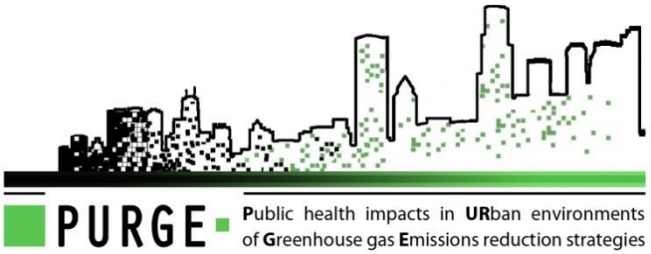

SEVENTH FRAMEWORK PROGRAMME

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Guide to study findings for policy makers

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Public health impacts in urban environments of greenhouse gas emissions reduction strategies

Guide to study findings for policy makers

Greenhouse gas reduction

To date, global progress in reducing greenhouse gas (GHG) emissions has fallen far short of the action required to achieve a low risk of disruptive climate change over this century. The needed mitigation targets are challenging, and no region, nation or city examined in this project has both an adequate set of mitigation targets and convincingly demonstrated that it is moving with sufficient pace to achieve them. The PURGE project has sought and found evidence that the transition to a low carbon economy has potential for appreciable benefits to population health particularly in urban environments – an observation that should give added impetus for the acceleration of policies to reduce GHG emissions.

GHG reduction measures and their impact on health

Modelling studies were carried out in several European countries, China and India to examine the potential impact of GHG emission reduction measures in relation to transport, housing, food and agriculture, and electricity generation.

Transport

- Models based on travel data for London demonstrated potentially substantial benefits for cardiovascular health and cancer reduction of interventions which increase active travel (walking and cycling) and reduce use of motorized vehicles. Overall, such benefits greatly outweigh the potential disadvantage of increased risk of road traffic injury. An analysis of existing travel patterns suggested that realistic mode shifts towards increased active travel may largely be limited to short journeys of up to 1 km for walking and up to 5 km for cycling. Though potentially important for public health, such shifts in modes of travel would have relatively modest impact on the totality of transport-related GHG emissions for London, and would therefore need to be combined with measures to switch to renewable energy sources.
- In India, models were developed for two cities (Delhi and Vishakhapatnam), in both of which a little over 50% of all trips are currently by non-motorized modes (walking, cycling and cycle rickshaw) suggesting limited potential to increase non-motorized shares in future, and about 75% of the car and motorcycle fleet is less than 5 years old. Nonetheless, as the share of cycling is low (<10%), there is potential to shift some car and motorcycle trips to this mode in the future, and there is some potential with more efficient public transport systems to shift some car trips to bus and metro, though the high incidence of road traffic injuries (10-15 fatalities per 100,000 persons per year) will have to be reduced to make non-motorized modes more acceptable. For both cities plausible measures could reduce CO_2 emissions due to traffic by 0.8-1.0 tonnes per capita per year by 2030 and achieve appreciable estimated reductions in fatalities and morbidity – primarily due to the increase in physical activity, some changes in road traffic fatalities and the effects of reduction in pollution.

Housing

- Studies in the UK (London and Milton Keynes) and elsewhere suggest that housing energy efficiency interventions also have the potential for appreciable net benefits to health. However,

when designing for low energy use and good health there are frequently important trade-offs. For example, an increase in the air-tightness of dwellings to help reduce energy demand will tend to increase the concentrations of pollutants derived from indoor sources, although protecting against the ingress of pollution from outside. Particular risks may arise in relation to radon, second-hand tobacco smoke, particle pollution from indoor sources, mould growth and volatile organic compounds. In general, healthy and low-carbon pathways may be best achieved by combination of decarbonizing the energy sources (electricity grid) in conjunction with a partial retrofit with simple energy efficiency measures to the building envelope rather than relying heavily on extensive and costly retrofit measures.

- In Delhi, there is also potential for substantial reduction in both CO_2 emissions and health exposures to most airborne pollutants. A 50% reduction in CO_2 emissions would be achievable through simple, inexpensive housing interventions and some decarbonization of the power supply. However, given high outdoor particle levels, even with reductions in indoor sources and the use of extraction fans for cooking, the daily mean of $PM_{2.5}$ for a person involved in cooking would typically exceed 75 $\mu g.m^{-3}$ – emphasising the need for more ambitious action to reduce ambient particle concentrations.
- In Beijing, depending on the type of dwelling, the application of retrofit energy efficiency measures could achieve annual energy savings of up to 50%. High levels of exposure to indoor particles are common, however, with substantial contributions from cooking activity. The most critical dwellings are those with no mechanical ventilation. The median indoor level of $PM_{2.5}$ in such dwellings is up to six times greater than the already very high ambient concentrations. It is possible to reduce indoor particle concentrations by an order of magnitude by 2050 by mandatory use of high-capacity kitchen exhaust fans compliant with the Chinese Residence Design Standard GB50096-1999.
- In Belgrade and Nis (Serbia), business-as-usual actions are projected to result in only small reductions in energy use and consequently GHG emissions (21% for the Belgrade domestic stock, 27% for Nis by 2050 compared with 2006). Plans for more demanding and expensive thermal retrofitting measures could achieve theoretical reductions of 50%-54% by 2050 compared with 2006 for both cities, with accompanying reductions in $PM_{2.5}$ especially in single family homes.

Food and agriculture

- GHG emissions associated with food and agriculture make a substantial contribution to national GHG emissions totals and modifications to dietary patterns could help achieve both health and climate change mitigation goals. Modifying the UK diet to comply with WHO dietary recommendations would achieve a 17% reduction in GHG emissions, saving almost 7 million years of life lost prematurely in the UK over the next 30 years and increasing average life expectancy by over 8 months, primarily due to reduced coronary heart disease. Larger reductions in GHGs could be achieved by reducing consumption of animal products and soft drinks and increasing consumption of fruit, vegetables and cereals. These changes would also be accompanied by further improvements in population health. However, to achieve more than a 40% reduction in GHGs would require radical, and probably unacceptable, changes to current diets.
- The current diet in Spain is also far from healthy for both men and women at all ages. The intake of proteins, fats, saturated fats, cholesterol, free sugars and salt is too high, while the intake of carbohydrates and fibre is too low. Only the consumption of fruits and vegetables is broadly in line with health guidelines. The average diet of males between 18-65 years contributes 246 kg of CO_2e a month, while for the average women the emissions are about 201 kg CO_2e. Of the total emissions, 27%-32% comes from the consumption of meat, 17%-20% from

dairy, and 17-20% from fruits and vegetables. A shift to a healthier diet would bring an incidental 13% reduction in CO_2 emissions, but optimizing the diet to meet both nutritional and stringent CO_2e reduction goals would require very large increases in consumption of commodities such as rice, low fat spreads and unprocessed potatoes, while reducing the consumption of meat, milk and milk products, and sugary products by around 40% to 60%. In a scenario in which there is no cap in the subsidies on food, there would be no increase in individual spending on food, and the combination of the taxes and subsidies would result in an annual net tax receipt by the government on the order of €16 billion.

- The current average diet in China is closer to WHO recommendations than most European diets, but the trend is for increased sugar and animal products which will have negative consequences for both health and GHG emissions. Measures to halt and reverse this trend will therefore be required to meet longer term health and environmental objectives.

Electricity generation

- In China, emissions of particles and other pollutants arising from coal-based generation of electricity are substantially higher than in Europe in both absolute terms and per terawatt hour of generation. At the country level, the total external cost of electricity generation (in terms of monetized adverse health impacts) lies in the range $65 to $530 billion at 2010 prices, with a mean estimate of $322 billion. The latter mean cost estimate represents more than 5% of China's GDP in 2009. Per kWh of electricity, this is a cost of 5.71 US ¢ (2010 prices), a value 50% greater than the price of coal consumption per kWh (0.22 Yuan per kWh), and more than double the damage cost of coal-based generation in Europe (2.4 US ¢ per kWh). Just 13% of installations contribute 50% of the overall damage cost.
- These figures suggest the potential for appreciable gains to health from reduced dependence on coal and other fossil fuel-based generation which in part could offset the costs of low carbon policies. Using the marginal damage costs (€/kg emission) to calculate the health impacts and damage costs of future emission scenarios suggest that the use of a 'Carbon Cap' would result in the lowest future damage costs.
- Models of electricity production to 2050 suggest that, without strong climate policies, fossil fuels will dominate future generation, with coal the fuel of choice in China and India. For Western Europe, natural gas provides about 30% of demand in 2050. With increasing carbon price, carbon capture and storage (CCS) accounts for about half of the electricity generation by the middle of the century, along with a strong presence of nuclear and renewables (notably solar in India). Electrification of the transportation sector accounts for about 10% of the final electricity demand in Western Europe. Industry accounts for at least 40% of the electricity demand, followed by commercial and residential end-users. Residential electricity use increases significantly in China and India due to rapid urbanization, but only marginally in Western Europe primarily due to fuel switching (e.g. gas to electricity for heating).
- Depending on assumptions of technology readiness (CCS) and social acceptability of energy options (nuclear), global and regional carbon emissions vary by a factor of two to three in 2050. Under plausible scenarios, there would be downward trends which would continue for the rest of century, with Western Europe reducing its emissions by 95% against 2005 by 2100. Emission intensities of other pollutants, such as particulate matter, nitrogen dioxide (NO_X) and sulphur dioxide (SO_2), also decrease noticeably over time across all regions and scenarios.
- Cross technology gap costs decrease over time; this is especially the case for solar power generation. Fossil fuels become less competitive as carbon price increases. Cost curves do not take into account the full impact of environmental and health damage costs (externalities), other than the effects of CO_2. Fuel prices, and technology development (backup storage) and

deployment (nuclear power or CCS) assumptions have a strong impact on future electricity prices.

- Current generation bio-fuels can reduce vehicle fleet CO_2 emissions by between 10 and 17%. The lower figure applies to feedstocks that impact land use changes (LUC), such as rapeseed. Future bio-fuels based on cellulosic feedstocks and non-food crops (algae) are expected to have much lower lifecycle carbon emissions (half of current fuels), higher yield rates, and will compete less for croplands.
- All things being equal, future transition pathways that rely on nuclear and renewable energy sources have the lowest cumulative CO_2 emissions. However, timely implementation of nuclear is critical to its effectiveness in limiting carbon emissions. Delaying nuclear construction by 10 years, for example, reduces cumulative CO_2 emissions in 2050 against 2010 levels to 36% vs. 41% savings without the delay. Aggressive behavioural modifying interventions over the same time period would yield equal or potentially higher saved carbon emissions, on top of greater benefits on local air quality and hence health.

Changes in outdoor air pollution arising from mitigation strategies

- Models of the health impacts and costs of lifecycle emissions of particulate matter, SO_2 and NO_X provide evidence on air pollution-related effects in the transport sector of modal shifts, changes in mobility technology, and active transport (i.e. walking/cycling). These suggest that behavioural changes (e.g. shifting to public transportation, walking instead of driving, driving electric vehicles, purchasing more fuel efficient cars, etc.) are as effective in reducing overall damage costs as technology options, such as switching from fossil fuel-based generation to nuclear power, or relying on end of pipe fixes such as CCS. More importantly, behavioural changes bring greater improvements in local air quality because displaced emissions are ground-level emissions, whereas stack emissions occur far away from where the traffic is located, and high up in the air, which leads to greater dilution and lower urban population exposure.
- In China, the emissions of air pollutants increase appreciably under business-as-usual (BAU) trajectories, with hotspots in southern Beijing, central Tianjin and north-eastern Hebei. However, under a climate mitigation (CMP) scenario, emissions of pollutants harmful to human health in Beijing decrease significantly, although emissions from surrounding regions remain similar to those in 2010. Compared with 2010, in Beijing under the BAU scenario, average NO_2, SO_2 and $PM_{2.5}$ concentrations will increase by 22-24%, 20-23%, 18-23% by 2015, and by 40-43%, 37-41%, 30-42% by 2020, while under the CMP scenario, average NO_2, SO_2 and $PM_{2.5}$ concentrations in Beijing will decrease by 0-8%, 0-8%, 4-9% by 2015, and by 4-24%, 6-24%, 14-26% by 2020. Without climate mitigation measures and improvements in emission control technologies, the air pollution problem in Beijing and its surrounding regions would deteriorate. Implementation of measures in the 12th Five-Year Plan, including a 17% cut in CO_2 intensity by 2015 on the national scale could prevent deterioration of air pollution, but would result in little improvement compared with 2010.
- Our study suggests that, comparing industry and power sectors, using natural gas to replace coal in residential sector should have the highest priority in improving air quality in the region of Beijing-Tianjing-Bebei province. Coal is the dominant energy source in Beijing and its surrounding region (megacity Tianjing and Hebei Province), and therefore responsible for severe air pollution in this region. Replacing coal with natural gas is proposed as one of the most important policy for air quality improvement. An integrated analysis based on GAINS-China and WRF-Chem was conducted to analysis the effectiveness of this policy.
- We found using natural gas to replace coal in residential sector will achieve the largest reduction in SO_2 and $PM_{2.5}$ concentrations in Beijing, Tianjin and Hebei province and hence the

largest health benefits. While replacing coal with natural gas in industrial sector will achieve the largest reduction in NOx concentration. There is no significant change of surface PM2.5 concentration in POWER and INDUSTRY scenarios compared with BASELINE, but RESIDENTIAL scenario achieves highest reduction in PM2.5 concentrations across the Beijing-Tianjin and Hebei Province.

- In Delhi the estimated shares of $PM_{2.5}$ and carbon monoxide (CO) emissions were 17% and 18% for vehicle exhaust, 16% and 31% for power plants, 15% and 12% for brick kilns, 14% and 15% for industries, and 12% and 14% for domestic, respectively. In Vishakhapatnam, the $PM_{2.5}$ shares are estimated at 39% for power plants, 29% transport, 14% manufacturing industries, and 8% domestic. Annual mortality due to particulate matter in 2011 is estimated to be 550 per million population per year in Delhi (165 due to transport) and 765 in Vishakhapatnam (275 due to transport). Switching of coal-powered electricity generation plants to natural gas in Delhi by 2030 could result in a reduction of 50 fatalities and 1,062 disability-adjusted life-years (DALYs) per million per year. Adopting Euro5 fuel norms by 2020 for the transport sector could result in a saving of 128 lives and 2,767 DALYs in Delhi.

Achieving change: evidence on choices

- Evidence on the influence of economic factors in determining energy use and energy efficiency investments by households was examined in the Czech Republic, Italy, Spain and China. Use of price as a measure of demand management may indeed offer an effective method to influence energy consumption by households. Estimates of long-term 'price elasticity' of residential energy demand suggest that a 1% increase in price would result in about -1.0% change in gas consumption in Spain and in electricity consumption in China, and a -0.4% to -0.87% change for gas in the Czech Republic and for electricity demand in Spain, respectively. These estimates of price elasticities imply quite large 'direct rebound effects'. However, considering the methodology we have followed in these studies, these estimates provide an upper bound – rather conservative – estimate of the direct rebound effect.
- The household survey on energy use conducted in Spain revealed that if the residential energy efficiency of electricity increased by 10%, an estimated energy saving of only 1.34% would be realized, whereas for the same improvement in gas efficiency there would be an increase in the demand for heating and domestic hot water by 0.94% (a 'backfire effect' where the rebound effect is larger than 100%). The estimate of electricity price elasticity also implies a backfire effect in China, meaning that the improvement in energy efficiency may result in greater, not less, consumption of energy. However, at least in the case of gas demand by Czechs and of electricity demand by Spanish, improvements in energy efficiency will save energy and hence lower GHG emissions.
- Despite large direct rebound effects, upgrades in dwelling energy efficiency may generate positive effects in terms of increasing the market value of dwellings and helping to reduce fuel poverty (almost 17% of Spanish households admitted to not having been warm enough during the winter that preceded the survey).
- In Italy, evidence from analysis of population surveys suggests that respondents prefer policies that promote renewables over policies that target energy efficiency and prefer incentive-based policies over policies that impose taxes. Their willingness to pay is €130 per tonne of CO_2 emissions avoided. However, in relation to home energy efficiency investments, around 78% of the beneficiaries of an Italian efficiency programme were found to be 'free-riding', meaning that they would have replaced their heating system even without financial assistance. In such circumstances, financial assistance of the programme may therefore lead to further spending and rebound effects. Such effects were found to be appreciable in all countries where behaviour of residents was analysed.

- Both subsidies and taxes could persuade consumers to switch from a standard domestic appliance to a more efficient one. Czech respondents would be more likely to purchase energy efficient domestic appliances (washing machine) when its price was lowered by a rebate rather than if the price of a less efficient machine was taxed. However, a tax on non-labelled appliances in Spain was found to be more cost effective in reducing energy consumption, with typically lower policy costs and lower social welfare losses than subsidies. A mixture of taxes and subsidies (the so called 'Bonus-Malus approach') is a good compromise from both an economic and social point of view.
- Analysis of survey data for Spain suggests that, if the goal is to reduce electricity consumption, households should diversify the fuels they use for heating and hot water. If the goal is to reduce natural gas consumption, because of evidence of a backfire effect, households should seek to improve the energy efficiency characteristics of their homes, but continue using natural gas as an energy source for heating and hot water.
- The large-scale "Green For Saving Program" to support thermal insulation of family houses in the Czech Republic resulted in reduced energy consumption. For such investments, a 10% increase in energy efficiency reduces gas use by only about 6% (i.e. there is a rebound effect of about 40%).
- In China, high-income households show greater change in electricity consumption in response to a change in long-term electricity price. Hence, low income groups will bear a heavier burden of electricity spending and suffer greater welfare loss due to their inelastic demand if there is a simple policy of price increases. The role of electricity as a life necessity is more obvious in low income groups in urban China and with their income growing they will increase electricity consumption. The policy implication of this study is that since price and income elasticities of electricity consumption differ greatly among different income groups, if an electricity tariff reform is implemented, then either directly subsidizing low-income families or rationally setting the price levels of different income groups can help to mitigate adverse redistributive (social) effects.
- Analysis of household-level data for 10 OECD countries shows that those who are motivated to save energy tend to take action on multiple fronts, for example through every-day actions (e.g. turning off lights) and investing in energy efficiency retrofits. The practical implication of this is that increasing the motivation of individuals to save energy is likely to affect all types of energy-saving behaviour. This study also shows that the promotion of energy-saving behaviour can be achieved by lowering the difficulties of taking energy-saving activities.
- The health benefits of a tax incentive program targeting electricity consumption of European domestic hot water systems has shown that the benefit in physical terms would amount to saving one life per million homes per year. The social cost benefit would be around €2 million per million homes per year. The theoretical limit, assuming full implementation across the housing sector, comes to €0.4 billion annually.

Some methodological issues

- The PURGE project entailed the development of modelling tools to assess the impact on health and CO_2e emissions of sector-specific interventions aimed at GHG emissions reduction. Desirable features of such models were found to include the use of population-representative data from local surveys, the ability to compare a range of policy choices with costs and benefits calculable for different target groups, and the monetization of impacts on health and in different sectors. The estimation of targeted individual-level health impacts can provide important detail on the "winners" and "losers" of a given policy. A model for assessing the health impacts of housing-

related energy efficiency interventions in England is currently being tested as a support tool by the Department of Energy and Climate Change in the UK.

- Methodological developments undertaken as part of the project also focused on the use of semi-analytical methods to quantify and propagate uncertainties in such modelling, and the use of multi-objective optimization (as an example of a multi-criteria decision analysis method) to compare alternative mitigation strategies across several competing objectives or criteria. These methodological refinements have potential importance for assessing complex policy choices.
- In terms of attaching costs and economic values to the health consequences of GHG reduction policies, we reviewed studies which examined the social costs of pollution on health, in particular health expenditures (either paid by the local public health system or out-of-pocket expenses incurred by sick individuals), loss of productivity (valued in terms of labour productivity loss, or wage losses plus replacement costs for hiring temporary workers plus indirect costs from loss of business activity), and loss of welfare due to sickness-related inconveniences. For a given health endpoint, these costs vary between countries in relation to economic wealth, and social healthcare system characteristics. In Europe, costs across countries typically vary by a factor of 2 to 3, with differences reaching an order of magnitude between West and East Europe. Productivity loses are significant.
- Concerning values for mortality risk reduction, the value of statistical life (VSL) for adults lies in the rage of €1.2 and €6 million in Europe. A meta-analysis carried out for the OECD by Navrud and Lindhjem (2011) suggests a 'central' value of €3.6 million. For children, for whom a child risk premium multiplier of 1.5 appears appropriate, the VSL is therefore estimated to be between €1.8 and €9 million, with a central figure of €5.4 million. For economic valuation of cancers, the value of a life year (VOLY) is needed (€90,000), from which the cost of cancer death is obtained by multiplying the VOLY by the loss of life expectancy of the specific cancer in question. The cost of illness and productivity loss may be added to this. The equivalent cost of the Quality Adjusted Life Year (QALY) in Europe is estimated to have a value of around €64,000 (€40,000 to €200,000).
- Health costs in China and India (after adjustment for differences in GDP purchasing price parity per capita and income elasticity), are considerably lower than in Europe. As an example, the social cost of an adult statistical life (VSL) is 1/3rd of the European value in China and 1/8th in India. The QALY follows the same trend as the VSL. Compared to Europe, morbidity costs are between 16%-47% (China) and 8%-16% (India) lower for asthma and anxiety health end-points. These differences have evident implications for the comparison of policy choices across settings.
- As a further resource, a database has been compiled of the characteristics of selected Asian and European cities aimed at providing substrate for the assessment of potential greenhouse mitigation strategies with co-benefits for public health.