacts on soil quality.

3. Good health and well-being
Reducing air pollution helps to mitigate the risk factors for non-communicable diseases such as respiratory and cardiovascular diseases, including cancers.

6. Clean water and sanitation
Water pollution is notably linked to depositions from air pollution. Consequently, one way of reducing water pollutants is to reduce air pollution.

7. Affordable and clean energy
Given that a major source of air pollution is energy production, consumption and transport, increasing the share of renewable energies and improving energy efficiency under this SDG will serve to reduce air pollution. Investing in clean technologies in this sector, as called for under this SDG, will also achieve reductions in air pollution.

8. Decent work and economic growth
A focus of the green economy is to improve and increase jobs while focusing on cleaner sectors and technologies that are sustainable which includes sectors that have a reduced impact on air pollution such as renewable energies or improved transport, as promoted under this SDG.

9. Industry, innovation and infrastructure
Old industries and technologies are a major source of air pollution, and upgrading and retrofiting many facilities, as called for under this SDG, will serve to significantly reduce air pollution. Investment in research and innovation will also provide options for achieving improvements in industrial production while reducing waste and air pollution.

11. Sustainable cities and communities
Under SDG 11, there is an explicit target linked to improving air quality: "by 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality, municipal and other waste management". Reducing air pollution at the national level also helps to improve air quality at the city level.

12. Responsible consumption and production
Improvements in life cycle management of chemicals and all wastes will contribute to reducing air and water pollution. Improving companies’ practices with a focus on complying with international and national norms will also serve to reduce emissions of air pollutants.

13. Climate action
As greenhouse gases and some key air pollution have the same sources, combating climate change will bring improvements to air quality. In turn, reducing air pollution will help in bringing about climate co-benefits.

14. Life below water
Reducing air pollution, particularly nutrient (nitrogen) pollution will help reduce marine pollution from land-based activities.

15. Life on land
Reducing air pollution helps mitigate effects on ecosystems and biodiversity.
Grazie per la vostra attenzione