K4D Knowledge, evidence and learning for development

Interventions in LICs and LMICs to improve air quality and/or mitigate its impacts

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Question

What is the evidence base for interventions in low and lower middle incomes countries to improve air quality and/or mitigate its impact on health outcomes for populations, with a focus on children under 5 years old? (This should include an overview of assessments on cost-effectiveness of interventions; include policy, planning, regulation, legislation, legal enforcement, market based approaches etc.)

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1. Summary

This rapid literature review summarises evidence on air quality interventions in LICs and LMICs to improve air quality and/or mitigate its impacts. **The review found limited evidence derived from such countries and instead draws on evidence from reviews and compilations compiled by bodies such as Public Health England (PHE) and the World Health Organisation (WHO).** In particular, the review draws heavily on two key sources of information; a review commissioned by the Department for Health and Social Care (DHSC) to review the evidence for practical interventions to reduce harm from outdoor air pollution and World Health Organisation's (WHO) guidance on interventions to address indoor and outdoor air pollution.

The evidence base for what works where and why is limited, inconsistent and requires further assessment. This is particularly the case when trying to identify interventions that are focused on children under 5 years old, indeed such interventions are often embedded within broader air quality management efforts. Interventions can have co-benefits e.g. encouraging more active travel or addressing sources of inequality, or unintended consequences e.g. disproportionately impacting upon socially disadvantaged groups, or rebound effects e.g. reduction in expected gains due to behavioural or system responses. These considerations entail the need for long term monitoring of interventions using a broad range of outcome measures. Examples of the complexity of analysing such interventions is highlighted by the conflicting views of the Ahmedabad Bus Rapid Transport System in India, heralded by UNEP as a best in-class example of sustainable transport whilst criticised by other commentators for having a negative impact on the poor and marginalised.

It is broadly acknowledged that cooperation across sectors and at different levels - city, regional and national - is crucial to effectively address air pollution. According to the WHO, policies and investments supporting cleaner transport and power generation, as well as energy-efficient housing and municipal waste management can reduce key sources of outdoor air pollution. These interventions not only improve health but also reduce climate pollutants and serve as a catalyst for local economic development and the promotion of healthy urban lifestyles[1].

An array of interventions are identified in this rapid literature review and clustered around 7 areas. It is important to note that these interventions require further interrogation and an appraisal of the context in which they may be implemented. Issues surrounding the uptake of clean cookstoves highlights that whilst interventions may have a beneficial impact on air quality, matters such as perception awareness and socio-cultural proclivities may hinder uptake. Example initiatives include:

- **Cities**: Energy efficient transport, healthy urban planning, healthy urban diets, slum upgrading, healthy energy efficient housing and improved urban waste management.
- **Transport**: Public transport, active travel (walking and cycling), land use and built environment, vehicle technologies and fuel technologies
- **Housing**: Switching to cleaner fuel sources and household design.
- **Industry**: Improved brick kilns and coke ovens, control of fugitive emissions

[1] https://www.who.int/airpollution/ambient/interventions/en/

- **Power generation**: switching from fossil fuels to renewables and preplacing or supplementing diesel generators.
- **Agriculture**: alternating irrigation; improved manure management; reduced open burning and moving towards plant-based diets.
- **Regulation**: improved regulatory mechanisms and legislative processes, improvements in achieving clean air policy implementation and compliance.

It is important to note that single interventions are unlikely to have a significant impact on long-term air pollution trends, but a set of well-designed and implemented interventions can reap benefits. The effectiveness of various intervention components depends on local geography and meteorology, as well as on environmental, social and political situations and behavioural responses. Because each location is unique, similar interventions may not result in consistent effects across cities or regions. Each intervention project is unique and should be evaluated individually. Particular attention should be given to socioeconomic and health inequalities, as deprived communities are particularly susceptible to the adverse effect of air pollution.

2. Air Quality Interventions: Approaches

Addressing air pollution can save and improve the quality of children's lives. It can help reduce the incidence of acute and chronic respiratory infections such as pneumonia and asthma among children. Reducing air pollution would reduce complications during pregnancy and childbirth, as well as improve children's development, helping them to lead longer and more productive lives, and benefit sustainable development and climate change mitigation (WHO, 2018).

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Within government ministries, air pollution cuts across environment, health, social welfare, energy, finance and regulatory sectors. It also needs to be addressed across the public, private and civil society sectors and requires harmonised approaches to address the multitude of forces that cause air pollution – from consumer behaviour patterns to organisational and regulatory actions (Rees, 2016). This, in turn, requires more institutional capacity and coordination, as well as resources for programming. It will require working in a more integrated and effective manner – including across agencies and in line with the 2030 Agenda for Sustainable Development.

In order to assist in the implementation of these interventions, WHO provides country-level technical support on best practices to both reduce air pollution and implement mitigation strategies. WHO also employs a number of tools in order to evaluate the effectiveness and feasibility of abatement efforts. Examples include cost-benefit and cost-effectiveness analyses and health impact assessments. Four elements are considered central to the WHOs road map

[2] https://www.who.int/airpollution/ambient/interventions/en/

for an enhanced global response to the adverse health effects of air pollution, these include (WHO, 2016):

- Expanding the knowledge base, by building and disseminating global evidence and knowledge on the effects of air pollution on health and the effectiveness of interventions and policies to address it.
- Enhancing systems to monitor and report on health trends and progress towards the air pollution related targets of the Sustainable Development Goals.
- Leveraging health sector leadership and coordinated action at all levels – local, national, regional and global – to raise awareness of air pollution.
- Enhancing the health sector's capacity to address the adverse health effects of air pollution by training, guidelines and national action plans.

In the UK, Public Health England (2019), conducted an evidence review of interventions to improve outdoor air quality and public health, suggesting that a systems or model approach may provide a means to develop a hierarchy of measures to address air pollution. The hierarchy provides a way of prioritising interventions to address air pollution problems from the polluting activities, to the environment, to the people who are exposed to the pollution.

Figure 1: ***Air pollution intervention hierarchy***

Source: PHE (2019: 180), licensed under Open Government Licence v3.0

Prevention: Prevention applies to emissions of pollutants rather than activities. The global shift to clean growth and development of clean energy and innovative technologies offers future economic opportunities.

Mitigation: If emissions cannot be fully eliminated, one should consider how environmental pollution could be reduced. Examples are keeping sources of pollution away from people, redesigning spaces to introduce barriers to separate people from pollution, and displacing pollutant emissions outside hotspots and populated areas to reduce population exposure.

Avoidance: If environmental pollution cannot be reduced or displaced, the last step is to consider how people can avoid exposure, setting out interventions to support exposure reduction (such as using travel plans based on less polluted routes).

In a somewhat similar vein, focusing on protecting children, UNICEF (Rees et al., 2016: 80-81) identify a four-pronged approach:

- **Greater efforts to reduce air pollution**. Reducing air pollution will require a multitude of actions at various levels, from government to households and local communities – including actions to reduce fossil fuel combustion, investments in sustainable energy and low-carbon development policies. Within households, it requires supporting the emerging clean cooking sector and ensuring that high-quality cook stoves and fuels are accessible and adopted by households, as well as cleaner heating and cooling systems. It might also include provision of solar panels and other alternatives to diesel generators.

  Within communities, it requires better management of community resources, including waste disposal, better public transportation options, and information and knowledge on reducing pollution. Nationally and internationally, technology and legislation that reduces harmful pollutants from vehicle emissions, and actions to reduce transport emissions in general, can make a big difference in mitigating outdoor air pollution.
- **Minimise children's exposure to air pollution**. Minimising exposure includes better waste management systems, and improved ventilation. It can mean better ventilation and design-construction in homes to minimise exposure to both indoor and outdoor pollutants. This, in turn, will necessitate child sensitive urban planning so that polluting sources are kept away from places where children spend significant time, such as schools.
- **Improve children's overall health, so that when they are exposed to air pollution the risks of further health complications are reduced**. The pre-existing health of a child can greatly affect the degree to which air pollution affects their health. Providing all children with access to quality and affordable medical care, including vaccines and medicines that prevent infections that can lead to pneumonia, as well as exclusive breastfeeding, better nutrition, and universal access to antenatal and maternal health care, helps build their resilience to many of the negative effects of air pollution. Access to safe water and sanitation is also crucial in supporting children's health and risks associated with air pollution.

  The children who are most vulnerable to air pollution are the ones who already suffer from poor health. Air pollution exacerbates this inequity, as it further compromises their health, their future livelihood, and even their potential survival. Helping to improve the quality of the air breathed by the poorest children will be crucial in combatting inequity and preventing intergenerational cycles of poverty.
- **Better monitoring of air pollution and its link with children's health**. Air quality can fluctuate rapidly, both within and between geographical areas and over the short and longer time periods. For example, cooking or heating with biomass in the home can cause a rapid, temporary short-term peak in pollutant levels. Also, urban ambient pollution tends to be highest during rush hour in most countries, often when children are making their journey to or from school. Waste-burning is often worse at certain times of the day. Capturing measures of personal and micro environmental pollutant exposure can guide educational and behavioural approaches to reduce harmful air pollution exposure at individual, household and community levels.

Air quality monitoring devices and systems that help individuals, parents, families, communities and local and national governments visualise and respond immediately to prevailing and real-time air quality conditions will help minimise exposure and raise awareness and educate the public and policymakers on key health risks. Better monitoring can also inspire action by a range of stakeholders. It can also lead to improved government standards, regulation and policies that work towards the realisation of health-based WHO air quality guidelines. Links between air pollution and child health should also be monitored, including through early diagnosis of illnesses and registration at health clinics, to help prevent the compounding negative impacts of air pollution on children's health. Improved health information systems and integration with national and regional vital statistics enables high quality epidemiological research and progress tracking for intervention measures. These mechanisms also may include improved surveillance and early warning systems of child health and air pollution risks.

Single interventions are unlikely to have a significant impact on long-term air pollution trends, but a set of well-designed and implemented intervention, which together form a "complex intervention" can reap benefits (PHE, 2019; MRC, 2019). The effectiveness of various interventions depends on local geography and meteorology, as well as on environmental, social and political situations. Because each location is unique, similar interventions may not result in consistent effects across cities or regions. Each intervention project is unique and should be evaluated individually. Particular attention should be given to socioeconomic inequalities, as deprived communities are particularly susceptible to the adverse effect of air pollution.

See: Table 1: Examples of actions that can be taken include

Reduce air pollution	**Reduce exposure**
• Support households to reduce indoor air pollution from cooking and heating with solid fuels. • Adopt cleaner cooking and heating fuels to reduce household air pollution. • Apply low-carbon development strategies in energy generation, housing and industry. • Install good quality filters on smokestacks. • Design traffic and levels are high. Urban spaces to avoid generating air pollution.	• Raise awareness of the harm pollutants cause children and pregnant women. • Restrict household air pollution around children as much as possible. • Install good quality air ventilation and/or filtration systems in homes and areas where children spend time. • Limit exposure of children to air pollution when Design traffic and levels are high. • Reduce children's exposure to second-hand tobacco smoke. • Improve air quality in children's environments through better urban planning, including green spaces.
Improve child health	**Improve policy and monitoring**
• Provide children with access to good quality healthcare and WASH to improve their health and protect them from the negative effects of air pollution. • Encourage and support children and youth to participate in local environmental activities.	• Develop and implement national laws and regulations for the detection of environmental diseases. • Develop and build consensus on children's environmental health indicators. • Monitor air quality systematically.

• Increase understanding that child health, growth and development depends on both controlling root environmental causes of poor health, and clinical responses to disease. • Provide proper medical treatment to children with asthma, and other chronic respiratory conditions. • Increase the coverage of pneumococcal vaccines and treatment in community care centres. • Provide oxygen treatment innovations such as low-cost oxygen concentrators. • Provide amoxicillin dispersible tablets as a first-line treatment. • Promote exclusive breastfeeding in the first 6 months to help prevent pneumonia. • Improve child nutrition to help fight air pollution related diseases. • Provide prenatal and postnatal healthcare for mothers and children.	• Fully recognise the important role of environmental protection in child survival, development and protection. • Utilize accurate and low-cost devices to easily diagnose pneumonia. • Give special policy attention to disadvantaged children who are closer and more vulnerable to environmental hazards. • Strengthen coordination and cooperation among government departments on air pollution. • Local governments should actively disseminate health warnings so that people can better protect themselves, and children, from air pollution. • Recognize the danger signs of pneumonia and seek care quickly • Make sure that children's rights and their special vulnerabilities are systematically taken into account in discussions and negotiations on environmental agreements.

Source: Rees et al., 2016, p. 82-83, reproduced with kind permission from UNICEF

Public Health England (PHE) (2019) provide an overview of interventions across five areas: vehicle/fuel interventions; planning/structural design interventions; agricultural interventions and behavioural interventions. In turn, the WHO identifies interventions by sector: cities; transport; housing; industry; power generation; waste management and agriculture.

There is evidence, some of it strong, for effectiveness of interventions across these areas or sectors which can reduce emissions of harmful pollutants. Commentators acknowledge that few existing studies directly examine the effects of these interventions on environmental concentrations and even fewer the impacts upon objective health outcomes (PHE, 2019) – this evidence gap is particularly evident in countries in the Global South. Health benefits of interventions are often inferred from the reductions in emissions. Studies examining the cost-benefits of interventions are more limited, making it difficult to stratify by cost and health benefits. Certain crosscutting principles are required to ensure that interventions are impactful. According to PHE (2019: 9-10), these may include:

- **Different air pollutants should be considered and tackled together**. Interventions to reduce individual pollutants should not be considered in isolation from other pollutants, otherwise reducing harm from one may be countered by an increase in another.
- **Authorities need to work together**. Neighbouring authorities and scales of government need to work together, especially on interventions that apply to defined spatial areas, such as clean air zones. These can be effective in reducing harm from air pollution in cities and must be carefully designed to reduce all pollution and to avoid displacing it from one area to another.
- **Effective strategies require a coherent approach**. This should be between government functions (such as environmental and public health, transport, and spatial planning) and between government and local communities, as well as other public and private sector organisations.

- **Everyone has a role to play**. Behaviour change is needed to reduce exposure and contribution to pollution. Local authorities are at the centre of local leadership and should coordinate and lead action. Employers, private and public-sector organisations should engage with local initiatives and play their part. The public sector should lead by example and national government needs to ensure a policy environment supportive of local action and create the right incentives.
- **Reduction of air pollution at source is better than mitigation of consequences**. There is a hierarchy of interventions with preventing, reducing or replacing polluting activities to reduce emissions as the first priority. Actions to reduce the concentration of air pollution once it has occurred is the second priority, and individual avoidance of exposure is the third.
- **Improving air quality can go hand in hand with economic growth**. People prefer to live, and employers are likely to prefer to establish businesses, in places which are clean and support a healthy workforce.
- **As action is taken some groups may need particular support**. Some actions may disproportionally affect some groups of people. For example, those whose livelihoods depend on driving but who do not have access to or the resources for cleaner vehicles may need particular support because some of the most effective interventions target road vehicle emissions. Without such support, action on air quality may have the perverse impact of increasing inequalities.

Intervention considerations

Review authors note that one difficulty with providing empirical evidence for approaches to preventing, mitigating or avoiding air pollution is the lack of high-quality evidence. PHE (2019) note that there are limited studies, and those that do exist rely on either an environmental or health impact assessment methodology which estimates the changes in exposure or health outcomes based on a deterministic model.

It is difficult to design robust intervention evaluations (e.g. randomised clinical trials) and most air pollution interventions will not occur alone, therefore determining the impact of a single intervention on air quality is not simple. Due to meteorology and atmospheric variability, a long time series (e.g. 5-10 years) is recommended for detecting whether interventions have a significant effect on air quality. Additionally, studies must account for background sources, and other temporal variables which may affect emissions, such as economic downturns or upturns. Policies and planning approaches aiming at reducing air pollution should vary from region to region to accommodate for differences in terrain and land use characteristics (PHE, 2019).

More research and analysis are needed on air pollution concentrations, and on co-benefits and unintended consequences, and the resultant overall impact on health outcomes pre- and post-implementation of interventions to strengthen the evidence base.

Co-Benefits, Unintended Consequences and Rebound Effects

The potential for health, environmental economic and societal impact from reducing air pollution is significant, but it is increasingly important that a systems-based approach is taken in identifying the arising costs or benefits of policy from across policy domains. Delivery of clean air policy involves multiple stakeholders operating within a highly interconnected and interdependent system with complex interactions and feedback. This is often viewed as a set of discrete subsystems, rarely considering the landscape in its entirety and thereby limiting effective anticipation of the wider impacts and unintended consequences of policy decisions. Developing the scientific foundation and robust evidence base to inform clean air policy making processes is critical, to ensure all decisions maximise desired outcomes and mitigate adverse impacts.

It is particularly important to consider whether interventions may exacerbate pre-existing inequalities. A systematic review that explored the impacts of transport interventions on social inequalities by Khreis et al (2017) found that social inequality impacts were hard to establish but interventions such as regulatory restrictions, low emission zones, parking controls, new rail services, freight bans may increase inequalities. On the other hand, interventions such as bus and public transport services, bus priorities, and concessionary fares may decrease inequalities. In addition, community severance can result from infrastructure policies (particularly new road and rail lines) and from heavy traffic which can arise from conventional traffic management. Conversely, community severance can be reduced if heavy traffic flows are reduced, which can result from some traffic reduction policies such as access restrictions and road pricing.

Rebound effects may also occur, whereby if energy efficiency is improved, direct changes in product use can occur, such as increased usage of a fuel-efficient stove or driving longer distances in a less polluting vehicle. In addition, among more affluent groups, costs saved from effective interventions may be used for alternative more polluting behaviours, thereby partly negating air pollution and energy savings.

For these reasons it is recommended that a systems-based clean air policy approach, including effective inter-sectoral coordination is adopted to optimise desirable co-benefits, whilst mitigating negative consequences or rebound effects at both policy formulation and implementation stage.

3. Interventions

This section has grouped interventions according to the sectors identified by the WHO. The identified interventions should not be considered exhaustive.

Cities

According to PHE (2019: 71-72):

- Interventions with the highest potential to be effective both at national and local levels are related to traffic. Driving restrictions produced the largest scale and most consistent reductions in air pollution levels.
- The intervention effectiveness strength was low, and the uncertainty range was high, with only 1 exception (driving restrictions). PHE (2019) stress that the paucity of evidence of effectiveness should not be confused with or assumed to be evidence of ineffectiveness.
- Interventions comprise structural and planning measures. The former referred to road and green infrastructure and the latter referred to traffic related measures, as well as to the promotion of active travel.
- Measures, such as Low Emission Zone (LEZ) and road pricing, produced reductions in traffic, but not necessarily great improvements in air quality, perhaps due to localisation of emissions, for example by displacement. LEZ are potentially effective at reducing air pollutant levels (more effective for particulate matter, PM_{10} than for nitrogen dioxide, NO_2)

in cities. They are expected to work better for NO_2, if combined with interventions that incentivise the use of Euro 6 standards for both heavy and light duty vehicles.

- Potential to improve air quality and public health outcomes is associated with the co-implementation of a mix of various measures that provide/improve green and active travel infrastructure, prioritise road safety, provide public transport and discourage travel in private cars, together with policies focussing on reducing the emissions of vehicles.
- Green Infrastructure (GI) such as trees, parks, and green walls – determines where air pollution is produced, and how it disperses. It is therefore potentially effective not only to improve air quality related public health outcomes, but also to improve health inequalities in urban areas and promote health and well-being. Green infrastructure has also the potential to impact positively on urban heat islands and reduce the negative impacts of flooding.. Built environment professionals should consider air quality at all stages of urban design and development (Ferranti et al., 2019).
- For speed limitation (e.g. traffic calming measures) and encouraging modal shift to active transport, the public health 'co-benefits' outweigh benefits associated with reduction of exposure to air pollution alone, as speed limitations are associated with a reduced risk of pedestrian injury and traffic collisions, and increased physical activity is associated with multiple public health benefits (improved cardiovascular outcomes and improved weight status among children, adults and older adults).

Energy-efficient transport[3]

The WHO asserts that safe, equitable, and energy-efficient urban transport can help achieve multiple health and sustainability goals. They continue that shifting urban design and infrastructure investments into public transport networks that prioritise rapid bus transit or light rail over private vehicles can reduce the long-term trajectory of both air pollution and climate emissions generated by private transport – and improve health equity by providing those lacking cars with better mobility.

Diesel vehicles are identified as the heaviest source of particulate (PM) emissions, including black carbon climate pollutants (a short-lived climate pollutant (SLCP) that is a component of particulate pollution).

Low-sulphur diesel fuels and low-emissions vehicles, as well as a modal shift to public transport and non-motorised modes, both are essential in order to reduce pollution and SLCP climate emissions. In developing cities, in particular, the absence of strong urban rapid transit and non-motorised transit systems, means that improvements in vehicle technologies are typically overtaken by increasing vehicle traffic – driving up pollution to previous levels and perpetuating a trajectory of higher short-lived (black carbon) and long-lived (CO_2) climate emissions. This is a common cycle in many rapidly-growing low- and middle-income cities of Africa and Asia today, which face strong pressures for more travel – and weak public transport systems.

Complementary walking and cycling infrastructures are comparatively easy and inexpensive for local authorities to develop – when the political will exists. These can immediately reduce injury risks for a very large proportion of urban dwellers. For instance, in Nairobi it is estimated that

[3] https://www.who.int/sustainable-development/cities/strategies/transport/en/

some 40% of daily trips are on foot and another 40% of travel is via informal and poorly organised “matatus”, or shared taxi systems – while only 9% of travel is by private vehicles.

Over time, investments in rapid transit and non-motorised travel systems can support healthy physical activity and further reduce air pollution and climate emissions with zero- emissions transport modes, as urban populations become more mobile (Cepeda et al., 2017).

Compact cities served by transit and dedicated walking and cycling networks are more energy-efficient and safer for pedestrians and cyclists. Long-term studies in cities such as Shanghai and Copenhagen have found a 30% lower annual mortality risk among cycle commuters – the gains in life expectancy from improved physical activity in these cities also outweighed increased exposures to injury and pollution. Cities built around transit and active transport also offer efficient and equitable access to jobs, health facilities, and other urban services; such transportation infrastructure is important to youth, elderly, disabled, and low-income groups.

Traditional vehicle-based strategies foster sprawl due to the needs for larger roads and expanses of parking between buildings. As cities expand horizontally, to accommodate road and parking infrastructure needs, public transport becomes increasingly inefficient as does non-motorised transport, due to longer urban trips. New roads induce more vehicle travel, and progressively longer urban trips, in a vicious cycle. Sustainable transport solutions are therefore crucial for urban planning and design in order to increase accessibility without increasing travel times, pollution, and environmental risks.

Healthy urban planning[4]

Urban planning offers the opportunity to envision and implement sustainable settlement patterns. In North America, strict zoning regulations has caused physical separation of residential neighbourhoods and other functions – reinforcing dependence on private vehicle travel between homes and daily destinations, such as schools, shops, and health services. In many North American cities, 90% or more of daily trips may be by private vehicle.

Conversely, in European cities such as Copenhagen or Zurich, which have a more “integrated” approach to zoning, whereby new housing is developed alongside schools, clinics and small businesses, up to two-thirds of trips are by public or non-motorised transport and only one-third of trips may be by private vehicles.

Developing Asian, Latin American and African cities are characterised by a mix of approaches – with some land use replicating North American models of suburban malls and gated communities accessible only by private vehicles; Asian cities often develop with high-rise skylines. Other cities are attempting a mid-rise, mixed-use, approach. Notable examples include Curitiba, Brazil and Bogota, Colombia.

Mid-rise urban areas are often favoured more by pedestrians. Urban concentrations of high-rise buildings can exacerbate heat-island impacts by creating large expanses of concrete, which absorb heat, and block natural breezes, or conversely, create “wind-tunnels” and block sunlight.

[4] http://www9.who.int/sustainable-development/cities/strategies/urban-planning/en/

Proven methods for cooling the urban environment include: open skyline design to allow cooling winds; green design of buildings and of building rooftops; other “vertical” urban garden strategies; green, porous parking surfaces, and parks built above underground parking lots; fountains and urban pocket parks or urban arterial parks laced by walking and bikeways. Reducing urban heat-island impacts also reduces energy requirements for air conditioning, smog levels, and health risks due to heat stress and poor air quality.

Planning can overcome these obstacles, e.g. careful spatial planning of high-rises and the lining of key pedestrian corridors with street-level windows and businesses, trees and greenery, and amenities such as street furniture. Whether the approach is mid-rise or high- density cities, development of space-efficient rapid transit infrastructures and green spaces is critical to support physically active lifestyles. For instance, clustering homes around green areas, well planned pedestrian and cycle paths, and efficient public transport promote air quality, children’s mobility and reduced traffic injuries.

Healthy urban diets[5]

In cities around the world, municipal and community initiatives to promote healthy urban eating have the potential to mitigate both health risks and environmental impacts. Such initiatives can include urban farmers’ markets connecting consumers with local producers of fresh fruits and vegetables and other foodstuffs, rooftop and community gardens which can promote local production and increase education and awareness of food production techniques, and peri-urban projects which set aside land to grow fresh produce within a short distance of city limits.

Urban agriculture projects can help reduce the prevalence of ‘food deserts’ by providing accessible, healthy food within inner-city neighbourhoods, particularly to residents of low socioeconomic status. Furthermore, integration of government nutrition program with farmers’ markets and other community initiatives can be used to increase the benefits and affordability of fresh food to low-income consumers.

Slum upgrading[6]

Globally, slums are home to an estimated 828 million people, representing around one third of the world’s urban population. In some developing cities, the slum population can reach up to 80%. Hence, informal settlements that result from unplanned growth offer unique opportunities for city planners to achieve improvements in both climate and health.

Many current slums are vast islands of informal economies, social exclusion, poor housing and underdevelopment. Smart, productive cities of the future can transform these areas into vibrant neighbourhoods that are fully integrated into urban design management systems.

Refurbishing slums with street networks, expanded green spaces, and upgraded infrastructure improves the physical living conditions, quality of life, and access to services and opportunities. It also decreases the prevalence of health risks associated with unhealthy living conditions. To

[5] http://www9.who.int/sustainable-development/cities/strategies/healthy-diet/en/

[6] http://www9.who.int/sustainable-development/cities/strategies/slum-upgrading/en/

achieve this, local participation can be a powerful instrument to mobilise low-income communities around the planning, management and governance issues of their neighbourhoods.

Simple, climate-friendly housing initiatives in slum areas have included innovations such as: roof insulation; installation of rooftop solar hot-water heaters; PV solar panels for lighting and grid electricity backup; improvements in piped drinking-water and sewage infrastructure; and the creation of pedestrianised corridors in narrow alleyways to keep out motorcycle traffic, reduce noise, and protect children's safety.

One new innovation in sustainable transport in rugged mountainside Latin American "favelas" has seen the creation of airborne cable cars, or gondolas, to improve neighbourhood connections with the downtown area – thus improving access to jobs, education and services. Rio de Janeiro, Brazil, Medellin, Colombia and Caracas, Venezuela, and La Paz, Bolivia have been among the early adopters of this clean, quiet and efficient transport mode.

WHO estimates that annually 4.3 million people die prematurely from illnesses linked to household air pollution, primarily from stroke, cardiopulmonary illnesses, acute and chronic respiratory disease, and certain cancers. Cleaner household cooking and heating sources in urban areas may include the replacement of coal and low-efficiency biomass stoves with cleaner fuels and technologies, such as induction electric stoves, now becoming more accessible in cities of South Asia, liquefied petroleum gas (LPG), which is generally more available in the city than countryside; or industrially produced renewable fuels such as ethanol and biogas.

Healthy, energy-efficient housing

Structurally sound, safe, climate-adapted and energy-efficient housing design can reduce exposures not only to household air pollution, but also to excessive heat, cold, and dampness – all of which are risk factors for stroke, heart attacks, respiratory illnesses and other cardiopulmonary diseases as well as improving mental health outcomes.

This involves effective strategies in building orientation, shading and shrubbery, window placement and the choice of building materials so as to create a "thermal envelope" adapted to local climates. This means absorbing solar radiation and preserving heat indoors in temperate climates and cool weather, and in hot climates, selectively filtering and shading from the sun.

Effective use of natural ventilation helps to reduce indoor temperatures in warm months and hot climates, reducing health risks from heat stroke. Natural ventilation can also reduce health impacts from indoor dampness and mould, as well as from air conditioning, which create noise, add to urban heat-island impacts, and can recirculate indoor pathogens. In terms of climate, air conditioners are not only are high energy consumers but also are fabricated with hydrofluorocarbons (HFCs), short- lived climate pollutants with a global warming potential many times more powerful than CO_2.

Improved urban waste management[7]

Strategies for waste reduction, separation, processing, management and recycling and reuse are feasible, low-cost alternatives to the open incineration of solid waste, which is common in

[7] https://www.who.int/sustainable-development/cities/strategies/urban-waste/en/

developing cities. Where incineration is unavoidable, then combustion technologies with strict emissions controls are critical.

Improved collection, management and disposal of urban waste is one important strategy that can yield multiple improvements in both climate and health. Using anaerobic digestion, methane emissions can be captured from sewage, livestock manure, and landfill solid waste, and used as biogas or bio-methane, a fuel for cooking, heating or power needs.

Anaerobic bio solid digestion systems can produce a gas composed of 55%-70% methane, which is typically much cleaner than biomass combustion, although not as low-emissions as natural gas. As a renewable fuel, methane capture and use, however, has many other health and environment advantages. The process reduces methane emissions to the atmosphere that contribute to ozone, which are a factor in chronic respiratory illnesses, as well as a contributor to climate change. Finally, if biogas replaces biomass or coal combustion in household cooking or heating, then household and outdoor air pollution will also be significantly reduced.

Millions of rural households in China, and thousands in Nepal, already generate biogas cooking fuel from animal waste in small, simple digesters. Insofar as these also process household sewage waste, biogas production also requires a hook-up to an improved latrine, which has a sanitation benefit as well.

In larger, industrialised plants that exist at urban level, recovery of over 90% of methane gas can be achieved with established technologies. Improved urban wastewater treatment systems can also provide a source of methane capture and purification, and the resulting fuels may be used as a clean source of urban power generation as well as for households.

The UNEP-affiliated Climate and Clean Air Coalition has launched a municipal solid waste initiative which fosters technical training and awareness-building to assist cities around the world in mitigating methane emissions from municipal solid waste landfills.

- Climate and Clean Air Coalition Municipal Solid Waste Initiative

Sustainable waste management activities can serve as a catalyst for local economic development. For instance, a joint U.S.-Brazil initiative, created in collaboration with municipal authorities, and with the support of financing from the UNFCCC's Clean Development Mechanism, created a methane capture system in Rio de Janeiro's Gramacho landfill. This biogas project improved waste enclosure and drainage, a sanitation benefit for the city, as well as introducing methane flaring and connection to purification for use as an income and energy source. The project is anticipated to produce 90 million normal cubic metres (Nm_3) of biogas on average over 20 years.

- Rio de Janeiro's Gramacho landfill biogas project

*Table 2: **SLCP mitigation actions in the waste management sector***

Sector and Mitigation Action	Certainty of major SLCP related climate benefit	Aggregate level of potential health benefit	Indicative health benefit(s) (red = direct benefits of reduced air pollution; blue = indirect benefits of reduced air pollution; green = ancillary health benefits)	Potential level of CO2 reduction co-benefit
Landfill gas recovery	Medium	Low	Improved air quality Less crop damage and extreme weather Reduced noise	Low-medium
Improved wastewater treatment (including sanitation provision)	Medium	Medium-high	Improved air quality Less crop damage and extreme weather Reduced infectious disease risk	Low-medium

Source: Climate and Clean Air Coalition & WHO, 2015: 11, licensed under CC BY-NC-SA 3.0 IGO

Transport

According to PHE (2019: 50)

- Air quality within urban areas is likely to be improved by interventions that promote the uptake of low and zero-exhaust emission vehicles, particularly electric vehicles. There is a lack of evidence of the generation and health impact of non-exhaust particulate matter (PM) emissions, which remain a potential issue.
- The effectiveness of Low Emission Zones (LEZs) can be improved if combined with the newer emission standards of road vehicles (Euro 6).
- Traffic management interventions, such as road pricing and access restrictions, have the potential to improve air quality and encourage the public to consider travel behaviour change and active travel options.
- Active travel interventions at a limited scale do not generally improve air quality significantly, but the added physical exercise benefit makes them very effective transport interventions for improving public health outcomes.
- In general, road transport interventions need to be combined to achieve a greater impact, as most existing measures on their own may only generate a small reduction in road vehicle emissions.

- In the aviation sector effective actions include the electrification of Ground Support Equipment, reduction in Auxiliary Power Units, pushback control, take-off thrust reduction and alternative aviation jet fuels.
- In the maritime sector, few interventions have been identified but regulation of the sulphur content in marine fuels can lead to sulphur dioxide (SO_2) emission reduction, and fuel-based interventions have the potential to reduce other pollutants.
- In the rail sector, the introduction of bi-mode trains (i.e. diesel/electric hybrid) and the electrification of the fleet would be effective measures at reducing emissions, but cost and operational limitations are potential barriers to electrification of the rail network.

The assessment of local measures implemented in the UK as reported by Local Authorities, suggests that most existing measures on their own may only generate a small reduction in road vehicle emissions. Indeed, the evidence suggests that greater reductions in nitrogen oxides (NO_X) and improvements in air quality may occur when several measures are integrated and packaged together. For example, a LEZ designed to target the higher polluting vehicles can be supported by a package of complementary measures which are designed to improve public acceptability. Such complementary measures can include: improvements in walking, cycle, bus and train facilities; traffic management and pricing mechanisms (to discourage, for example, zone peripheral parking, and peripheral cut through routes); and incentives to encourage uptake of interventions, such as retrofit or scrappage schemes, to meet vehicle emission compliance. If designed appropriately, such measures not only reduce air pollutant emissions but can also provide climate change benefits, as well as wider benefits such as noise reduction, congestion alleviation, improved neighbourhood cohesion, and economic development.

Table 3: ***SLCP mitigation actions in the transport sector***

Sector and Mitigation Action	Certainty of major SLCP related climate benefit	Aggregate level of potential health benefit	Indicative health benefit(s) (red = direct benefits of reduced air pollution; blue = indirect benefits of reduced air pollution; green = ancillary health benefits)	Potential level of CO2 reduction co-benefit
Support active (and rapid mass) transport	High	High	Improved air quality Less crop damage and extreme weather Increased physical activity, Reduced noise, Fewer road traffic injuries	High
Ultra-low-sulphur diesel with diesel particle filters	Medium-high	Medium	Improved air quality Less crop damage and extreme weather	None
Stricter vehicle emissions/efficiency standards	High	Medium-high	Improved air quality Less crop damage and extreme weather	High

Source: Climate and Clean Air Coalition & WHO, 2015: 6, licensed under CC BY-NC-SA 3.0 IGO

Public transport[8]

Shifting from private motorised transport to rapid transit/public transport, such as rail, metro and bus, is associated with a wide range of potential health and climate benefits, including: lower urban air pollution concentrations, lower rates of traffic injury risk, less noise stress and improved equity of service and amenity access for people without cars.

By clustering many passengers together in one vehicle, public transport modes reduce total traffic emissions of climate and air pollutants. Public transport use is also associated with more physical activity and less obesity, since public transport services are often accessed by walking and cycling.

Strong public transport systems tend to have the advantage of reducing traffic intensity, which is associated with road traffic injuries and noise-related health impacts. In developed countries, for instance, the injury risk for public transport users is much lower than the risk for car users.

Investment in mass public transport can also yield equity benefits by improving the mobility of women, elderly and the poor, who often lack access to private vehicles. There are also recognised benefits for reducing social isolation and achieving mental health benefits. This, in turn, provides employment, education, health services and recreational opportunities.

Walking and cycling

Lack of physical activity is linked to over 3 million deaths per year globally and is a major risk factor for the four leading Non-Communicable Disease (NCD) categories worldwide (cardiovascular disease, respiratory disease, diabetes and cancer). Inclusion and improvement in the quality of pedestrian and bicycle paths encourages people to walk and cycle, thereby promoting a healthy lifestyle. Other interventions targeting the built environment have been shown to enhance the appeal of physically active forms of transport. Examples include:

- improvements in urban aesthetic features and attractiveness;
- decreased travel time between neighbourhoods;
- access to green and recreational spaces;
- good lighting;
- road safety.

Safe infrastructure for walking and cycling is also a pathway for achieving greater health equity and improved economic productivity. For the poorest who often cannot afford private vehicles, walking and cycling can provide a form of transport while reducing the risk of heart disease, stroke, certain cancers, diabetes, musculoskeletal conditions and even death. Accordingly, improved active transport is not only healthy; it is also equitable and highly cost-effective.

[8] https://www.who.int/sustainable-development/transport/strategies/public-transport/en/

Land use and built environment[9]

Land use patterns are important drivers of personal vehicle use and transport-related emissions in cities. Urban planning strategies that prioritise compact development, by placing residential and commercial areas in close proximity, can improve health by reducing the reliance on private motor vehicles and encouraging a shift towards healthier modes of travel. Patterns of land use characterised by sprawl and low-density planning make walking, cycling and public transport impractical and thus are associated with greater private vehicle use and more energy consumption.

In contrast, urban areas characterised by greater urban density, mixed land use, and better street design and connectivity are associated with reduced travel demands, higher volumes of walking and cycling, increased accessibility to public transit networks, and therefore, lower energy consumption. For example, a study in Santiago, Chile estimated that relocating schools closer to existing residential areas could reduce transport-related climate emissions by 12% at a cost of only US$ 2 per ton of carbon reduction over 20 years (Wright & Fulton, 2005).

Shifting transport modes from private vehicles to active and rapid/public transport must be combined with shifts in planning. Emphasis on "proximity planning" makes walking, cycling and public transport to access schools, jobs and services more feasible. Since compact and mixed land use improve accessibility of destinations via walking and cycling vulnerable groups are likely to benefit from such land-use measures.

An important consideration when discussing bus rapid transport systems (BRTS) is the extent to which they may have inequitable or unintended consequences. A pertinent example is provided in Ahmedabad where the implementation of such as system has been heralded by some e.g. receiving the Sustainable Transport Award from the United Nations Environment Programme in 2010. Others have challenged this perceived success, most notably questioning whether it is an affordable option for poor people (Mahadevia et al., 2012). Further, the advent of the BRTS has also led to the neglect of the city's old bus transport system, the Ahmedabad Municipal Transport System (AMTS), which has a larger coverage and lower fares. In addition, the BRTS project involved the demolition of slum houses and the displacement of street vendors in some areas, undermining a key source of livelihoods for poor urban families and removing an important aspect of the city's character (Mahadevia et al., 2013).

Vehicle technologies[10]

Improved vehicles and technologies have helped mitigate some major health impacts of vehicle travel, namely air pollution and injury. For example:

- Lighter, more fuel-efficient vehicles that are driven at lower speeds are suggested to have injury reduction co-benefits.
- Bus fleet improvements, such as the inclusion of particle filters, low-sulphur diesel and the transition from diesel vehicles to compressed natural gas (CNG), electricity, or other alternative fuels significantly decrease harmful particle emissions.

[9] https://www.who.int/sustainable-development/transport/strategies/land-environment/en/

[10] http://www9.who.int/sustainable-development/transport/strategies/vehicle-technologies/en/

- Hybrid, electric and gas fuel private vehicles also decrease local air pollution as well as noise pollution – although quieter vehicles can also create new injury risks and they do not support more physical activity.

While cleaner vehicle technologies are an important element of air pollution and climate mitigation, reducing reliance on private vehicles and motorised transport is as important, and can yield additional benefits to health, such as physical activity.

Fuel technologies[11]

Diesel: Diesel emissions contain significant health-harmful particulate pollution and diesel exhaust has been identified as a carcinogen (IARC, 2013).

Although diesel fuel offers a slight climate benefit (in terms of CO_2 emissions), this is offset by their proportionately higher emissions of black carbon, which is a component of particulate emissions (soot), and a powerful short-lived climate pollutant.

The Climate and Clean Air Coalition (CCAC) Heavy Duty Diesel Vehicles and Engines Initiative is pushing for major reductions in black carbon emissions through adoption of cleaner fuels and stricter vehicle regulations, particularly in developing countries and emerging economies where diesel fuel is often of a lower quality. The coalition has worked in Latin America and Asia to produce black carbon inventories, form national task forces and regional coalitions and to set target dates for improved national fuel standards.

Compressed natural gas: In comparison to diesel fuel, compressed natural gas (CNG) can reduce both carbon dioxide and particulate emissions, producing health and climate benefits. Many low- and middle- income countries have already adopted CNG bus and light-duty freight vehicle fleets, partly due to lower fuel costs.

The use of CNG for buses and taxis is now also being required as a means of reducing urban pollution emissions. While the ability of CNG to reduce pollution is highly dependent on the available technology, evidence suggests its use in the public transport and freight domains could lead to significant health benefits.

It is important to note that CNG also has its critics, with much debate as to whether CNG is also a pollutant or indeed creating new source of pollution. This is an area of much debate and requires further research.

- Centre for Science and Environment refutes CSIR findings on CNG vehicles

Biofuels: The use of biofuels in the transport sector has received much attention, yet the evidence is unclear as to whether biofuels reduce health-relevant emissions and greenhouse gases. Certain biofuels, such as ethanol, can contain lower levels of black carbon and particulate emissions in comparison to gasoline – a benefit for health. However, the overall impact of biofuels on climate emissions and health may be dependent on the local context, including water, energy and chemical inputs required to grow the fuel.

[11] http://www9.who.int/sustainable-development/transport/strategies/fuel-technologies/en/

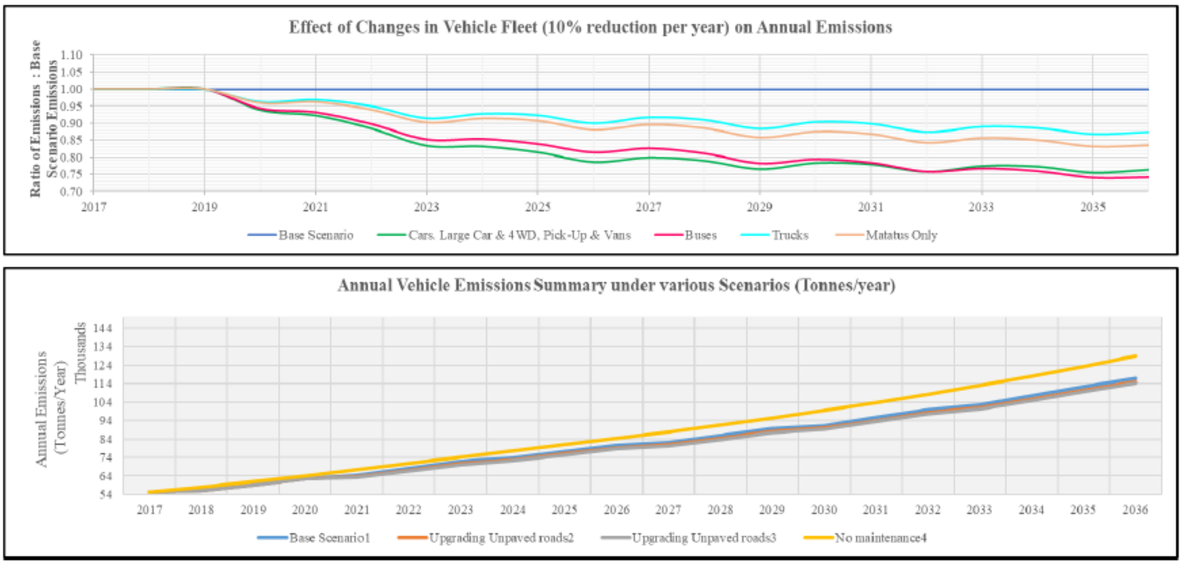
There are also significant concerns regarding biofuels' production impacts on food security and nutrition of the poor. Biofuels derived from food sources or grown on land that could otherwise be used to cultivate food sources could lead to deforestation and threaten food security and food markets, especially in the world's poorest regions.

Highways Development Model – 4

The Highway Design and Maintenance Standards Model (HDM-4), developed by the World Bank, has been used for over two decades to combine technical and economic appraisal of road investment projects, standards and strategies.

Calibration of the HDM-4 model with an improved emissions inventory, as undertaken by the ASAP research team, has allowed for analysis of the road transport emissions in East Africa under a range of scenarios, including: systematic maintenance of the urban road network, paving of all unpaved roads, electrification of the vehicle fleet (from gasoline/diesel). The analysis of each scenario has been complemented with an economic analysis relative to the economic saving projected for the period 2017 – 2036 connected with each scenario relative to the upgrading of the unpaved road.

Figure 2: ***Graphs showing the results of the scenarios produced using HDM-4 calibrated for the city of Nairobi, Kenya.*** *The top panel shows the effect of vehicle fleet progressive substitution from gasoline/diesel based to electric engines. The bottom panel provides the annual change in vehicle emissions under various scenarios connected with the systematic maintenance and progressive paving of all the urban road network. Both scenarios have been created from the base year 2017 with a 20 year of extension, to 2036.*



Source: Gichuki M.C., Mazzeo A. and Burrow M., this graph is part of an article still in preparation. Reproduced with kind permission.

Housing[12]

Table 4: ***SLCP mitigation actions in the household energy and built environment sectors***

Sector and Mitigation Action	Certainty of major SLCP related climate benefit	Aggregate level of potential health benefit	Indicative health benefit(s) (red = direct benefits of reduced air pollution; blue = indirect benefits of reduced air pollution; green = ancillary health benefits)	Potential level of CO2 reduction co-benefit
Low-emission cook stoves and/ or fuel switching to reduce solid fuel use	Medium-high	High	Improved air quality Less crop damage and extreme weather Lower violence and injury risk during fuel collection Fewer burns	Medium
Improved lighting to replace kerosene lamps	Medium	Medium	Improved air quality Less crop damage and extreme weather Fewer burns Fewer poisonings	Low-medium
Passive design principles	Low-medium	Medium	Temperature-related morbidity and mortality Improved indoor air quality	Medium

Source: Climate and Clean Air Coalition & WHO, 2015: 6, licensed under CC BY-NC-SA 3.0 IGO

Insulation and thermal envelope: A thermal envelope refers to a shell serving as a barrier to unwanted heat or mass transfer between the building interior and exterior. Improvements in household thermal envelopes can yield significant health gains.

Insulation is a critical factor that determines the quality of a thermal envelope. Improvements in insulation can reduce human exposure to temperature extremes and dampness, thereby decreasing vulnerability to asthma and allergies, stroke, heart and lung diseases. Improving the thermal envelope can be done through 3 major routes:

- insulation material;
- window modifications;
- prevention of air leakage.

While an improved thermal shell has benefits, it can reduce ventilation, also important to health. Poor air circulation can increase indoor air pollution, and concentrations of moulds and other biological contaminants. Improved insulation measures must thus be combined with adequate ventilation to ensure optimal health outcomes.

[12] https://www.who.int/sustainable-development/housing/strategies/en/

Heating systems: Energy-efficient homes and home heating systems can generate multiple health benefits directly and indirectly.

Energy efficient home construction, including the use of climate-appropriate design principles for insulation, window placement and daylighting, enables the effective use of passive solar - based home heating methods, which capture the radiant heat of the sun for improved space heating.

Passive solar design strategies not only reduce the total amount of energy required to heat a home, and associated pollution emissions, but also tend to improve indoor thermal comfort levels, and by doing so, reduce risks of respiratory illnesses as well as other health risks related to exposure to cold and damp. Thermal solar systems can also be used for hot-water heating, for better personal and kitchen hygiene, as well as for additional space heating capacity. According to the Intergovernmental Panel on Climate Change, passive solar home design and solar panel systems may reduce purchased heating energy by factors of 5 to 30. When combined with a high-performance thermal shell in a building, 50-75% of heating and cooling energy needs can be met through solar design, thereby reducing overall emissions from heating systems.

Shifting to cleaner and more efficient household heating fuels and technologies is the other strategy for reducing indoor and outdoor pollution emissions that are generated directly by heating systems. For homes using stand-alone, portable heating systems, ensuring that systems are closed and equipped with sealed chimneys or flues so that emissions are evacuated outdoors, is essential to reducing household air pollution, as well as reducing risks of burns and injuries from fuel spills. WHO guidelines discourage the use of kerosene and unprocessed coal systems, due to their very high level of indoor or outdoor air pollution emissions.

More efforts are required, however, to understand how best to support household transitions to cleaner fuels. This includes developing a better understanding of not just the economic drivers of biomass use but also socio-cultural factors that influence fuel use practices. ASAP researchers have undertaken initial scoping work in Namuwongo (Kampala) on this issue, also exploring the potential for locally generated solutions to indoor air pollution (i.e. briquettes manufactured in the community from household waste by a women's collective).

- Okello et al. (2020). Understanding Household Fuel Transitions.

For homes and buildings with central heating systems, shifting from coal, diesel and fuel oil combustion to natural gas, LPG, and geothermal or electric heat-pump technology can reduce energy costs, as well as climate and health impacts related to outdoor air pollution exposures.

To optimise health outcomes, multiple targeted home improvements are required.

Natural ventilation: Inadequate ventilation allows for the accumulation of a variety of pollutants from building materials, fuel burning, and radon gas emissions. Moulds, a risk factor for allergies and asthma, thrive in unventilated areas. Vectors, such as mosquitoes that carry dengue and malaria, pose a greater risk to those dwelling in homes with trapped air. Together, the accumulation of harmful environmental threats in unventilated homes poses a significant risk to health. Improved design for ventilation can increase air exchanges and air quality, thereby reducing these health risks. It has been estimated that improved natural ventilation reduce lung-related illnesses by up to 20%.

Natural ventilation also can enhance the cooling of buildings, yielding up to 25-50% in energy savings. Many traditional building styles enhance natural ventilation by providing for high ceilings, and air spaces at ceiling level or below the eaves to enhance the daytime venting of heat, and night-time cross ventilation.

Natural ventilation can provide significant health benefits but must be examined to prevent predictable risks. For instance, natural ventilation in settings where outdoor air pollution is greater than indoor air pollution may not be beneficial. Similarly, ventilation without screening measures can allow for the entry of pests that carry diseases in certain environments. And open windows at street level can pose a security risk in neighbourhoods where crime is a serious issue.

Cooling and air conditioning: Cooling methods for buildings can promote reduced energy use and improve health outcomes.

According to the Intergovernmental Panel on Climate Change, principles of design that can be used to cool buildings include:

- clustering buildings to promote shading;
- using highly reflective material to reflect light;
- orienting a building to minimise wall area facing direct sunlight;
- window shading and window placement;
- double walls or lattice work, or vegetation, particularly along the southern exposures;
- design for cross-ventilation and natural ventilation to promote night-time cooling;
- selective use of insulating building materials that deflect, rather than absorbing heat (e.g. stone).

Air conditioning is increasing in use worldwide and offers immediate protection from heatwaves. Its use has also been associated with vector control and protection from the impacts of heavy outdoor air pollution hotspots.

However, the benefits of air conditioning are not without consequences. Cooling units often utilise hydrofluorocarbons (HFCs) that can leak into the environment and contribute to climate warming. Furthermore, many air conditioning systems are highly energy-intensive, with significant demands for electricity and fossil fuel use which can undermine energy security and exacerbate climate change. These units can also provide a breeding ground for microorganisms such as Legionella which can cause lung disease. Noise for neighbours, inequitable access and excessive heat production are other undesirable effects of cooling technology.

Solar-powered lighting, appliances and hot water heating: Solar photovoltaics that transform the sun’s energy into electricity have the potential to meet many household lighting and appliance needs, while reducing pollution (e.g. from kerosene), and increasing access to refrigeration (e.g. new generation refrigerators can operated on direct current (DC) provided by PV solar systems, storing excess energy in ice or coolants). In addition, thermal solar water heaters can provide 50-90% of annual hot water needs in warm countries. Small off-grid photovoltaic and passive solar systems are being used increasingly for household lighting and water heating across Asia, Africa, and Latin America.

Solar technologies can allow for greater health equity, improving access not only to electricity but to improved personal and kitchen hygiene (e.g. hot water access can reduce transmission of common bacteria found in kitchens). Replacement of kerosene lamps with solar lights or lanterns not only reduces indoor air pollution, but also the risk of domestic burns and eye diseases and can improve lighting conditions for children within the home. Although many potential benefits exist, special attention must be paid to occupational and environmental hazards associated with solar panel production and disposal of lead-acid batteries that are often used to store solar energy.

Lighting and daylighting: Provision of adequate light, both natural and artificial, is a determinant of health. Sufficient natural light exposure is a factor in biophysical performance, mental health and injury prevention. Exposure to natural light is important for vitamin D production, sleep cycle regulation and mood. Lighting is also important for the prevention of falls and injuries among the elderly.

According to the Intergovernmental Panel on Climate Change, lighting energy use can be reduced 75-90% through:

- Day lighting systems, which use building design to increase the use of natural lighting through building form, skylights, and windows
- efficient lighting devices such as solar-powered LED lamps or lightbulbs. These are being introduced widely now in Africa and Asia to replace fuel-based kerosene lamps which emit high quantities of particulate matter, including black carbon, a short-lived climate pollutant
- sensors to dim unnecessary lighting, increased use of ambient and task-specific lighting

Cleaner cooking stoves: Over 3 billion people in LICs and LMICs rely on solid fuels (wood, animal dung, charcoal, crop wastes and coal) burned in inefficient and highly polluting stoves for cooking and heating, currently resulting in some 4 million premature deaths annually. These same household pollutants, such as black carbon, also have climate warming effects.

More efficient stoves and cleaner fuels that meet WHO indoor air quality guidelines have the potential to avert millions of deaths each year caused by household air pollution, while also reducing emissions that impact climate change.

Among the available technologies, cleaner fuels such as biogas, ethanol, LPG, and natural gas along with electricity are the best alternatives to solid fuels for reaching WHO air quality guideline levels for household air pollution.

Advanced biomass stoves can offer an important transition technology that reduces emissions levels common to traditional biomass stoves. Nevertheless, many improved biomass cook stoves still do not meet WHO air quality guideline levels, despite their improved fuel efficiency and somewhat reduced emissions of particulate matter. Use of unprocessed coal or kerosene stoves is meanwhile discouraged by the guidelines altogether due to their very high level of air pollution emissions.

See: Table 5: Emission parameter assumptions (Jeuland & Tan Soo, 2016: 19),
https://www.cleancookingalliance.org/binary-data/ATTACHMENT/file/000/000/355-1.pdf

Other benefits of more efficient cooking appliances include fuel cost or collection savings, injury reduction, reduced opportunity costs and better temperature and indoor environment control. Cleaner cook stoves and fuels have the potential to achieve gains in health, gender equity, and sustainability across the developing world.

Improved building materials: Building materials such as asbestos and lead have the potential to damage human health. Insulation, paint and dust derived from harmful materials can result in cancer, lung disease and impaired growth and development.

Thus, measures must be taken to improve existing dwellings by replacing hazardous substances in rooftops, walls, floors, pipes, or other household components with less harmful materials. In addition, improved regulations in developing countries can ensure that new housing developments assess all materials for potential environmental and health risks. This will reduce the risks of building-related toxic substances having negative impacts on ecosystems and human well-being.

While dwellers may suffer from exposure to these materials in existing structures, workers may also suffer from exposure during the building and renovation process. Focused measures need to be in place to reduce both residential and occupational exposures to prevent adverse health outcomes.

Urban planning and residential environments: Urban design impacts powerfully on residential environments and, in turn, on health outcomes. Medium housing density, with easy pedestrian access to local businesses, schools, and green spaces, is associated with safe, accessible pedestrian environments, more access to healthy physical activity and to basic services for women, children, elderly and those without cars.

Clustered housing also can lower heating costs with shared walls, and medium-building heights can also facilitate natural ventilation and cooling. Connectivity to public transport, walking and cycling in neighbourhoods provides opportunities for physical activity while lowering pollution and traffic noise. Urban landscaping of trees, green spaces and water sources promote cooling, thermal comfort, sanitation and mental health. Collectively, these aspects of healthy urban planning are also key to healthier housing environments.

Healthy home behaviours: Behaviours and preferences related to ventilation, protective clothing, temperature and pest control result in actions that may or may not be healthy or environmentally friendly.

For instance, overuse of heating or air conditioning systems for temperature changes is often behaviourally driven, even though adequate hydration, clothing, and bedding can mitigate extreme temperatures with less climate and pollution impacts. These measures also can benefit health more directly in settings where forced air heating or air conditioning systems recirculate bacteria and other pathogens. While behaviours are important factors that contribute to healthy home environments, they must be addressed by staged and multi-faceted educational and promotion strategies for long-term change.

Industry

There is often limited information available on variation in damage and exposure from industrial emissions for different areas. It is acknowledged that there will still be groups, who are affected disproportionately by industrial emissions. However, there will be no systematic relationship between proximity to industry, or working in industry, and exposure to pollutants outside of the workplace. With this in mind, it is not possible to factor equity or distributional issues into considerations.

There is a wide range of industrial sectors, processes, pollutants, geographical locations or levels to which the interventions can be implemented. In order to be able to prioritise interventions, for example based on the cost-effectiveness or health impacts, further analysis is needed and any such prioritisation is best performed on a case-by-case basis taking all the specific factors of a particular case into account. PHE (2019: 86) commented:

- There was a clear distinction between policy-level interventions that set overarching targets and have the potential to widely reduce industrial air pollutants, and technological interventions implemented at the individual installation level (to meet policy-level intervention targets) that have potential benefits for local air quality and national air quality if implemented at scale.
- Evaluations of policy interventions were generally based on evaluating specific existing or prospective policy options, whilst evidence of technological interventions was primarily based on evaluations of best available (industrial) techniques (BAT)
- The evidence found primarily related to evaluations of interventions' effects on emissions (sources), from which consequent benefits to air quality and health are inferred. Few interventions directly evaluated effects on environmental concentrations, and fewer still directly evaluated health outcomes. Therefore, more evidence is needed to identify the links between specific interventions, air quality and improved health outcomes
- For some aspects of interventions, little or no evidence was found. For example, there was little evidence of industrial interventions' effects on health inequalities or of co-benefits.
- For technological interventions, each had a range of potential cost: benefit ratios, which could be estimated using established damage costs methodology
- For policy interventions to be effective, proven technological interventions are required to be able to implement them.

Table 6: ***SLCP mitigation actions in the industrial sector***

Sector and Mitigation Action	**Certainty of major SLCP related climate benefit**	**Aggregate level of potential health benefit**	**Indicative health benefit(s) (red = direct benefits of reduced air pollution; blue = indirect benefits of reduced air pollution; green = ancillary health benefits)**	**Potential level of CO2 reduction co-benefit**
Improved brick kilns	Low-medium	Medium	Improved air quality Less crop damage and extreme weather	Low-medium
Improved coke ovens	Low-medium	Medium	Improved air quality Less crop damage and extreme weather	Low-medium
Control of fugitive emissions from the fossil fuel industry	High	Low	Improved air quality Less crop damage and extreme weather	Low-medium

Source: Climate and Clean Air Coalition & WHO, 2015: 10, licensed under CC BY-NC-SA 3.0 IGO

Improved brick kilns and coke ovens[13]

Industrial processes that emit large amounts of black carbon include brick production and the use of coke ovens. Every year, billions of bricks are produced globally, with China and India the top producers. Kiln designs vary widely, but in many LICs, bricks are often fired in traditional kilns that release high levels of heath-relevant pollutants, including $PM_{2.5}$ and black carbon, worsening local air quality and leading to high occupational exposures.

Coke is a fuel produced by heating coal to high temperatures. The fuel product (coke) has few impurities and is often used in iron smelting and steel production. As with brick kilns, inefficient low-technology coke ovens are widespread in many developing countries and are characterised by high emissions when compared to more modern production processes.

Technologies reducing black carbon emissions from traditional brick kilns and coke ovens can reduce high levels of human exposure to particulate matter from these sources for workers and communities living near these industries, providing an important health-enabling opportunity for both occupational and community health.

Improved kiln designs generally focus on increasing combustion efficiency and reducing exposures through chimney design. The main strategy to reduce emissions from coke ovens, focuses on replacing traditional coke ovens (such as the “beehive” kiln) with more modern designs using pollution abatement technologies.

Control of fugitive emissions from the fossil fuel industry

The fossil fuel industry is a key source of methane emissions, which contribute to tropospheric ozone. Recovery and use of gas released during fossil fuel production and distribution can reduce methane emissions and the production of ozone. Specific actions include the recovery and use of coal mine methane and methane released from oil and natural gas production processes, as well as reducing leakages, such as during pipeline distribution.

[13] http://origin.who.int/airpollution/ambient/interventions/industry/en/

Power Generation

Table 7: ***SLCP mitigation actions in the energy supply/electricity generation sector***

Sector and Mitigation Action	Certainty of major SLCP related climate benefit	Aggregate level of potential health benefit	Indicative health benefit(s) (red = direct benefits of reduced air pollution; blue = indirect benefits of reduced air pollution; green = ancillary health benefits)	Potential level of CO2 reduction co-benefit
Replace or supplement diesel generators with renewables	Low-medium	Low-medium	Improved air quality Less crop damage and extreme weather Reduced noise	Low-medium
Switch from fossil fuels to renewables for large-scale power production	Low	High (coal/oil) Low-medium (gas)	Improved air quality Less crop damage and extreme weather Fewer occupational injuries	High (coal/oil) Medium-high (gas)

Source: Climate and Clean Air Coalition & WHO, 2015: 10, licensed under CC BY-NC-SA 3.0 IGO

Switching from fossil fuels to renewables for large-scale power production

The dominant mode of contemporary electricity generation is from conventional large-scale power plants using fossil fuels. In general, coal, and oil produce high levels of both greenhouse gas emissions and fine particulate matter, whereas natural gas performs substantially better, particularly with regard to $PM_{2.5}$. It is possible to mitigate fossil fuel emissions through technological solutions (e.g. carbon capture and storage), but the benefits are likely to be smaller than those from switching away from coal and oil to other energy sources, namely by increasing the share of natural gas, nuclear, and renewables in particular. Renewable energy sources, which include hydropower, wind, geothermal, solar, and biomass energy, comprise only a small proportion of the total energy supply, but this is changing with improved technology, lower costs and the substantial environmental and health benefits.

See: Figure 3: Primary Energy: Consumption by fuel (% of total) 2019 (BP Statistical Review of World Energy 2020, p.10), https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2019-full-report.pdf

Replacing or supplementing diesel generators with renewables

The rapid increase in the use of stand-alone diesel generators to respond to the demand for power in regions that are off-grid or have unreliable access to grid electricity is a trend that has been noted with concern. Portable diesel generators produce large quantities of health-damaging particulate emissions that are rich in black carbon. Substitution or supplementation of such generators with renewable sources, such as photovoltaic solar power systems, is a promising intervention that would reduce local air and noise pollution around homes and health clinics, and also create a more reliable source of electricity for low-income households and communities. High initial costs may be a barrier in some locations, but rapid declines in the price of renewables are closing the gap. Other climate (mainly CO_2) mitigation actions in the sector include increasing efficiencies during electricity transmission and distribution.

Agriculture[14]

PHE (2019: 101) comment that.

- Several opportunities for reducing ammonia (NH_3) emissions at farm level were identified: urease inhibitors and slow-release nitrogen (N) fertilisers, slurry acidification, low NH_3 emission storage and spreading, air filtration systems, and low protein feeding.
- The actual impact of such interventions, however, will depend on the extent of uptake on farms as current mitigation strategies rely on voluntary uptake (in the UK). Understanding the current level of uptake of mitigation measures will be necessary for monitoring progress in reducing emissions against emission targets.
- It has not been possible to evaluate the interventions' potential impact at a national scale. This was primarily because limited information was available on the existing uptake of these measures.
- A combination of regulations, incentives, and awareness-raising measures will be needed to overcome the barriers to widespread adoption.
- No studies evaluated the health and cost impacts related to these interventions. PHE were therefore unable to advise on which intervention has the highest health and economic impact – this is an area requiring further work.
- To maximise co-benefits and minimise negative trade-offs, it will be important to align agricultural interventions with other sector strategies and policies.

[14] http://origin.who.int/airpollution/ambient/interventions/agriculture/en/

Table 8: ***SLCP mitigation actions in the agriculture sector***

Sector and Mitigation Action	Certainty of major SLCP related climate benefit	Aggregate level of potential health benefit	Indicative health benefit(s) (red = direct benefits of reduced air pollution; blue = indirect benefits of reduced air pollution; green = ancillary health benefits)	Potential level of CO2 reduction co-benefit
Alternating wet/dry rice irrigation	Medium-high	Low-medium	Reduced vector-borne disease Improved food security	Low
Improved manure management, including biogas capture	Low-medium	Low-medium	Improved air quality Reduced zoonotic disease	Low
Reduced open burning of agricultural residues	Medium	Low-medium	Improved air quality Less crop damage and extreme weather	Low
Promoting healthy diets low in red meat and processed meats and rich in plants-based foods	High	High	Reduced obesity and diet-related non-communicable diseases	Medium-high
Reducing food waste	Medium-high	Low-medium	Reduced food insecurity/ undernutrition	Medium-high

Source: Climate and Clean Air Coalition & WHO, 2015: 8, licensed under CC BY-NC-SA 3.0 IGO

Alternating wet/dry rice irrigation

Rice is the staple crop for a large proportion of the world's population, responsible for methane emissions through the anaerobic decomposition of organic matter. In place of continuous flooding, rice management that employs intermittent irrigation alternating between wet and dry periods can reduce methane emissions. Alternating wet-dry irrigation may provide a number of indirect health benefits through better control vector-borne diseases, particularly in places where vectors use rice paddies as breeding grounds.

Improved manure management, including biogas capture

Improving manure management can involve the capture of biogas, a relatively clean energy source that can be used for fuel in the household, for example by rolling out anaerobic digesters both for large-scale producers and at the household level. If biogas replaces coal and biomass fuel use in households, which is associated with adverse cardiorespiratory effects, the health benefits could be substantial. Other approaches to mitigate manure methane emissions include: cooling or covering manure sources, separating solids from liquids, and more precisely timing manure applications to crop lands.

Reduced open burning of agricultural residues

Farmers around the world burn crop residues to clear land and fertilise soil. However, such practices emit large amounts of health-damaging black carbon and particulate air pollution. Reductions in the open burning of agricultural residues can have important benefits on air quality.

Initiatives in India that have collected crop residue to produce energy sources for factories have been shown to have some benefit.

- https://www.a2penergy.com/#home

Moving towards diets rich in plant-based foods

Animal-sourced foods tend to be associated with higher greenhouse gas emissions, such as methane and nitrogen dioxide. In addition to their climate impact, the intake of red and processed meats has been linked to adverse health outcomes including cancer, diabetes, and heart disease. Reducing the consumption of animal-sourced foods (particularly processed meats and red meat) in favour of healthier plant-based alternatives has the potential to both reduce methane emissions associated with livestock production and improve population health.

Behavioural interventions

PHE (2019) comment that:

- Behavioural interventions comprised educational or awareness-raising initiatives. Other approaches highlighted in the studies included incentivisation and training.
- The highest potential to improve air quality and public health outcomes is associated with combining behavioural interventions with other policy or infrastructure-based interventions (e.g., improving public transport or cycling infrastructure and then using behavioural interventions to maximise its use). In this way, behavioural interventions can be used in parallel with other interventions and maximise their potential effectiveness.
- For all the behavioural interventions identified, the effectiveness to reduce emissions of air pollution was low and the uncertainty range was high, except for 2 interventions (eco-driving training and large-scale national events, which the rapid evidence assessment considered of medium effectiveness strength and uncertainty range). However, the paucity of evidence of the behavioural interventions’ effectiveness should not be taken as evidence of ineffectiveness.
- Little evidence was identified of behavioural interventions that promote alternative methods of transport as having a direct impact on air pollution or health outcomes.

However, they should not be discounted, as there is evidence showing that removing vehicles from the road can reduce emissions. There is also strong evidence for the health benefits of physical activity associated with active travel, such as walking and cycling

- Raising awareness in itself is not enough to effect change: it must be done in conjunction with other behavioural and non-behavioural interventions

4. References

BP Statistical Review of World Energy (2020). Statistical Review of World Energy 2020. 69th Edition. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2020-full-report.pdf

Cepeda M, Schoufour J, Freak-Poli R, et al. (2017). Levels of ambient air pollution according to mode of transport: a systematic review. Lancet Public Health. 2 (1): e23–e34. doi:10.1016/S2468-2667(16)30021-4

Climate and Clean Air Coalition & WHO (2015). Reducing Global Health Risks Through Mitigation of Short-Lived Climate Pollutants: Scoping Report for Policymakers. Climate and Clean Air Coalition & WHO. https://apps.who.int/iris/bitstream/handle/10665/189524/9789241565080_eng.pdf?sequence=1&isAllowed=y

Conlan, B. et al. (2018). Rapid Evidence Assessment of Interventions to Improve Ambient Air Quality: Transport. Institute of Occupational Medicine. https://app.box.com/s/kt5m8gugipky7lif3xyskjjwf3o5s1m6/file/344999550092

Ferranti, E. J. S. and MacKenzie, A. R. and Levine, J.G. and Ashworth, K and Hewitt, C.N. (2019) *First Steps in Air Quality for Built Environment Practitioners.* Technical Report. University of Birmingham & TDAG. (Unpublished)

Gichuki M.C., Mazzeo A. and Burrow M (n.d.). Unpublished article still in preparation. University of Birmingham: UK.

IARC (2013). Air Pollution and Cancer. IARC. https://publications.iarc.fr/Book-And-Report-Series/Iarc-Scientific-Publications/Air-Pollution-And-Cancer-2013

Jeuland, M. & Tan Soo, J0S. (2016). Analyzing the costs and benefits of clean and improved cooking solutions. Duke Global Health Institute. https://www.cleancookingalliance.org/binary-data/ATTACHMENT/file/000/000/355-1.pdf

Khreis, H. et al. (2017). Exposure to traffic-related air pollution and risk of development of childhood asthma: A systematic review and meta-analysis. Environ Int.;100:1-31. https://www.ncbi.nlm.nih.gov/pubmed/27881237

Loh, M. (2018). Rapid Evidence Assessment of Interventions to Improve Ambient Air Quality: Structural/Planning Interventions. Institute of Occupational Medicine. https://app.box.com/s/kt5m8gugipky7lif3xyskjjwf3o5s1m6/file/344994880153

Okello, G. et al. (2020). Understanding Household Fuel Transitions: The Case of Namuwongo (Kampala).

https://static1.squarespace.com/static/5a6b5aad12abd97ed4679071/t/5e56b1bba6cc764ba8a477e9/1582739909486/ASAP+-+East+Africa+-+Understanding+Household+Fuel+Transition+-+Kampala+Final.pdf

Mahadevia, D. Brown, A. Lyons, M. Vyas, S. Jajoo, K. & Mishra, A. (2013) Street Vendors in Ahmedabad: Status, Contribution and Challenges. Working Paper 20. Ahmedabad: Centre for Urban Equity, CEPT University.

Mahadevia, D., Joshi, R. and Datey, A. (2012) Sustainability and Social Accessibility of Bus Rapid Transits in India. Roskilde: UNEP Risø Centre.

Medical Research Council (2019). Developing and evaluating complex interventions. MRC. https://mrc.ukri.org/documents/pdf/complex-interventions-guidance/

Public Health England (2019). Review of interventions to improve outdoor air quality and public health. Public Health England. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/795185/Review_of_interventions_to_improve_air_quality.pdf

Rees, N. (2016). Clean the air for children. UNICEF. https://www.unicef.org/publications/files/UNICEF_Clear_the_Air_for_Children_30_Oct_2016.pdf

WHO (2016). Health and the environment Draft road map for an enhanced global response to the adverse health effects of air pollution. WHO. http://apps.who.int/gb/ebwha/pdf_files/WHA69/A69_18-en.pdf?ua=1&ua=1&ua=1

WHO (2018). Air pollution and child health: prescribing clean air. WHO. https://www.who.int/ceh/publications/air-pollution-child-health/en/

Wood. (2018). Interventions to improve ambient air quality – Industry. Wood. https://app.box.com/s/kt5m8gugipky7lif3xyskjjwf3o5s1m6/file/344999991562

Wright, L. & Fulton, L. (2005). Climate Change Mitigation and Transport in Developing Nations. Transport Reviews. Volume 25, Issue 6. https://doi.org/10.1080/01441640500360951

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About this report

This report is based on six days of desk-based research. The K4D research helpdesk provides rapid syntheses of a selection of recent relevant literature and international expert thinking in response to specific questions relating to international development. For any enquiries, contact helpdesk@k4d.info.

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