



# Air Pollution and Climate Change

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## Editorial

### Combined policies for better tackling of climate change and air pollution

Continued reductions in air pollution and greenhouse gas (GHG) emissions are essential, as they pose serious threats to both people's health and the environment across the world. Air quality and climate policies can provide mutual benefits: climate change mitigation actions can help reduce air pollution, and clean air measures can help reduce GHG emissions leading to reductions in global warming. There can also be trade-offs, if reducing a particular pollutant emission leads to additional atmospheric warming rather than cooling.

Furthermore, air pollution and climate change influence each other through complex interactions in the atmosphere. Increasing levels of GHGs alter the energy balance between the atmosphere and the Earth's surface which, in turn, can lead to temperature changes that change the chemical composition of the atmosphere. Direct emissions of air pollutants (eg black carbon), or those formed from emissions such as sulfate and ozone, can also influence this energy balance. Thus, climate change and air pollution management have consequences for each other.

Given that emissions are linked to air quality and climate change, this thematic issue presents recent research that investigates the trade-offs and co-benefits that may be gained from reducing both long-lived GHGs, responsible for climate change, and air pollutants, responsible for adverse impacts on human health, ecosystems and the climate.

*(Continued on page 2)*

## Contents

Page

|  |           |
|--|-----------|
| <b>Reducing black carbon emissions benefits both climate and health</b>  | <b>4</b>  |
| Research concludes that reducing black carbon emissions would prevent millions of premature deaths as well as helping meet climate change mitigation targets.                      |           |
| <b>Do climate policies need a 'pollution safety margin'?</b>   | <b>5</b>  |
| Climate change policies may need to make greater GHG reductions in order to accommodate the warming of reduced air pollution, say researchers.                                     |           |
| <b>How climate change could affect European ozone pollution</b>  | <b>6</b>  |
| Average ozone concentrations will increase more in Southern Europe than in more Northern regions under the influence of climate change in the 21st century, according to research. |           |
| <b>Climate impacts on air pollution could increase respiratory disease</b>   | <b>7</b>  |
| Rapid reductions in emissions from fossil fuel burning are needed to curb increases in ozone and protect public health, say researchers.   |           |
| <b>Integrated climate change and air pollution strategies: a winning combination</b>   | <b>8</b>  |
| According to research, combining policies that tackle local air pollution and global climate change will deliver enhanced benefits for climate change mitigation.                  |           |
| <b>Unravelling the complex chemistry of the atmosphere</b>   | <b>9</b>  |
| There have been significant advances in the understanding of atmospheric processes in the last decade, but a recent study suggests that uncertainties continue to grow.            |           |
| <b>Related articles</b>  | <b>10</b> |
| A selection of recent articles from the Science for Environment Policy News Alert service.   |           |
| <b>Related research projects</b>   | <b>11</b> |
| A selection of research projects funded under the EU's 7th Framework Programme for Research.   |           |



Although reducing particulate matter (PM) has clear health benefits, understanding the impact of this reduction on climate change is essential if mutual benefits for climate and health are to be delivered. The overall impacts of reductions are complex because PM is made up of many different chemical components with different physical properties, some of which lead to warming of temperatures (eg black carbon) by absorbing heat from the sun, whilst others (eg sulfates) bring about cooling effects by reflecting sunlight.

Several studies suggest that, in addition to health benefits, reducing black carbon sources would lead to cooling of global temperatures (see: **'Reducing black carbon emissions benefits both climate and health'**). On the other hand, other studies point out that reducing air pollution could worsen climate change in the short-term by contributing to an increase in global temperatures (see: **'Do climate policies need a 'pollution safety margin'?'**). This is still an area of active research with many uncertainties to resolve.

Poor air quality is also caused by emissions of nitrogen oxides, methane and other volatile organic compounds that combine in the lower atmosphere to produce ozone. Ground-level ozone is a serious pollutant, which at high levels, damages human health and vegetation, including crop yields. In addition, ozone is a short-lived GHG contributing to climate change.

Changing environmental conditions, including rising temperatures caused by climate change, are expected to increase concentrations of ground-level ozone. Policies and management strategies to reduce ozone levels must be designed in light of evidence that there is a "climate penalty" since increased temperatures make it more difficult to reach targets for ozone (and PM) in summertime. In particular, policies must incorporate evidence of how climate change is likely to affect different regions of Europe, if they are to be effective. The article, **'How climate change could affect European ozone pollution'**, reports on research which suggests that climate change will lead to higher ozone levels across southern Europe this century.

The health costs of ozone pollution are likely to worsen under climate change. The impacts of climate change on air quality, ozone levels and ill-health are presented in **'Climate impacts on air pollution could increase respiratory disease'**.

*(Continued on page 3)*



A reduction in pollutant emissions that produce ozone would not only improve public health but would also provide climate benefits. Integrating climate change and air quality policies would be the most effective approach.

One article, '**Integrated climate change and air pollution strategies: a winning combination**', compares the costs and benefits of implementing reductions in local air pollution and climate change actions separately or in combination. The message, again, is that simultaneous achievements in welfare and climate change are possible when decision-makers integrate both sets of policies.

Designing policies to combat future climate change is complicated by the many uncertainties associated with predicting the complex interactions governing long-term changes in climate and air pollutants. A recent study, detailed in '**Unravelling the complex chemistry of the atmosphere**', has reviewed progress in understanding the interactions between atmospheric chemical composition and climate. Continued and improved networks of measurements that provide long-term data are essential to gain a more robust understanding about past and present changes in concentrations of air pollutants and GHGs.

Such networks include surface, aircraft and satellite monitoring. Aircraft experiments combined with analysis using numerical models have proved to be particularly useful in advancing our knowledge about key chemical and physical processes in the atmosphere. There is also a clear need for improved emission inventories that track changing sources of air pollutants and GHGs over a wide range of locations and from year to year.

Ongoing research can provide opportunities for decision makers to choose policies that not only reduce GHGs but improve air quality and meet health goals.

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## Reducing black carbon emissions benefits both climate and health

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**Theme(s):** Air pollution, Climate change and energy, Environment and health

“Black carbon is estimated to be responsible for approximately 15 per cent of the current excessive warming of global temperatures. In addition, short-term reductions in black carbon can potentially delay the impact of global warming by approximately 10 years.”

A recent assessment suggests that reducing black carbon emissions, produced by burning carbon-based materials, would prevent millions of premature deaths in developing countries as well as helping meet climate change mitigation targets.

When carbon-based fuels are burned, incomplete combustion causes the emission of carbon dioxide (CO<sub>2</sub>) and other pollutants, including particulate matter (PM) (aerosols), which include particles that can cool or heat the Earth's climate by reflecting or absorbing the radiation of the sun.

One type of PM, namely black carbon (BC), remains in the atmosphere for a relatively short time (one week), but strongly absorbs solar radiation. BC emitted from domestic burning of solid fuels, particularly indoors, and high-emitting diesel engines is likely to contribute to climate warming.

In addition to the impact on climate change, PM is a major contributor to local air pollution, although concentrations vary according to the source of combustion. Exposure to PM can have a significant impact on ill-health. This applies particularly to poor countries, where, for example, high reliance on solid fuel, such as wood for indoor cooking, is estimated to be responsible for 1.8 million deaths from indoor smoke pollution, including BC. Polluting industries and the running of older vehicles also contribute to high BC pollution in urban air in developing countries.

This study assessed the potential of reducing BC emissions to mitigate climate change. In addition, the researchers investigated the health- and climate-cost-effectiveness of substituting less polluting technologies for indoor cooking and heating stoves using solid fuels, as well as interventions to reduce emissions from diesel transport.

Overall, the study found that reducing BC emissions, particularly from confined combustion sources (such as stoves and engines), delivers combined health and climate change benefits. This is because BC is estimated to be responsible for approximately 15 per cent of the current excessive warming of global temperatures. In addition, short-term reductions in BC can potentially delay the impact of global warming by approximately 10 years, “buying” time for more research and action. Nevertheless, efforts to reduce BC emissions should not replace measures to reduce CO<sub>2</sub> emissions which in the long term will dominate climate change.

In terms of health benefits, it is significantly cheaper to change indoor cooking practices than it is to control vehicle emissions, although both of these types of interventions would produce similar climate change mitigation benefits.

Replacing indoor solid fuel stoves with clean-burning stoves using biomass (plant material) provided the greatest combined health and climate benefits compared with costs. This is a win-win situation, particularly as this solution affects large populations in China, South Asia and parts of Africa. Reducing emissions from “super-emitting” diesel trucks and buses is the most attractive option in terms of vehicle interventions.

**Source:** Source: Kandlikar, M., Reynolds, C.C.O., & Grieshop, A.P. (2010). A Perspective Paper on Black Carbon Mitigation as a Response to Climate Change. Copenhagen Consensus Center report.

Download from: <http://fixtheclimate.com/component-1/the-solutions-new-research/black-carbon/>



## Do climate policies need a 'pollution safety margin'?

A recent analysis suggests climate change policies may have to include a 'pollution safety margin' which accounts for the warming impact of many air pollutants. Available evidence suggests that policies to reduce the harmful effects of air pollutants could accelerate climate change over coming decades by cutting emissions that currently contribute to cooling the climate.

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"Increasingly, research indicates that future air pollution, even with maximum feasible abatement, is likely to contribute to increasing temperatures. This suggests that climate change policies may need to seek greater reductions in greenhouse gases."

Debate continues as to whether air pollution policies support efforts to tackle climate change or whether they effectively enhance climate change. Air pollutants have a complex relationship with climate change. Some pollutants, such as black carbon and ozone, increase warming by trapping heat in the atmosphere, while others, such as sulfur dioxide forming light reflecting particles, have a cooling effect on the climate.

Since some air pollutants clearly increase warming, there is considerable interest in understanding the co-benefits of managing air pollution and climate change. Air pollutants are relatively short-lived, particularly compared with long-lived greenhouse gases, such as carbon dioxide (CO<sub>2</sub>), and measures to control air pollutants could have an effect on climate change in the short-term. However, whether air pollution control measures will always work in harmony with climate change mitigation is still an open question.

The problem is that the models used to predict the effects of reductions in air pollutants do not adequately capture the complex interactions between air pollutants themselves and between air pollutants, other gases, and climate change. Many other interactions which are not adequately captured in current models could affect the impact of air pollutants on climate, such as the interactions between, land ecosystems and air pollutant chemistry. As an example, far-reaching measures to control air pollution that would significantly reduce the cooling pollutants might worsen climate change in the short-term. In the long-term though, the long-lived climate forcers, such as CO<sub>2</sub>, will dominate by their heating effect.

Recent chemistry-climate modelling studies have attempted to account for geographical differences in patterns of air pollution emissions and to consider the way these pollutants interact in the atmosphere. These models which explored the effects of a variety in projected future changes in short-lived air pollutants suggest that these species are likely to contribute to further warming by 2050. For example, studies considering pollution aerosol particles and air pollution abatement strategies in the energy and transport sectors suggest that, even with maximum abatement strategies, changes in air pollution patterns are likely to contribute to an increase in temperatures.

Given the negative human health impacts of air pollutants, the question is not whether to implement air pollution policies but rather, what impact these policies will have on climate change. Increasingly, research indicates that future air pollution, even with maximum feasible abatement, is likely to contribute to increasing temperatures. This suggests that climate change policies may need to seek greater reductions in greenhouse gases to provide a 'pollution safety margin' that can accommodate the potential warming effects of air pollution control measures.

Source: Arneth, A., Unger, N., Kulmala, M., Andreae, M.O. (2009). Clean the Air, Heat the Planet? *Science*. 326:672-3.



## How climate change could affect European ozone pollution

A study by Swedish scientists provides new insights into how climate change could affect future ozone concentrations in European countries. The findings of this study suggest that average ozone concentrations will increase more in Southern Europe than in more Northern and mountainous regions under the influence of climate change in the

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“Average summer ozone concentrations will increase more in southern Europe than in northern Europe and the Alps over the remainder of this century. Daily maximums will increase significantly in southern, north-western continental, central Europe and Britain.”

Ground-level ozone is one of the most serious air pollutants in Europe today<sup>1</sup>. High levels of ozone can affect the respiratory system and increase morbidity and mortality, particularly in sensitive groups of the population. Ozone also damages vegetation, reduces crop yields and corrodes building materials. Ozone concentrations are highly dependent on environmental conditions, including temperature. It is thought to be likely that long-term changes in climate will affect levels of future ozone pollution. Concentrations in Europe tend to be highest in the hottest months of the year, between April and September.

In a modelling study of ozone concentrations in Europe, the researchers investigated the effects of climate change on the factors that influence ozone concentrations. They focused mainly on two factors in particular: emissions of isoprene (a volatile organic compound acting as a fuel for ozone formation) that are produced by trees, and “dry deposition” – the uptake of ozone by plants. They used a chemistry transport model (MATCH), developed for assessing European air quality problems, to model chemical changes in the atmosphere in a future climate change scenario. According to the model, a warmer climate increases the emissions of isoprene from trees and a warmer, drier climate will reduce the uptake of ozone in plants.

According to the study, average summer ozone concentrations will increase more in southern Europe than in northern Europe and the Alps over the remainder of this century. Daily maximums will increase significantly in southern, north-western continental, central Europe and Britain.

Uptake by plants will be more important than isoprene emissions in influencing ozone concentrations in southern Europe, say the researchers. Plant uptake will decrease under climate change and may be responsible for up to 60 per cent of the change in ozone levels. However, in mountainous regions, such as the Alps, a decrease in snow cover may help increase uptake by plants, particularly in the winter, reducing ozone concentrations.

Climate change is predicted to nearly double isoprene emissions. The researchers estimate that up to 30 per cent of future increased ozone concentrations will be due to increased isoprene emissions. Changes in mixing between upper and lower layers of the atmosphere may also affect ozone concentrations with more stable weather conditions in southern European countries acting to increase concentrations.

The researchers note that their results are based on just one climate simulation and that different emissions scenarios and climate models could produce different results.

Source: Andersson, C. and Engardt, M. (2010). European ozone in a future climate. *Journal of Geophysical Research*. DOI: 10.1029/2008JD011690.

1. European Environment Agency. (2009). Assessment of ground-level ozone in EEA member countries, with a focus on long-term trends. EEA Technical report series, ISBN 978-92-9213-003-9, DOI 10.2800/11798.



## Climate impacts on air pollution could increase respiratory disease

Evidence from modelling studies suggests that climate change is likely to increase concentrations of ozone, one of the most important urban air pollutants responsible for respiratory problems. Under this assumption, rapid reductions of emissions from fossil fuel burning are needed to protect the health of both current and future generations.

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**Themes:** Air pollution, Climate change and energy, Environment and health

“The researchers suggest that future air quality could decline without increased regulations to reduce greenhouse gas emissions, and the development and deployment of new emission abatement technologies.”

Climate influences the state of the atmosphere and in turn has an impact on the development and flow of air pollutants, for example, it can change the height of different atmospheric layers and the rate of chemical reactions in the air. There is therefore concern that climate change could change the burden of illness and mortality associated with air pollution. However, it is difficult to predict exactly how air quality will be influenced by future climate change and in turn influence human health.

The researchers analysed available scientific literature for the impacts of climate change on air quality and the impact of air quality on health. However, there are relatively few studies of ozone concentrations in a changing climate, and even fewer for concentrations of particulate matter. Additional research is thus needed to improve our understanding of climate change's possible impacts on air pollution-related health problems. In Europe, it is currently estimated that around 21,000 hospital admissions a year can be linked to ozone exposure, and admissions linked to particulate matter exposure are almost five times greater<sup>1</sup>.

Of further concern, most studies so far into the impacts of climate change on air quality have focused on developed countries, when in fact air pollution is likely to be greater in the developing world.

The analysis finds that there are two main reasons why the precise future health impacts of air pollution – and specifically ozone – are difficult to predict. The first is that we cannot predict accurately how emissions of the chemicals that form ozone (the ‘precursor emissions’ - nitrogen oxides and volatile organic compounds) will change over time. The second is that we do not know how changes in weather patterns under climate change will affect ozone concentrations.

Although exact figures are difficult to predict, the overall available evidence suggests that regional ozone concentrations will increase to some degree under climate change. The researchers therefore argue that precursor emissions need to be reduced to protect vulnerable populations. They suggest that future air quality could decline without increased regulations to reduce greenhouse gas emissions, and the development and deployment of new emission abatement technologies.

**Source:** Ebi, K.L. and McGregor, G. (2008). Climate Change, Tropospheric Ozone and Particulate Matter, and Health Impacts. *Environmental Health Perspectives*. 116(11):1449-1456.

1. European Commission. (2005). CAFE Cost-Benefit Analysis: Baseline Analysis 2000 to 2020, EUROPA. Online: <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52001DC0245:EN:NOT>



## Integrated climate change and air pollution strategies: a winning combination

Combining policies that tackle local air pollution and global climate change will deliver enhanced benefits for climate change mitigation, according to researchers. Medium-term efforts to control air pollution will provide additional benefits to long-term strategies that aim to curb climate change.

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“Combining local air pollution and global climate change mitigation policies provides a win-win situation whereby medium-term efforts to control air pollution will support long-term strategies that aim to curb climate change.”

Modern consumption patterns and energy production contribute significantly to both climate change and air pollution. Instead of tackling these problems separately, there are technological solutions that address both concerns at the same time: for example, switching from fossil fuels to renewable forms of energy cuts down on air pollution emissions, (eg particulate matter (PM), sulfur dioxide and nitrous oxides), whilst simultaneously reducing emissions of the greenhouse gas, carbon dioxide (CO<sub>2</sub>).

This study compared the costs and benefits of separate strategies for global climate change mitigation (GCC) and reductions in local air pollution (LAP), in addition to the impacts from combining these two sets of policies. Benefits of LAP policy focused on avoided early deaths from long-term exposure to PM pollution produced by fossil fuel combustion, while benefits of GCC policy focused on the avoided loss of GDP as a result of CO<sub>2</sub> emissions.

Overall, the study found that environmental policies that mitigate CO<sub>2</sub> emissions and PM pollution, either alone or combined, provide greater benefits than the costs of the policies.

In addition, the study found:

- Combined GCC and LAP policies bring about greater CO<sub>2</sub> reductions than either strategy alone. For example, combined GCC and LAP policies generate an extra 15 per cent reduction in CO<sub>2</sub> emissions in Western Europe. However, combined GCC and LAP policies have little effect on further reducing PM emissions compared with LAP policies alone.
- GCC policies provide additional welfare benefits (co-benefits) to those delivered by LAP policies. For example, carbon-free technologies, such as renewable energy also reduce PM emissions. LAP policies deliver significant welfare gains from local improvements in air quality but provide almost no GCC benefits.
- Integrated GCC and LAP policies deliver greater welfare gains than the total gains from both policies acting independently.

Although the researchers suggest priority should be given to reducing LAP over GCC, due to related air quality and health benefits, climate change policies should not be postponed. Combining both sets of policies provides a win-win situation whereby medium-term efforts to control air pollution will support long-term strategies that aim to curb climate change.

Source: Bollen, J., van der Zwaan, B., Brink, C., Eerens, H. (2009). Local air pollution and global climate change: A combined cost-benefit analysis. *Resource and Energy Economics*. 31: 161-181.



## Unravelling the complex chemistry of the atmosphere

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**Themes:** Air pollution, Climate change and energy

“Important advances have been seen in satellite observations in the last three years, with satellites providing new data on the distribution of various gases in the atmosphere, including methane and ozone.”

Although there have been significant advances in the understanding and monitoring of atmospheric processes in the last decade, a recent study suggests that uncertainties in their assessment continue to grow and more complex studies are required to understand the precise relationship between atmospheric chemicals, such as air pollutants, and climate change.

The effects of increasing emissions of well known greenhouse gases (GHGs), such as carbon dioxide (CO<sub>2</sub>), are widely recognised, but the chemistry of the atmosphere is complex and the interactions of many other chemicals must be factored into climate models.

Since the last IPCC assessment report<sup>1</sup>, published three years ago, significant advances have been made in the understanding of the complex chemistry of the atmosphere and its interactions with the climate. In this analysis, researchers summarised scientific advances since the report in order to provide a more up-to-date assessment of the current state of knowledge about atmospheric chemistry in relation to climate change.

A key chemical in the atmosphere with respect to climate change is the hydroxyl radical, which reacts with many different gaseous compounds and has important interactions with methane, a more potent GHG than CO<sub>2</sub>. Methane levels levelled out in the last decade and some scientists think this is due to an increase in hydroxyl concentrations in the atmosphere. The researchers say more needs to be known about the processes governing hydroxyl trends.

Nitrogen oxides, which have important industrial sources, are also important players in governing the levels of hydroxyl in the atmosphere. They are also an important source of tropospheric ozone, a pollutant and GHG. Ozone levels can be curbed by future emissions reduction policies.

Important advances have been seen in satellite observations in the last three years, with satellites providing new data on the distribution of various gases in the atmosphere, including methane and ozone, as well as other chemicals involved in interactions that produce ozone. In addition, advances in computing have improved scientists' abilities to model and predict the effects of climate change. These new observations indicate a larger complexity of atmospheric chemistry than presently captured by models and hence call for more detailed studies of key atmospheric processes.

In particular, there are still some large uncertainties in the impact of aerosols produced by human activities on climate change. In this area, the researchers note, estimates span a larger range than ever before due to recently discovered indirect climate effects.

**Source:** Isaksen, I.K.A. Granier, C., Myhre, G. *et al.* (2009). Atmospheric composition change: Climate-chemistry interactions. *Atmospheric Environment*. 43: 5138-5192.

1. IPCC. (2010). Assessment Reports. IPCC. See: [http://www.ipcc.ch/publications\\_and\\_data/publications\\_and\\_data\\_reports.htm#1](http://www.ipcc.ch/publications_and_data/publications_and_data_reports.htm#1)



## **A selection of articles on air pollution and climate change from the *Science for Environment Policy* news alert.**

### **Global footprint of commercial aviation emissions (16/9/10)**

New research has estimated the global footprint of emissions from commercial aircraft. In 2006 nearly 190 million tonnes of fuel were burnt and 162 million tonnes of carbon from CO<sub>2</sub> were emitted. The vast majority of the fuel was burned in the Northern hemisphere and half the emissions were over the US, Europe and East Asia.

### **Air quality co-benefits should be considered in climate policies (25/3/10)**

Measures to reduce greenhouse gas (GHG) emissions have the additional benefit of reducing air pollutants. However, these benefits are rarely included in the design and evaluation of climate change policies. A new study suggests that considering these benefits in climate change policy could reduce the cost of such policies, and engage stakeholders who are otherwise unmotivated to tackle climate change.

### **Fine particles trap more heat in atmosphere than previously thought (18/3/10)**

Putting a price on carbon emissions from deforestation is unlikely to prevent tropical forests being cleared for palm oil production, according to a recent study. Additional measures should be included in climate policies to protect forests from increasing global demands, such as biofuels.

### **A hydrogen future: clean and cool? (18/2/10)**

A new study suggests that widespread adoption of hydrogen fuel could have major benefits for tackling climate change and air pollution. The researchers modelled the impacts of replacing petrol with hydrogen as a fuel for cars and claim their methods, which employ a new modelling tool, could be useful in planning and policymaking.

### **Benefits to integrating climate change into air quality policy (14/1/10)**

New research suggests potential benefits in integrating air quality and climate change policy. It predicts that accounting for the climate impact of certain air pollutants in the EU, USA and China could complement policies designed to reduce the air quality impacts of these pollutants.

### **Linking air quality and climate change can be cost-effective (7/1/10)**

A recent study has investigated two carbon credit payment schemes which the authors say could provide incentives for forest managers to increase forest land and lengthen rotation time between harvests.

To view any of these articles in full, please visit: [http://ec.europa.eu/environment/integration/research/newsalert/index\\_en.htm](http://ec.europa.eu/environment/integration/research/newsalert/index_en.htm), and search according to article publication date.



## Related research projects

There are many interesting and promising air pollution related research projects funded under the EU's 7th Framework Programme for Research. Here is a small selection:

- MEGAPOLI (Megacities: emissions, urban, regional and global atmospheric pollution and climate effects and integrated tools for assessment and mitigation):  
<http://megapoli.dmi.dk/index.html>
- CITYZEN (Megacity: zoom for the environment):  
<https://wiki.met.no/cityzen/start>
- ESCAPE (European study of cohorts for air pollution effects):  
<http://www.escapeproject.eu/index.php>
- HEREPLUS (Health Risk from Environmental Pollution Levels in Urban Systems):  
<http://www.hereplusproject.eu/>
- MONARCH-A (High latitude climate change monitoring):  
<http://www.gmes.info/pages-principales/projects/project-database/database-of-projects/?idproj=205&what=1&page=9&cHash=adebc00eee17ed63039a7a118b736e08>
- TRANSPHORM (Transport related Air Pollution and Health impacts – Integrated Methodologies for Assessing Particulate Matter):  
<http://www.tmluven.be/project/transphorm/home.htm>

More information about EU-funded research projects under the Environment Theme of the 7th Framework Programme for Research can be found here:

[http://cordis.europa.eu/fp7/environment/home\\_en.html](http://cordis.europa.eu/fp7/environment/home_en.html)

Climate Change related EU-funded research projects:

[http://ec.europa.eu/research/environment/index\\_en.cfm?pg=projects&area=climate&ftab=fp7](http://ec.europa.eu/research/environment/index_en.cfm?pg=projects&area=climate&ftab=fp7)

Environment and Health related EU-funded research projects:

[http://ec.europa.eu/research/environment/index\\_en.cfm?pg=projects&area=health&ftab=fp7](http://ec.europa.eu/research/environment/index_en.cfm?pg=projects&area=health&ftab=fp7)



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