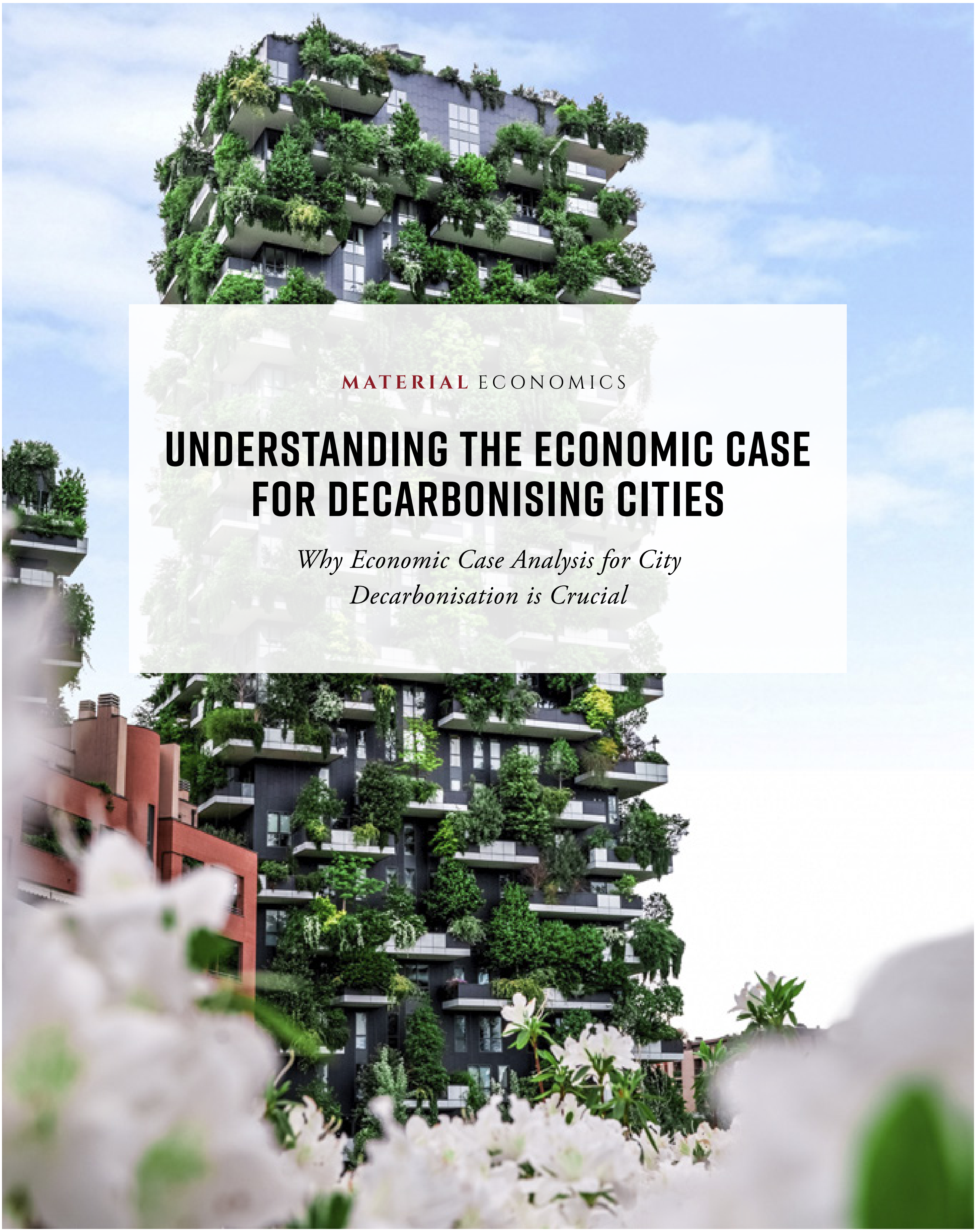
MATERIAL ECONOMICS

UNDERSTANDING THE ECONOMIC CASE FOR DECARBONISING CITIES

Why Economic Case Analysis for City Decarbonisation is Crucial



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Publication details

Please refer to this report as: Material Economics (2020). Understanding the Economic Case for Decarbonising Cities - Why Economic Case Analysis for City Decarbonisation is Crucial.

IN SUPPORT OF THE TOOL AND APPROACH

"Today, cities are working on enhancing their capability to address many of the complex challenges facing them, such as job creation, health, and climate. The first step in addressing a complex challenge is to understand it better. The model developed by Material Economics in collaboration with EIT Climate-KIC is one important tool for cities to deploy to gain insights and understanding of the complex challenges they are seeking to address. Today the outcome of the first iteration is being used in Malmö to gain additional insights and supports Malmö's elected politicians and other decision-makers in making informed decisions."

Jonas Kamleh, Strategist, Malmö Environmental Department, and governing board member, EIT Climate-KIC and ViableCities

"Every city needs to invest billions to respond to the climate emergency and build a resilient and sustainable future. To mobilise at this scope and scale, each city needs a tool to understand and communicate the economic case for the investments they must figure out how to make."

Thomas Osdoba, Senior Cities Advisor, EIT Climate-KIC

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June 2020

EXECUTIVE SUMMARY

Cities have a clear and fundamental role to play in addressing the climate emergency and achieving the UN Sustainable Development Goals. Many are working hard to decarbonise, but face significant challenges due to inertia in existing systems, pre-existing policy environments, and limited budgets. A key obstacle is the seemingly high cost of reshaping key CO_2-emitting sectors in the city, from transport, to buildings, to the power supply, as well as challenges in understanding who needs to pay and who stands to benefit. This makes decision-makers hesitant to pursue change. However, many recent global reports show clear economic opportunities in decarbonisation that are often attractive for multiple reasons, including improved public health and other co-benefits. The problem for city leaders is how to translate those analyses, which are often generic, into estimates of the economics of change for individual cities.

To help cities analyse the economic implications of specific climate actions, Material Economics & EIT Climate-KIC have developed a tool to enable cities to build their intelligence on potentially effective climate actions to reduce emissions and secure a more resilient future.

Using Excel, the tool helps cities test different scenarios to understand the socioeconomic case for reducing CO_2 emissions in cities. It evaluates the CO_2 reduction potential, air pollution reduction (NO_x and PM), investments needed, cost savings, and other societal co-benefits generated for key sectors (such as transport, heating, and electricity) and 15 specific decarbonisation measures (such as electrification of buses) in the city, relative to a baseline development scenario. A key advantage of the tool is that it includes co-benefits such as improved air quality, reduced traffic accidents, and better physical health. These are second-order benefits that arise from actions that have another primary intent. For example, improved air quality (and thus health) comes from the reduced air pollution that occurs when, in an effort to reduce CO_2 emissions, diesel-fuelled buses are replaced with electric buses.

For cities starting to work on decarbonisation, the analysis can help them to quickly understand the approximate potential and economics of key decarbonisation initiatives they can pursue, helping them prioritise. Yet the tool is also useful for cities, both large and small, that are at various stages of climate engagement. It has already been applied in several European cities as part of the Healthy, Clean Cities Deep Demonstration, including in Milan, Malmö, Leuven, Krakow, and Orléans, among others.

Working with these cities provided valuable insights on the economics of decarbonisation. Typically, the overall socioeconomic case is positive when co-benefits are included. This indicates the importance of taking a society-wide view of the benefits of decarbonisation. While the case is positive for all cities that have used the tool, the results vary considerably, reflecting differences among the cities and highlighting the importance of city-specific analyses. The work has also shown that ambitious decarbonisation is possible with all the measures analysed, but individual options may have positive or negative impact in different contexts, and also have very different decarbonisation curves. This means it is important for cities to view the 15 measures as a package, to avoid missing out on significant potential that exists with initiatives that on their own might not have the strongest economic case. It also is crucial to remember that although individual citizens stand to benefit the most, they are also the ones who especially will need to change behaviours.

The analyses made with the tool can help city decision-makers and stakeholders deepen their understanding of the economic impact of available decarbonisation options, identifying the initiatives that are likeliest to have a significant economic return to society, and quantifying the potential cost. The findings are useful across a city's whole policy development cycle, from developing a baseline, to prioritisation and decision support, to execution and validation of projects.

It is important to note, however, that although the tool is applied in collaboration with the city and uses internal city-specific data, in addition to established research, it is also an approximation and will not answer every question about decarbonisation that a mayor will have, especially in terms of evaluating specific policies and implementing measures. More work is needed for that, and new types of tools and analysis should be developed. Building on this analysis, cities should continue deepening and widening their understanding of the economic case in more detail, analysing a wider set of co-benefits, such as employment, and analysing on a more neighbourhood-level scale. They can then also evaluate the effectiveness of specific policies to realise initiatives, and design and execute pilots to test the effectiveness in practice.

With that in mind, this report should be seen as a living document that will be further updated as more and deeper work is conducted with cities as part of the Deep Demonstration, and the effectiveness and use of the tool is proven further.

Cities need to understand the economics of equitable, inclusive sustainable development, including all direct and indirect economic impacts, to support informed decision-making.

THE NEED FOR ANALYSING THE CITY ECONOMIC CASE

PURPOSE

Cities have a clear and fundamental role to play in addressing the climate emergency and achieving the UN Sustainable Development Goals. This reality is well understood, and the areas of action are described in numerous reports and research studies, including work from the Global Covenant of Mayors and the Coalition for Urban Transitions. Most cities are well into their second decade of work on climate actions, building sustainability and resilience strategies as part of the process.

Even for cities with the most advanced and sophisticated strategies, and those that have made the most progress in reducing their greenhouse gas emissions, the end goal of getting to net-zero carbon emissions and a resilient, sustainable future remains extremely hard to reach.

A significant part of the challenge is to keep experimenting and learning how to accelerate actions with deeper impacts, and how those actions fit within a systemic approach rather than as individual initiatives. Healthy, Clean Cities was created to help cities address this challenge. For cities to take actions of the scope and scale needed to achieve carbon neutrality, they have to understand their choices and the relative implications of them. This truth is no more evident than in the lack of actionable information on the economics of transforming urban communities to be carbon-neutral. As cities learn more about urban transformation, it can be seen that this actionable information must address issues of economic growth, health, inclusion, and equity. The anecdotal and case-study evidence base is encouraging, but cities lack the tools to examine the economic implications of future scenarios that require much more aggressive policies, programmes, and projects.

Many studies have been conducted to explore the economics of climate action, quantifying the investments needed to avoid catastrophic impacts and to adapt to unavoidable climate change impacts and an uncertain future. Those studies overwhelmingly show that aggressive climate action would be economically advantageous, far more than inaction. The key take-away is that the world will be better off if we do everything possible to reduce emissions enough to keep the global temperature increase well below 2°C.

The world will be better off if we do everything possible to reduce emissions enough to keep the global temperature increase well below 2°C.

Cities and their citizens can see how the future could unfold in economic terms and how climate action can contribute to economic security.

ACTIONABLE KNOWLEDGE

These global studies are very useful for understanding the big picture, but they do not provide enough guidance to help individual cities take the actions they need to achieve climate goals. Each city needs to understand the economics specific to its own context. Much more aggressive policies and programmes need to be advanced based on a credible understanding of the economic implications. City officials will need to be able to make explicit and compelling arguments in support those actions, because systemic changes are not going to be easy and will face significant resistance.

Material Economics' and EIT Climate-KIC's work to develop the economic case for carbon neutrality for each city participating in Healthy, Clean Cities responds to the need for actionable knowledge, so local leaders can engage their citizens and stakeholders with a robust economic argument to accompany the scientific rationale for aggressive decarbonisation. This economic argument is part of the broader societal case for action, as it is clear that citizens and governments will consider climate actions alongside numerous goals and aspirations such as economic growth, better health, and equality.

TRANSFORMATIONAL CAPACITY

Cities have built significant capacity and knowledge for climate action among their policy-makers, planners, engineers, and programme and finance staff. This growing capacity is very important, but cities generally lack the ability to consider the systemic costs and benefits of their actions. Cities need to understand the economics of equitable, inclusive, sustainable development, including all direct and indirect economic impacts.

Consider the challenges that city policy-makers face as they strive for more aggressive climate actions. Measures to reduce building energy use or shift to clean transportation or reduce waste all have direct costs. Those actions also have broader impacts, whether reducing energy costs or supporting deployment of new services or technologies. Every aspect of an action contributes to the overall economic impact.

• **Actions can reduce** costs and create new revenue streams, both of which influence whether that action has a net economic cost or benefit. Easy examples are energy savings from efficiency improvements and revenues from renewable energy generation.

• **Jobs are created** through the procurement of services or deployment of technologies, and this has additional direct and indirect benefits to the economy. Retrofitting hundreds of buildings requires significant increases in the number of people employed to do that work, with salaries and the multiplier benefits of their spending in the wider economy.

• **Actions can contribute** to better public health or reduce congestion, which add new layers of benefits: better air quality, reduced respiratory and cardiovascular illnesses, reducing absenteeism and health care spending. Less congestion can also make it easier for people to walk or ride a bicycle, which allows them to save money they might otherwise spend on fuel and car expenses.

• **All actions affect** an array of risks to the city, and those risks contribute to the costs and benefits.

• **Political controversy** or rejection of measures by citizens can create uncertain policy-making environments and increase costs and risks for long-term capital projects. Deep and ongoing citizen engagement is therefore needed to ensure continued social acceptance of climate actions.

These layers of complexity need to be understood in order to create better decision-making capabilities.

DECISION SUPPORT TOOLS

Healthy, Clean Cities was created to help cities take action in support of much more urgent needs to reduce greenhouse gas emissions, lessen the impacts of irreversible climate change, and build a more resilient and sustainable future. The programme is designed to foster systems change through strategic innovation, using a rigorous and structured methodology to overcome institutional inertia, siloed and incremental actions, and enable rapid replication and scaling of actions that can contribute to achieving these targets.

Work of this nature demands tools appropriate to the challenge. Cities will be identifying and testing multiple options for taking action. They need to clearly understand the implications, test alternative scenarios, and engage openly and collaboratively with key stakeholders. Otherwise, resistance to change will make these actions almost impossible to implement and increase the risk of further societal polarisation.

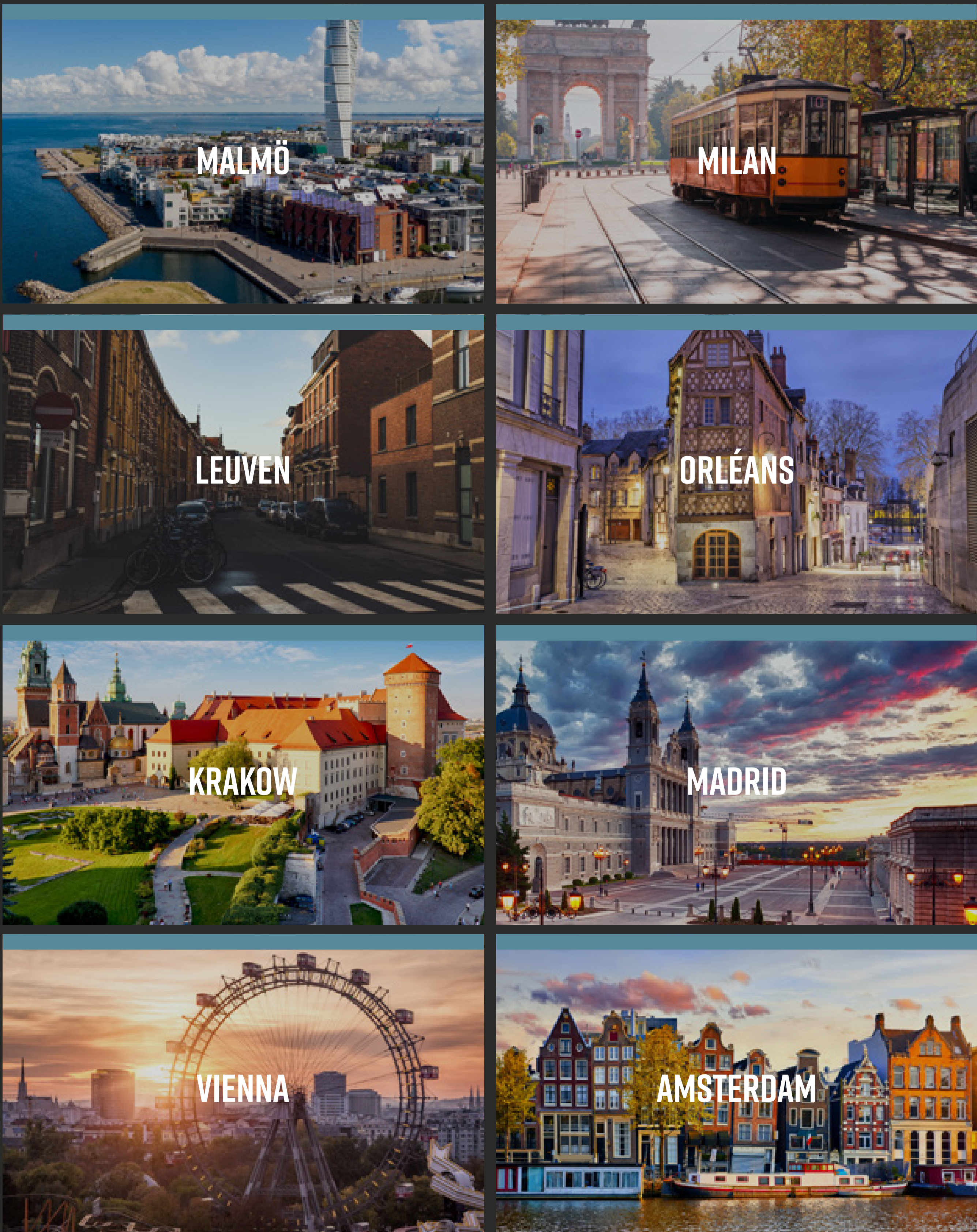
A socioeconomic case tool to show the economic implications of climate action and make them easy to understand can help build a foundation for systems change. Cities and their citizens can see how the future could unfold in economic terms and begin to understand in very tangible ways how climate action can contribute to economic security and stability. Every new initiative can be tested with such a tool to demonstrate that value is created through aggressive actions, and while substantial investments of resources are needed upfront, the overall economic case can be made for these investments. The sources of those investments, whether private or public capital, need this information in order to make the commitments these cities will need.

This analysis helps to build the collective intelligence on effective and needed climate actions and helps society to embrace the changes needed to secure a more resilient future. It also can create an environment in which innovation is welcome, in which experiments can be designed and tested quickly in order to advance our learning about what is possible and what is necessary.

This analysis is flexible and applicable to cities of all shapes and sizes. As part of the Healthy, Clean Cities pilot, Material Economics and EIT Climate-KIC are already working with nine European cities (Exhibit 1, and more recently also Skopje) with different populations and characteristics to determine the economic case for their decarbonisation.

Exhibit 1

THE SOCIOECONOMIC CASE IS BEING DEVELOPED FOR EIGHT CITIES IN EUROPE



UNDERSTANDING ECONOMIC CASE ANALYSIS AND WHAT IT ACHIEVES

The tool developed by EIT Climate-KIC and its partner Material Economics and applied in the Healthy, Clean Cities Deep Demonstration programme combines global data and insights with city-specific information. This chapter describes how the tool can be and has been used, conclusions from the pilot work, and additional analysis that could be done based on initial findings. It is important to stress that just as the inputs are city-specific, so are the findings.

TYPES OF ECONOMIC ANALYSIS THAT CAN BE DONE FOR CITIES

Economic analyses for cities can be done on an aggregate, global, or national level, as several studies by the Coalition for Urban Transitions, within a specific city, or even at the neighbourhood level.

Forward-looking analyses, in turn, can either be predictive or scenario-based. Predictive analysis forecasts the likeliest future outcome based on various parameters, while a scenario analysis investigates what a potential economic outcome could look like given a pre-defined "end-state" in the form of various targets and assumptions.

A third useful distinction is between bottom-up and top-down analyses, which have their own pros and cons. A top-down analysis typically starts from high-level assumptions about an area, such as a target share of electrification, and calculates the resulting impact. A bottom-up analysis, on the other hand, might look at individual car ownership data, to determine the age of each car and when it can be replaced to get to a target electrification share.

The economic case tool conducts scenario analysis at the city level and sets overarching sectorial targets top-down, but also takes a bottom-up approach to calculating emissions, costs, and demand from actual sources such as cars, buses, trucks, etc.

WHAT DOES THE ECONOMIC CASE ANALYSIS DO?

The economic case for decarbonisation tool is an Excel tool based on both top-down and bottom-up analysis that helps cities understand the societal economic case for reducing CO_2 emissions in cities. It evaluates the CO_2 reduction potential, air pollution reduction (NO_x and PM), investments needed, cost savings, and other societal benefits generated for a number of sectors and 15 specific urban decarbonisation measures, summarised in Exhibit 2, relative to a baseline development. More details on the tool and how it addresses co-benefits are presented later in this section.

THE TOOL IS BUILT TO DO FOUR MAIN THINGS:

1. Quantify the city's emissions today and estimate them until 2030 in a baseline scenario without additional climate action from the city and only normal technological development;

2. Assess the 15 climate measures and their impact on emissions and other parameters, such as air quality, physical health, road safety, urban noise, employment, etc.;

3. Quantify the overall economics of the 15 climate measures, based on their societal impacts, cost savings, and investment requirements; and

4. Generate the overall economic case for climate action in the city, including how costs and benefits would be distributed across different stakeholders.

QUANTIFYING BASELINE EMISSIONS AND COSTS

The tool quantifies a baseline of the current emissions of GHG and other air pollutants, including PMs and NO_x from transport (passenger and freight), buildings and heating, and electricity sectors in a city based on bottom-up data such as passenger km, heat demand, electricity demand, etc. The data are collected from and developed together with the city and local experts/partners (e.g. local transport authority, energy providers, etc.). The results are thus very specific to the city and rely on the most up-to-date data available. Where city-specific data are not available, the tool uses average European/Eurostat data. This baseline is compared with reported CO_2 emissions to ensure that the bottom-up estimate roughly matches reported data for the city.

The tool then estimates how these emissions and costs would develop until 2030 if the city didn't take significant additional actions to reduce emissions in these sectors. This baseline development is based primarily on four main things:

- Expected population growth in the city;

- Standard levels of development for key parameters (e.g. a baseline standard renovation rate for buildings, typically 0.5–1% per year, or an average car replacement cycle of 10 years);

- Existing regulations already set at the EU or country level (e.g. new passenger cars have an improved average emission intensity stemming from tighter EU regulations over time, i.e. 95 gCO_2/km in 2021);

- Expected investments and ongoing costs required to maintain and realise this baseline development (e.g. cost to replace and maintain car fleet, cost of ongoing renovations, and the costs of the energy used in each of the identified sectors).

Exhibit 2

FIFTEEN MEASURES ARE INCLUDED IN THE SOCIOECONOMIC CASE TOOL

DECARBONISATION INITIATIVES INCLUDED

TRANSPORT

Reduced passenger transportation need
Increased car-pooling
Reduced & optimized logistics
Shift to public & non-motorised transport
Electrification of passenger cars
Electrification of public transport
Electrification of freight transport

ELECTRICITY

Shift to renewable electricity (rooftop solar and large-scale centralised wind/solar parks)

WASTE

Increased recycling of waste

BUILDINGS & HEATING

New buildings highly energy-efficient
Building energy-efficienct renovations
Efficient lighting & appliances
Decarbonising heating

REFORESTATION

Planting trees within the city and in surrounding areas

SCOPE 3

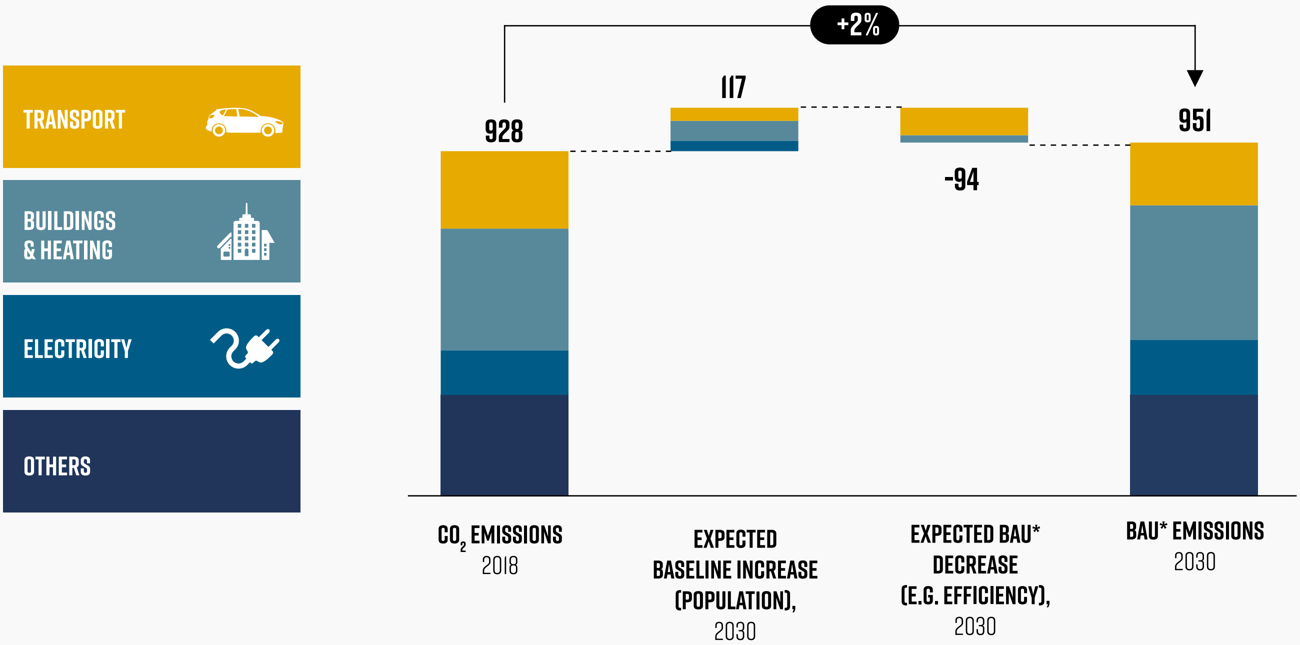
Reduced building materials

SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

Exhibit 3

MALMÖ WOULD SEE A 2% GROWTH IN EMISSIONS IN A BASELINE SCENARIO

CO_2 BASELINE EMISSIONS BY 2030 IN MALMÖ
KTON CO_2E / YEAR



**BAU: Business as usual*

SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

An example of baseline development from Malmö can be seen in Exhibit 3. This shows that if Malmö did not pursue additional decarbonisation measures, emissions would increase by 2% by 2030. The baseline does not consider existing ambitious decarbonisation plans, such as to electrify the bus fleet, but instead considers them as part of the 15 climate measures and evaluates them as part of the total socioeconomic case for decarbonisation.

It is necessary to estimate the baseline development of emissions over time to have an approximate understanding of where the city is heading if nothing else is done, and also to be able to accurately estimate the relative effect on emissions over time of additional decarbonisation initiatives of the relevant sectors without also including what would have happened anyway. This gives a fairer representation of the measures.

If Malmö did not pursue additional decarbonisation measures, emissions would increase by 2% by 2030.

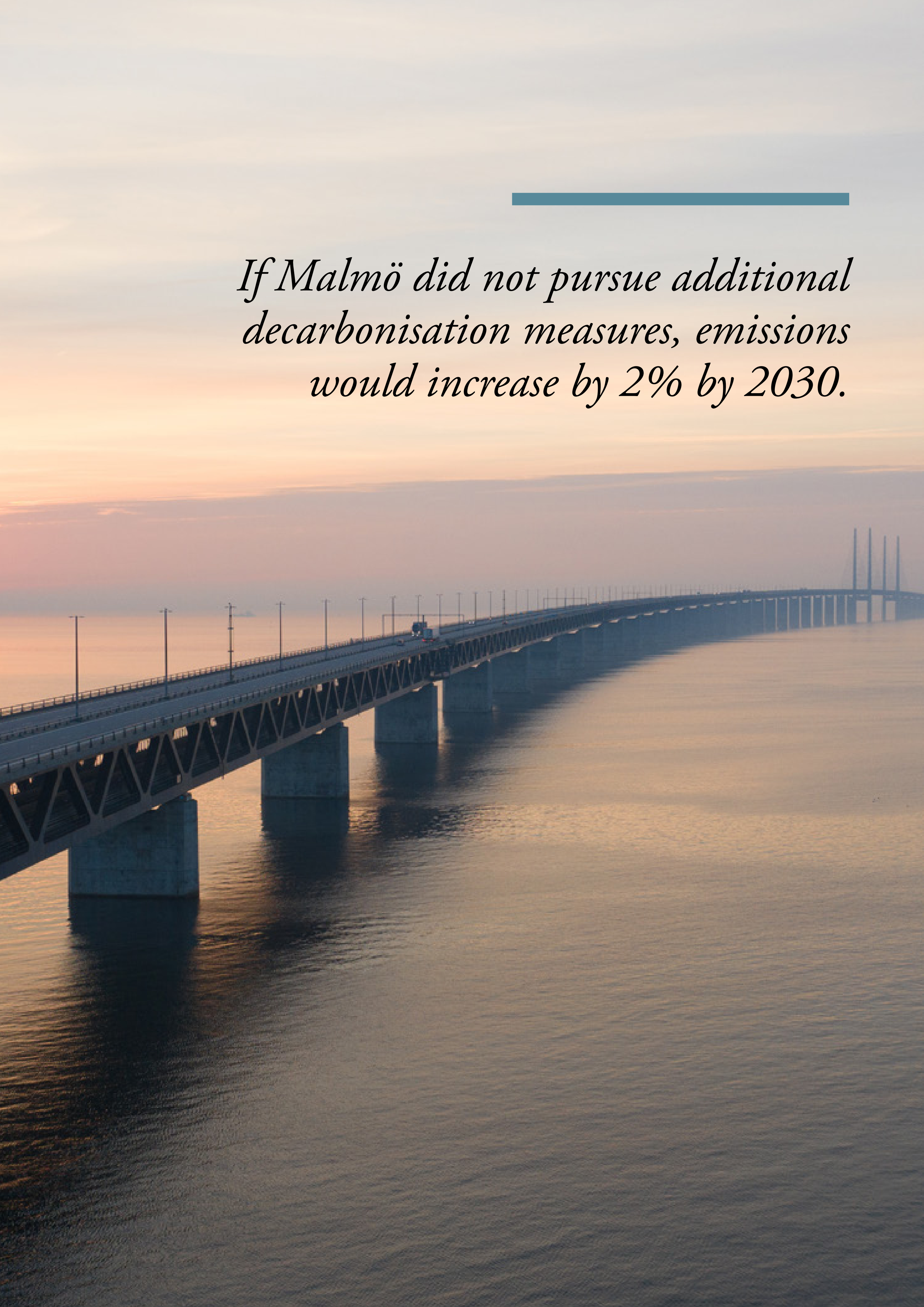
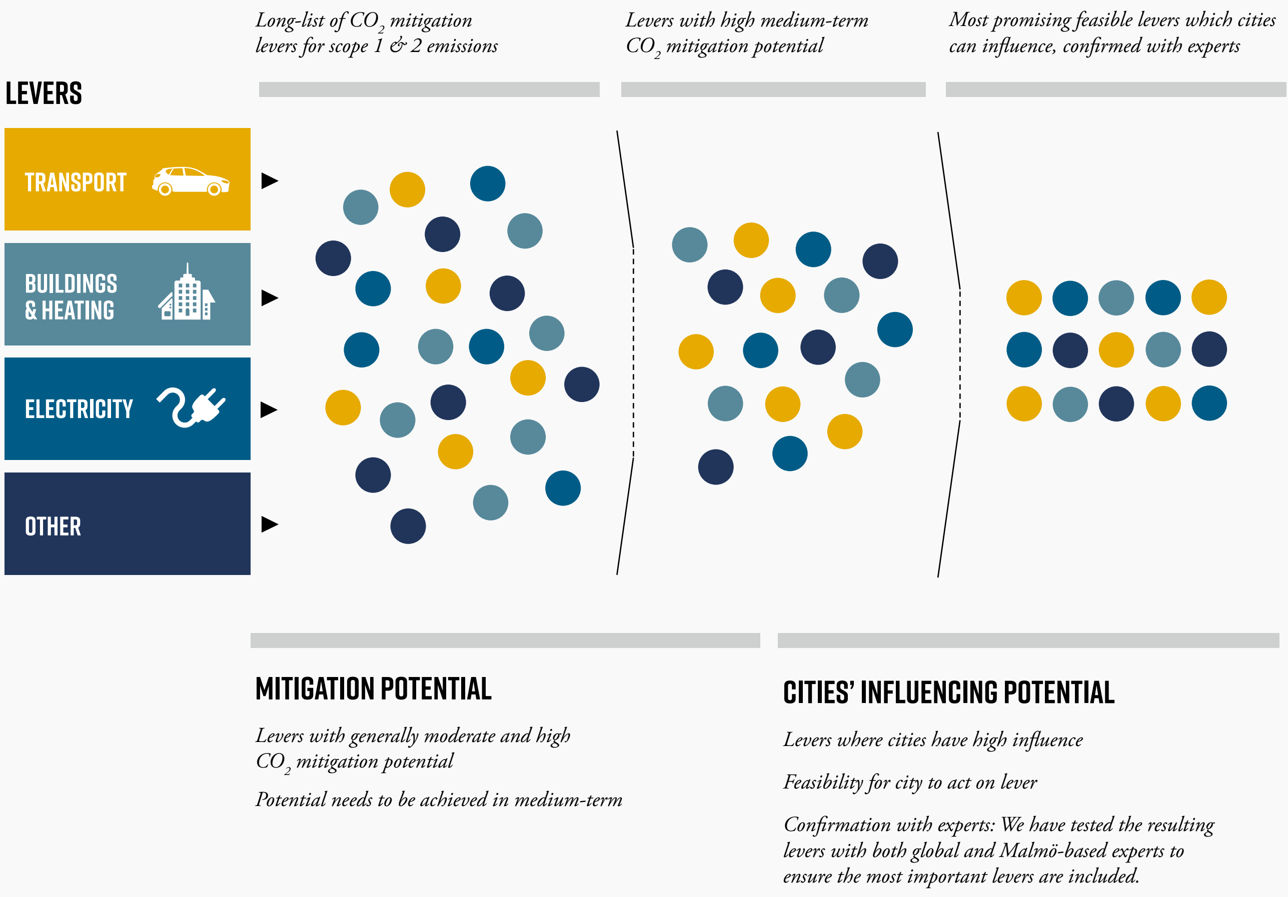


Exhibit 4

A THREE-STEP APPROACH WAS TAKEN TO IDENTIFY THE 15 MEASURES



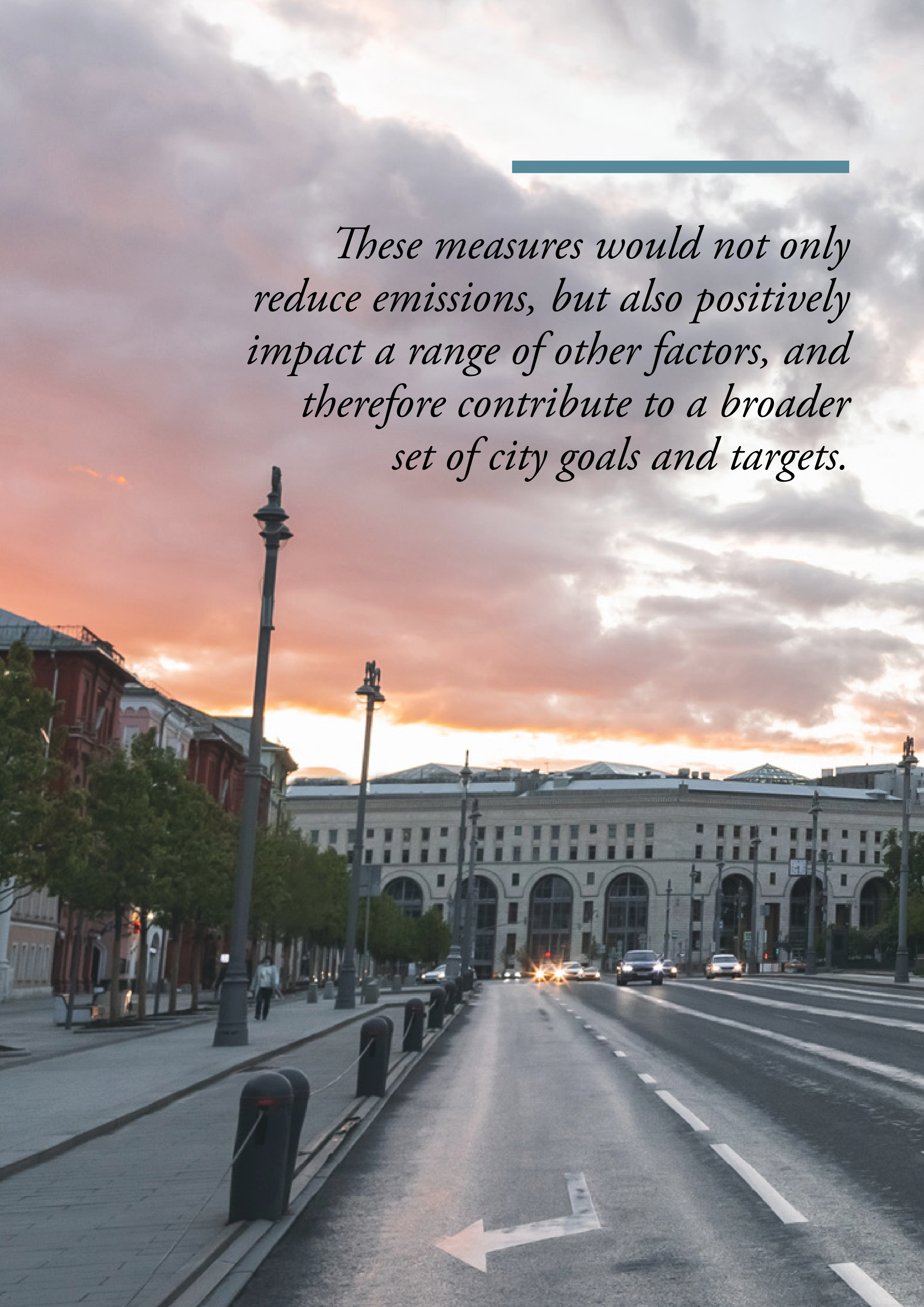
SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

ASSESSING 15 CLIMATE MEASURES

The 15 potential climate measures were identified through a three-step approach. This started with developing a long list based on Material Economics' and EIT Climate-KIC's own expertise, as well as various research reports (e.g. from the Coalition on Urban Transitions), and discussions with experts in cities and at research institutes. The initiatives were then filtered to include only ones with high potential to decrease city emissions in the medium term (until 2030) and where a city has relatively high potential to influence the lever. The prioritised short list was finally tested and confirmed with various experts. An overview of the process can be seen in Exhibit 4.

These measures would not only reduce emissions, but also positively impact a large range of other factors (co-benefits) and therefore would contribute to many of a city's goals and targets. They are also relevant to several SDGs in addition to Climate Action, including: 3. Good Health & Well-being, 7. Affordable and Clean Energy, 8. Decent Work & Economic Growth, 11. Sustainable Cities & Communities, 12. Responsible Consumption & Production, and 15. Life on Land.

These measures would not only reduce emissions, but also positively impact a range of other factors, and therefore contribute to a broader set of city goals and targets.



The tool calculates the approximate incremental effect of each of these initiatives on top of the baseline development on demand (e.g. passenger km, heat demand, etc.), CO_2 emissions, and other societal parameters such as air pollution emissions (PM and NO_x), noise pollution, road safety, physical health, employment, etc. This is based on 2030 targets set together with the city in addition to a significant underlying database of key parameters for each initiative based on multiple research reports and city-specific data. This effect is then used to estimate the approximate investments required, resulting cost savings/increases, and societal economic savings for each initiative. An example of this can be seen from Malmö and the electrification of buses there. This is described in more detail in Exhibit 5.

QUANTIFYING THE ECONOMICS OF EACH MEASURE

Once the demand changes, emissions development, and societal parameters have been calculated it is possible to estimate the socioeconomic case for each measure, based on three main things:

- **Incremental investments needed from 2020 to 2030 to realise the initiative:** For example, for electrification of passenger cars, this includes the additional charging infrastructure needed and the additional costs for an electric vehicle vs. a petrol/diesel car.

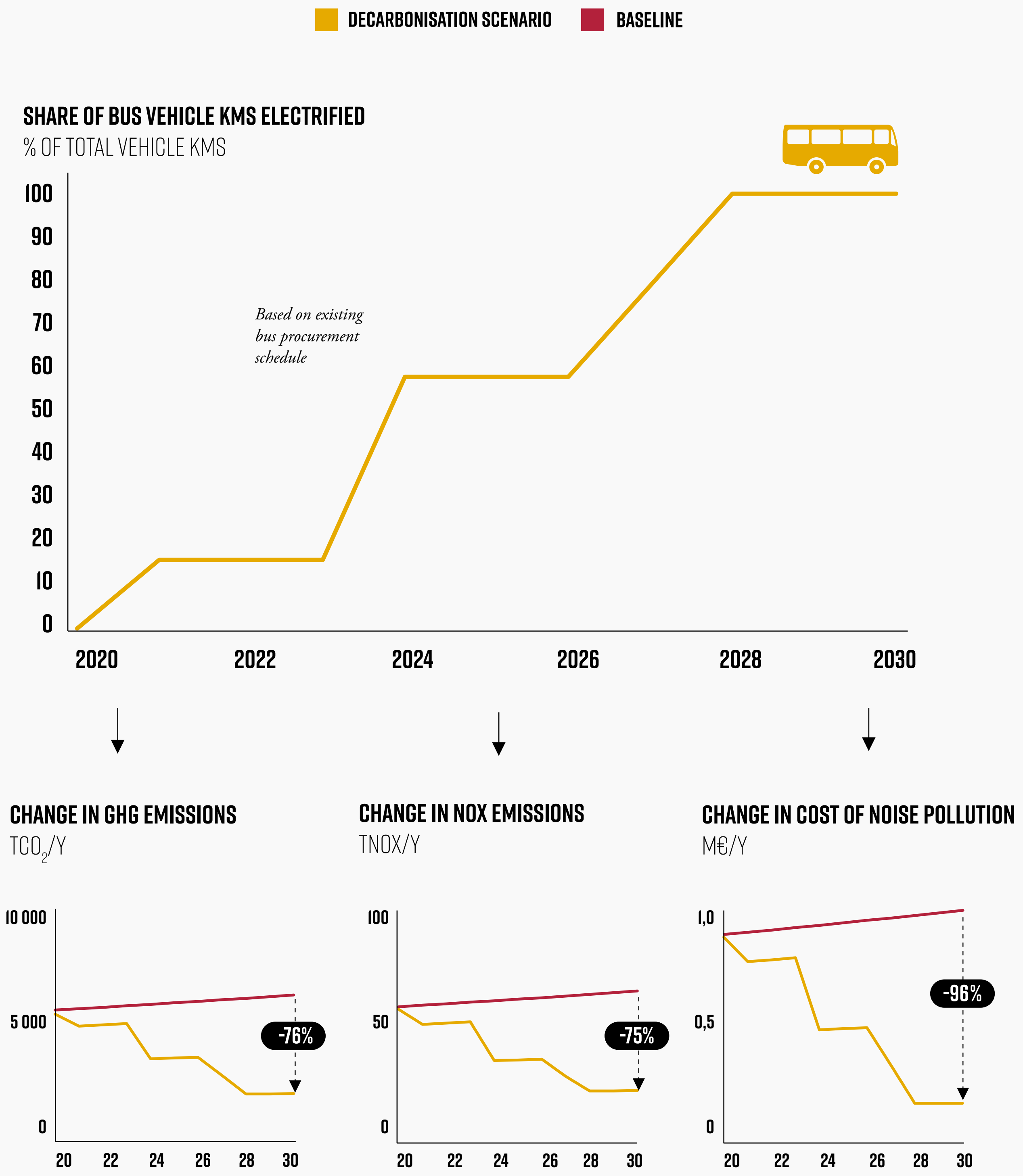
- **Resulting cost savings:** As investments have various lifetimes, from 10–40/50 years (in the case of a district heating network), the cost savings considered go further into the future than the investments. This comes from the fact that if an electric vehicle is bought in 2030, for example, it only generates cost savings from 2030 to 2040/45. Cost savings for electric vehicles include, for example, the relatively lower cost of energy (electricity vs. petrol) as well as lower operation and maintenance costs (electric vehicles require less).

- **Societal economic savings from co-benefits:** This is based on research quantifying the effect of improving certain societal parameters in monetary terms. This is done in different ways, but for health-related co-benefits, it typically looks at the increase in quality-adjusted life years saved and connects this to e.g. each tonne of air pollution emitted. In the car example, this includes lower health costs stemming from improved air quality from lower concentrations of air pollutants such as PM and NOx stemming from lower emissions.

Exhibit 5

ELECTRIFYING THE BUS FLEET DRAMATICALLY DECREASES BOTH GHG AND AIR POLLUTANT EMISSIONS

EFFECT OF ELECTRIFYING THE BUS FLEET IN MALMÖ



SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY


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Exhibit 6

CO-BENEFITS ARE SECOND ORDER BENEFITS ARISING FROM A PARTICULAR ACTION

OVERVIEW OF CO-BENEFITS CONSIDERED IN THE TOOL

Co-benefits are second-order benefits that arise from a particular action that is not the primary focus of said action. For example, better air quality (and thus health) comes from reduced air pollution when electric buses are used to reduce CO_2 emissions.

SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

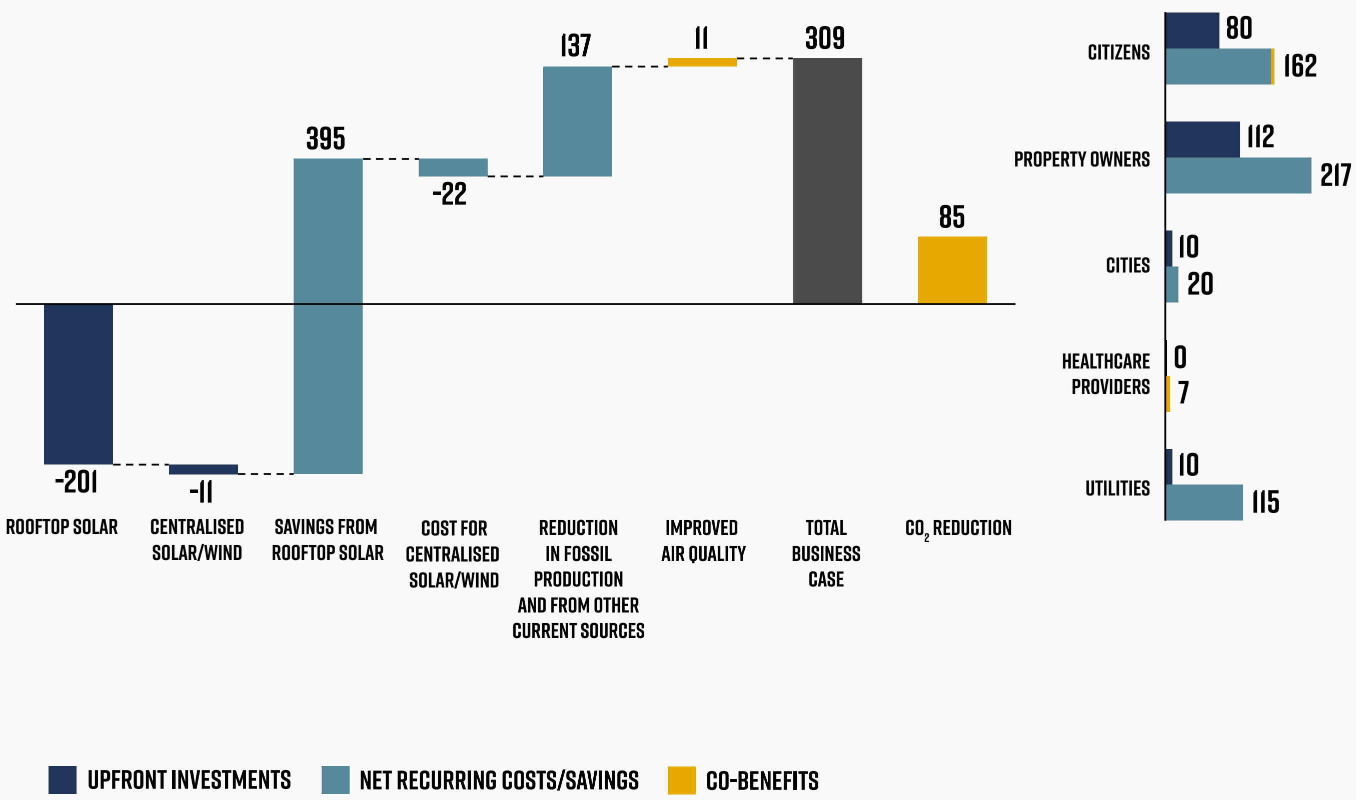
As shown in Exhibit 6, a number of co-benefits, such as greater equality, are not quantified in the tool. This is because there is limited established research quantifying an equivalent financial impact in euros of the co-benefits. Even if they are not included, however, that doesn't mean that they aren't positively impacted by decarbonisation initiatives. One exception is employment, where the financial multiplier effect of additional job creation is well understood. This is not included in the tool, as it would make it more unwieldly and thus less user-friendly. Additional analysis based on this work, especially in these times of economic difficulties, should likely focus on further evaluating the job creation potential and the resulting multiplier effects. The tool can be used as a starting point and can be updated to include these additional co-benefits.

Exhibit 7

DECARBONISING ELECTRICITY IN LEUVEN HAS A POSITIVE CASE FOR ALL INVOLVED STAKEHOLDERS

ECNOMIC CASE FOR DECARBONISING ELECTRICITY IN LEUVEN
M€, NPV OF INVESTMENTS 2020-2030 & BENEFITS 2020-2050

COST/BENEFIT DISTRIBUTION
M€, NPV 2020-2050



SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

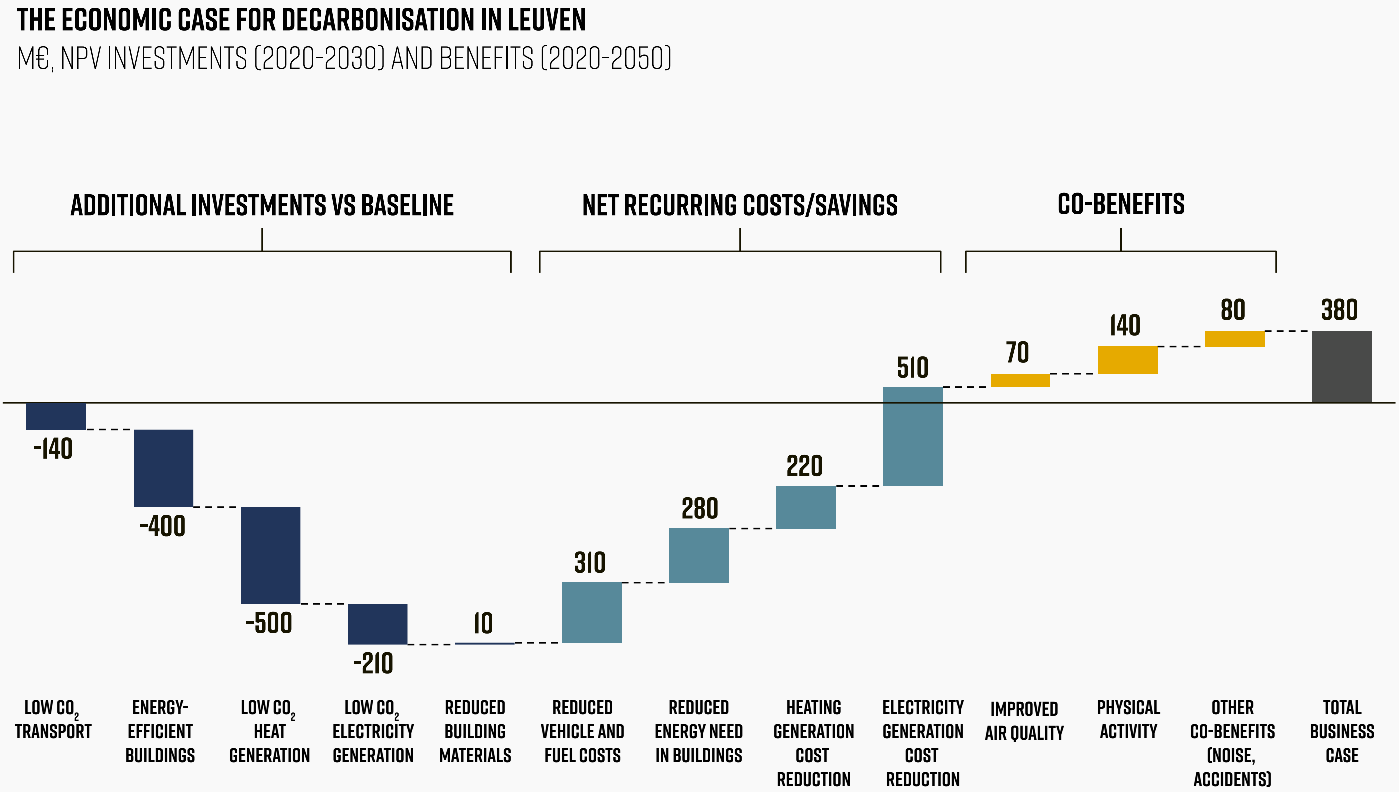
Each of these investments, costs, savings, and co-benefits is ultimately assigned to the relevant stakeholders across the city – such as the municipality, citizens, property owners, etc. An example of how these costs are calculated and distributed per stakeholder can be seen from decarbonising electricity in Leuven in Exhibit 7.

GENERATING THE OVERALL ECONOMIC CASE

It is important to recognise that many initiatives are interrelated and have an impact on one another. For example, increasing the number of electric vehicles and electrifying heat will increase demand for electricity, and thus the need for renewable electricity generation. Therefore, before calculating the total economic case and decarbonisation potential, these interactions are considered by establishing a hierarchy of initiatives, with efficiency initiatives (e.g. reducing private transportation or building renovations) coming before technology change initiatives (e.g. electrification of cars). Once this is done, all the costs, savings, and investments can be calculated over time.

Exhibit 8

THE SOCIOECONOMIC CASE FOR LEUVEN IS POSITIVE



SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

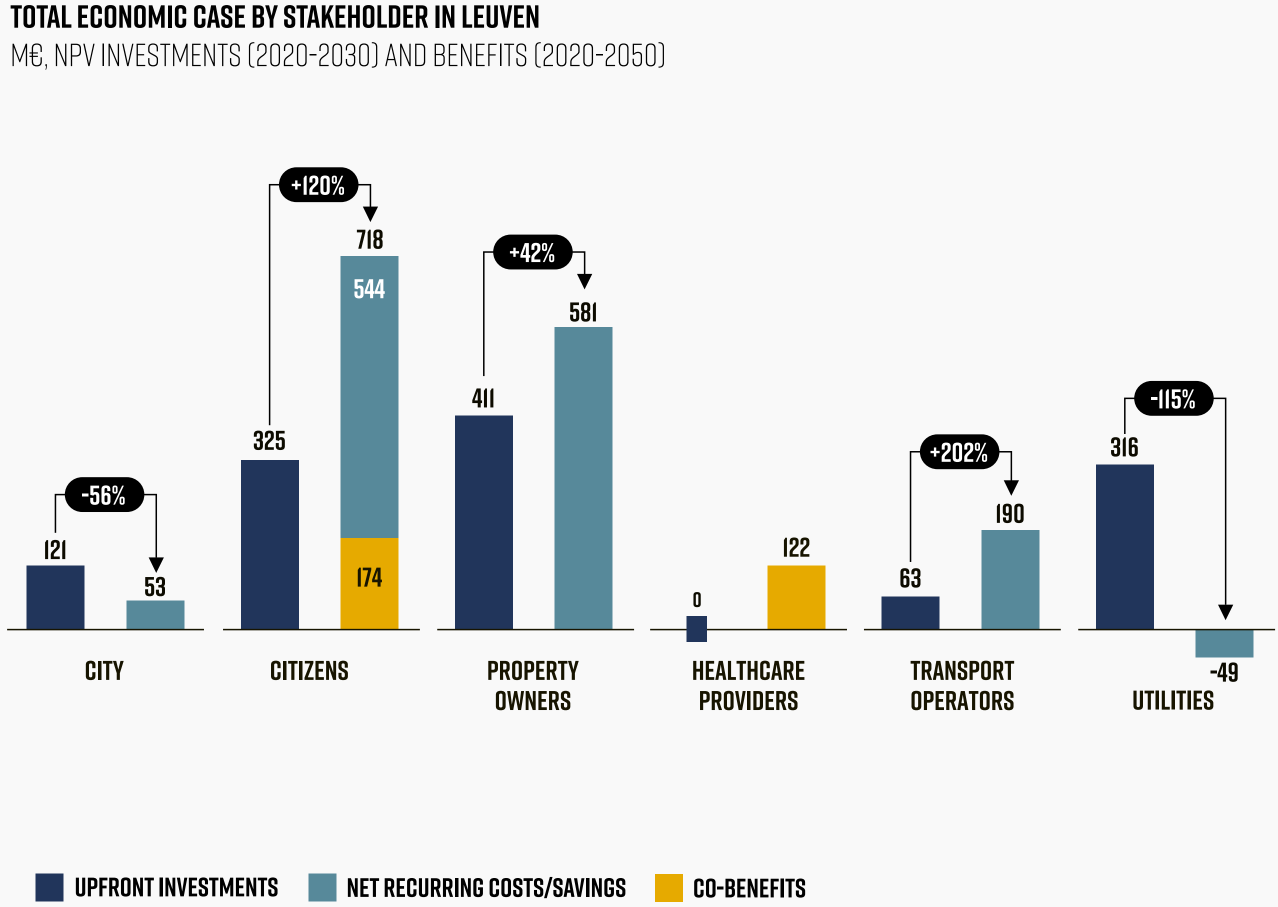
From this complete societal economic case it is possible to see what the total return on investment is for society, both for each measure individually and in aggregate. An example from Leuven is shown in Exhibit 8.

It is important to note that the values are recalibrated back to 2020 using a discount factor to determine the overall societal economic case. This discount factor is a key parameter that determines how much the future cost savings are valued today and is often the subject of heated debate among economists. The standard setting in the tool is to use a 3.5% discount rate, based on various research reports. A survey of 200 economists suggested a discount range of 0–10% with an average of 2%, meaning that the rate used is slightly more conservative, as the future value of cost savings becomes relatively less valuable with a higher discount rate.

The overall case is positive for all analysed cities when including co-benefits.

Exhibit 9

DISTRIBUTION OF THE SOCIOECONOMIC CASE BY STAKEHOLDERS IN LEUVEN



SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

WHAT HAS THE SOCIOECONOMIC ANALYSIS SHOWED US?

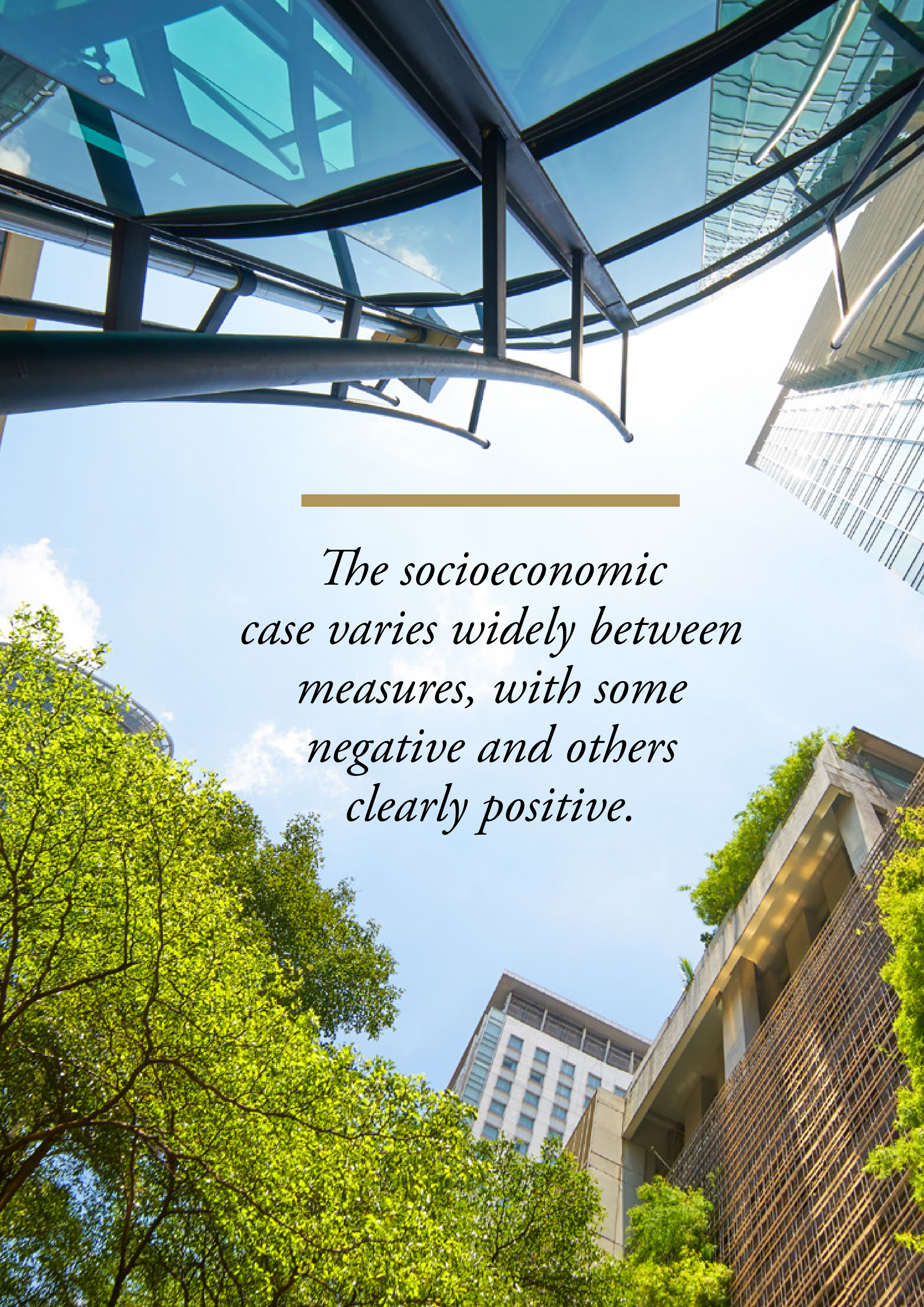
Several insights can be drawn from the analyses already conducted with cities in the Deep Demonstration. These are discussed in more detail below.

1. Overall, the case is positive for all cities when co-benefits are included; it mostly involves shifts from running costs (operational expenditures or OPEX) to upfront investments (capital expenditures or CAPEX). However, the socioeconomic case varies widely between measures, with some negative and others clearly positive.

2. Decarbonisation over time can take many different forms, and the pace of the transition varies significantly by measure.

3. The investments, cost savings, and co-benefits are distributed differently among stakeholders, with citizens typically benefiting the most from decarbonisation. However, citizens also have a high burden in terms of shifting behaviours.

4. There are different patterns in individual sectors; for example, transport measures typically have a positive case, but often require significant behavioural change. These insights are discussed in more detail in the next chapter.



The socioeconomic case varies widely between measures, with some negative and others clearly positive.

1. OVERALL ECONOMIC CASE

For all analysed cities, ambitious climate action has a clearly positive economic return for society. Even if CO_2e emissions were disregarded, it is economically rational on a societal level to implement urban climate actions for other reasons. Exhibit 10 provides an overview of the business cases for the cities with which Material Economics and EIT Climate-KIC have worked using the tool.

The economic case for decarbonisation is positive for all cities because the economic value of improved air quality, more physical activity, less noise, etc., is accounted for. These co-benefits are often decisive in making a positive overall economic case for climate action. This reinforces that decision-makers need to consider the society-wide benefits of decarbonisation investments and not just look at the financial returns for those making the investments.

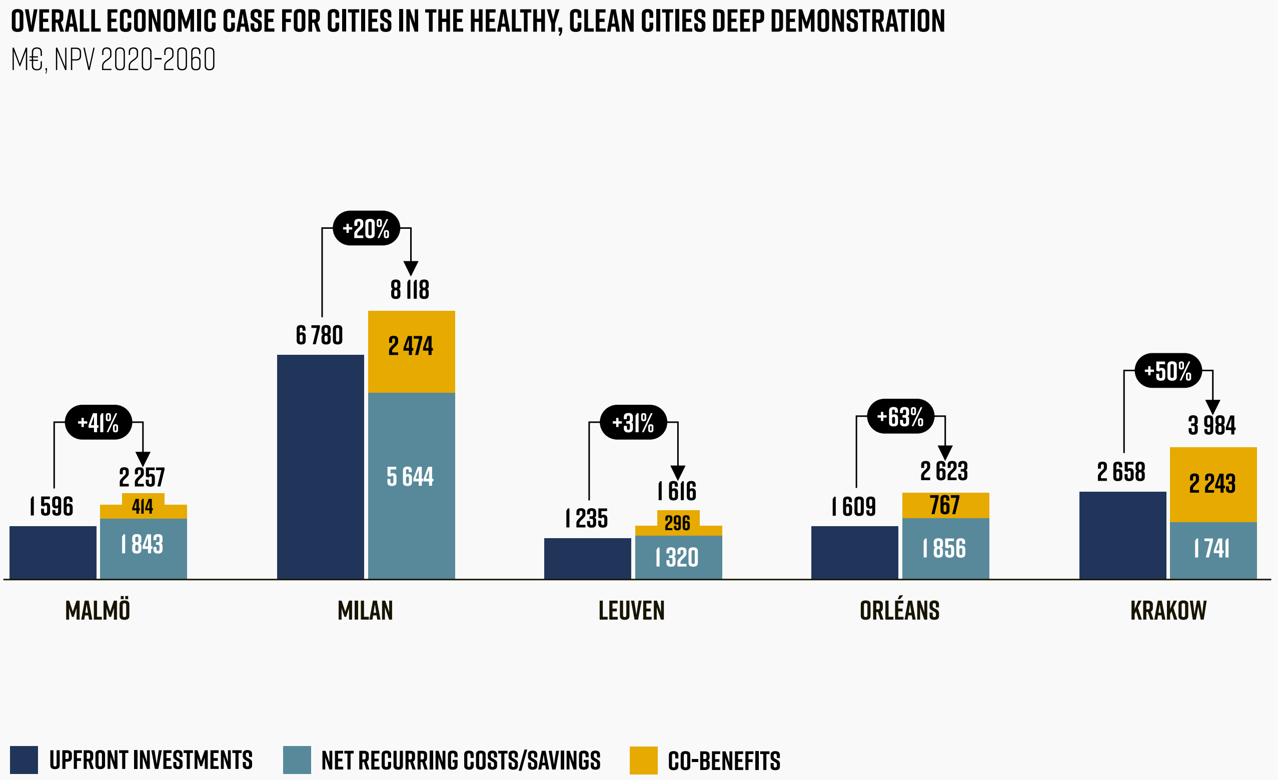
Although the overall socioeconomic case for urban climate action is always positive, there are large differences among cities. For example, Malmö, Leuven, and Orléans have positive cases even when including only net recurring savings, while Milan and Krakow need to include co-benefits to have a positive socioeconomic case. Also, the return on investments varies, from 20% in Milan to 63% in Orléans. There are many reasons for this. For example, Malmö has a comprehensive district heating network; several other cities have none. The price of electricity also varies significantly; it is much lower in Malmö than in Milan. There are many more traits that affect the economic case; this is why it is crucial to conduct individual, city-level analyses.

Both the economics and emissions reduction impact of individual climate measures also vary considerably. This is why it is important to view the interventions as a package; if only the measures that show positive economic results are adopted, a city may miss out on a significant share of the potential to systematically decarbonise key sectors.

As with the package as a whole, most individual measures typically require a shift from operational expenditures – energy costs –to upfront investments (e.g. electric cars). In addition, significant long-term co-benefits, mostly in the form of improved health, can be seen. Our analysis has shown that the co-benefits can represent ~15–55% of the total incremental cost savings in a decarbonisation programme, depending on the city. However, in addition to those quantified, there are many more co-benefits that are not included in the calculation – for example, the reduced need for car infrastructure, potentially increased job creation, reduced travel times, better social cohesion, equality, etc.

Exhibit 10

THE SOCIOECONOMIC CASE IS POSITIVE FOR ALL CITIES ANALYSED



SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

2. DISTRIBUTION OF COSTS AND BENEFITS

The investments, costs, and benefits associated with climate measures are distributed across many different stakeholders in each city – the municipality, citizens, real-estate owners, etc. Often it is citizens who stand to gain the most, for instance, from lower energy and transport costs and improved health. However, it is also clear that many of these initiatives require citizens to change their behaviour. This is another form of burden, and it needs to be addressed through wide-ranging citizen engagement programmes.

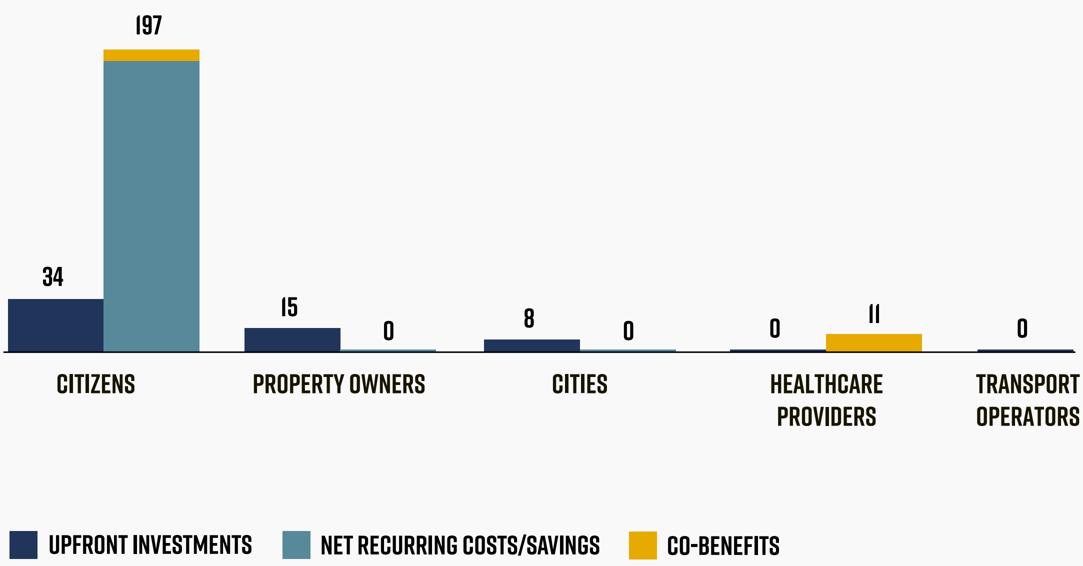
A key challenge that becomes apparent from the analysis involves agency. In many cases, one stakeholder must invest, but another receives the benefit. The tool helps cities identify where this is the case for their specific circumstances and estimates the magnitude of these issues. Across the different cities, as noted earlier, the municipality itself will often face net costs from the measures. This doesn't mean that they shouldn't be undertaken; a municipality's role is to invest on behalf of citizens in order to improve their quality of life. Also, a significant part of the returns are co-benefits, something the municipalities do not receive, as most co-benefits are related to health benefits, which accrue to citizens and healthcare providers.

An example from Malmö in Exhibit 11 shows that while electrification of passenger cars has a positive economic case overall, it is negative for property owners and cities (as they need to invest in charging infrastructure without necessarily reaping the benefits).

Exhibit 11

CITIZENS HAVE A POSITIVE CASE FOR ELECTRIFICATION OF PASSENGER CARS IN MALMÖ; PROPERTY OWNERS AND THE MUNICIPALITY DON'T

OVERALL ECONOMIC CASE FOR CITIES IN THE HEALTHY, CLEAN CITIES DEEP DEMONSTRATION
M€, NPV 2020-2060



SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

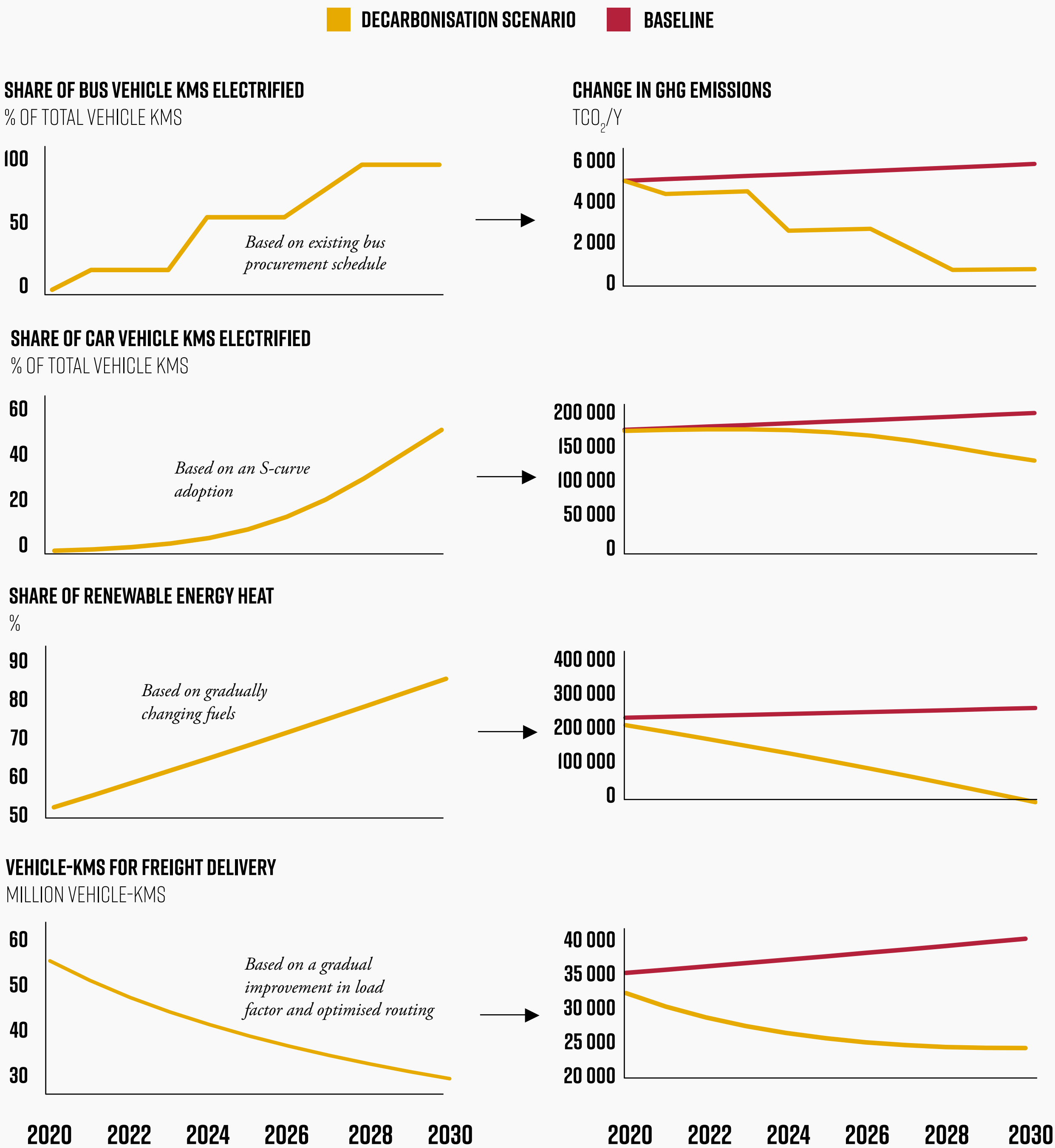
3. DECARBONISATION OVER TIME

Many people imagine decarbonisation will occur along a familiar pattern – either a gradual linear improvement or an exponential decrease. The Healthy, Clean Cities Deep Demonstration, however, has showed that this is not necessarily the case. It is possible that some initiatives will develop linearly or more exponentially, but others may not. This is important to understand because politicians may only see effects of their actions after a few years, and they need to understand that they have the tools and policies to shape the trajectory. Examples of different trajectories are shown in Exhibit 12.

Exhibit 12

DECARBONISATION CAN HAVE DIFFERENT TRAJECTORIES

EXAMPLES OF DIFFERENT DECARBONISATION CURVES



SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

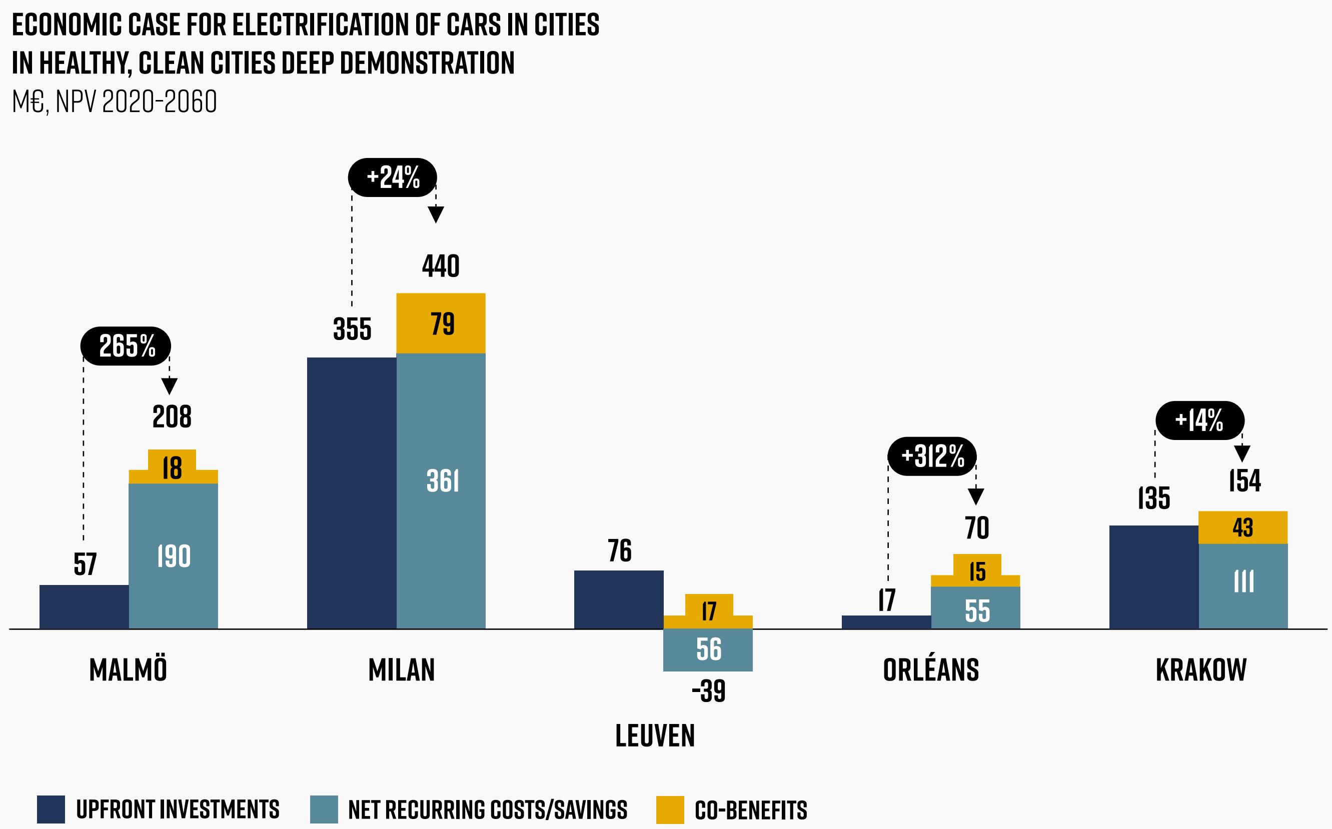
4. KEY TAKEAWAYS FROM EACH SECTOR

Each city has its unique outlook across the sectors analysed, but a few cross-cutting takeaways can be seen.

Transport: Most initiatives to decarbonise the transport sector have positive economic cases. There is a significant share of the returns stemming from co-benefits, especially when considering a shift to public transport and walking/cycling, as the improved health effects from increased physical activity are very large. For electrification initiatives, the co-benefits are less significant, with most of the case coming from lower energy costs. However, the net costs or benefits are highly dependent on electricity prices and utilisation rates. For example, in Malmö, passenger car electrification had a positive case, but in Leuven it was negative, due both to low utilisation of the car fleet and expensive electricity. In fact, for Leuven the high costs of electricity meant that using electricity instead of petrol was actually more expensive, resulting in higher recurring costs relative to the baseline. See Exhibit 13 for an overview of the analyses for electrification of cars across cities.

Exhibit 13

ALL CITIES EXCEPT LEUVEN HAVE A POSITIVE ECONOMIC CASE FOR PASSENGER CAR ELECTRIFICATION

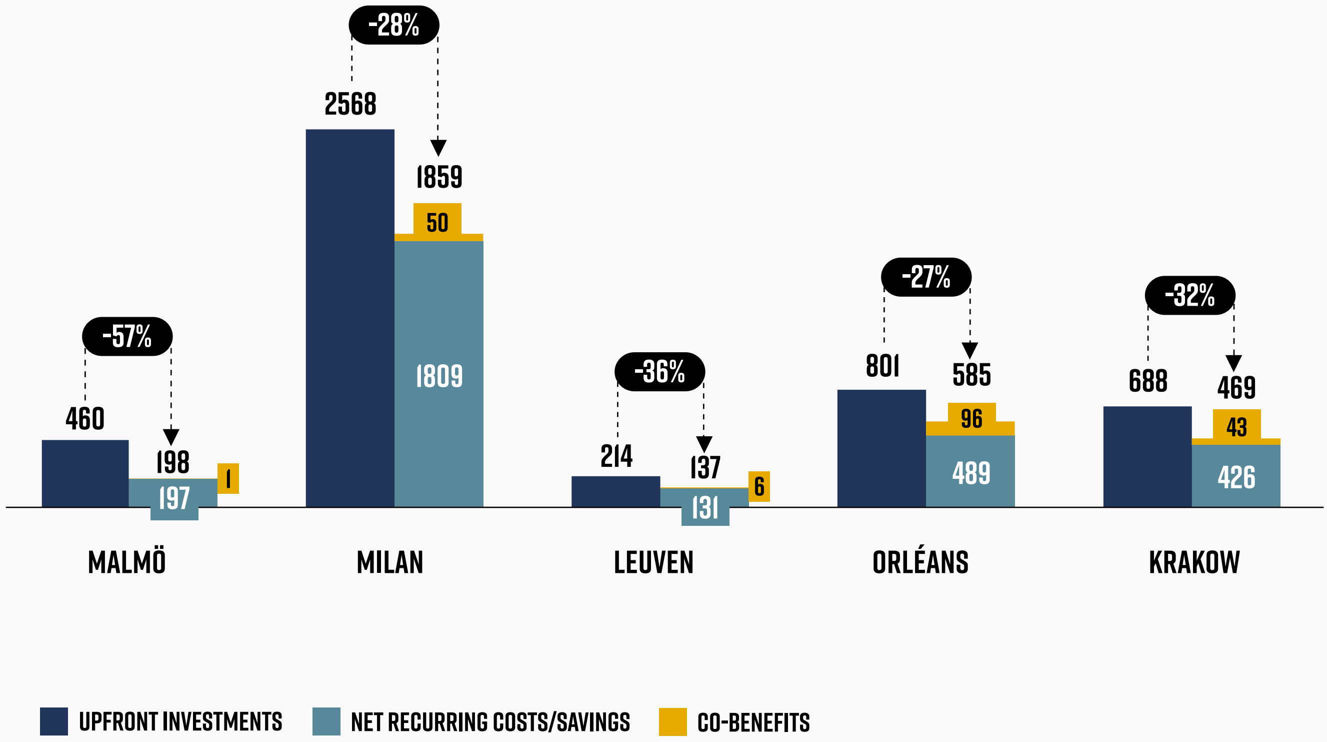


SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

Exhibit 14

RETROFITTING BUILDING ENVELOPES SHOULD BE COMBINED WITH HEATING SYSTEM IMPROVEMENTS

ECONOMIC CASE FOR BUILDING RENOVATIONS IN CITIES IN HEALTHY, CLEAN CITIES DEEP DEMONSTRATION
M€, NPV 2020-2060



SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

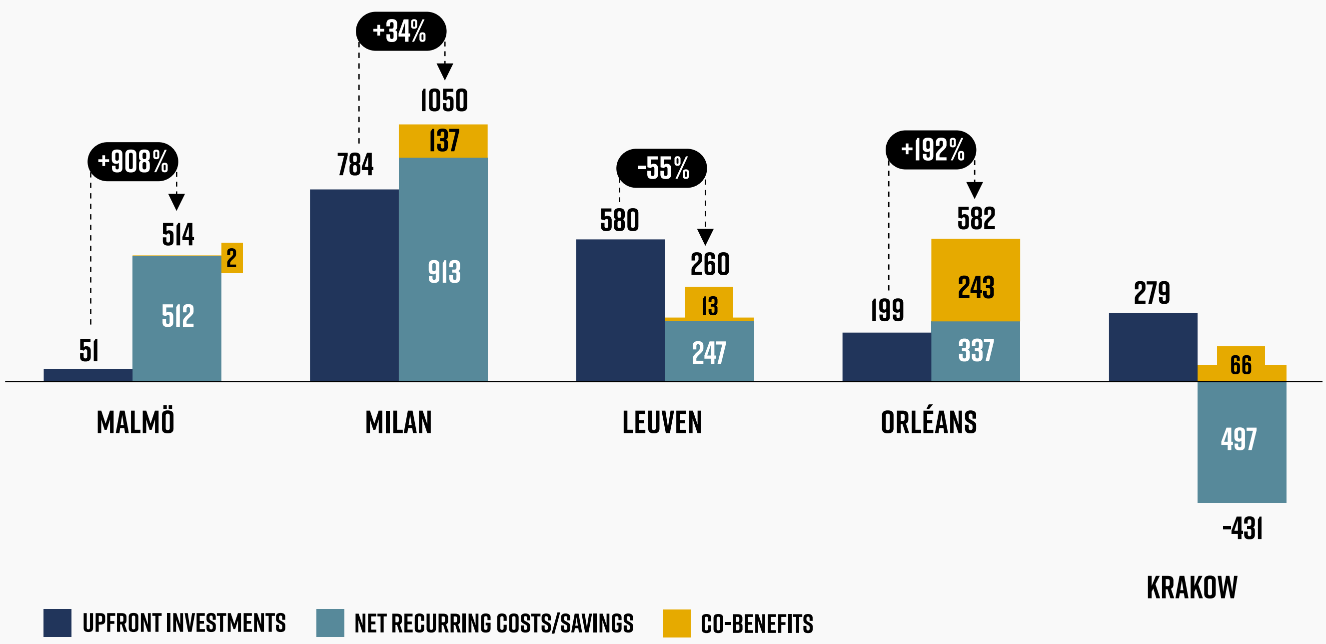
Building retrofits: Retrofitting buildings can be economically attractive, but to establish savings accurately, a performance assessment needs to be done at the building level, and not for the entire building stock. Our tool analyses the building stock, meaning that it likely presents an overly pessimistic picture, as calculating estimated savings from the average building energy performance is less accurate than looking, for example, at the 25% worst-performing buildings. Exhibit 14 gives an overview of the cases for building renovations for the cities analysed. Typically, what is observed is that it is important to combine improved building envelope retrofitting with more efficient and cleaner heat production in order for the economic case to be improved.

Heating: Decarbonising heating can mainly be done in two ways: using a decarbonised district heating system or installing decarbonised local heating (e.g. electric air or geothermal heat pumps). The relative economic case of the different options highly depends on the current state of the city. Where a network already exists, it is often economical to decarbonise it, especially if significant reinvestments were needed anyway. However, building new district networks is typically quite expensive. This can be seen in Exhibit 15 for Leuven, where an expensive district heating network would need to be built in combination with accounting for large stranded assets in the form of an extensive gas network. On the other hand, the case is positive in Malmö, as in a baseline scenario, the utility still needs to reinvest significant amounts in the existing district heating system, given its age.

Exhibit 15

THE CASE FOR DECARBONISING HEATING DEPENDS ON WHAT THE EXISTING SYSTEM LOOKS LIKE

ECONOMIC CASE FOR HEATING DECARBONISATION IN CITIES IN HEALTHY, CLEAN CITIES DEEP DEMONSTRATION
M€, NPV 2020-2060



SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY


GRATIS FIETSENSTALLING

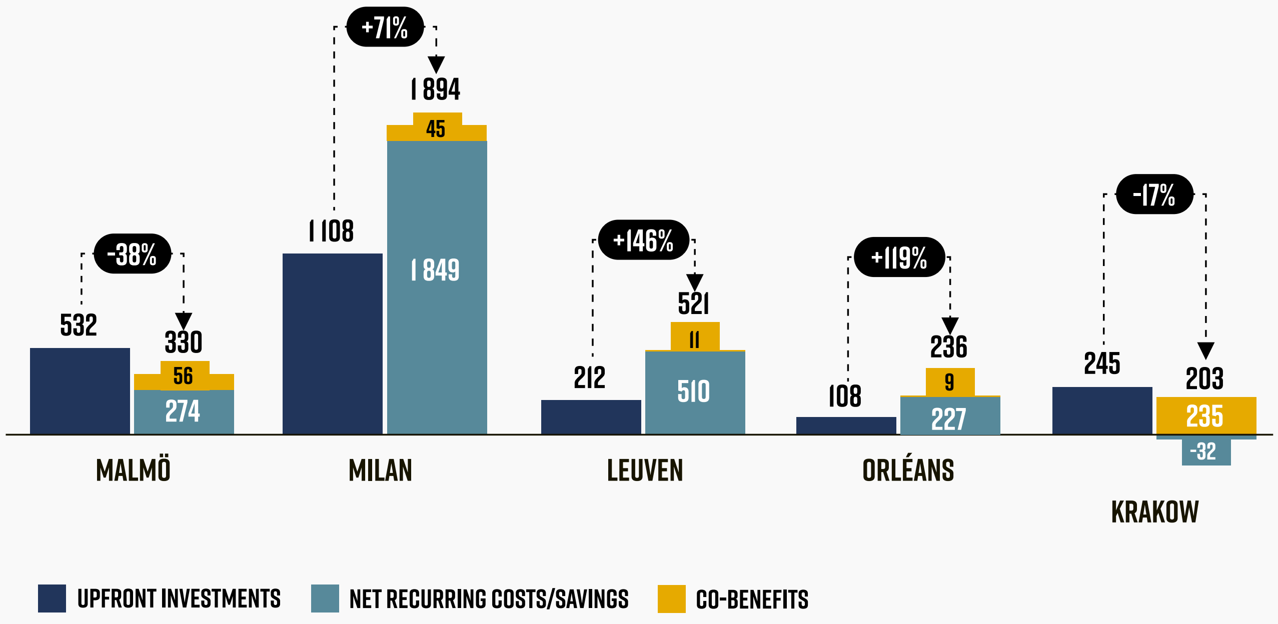
MIDDELGRUNDEN, AN ENERGY COMMUNITY PROJECT IN COPENHAGEN

A successful development of energy communities can be seen in Copenhagen, where citizens together with the city own the wind farm Middelgrunden just off the coast of the city.

Exhibit 16

DECARBONISING ELECTRICITY OFTEN HAS A POSITIVE SOCIOECONOMIC CASE

ECONOMIC CASE FOR ELECTRICITY DECARBONISATION IN CITIES IN HEALTHY, CLEAN CITIES DEEP DEMONSTRATION
M€, NPV 2020-2060



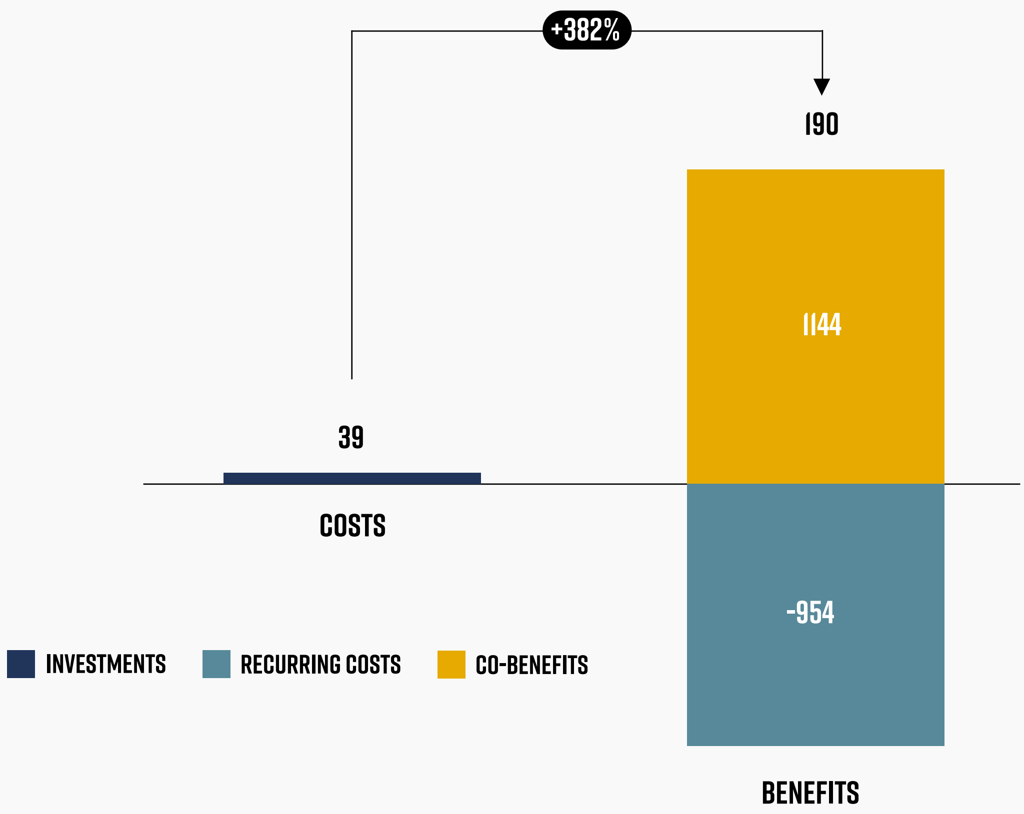
SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

Electricity: Rooftop renewable electricity and community solar systems are especially cost-effective in places with higher electricity prices, but there are quite a few regulatory challenges that may hinder rapid deployment, such as energy community regulations and historical building classifications. This is clear in Malmö, where low electricity prices mean that the economics of installing renewable electricity are worse than Milan, as shown in Exhibit 16. Also, in areas with very coal-dependent electricity, the co-benefits from decarbonising electricity are significant, as is the case in Krakow. A successful example of established energy communities can be seen in the Middelgrunden wind farm in Copenhagen.

Exhibit 17

REFORESTATION IN MILAN GENERATES SIGNIFICANT BENEFITS

TOTAL ECONOMIC CASE FOR REFORESTATION IN MILAN
MILLION €, NPV INVESTMENTS (2020-2030), RECURRING COSTS (2020-2050) AND CO-BENEFITS (2020-2050)



SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

Reforestation and afforestation: Planting trees and greenery in cities – alongside streets or in expanded parks – is a widely embraced climate strategy. It can take the form of reforestation (restoring trees in green areas) or afforestation (newly planting trees in areas that were previously built-up or paved over). Planting and maintaining urban trees requires upfront investments and ongoing maintenance costs, but doesn't generate any significant direct financial cost savings. However, there are significant benefits in the form of better air quality, better water regulation, reduced heat island effects, and improved property values. When these co-benefits are included, there is typically a positive economic case. However, the effects are also primarily local for the people living near the reforested areas. An example from Milan shows a plan to plant 3 million trees could generate an ROI of more than 380% (see Exhibit 17). This doesn't even take into account the adaptation benefits from reforestation, as planting trees can have e.g. significant flood prevention benefits.

WHAT CAN THE ANALYSIS BE USED FOR?

In general, an analysis with this tool can help decision-makers to better understand their options and prioritise, so they can approach decarbonisation in a strategic, efficient, and data-driven way. It can enable them to analyse a broader range of socioeconomic factors when evaluating new initiatives and gain a deeper understanding of the economic implications of different parameters. The results can show which initiatives hold the greatest promise and seem most economically viable, and also where financial support might be especially important. It is a good starting point for cities to make better and more informed decisions about decarbonisation.

The tool and its results can be used to support a city's decarbonisation work across the entire policy planning cycle:

1. Analyse the baseline

2. Set targets for individual initiatives

3. Prioritise and decide on decarbonisation actions

4. Communicate and engage with citizens and other stakeholders

5. Execute experiments for specific initiatives

6. Validate and iterate preliminary results

Finally, while the tool is based on detailed underlying data from established research articles, reputable sources, and the cities themselves, it is a top-down approximation and cannot answer every question a mayor may ask. Most importantly, the tool doesn't evaluate exactly what a city needs to do to achieve a specific outcome – for instance, the specific policies it must adopt. That is discussed in more detail later in this chapter.

1. ANALYSE THE BASELINE

The tool is built to be able to quickly estimate city-specific baseline emissions and economic cost of key sectors, using relatively easily accessible data from the city. This allows policy-makers to understand where the city stands today and where it is heading if nothing else is done. In Krakow, for example, prior to using this tool, city officials had only a very high-level view of CO_2 emissions. With the tool they were able to see roughly how total emissions are split by different sectors (e.g. heating vs. transport) and sub-sectors (e.g. freight vs. public vs. private transport), and how they are likely to develop over time.

2. SET TARGETS FOR INDIVIDUAL INITIATIVES

Cities can easily input their current targets and goals on specific areas – for example, the share of trips they want to occur on public transport – and see how far they get in terms of decarbonisation and the socioeconomic effect of realising these targets. The tool quickly builds a picture of how the different targets add up to an overall level of ambition and shows where there is scope to potentially increase ambition. This is helpful during reviews of climate targets, for example, and can help develop a data-driven argument for increased ambition. Here it is possible for the city to input different assumptions for potential targets, e.g. the percentage of electrified buses, a target modal share of public transport, an estimated increased renovation rate, etc., and see those targets' effect on overall decarbonisation of the city and the approximate socioeconomic effect. This became quite apparent in Milan, where the identified targets only contributed to a roughly 30% decrease in GHG emissions until 2030 overall, indicating clear potential for increasing targets in some areas.

Given these targets, it also is possible to have a high-level estimate of the approximate number of citizens who will need to be involved in certain measures, such as the number of households that need to install rooftop solar or the number of workers who need to shift from private car to public transport. This can help inform citizen engagement strategies.

3. PRIORITISE AND DECIDE ON DECARBONISATION ACTIONS

The tool allows city decision-makers to compare different possible actions to reduce emissions and their relative socioeconomic abatement costs. This helps them better understand which actions are likely to be most important and impactful in their city. For example, in Leuven, officials did not realise the large decarbonisation potential in freight and had not previously considered relevant measures (see Exhibit 18).

It is also possible to identify the highest potential decarbonisation levers to investigate further, design experiments for, and identify potential challenges that require new policy initiatives.

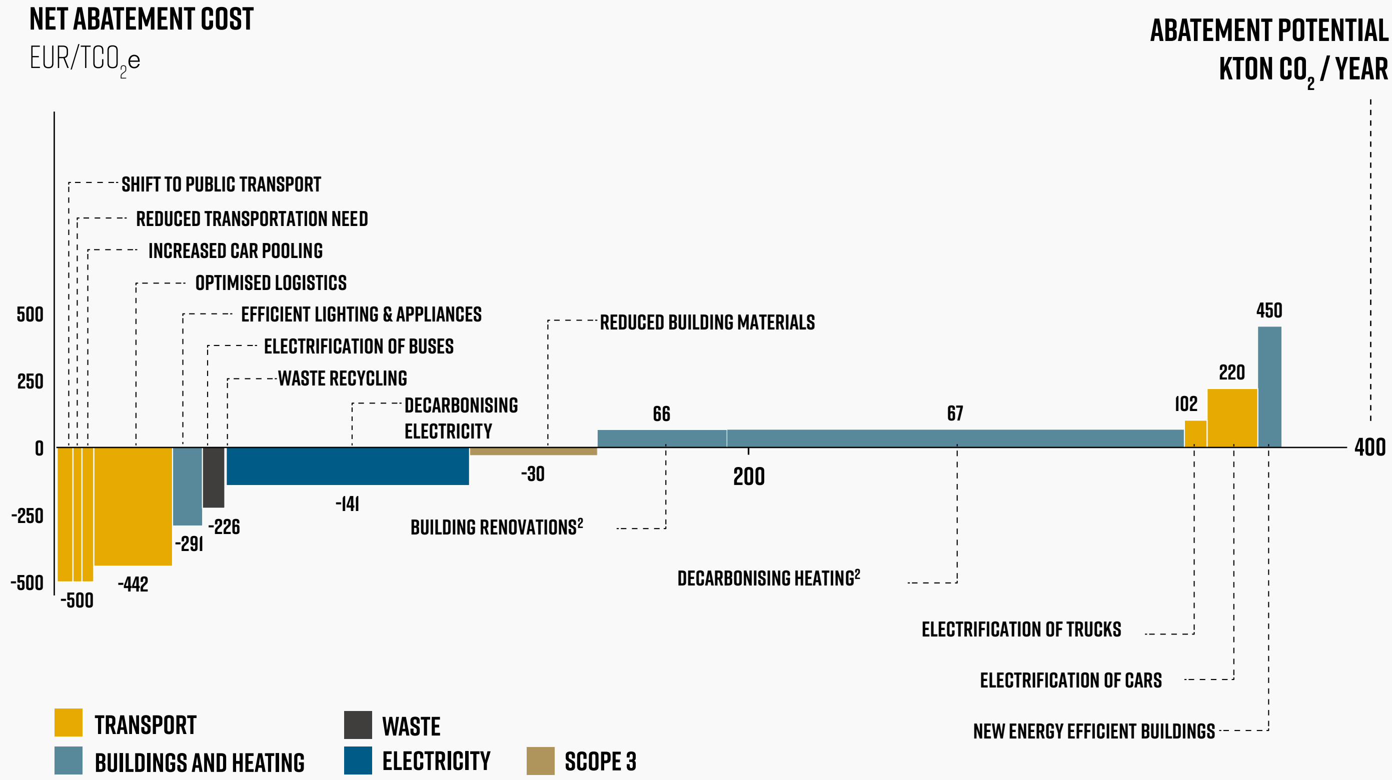
- **In Leuven,** for example, city officials saw the potential of energy communities to decarbonise electricity locally, but also realised that they would need a strategy to exert additional pressure on the region and state to reduce regulatory barriers to renewable energy as quickly as possible.

Exhibit 18

THE ABATEMENT COST CURVE ALLOWS A CITY TO COMPARE DIFFERENT INITIATIVES

LEUVEN ABATEMENT COST CURVE, KTON CO_2e EMISSIONS IN 2030

Abatement costs and benefits annualised based on investments in 2020-2030, and recurring costs/savings and co-benefits in 2020-2050



NOTE: DIFFERENT TIME PERIODS DEPENDING ON THE SPECIFIC COST SAVING/CO-BENEFIT AND LEVER.
ENERGY EFFICIENCY MEASURES ONLY INCLUDE HEAT ENERGY, AND LOOKS AT MEASURES SUCH AS BUILDING ENVELOPE IMPROVEMENTS AND IMPROVED CONTROL SYSTEMS, NOT HEAT PUMPS (THIS IS INCLUDED IN DECARBONISING HEATING)

SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

• **Milan, meanwhile,** identified retrofits as a high priority, but also the need for deeper building stock analysis to be able to identify the performance improvement potential in detail, given the limitations of an approximated analysis.

The tool also evaluates which stakeholders stand most to gain from decarbonisation initiatives and which stakeholders need to adjust the most.

• **In many cities,** for example, it is clear that property owners will need to pay for building retrofits, but existing rent agreements mean they may not be able to recoup the costs through higher rents. Citizens, on the other hand, would benefit from lower energy costs as well as better health outcomes (from reduced pollution associated with energy generation) and a better interior climate.

• **Similarly,** in order to increase reliance on public transport, the transport operator (in many cases the city) will need to pay to upgrade the system, while citizens benefit from lower transport costs and better health outcomes.

4. COMMUNICATE AND ENGAGE WITH CITIZENS AND OTHER STAKEHOLDERS

It is important that the communications from the city on decarbonisation are informed by reliable data and tell a positive and engaging story. The results from the tool can help with this, and thus support dialogue on climate initiatives within the municipality and related organisations, and externally with citizens.

Often there can be a certain amount of scepticism within the municipality on the importance of climate initiatives relative to other priorities, such as employment, public health and safety. The tool can show the broad economic (and other) benefits of decarbonisation, e.g. air quality improvements or job creation potential. For example, the results from the analysis in Malmö are being used to support arguments for strong investments in decarbonisation. This may become particularly valuable during times of economic difficulties, such as now, during the COVID-19 pandemic.

Results from the tool can support informed, data-driven citizen engagement campaigns that show the significant benefits people can realise by either changing their behaviours or pushing local, regional, and national politicians to make certain policy changes or promote investments – for instance, through new subsidies.

5. EXECUTE EXPERIMENTS FOR SPECIFIC INITIATIVES

The tool also can provide practical information such as which stakeholders need to be involved, important parameters to measure (e.g. road accidents or air quality improvements), and expected results. It is important to have a picture of this when starting to design and execute experiments.

6. VALIDATE AND ITERATE PRELIMINARY RESULTS

The results from experiments and implementation of different initiatives can be reinserted into the city tool to allow decision-makers to continue to have an overarching, but updated view of what the real-life experiments mean for the case for decarbonisation in the city. For example, it would be possible to feed the actual impact on vehicle-km and average load factors of a more coordinated logistics pilot from a specific neighbourhood into the model to refine the economic case for doing this on a wider scale.

WHAT THE SOCIOECONOMIC CASE TOOL DOESN'T DO

The tool does not analyse all aspects of decarbonisation, especially not specific policies. Key things that the tool does not do, but that are important for decision-makers as well, include:

• **Estimate rebound** effects and other impacts from behavioural change as a result of the initiatives;

• **Calculate the impact** of specific policy initiatives (e.g. congestion charges, higher parking fees, solar panel subsidies etc.);

• **Consider very specific** local (differences within a city) circumstances, e.g. technical standards of individual buildings, potential electricity grid improvements, etc.;

• **Include economic multiplier** effects from generating additional jobs in the market;

• **Quantify the economic effect** of increased property values (except for reforestation), reduced congestion, and several other co-benefits.

These have not been included for various reasons, but mostly due to the fact that the purpose of the tool is to give an initial indication of what areas have the highest potential and approximate what the socioeconomic case looks like, rather than analysing all aspects in detail. This is because it is important to be able to develop a good estimate quickly to support prioritisation and decision-making without spending too much time and resources upfront. Additionally, if too many aspects and details are included, it makes the tool unwieldy and difficult to use, which means its uptake is much less likely.

Much more analysis can and must be done to realise change and deep decarbonisation.

A city that wants to effect change can take a thematic approach, such as taking a holistic view on improving a specific neighbourhood.

WHAT ADDITIONAL ANALYSIS CAN BE DONE BASED ON THIS?

The tool provides results that are very valuable for starting to take a data-driven and broad-based view of decarbonisation. However, much more analysis must be done to achieve deep decarbonisation.

A city that wants to effect change can take a thematic approach – such as revamping the transport sector – or a geographic approach, such as taking a holistic view on improving a specific neighbourhood. The types of analyses needed for these processes will vary, but the economic case tool can serve as a good starting ground for both. In a thematic approach it is especially important to show additional co-benefits and impacts on other urban priorities, and to sponsor a broader education campaign across the city. On the other hand, a geographic approach will require a cohesive "package" of interventions and a very clear understanding how this affects the specific neighbourhood in detail.

Working from the conclusions from the economic case tool, examples of additional analyses that may be needed include:

- More specific city- and neighbourhood-level analysis;
- Adjustment of analysis based on real-life experimentation;
- Design and evaluation of policy interventions and financing models;
- Setting the analysis into the specific city target context;
- Analysis of co-benefits relevant to the city;
- Decarbonisation trajectory analysis;
- Detailed analysis of influencing potential.

These are described in more detail below. These additional analyses would likely require more bespoke, city-specific Excel (or other software) tools. They can likely be based on and use data from the socio-economic case tool. However, incorporating additional functionality or building on top of this tool would probably be inefficient, as this tool is not fit for every type of analysis that a mayor or city would want/need to do.

1. MORE SPECIFIC CITY AND NEIGHBOURHOOD-LEVEL ANALYSIS

As the tool combines top-down assumptions and bottom-up data, the results give a good approximation of socioeconomic case for the city as a whole. However, as there is significant granularity within cities – for instance, on district heating availability, individual building energy performance, public transport availability, etc. – additional analysis is needed to inform actual financing models. Cities may thus want to conduct deeper, more detailed neighbourhood-level analyses in specific areas, especially on buildings and energy and, to some extent, public transport. This may require bespoke neighbourhood-level tools. Alternatively, the socioeconomic case tool could be adapted with specific neighbourhood data, depending on the specific context.

Additionally, the tool uses an approximation of the impact of reduced NO_x and PM emissions on a per tonne basis, but it is more accurate to determine the health effects of concentrations of pollutants, which can vary significantly by neighbourhood. Many cities have access to more detailed air quality models that can be used to more accurately determine the health improvement effects of initiatives. This is especially important in cities where air quality concerns are pressing, and can lend significant credibility to the argument and positioning that decarbonisation initiatives are a good way to improve air quality and public health.

Another crucial parameter that should be quantified further for a city is the job creation potential of the identified decarbonisation initiatives, and the multiplier effects. The tool only does this at a very high level for some measures, and a more detailed understanding of these will be useful in many situations. That may be particularly important today, given the increased unemployment caused by COVID-19.

2. EVALUATION OF REAL-LIFE EXPERIMENTS

The tool provides valuable estimates, and when feasible, it helps to test ideas in real life before launching large-scale initiatives or making significant investments. Data from the tests, including actual outcomes, costs, and benefits, can be used to improve the citywide analysis. (Note that this will not be possible for some benefits, such as improved health from less air pollution, as this is a co-benefit that is realised over the long term.)

For example, a city could test electrification of the bus fleet by starting with only a few bus lines. Another example is building retrofits through Climate-KIC's Million Homes initiative, which started with about €50 million in Utrecht before expanding to a €1 billion fund.

3. DESIGNING AND EVALUATING SPECIFIC POLICY INTERVENTIONS AND FINANCING MECHANISMS

It is important to analyse specific policies to achieve decarbonisation. For example, if a city wants to reduce car traffic, it has a few options, such as increasing parking fees or introducing congestion charges. However, it is not clear which one is best, so it is very important to understand the effectiveness of each before choosing the path to take.

Additionally, when looking at specific policies to reduce emissions, it is important to compare the resulting cost savings and co-benefits of alternative policies unrelated to decarbonisation that could also impact the co-benefits analysed (e.g. mandating additional exhaust filters to reduce NO_x).

Finally, many initiatives will require innovative financing structures to reduce the upfront investment barriers that often occur, for example, with retrofits or renewable energy installations, and enable external investors with significant resources to fund decarbonisation initiatives. This will require deeper specific cash flow analysis, for instance, to be able to set up a fair and attractive financing structure for all parties. The retrofitting case from Utrecht is a good example. Tenants do not need to invest anything upfront and keep the same energy costs over time, but get much more efficient and retrofitted apartments, while investors pay upfront and get a return in the form of the future difference in energy costs.

4. SETTING RESULTS IN THE CONTEXT OF CITY-SPECIFIC TARGETS

Many cities have very specific targets and metrics for priorities such as employment, housing, climate, safety, etc. Reinterpreting the results to directly show how the decarbonisation initiatives affect the different targets and metrics would be useful both to help decision-makers see the wider benefits in a very city-specific context and to help understand how decarbonisation would help the city achieve its top priorities.

5. CONSIDER OTHER CO-BENEFITS RELEVANT TO THE CITY

The tool quantifies only a limited number of co-benefits for which there is well-documented literature on financial impacts. There are many other parameters that are more difficult to quantify which could be analysed in more detail, such as reduced energy poverty, job creation, more equitable access to transportation, time savings from reduced congestion, etc. Many of these co-benefits are very city-specific, with different priorities for different cities. Therefore, it could make sense to identify highest-priority co-benefits for each city and further analyse the initiatives' impact on those priorities for the city in question. For example, better socioeconomic integration is a high priority in Malmö. This is something that a better and expanded public transport network could help address, but it is currently not included in the tool.

6. DECARBONISATION TRAJECTORY ANALYSIS

Different initiatives will have different decarbonisation paths. For example, a city can replace existing buses with electric buses relatively fast, but it can be more challenging to replace passenger cars, as that is done by individuals, and each car has an approximate lifetime of 10–15 years. This means that the large mass of passenger cars will likely be replaced later in the decade, not earlier. The tool gives an approximate understanding of these different profiles, but analysing them in more detail can be important to educate policy-makers on what decarbonisation will likely look like for different sectors and initiatives.

7. DEEPER ANALYSIS OF INFLUENCING POTENTIAL

Understanding in detail who is responsible for and capable of enacting policies and interventions is very important, as it can define the optimal approach. For example, if the public transport is managed at the regional level, it becomes very important for the city to involve and lobby for the region to also prioritise and enact specific policies to decarbonise or expand public transport. This is the case in Malmö, for example, where the public transport authority, Skånetrafiken, is under the control of the region.

HOW THE ECONOMIC CASE ANALYSIS WORKS

SCOPE OF THE TOOL

As described in more detail earlier in this document, the tool does four main things:

- Quantifies the city's emissions today and until 2030 in a baseline scenario without additional climate action from the city;
- Assesses 15 climate measures and their impact on emissions and other societal parameters, such as air quality, physical health, road-safety, urban noise, employment, etc.;
- Quantifies the economics of the 15 measures, based on their societal impacts, cost savings, and investment requirements;
- Generates the overall economic case for climate action in the city and shows how costs and benefits are distributed across different stakeholders in the city.

Going one step deeper to understand what is included in this analysis, four things need to be described in more detail:

1. CO_2 scope: Which emissions are included?

2. Decarbonisation levers/initiatives analysed: Which measures are modelled?

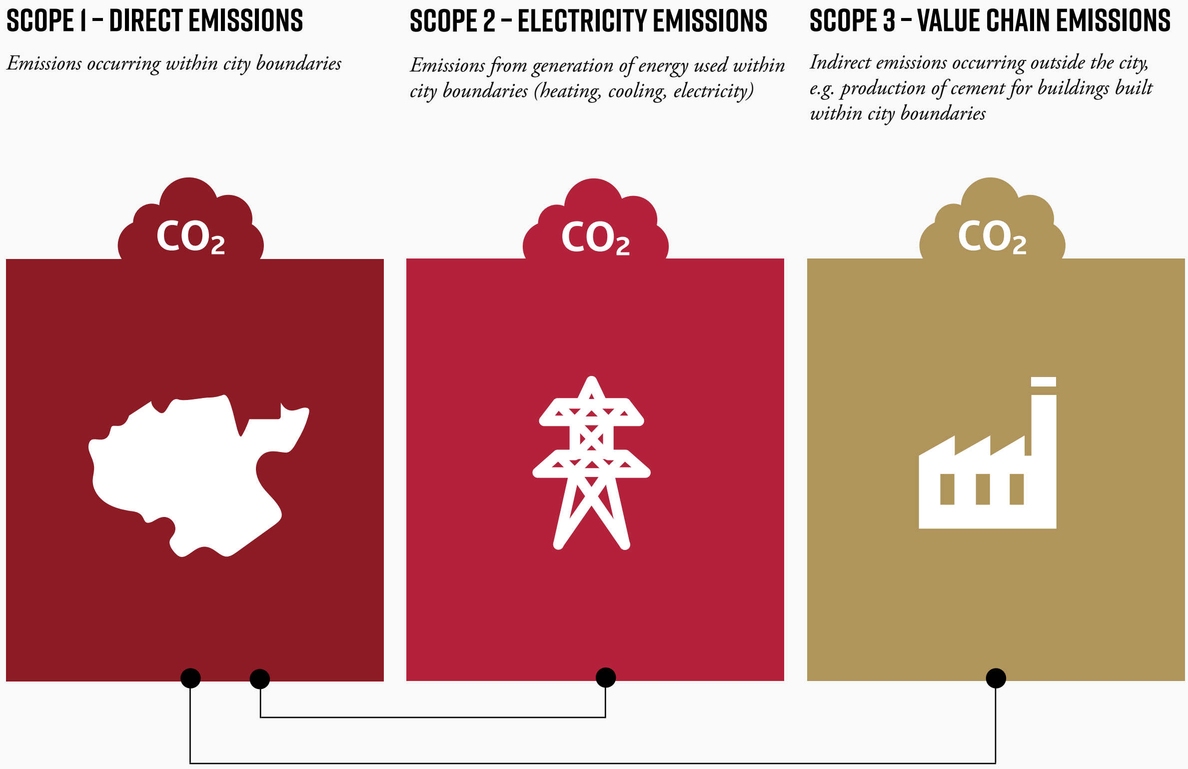
3. Financial costs and benefits: Which financial costs and benefits are included in the analysis?

4. Time frames for investments, costs, and benefits


Metro
Plaza de España

Exhibit 19

SCOPE 1, 2, 3 EXPLAINED



SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

1. CO_2 SCOPE

There are different types of CO_2 emissions, and these are often split into three "scopes", as defined by the Greenhouse Gas Protocol, the most widely used international accounting tool to quantify and understand emissions. These different scopes are explained below.

Scope 1 and 2 emissions occurring within the city limits are included in the analysis, both for baseline development and for abatement potential. This means that direct emissions from cars within city limits, for instance, are included, and so are indirect emissions from the production of electricity and heat used (but not necessarily produced) within city limits.

The focus has been on these emissions vs. Scope 3, as it is much more difficult for cities to influence the emissions from the production of vehicles, for instance, but they can choose to buy or promote the use of electric vehicles.

Some analysis on the estimated Scope 3 emissions from food and building material production is also included in the analysis and can be used to give an indication of their relative importance compared with Scopes 1 and 2.

Exhibit 20

FIFTEEN INITIATIVES ARE INCLUDED IN THE SOCIOECONOMIC CASE TOOL

DECARBONISATION INITIATIVES INCLUDED

TRANSPORT

Reduced passenger transportation need
Increased car-pooling
Reduced & optimized logistics
Shift to public & non-motorised transport
Electrification of passenger cars
Electrification of public transport
Electrification of freight transport

BUILDINGS & HEATING

New buildings highly energy-efficient
Building energy-efficienct renovations
Efficient lighting & appliances
Decarbonising heating

ELECTRICITY

Shift to renewable electricity (rooftop solar and large-scale centralised wind/solar parks)

WASTE

Increased recycling of waste

REFORESTATION

Planting trees within the city and in surrounding areas

SCOPE 3

Reduced building materials

SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

2. MEASURES/INITIATIVES INCLUDED IN THE TOOL

There are 15 measures (or policy levers) included in the analysis. These were chosen based on both medium-term abatement potential and the possibility for cities to influence them, as described earlier in this report. Several key assumptions dictate a measure's development over time in a city, as shown in Exhibit 20.

Exhibit 21

QUANTIFIED CO-BENEFITS INCLUDE SECOND-ORDER BENEFITS ARISING FROM A PARTICULAR ACTION THAT IS NOT THE PRIMARY FOCUS OF SAID ACTION

NON-QUANTIFIED CO-BENEFITS | QUANTIFIED CO-BENEFITS

ECONOMIC GROWTH	EMPLOYMENT	*Creating additional jobs in the city*
	TIME SAVINGS	*Allowing citizens to have more time to spend, e.g. by reducing congestion*
	PROPERTY VALUE	*Increasing the value of property in a specific location [Reforestation only]*
HEALTH	AIR QUALITY	*Improving health with a reduction in air pollutant emissions (NOX & PMs)*
	NOISE	*Improving health with a reduction in noise pollution*
	ROAD SAFETY	*Reducing the number of road accidents*
	PHYSICAL HEALTH	*Improving physical health to reduce the probability for future sickness*
	WELL-BEING	*Improving mental health to reduce the probability for future sickness*
	ECOSYSTEM HEALTH	*Improving ecosystems in the city through reduced pollutants and waste*
	WATER QUALITY	*Improving water regulation with less runoff [Reforestation only]*
INCLUSIVITY	EQUALITY	*Promoting more equal access to various products and services*
	COMMUNITY ASSETS	*Developing publicly owned and free-to-use areas and assets*

SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

3. FINANCIAL COSTS AND BENEFITS INCLUDED

The tool takes a holistic view of the costs, including costs and benefits for all stakeholders within the city – that is, residents, the municipal government, property owners, the state, utilities, etc.

When calculating the economic case for decarbonisation, several different costs and benefits are included, including upfront investments, financial operational costs/savings, and quantifiable co-benefits.

Upfront investments include various types of investments, such as new infrastructure (walking/cycling paths, charging infrastructure, etc.), new vehicles (electric cars, buses, etc.), and other investments (renovation costs, etc.).

Financial operational costs/savings include ongoing costs/savings that arise from the investment, e.g. lower energy costs from less demand/shifting to electricity from fossil fuels, operations and maintenance costs, etc.

Quantified co-benefits include second-order benefits arising from a particular action that is not the primary focus of said action. The co-benefits that have a quantified value in the tool are only those with reliable and established cost data from literature, and can be seen in the figure below.

All of these costs and benefits are discounted to 2020 using a discount rate of 3.5%, which is a conservative value based on various research reports and experts.

4. TIMING OF INVESTMENTS, COSTS, SAVINGS, & BENEFITS

The investments included in scope are done over the period 2020–2030 to ensure that the tool focuses on what can be done to aggressively reduce emissions until 2030.

The operational costs/savings/benefits over time are estimated through 2030/40/50/60 depending on the estimated lifetime of the investment made (e.g. a car has a shorter lifetime than a district heating network). This is done to fairly count the benefits of an investment made to have an accurate representation of the ROI.

Exhibit 22

INPUTS NEEDED FOR THE TOOL

CITY-SPECIFIC DEMAND LEVERS	*Includes basic data on the city, including population size and expected growth, as well as how much is "consumed" of different important aspects, e.g. how large the building stock is, how many vehicle-kms are driven with different modes of transport, how much heat and electricity is consumed, how many cars are registered in the city, etc.*
CITY TARGETS AND ASSUMPTIONS	*These are the targets set by the city on different aspects (e.g. modal share of public transport) until 2030, related to the levers included and are used to determine how far the city is aiming to get to by 2030. If no targets exist or if these are deemed much too conservative, assumptions are developed together with city representatives to ensure the scenario modelled is ambitious.*
EMISSION FACTORS	*Emission factors for both CO_2 and air pollution (NO_X and PMs) for a wide variety of actions are needed in order to determine baseline emissions as well as how these change in a decarbonisation scenario. These are taken both from literature, Eurostat data, as well as directly from city data. Where relevant EU targets are also used to determine baseline developments. Examples of these include the emission intensity of district heating and electricity.*
UPFRONT INVESTMENTS	*Average investments needed are based on literature. Estimated future developments (reductions) of these costs are also found in literature. Examples of these include the additional cost of an electric bus vs a combustion engine bus, and the cost of conducting a deep building retrofit.*
OPERATIONAL COSTS	*Approximate operational costs are also based on literature or in some cases data from the city. Examples of these include average fuel and electricity prices, and the cost of operations and maintenance of electric and combustion engine vehicles.*
LEVER IMPROVEMENT RATES	*For certain levers, e.g. building renovations, the improvement rate in performance is needed. This is also taken from literature or from the city itself if they have city-specific data. An example of this could be the energy savings from minor versus major building retrofits.*

SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

INPUTS NEEDED FOR THE TOOL

The tool uses many different data points to calculate the baseline emissions development, decarbonisation potential, and economic case, but can be categorised into six main types of data, as shown below.

HOW THE DIFFERENT LEVERS INTERACT

As there are several levers affecting and using similar and interlinked factors e.g. the total vehicle-km or electricity use, the tool is interlinked to ensure that decarbonisation potential or costs are not double-counted. This is done by having a hierarchy of levers for each sector, where the baseline is successively updated by each lever that is enacted.

For example, when considering passenger transport, the first levers that occur are those which reduce the demand for vehicle-km, levers such as increased carpooling or reduced private transport. This results in a new (and lower) total vehicle-km need, which requires fewer passenger cars, and thus fewer cars that need to be electrified. Finally, the electrification of passenger cars increases the demand for electricity, which means additional electricity will need to be decarbonised.

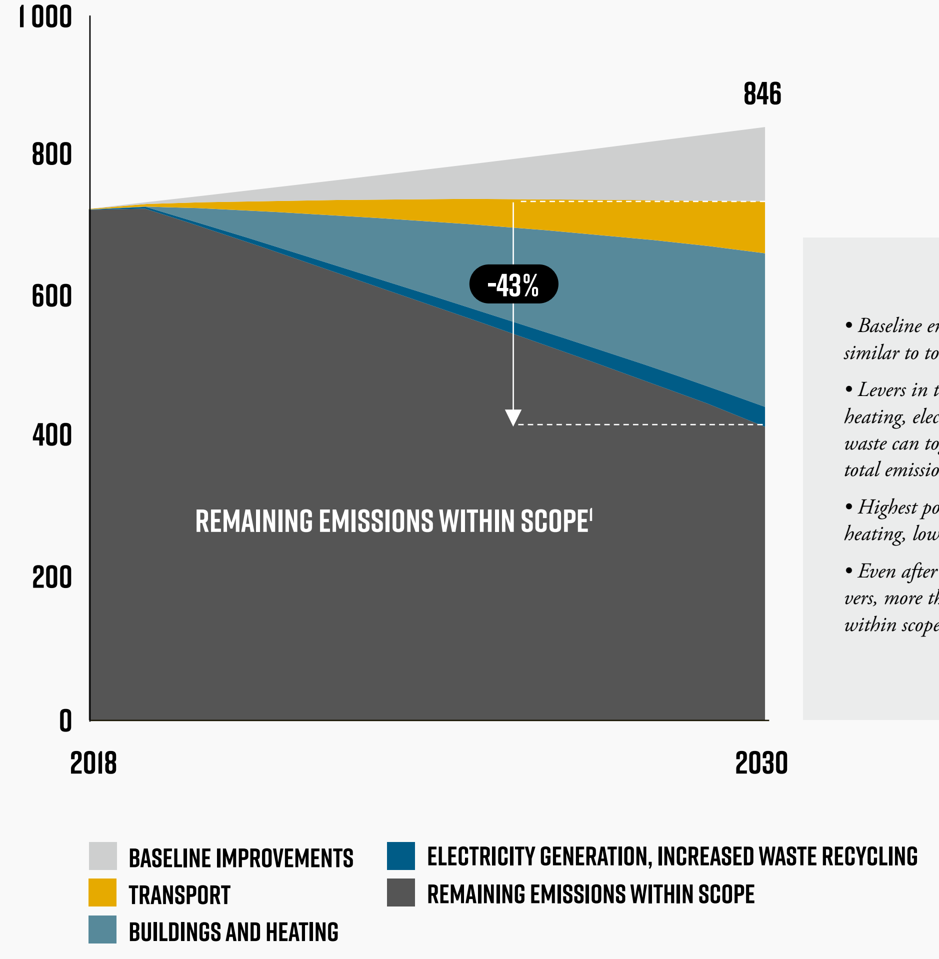
OUTPUTS OF THE TOOL

The tool can produce several different outputs based on the analyses conducted. These are shown in Exhibit 23, 24, 25, 26, 27 and 28 on the next page.

Exhibit 23

CO_2 REDUCTION POTENTIAL OF SELECTED LEVERS, RELATIVE TO BUSINESS AS USUAL, UNTIL 2030

CO_2 ABATEMENT CURVE FOR ORLÉANS TOTAL EMISSIONS IN SCOPE
KTON CO_2 PER YEAR



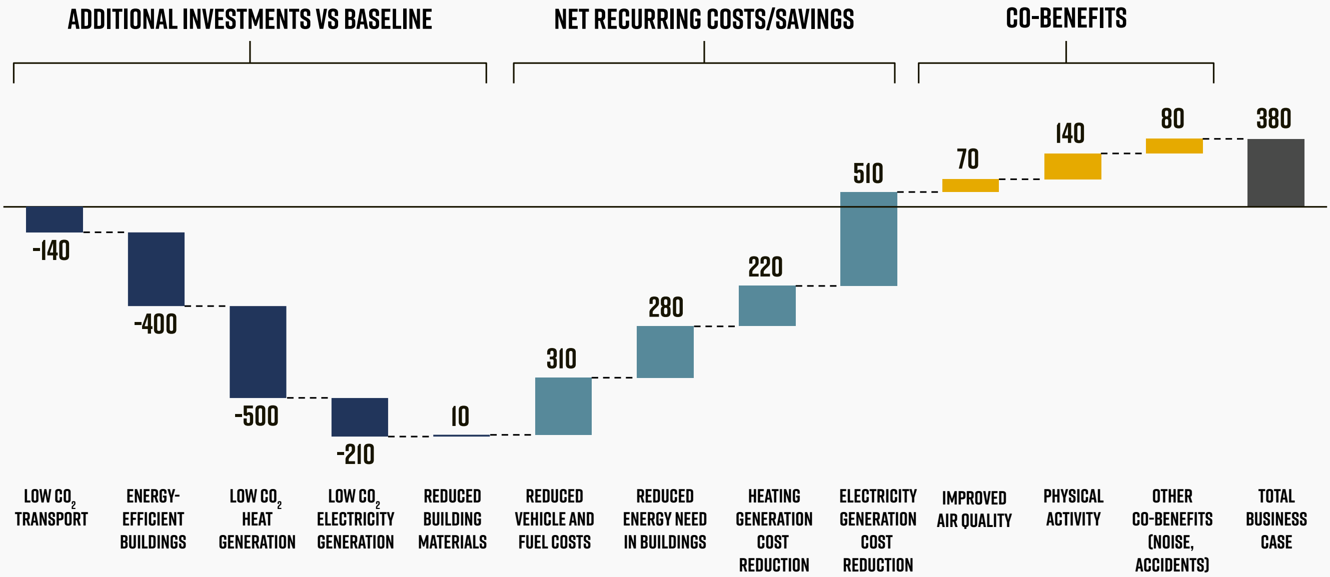
- *Baseline emissions in 2030 are similar to today.*
- *Levers in transport, buildings and heating, electricity generation and waste can together reduce 43% of total emissions.*
- *Highest potential in buildings and heating, lowest potential in waste.*
- *Even after implementation of the levers, more than 400 kt CO_2 emissions within scope remain.*

NOTE: TRANSPORT, BUILDINGS AND HEATING, ELECTRICITY GENERATION AND WASTE. EMISSIONS FROM E.G. AGRICULTURE AND INDUSTRY EXCLUDED.
SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

Exhibit 24

OVERALL ECONOMIC CASE OF CITY DECARBONISATION, IDENTIFYING THE OVERALL ROI AND KEY INVESTMENT, COST SAVINGS, AND CO-BENEFIT CATEGORIES

ECONOMIC CASE FOR DECARBONISATION IN LEUVEN
M€, NPV INVESTMENTS (2020-2030) AND BENEFITS (2020-2050)



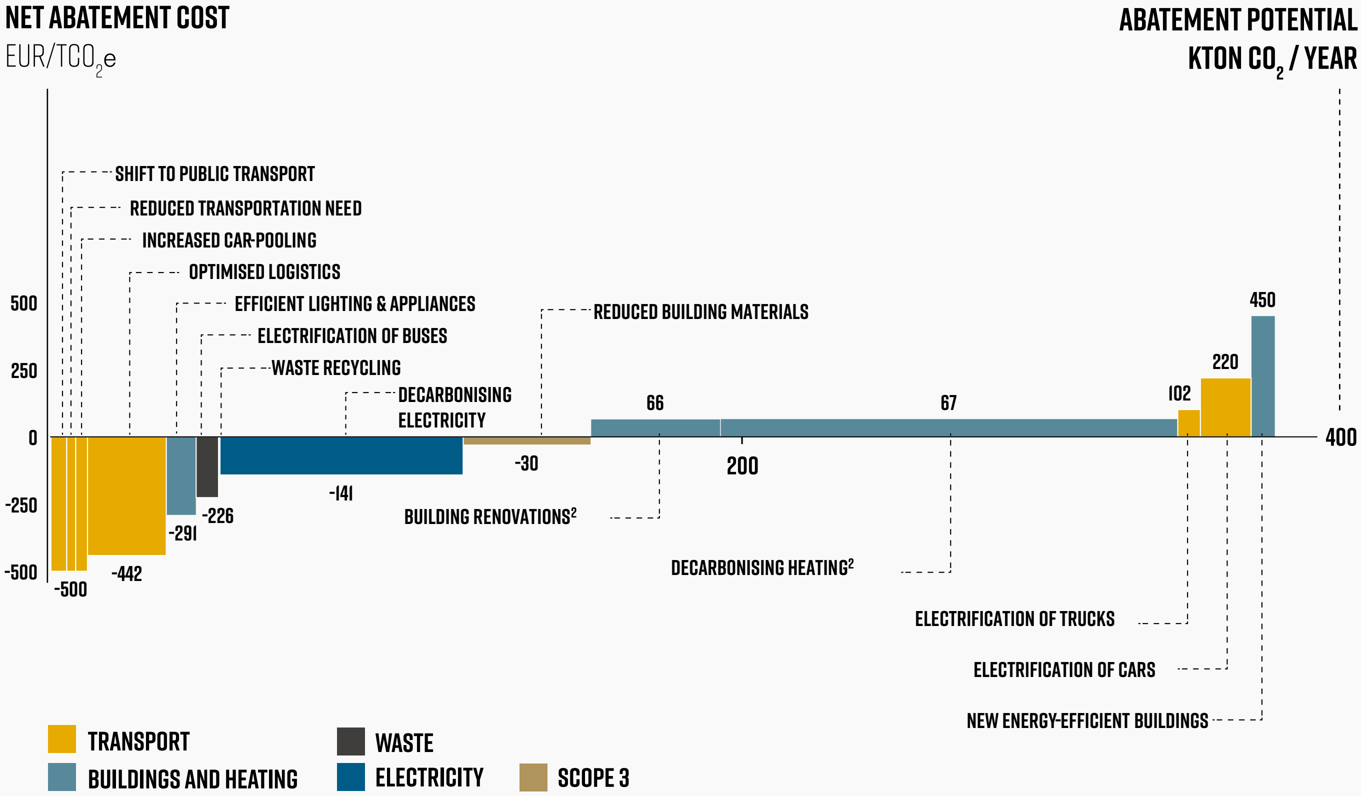
SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

Exhibit 25

THE ABATEMENT COST CURVE ALLOWS A CITY TO COMPARE DIFFERENT INITIATIVES

LEUVEN ABATEMENT COST CURVE, KTON CO_2e EMISSIONS IN 2030

Abatement costs and benefits annualised based on investments in 2020-2030, and recurring costs/savings and co-benefits in 2020-2050[1]



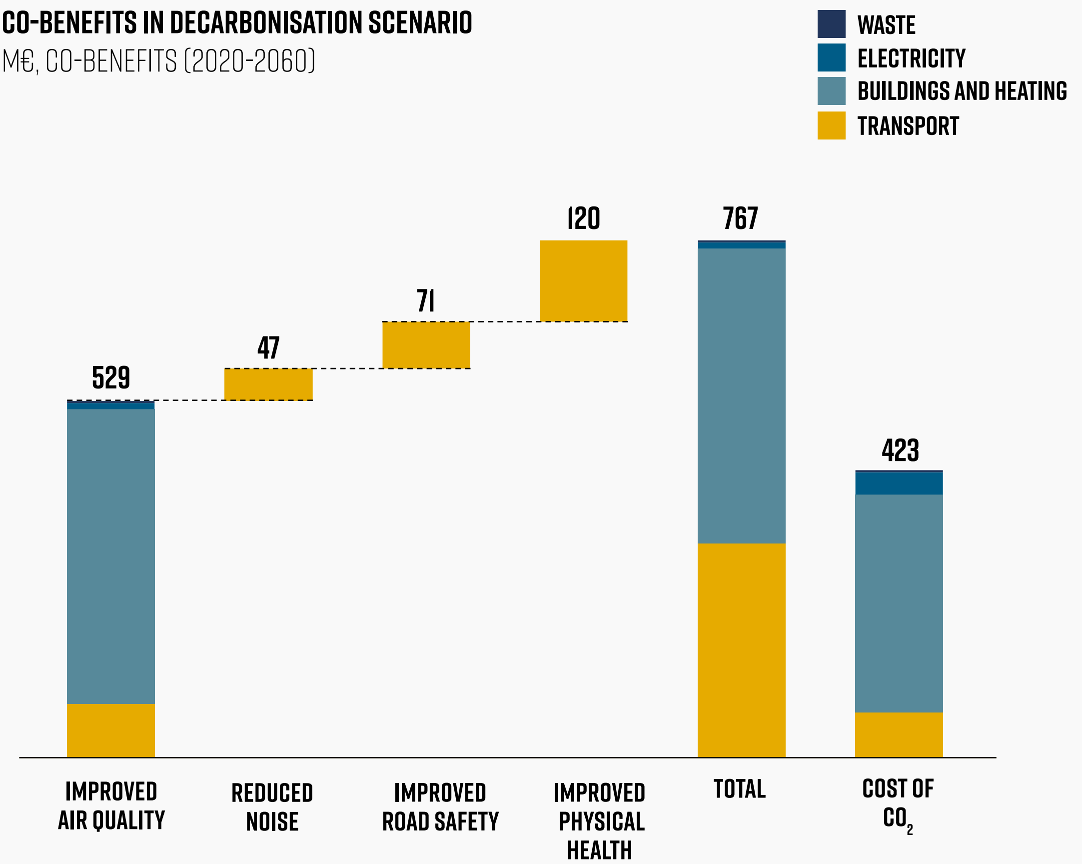
NOTE: DIFFERENT TIME PERIODS DEPENDING ON THE SPECIFIC COST SAVING/CO-BENEFIT AND LEVER.
ENERGY EFFICIENCY MEASURES ONLY INCLUDE HEAT ENERGY, AND LOOKS AT MEASURES SUCH AS BUILDING ENVELOPE IMPROVEMENTS AND IMPROVED CONTROL SYSTEMS, NOT HEAT PUMPS (THIS IS INCLUDED IN DECARBONISING HEATING)

SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

Exhibit 26

CO-BENEFITS ARISING FROM CITY DECARBONISATION, IMPACT OF IMPROVED AIR QUALITY AND HEALTH

CO-BENEFITS IN DECARBONISATION SCENARIO
M€, CO-BENEFITS (2020-2060)



Improved air quality
- *Mainly from decarbonised heating, reduced transportation and electrification of vehicles*
- *Reduces health care cost*

Reduced noise
- *Reduced transportation and electrification reduce noise levels*
- *Cost savings from reduced annoyance and improved health*

Improved road safety
- *Reduced transportation decrease risk of road accidents, and thus cost of medical care*

Improved physical health
- *Significant health benefits from increased walking and cycling*

Cost of CO_2
- *Cost of carbon at 100 EUR/ton CO_2*
- *Price to cover for global warming risks, e.g. rising health care costs, destruction of properties etc.*

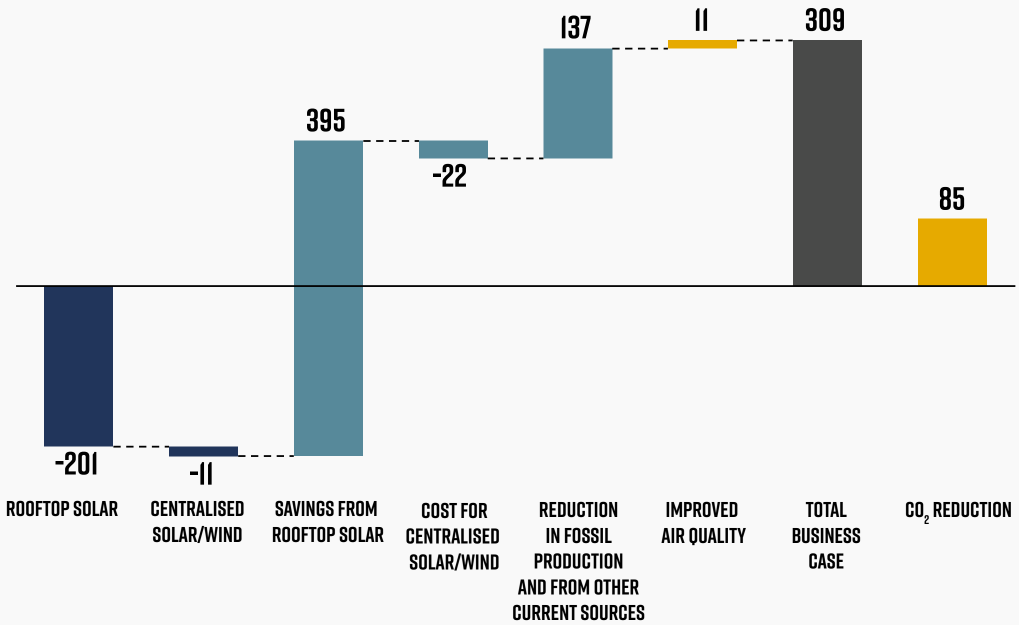
SOURCE: MATERIAL ECONOMICS MODELLING

Exhibit 27

INDIVIDUAL ECONOMIC CASES PER LEVER, ACCOUNTING FOR INVESTMENTS, COSTS AND CO-BENEFITS

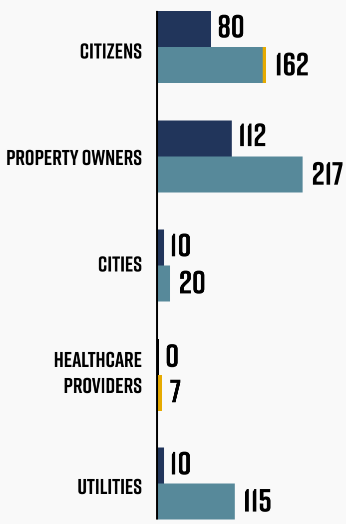
ECONOMIC CASE FOR DECARBONISING ELECTRICITY IN LEUVEN

M€, NPV OF INVESTMENTS 2020-2030 & BENEFITS 2020-2050



COST/BENEFIT DISTRIBUTION

M€, NPV 2020-2050

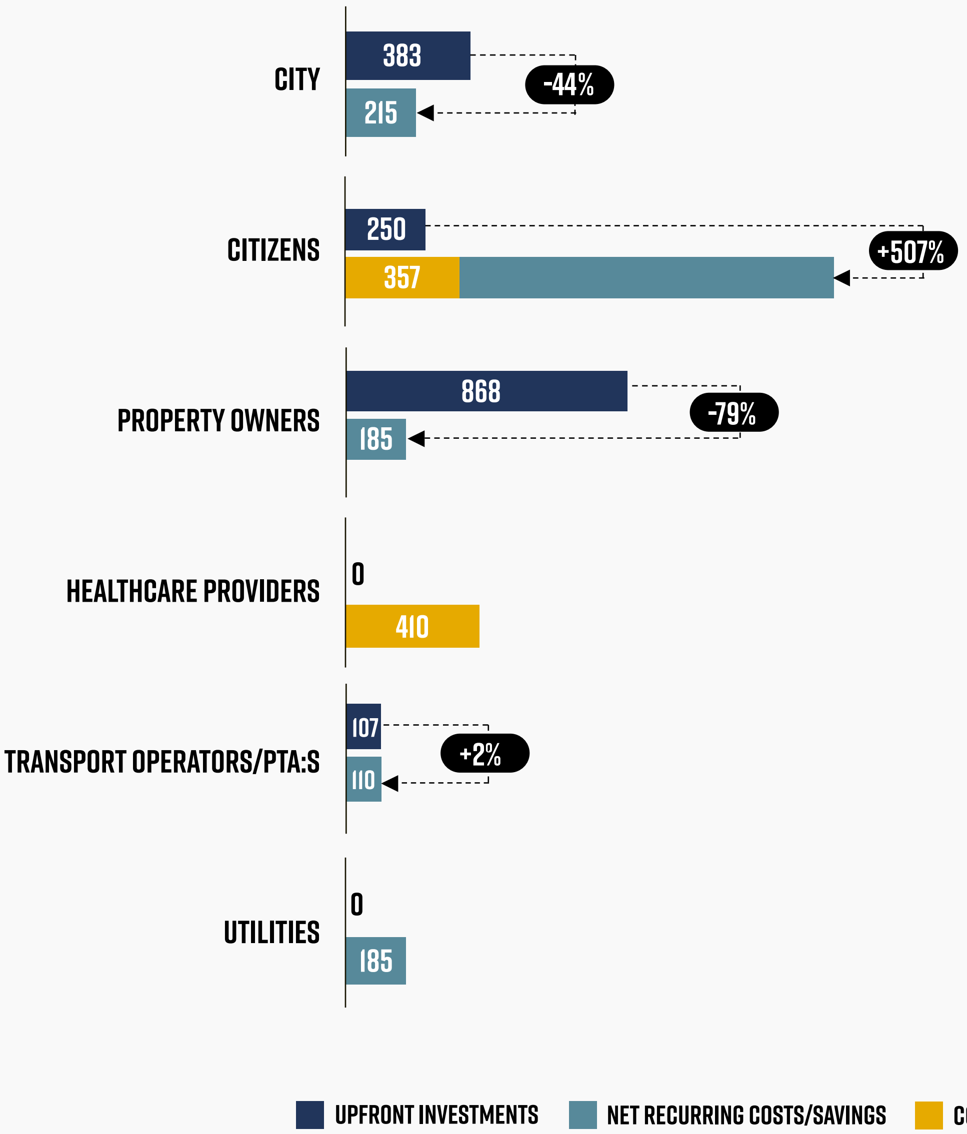


SOURCE: MATERIAL ECONOMICS ANALYSIS BASED ON MULTIPLE SOURCES, SEE BIBLIOGRAPHY

Exhibit 28

DISTRIBUTION OF COSTS AND BENEFITS ACROSS CITY STAKEHOLDERS

TOTAL ECONOMIC CASE BY BENEFICIARY
M€, NPV INVESTMENTS (2020-2030) AND BENEFITS (2020-2050)



- *Cities typically cover costs for public charging and walking/cycling infrastructure, lower land costs for developers building energy efficiently, and retrofits in social housing.*
- *Citizens receive benefits from the investments they make, investments in infrastructure made by property owners & the city, and co-benefits from better air quality and walking/cycling.*
- *Property owners are significant investors, but yield benefits from decarbonising local heating and electricity (e.g. through rooftop solar).*
- *Healthcare providers receive co-benefits from a healthier population without requiring any specific investments other than in renovations of their own properties.*
- *Transport operators typically receive benefits from optimised logistics and reduced transportation need, but must invest in/maintain costly trucks and an expanded public transport system.*
- *Utilities in Orléans will need to pay for small investments in the district heating system as well as avoid investments in fossil-based technologies, but also will receive the benefits from lower costs.*

SOURCE: MATERIAL ECONOMICS ANALYSIS

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UNDERSTANDING THE ECONOMIC CASE FOR DECARBONISING CITIES

Why Economic Case Analysis for City Decarbonisation is Crucial

Cities have a clear and fundamental role to play in addressing the climate emergency and achieving the UN Sustainable Development Goals. Many are working hard to decarbonise, but face significant challenges due to inertia in existing systems, pre-existing policy environments, and limited budgets. A key obstacle is the seemingly high cost of reshaping key CO_2-emitting sectors in the city, as well as understanding who needs to pay and who stands to benefit. This makes decision-makers hesitant to pursue change. However, many recent global reports show clear economic opportunities in decarbonisation that are often attractive for multiple reasons, including improved public health and other co-benefits. The problem for city leaders is how to translate those analyses, which are often generic, into estimates of the economics of change for individual cities.

To help cities analyse the economic implications of specific climate actions, Material Economics and EIT Climate-KIC have developed a tool to enable cities to build their intelligence on potentially effective climate actions to reduce emissions and secure a more resilient future. The analyses made with the tool can help city decision-makers and stakeholders to deepen their understanding of the economic impact of available decarbonisation options, identifying the initiatives that are likeliest to have a significant economic return to society, and quantifying the potential cost.

MATERIAL ECONOMICS

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