Climate neutral cities – estimating the financial investments needed

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Abstract

Creating more sustainable societies requires decarbonizing activities more rapidly, including at the city level. We designed a model to help cities calculate the investments needed to become climate neutral, based on a study of nine Swedish We created five "strategy mixes", consisting of different mitigation categories, and three options for emission forecasts by 2030. This resulted in a preliminary assessment of the mitigation potential and investment needs across these nine cities for 15 scenarios. The results here are preliminary, with further work planned in 2022; nevertheless, these initial calculations indicate that we can determine the financial feasibility of achieving climate neutrality in these cities.

1. Introduction

To create more sustainable societies, we need to decarbonize our activities more rapidly, applying strategies such as those identified in the Exponential Roadmap (Falk et al., 2020). Cities have a substantial impact on the climate and are therefore an essential actor for addressing climate change. For example, cities account for over 70% of carbon emissions and around two-thirds of all energy consumption (UN Habitat, 2011).

For Sweden, where 59% of the population lives in cities with more than 50,000 inhabitants (SCB, 2021a), challenges at the city level include overcrowding and segregation, air pollution, providing clean, adequate public transport, accessibility, and usability of cities, in addition to building climate change resilience and lowering high consumption-based greenhouse gas emissions (Swedish Government, 2017). An assessment of how nine Swedish cities address climate change mitigation in their municipal plans shows that while these municipalities have sufficient political support, a clear vision, and goals or targets, they also have gaps in their plans and strategies, actions or instruments and institutional capacity (Vanhuyse et al., in review). Under institutional capacity (the knowledge, resources, and collaboration within the city to mitigate climate change), the authors found that no municipalities in their sample specify the level of investments needed to achieve climate neutrality.

To date, the small body of research on financial investment that would be needed to reach climate neutrality tends to be global or regional. Current estimates are €2.5 billion per year for the period 2026–2040 to reach climate neutrality globally (IEA, 2018); an estimate of an additional €180 billion per year to achieve the 2030 climate and energy targets in the EU (European Commission, 2018) and a revised figure of €260 billion per year to reach the even more stringent emission reductions set in 2019 across the EU (European Commission, 2020, 2019). Climate-related projects are estimated to take up 30% of the total expenditures from the EU's budget for 2021–2027 and Next Generation EU (European Council, 2021).

For cities, a few estimates have been published, such as by Gouldson et al. (2015), who made the economic case for low-carbon measures in cities in Europe (Leeds, UK), Latin America (Lima, Peru) and Asia (Kolkata, India; Johor Bahru, Malaysia; and Palembang, Indonesia). Sudmant et al. (2016) have estimated the amounts needed for 11 clusters of low carbon measures to be implemented in cities globally.

We know of only one calculation that includes a Swedish city, namely the one of Material Economics (2020). They calculated that, using scope 1 and scope 2 emissions, to achieve climate neutral transport, building and electricity by 2030, cities with 100 000 inhabitants would need to invest €961 million or about €10 000 per citizen per year. However, detail on this calculation is lacking.

Here we present the model we developed under the Viable Cities' Finance project to calculate the investment needs in nine Swedish cities. We designed this model to make the discussion around climate neutral cities more tangible, and to bring about new discussions on whether municipal governments have the resources to reach climate neutrality.

This paper is structured as follows. In section 2, we describe the model we designed to calculate the investment needs and explain the sample of cities for which we provide calculations. In section 3, we provide the results of our calculations, then conclude and discuss next steps in section 4.

2. Materials and methods

2.1. Calculating the investment need – the model

To calculate the financial investments needed for climate neutral cities, we developed a model consisting of a series of databases and calculations. Figure 1 shows the model structure.

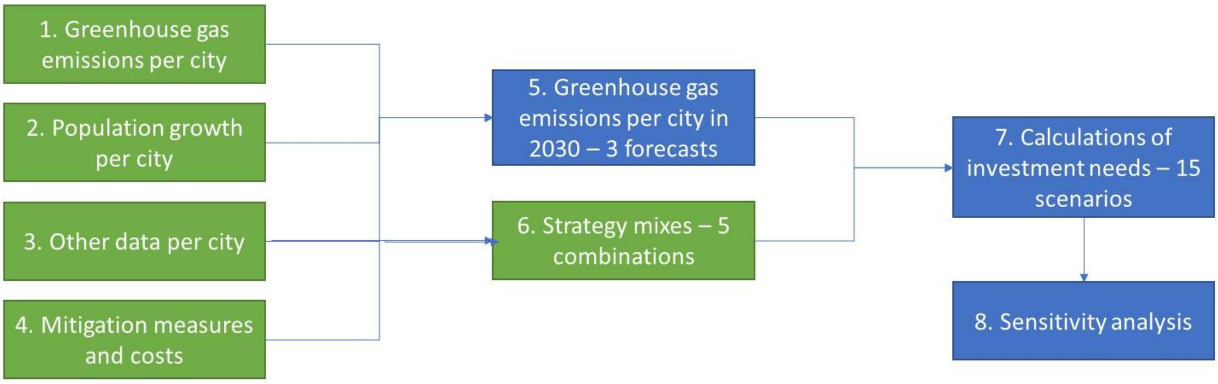

Figure 1. Model structure.

Source: own elaboration

We use four databases in our model: 1) greenhouse gas emissions at the municipal level; 2) population growth per city from 2017 to 2020; 3) "other data" per city; and 4) mitigation measures and costs. The greenhouse gas emissions per city were obtained from the Formas-funded project "Accelerating Agenda 2030: municipal planning for reduced climate footprints", led by the Stockholm Environment Institute (grant number: 2019-00223). It follows the classification of the Swedish Statistical Agency and is broken down in several categories: food, clothing, housing (excluding heating), health, transport services (excluding air transport), air transport, communication, recreation, education, restaurants and hotels, vehicles (mainly cars), electricity, district heating, house heating, and "other sources of emissions" do not fit in the previously listed categories (SCB, 2021b). Each category is broken down to smaller sub-categories (115 in total), to provide a better overview of the sources of emissions.

This new work presents data at the city level, using scaled-down consumption-based emissions – a perspective that is rarely reported in the literature. As the project is ongoing, we report here preliminary results for emissions data at the household level; next steps will be to examine local government and national government contributions, for which data are not yet available for consumption-based emissions. We plan to update our calculations as soon as the full consumption-based profiles become available.

Our second database contains the population growth in the nine cities, also obtained from SCB (SCB, 2021c). We extrapolated population estimates by 2030 based on this data.

In a third database, we collated "other data" that are relevant for our calculation, such as ownership, type and size of dwellings; number and type of cars in the city; composition of the public transport fleet; and information on the heating and energy sources used in the city. Using this "other data", we could allocate the financial investment needs to three stakeholders: private citizens; government; and businesses or industry. As with the second database, we extrapolated all figures to 2030.

Our fourth database, with mitigation options and costs, consists of a list of measures, organized to match the categories identified for the emissions sources in the first database, such as food, clothing, housing, and transportation.

In our calculation, key assumptions pertain to electricity production. While some of the proposed measures will reduce electricity consumption (e.g., energy-efficient household appliances), electricity demands will spike from, for example, the electrification of vehicles. Using fossil fuels to generate the additional electricity needed will counteract the mitigation potential of electrification for transportation. And not all renewable energy sources will fit: in some countries, like Sweden, the environmental impact of solar panels is negative (Martinopoulos, 2020). Similar conclusions are reached by Papageorgiou et al., (2020), who provided a detailed analysis based on the specific case of the Swedish electricity market. In our assessment, we assume that additional electricity needs will be met by renewable energy sources, which currently provide 54% of the energy consumed in Sweden (Zhong et al., 2021).

Financial costing estimates were added, using business cases from various technologies, as explained by, among others, Dubois et al (2019), Gillingham and Stock (2018); and McKinsey & Company (2020). All costs were converted to Swedish kronor (SEK), with 1 SEK equalling €0,1.

In a fifth step, we forecasted the 2030 emissions at the municipal level under three alternative options: 1) business as usual (BAU); 2) an increase in emissions; and 3) a reduction in emissions. In the first option, for BAU, we assumed consumption patterns and per capita emission profiles of 2017 will be the same in 2030. As a result of population growth, even though per capita emissions are the same, the total emissions by 2030 will increase. In our second option, we assumed an increase in emissions of 17%, building on the research of Harris et al (2020). These authors foresee a 33% increase in emissions in the period 2007–2050, using data from nine cities in continental Europe, including Malmö, Sweden. Some cities in their research cohort might be less relevant to a Swedish setting, such as Istanbul, Turkey, but the increase experienced by Istanbul is at least partially offset by Turin and Milan, Italy, where the emissions are expected to decrease in 2050 because of slower economic growth compared to the other cities in the sample.

In our study, we employ a very conservative approach to increases, compared to, for example, Material Economics (2020) who estimated that emissions in Malmö would increase by 2% by 2030. However, should future emissions be significantly lower than expected, the investment needed would indeed be lower as well.

In our third option, we assume emissions will decrease with 6%, building on the research of Wood et al (2020). Using the Nationally Determined Contribution scenario for Sweden, they estimate a 6%

reduction in carbon emissions by 2030, excluding other greenhouse gases. As carbon emissions represent between 80% and 85% of total Swedish emissions (SCB, 2021b), we assume that greenhouse gas emissions should reduce by 6% as well by 2030. This is probably a conservative assumption, noting that according to Höglund-Isaksson et al (2020), methane emissions, the second largest greenhouse gas in Sweden after carbon, could be reduced by much more by 2030.

Five alternative Strategy Mixes were designed for our sixth step, with each suggesting different mitigation categories and targets across categories (Table 1). The five Strategy Mixes represent a combination of investing in clean technologies as well as changing behaviour to reduce municipal carbon footprints. Shifts in habits may include, for instance, a share of the population adopting a vegetarian or vegan diet, reducing air transport or using only public transit. Investing in clean technologies entails mostly purchasing non-fossil-fuel vehicles, investing in electric vehicle charging stations, and expanding the capacity of renewable energy. The Strategy Mixes are ranked from 1 to 5, with Strategy Mix 1 having the lowest mitigation potential and therefore requiring the least effort (in terms of investment, changing behaviours and instruments) to Strategy Mix 5, the largest mitigation potential requiring substantial commitment. For example, in Strategy Mix 1, about 15% of the private cars are the same proportion of diesel and petrol as were on the road in 2017, while in Strategy Mix 5, people either switch to public transport or replace their cars with non-fossil-fuel ones. In Table 1, we also provide a baseline, or the current level, for each strategy in Sweden.

Table 1 Strategy mixes for our calculation

Scenarios – strategy mix (by 2030)	**Baseline 2017**	**Strategy Mix 1**	**Strategy Mix 2**	**Strategy Mix 3**	**Strategy Mix 4**	**Strategy Mix 5**
Food						
Population that is vegan	2%	5%	10%	15%	20%	25%
Population that is vegetarian	8%	10%	15%	20%	25%	30%
Population that reduces meat consumption		5%	10%	15%	20%	25%
Population that is omnivore or pescatarian	90%	80%	65%	50%	35%	20%
Clothing						
Population reducing clothing consumption by one-third		50%	50%	50%	50%	50%

Population doubling the life of their garments		50%	50%	50%	50%	50%
Housing (excl. heating)						
Population halving furniture consumption		50%	55%	55%	60%	80%
Health						
Transport service (excl. air)						
Public buses that are electric	0,2%[1]	100%	100%	100%	100%	100%
Air transport						
Reduction in air travel		70%	75%	80%	80%	80%
Communication						
Phones per capita	1,06	No	No	No	1	1
Recreation						
Population doubling the life of their recreation equipment		40%	45%	50%	55%	60%
Population going pet-free		45%	45%	45%	50%	55%
Population that drop package holidays		40%	40%	45%	50%	55%
Education						
Restaurants and hotels						
Catering service providers that reach the reduction identified by (Eriksson et al., 2017)		55%	55%	60%	65%	75%
Others COICOP						
Vehicles (car)						
Cars that will remain in the fleet (electric only)	7%	50%	50%	50%	50%	30%
Cars that will be given up in favour of public transport	0%	35%	35%	40%	45%	70%

[11] In 2017 in Sweden, 44 of the 10 191 buses (0,2%) were electric and 292 (3%) were running on ethanol (Svenk Kollektivtraffik, 2017). "Fordonsgas" (gas used in vehicles) is a mixture of biogas, methane and gas from fossil deposits.

Cars that will remain in the fleet (fossil-fuel)	93%	15%	15%	10%	5%	0%
Electricity						
Households that implement the Best Available Technology household appliances as identified by Dodoo et al., (2017a, 2017b and 2018)		50%	50%	55%	60%	70%
District heating						
House heating						
Squared metres where indoor temperature is reduced to 20°C		50%	50%	50%	55%	55%
Squared metres where the energy consumption is kept as it is right now		10%	10%	10%	0%	0%
Squared metres where the measures of (Savvidou and Nykvist (2020) are implemented		40%	40%	40%	45%	45%

Source: own elaboration, based on Dodoo et al., (2018, 2017b, 2017a); Eriksson and Spångberg, (2017); Savvidou and Nykvist (2020)

In a seventh step, we calculated the investment needs for 15 alternatives (each of the five Strategy Mixes under the three possible 2030 emissions forecasts). Annual per capita expenditure was obtained by allocating the total investment to each of the 14 years (2017–2030) using population size as a denominator. The advantage of such an approach is that the per capita annual investment need is constant throughout the years for a given scenario and a given Strategy Mix; in other words, the total annual investment will increase by the same rate as the population.

Two additional notes on our calculations: first, we calculated the additional financial investments needed; for some categories, we already assumed a linear increase, using our database 3 “other data” as a baseline. Second, other “hidden” costs such as foregone revenues, accompanying changes in consumption patterns, and their subsequent impact on the financial performance of some businesses are not considered.

The investments were calculated as follows *(1)*:

(1),

$$C_i = N_{2030} CS \frac{P_i}{\sum_{t=2017}^{2030} P_t} \frac{1}{P_i}$$

where $C_i$is the per capita annual expenditure in year i, N_{2030} is the forecasted number of items by 2030 (e.g., the number of private cars and the number of dwellings in the municipality), and P_i represents the population size in the given year. The per-item cost of the measure, C, could be the cost of an electric car or the cost of insulation; the share of items that are affected by the strategy, S, could be the share of electric cars or the share of the dwellings that will be retrofitted.

Our calculation *(1)* can be simplified to

$$C_i = N_{2030} CS \frac{1}{\sum_{t=2017}^{2030} P_t} \quad (2).$$

The total required investment is represented by the numerator in *(2)*, which is then allocated per person in the municipality according to the population size. This calculation does not depend on the time index *i,* meaning that in any year, the necessary annual per capita investment will be the same. This can give rise to conclusions such as: "a household of 2 will have to invest 2*C_i every year in a certain sector to achieve the foreseen emissions reduction. If the household's size increases to 3 in a given year, the household will then have to pay 3*C_i from then on".

In a final step, given the high uncertainty regarding the future costs of the technologies, we provided a +/–5% interval of the final necessary investments. Based on the evidence that green electricity production has become cheaper in recent years, the general view predicts a decrease in green technology costs; however, we cannot rule out that other elements may emerge in the next decade to threaten the economic competitiveness of the measures adopted. For instance, major disruptions along the supply chain, such as a spike increase in the price of raw materials, is a possibility to consider.

2.2. Our sample of cities

Prior to 2020, nine Swedish cities (Gothenburg, Linköping, Lund, Malmö, Nacka, Örebro, Östersund, Västerås and Vellinge) issued a green bond: a labelled financial instrument that requires the issuers (i.e., the nine municipal governments) to review their investment portfolio and to assess which green projects they intend to fund with the proceeds of the green bond (ICMA, 2021). Projects can focus on renewable energy, energy efficiency, pollution prevention and control, clean transportation and so on.

As each city had undergone such an investment assessment, we decided they would be the focus of our Viable Cities' Finance project. To date, we have assessed their climate neutrality plans (Vanhuyse et al., in review), how they engage with research and experimentation (Vanhuyse and Jokiaho, 2021), and their budgets (Vanhuyse et al., 2021). We also reviewed how they engage with sustainability challenges overall (Sjöström et al., 2020).

3. Results

Overall, we calculated 135 possible results. These stem from the three options for 2030 emissions, the five Strategy Mixes, and the nine municipalities, using preliminary 2017 consumption-based emissions at household level, excluding the emissions from local and national governments.

Some of the scenarios, such as Strategy Mix 5 and option 1, Strategy Mix 4 and option 3, and Strategy Mix 5 and option 3, would put the municipalities on track to meet the Swedish government's target of less than 1t CO_2-e per capita by 2045 (Swedish Government, 2017). In Table 2, we provide an overview of the cities and all scenarios, and colour coded under which scenario they would meet the maximum emissions per capita, assuming a linear emission reduction from 2017 to 2045. For example, Gothenburg's per capita emissions in 2030 should maximum be 3,68t CO_2-e per capita, and under scenario 5, 13-15, Gothenburg would be close or below to that target (green). Under scenario 4, Gothenburg would be maximum 5% over the target of 3,68t CO_2-e per capita (orange). Under the other scenarios, scenario 1-3 and 6-12, the city of Gothenburg would be at least 5% over the target of 3,68t CO_2-e per capita.

Out of the nine municipalities, Vellinge would experience the largest reduction in emissions, under all 15 scenarios, given its current high dependency on private cars and air travel. Under Strategy Mix 5 and option 1, BAU, Vellinge could reduce its carbon footprint by as much as 52% compared to 2017. Under Strategy Mix 5 and in option 3, a reduction in emissions, it could reduce its carbon footprint by 48%. The smallest identified reduction is observed in Örebro, under Strategy Mix 1 and option 2, with a reduction of 17%.

Table 2. Associated annual per capita emissions in the 9 municipalities under the 15 scenarios, in t CO_2-e

No	Forecast 2030 x Strategy Mix (SM)	Gothenburg	Linköping	Lund	Malmö	Nacka	Örebro	Östersund	Västerås	Vellinge
Max emissions in 2030 to meet the target of 1t CO_2-e by 2045, under the assumption of linear emission reductions		3,68	3,81	3,75	3,67	3,93	3,69	3,88	3,87	4,13
1	BAU as 2017 x SM1									
2	BAU as 2017 x SM 2									
3	BAU as 2017 x SM3									
4	BAU as 2017 x SM4									
5	BAU as 2017 x SM5									
6	Increase by 2030 compared to 2017 x SM1									
7	Increase by 2030 compared to 2017 x SM2									
8	Increase by 2030 compared to 2017 x SM3									
9	Increase by 2030 compared to 2017 x SM4									
10	Increase by 2030 compared to 2017 x SM5									
11	Reduced by 2030 compared to 2017 x SM1									
12	Reduced by 2030 compared to 2017 x SM2									
13	Reduced by 2030 compared to 2017 x SM3									
14	Reduced by 2030 compared to 2017 x SM4									
15	Reduced by 2030 compared to 2017 x SM5									

Source: own elaboration. Red: at least 5% over the 2030 emission target; Orange: between 2,5% and 5% over the 2030 emission target; green: maximum 2,5% over the 2030 emission target.

The required per capita annual investments vary a lot among the different municipalities because of their heterogenous socio-economic conditions. In Nacka, for example, total annual per capita investment needs are the lowest, at 19 271 SEK under Strategy Mix 1. In Östersund, total annual per capita investment needs are the highest, at 30 083 SEK under Strategy Mix 5.

With regard to the type of stakeholder, we note that in Nacka, under Strategy Mix 1, private citizens need to invest 13 215 SEK per year. In Östersund, under Strategy Mix 5, they need to invest 23 431 SEK per year. The local government's investment share ranges from 1778 SEK per year in Nacka under Strategy Mix 1 to 4709 SEK per year in Örebro under Strategy Mix 5. Industry needs to invest at least 1923 SEK per year in Vellinge under Strategy Mix 1 to 4022 SEK per year in Lund under Strategy Mix 5. Compared to the average total earned income in 2017 in these nine municipalities (SCB, 2021d), we find that private citizens need to invest at least 3% of their annual income in climate mitigation technologies (Nacka) and at most 8% (Östersund).

Figures 2 and 3 depict the preliminary results for the city of Malmö, noting again that the municipal footprint data so far only contain household level emissions, not local or national government emissions. The total mitigation reduction that could be achieved ranges from 17% in the scenario Strategy Mix 1 and Option 1, to 51% for Strategy Mix 5 and Option 3. The per capita investments required range from 19 790 SEK per year to 23 765 SEK per year under these scenarios.
Broken down per type of stakeholder in Malmö, private citizens would be responsible for per capita 14 505 SEK to 17 795 SEK per year; government for 2389–3560 SEK per year; and industry for 2409–3058 SEK per year. When incorporated into costs for houseowners – including mortgages, heating, water, and garbage collection, as well as maintenance and repairs -- retrofitting in Malmö would amount to about 2.0–2.5% of average Swedish household expenditures (SCB, 2021e).

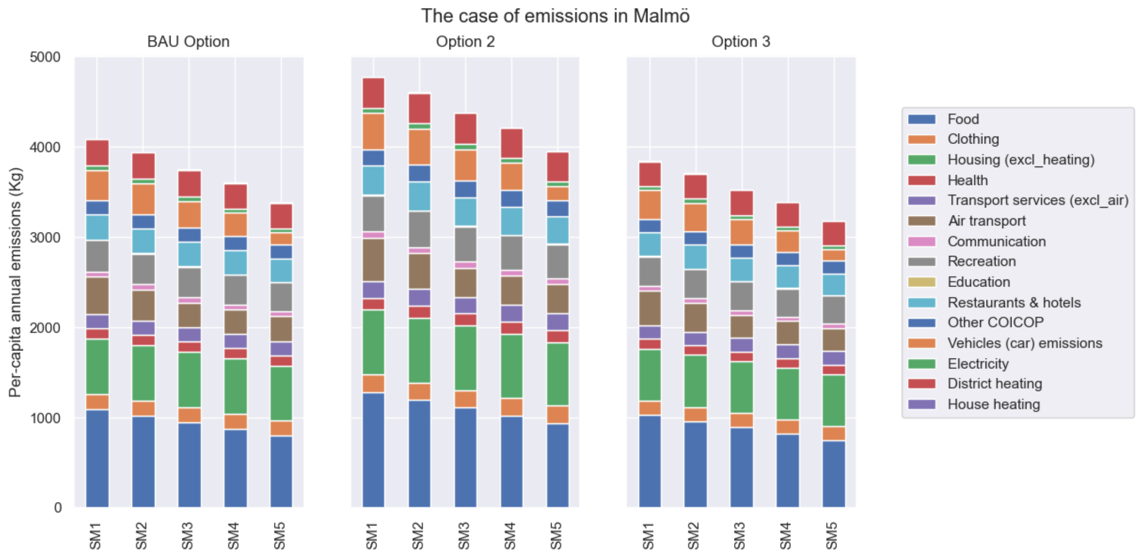

Figure 2. Emissions in the municipality of Malmö under different options and Strategy Mixes (SM)

Source: own elaboration

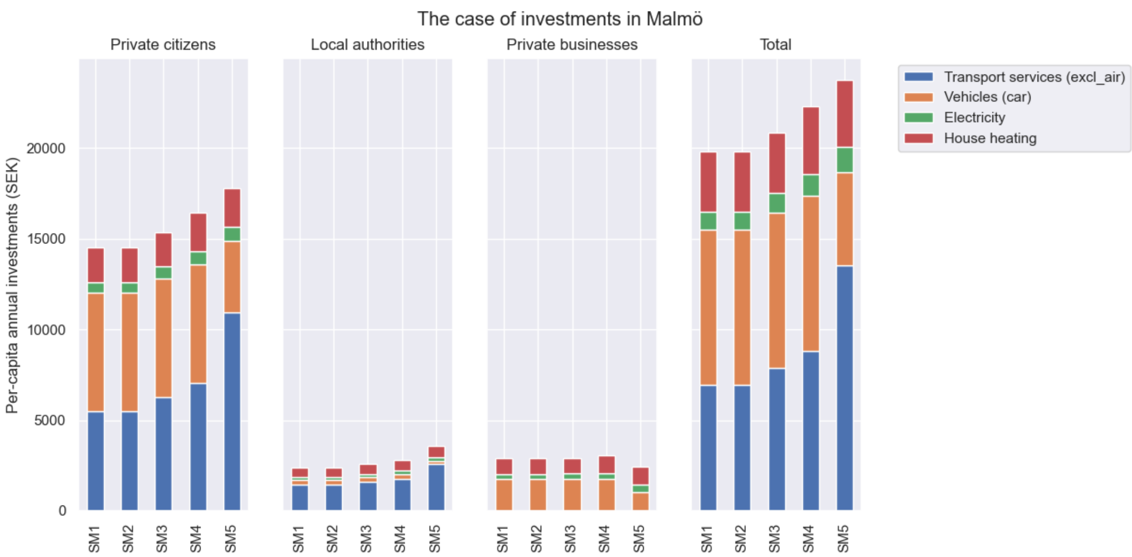

Figure 3. Investments required in the municipality of Malmö for the different stakeholders under the five Strategy Mixes

Source: own elaboration

4. Conclusion

With this paper, we present scenarios to reach climate neutrality and present preliminary calculations of the investments required to meet climate mitigation targets in nine Swedish cities. While our emissions dataset is incomplete, our findings show that meeting Swedish climate targets could be achievable, even though they require a substantial shift in food consumption behaviours. The scenarios also appear to be financially viable. Once full data become available for local and national government emissions, we will revise our calculations accordingly. The mitigation potential and financial costs of the technologies will also be updated at that point. We welcome our readers to provide feedback on our assumptions and model structure.

Further work could also be warranted to fine-tune the Strategy Mixes presented here. In 2022, we plan to hold workshops with municipal governments for that purpose. In addition, deepening the assessment of the viability of the investments required per stakeholders is necessary, to understand whether the level of investments, and as a consequence climate mitigation targets, will be met. Further assessment would foster understanding of whether any groups in society are particularly unable to make the needed investments, and whether national and municipal governments would need to design economic instruments (e.g., subsidies and other support) to assist with the transition.

5. Acknowledgement and data availability

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The dataset used for this calculation originates from the ongoing Formas-funded project "Accelerating Agenda 2030: municipal planning for reduced climate footprints", led by the Stockholm Environment Institute (grant number: 2019-00223). We thank Elena Dawkins for providing us with preliminary emission level data, consisting of household emissions. We will update our calculations as soon as the full consumption-based profiles become available for local and national government contributions. Until then, we are unable to share our model and the data used for the calculations.

6. Author contribution

FV – conceptualization, methodology, validation, writing - original draft, review and editing, supervision

TP – data curation, formal analysis, writing – original draft, review and editing

The authors declare no conflict of interest.

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