RE-CITY
INTERNATIONAL PLATFORM
FOR SOCIAL SUSTAINABILITY

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RAPPORTEURSHIPS "FACING CLIMATE CHANGE"

"CLIMATE CHANGE AND HEALTH"

SESSION WITH **ALISTAR WOODWARD.**

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Climate change and health: disruption, risk, opportunity

Invited Speaker: Dr. Alistair Woodward. University of Auckland, New Zealand

Contents

This report is a synthesis of the debate carried out with Prof. Alistair Woodward in the conference series “Facing climate change” organised by Catalunya Europa Foundation in the context of the Re-City project. This session, entitled "*Climate change and health: disruption, risk, opportunity*" consisted of a public lecture, a seminar with participants from the academic sector of Catalonia and a lunch-debate that brought together personalities from the economic, social, political and business sector of Catalonia. The mentioned activities were held in Barcelona at the Antoni Tàpies Foundation on November 2018. The content order along the report is thematic and does not represent the order in which it was exposed by Alistair Woodward. The conference series “Facing climate change” is developed in collaboration with BBVA, Generalitat de Catalunya, Àrea Metropolitana de Barcelona and Barcelona City Council.

Biography

Dr. Alistair Jack Woodward is the Head of Epidemiology and Biostatistics Department at the Faculty of Medical and Health Sciences of the University of Auckland, New Zealand. Woodward obtained his Bachelor of Medicine & Bachelor of Surgery (M.B., B.S.) and his Master of Medical Sciences with postgraduate qualifications in public health and epidemiology. Furthermore, he obtained his PhD in Epidemiology and the Fellowship of the New Zealand College of Public Health Medicine (FNZCPHM). Woodward led the Departments of Public Health at the University of Otago Wellington, and the University of Adelaide. Later, he was the Head of the School of Population Health at Auckland from 2004-2012.

Throughout his career, Woodward has published several papers and some books about tobacco, environmental health and the social determinants of health. Woodward collaborated in the Anthony McMichael's book "Climate Change and the Health of Nations" (2017). Besides his papers and books, Woodward –and Kirk Smith– led the writing of the health section of the 5th assessment report (AR5) for the Intergovernmental Panel on Climate Change (IPCC). He is also a lead author for the Australia and New Zealand chapter in AR6, which is underway in 2019. On the other hand, Woodward is also working with colleagues from China Centres for Disease Control on environmental health issues and in New Zealand on studies to test the effects of street changes on walking and cycling.

Summary

"How would you explain in two minutes to President Donald Trump that climate change exists?" This is the question that Professor **Alistair Woodward** asked his students at the University of Auckland, in New Zealand. And most chose an image, more convincing than any explanation –the image was a graph which explains the evolution of temperatures since 1861 and shows how global warming has occurred. Specifically, the graph shows the progressive increase of temperatures in the lower part of the atmosphere and how they cool in the upper part, as a result of the greenhouse effect (Figure 1). "Climate change is real, there is no doubt. Just as we know that gravity exists, climate change exists", said the environmental health expert invited by Catalunya Europa Foundation to participate in the Conference Series "Facing climate change" on November 22nd.

Alistair Woodward said that "climate change is a very dangerous disruptive change because it is happening at a great speed and, in addition, it is happening on a large scale, and that we are already suffering its effects in a clear way". Some examples are the increase in floods, now six times more likely than at the end of the 20th century; or diseases caused by mosquitoes that are expanding because of heat, as shown by the first case of autochthonous dengue detected recently in Barcelona, the sixth produced in Spain in a short time.

The expert was forceful: "If we want to face climate change, it will not be enough to reduce carbon dioxide emissions. We have to introduce changes in our lifestyles and be radical. Otherwise we will not achieve the objective of the Paris Agreements of limiting global warming to 2ºC", a limit cut to 1.5ºC by the UN Intergovernmental Panel on Climate Change (IPCC). Therefore, Woodward raised some controversial measures such as the introduction of a tax on meat or food to curb the emission of greenhouse gases. He also proposed to equip the houses better so that the heat is not lost and less is spent on heating; and go by bicycle instead of the car or the motorcycle or limit the private transport in the centre of the cities. "Electric cars are a good solution to avoid causing carbon dioxide emissions, but they are not the solution to the congestion of cities. Whether they are electric vehicles or not, the problem of mobility is that there are too many cars. We need help with public transport and electric bicycles, so we can reduce 60% of carbon emissions". Currently, added the expert, "air pollution is the main challenge of climate change, caused by the combustion of carbon fossils. The combination of poor air quality with the increase in temperature produces an impact on health even more harmful".

Given this, Alistair Woodward affirmed that climate change "is a challenge at all levels but it is possible to face it, and it makes sense to try it". However, it requires political measures and consensus to guarantee its application", said the person who is also a member of the IPCC experts of the UN. In this regard, he explained that New Zealand is drafting a law to achieve zero carbon dioxide emission before 2050 and spoke of a

newly created figure, the ombudsman of environment, to ensure that actions are taken with the least possible impact in the environment.

The speaker also appealed to the role of cities as drivers of change. "Cities can respond in a creative way, since climate change can be a stimulus for the regeneration of cities. Climate change can make cities safer, healthier, more sustainable and more cheerful, because people smile more when they walk". Cities, Woodward added, must establish collaborative networks and make cross-cutting environmental policies in areas such as mobility and transport, bicycle use, waste management, pollution and air quality, or building renovations to make them more efficient.

The expert ended his lecture with an optimistic message and with a quote from the former mayor of New York, Michael Bloomberg, in his book "A Climate of Hope" (Bloomberg & Pope, 2017): "We must change the way we think about climate change, go down to up, from cost to benefits and from tomorrow to today". He concluded saying that the climate change challenge cannot be postponed and that, at the same, time is an opportunity to move towards a better society.

Climate change is real. Just as we know that gravity exists, climate change exists

To demonstrate that climate change is actually happening, Woodward used a figure showing that since 1900 the atmosphere has been getting warmer at low altitudes (Troposphere) and colder at high altitudes (Stratosphere, Figure 1). This phenomenon is caused by the increase of the atmospheric greenhouse blanket, located around 16 km above the Earth's surface. This is a clear example of the human fingerprint on climate change, which can explain what and why is happening.

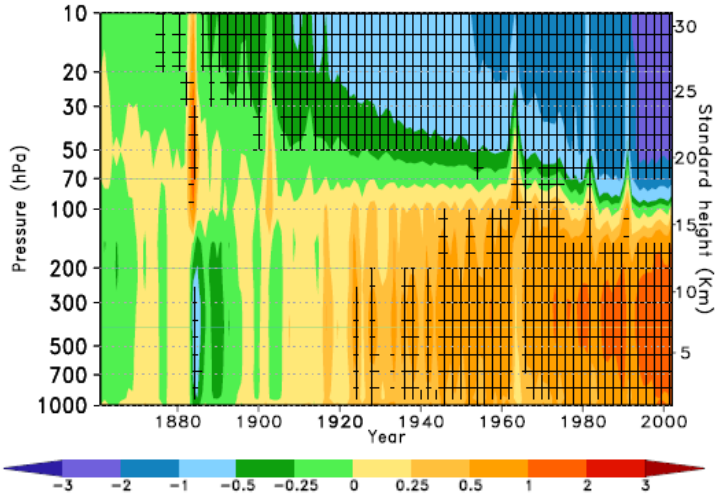

Figure 1. Evolution of the global, annual-mean temperature change relative to 1861 due to all known forcing agents. Retrieved from: Woodward (2018).

In our planet, there is a certain temperature that allows life on it. This means that our life will be threatened if a certain temperature threshold is surpassed. Guo *et al.* (2014) studied excess daily mortality as a function of daily temperature in percentile, using data from twelve countries/regions scattered around the world. They observed that the minimum-mortality temperatures were higher in countries with high temperature. They also determined that the minimum excess mortality occurred on average around the 75th percentile of the daily temperature in most of the countries. As we moved away from that value, there was an increase in mortality, which was more or less prominent depending on the country. This temperature, associated with the minimum risk, ranged from 66th percentile in Taiwan (26.5ºC) to 80th in UK (15ºC). In Spain, the minimum excess mortality temperature occurred in the 74th percentile that corresponds to 20.5ºC (Figure 2).

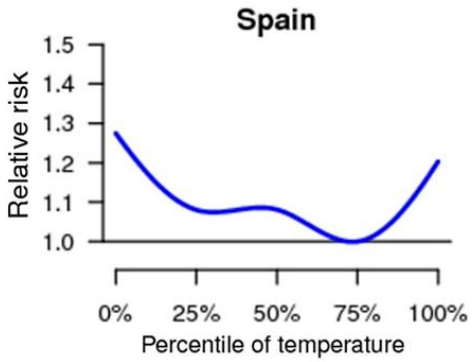

Figure 2. The pooled overall cumulative relationship between temperature and relative risks over lags of 0-21 days in Spain. Extracted from: Carleton and Hsiang (2016).

From this study, it emerges the concept that 75th percentile of the daily temperature is the temperature that allows life in our planet. For this reason, climate change will influence our survival, as we are constantly increasing the greenhouse effect and thus temperature is increasing as well.

Moreover, as stated by Woodward, **climate change not only affects the mortality.** In fact, other variables are affected as well by this phenomenon, including maize yields, agricultural income, math test scores, gross domestic product, total factor productivity, human working capacity, household migration, profanity in social media and health.

Climate change is disruptive because it affects almost all aspects of our lives. Further, fast-moving, large-scale and irreversible disruptive threats are the most dangerous, and climate change includes them all. It is critically important how fast our society leaves the minimum excess mortality temperature as a response to climate change. This is relevant because the speed of change determines the capacity to adapt to it, as adaptation is essentially rate-limited. In other words, it is easier to cope with a transformation that is happening slowly rather than fast. In the case of climate change, the global increase in greenhouse gas levels has been the most rapid growth in more than 400 thousand years, and the rise in global temperature has been 170 times faster than any in at least 7 thousand years. Moreover, the acidification of the oceans has been the most rapid in at least 66 million years. Thus, **climate change is a dangerous disruptive change because it is fast and global.**

Climate change has different types of risks to human health. The most notably affectations derived from climate change are the deaths caused by heat waves, air pollution, flooding episodes, etc. However, as mentioned by Woodward, **there are other climate change's health implications besides deaths that must be measured as well, such as diseases or chronical illnesses**. Woodward gave the example of New Zealand. They have a lot of water supplies that are not treated. Therefore, lots of people drink non-chlorinated water because they have acted this way traditionally. However, when there are episodes of heavy rainfall, there are large amounts of waste pouring into water supplies, so the water becomes polluted with salmonella, etc.

Woodward also stated that climate change's direct effects on human health happen even in most developed countries. For instance, during Hurricane Harvey, the hospitals collapsed. Globally, this phenomenon meant $190 billion cost for America in 2017.

Natural systems also change due to climate change. As a consequence, **agriculture** can be threatened as well. In parallel, **mosquito-borne diseases**, such as dengue fever, can appear in new geographical areas that become warmer and wetter. Indeed, this is the reason why dengue fever is more and more common in Singapore and is not increasing its occurrence that much in Hong Kong, as this latter city has some cold periods during the year (semitropical climate). Recently, Catalunya has experienced its first autochthonous case of dengue. It was in November 2018. The patient was a young man who had not travelled to an endemic dengue's zone or any other area of Spain such as Cádiz and Murcia, where another five cases happened in October 2018. In Catalunya, there is one of the two dengue-bearing mosquitoes, i.e. the tiger mosquito (*Aedes albopictus*). 80% of the cases are asymptomatic, so dengue disease is often not detected, and exported to other territories consequently.

Social disruption can be a consequence of climate change as well: "The past 10,000 years should have taught us two things: when climate changes, people move, and when states can't feed their people, they fall" (McMichael *et al.*, 2017). An emergency preparedness and management plan are necessary to ensure that health facilities can function during extreme events and to prepare them to cope with economic and social disruption from climate change –such as forced migration or food and water shortage. For instance, flooding events can cause displacement and social disruption leading to mental health problems. For children, disruption can cause significant behaviour problems; for adults, it can lead to alcoholism or substance abuse.

As it is known, **air pollution is related to climate change as well** and Woodward argues that air pollution is the most important topic that we are facing. Furthermore, in a global warming world is important to bear in mind that people exposed to contaminated air have more harmful affectations if they are also exposed to high temperatures. However, as the effects of air pollution on people normally take some time to appear, it is important to look for early effects in order to determine how to adapt to air pollution and prevent health impacts. For example, in Beijing, which has a very high polluted air, people wearing a facial mask is less propense to health and heart problems.

One thing is clear: to reduce pollution, a reduction in greenhouse gas emissions is required, and to achieve this goal, we must make a deep change in our society –we need other mechanisms for heating our buildings, transporting people, etc. According to Woodward, the transformation towards a clean air is feasible because, although it means a drastic change in our systems, we have been through an **industrial revolution** before. That revolution was very disruptive and risky, but yet we found the solutions required at that time. In this context, Woodward pointed that we should learn from the past. For instance, in the industrial centres, there was a loss of more than 10 years

of life expectancy despite the rapid economic growth. The urban industrial penalty was overcome in UK by enabling central direction (Public Health Acts, General Register Office, Sanitary Commission, etc.); creating local agencies like local government (some mayors) and Medical Officers of Health; and by promoting accountability, for example, reporting mortality every 3 months, city by city.

We must act creatively, change the way we think and see climate change as an opportunity to improve and not as a cost.

Woodward stated that an effective response to climate change will require radical changes in the way we live, although big changes can be risky. We must take care of our actual and future situation because it can have negative effects on our lives. Responding to climate change will disrupt stablished patterns of energy use, transport, how the economy works, building design and health care. Good practices discussed with Alistair Woodward during his session are detailed below.

A tax on emissions to mitigate climate change

To have a 50% chance of not exceeding the 2ºC increase above pre-industrial levels, we need to cut approximately 40 billion tons of CO_2 by the end of the century (Figure 3).

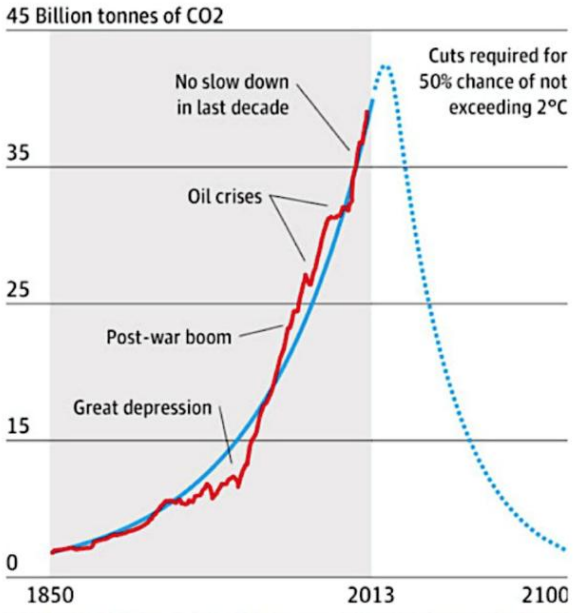

Figure 3. CO_2 emissions since 1850 (red); exponential growth (blue); cuts to hit climate target (dashed). Retrieved from: Clark (2013).

How can we move away from the global carbon dioxide emissions? An important step is to convince all governments that it is possible to decarbonize the economy without weakening human health. Costa Rica and United States have the same life expectancy

although the latter has emitted up to 10 times more than the former. Further, South Africa and Russia have a lower life expectancy than countries with similar carbon emissions, such as United Kingdom or Japan (Steinberger *et al.*, 2012). These examples show that life expectancy is not always related to the carbon emissions of the country.

Woodward is convinced that **a key factor in reducing GHG emissions would be to introduce a tax on these emissions** –for instance, 200 US$ per ton of CO_2, which will represent about 20% of the UK drug budget. According to the latest publications in 2017, the global average costs of a ton of CO_2 are 400 US$. In Spain, there is the Spanish Green Growth Group (GECV), which is an association created to promote public-private collaboration and face altogether the main challenges about sustainability, such as the adaptation and mitigation to climate change, the decarbonisation of economy or the promotion of circular economy. The enterprises attached to this group believe as well that a tax should be introduced. In fact, the Spanish Government presented, last November 2018, the draft of the Climate Change and Energy Transition Law, which does not include any tax on emissions. According to GECV's approaches, **if there would be a tax of 20 € per ton of CO_2, about 6 billion € would be recollected in Spain**, as we emit 300 million tons. **This great amount of money could be invested in the energy transition that the country must undergo**.

Furthermore, some experts believe that social costs should be taken into account. Until now, it has been considered that poor people were the most affected group by climate change. However, there are some current studies that are observing how rich countries are also being affected. For instance, the number of fires in California, which is a rich state of the United States, has increased due to climate change. This may change the paradigm about climate-related inequalities and how to face this issue.

A tax on meat or food to curb the emission of greenhouse gases.

According to Woodward, taxing greenhouse gas emissions from food production could be a good choice to be made. Although it seems to be a simple idea, it is difficult to put into practice. Woodward proposed to categorize foods and apply different taxes to these categories. The study conducted by a researcher group from the Oxford Martin Programme on the Future of Food and the International Food Policy Research Institute in Washington DC (Springmann *et al.*, 2016) is the first global analysis to estimate the impacts that levying emissions prices on food could have on greenhouse gas emissions and human health. The results show that **implementing emissions pricing on foods could avoid about one billion tons of greenhouse gas emissions in the year 2020, which is more than the total current emissions from global aviation**. However, the authors remark that we need to make sure that such policies did not impact negatively on low-income populations.

Much of the emissions reduction would stem from higher prices and lower consumption of animal products, as their emissions are particularly high. The researchers found that beef would have to be 40% more expensive globally to pay for

the climate damage caused by its production. The price of milk and other meats would need to increase by up to 20%, and the price of vegetable oils would also need to increase significantly. **The researchers estimated that such price increases would result in around 10% lower consumption of food items that are high in emissions.**

The research team modelled the emissions generated by the production of different foods, the climate damages that those emissions are expected to cause, changes in consumption that would result from including the cost of climate damage in the price of foods, and changes in the likelihood of dying from diet-related chronic diseases such as type 2 diabetes, coronary heart disease, stroke and cancer**. The results indicated that the emissions pricing of foods could, if appropriately designed, be a health-promoting climate-change mitigation policy in high-income, middle-income, and most low-income countries**.

Special policy attention would be needed in those low-income countries where a high fraction of the population is underweight, and possibly for low-income segments within countries. For instance, pairing emissions pricing with income compensation, or with subsidies for fruit and vegetables would result in net positive health impacts in all 150 countries included in the study. The benefits amount to about half a million lives saved per year in 2020 due to a lower consumption of red meat, increased consumption of fruits and vegetables, and a decrease in the number of people who are overweight or obese, which exceed the changes in underweight-related impacts. Further, Woodward highlights equality in economy as the key to reverse climate change, as those who has less money have more problems to evolve, manage water, etc. Hence, to properly manage the situation, taxes should not punish the more vulnerable population. According to Woodward, inequalities agenda is the same agenda of providing climate stability and adaptation.

But why taxing food and not considering other goods? Woodward states that taxing food is a good action because cattle has an influence on carbon dioxide emissions but also on methane emissions, thus being a great contributor to climate change. However, other goods should be considered besides the food. For instance, Woodward believes that the use of vehicles should be regulated through a carbon tax as well.

A tax for the use of petrol

An example can be found in Auckland, where there is **a regional fuel tax** –i.e. an extra tax on petrol–, and the money collected is invested in improving bicycle paths, greening the roadways, etc. Like with the tax on meet and food, this kind of tax is likely to be unfair, as wealthy people will pay for it because they are able, while average and poor people will not. However, some studies in Barcelona have found that the average income of people that use private cars to come to the city is higher than those who use other transport methods, so that the fuel tax will not affect poor people. According to Woodward, a portion of the money raised by the regional fuel tax should be invested

in public transport in those areas where it is currently weakest. This measure will reduce the regressive effect in some degree.

A tax to go by car to the city centre

Other types of actions have been tested in cities like Milan, London and Stockholm, where there is a tax to pay when people drive in the city centre during rush hours. In the case of London, this action was successful in terms of traffic reduction in the inner city. In Barcelona, there are some congestion taxes being created in order to regulate the access to the city. However, there is still a great amount of people coming to Barcelona by car. Therefore, other actions are needed as well.

A Pay-As-You-Drive car insurance

The action that would have the greatest impact on GHG mitigation in US cities is the Pay-As-You-Drive (PAYD) auto insurance, followed by low-rolling resistance tires –both of them are policy actions carried out at the city-scale (Figure 4). PAYD insurance is a type of vehicle insurance whereby the costs are dependent upon type of vehicle used, measured against time, distance, behaviour and place.

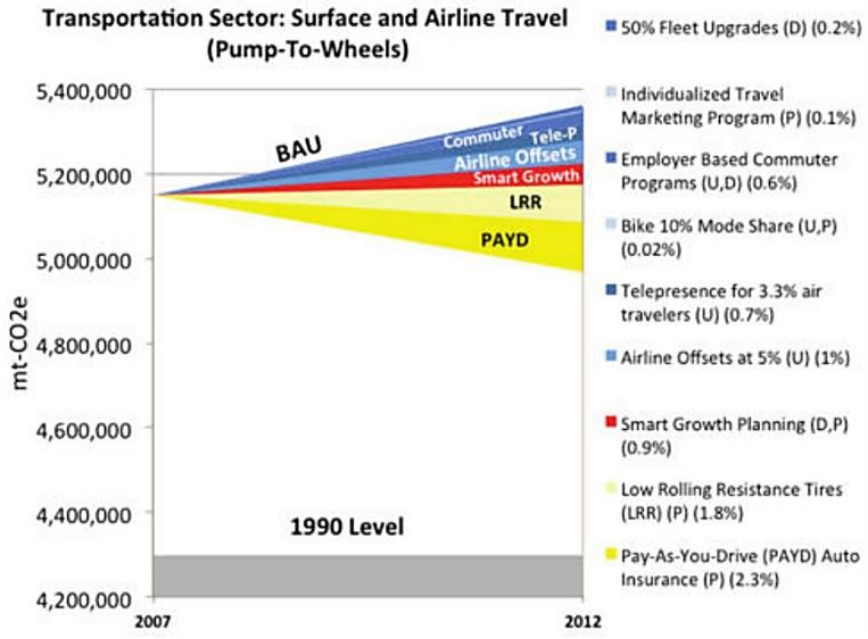

Figure 4. GHG mitigation wedges showing impacts of actual and hypothetical programs by actor category in transportation sector in US cities. mt-CO2e represents the global warming potential of all six GHGs expressed in metric tonnes of CO_2-equivalents. Voluntary actions primarily initiated by individual users (U) and infrastructure designer-operators (D) are shown in blue–green. Policy actions (P) at the city-scale are in red–orange, and those at the state- or regional-scale are in yellow. Many individual actions are not apparent due to their very small impact (<1%) on % GHG mitigation, as reported in the legend alongside each action. These smaller impact actions appear grouped together while the higher impact actions appear individually distinct. Extracted from: Ramaswami *et al.* (2012).

With insurance costs that vary with miles driven, people would have an incentive to drive less, thus decreasing the harm that more miles have on society. Under this system, higher-risk drivers would still pay more per mile than lower-risk drivers, and the effect of PAYD on miles travelled and gasoline consumption would be between a 6.5 and 20 percent reduction, representing a 2.3% of GHG mitigation (Ramaswami *et al.* 2012).

Transforming city centre into a car-free area would be a successful action

When trying to reduce CO_2 emissions, there are also win-lose situations. For instance, the reduction in GHG emissions related to diesel vehicles caused a greater amount of particulate pollution due to this type of vehicles. Woodward proposed as one possible radical action to be taken in Barcelona to transform the city centre into a car-free area. This action is beneficial to fight climate change while our health is improved as well. This approach is being considered in Auckland, and it has been implemented in some cities internationally and locally. As stated by Woodward, the business sector is generally not comfortable with this proposition because enterprises believe that it would affect negatively to their businesses. For example, they may believe that the number of costumers would diminish if they cannot park near the shop. Therefore, this sector is usually not willing to invest its money in this transformation. This is what happened in Sant Cugat del Vallès and Granollers, where the City Council decided to transform the city centre into a walkable zone and the commercial sector denied the proposal. However, an increase in the amount of people walking and shopping in the city centre was observed upon implementing the car-free area.

Although this approach is successful, forbidding any vehicle in the city centre may be too restrictive action to implement in some cases. **A more conservative action could be to forbid private fuel vehicles circulation but to allow electric vehicles and public transport**, although Woodward states that **electric vehicles are an energy solution but neither a traffic nor a health solution**. Another conservative possibility is to combine fast and slow lines in the city. In this case, fast lines should be greened because trees have a high capacity to remove the particulate pollution caused by vehicle circulation, while slow lines should be located in residential zones.

In November 2018, the Spanish government said that they pretend to reduce the use of fuel cars and promote electric vehicles. A main problem affecting electric cars is that it takes a long time to charge them and their autonomy is not very high. Moreover, Spanish houses are not adapted to recharge electric vehicles, and this shift is costly. However, Woodward believes that this transformation is one of the easiest goals to achieve in the climate change mitigation agenda. Further, Woodward remembered that it is important to shift into electric vehicles, but it is more beneficial to make the switch towards the active transport.

To bonus and promote the use of active transport/public transport

Instead of taxing the use of car or fossil fuels, Rodó believes that it will be fairer **to bonus people who act in a sustainable way while improving the transport system**, e.g. to go by bicycle instead of car or motorcycle.

Woodward agreed that using **public transport service is not as comfortable as using private vehicles** because it usually does not allow people to go exactly where they want to, as stations and bus stops are stablished. However, it has benefits in health and productivity. Moreover, commuting has the parking issue. For instance, in hospital parking lots, there is a competition for car parking because the number of places is limited. Therefore, Woodward and his team are trying to enhance other ways to go to work, such as paying **subsidies to employers to use electric bicycles**. This action would have benefits not only for the hospital, as parking lot would be less full, but also for workers, as they would avoid traffic jams and exercise.

In 2004, transport accounted for almost a quarter of carbon dioxide emissions from global energy use. Woodward and other researchers modelled the effects of urban land transportation on carbon dioxide emissions and health through designed scenarios with reference to a large city in a highly motorised country (London, UK), and a large city in a country that is becoming rapidly motorised (Delhi, India). The study concludes that important health gains and reductions in carbon dioxide emissions can be achieved through replacement of urban trips in private motor vehicles by active travel in high-income and middle-income countries (Woodcock *et al.*, 2009). Although technological measures to reduce vehicle pollutants might reduce emissions, the health effect would be smaller. **Largest health gains would be from reductions in the prevalence of ischaemic heart disease, cerebrovascular disease, depression, dementia, and diabetes.**

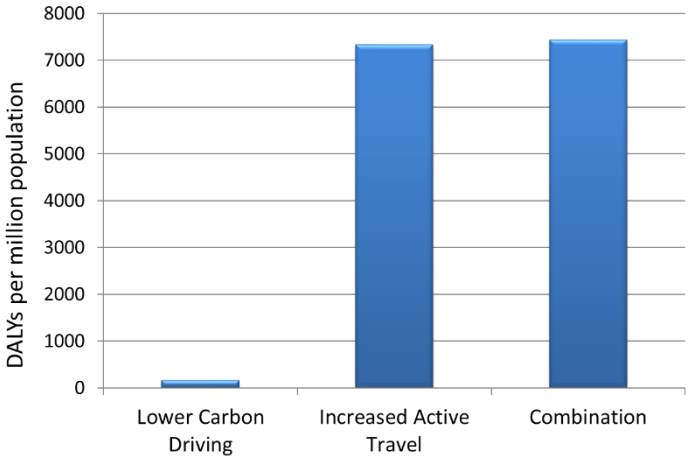

Figure 5. Disability Adjusted Life Years (DALYs) from different ways of reducing transport emissions by 60% in 1 year in London. Extracted from: Woodcock *et al.* (2009).

In addition, the health impact of reducing transport emissions in 1 year in London was measured in Disability Adjusted Life Years (DALYs), which combines both years of life

lost, and years of healthy life lost from a disability. **Woodward found a much larger health benefit from increased active travel** –through combined changes in air pollution, physical activity and injury– **than he found from lower carbon driving** – changes only in air pollution. The benefit in the combined scenario –i.e. combining both more walking and cycling and lower carbon driving– found the largest benefit (Figure 5).

Woodward stated that the combination of reduced reliance on motorised travel and substantial increases in active travel with vigorous implementation of low-emission technology offers the best outcomes in terms of climate change mitigation and public health. Nevertheless, reducing motor vehicle use could also have negative effects on pedestrians and cyclists –it would decrease the injury risk for existing pedestrians and cyclists, but if many more people would walk and cycle, there might be an increase in the number of pedestrian and cycle injuries, since more people would be exposed to the remaining risk. Therefore, **Woodward pointed that an increase in the safety, convenience, and comfort of walking and cycling, and a reduction in the attractiveness of private motor vehicle use (speed, convenience and cost) are essential to achieve the modal shifts needed.**

Woodward and other researchers used system dynamics modelling (SDM) to compare the effects of policies to increase bicycle commuting in a car-dominated city and explored the role of participatory modelling to support transport planning. They incorporated best available evidence to simulate five policy scenarios over the next 40 years in Auckland. This was the first integrated simulation model of future specific bicycling policies. **Their model projections suggested that transforming urban roads over the next 40 years, using best practice physical separation on main roads and bicycle-friendly speed reduction on local streets, would yield benefits 10-25 times greater than costs** (Macmillan *et al.*, 2014). Looking at the results, Woodward believes that participatory SDM can be a helpful method for integrating health and environmental outcomes in transport and urban planning.

To redesign and decentralise the public transport network in the metropolitan area

Many people living in Barcelona use the public transport system rather than their private vehicles. The private transport method is more extended among people from other municipalities that come to Barcelona every day to work or study. For this reason, decision-makers should consider the whole metropolitan area for their mitigation policies, such as the resetting of the public metropolitan transport system. For instance, students of the Universitat Autònoma de Catalunya (Cerdanyola del Vallès) coming from Mataró have to go to Barcelona first because there is no public transport service that directly connect these two cities. The difference lies in investing more than 3 hours per day in public transport or 1 hour if the private vehicle is used. This will require a very large investment, but it is needed.

Companies should assume the cost of the transport of their employees

Some companies are in industrial parks, where there is no connection to the public transport. In order to reduce the use of private cars, GHG emissions and traffic congestion, the companies should assume the transport cost of the employees and promote shared transport, for example through organizing bus shuttles.

To use vehicles with low-rolling tires

On the other hand, low-rolling resistance tires are designed to reduce the energy loss as a tire rolls, decreasing the required rolling effort and improving vehicle fuel efficiency. Approximately 5-15% of the fuel consumed by a typical car may be used to overcome rolling resistance. Thus, some studies estimate that adoption of low-rolling resistance tires could save 1-4.5% of all gasoline consumption (Ramaswami *et al.*, 2012).

Subsides to better insulate houses

As a good practice, Woodward gave the example of New Zealand. There, they have a particular issue on housing insulation as an opportunity to reduce emissions. Woodward showed how they organized community trials of insulation and clean heating (WARMUPNZ, 2018), in which the government put a lot of money. Woodward and his partners tried to determine whether insulating existing houses increased indoor temperatures in order to cope with cold weather and improving occupants' health and wellbeing. The design was community-based considering seven low-income communities in New Zealand. Altogether, 1,350 households containing 4,407 participants were studied. The intervention done was the installation of a standard retrofit insulation package. Main outcome measures were: indoor temperature and relative humidity, energy consumption, self-reported health, wheezing, days off school and work, visits to general practitioners, and admissions to hospital (Howden-Chapman *et al.*, 2007).

Woodward found that insulation was associated with a small increase in bedroom temperatures during the winter (0.5ºC) and decreased relative humidity (-2.3%), despite energy consumption in insulated houses being 81% of that in uninsulated houses. Bedroom temperatures were below 10ºC for 1.7 fewer hours each day in insulated homes than in uninsulated ones. These changes were associated with reduced odds in the insulated homes of fair or poor self-rated health, self-reports of wheezing in the past three months, self-reports of children taking a day off school, and self-reports of adults taking a day off work. Visits to general practitioners were less often reported by occupants of insulated homes as well. Hospital admissions for respiratory conditions were also reduced, but this reduction was not statistically significant. In conclusion, insulating existing houses and clean heating led to higher

temperatures, lower power consumption and lower disease rates (Howden-Chapman *et al.*, 2007).

A similar program was applied in Australia, but with the goal of cooling instead of warming (GoAUS, 2017).

To create the figure of an ombudsman for the environment

In New Zealand, they recently have created a figure of a kind of ombudsman for the environment in order to ensure that it is acted with the least possible impact on the environment.

Society and politicians must be willing to mitigate climate change

As stated by Woodward, it is feasible to reach zero-carbon emissions and, thus, it is feasible to mitigate climate change. However, is it possible to reverse the global warming through our technologies or is it too late? Woodward believes that **besides improving our tools and methods, it will require political determination to make changes in regulations and promote good practices. Transition requires political measures and consensus to guarantee its application.** Further, it is also important that regulations and laws are accepted by the society if they have to be efficient. **Society and politicians must be willing to mitigate climate change.** This is the case of New Zealand. Woodward stated that the Government of New Zealand has been willing to help parties and other organizations in order to shift into a zero-carbon country. In New Zealand, as well as in UK, there is a Climate Commission, which is an independent group that monitors and advises about how to proceed to cope with climate change.

An example of political determination was the **Paris Agreement**. Woodward stated that, although it did not lead to mandatory carbon emission reduction, **it was a clever step to shift from top-down decisions on contributions to bottom-up** –countries make their own achievable and meaningful contributions and afterwards they report back the progress periodically to inform the rest of the countries. Woodward considered this agreement as a good framework to work with.

Moreover, the IPCC is an example of the collaboration between science and international diplomacy. The issue that people in IPCC was more sensitive about was the issue of liveability. As stated by Woodward, the health issue of climate change can be seen as a race between climate change effects on health and urban systems, and people's capacity to adapt to it. He is optimistic about our ability to adapt to and mitigate climate change. However, **in order to keep governments active, IPCC reports**, which are checked and rechecked by specialised experts, **are conservative about climate change mitigation effects.**

Cities are the main actors in facing climate change

According to Woodward, cities are important to consider in climate change mitigation and adaptation strategies because they have become the predominant human habitat in every continent. Furthermore, cities are the source of the problem in many ways. On the other hand, cities are also where there is the opportunity to make the transformations needed. Therefore, Woodward believes that people should work in cities to find solutions that lead us to better ways of living, considering the economy and sustainability.

What are the different types of profound transformations that cities must undertake to adapt to climate change? Woodward mentioned that New Zealand is developing a good practice to legislate for a process whereby progressive and permanent reductions in greenhouse gas emissions could be achieved over time (PCE, 2018). Further, many cities around the world are doing great efforts to reduce emissions and carbon footprint, and to transform their systems into more sustainable ones. However, there is not a perfect sustainable city yet. For instance, some cities are improving their **waste management system, such as London**. During 2015-2016, poor waste management practices in the domestic rented sector of London were commonly identified as having a negative impact on recycling performance. In response, a project was set up to find practical solutions that can be put in place in the short to medium term (EUNOMIA, 2017). On the other hand, other cities are working on **urban food system, such as Paris**. Urban farming is flourishing in Paris thanks to the project "Parisculteurs" launched in 2016 by the Paris government of Anne Hidalgo, the city's mayor. This project aims to cover the city's rooftops and walls with 100 hectares of vegetation by 2020, and one third of this green space should be dedicated to urban farming (http://www.parisculteurs.paris/).

Moreover, **Singapore is a relevant example of greening the city**. Singapore has a hospital with rooftops turned into gardens that provide food for the patients, and are sociable areas where people are gathered together. As a side effect, the greening of the hospital improves the healing of their patients (RAMBOLL, 2016). Another city that can be considered as **a good example of greening is New York**. The government of the city released in 2017 the report “Aligning New York City with the Paris Climate Agreement” (NYC, 2017). As part of the city’s ambitious climate plan, large buildings will be required to meet fossil fuel caps and implement efficiency upgrades. In addition, city government and operations will switch to 100% renewable electricity. On the other hand, NYC Parks is actively working toward a holistic approach to GHG emissions reduction that combines planning and design of new construction projects; retrofitting, retro-commissioning, and upgrading existing systems; preventive and predictive maintenance of equipment; energy monitoring and performance tracking; and training for all levels and aspects of agency operations.

Nevertheless, climate actions cannot always be generalized. For instance, New Zealand’s cities are not like most European cities such Barcelona. Therefore, urban

plans and transformations that work for the New Zealand model must be adapted depending on the density, emission profile or political dynamics of other cities. In this context, Creutzig *et al.* (2015) stated that mitigation interventions related to urban form have the highest potential during early phases of urban development. This window of opportunity exists especially for low-emissions cities in Asia, the Middle East, and Africa. However, demand-side policies, such as increased gasoline prices, encouraging compact and accessible urban forms, along with idiosyncratic urban design options, can also reduce urban energy use in developed cities. The model also showed that urban planning and transport policies –i.e. urban form modifications and increases in gasoline prices, respectively– can limit the future increase in urban energy use to 540 EJ in 2050, which means a reduction of 26% from the original estimated value, and can contribute to climate change mitigation.

Another example is the implementation of green areas. Urban green spaces have multiple benefits, even the rudimentary ones. It may not have large benefits in cooling, as stated by Koen De Ridder in his session (See: De Ridder (2018)), but it has large benefits in air quality, mental health, etc. For example, children exposed to green spaces have some areas of the brain more developed. Moreover, people living closer to green spaces have better mental health caused by biochemical effects. However, not all kind of cities benefit from the implementation of green areas. Woodward compared the efficiency of urban green spaces between low-density and high-density cities. In Europe, most of the cities have a high density, thus giving much relevance to green spaces within the city. In Barcelona, urban green spaces close to population access are considered to be good actions to be taken as people can benefit from it – cooling effect, cleaning the air, etc. For instance, the Ciutadella park occupies 101km^2 and is located in the city centre. Contrarily, low-density cities such as those in New Zealand or Australia already have extended green areas around the city. For example, in Auckland, the green spaces occupy 4,900km^2. Consequently, urban greening is less associated with health benefits in those countries. Similarly, the effects of green areas are less prominent on people living in a rural environment than in the city. In conclusion, Woodward stated that there are different approaches about the optimum urban green space model and it has to be adapted according to the city density. Furthermore, we should also take into account that some effects of urban green spaces cannot be seen immediately. Therefore, it is important to have a big data collection in order to consider the whole lifespan of people. Further, the more diverse the green space is, the more benefits it provides. As a consequence, Woodward remarks that less diverse green zones may provide suboptimal solutions.

In this context, **C40 network** provides good practices to cities, energy reforms, the creation of low-carbon buildings, mobility policies and waste management. Interestingly, C40 adapts these different types of transformations to each kind of city by giving the transformations as a function of the density of the city, among others (McKINSEY, 2017). For this reason, Woodward believes that it is important to be a member of the **C40 network**, as Barcelona and Auckland do.

Although most of the transformations have to be adapted depending on the city context, there are some approaches that are quite universal. It is important to reduce the transport use, and to find better ways to transport people within the city. Other considerations are to promote low or zero-carbon buildings, as well as improve the waste management. Woodward was optimistic, although he was aware of the difficulty of some transformations, he remarked that there are a lot of actions to be done to adapt and mitigate climate change. Woodward also stated that we should consider how we want to live in order to decide which transformations we must make. Woodward gave the example of living underground in order to avoid the warming –it will be an adaptation to climate change, but he was sure that this is not the kind of life that society wants.

Why is important to measure benefits of climate change's actions?

There are lots of problems to be addressed in the world –800 million people are starving, 940 million people are illiterate, 2 billion people are lacking sanitation, several billion people will be affected by global warming, etc. In an ideal world, we could solve all these problems. However, we cannot do it and thus, we need to prioritize and choose which ones should be solved first. Lomborg (2005) identified 10 of the biggest challenges in the world and sought to establish priorities for advancing global welfare using methodologies based on the theory of welfare economics, by the means of cost-benefit analysis. According to these analyses, the worst projects in terms of net benefits and efficiency are those addressing climate change, e.g. carbon taxes and Kyoto Protocol. This means that what we can do to address climate change is very little and has a very high cost. However, Woodward argued that this criterion - to invest in the priorities that solving them would mean less cost and more benefits - is not good enough. He remarked that facing climate change must be a priority because our lives depend on what happens to the Earth's climate. That's why **Woodward highlighted the importance of measuring the benefits of climate change actions, to promote the investment in transformations that face this challenge.** Therefore, we have to study the positive and negative consequences of climate change actions, and measure the net benefit of these action to motivate and guide mitigation and adaptation**.** In this context, **C40 network** helps and supports the research on measuring the benefits of climate change actions. These benefits are described in the document "Benefits of Climate Action" of C40 Cities and the final report (C40, 2016, 2017). For instance, the EcoBici bike share scheme of Mexico City, which was launched in 2010, counts more than 6,000 bikes, 444 docks and over 100,000 users and is expected to replace around 24,000 car kilometres per year. This action increases physical activity, improves quality of life and saves nearly 1,190 tonnes greenhouse gas emission per year. Moreover, the monetised health benefits gained by shift from cars to EcoBici are estimated at $26 million.

Woodward stated that cascade effects should be considered in climate change action's benefit assessment, and outputs should be measured. Reporting net benefits of climate action will be important to motivate and guide mitigation and adaptation of climate change (C40, 2016). Indeed, **the total cost of potential co-benefits of climate actions** –related to housing, reducing air pollution, promoting renewable energy sources, etc.–, including health savings from those co-benefits, **is probably sufficient to pay for climate action**. For instance, the global costs of climate change for 2070 are estimated to be about 16 trillion US$, while the cost of acting is clearly much lower. In India, 90 billion US$ are estimated to be lost due to climate change effects.

In New Zealand, large amounts of money could be saved in public health at the same time that GHG emissions would be reduced. Since 1990, New Zealand's gross emissions have increased by 19.6%. The two emission sources that contributed the most to this increase were road transport (carbon dioxide) and dairy cattle (methane from livestock digestive systems). The increase in transport has represented an 82.1% growth in GHG emissions since 1990, most of it occurring in cities, which means a cost

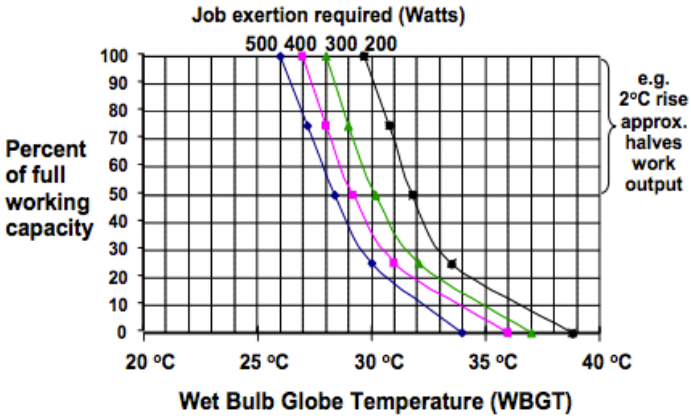

Figure 6. The relation between heat and work – a function of ideal human physiology and a pointer to fundamental temperature thresholds. The temperature considered is not the air temperature but the Wet Bulb Globe Temperature (WBGT), which is a measure of heat stress that is sensitive to air temperature, radiant temperature, humidity and wind velocity. Extracted from: ISO (1989).

of $1 billion a year related to traffic congestion. At the same time, 1/3 of New Zealand's adult population is obese. As stated by Woodward, **shifting 5% of short car trips to bikes would save 22 million litres of fuel, avoid 116 deaths per year with net savings of about $200 million,** and reduce transport GHG emissions by 0.4% (GoNZ, 2018). Therefore, as previously stated, large amounts of money would be saved in public health at the same time that GHG emissions would be reduced. It is also **important to consider long-term benefits and costs** and processes because a certain action may not have immediate effects but provide huge benefits in the future. Woodward highlighted the need of quantifying these long-term benefits and cost.

Woodward further indicated that as problems open the door to opportunities, climate change provides unparalleled opportunities for public health. **The most effective adaptation measures for health in the near-term are programs that implement or improve basic public health measures** where needed. This is particularly important in the poorest countries as climate change opposes health gains achieved by social

development and it might hold back progress in these countries. Further climate-specific measures (such as early warning systems for extreme weather) will be needed to protect the health of the population, even in high-income countries, as climate change proceeds.

Woordward stated that society also needs to look at the new climate economy. Working capacity and financial stability are also affected by climate change. For example, human working capacity diminishes as temperature rises. A 2ºC rise approximately halves work output (Figure 6). If certain threshold is surpassed, workers cannot operate anymore, implying negative consequences to the economy.

Financial stability also depends on climate change. According to Mark Carney, Governor of the Bank of England, climate change is very important to financial stability because of the physical risks, the liability risks and, most important, the transition risks. Physical climate impacts increasingly confront investors with unplanned and abrupt changes or disruptions to businesses or assets. Moreover, investors face transition risk to a low-carbon and climate resilient future. This has different angles: changes in climate and energy policies, a shift to low-carbon technologies and liability issues. Transitional impacts can vary substantially depending on scenarios for policy and technology changes.

Big gaps on climate change policies

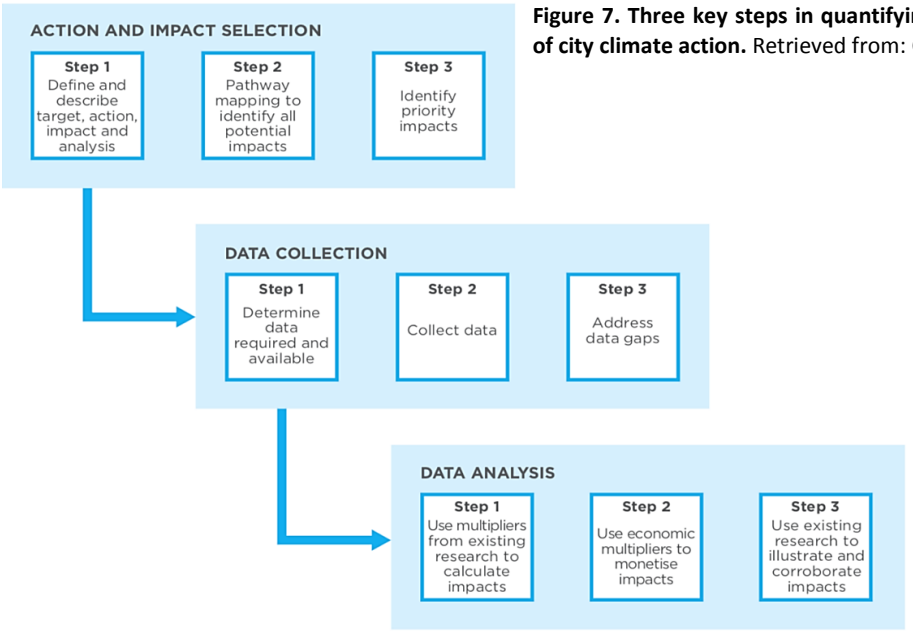

Figure 7. Three key steps in quantifying the impact of city climate action. Retrieved from: C40 (2018).

According to C40 Cities, the three steps to quantify the impacts of climate action on cities are: action and impact selection, data collection and data analysis. First, before any data collection and analysis can be undertaken, there must be a clear understanding and definition of what is to be measured and why. Having defined

exactly what is to be measured, the next step is to plan and undertake data collection. After harvesting all the data, possible gaps will likely remain. Therefore, analysis then needs to be undertaken to fill any remaining data gaps (C40 (2018), Figure 7).

Woodward remarked that we should investigate which data is needed for the measurement of the benefits of climate action, especially, relating to urban food systems, transport and housing. The main gaps in this regard are analysing the disbenefits of climate actions, determining the cause and effect between two variables, and taking inequalities into account when planning a climate action.

Woodward remarked that we should be careful –the co-benefits agenda is an excellent engagement agenda, a great place to start conversation, but it does not take us all the way in terms of providing solutions. Climate and health agendas do not always align perfectly, as there are trade-offs as well as synergies. **Woodward highlights the relevance of knowing the possible negative outcomes of climate change actions, because these possible disbenefits lead to suboptimal trade-offs.** For instance, a solution to the growth in transport GHG emissions may be the electric cars. Since electric cars do not use fossil fuels, they favour a reduction in GHG emissions. However, 40% of total emissions from cars come from dust, breaks, etc. As a consequence, local air pollution is not properly faced with the implementation of electric cars. In addition, electric cars are as big as fuel cars and thus the congestion problem is not solved. Moreover, one third of New Zealand adults are obese, and electric cars will do nothing for reducing obesity. Therefore, Woodward stated that electric cars may be an energy solution, but they are neither a transport nor a health solution. The question to be addressed is how electric vehicles can improve health and reduce GHG emissions. Woodward pointed that there is an information gap in this topic, in which scientists can contribute.

Frequently, benefits and disbenefits of cascade effects occur in different areas, thus being difficult to balance. Woodward gives the example of Bus Rapid Transit. Implementing the programme of the bus rapid transit will ultimately provide several benefits, such as the improvement of employment opportunities, the reduction of air pollution and consequently also the risk of diseases, the decrease of congestion and thus also the travel time, the diminution of fatal and non-fatal injuries, and the reduction of the costs related to personal vehicle maintenance.

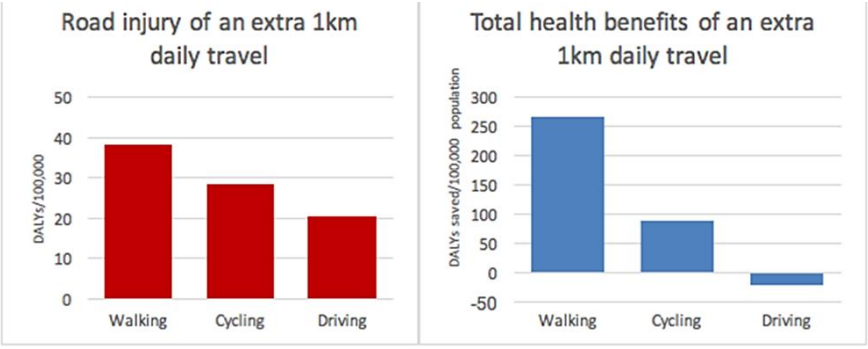

Figure 9. Comparison of health and injury outcomes of walking and cycling with driving. Disability Adjusted Life Years (DALYs) combines both years of life lost and years of healthy life lost from a disability. Retrieved from: Woodward (2018).

However, there are also disbenefits emerging from this programme, like the increase in the property prices. Therefore, the Bus Rapid Transit is good for air quality, employment, health and private wealth, but bad for housing affordability. In the same way, an action that wants to promote active transport have to consider that people who drive are more unlikely to have a road injury in comparison to those who walk and cycle. However, the total health benefits are lower for the people that drives (Figure 8). Overall, it is important to balance all possible beneficial and dis-beneficial outcomes before implementing a climate action.

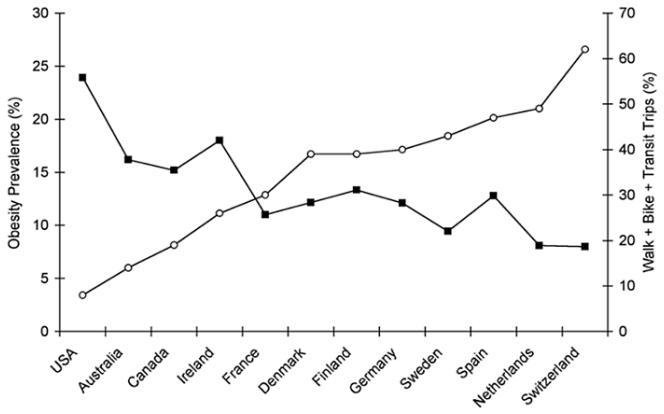

Figure 8. Percentage of active transport among total transport use (white dots) and obesity prevalence (black dots) of several countries from around the world. Retrieved from: Bassett *et al.* (2008).

As stated by Woodward, demonstrating causality is particularly challenging and resource intensive. Therefore, **it is especially important to coordinate research efforts on causation on the most critical data gaps**. For example, the relation between active transport and obesity prevalence is inversely proportional, as the obesity increase with lower use of active transport (Figure 9). However, the correlation is not strong. Hence, much more research in this line is needed to obtain a strong evidence.

Among other effects, climate change is generally determined as the cause of the increase of the extreme events' frequency, such as flooding events. However, some people assure that maybe there are some other factors causing more hurricane events. In AR5, the conclusions provided regarding extreme weather events were not exactly

those that researchers wanted to explain because there is also a diplomatic influence. For instance, they estimate a Harvey-like flooding is 6 times more likely nowadays than in the late 20th century. Therefore, the likelihood that this event was caused by climate change probability is 5 to 1 or in proportions 5/6. Else, considering estimate rainfalls of this intensity in Texas, in the period 1980-2000 it had 1% annual probability, whereas it has 18% by 2100 under RCP8.5 –if the increase over time is linear, then in 2017 the probability was about 6%. Woodward asked himself: can we say that climate change causes certain effect based on probabilities? In the British system, Courts have to decide based on the balance of probabilities. On the other hand, other countries may act in a deterministic way instead of a probabilistic one. An example of this is the case of the tobacco. Although tobacco is known to be a very harmful product, Tobacco's industry and manufacturers are not blamed and punished for deaths related to tobacco, because the probability of having lung cancer caused by smoking is not 100%.

In the context of climate change, the increase in temperature and sea level are both phenomena that are almost certainly associated with climate change. Therefore, Xavier Rodó believes that companies that highly contribute to air pollution should be judged. Nevertheless, it is a difficult issue to address, since there is a remarkable difference between tobacco and climate change as a person can avoid smoking but cannot avoid using energy, which will ultimately provoke the emission of GHG caused by the use of fossil fuel.

Woodward stated that **there is very little literature about climate change inequalities**. Indeed, considering a total amount of 26,230 papers, only 37 of them (from 35 different studies) were studying this topic –10 were empirical studies, whereas 25 were modelling studies. According to the trend in mortality of the low-socioeconomic population and the high socioeconomic population after implementing a given action, there are 3 different types of outcomes. The most desirable situations are such in that the mortality and the absolute inequalities are reduced, whereas the relative inequalities are maintained or reduced as well. Other less desirable options but still acceptable include those that reduce the mortality of both socioeconomic groups while maintaining or reducing absolute inequalities but increasing relative inequalities. The worst situations are the ones in which the mortality is increased or maintained but along with an increase in both absolute and relative inequalities (Figure 10). Thus, when designing a new action, **it is important to assess whether the expected outcome of climate actions reaches the whole population, especially the vulnerable people**.

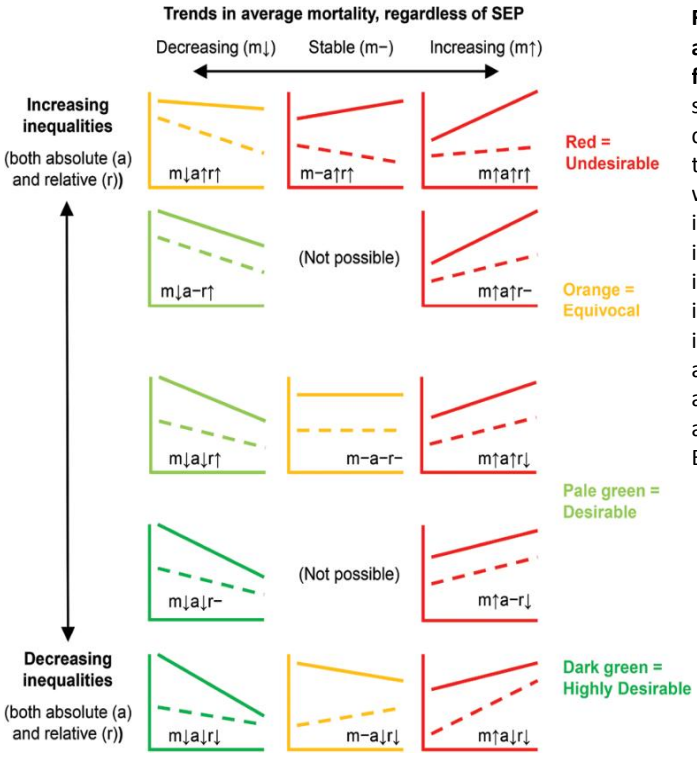

Figure 10. Typology of population average and inequality trends in mortality (schematic figures). y axis = mortality rate, x axis = time; solid lines = low-socioeconomic group trend, dashed lines = high socioeconomic group trends. The criteria for coding, and colouring were highly desirable must include reductions in the average mortality rate and absolute inequalities, and no increase in relative inequalities; desirable must include reductions in the average mortality rate and no increase in absolute inequalities; undesirable included any increasing average mortality rate, or stable average mortality with widening inequalities; and equivocal included the remaining types. Extracted from: Blakely *et al.* (2017).

An example of a highly desirable outcome is to promote active transport in deprived zones in central Auckland. More deprivation involves more health gains potentially as a consequence of more active transport. However, there are some exceptions –for example, there are studies that states that more cycling involves more polluted air breathed. Nevertheless, Woodward believes that the benefits of active transport always surpass the negative consequences of breathing polluted air. Therefore, he argued that in order to make climate change policies, policy-makers have to consider the relationship mentioned –i.e. that more deprivation involves more health gains potentially.

Woodward finally emphasised the importance of highlighting the impact side of the events, because politicians, policy makers and the whole society would be challenged by it.

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