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Amman Urban Growth Scenarios:

Pathways Toward a Low-Carbon Future

Final Report

Cover design: CAPSUS.

Acknowledgements

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Glossary.

Urban concerns are the most significant problems that a city faces. These “challenges” can be derived from different sources of information, such as literature review, benchmark comparison, and interviews with experts. Urban concerns are strongly based on the perspectives of the local stakeholders in each municipality.

Possible solutions are urban development projects, instruments, or policies that local stakeholders envision as potential interventions to deal with urban concerns. Possible solutions can be exposed as detailed plans or conceptual ideas. Indicators are numeric values that describe the conditions and issues of a city.

Indicators are any of a group of statistical values (such as urban footprint, energy consumption, and GHG emissions) that taken together demonstrate or suggest the existing state of affairs.

Scenarios are “possible future conditions” that can be projected using statistical models and spatial data. Developing scenarios help forecast what a city will be like in the future. To do so, practitioners analyse historical data and identify the key factors that led the city to its present conditions.

Horizon year is a selected year in the future in which scenarios take place. Defining a horizon year is key to avoiding bias when comparing scenarios. The definition of a horizon year strongly depends on the availability of historical data. Normally, the range between the base year and the horizon year is equal to or less than the range of the historical data.

Urban form describes a city’s physical characteristics. The concept considers the size and shape of the city at all scales. It also comprises the spatial configuration and elements contained within it. Key characteristics of the urban form are 1) population density, 2) the spatial arrangement, patterns, and impacts of buildings and streets, as well as 3) transport infrastructure (Dempsey et al., 2010). Additional attributes are building types, land use, and non-physical features (Dempsey et al., 2010).

The analysis undertakes broad or localised scales, for example, it could determine the spatial arrangement of streets and buildings or characterise the building materials. Infrastructures such as the water and electricity networks also play an important role in the urban form assessment for developing countries (Živković, 2018; Dempsey et al., 2010).

Urban growth scenarios are a system of data and inferences presented as a mathematical and spatial description of a selected area. It is a simulated representation of the characteristics by means of the functioning of another. Each scenario is a specific combination of policy levers.

Scenarios contribute to an efficient communication of urban initiatives. They rely on indicators, which provide a “common language” based on numerical data and represent a consistent, transparent, and systematic approach to urban concerns. Scenarios can serve as a dialog platform between stakeholders. They can be used to assess synergies between initiatives, develop integrated solutions, understand the interdependency of possible solutions, or create a multi-level and multi-sectorial consensus, among others.

Policy levers are the selected interventions and investments that may potentially trigger changes in the performance of a specific area. Policy levers can include investing in new lines for mass transport systems, the penetration of green building codes, containment measures to urban expansion, among others. The performance of the area is presented through different indicators.

Urban Performance calculator includes a database and the indicators estimation processes. The database contains spatial and numeric data related to the urban areas’ conditions in the base year, as well as the information to model the policy levers for the different future scenarios.

Executive summary.

Although Jordan is a small contributor to global greenhouse gas (GHG) emissions, its emissions have rapidly increased in the last four decades. Transport and energy prove to be the two sectors with the highest GHG contribution. The increase in GHG has also been related to the rapid population growth and urbanisation process. GHG emissions are spatially concentrated around urban centres like Amman, Zarqa, Russeifa, and Irbid. Amman, the capital of Jordan, contributes 59.5% to the GDP (Jordan News Agency, 2019), and hosts 40% of the country's population.

The Greater Amman Municipality (GAM) has been transitioning towards climate change mitigation and adaptation strategies. It has developed a comprehensive Climate Action Plan and climate change measures to reduce exposure to environmental hazards and reduce GHG emissions. These strategies have the objective to achieve a resilient city and promote sustainability in the city.

The objective of this project was to provide analytical insights into the Jordan Climate Change Development Report (CCDR), focusing on the urban, transport, and energy sectors. The specific objectives for this analysis are 1) identifying the potential for greenhouse gas emission reduction from urban sprawl and city services, including transport and energy improvements; 2) determining the potential co-benefits associated with the GHG emission reduction strategies; and 3) selecting key urban planning and infrastructure priorities to guide policies and interventions.

The analysis of the city comprised a holistic approach through six steps.

1. **Step 1: Literature review** to recognize previous GHG emission reduction efforts in Jordan and the city of Amman. The literature review focused on key policy documents of the city to identify governmental strategies to tackle climate change and reduce emissions.
2. **Step 2: Working sessions with key stakeholders** to promote participatory processes, training, and capacity building. These sessions were developed with GAM and the World Bank team.
3. **Step 3: Collection of numerical and spatial data** from national and international sources. The consulted documents and spatial information included numerical and statistical data, as well as spatial information (shapefiles, KMZ or KML).
4. **Step 4: Model urban growth scenarios** related to GHG emissions from the urban form, transportation, and energy generation. These represented projections of possible future conditions of Amman. The description of scenarios was:
    a. **The Business As Usual Scenario (BAU)** forecasts how the city would perform in 2050 following the historical population growth and urban expansion trends.
    b. **The Plan Scenario** shows how the city would perform in 2050 according to the expected urban growth, the interventions and policies of the Greater Amman Municipality.
    c. **The Ambitious Scenario** reflects how the city would perform in 2050 with more aggressive solutions to achieve Jordan's INDC and the city's climate objectives. The scenario assumes a broader scope of effort per policy lever.
    d. **The Net Zero Scenario** illustrates how the city would perform in 2050 by reaching zero GHG emissions.

    The modelling processes comprised key indicators which provide a "common language" where scenarios can be evaluated, consistently and systematically.

5. **Step 5: Analyse the policy levers** or selected interventions and investments that may potentially trigger changes in the performance of a specific area. 13 policy levers were selected to assess the urban, transport and energy sector. Each lever has four possible options: a) Portrays the historical development trends, b) Shows planned changes or proposals by GAM, c) Presents recommended policy levers to maximise the benefits and reach the emission targets, and d) Portrays the best-case scenario achieving the net-zero emission goal.

   The policy levers analysed in the report were:

A. Urban expansion	defines the pattern in which the future population will settle, either in defined expansion areas or unoccupied land within the urban area.
B. Renewable energy contribution	analyses solar photovoltaic, wind, biogas, and hydroelectric generation in Amman.
C. Demand-side management	analyses energy measures related to the curtailing of the client's energy demand by numerous strategies, including behavioural changes and financial benefits.
D. Green building codes	analyses the potential contribution of implementing green building measures and guidelines as described in the Jordanian green code.
E. Electricity consumption in public lighting	analyses the required electricity for street lighting and the type of technology in operation (incandescent, LED, smart street lighting, solar, among others).
F. Electrification of transport	analyses the transformation from gasoline and diesel vehicles to electric technology.
G. Mass public transit	analyses an expansion of the public transport routes and an increase of capacity from buses to mass public transit (Bus Rapid Transit - BRT).
H. Pedestrianisation	analyses increased walkability measures and promotion of active mobility.
I. Controlled parking	analyses the implementation of an on-street parking system.
J. Waste management	assess the efficiency measures for the solid waste collection system.
K. Water management	contemplates the coverage of the water network and the water demand.
L. Green spaces and parks	comprises the increase of green spaces, parks, and urban forestry focused on underutilised land as described in the Amman Climate Action Plan.
M. Grey and green infrastructure	comprises green infrastructure to reduce the risks of floods in critical areas.

6. **Step 6: Develop recommendations** to describe the possible outcomes and challenges in terms of climate change mitigation and adaptation, given a historical context.

The scenario modelling analysis compares the performance of the urban, transport, energy sector, and their co-benefits between scenarios. The level of effort for each policy level is summarised in the following table.

Table 1 - Executive Summary. Scope of each policy lever.

Indicator	BAU Scenario 2050	Plan Scenario 2050	Ambitious Scenario 2050	Net Zero Scenario 2050
A. Urban expansion	Historical urban expansion.	Expansion areas forecasted by GAM.	Compact growth within a buffer zone of 2.5 km around the 2020 city boundaries.	A policy of zero urban growth.
B. Renewable energy contribution	No increase of local installed capacity from renewable energies.	Additional 14 MW of installed capacity of renewable energies.	Additional 138 MW of installed capacity, including a renewable energy supply of 60% for street lighting.	100% of renewable energy supply for Amman.
C. Demand-side management	The historical energy consumption trend.	$960 million USD in financial benefits that will potentially reduce energy consumption by 10%.	$1,920 million of USD in financial benefits that will potentially reduce energy consumption by 30%.	$ 2,560 million of USD in financial benefits that will potentially reduce the energy consumption up to 56%.
D. Green building codes	Non-implementation of green building codes.	The implementation of the green building code in 142,200 existing and new buildings.	The implementation of green building codes in 853,200 existing and new buildings.	100% of city buildings implement green building codes.
E. Electricity consumption in public lighting	50% LED street lighting.	100% LED street lighting.	The optimal reduction by replacing 46,600 traditional bulbs with LED technology and 186,300 with solar LED street lighting.	The maximum reduction by replacing 100% lamps with solar LED street lighting.
F. Electrification of transport	A gasoline and diesel transport system.	Electrification of 407,240 cars (50% of total cars), 150 public buses (25%), 100 trucks (10%), and an additional 1,800 2-wheelers (60%).	Electrification of 610,860 cars (75% of total cars), 300 public buses (50%), 240 trucks (25%), and an additional 2,000 2-wheelers (90%).	Electrification of 814,480 cars (100% of total cars), 600 public buses (100%), 960 trucks (100%), and 100% of 3,000 2-wheelers (100%).
G. Mass public transit	No additional BRT routes.	The development of approximately 60 km of BRT routes.	The development of approximately 110 km of BRT routes.	The development of approximately 110 km of BRT routes.
H. Pedestrianisation	No specific corridor development.	Maintenance and safety measures for the existing sidewalks.	The development of a complete corridor of 110 km. It includes the integration of mass public transit with proper sidewalks and bicycle lanes.	The development of a complete corridor of 110 km. It includes the integration of mass public transit with proper sidewalks and bicycle lanes.
I. Controlled parking	No additional parking measures.	200 ha of controlled parking zones.	3,000 ha of controlled parking zones.	3,000 ha of controlled parking zones.

Indicator	BAU Scenario 2050	Plan Scenario 2050	Ambitious Scenario 2050	Net Zero Scenario 2050
J. Waste management	The current waste management system.	12% waste reduction sent to landfills.	50% waste reduction sent to landfills.	70% waste reduction sent to landfills.
K. Water management	The required water network expansion to provide water services in the new areas of the city.	Water efficiency packages in 142,200 existing and new buildings to decrease by 15% the water consumption.	Water efficiency packages in 853,200 existing and new buildings to decrease by 30% the water consumption. In addition, the scenario considers a decrease of 70% in water distribution loss.	Water efficiency packages in all city buildings to decrease by 40% the water consumption. In addition, the scenario considers a decrease of 95% in water distribution loss.
L. Green spaces and parks	No additional parks.	3 new parks (1.5 ha).	7 new parks (2.1 ha)	7 new parks and green infrastructure (87.8 ha).
M. Grey and green infrastructure	No resilient infrastructure.	Phases 1 and 2 of the water drainage infrastructure to reduce pluvial and fluvial floods by 15%	Phases 1 and 2 of the water drainage infrastructure to reduce pluvial and fluvial floods by 15%.	Green infrastructure strategy, and water conveyance to reduce pluvial and fluvial floods by 25%.

Source: Urban Planning Scenarios for Amman, 2022.

Results depicted Amman's performance under the given scenarios and policy descriptions. The analysis compared the estimated future results for 2050.

The 2050 forecast for population density shows that GAM could implement more ambitious efforts to control the rapid urban expansion. Amman will reach more than four million inhabitants by 2050, a roughly 30% increase. The BAU scenario has the lowest population density compared to other future scenarios as the city will likely increase by 339.9 km^2 (59.6%). This land consumption and unregulated population distribution will likely increase by 5% GHG emissions. Under the Plan Scenario, the newly developed zones (214 km^2) will have the lowest population density, increasing the necessity to invest in amenities and social infrastructure. The Ambitious Scenario shows a different pattern. This scenario portrays strict measures for compact growth and promotes densification measures, reaching 70.9 inhabitants per square hectare (19.4% increase in population density from current density and 7.9% in the urban footprint). In the Zero Scenario, densification areas seek to increase accessibility to transportation and promote more active mobility. The population density in the Net Zero Scenario increases by approximately 30% (76.5 inhabitants per hectare).

The BAU and Plan Scenario hold the highest agricultural and natural land loss, with a decrease in green areas per capita. The BAU Scenario will suffer from a 137.9 km^2 loss of natural land and 329.1 km^2 of agricultural land. From the land loss in the Plan Scenario, there is around 11.1 km^2 loss of natural land and 117 km^2 of agricultural land. The Ambitious Scenario has the lowest land loss of the aforementioned scenarios, with 3.7 km^2 of agricultural land loss. With the implementation of densification measures, the agricultural and natural land loss in the Net Zero Scenario will be negligible. Additionally, the BAU, Plan and Ambitious Scenario suffer a decrease in the availability of green areas, from 0.9 m^2 per inhabitant in 2020 to 0.7 m^2 per inhabitant. The increase of green areas in the BAU, Plan and Ambitious Scenarios is limited to a maximum of 3 ha to follow the limited availability of public land, water shortages and maintenance challenges for these areas.

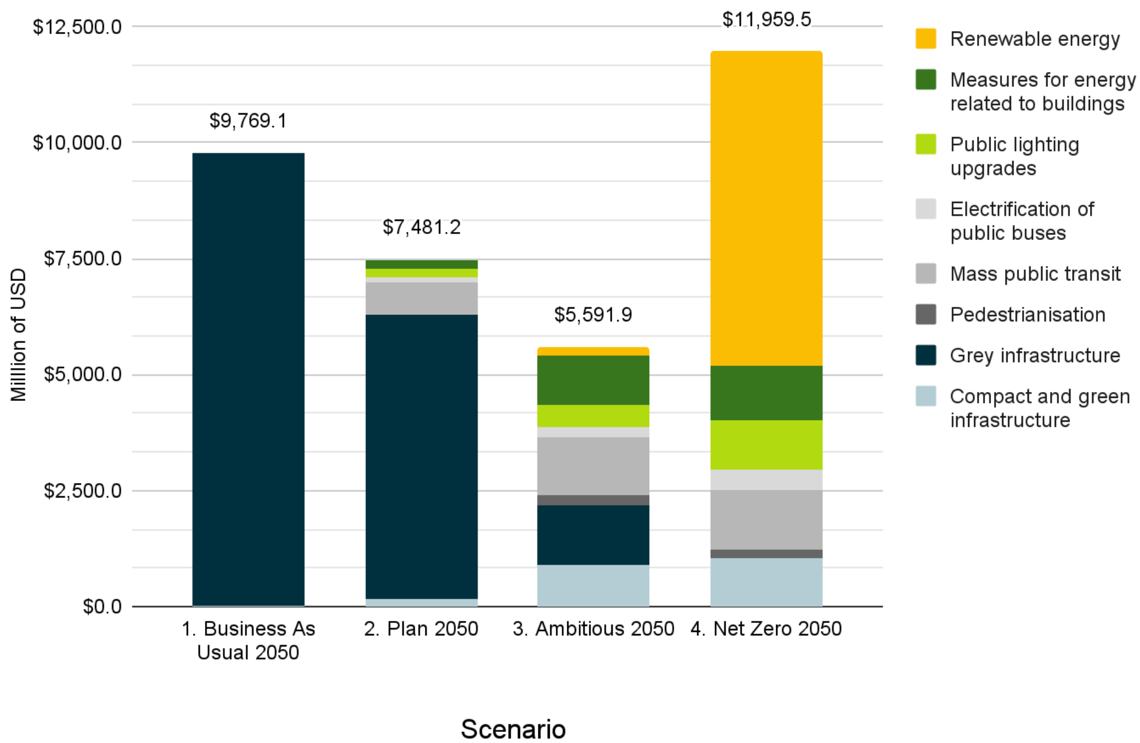
T**he urban form is important to promote more efficient mobility.** For example, proximity to public transportation decreases as the population is more dispersed and has less accessibility to the BRT system. Active mobility planning is limited to more ambitious scenarios. The BAU and Plan Scenario does not include cycling lanes or significant pedestrianisation measures. Proper urban policies may enhance the benefits of the planned infrastructure and generate more interest in more clean means of transportation in the city.

Efforts to reduce energy consumption and transition to a clean energy mix require more ambitious interventions to reach GHG emission reduction goals. The energy consumption related to buildings in the Plan Scenario is similar to the BAU scenario, which indicates areas of opportunities for the planned policies. The percentage of buildings participating in energy programs could bring a significant reduction in electricity consumption, as shown in the Ambitious scenario. The integration of mass transit, pedestrianisation measures, and changing fuel technology to electric vehicles produces a significant decrease in the energy consumption related to mobility. In addition, results show that the urban footprint strongly affects electricity consumption because the city requires more electricity to provide proper street lighting. The bigger the urban footprint, the bigger the demand for electricity-related to this service. The electricity-related wastewater does not change due to the actual capacity of the water treatment plant. Finally, the Net Zero Scenario brings significant changes as a clean energy mix would require decommissioning the non-renewable energy power plants that supply the city, greening the national grid, or creating distributed renewable energy systems to maintain the energy security in Amman.

The reduction of GHG emissions by the Plan Scenario is 12% compared to the BAU, the Ambitious 49%, and the Net Zero Scenario 99%. Amman would require more ambitious goals than those assessed in the Plan Scenario to reach the INDC objective. Policies and interventions need similar scopes as presented in the Ambitious Scenario to reach the national GHG emission reduction goals. On the other hand, to support the Net Zero goals, the municipality needs to double its financial efforts and set innovative solutions to reach a compact growth, proper public transport systems, and a clean and efficient energy sector.

Each scenario requires different financial efforts to reach GHG emission reduction and urban growth. Net Zero goals would require significant financial efforts to GAM, approximately 12 billion dollars. Under this scenario, the cost is particularly related to the transition to a clean energy mix. By contrast, the Ambitious Scenario has an equal distribution in different policies and intervention costs. Thus, the Ambitious Scenario is the less expensive of the analysed future scenarios. The BAU and Plan Scenario require a significant effort to support the economic cost of urban expansion and inaccurate population distribution in the territory. Grey infrastructure cost is above 90% of the total capital expenditures under these two scenarios.

Image 1 - Executive Summary. Total capital expenditure of new infrastructure and local policies.



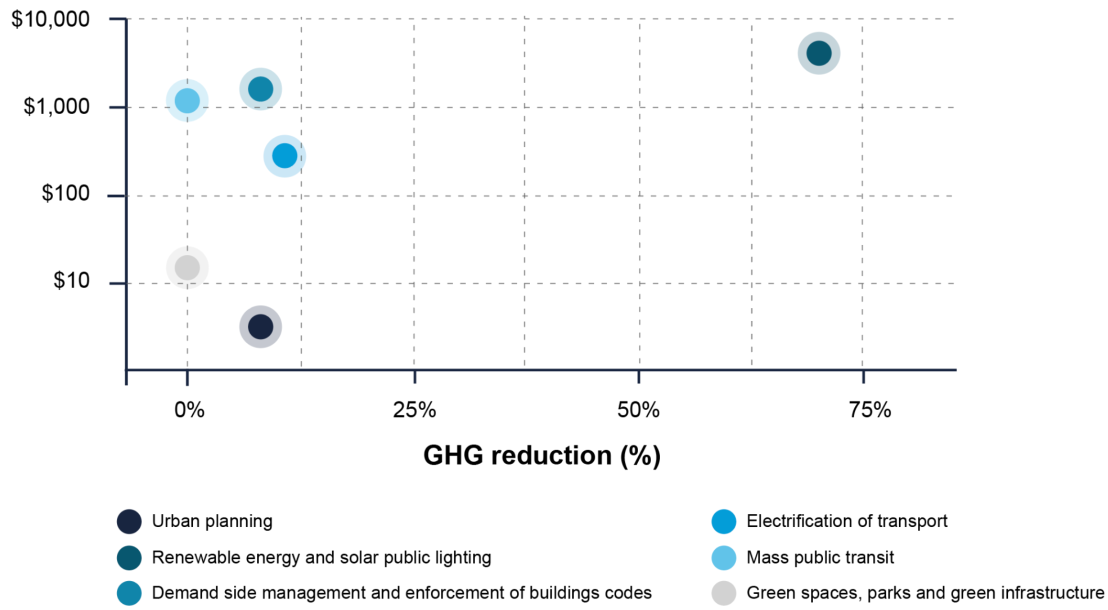
Note: grey infrastructure includes the development of public utilities in the urban expansion areas and provide retrofit in the areas that have a two-fold increase in their population

Source: Urban Planning Scenarios for Amman, 2022.

Co-benefits are proximity to urban facilities, decrease in water demand, efficient waste collection systems and reduction of the population exposed to hazards. Proximity to facilities is relevant for low carbon development, as it reduces commuting time and carbon emissions, promotes active mobility, benefits people's health, and reduces dependency on motorised vehicles. The new mass public transit routes enhance these percentages as the proximity to mass public transit increases significantly in the Plan, Ambitious and Net Zero Scenario. Also, the population exposed to hazards decreases with urban policies and green infrastructure investments. The proximity to facilities is strongly related to the urban footprint and the location of densification areas, thus it benefits from compact growth policies depicted in the Ambitious and Net Zero Scenario.

Synergies provide cumulative effects and boost green and sustainable strategies. Isolated measures could provide significant changes, but the integration of different policy levers produces rapid benefits to the climate change challenges in Amman. For example, the potential for GHG emission reduction from urban planning is up to 7-8% (212 kgCO2eq per capita per annum) and up to 11% in municipal service costs. Demand-side management and the enforcement of building codes could bring an 8-9% of GHG reduction. However, the combined effort of these two policies enhances GHG emission reduction by 50% and increases the benefits of the investments.

Image 2 - Executive Summary. GHG reduction and costs.



Source: Urban Planning Scenarios for Amman, 2022.

Amman will require more ambitious goals to achieve the INDC and net-zero scenarios. For example, the Amman Climate Action Plan and Green City Action Plan outline a collection of measures and policies that reduce GHG emissions. Those plans shape projects, programs, and policy actions tailored to address the most significant environmental issues in the city. However, the goals set under these plans reach 12% GHG emission reduction compared to a Business As Usual Scenario. More ambitious goals could benefit the overall city performance and enhance the benefits produced by the investments.

Background.

Rapid urban growth has become one of the major challenges worldwide. The United Nations estimates that by 2050, 68% of the world's population will live in cities with at least half a million inhabitants (2018). Cities and urban areas are positively associated with health (Helble & Aizawa, 2016), economic growth (Lewis, 2014), and has contributed to rising incomes and poverty reduction in both urban and rural areas (Kashcheeva & Tsui, 2015). Cities are the global foundation of economic growth as the top 100 account for 38% of the global total GDP (Dobbs et al., 2011). Though, it is crucial to understand the key trends of urbanisation of each region, as well as particular necessities to provide a sustainable development approach.

Cities and climate change have a strong relationship, which can facilitate solutions and guide strategies. Climate change is a global phenomenon that largely impacts urban life. Proper urban planning allows the development of compact and inclusive cities, with public transport and low carbon energy systems. Cities will need to plan and adapt to increased exposure to climate risks, for example, severe drought, landslides, food insecurity, storms, among others. These risks will have costly impacts on cities' basic services, infrastructure, housing, human livelihoods, and health (UNEP, 2021). Cities will need to develop low carbon and climate-resilient development, as responses and adaptation to a changing environment.

Coherent and targeted policy actions are needed to reduce total emissions from urban development. Cities are responsible for 75% of the world's carbon emissions and contribute to other major sources of greenhouse gas emissions (UNEP, 2021). Though, greenhouse gas (GHG) emission opportunities are across key sectors, such as urban form, transportation, and energy. Therefore, strategies towards decarbonization require a holistic analysis of transition options.

To address these challenges, decision-makers require a comprehensive urban planning and investment strategy for Greenhouse gas emission reduction. Within a changing global context, initiatives and interventions may be underpinned with the Paris Agreement and the UN Sustainable Development Goals (European Commission, 2018). Energy efficiency and renewable sources, transportation and logistics, reduced land loss, and additional cross-sector interventions can meet up the targets set out in the agreements.

In response to this, the World Bank offered the Hashemite Kingdom of Jordan technical assistance to estimate the Climate Change Development of the city, focusing on urban, transport, and energy sectors. This study is part of a set of efforts through scenario modelling. The Urban Growth Scenarios is a project developed in coordination with the Ministry of Planning and International Cooperation and the Ministry of Municipal Affairs, where Jordanian cities can discuss the cross-sector effects of public policies, create consensus, and make informed decisions that contribute to the sustainable development objectives of the key sectors and cities in the country.

2

Context and rationale

Urban Growth Model and Sustainable Urban Expansion

for Hashemite Kingdom of Jordan

Context and rationale.

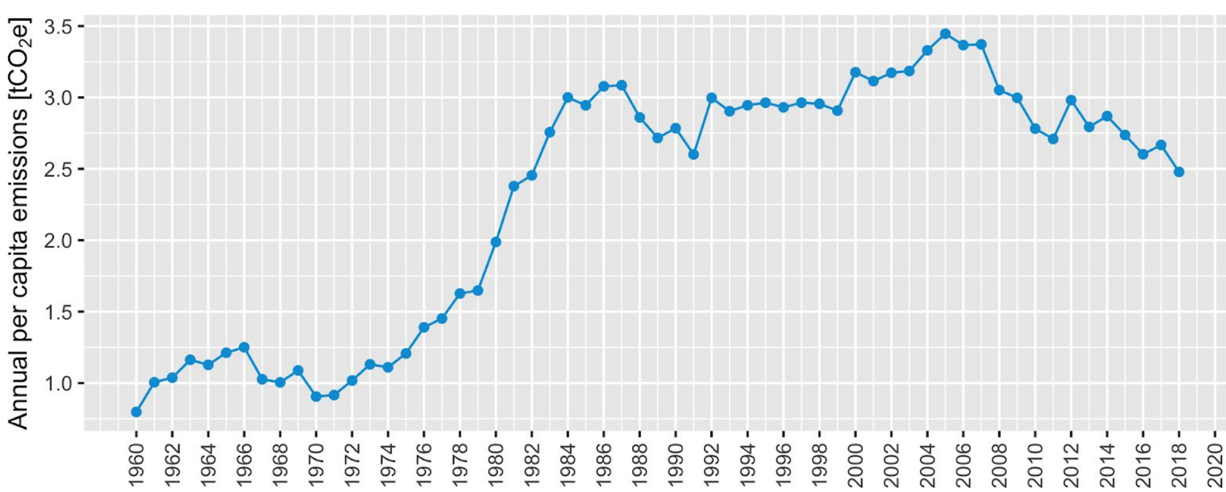
Climate change

The Middle East and North Africa (MENA) region is highly sensitive to climate change. Rapid urbanisation and climate change are expected to increase pressure on urban systems. Around 65% of Jordan's population lives in urban areas and it is projected to increase 33% by 2050 (The World Bank, 2022).

To tackle the increasing pressure of climate change hazards, and to improve services and livelihoods, urban areas are innovating towards green growth solutions. As part of GCAP initiatives, Saudi Arabia, Lebanon, and Yemen are taking actions and plans that seek to achieve mitigation co-benefits from ambitious emissions reduction. For example, Saudi Arabia's goal is to reduce up to 50 percent of their equivalent carbon dioxide (CO_2e) emissions, and according to UNDP reports, they have achieved to implement almost 70 percent of climate change mitigation measures, and 90 percent of adaptation measures are undertaken by local governments (KSCLG, 2022; Riyadh, 2015). Similarly, Lebanon is actively engaged in the fight against climate change through a network of private companies (UNDP, 2016).

Jordan has embraced climate change mitigation goals and has made significant progress, but its urban policy still has improvement opportunities. Despite Jordan's relatively low GHG emission, from 1980-2018 its emissions rapidly increased from 5.5 to 35.8 million tonnes of CO_2e as shown in Image 1. Recently, the mitigation measures of the country have had a positive impact on the country's per capita GHG emissions, as can be seen from a gradual decline of 36% during the last 15 years (The World Bank, 2021).

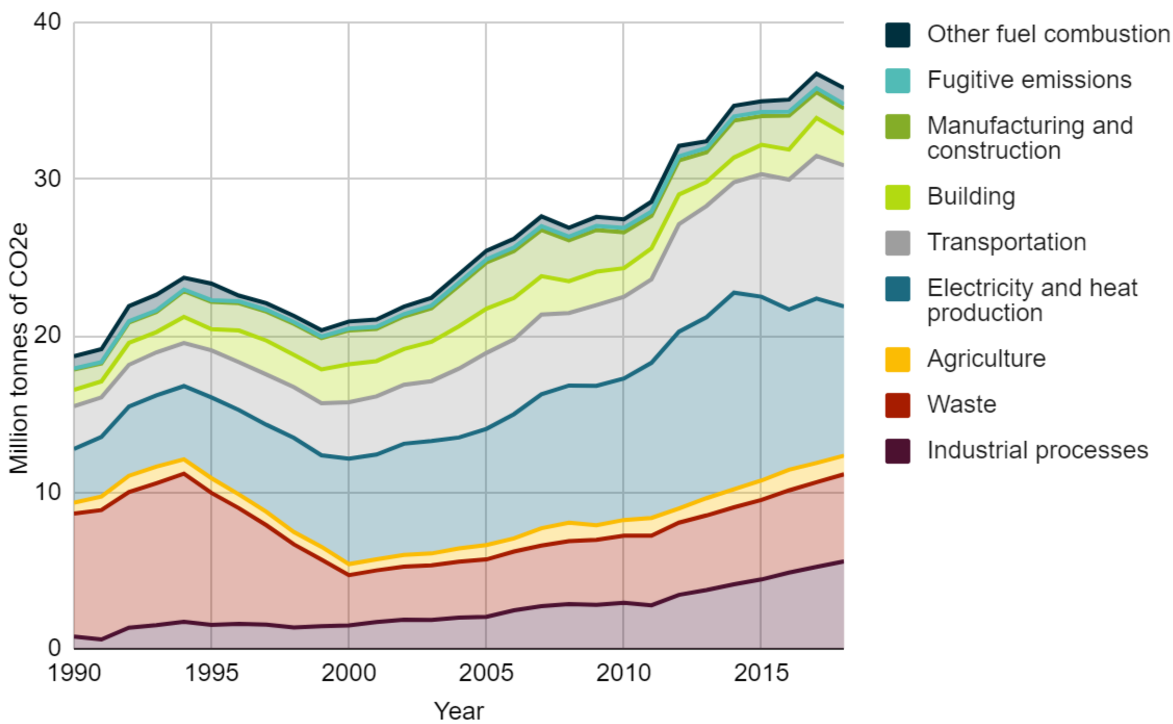
Image 1. Historical GHG emissions in Jordan.



Source: Data for up to 1990 are sourced from Carbon Dioxide Information Analysis Centre, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States. Data from 1990 are CAIT data: Climate Watch. 2020.

The sectors with the highest GHG contribution in Jordan are transport and energy. Both sectors had a steady increase which totals 18.7 million tonnes of CO_2e in 2016 (around 51% of total national emissions[1], as shown in Image 2). The country has invested in energy measures to increase the energy mix and achieve 80% of natural gas generation. This measure created a slight dip in emissions from 12.6 to 10.4 million tonnes of CO_2e between 2014 and 2016.

Image 2. GHG emissions per activity in Jordan.



Source: Data from the Climate Watch Data Portal, 2022.

Amman, the capital city of Jordan, has developed a comprehensive Climate Action Plan, but complementary measures are needed for reducing exposure to environmental hazards, improving water and energy efficiency, and upgrading waste management. In addition, cross-sector policies can potentially improve adaptation and mitigation activities, supporting transport policies, and resilient measures or preparedness for refugees' emergencies.

Population

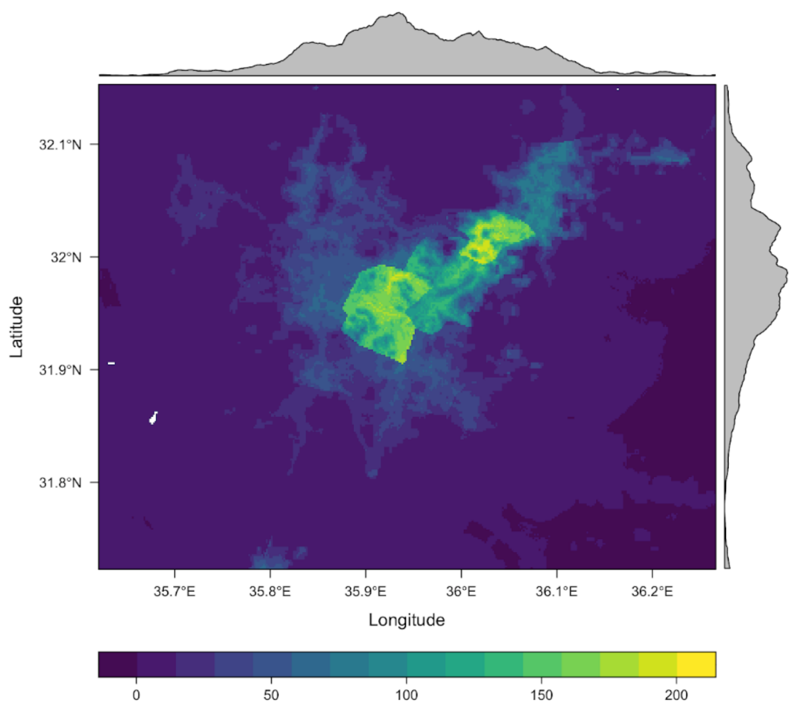
Jordan and its cities are experiencing increasingly rapid population growth. By 2021, the country's total population was 10 million inhabitants (The World Bank, 2022). But this trend has also been influenced by the refugee crisis[2] occurring in the Middle East. This demographic transition, with increased population and expected life expectancy, has meant major urban planning issues for Jordan cities, such as Amman, which have seen their population almost double during this decade. The total population of Amman in 2020 was 3,384,367 inhabitants (40% of the country's population) with a population density of 59.4 inhabitants per hectare. The

[1] The total CO2e emissions are around 36.82 tons.

[2] During 2011 and 2014 occurred the latest migration of 600,000 Syrian refugees.

spatial analysis depicts a higher density of population in the centre and the north-eastern part of Amman as shown in Image 3.

Image 3. Population density in Amman.



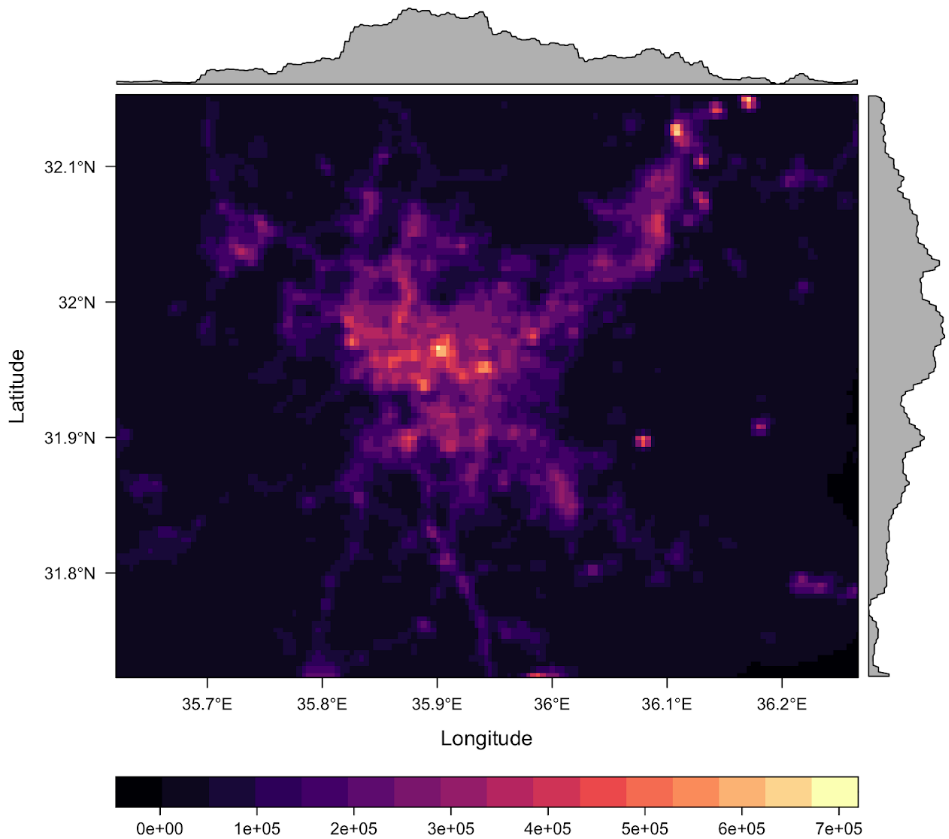
Source: Data from WorldPop, 2020.

Economic activity

Amman adds a significant percentage to the Gross Domestic Product (GDP) and exercises control over political responsibilities. During 2016, Amman contributed 59.5% to the GDP (Jordan News Agency, 2019). It is managed by the Greater Amman Municipality Council, which includes 37 members headed by the Mayor. The Council is responsible for planning town and streets, managing building licences, constructing public markets, public spaces, and parks, preventing flooding, protecting infrastructure, managing cultural and sports institutions, and spending the Municipality funds, among others. (Greater Amman Municipality, 2008)

Economic activity concentrates on the central part of the metropolitan area of Amman and extends towards Russeifa and Zarqa in the Northeast. Economic activity also concentrates in the Southeast in the vicinity of Queen Alia International Airport and towards Madaba, in the Southwest, as shown in Image 4. To identify economic clusters, GDP data from The World Bank Development Indicators (2022) and night-time light intensity from NOAA via WorldPop, 2020 were crossed.

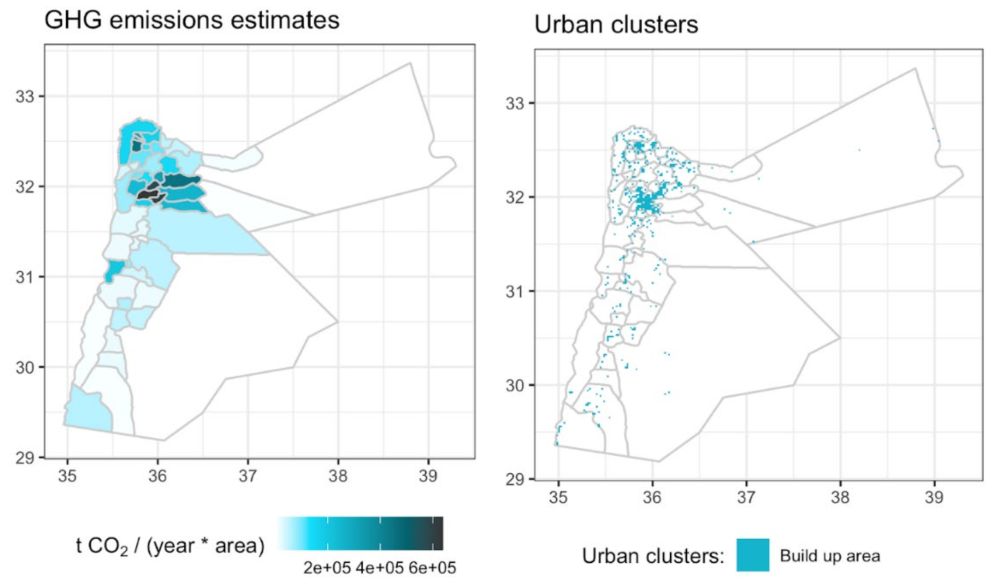
Image 4. Economic clusters.



Source: Data from NOAA via WorldPop, 2020.

At a territorial level, GHG emissions are spatially concentrated around urban centres like Amman, Zarqa, Russeifa, and Irbid. Image 5 shows GHG concentration estimates for the governorate in Jordan (left) and the location of main urban clusters (right). As can be seen from the figure, emissions are aligned with the location of urban clusters, with the highest concentration in the northern part of the country, where the largest cities are located; and extends to the south towards Aqaba.

Image 5. Spatial distribution of GHG emissions and urban clusters.



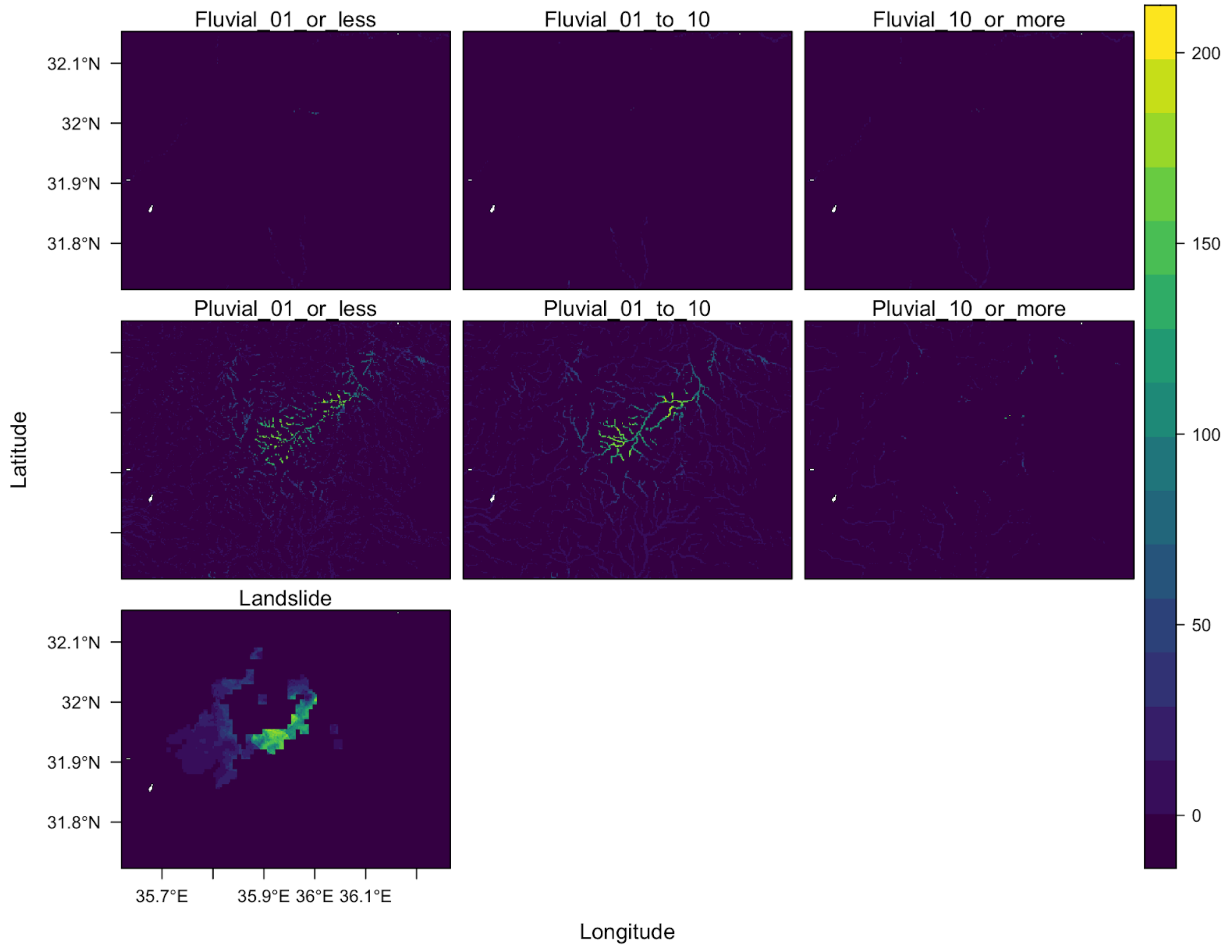
Source: Emissions estimates were developed with data from Emissions Database for Global Atmospheric Research. Area units are 0.1 x 0.1 degree. Build up area was retrieved from WorldPop, 2020.

Exposure to hazards

Regarding the geographical context, Amman is spread north of Mathaba and south of Zarqa. The city topography varies from 1,050 m in the West to 850 m in the east. The multiple hills and wadis increase infrastructure delivery. Amman is crossed by a climatic gradient. Its eastern part is semi-arid, under the 250 mm isohyet. It used to be pastoral land before the 1950s. Land in the west of Amman is fertile and privately owned. Amman has suffered rapid urban growth and loss of land.

Image 6 shows the spatial distribution of the population in Amman that is exposed to fluvial flooding, pluvial flooding, and landslides. Each column in the figure represents a different return period. The first column states the probability that a hazardous event occurs in a 100-year period. The second shows the probability that an event occurs between 100 and 10 years. Finally, the third column shows the probability that an event occurs every 10 years or less. Considering that each extreme event results in temporary relocation in affected locations for at least three days, the annual costs reach 67.2 million USD per year, affecting 1.7% of Amman's population. Calculations are based on return periods for each hazard. For climate hazards, the team used data from the Urban Climate Risk Analysis report for Jordan, from GFDRR City Resilience Program. The spatial distribution of the population was developed with data from WorldPop, 2020.

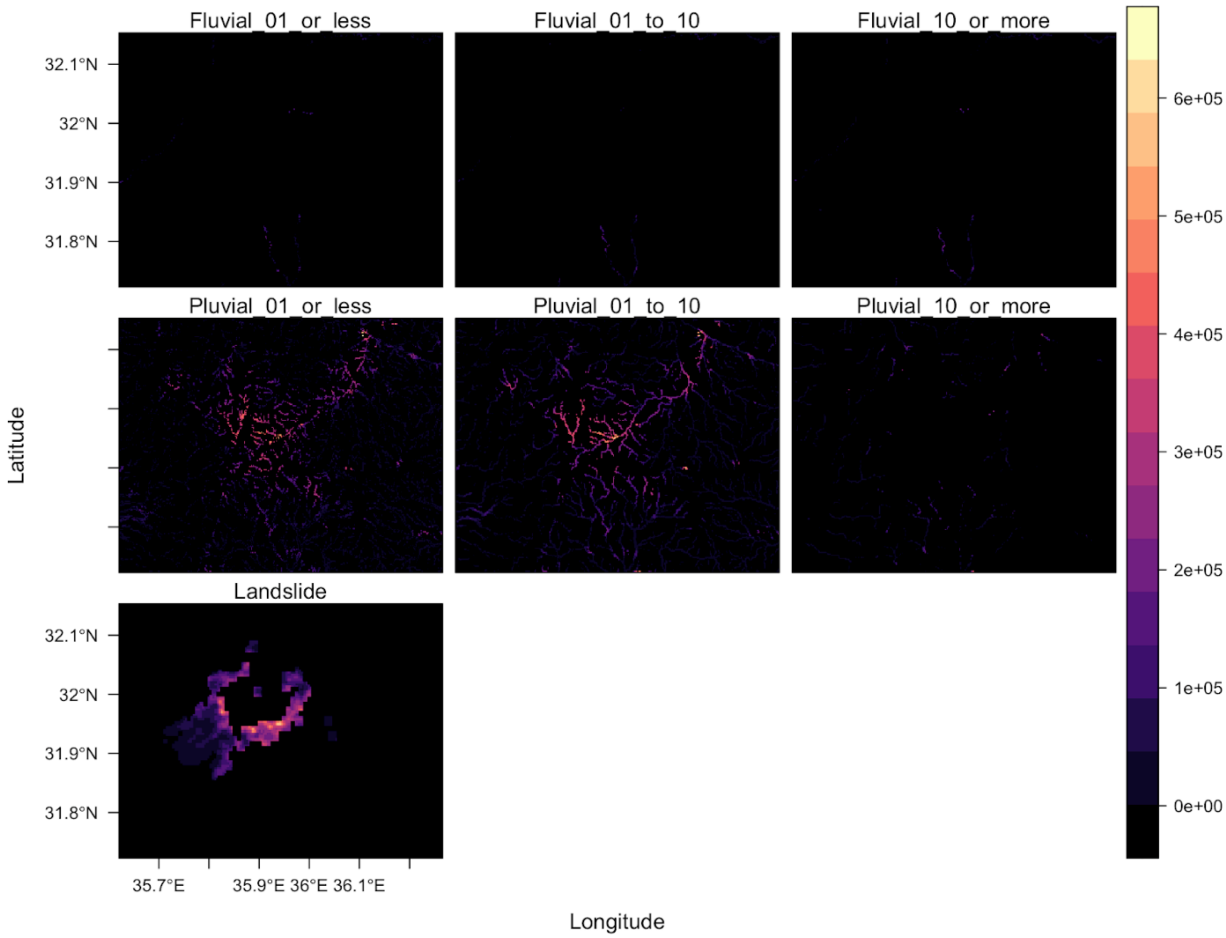
Image 6. Population in Amman is exposed to hazards.



Source: Hazards data from GFDRR, 2022; and Population data from WorldPop, 2020.

Image 7 shows the spatial distribution of GDP in Amman that is exposed to fluvial flooding, pluvial flooding, and landslides. Each column in the figure represents a different return period similar to Image 6. As can be seen from the figure, the highest exposure occurs in the central part of the metropolitan area. Considering that each extreme event stops economic activity in the affected location for three days, with no risk mitigation measures, Amman could lose 5.7 million USD per year in productivity. Calculations are based on return periods for each hazard. The spatial distribution of GDP was developed with data from the World Bank Group, Development Indicators, 2022, and from NOAA via WorldPop, 2020. For climate hazards, we used data from the Urban Climate Risk Analysis report for Jordan, from GFDRR City Resilience Program.

Image 7. Economic activity in the city that is exposed to hazards.



Source: Hazards data from GFDRR, 2022; Nighttime lights data from NOAA via WorldPop, 2020 and GDP data from World Bank Group, Development Indicators, 2022.

Though the city has the risk of flash floods, the groundwater levels have dramatically declined in Amman. Water shortages are an ongoing stress for the city, and it is a significant challenge to achieve a resilient city (Shawarbeh et al., 2020). Also, the increasing population and limited water-saving measures had boosted the resource strain. The Green Climate Action Plan of Amman states that the actual water extraction is likely to generate a water shortage that could constrain economic growth and potentially endanger public health (Greater Amman Municipality, 2019).

Objectives and scope.

The objective of this project is to **provide analytical insights to the Jordan Climate Change Development Report (CCDR)** focusing on urban, transport, and energy sectors, and other related activities being carried out by the World Bank on climate change and cities in Jordan.

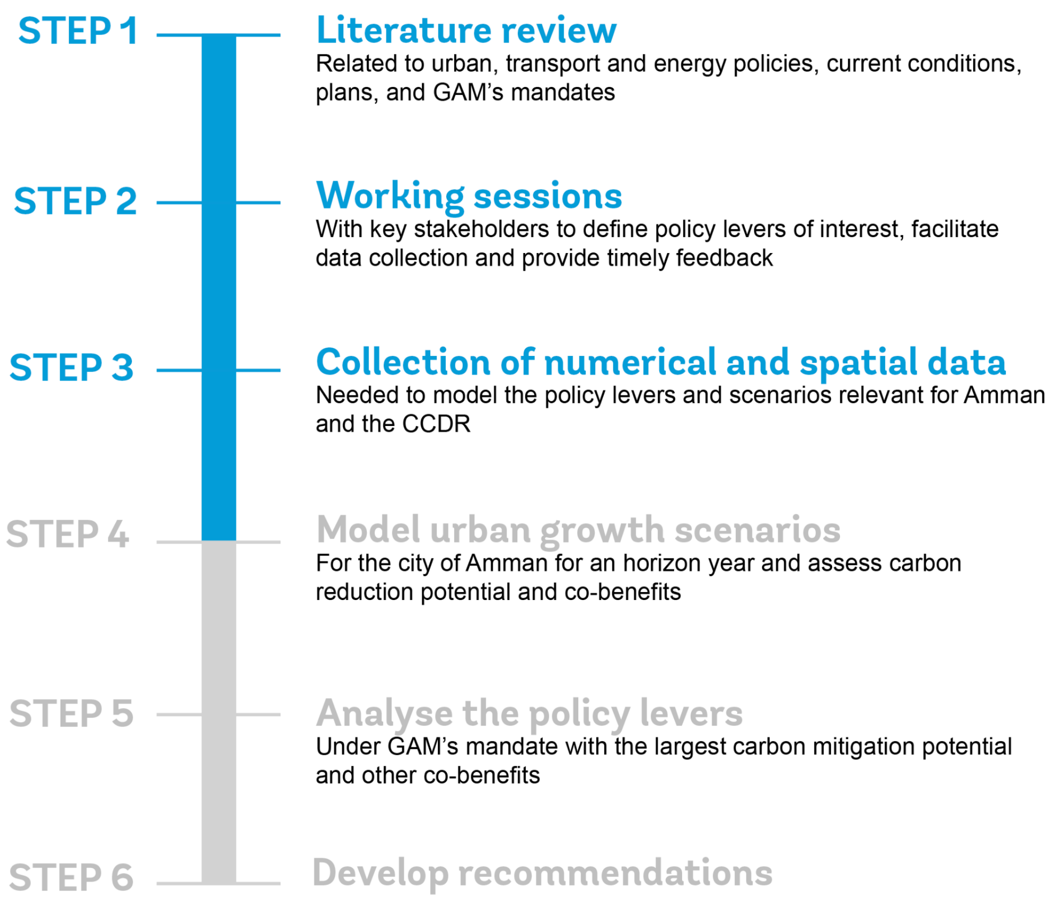
The analysis and recommendations are developed using tools and methodologies to assess spatial and sectoral linkages across Amman and neighbouring cities. The specific objectives for this analysis are:

1. Identify the potential for greenhouse gas emission reduction from urban sprawl and city services, including transport and energy improvements.
2. Determine the potential co-benefits associated with the GHG emission reduction strategies.
3. Select key urban planning and infrastructure priorities to guide policies and interventions.

Methodology.

The analysis of the city comprised a holistic approach through six steps: literature review, working sessions, collection of numerical and spatial data, model urban growth scenarios, analyse the policy levers and develop recommendations. The process included retrieving and reviewing the latest published information available, developing the collection and analysis of numerical and spatial data as inputs for the modelling process. After defining the investment projects and public policies that influence an urban cluster's development, results were obtained by the modelling exercise. The output of the analysis is a set of final recommendations of interventions and policies that the government of Amman could implement to enhance the existing effort of emission reduction. This section comprises the description of the six steps shown in Image 8.

Image 8. Methodology of the urban growth model and sustainable urban expansion.



Step 1: Literature review

This step consisted of recognizing previous GHG-emission reduction efforts in Jordan and the city of Amman. The literature review focused on key policy documents of the city to identify governmental strategies to tackle climate change and reduce emissions. This review included the following documents:

- Amman Green City Action Plan,

- Amman Resilience Strategy,
- Amman Climate Plan for 2050,
- Smart City Roadmap,
- Amman Resilience Strategy,
- Transport and Mobility Master Plan for Amman,
- The Second National Energy Efficiency Action Plan (NEEAP) for the Hashemite Kingdom of Jordan, and
- Hashemite Kingdom of Jordan Intended Nationally Determined Contribution (INDC).

This information defined the strategies assessed for the 2050 scenario. Also, the literature review guided the recommendations by providing political context, strengths, and areas of opportunity within the existing climate change strategy in the city.

Step 2. Working sessions

The process included working sessions with key stakeholders to promote participatory processes, training, and capacity building. These sessions were developed with the Greater Amman Municipality (GAM) and the World Bank team to define key aspects of the project development and modelling exercise. For example, the policy levers of interest, numerical data, and feedback on key messages or strategies taken by the authorities. All these elements were in conformity with the expected outcomes and the objective of the project.

Step 3. Collection of numerical and spatial data

The process included data collection from national and international sources. The consulted documents and spatial information included numerical and statistical data, as well as spatial information (shapefiles, KMZ or KML), including data from

- ➔ The Department of Statistics of Jordan (http://dosweb.dos.gov.jo/)
- ➔ The Intended Nationally Determined Contributions (INDCs; https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Jordan%20First/Jordan%20INDCs%20Final.pdf)
- ➔ WorldPop (https://www.worldpop.org/)
- ➔ Opens Street Maps (https://www.openstreetmap.org/)
- ➔ GFDRR City Resilience Program, Urban Climate Risk Analysis report for Jordan
- ➔ EDGAR (https://edgar.jrc.ec.europa.eu/)
- ➔ Climate Watch (https://www.climatewatchdata.org/)
- ➔ The Executive Action Plan of Jordan Energy Strategy 2020-2030
- ➔ Summary of Jordan Energy Strategy 2020-2030

The dataset was complemented with the following key inputs from the Amman Plan: Metropolitan Growth Report, the Amman Action Plan 2050 and the Amman Green City Action Plan. The retrieved numerical and spatial information included the following: population, population projections, employment statistics, current land uses, public transportation, characteristics of utilities coverage and efficiencies, energy consumption, and energy mix, among others.

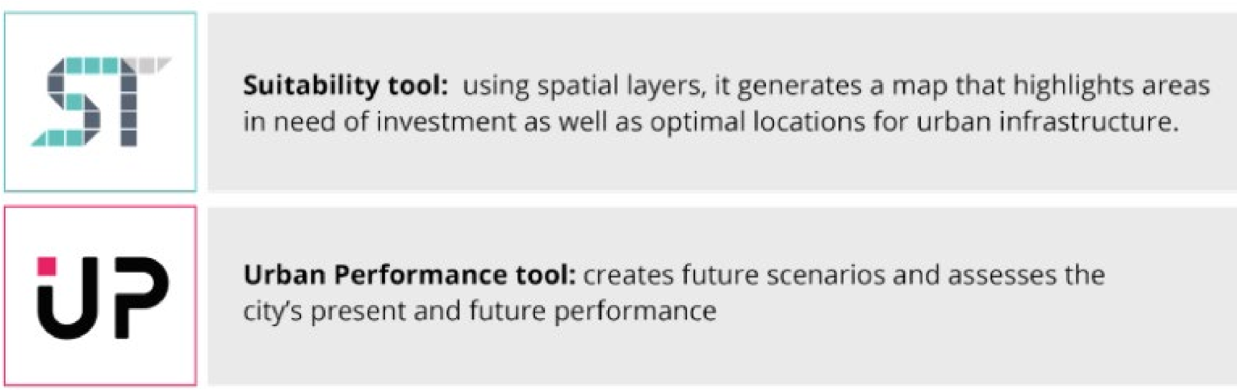
Step 4. Model urban growth scenarios

This step consisted in developing the urban growth scenarios, which represent projections of possible future conditions of an area of study. The scenarios were built either with (i) statistical models and spatial data, such as the analysis of historical trends, the identification of key intervention drivers for urban expansion and emission generation; or (ii) with a programmatic approach, in which stakeholders specify "what-if" conditions for the city. The urban growth scenarios portray different urban planning paths, enabling public officials and leaders to compare potential consequences and make informed decisions about future growth.

The modelling process comprised the analysis of the three categories related to GHG emissions: urban form, transportation, and energy generation and consumption. The results from the numerical and spatial data provided the parameters to acknowledge the potential for greenhouse gas emission reduction, development challenges, and the significant co-benefits. The urban form analysis described the characteristics and changes of land cover and the urban footprint. The transportation analysis identified the available routes of public transport in the city and the usage and elasticity of the different modes of transportation. Finally, the energy sector analysis outlined energy efficiency in public lighting, the energy mix from the city, and Building Codes to reduce energy consumption and emissions.

The research, analysis, and design protocol followed during this stage was based on the comparison of the urban performance between two or more urban growth scenarios. To analyse the different urban development strategies, two urban planning tools (UPTs) were used: The Suitability tool and the Urban Performance tool.

Image 9. Urban planning tools.



The scenarios were defined by establishing a baseline and alternative scenarios that combined the policy levers to obtain projections to a horizon year. The baseline or Base 2020 analysis was a collection of spatial and numeric data that sets the starting point or initial set of data used to model the policy levers and scenarios relevant for Amman and the CCDR. This layer of analysis was not considered a scenario because the results portray the city characteristics in 2020. This means that all future scenarios used 2020 as a base year and forecast to 2050 as the horizon year. The alternative scenarios are described as follows:

Business as Usual - 2050

The Business as Usual (BAU) scenario forecasts how the city would perform in 2050 following the historical population growth and urban expansion trends. The scenario adopts the patterns observed between 2000 and 2020. The analysis excludes public policies and interventions that support the city's sustainability. This implies that the renewable energy generation, infrastructure quality, and the number of amenities remain the same as in 2020. However, the BAU scenario includes the development of public utilities required to supply new urban areas, for example, new roads, public lighting, electricity, water, and sewage networks.

Plan scenario - 2050

The Plan Scenario shows how the city would perform in 2050 according to the expected urban growth by the Great Amman Municipality (GAM). The scenario shows the interventions and policies determined in the action plans for sustainable development agreed by GAM. The selection of interventions and policies was based on the sectors with the highest GHG contribution in the country: the urban, energy, and transport sectors. The main policy levers comprise city expansion, green building codes, energy efficiency measures, and carbon-efficient mobility systems. The Plan Scenario uses geospatial information provided by GAM.

Ambitious scenario - 2050

The Ambitious Scenario reflects how the city would perform in 2050 by implementing the proposed actions to achieve Jordan's NDC. It builds upon the results from the Plan Scenario and models more aggressive scopes for the policies and interventions to reach a reduction of 31% by 2030 from 2012 emissions (Ministry of Environment, 2021). Policies were focused in the energy, transport, and water sectors, with additional efforts to reach the national goals for GHG emissions. The scope of interventions was based on internal discussion between the World Bank and CAPSUS.

Net Zero - 2050

The Net Zero Scenario illustrates how the city would perform in 2050 by reaching zero GHG emissions. The scenario depicts the pathway to achieve roughly net zero emissions from the urban, energy and transport sectors. The scenario has the major air quality improvements, and it is consistent with limiting the global temperature rise to 1.5 °C (IPCC, 2018). The levers promote existing green technologies, endorse proper and clean mobility systems, and aim for resource efficiency. Thus, the interventions and policy levers were designed to reach net-zero emissions.

Scenarios for sensitivity analysis - 2050

In addition, two scenarios were developed as sensitivity analyses. The Shared Socioeconomic Pathways 1 and the Shared Socioeconomic Pathways 5. These scenarios are a collection of pathways that describe alternative futures of socio-economic development in the absence of climate policy intervention (IPCC, 2022). The parameters and definitions were developed by the IPCC to provide a useful integrative frame for climate impact and policy analysis (IPCC, 2022). Emissions scenarios present climate change projections based on climate impacts and adaptation measures (Riahi, *et al.*, n.d.).

The Shared Socioeconomic Pathways 1 (SSP1) estimates a gradual shift towards a more sustainable path that respects perceived environmental boundaries. This means that Amman will encounter low challenges to mitigation and adaptation. The SSP1 considers the regional stage of urbanisation and development including low material growth and lower resource and energy intensity (Hausfather, 2018; International Institute for Applied Systems Analysis, 2018).

The definition of SSP1 is based on the Sustainability – Taking the Green Road pathway which shows how cities would perform in 2050 according to the land use and urbanisation established (Hausfather, 2018). Also, it forecasts the changes according to the green building code and energy efficiency measures, and the carbon-efficient mobility system detailed for the Master Plans and Action Plans.

The Shared Socioeconomic Pathways 5 (SSP5) is a fossil-fuelled development pathway in which the global economy grows rapidly, but people face severe mitigation challenges. This means that Amman will encounter high challenges to mitigation but perform low challenges to adaptation. The SSP5 considers the regional stage of urbanisation and development including competitive markets, innovation, and participatory societies to produce rapid technological progress and development (Hausfather, 2018; International Institute for Applied Systems Analysis, 2018).

The definition of SSP5 is based on the Scenario of Fossil-fuelled Development – Taking the Highway pathway which shows how the city would perform in 2050 according to land use and urbanisation. Also, it forecasts the changes according to the green building code and energy efficiency measures, and the carbon-efficient mobility system detailed for the Master Plans and Action Plans.

List of indicators

The list of indicators used for this project was defined in terms of assessing the current and potential status of the urban, energy, and transport sector. The analysis comprises context-specific indicators, such as population density, energy consumption, GHG emissions or proximity to facilities, which provide a "common language" where scenarios can be evaluated both consistently and systematically.

The analysis took a broad scale of the urban form of Amman and indicators were based on key features of the urban form concept. The urban form considers the size and shape of the city based on the spatial configuration and elements contained within it. The analysis of the potential for GHG reduction and co-benefits comprises the elements of urban form, their relation with energy, transport and related sectors.

URBAN FORM

Describes a city's physical characteristics

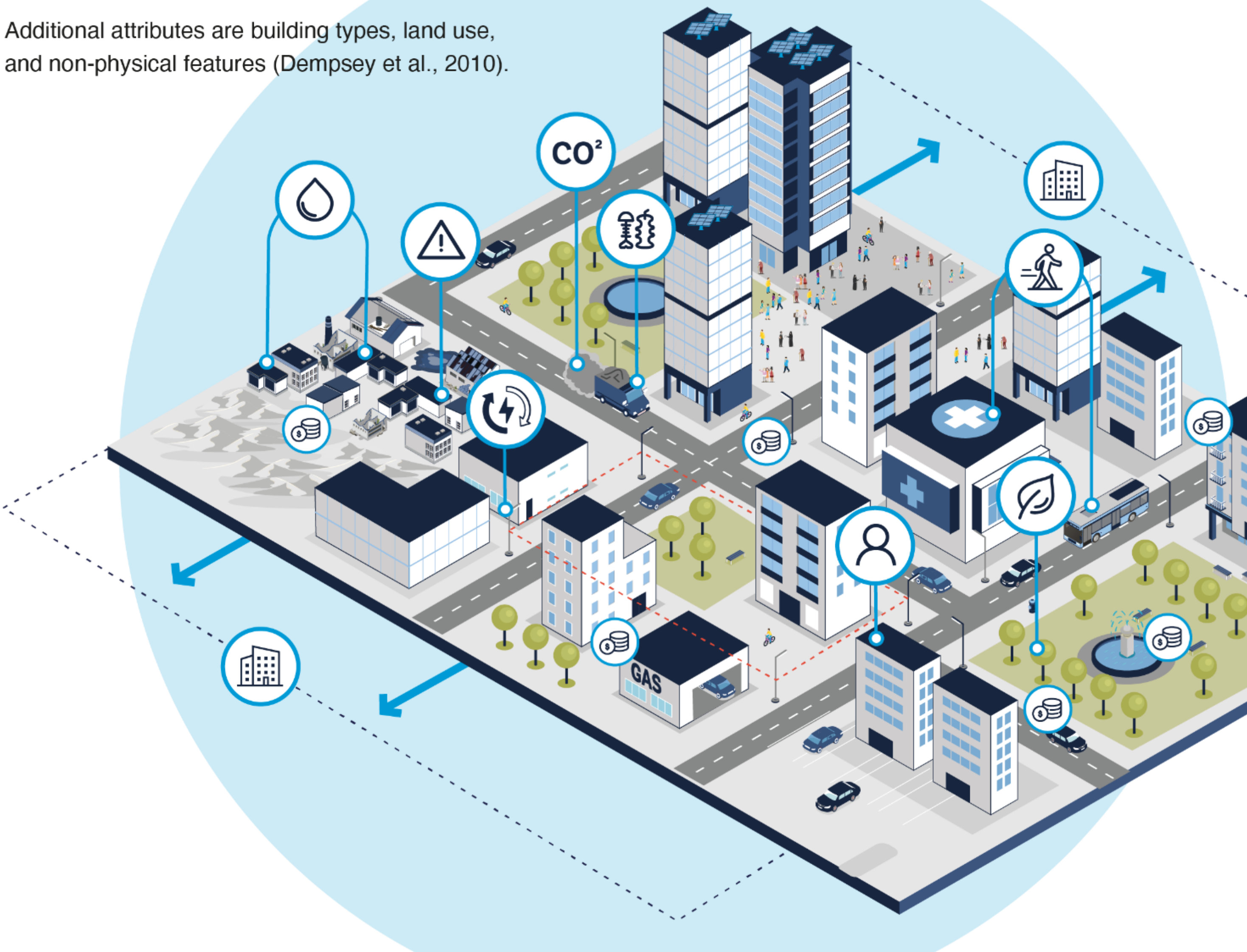
The concept considers the size and shape of the city at all scales. It also comprises the spatial configuration and elements contained within it. Key characteristics of the urban form are:

1) Population density

2) Spatial arrangement, patters and impacts of buildings and streets

3) Transport infrastructure

Additional attributes are building types, land use, and non-physical features (Dempsey et al., 2010).



Indicators

- Land consumption
- Population density
- Green areas per capita
- Energy consumption
- Greenhouse gas emissions
- Costs
- Solid waste coverage
- Water demand
- Proximity to facilities
- Population exposed to hazards

Additionally, the results include renewable energy characteristics of the city given the relation of clean energy generation and GHG emissions. The detailed list of indicators used in the analysis and presented in the section of Potential for greenhouse gas emission reduction are:

Land consumption

Population density

Green areas per capita

Energy consumption
- Commuting energy
- Energy related to buildings
- Electricity related to public lighting
- Electricity related to water and wastewater

Renewable energy

Greenhouse gas emissions

Solid waste coverage

Costs
- Municipal service costs
- Infrastructure infill costs
- Infrastructure expansion costs
- Capital investments

Water demand

Step 5. Analyse the policy levers

Policy levers are the selected interventions and investments that may potentially trigger changes in the performance of a specific area. Policy levers of the project included investments in new lines for mass transport systems, the penetration of green building codes, containment measures to urban expansion, among others. The modelling exercise assessed the impacts and benefits from each policy lever and the performance of the city was presented through the above-mentioned indicators.

Each scenario models the estimated impact of policy levers established by different stakeholders. These policy levers were defined in coordination with the local authorities and complemented with international experience, creating new levers or enriching those identified with local counterparts. Also, the scope and details of the policy levers for each scenario were based in local and national Action Plans and Master Plans. Table 1 presents the main sources used to define the policy levers of each scenario.

Table 1. Main sources for policy lever definition.

Baseline or scenario	Main sources
Business As Usual – 2050	The scenario does not promote green public policies and interventions. The historical trends were based on population statistics from the Department of Statistics of Jordan and spatial information.
Plan Scenario – 2050**	**1.** Amman Green City Action Plan published in 2021 by AECOM. **2.** The Amman Climate Plan a Vision for 2050 Amman published in 2019 by the Greater Amman Municipality. **3.** Transport and Mobility Master Plan for Amman published in 2010 by the Greater Amman Municipality.
Ambitious Scenario - 2050	**1.** Amman Green City Action Plan published in 2021 by AECOM. **2.** The Amman Climate Plan a Vision for 2050 Amman published in 2019 by the Greater Amman Municipality. **3.** Transport and Mobility Master Plan for Amman published in 2010 by the Greater Amman Municipality. **4.** The Intended Nationally Determined Contribution (INDC) by joining the NDC Partnership in March 2018.

Baseline or scenario		Main sources
	Net Zero - 2050	**1.** Amman Green City Action Plan published in 2021 by AECOM. **2.** The Amman Climate Plan a Vision for 2050 Amman published in 2019 by the Greater Amman Municipality. **3.** Transport and Mobility Master Plan for Amman published in 2010 by the Greater Amman Municipality. The Intended Nationally Determined Contribution (INDC) by joining the NDC Partnership in March 2018. **4.** Amman green projects and community benefits presented in 2021 by the Greater Amman Municipality.

**Note: The scenarios for sensitivity analysis – 2050 considered the same sources as the Plan Scenario.

Each policy lever has four possible options: 1) Portrays the historical development trends, 2) Shows planned changes or proposals by GAM, 3) Presents recommended policy levers to maximise the benefits and reach the emission targets, and 4) Portrays the best-case scenario achieving the net zero emission goal. This allows researchers to compare the effects and scope of the interventions and policies. The policy levers are described as follows:

A. Urban expansion

This policy lever defines the pattern in which the future population will settle, either in defined expansion areas or unoccupied land within the urban area. The scenarios include growth according to:

1. Historical urban expansion for the BAU Scenario - 2050. The historical trend depicts an urban expansion of 60%, approximately 340 km^2 outside the city boundaries.
2. Expansion areas forecasted by GAM for the Plan Scenario - 2050. The planned expansion sums approximately 214 km^2 (38% of the current urban footprint).
3. Compact growth and densification for the Ambitious Scenario - 2050. This strategy suggests that the municipality encourages the occupation of bare land within the current boundaries of the urban area. This includes the integration of suburban areas within a buffer zone of 2.5 kilometres around the 2020 city boundaries. By implementing these containment measures, the expansion would be around 8%, approximately 45 km^2.
4. A policy of zero urban growth for the Net Zero Scenario – 2050. This strategy suggests that the municipality will limit the urban expansion and occupy the bare land in the existing urban footprint. The distribution of the new population in the city will follow transport efficient densification parameters.

Urban growth change indicators related to population distribution models, energy consumption of the city, service coverage, and infrastructure proximity.

B. Renewable energy contribution

The policy lever analyses solar photovoltaic, wind, biogas, and hydroelectric generation in Amman. The objective is to reduce the dependency on non-renewable energy sources and decrease GHG emissions (Greater Amman Municipality, 2019). The policy lever scope includes:

1. For the BAU Scenario, no increase of local installed capacity from renewable energies.
2. For the Plan Scenario, a development of 14 MW[3] of installed capacity, with a proportional contribution from each renewable energy source. The installed capacity is based on the energy demand projection in this scenario and the potential renewable generation in Amman (Global Solar Atlas and Global Wind Atlas, 2022). This lever assumes that energy could be generated in renewable energy power plants located in Jordan.
3. For the Ambitious Scenario, four times the renewable energy generation in Amman. This target represents a rapid supply of 60% for street lighting, with a development of 138 MW[3] of installed capacity. The installed capacity is based on the electricity demand projection of streetlights in this scenario and the potential renewable generation in Amman (Global Solar Atlas, 2022).
4. For the Net Zero Scenario, 100% of renewable energy supply. The installed capacity is based on the energy demand projection in this scenario and the potential renewable generation in Amman (Global Solar Atlas and Global Wind Atlas, 2022). This lever assumes that energy could be generated in renewable energy power plants located in Jordan.

Renewable energy contributions impact the GHG emission indicator.

C. Demand-side management

The policy lever analyses energy measures related to the curtailing of the client's energy demand by numerous strategies, including behavioural changes and financial benefits. The policy lever scope includes:

1. For the BAU Scenario, the historical energy consumption trend.
2. For the Plan Scenario, the implementation of $31 million USD in financial benefits[4] that will potentially reduce energy consumption by up to 10%.
3. For the Ambitious Scenario, the implementation of $187 million of USD in financial benefits[4] that will potentially reduce energy consumption by up to 30%.
4. For the Net Zero Scenario, the implementation of $208 million of USD in financial benefits[4] that will potentially reduce the energy consumption up to 56%.

This measure benefits indicators such as energy consumption and GHG emissions. Additionally, demand-side management measures will promote optimal investments and synergies between public policies. For example, if energy consumption increases the proposed installed capacity of renewable energy will not be able to supply the full demand of the city in the Net Zero Scenario.

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[3] The installed capacity considers an equal contribution of all the potential energy renewable sources. The estimation is based on the potential of wind and solar generation in the region and an approximation to biogas and hydro generation (Global Solar Atlas and Global Wind Atlas, 2022). The installed capacity may increase or decrease according to the participation of any of the four renewable energies.

[4] The Amman Climate Plan determines that GAM will incentivize and partner with organisations to promote best practices in passive design and green construction. The team recommends addressing these goals by implementing financial benefits. The cost assumption was based on a successful case study of demand side management implemented in Greece, which provided a $220 USD subsidy per household to promote manual adjustments (Koasidis et al. 2022).

D. Green building codes

The policy lever analyses the potential contribution of implementing green building measures and guidelines as described in the Jordanian green code. The policy lever scope includes:

1. For the BAU Scenario, non-implementation of green building codes.
2. For the Plan Scenario, the implementation of green building code in 142,200 existing and new buildings[5]. This represents 15% of penetration, which follows the minimal penetration described in the Amman Climate Plan.
3. For the Ambitious Scenario, the implementation of green building codes in 853,200 existing and new buildings[5]. This represents 90% of penetration, which follows the topmost penetration described in the Amman Climate Plan.
4. For the Net Zero Scenario, the implementation of green building codes in 948,000 existing and new buildings5. This represents 100% of penetration.

Green building codes benefit indicators related to energy consumption and GHG emissions.

E. Electricity consumption in public lighting

The policy lever analyses the required electricity for street lighting and the type of technology in operation (incandescent, LED, smart street lighting, solar, among others). The policy lever scope includes:

1. For the BAU Scenario, the construction of new streetlights in new areas and the maintenance of LED public lighting. The municipality would provide 50% of the public service with LED technology[6].
2. For the Plan Scenario, the planned replacement of 232,900 traditional bulbs[7] with LED technology. To reach 100% LED street lighting.
3. For the Ambitious Scenario, the optimal reduction is by replacing 46,600 traditional bulbs[7] with LED technology and 186,300 with solar LED street lighting.
4. For the Net Zero Scenario, the maximum reduction is by replacing 465,800 lamps[7] with solar LED street lighting, to reach 100% of solar street lighting.

Changes in public lighting technology benefit indicators related to energy consumption and GHG emissions.

F. Electrification of transport

The policy lever analyses the transformation from gasoline and diesel vehicles to electric technology. The objective of this lever is to incentivize electric vehicles and show leadership by electrifying the municipal bus fleet, as described in The Amman Climate Plan for 2050. The policy lever scope includes:

1. For the BAU Scenario, a gasoline and diesel transport system.

[5] Estimation of buildings was based on Household Expenditures and Income Survey from the Department of Statistics, 2017.

[6] "According to Mohammad Faouri, director of traffic operations at GAM, the second phase of the LED street lighting project will be launched in the coming period" (The Jordan times, 2021; AECOM, 2021).

[7] The estimation of light poles considers an average distance of 38.8 metres between poles (Global Designing Cities Initiative, 2021).

2. For the Plan Scenario, the planned transport electrification. The fuel switch in the vehicle fleet[8] of the city will be approximately 407,240 cars (50% of total cars), 150 public buses (25%), 100 trucks (10%), and an additional 1,800 2-wheelers (60%).
3. For the Ambitious Scenario, paramount transport electrification. The fuel switch in the vehicle fleet[8] of the city will be approximately 610,860 cars (75% of total cars), 300 public buses (50%), 240 trucks (25%), and an additional 2,000 2-wheelers (90%).
4. For the Net Zero Scenario, complete transport electrification. The fuel switch in the vehicle fleet[8] of the city will be approximately 814,480 cars (100% of total cars), 600 public buses (100%), 960 trucks (100%), and 3,000 2-wheelers (100%).

Electrification of transport impact indicators related to commuting energy and GHG emissions.

G. Mass public transit

The policy lever analyses an expansion of the public transport routes and an increase of capacity from buses to mass public transit (Bus Rapid Transit - BRT). The objective of this lever is to prioritise low-carbon modes of transportation, as described in The Amman Climate Plan for 2050. The policy lever scope includes:

1. For the BAU Scenario, there are no additional BRT routes.
2. For the Plan Scenario, the development of approximately 60 km of BRT routes[9]. The scenario modelling considered the potential location of the existing and new routes for BRT project Phase 2 shared by the Greater Amman Municipality.
3. For the Ambitious Scenario, the development of approximately 110 km of BRT routes. The location of the additional routes was based on a spatial analysis performed by the CAPSUS team and discussions with the World Bank team. This lever includes the development of the BRT Phase 2 from the Greater Amman Municipality, and new routes to connect Al-Salt and Madaba, two towns near Amman.
4. For the Net Zero Scenario, the development of approximately 110 km of BRT lines. This lever includes the development of the BRT Phase 2 from the Greater Amman Municipality, and new routes to connect Al-Salt and Madaba, two towns near Amman.

Predictions of the extension and location of the mass public transit benefit indicators such as infrastructure proximity, commuting energy indicators, and GHG emissions.

H. Pedestrianisation

The policy lever analyses increased walkability measures and promotion of active mobility. The objective of this lever is to improve pedestrian and bicycling experiences and safety as described in The Amman Climate Plan for 2050. The policy lever scope includes:

1. For the BAU Scenario, there is no specific corridor development.
2. For the Plan Scenario, there is no specific corridor development. The Amman Climate Action Plan depicts the promotion of walkability within the city, though detailed interventions are not included in the document. Therefore, it is assumed that the intervention will include maintenance and safety measures to the existing sidewalks.

[8] Cars and trucks were estimated based on Amman Green City Action Plan and Transport and Mobility Master Plan for Amman (AECOM, 2021; GAM, 2010), the number of public buses were based on the report "Measuring Public Transport Satisfaction from User Surveys" (Imam, 2014), and the number of 2-wheelers was based on the publication by The Jordan times, 2018.

[9] Routes and length were based on GAM plans for mass public transport.

3. For the Ambitious Scenario, the development of a complete corridor of 110 km. It includes the integration of mass public transit with proper sidewalks and bicycle lanes. This complementary infrastructure is expected to improve public health and enhance the liveability of the city.
4. For the Net Zero Scenario, the development of a complete corridor of 110 km. It includes the integration of mass public transit with proper sidewalks and bicycle lanes. This complementary infrastructure is expected to improve public health and enhance the liveability of the city.

Pedestrianisation measures are related to infrastructure proximity, commuting energy, and GHG emission indicators.

I. Controlled parking

The policy lever analyses the implementation of an on-street parking system. The objective of this lever is to discourage the use of private cars and thereby reduce GHG emissions. The policy lever scope includes:

1. For the BAU Scenario, there are no additional parking measures.
2. For the Plan Scenario, 200 ha of controlled parking zones[10] along the mass public transit routes.
3. For the Ambitious Scenario, 3,000 ha of controlled parking zones[10]. The effort would reach approximately 25% along the public transit routes.
4. For the Net Zero Scenario, 3,000 ha of controlled parking zones[10]. The effort would reach approximately 25% along the public transit routes.

Controlled parking affects the elasticity of usage between cars and public transit. The decrease of private cars reduces the vehicle-kilometres travelled by this means of transport, which also reduces commuting energy and GHG emissions.

J. Waste management

The policy lever analyses the efficiency measures for the solid waste collection system. The objective of this lever is to create a waste reduction system in Amman by separating and diverting waste, and implementing recycling and composting programs, as described in The Amman Climate Plan for 2050. The policy lever scope includes:

1. For the BAU Scenario, the current waste management system. GAM will not invest in the expansion of management capacity, for example, new collection trucks, separation centres, and increase in the capacity of landfills.
2. For the Plan Scenario, the separation from the source by replacing 20,000 containers[11] available in the city. This includes investment in a new fleet and equipment for solid waste operations. The investment represents a minimal capital investment to reach 12% waste reduction sent to landfills (AECOM, 2021).
3. For the Ambitious Scenario, the separation from the source by replacing 20,000 waste containers[11], constructing one transfer station and one material recovery facility. This represents the topmost reduction described in the Amman Climate Plan and GCAP (50%).

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[10] Controlled parking zones were recommended to promote the installation of Intelligent Transport Systems (ITS) from the Amman Green City Action Plan (AECOM, 2021).

[11] Estimation based on BioCycle, 2011.

4. For the Net Zero Scenario, the separation from the source by replacing 20,000 waste containers[11], constructing one transfer station and two material recovery facilities. This represents a 70% reduction of waste sent to landfills.

Waste management measures benefit waste collection service coverage.

K. Water management

The policy lever contemplates the coverage of the water network and the water demand. The objective is to implement water-saving measures and water recycling or rainwater harvesting in municipal buildings. The levers include:

1. For the BAU Scenario, the policy includes the required water network expansion to provide water services in the new areas of the city.
2. For the Plan Scenario, the implementation of water efficiency packages in 142,200 existing and new buildings[12]. This represents a complete coverage and a decrease of water consumption by 15%. The efficiency packages could be coupled with the Green Building Code to enhance the investments' efficiency.
3. For the Ambitious Scenario, the implementation of water efficiency packages in 853,200 existing and new buildings[13]. The efficiency packages could be coupled with the Green Building Code to enhance the investments' efficiency. This represents a complete service coverage and a 30% water consumption decrease. In addition, the ambitious scenario considers a complete maintenance agenda of the 5,100 km of the water network[13].
   The measures will decrease the water distribution loss by 70%, as mentioned in the GCAP.
4. For the Net Zero Scenario, the implementation of water efficiency packages in all city buildings. This represents a complete service coverage and a 40% water consumption decrease. The efficiency packages could be coupled with the Green Building Code to enhance the investments' efficiency. In addition, the scenario considers a complete maintenance agenda of the 5,100 km of the water network[14].
   The measures will decrease the water distribution loss by 95%.

Predictions are related to the water demand and energy consumption of the city.

L. Green spaces and parks

The policy lever comprises the increase of green spaces, parks, and urban forestry focused on underutilised land as described in the Amman Climate Action Plan. In addition, the policy includes the cultivation of drought-tolerant plants and the installation of efficient irrigation systems. This will improve the quality of existing green areas and increase the 0.9 square metres of green areas per capita[14]. The levers include:

1. For the BAU Scenario, the maintenance of 93 existing parks. The green areas sum 0.7 square metres of green areas per capita.

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[12] Estimation of buildings was based on Household Expenditures and Income Survey from the Department of Statistics, 2017.

[13] Based on the integrated water resources management plan detailed in the Amman Green City Action Plan (AECOM, 2021).

[14] The approximation was based on spatial information and the GIZ program "Improving green infrastructure in Amman program" (GIZ, 2022).

2. For the Plan Scenario, maintenance of the 93 existing green areas in the city and the creation of 3 new parks. The increase of green areas is 1.5 ha, though the increase per capita is minimal.
3. For the Ambitious Scenario, maintenance of the existing green areas and an increase of 7 new parks. The increase of green areas is 2.1 ha, though the increase per capita is minimal.
4. For the Net Zero Scenario, maintenance of the existing green areas, an increase of 7 new parks (with an area of 2.1 ha) and the creation of green infrastructure to reach 0.9 square metres of green areas per capita. The green areas per capita improve significantly with the green infrastructure, which reaches 87.8 ha of green areas[15].

Green spaces benefit indicators related to the urban footprint, population density, exposure to hazards, and proximity to infrastructure.

M. Grey and green infrastructure

The policy lever comprises green infrastructure to reduce the risks of floods in critical areas. The levers include:

1. For the BAU Scenario, there is no resilient infrastructure.
2. For the Plan Scenario, the grey infrastructure strategy. This includes the development of Phases 1 and 2 of the water drainage infrastructure connecting the pond area to the Zarqa River (AECOM, 2021). This will reduce pluvial and fluvial floods by 15%.
3. For the Ambitious Scenario, the grey infrastructure strategy. The intervention includes the same scope as the Plan Scenario, this includes the development of Phases 1 and 2 of the water drainage infrastructure connecting the pond area to the Zarqa River (AECOM, 2021). This will reduce pluvial and fluvial floods by 15%.
4. For the Net Zero Scenario, the integrated green infrastructure strategy, and water conveyance and storage to reduce flood risk. This includes the development of Phases 1 and 2 of the water channels connecting the pond area to the Zarqa River and the increase in green areas as nature-based solutions (AECOM, 2021). This will reduce pluvial and fluvial floods by 25%.

Grey and green infrastructure benefit indicators related to exposure to hazards, proximity to amenities.

Sensitivity analysis levers

The scenarios for sensitivity analysis have an urbanisation and development level considering low material growth and lower resource and energy intensity for SSP1[16] and competitive markets, innovation, and participatory societies to produce rapid technological progress and development for SSP5[12]. Noteworthy, the scenarios for sensitivity analysis have the same lever assumptions as the Plan Scenario.

[15] The green infrastructure comprises between 100 and 200 m^2 of buffer zones with green areas along the Zarqa River. The buffer area includes the bare land and agricultural land. Further analysis should be considered to include cadastral and detailed land use information of GAM.

[16] The spatial information was based on the previous analysis developed by the World Bank Group.

The analysis depicts the different values of a set of independent variables affecting a specific dependent variable (CFI, 2022). Results supported the level of effort required for the Net Zero policy levers.

Step 6. Develop recommendations

The analysis of results described the possible outcomes and challenges in terms of climate change mitigation and adaptation, given a historical context. It comprised the comparison between the base characteristics of the city with scenarios given in the horizon year. By comparing results, it was feasible to determine the potential for emission reduction by sector. Recommendations focused on the areas of opportunity to strengthen the actual GHG emission reduction efforts.

It was required that the assessment allows comparisons with the planned results in the Jordan Climate Change Development Report (CCDR). The process includes the presentation of information which allows the integration of information within the CCDR. These descriptions and terminology had the objective to facilitate further analysis and development.

Potential for greenhouse gas emission reduction.

The following sections present the scenario modelling results of the city's future conditions. It compares the actual urban form, transport, and energy sector characteristics, as well as the climate change and resilience assessment with estimated future results in 2050. The scenarios include key strategies stated in the Amman historical urban expansion, whereas the Ambitious scenario analyses recommended projects that will enhance the efforts for climate change mitigation. The sections contain spatial and statistical analysis outcomes through indicators, maps, and graphics.

The potential for GHG is described through different indicators that relate to the urban, transport and energy sector. The chapter comprises the results and analysis of the 2050 forecast regarding the aforementioned indicators:

- Population and land consumption
- Population density
- Green areas per capita
- Proximity to transport
- Energy consumption and renewable energy
- Greenhouse gas emissions
- Costs

The description of solid waste coverage and water analysis are described in the Climate investment co-benefits section.

The descriptions for 2050 includes the comparison between the four scenarios. The levers are assessed to indicate the possible outcome if determined investments and policies are implemented in the city.

2050 Forecast for population and land consumption

The relationship between population growth and land-use change is useful for urban planning. This information matches demographic and ecological data into policy development and capital investments (UN, 2021). The increase in population is related to land consumption, density parameters, and resource management within the city. Thus, it provides challenges and opportunities to create green and inclusive solutions for the urban, transport and energy sector and increase accessibility and enhance benefits of future investments.

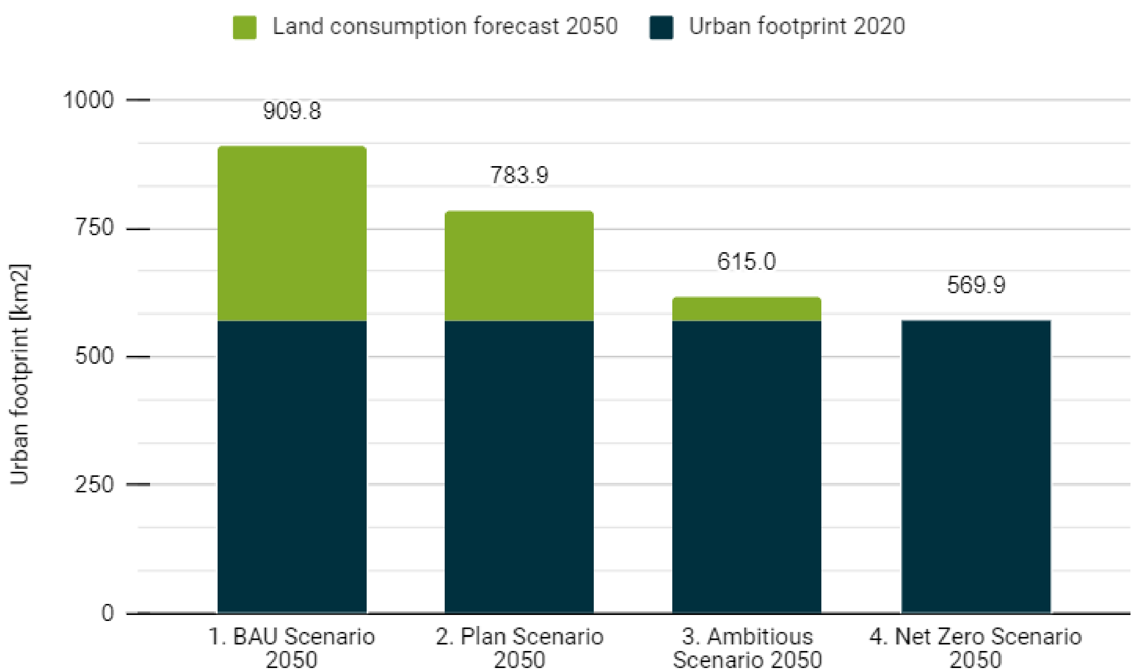
Amman will reach more than four million inhabitants by 2050, which adds up to 28.9%. It is essential to consider the population and land use relationship as the increase in population influences land-use patterns, social behaviours and productive activities (Jolly and Torrey, 1993). The municipality will need to plan according to the population increase to provide adequate public services while maintaining the quality of living. These will bring challenges in a broad scope of the city administration and the demand for resources in the city.

Future scenarios predict the potential urban land consumption and total urban footprint of the city for 2050 according to the urban form policy lever described in the methodology section. Noteworthy, land consumption is the uptake of land by urbanised land uses, which often involves the conversion of land from non-urban to urban functions. Thus, the urban footprint is identified as the total built-up area of a city including streets, agricultural and natural land.

The land consumption indicator accounts for the amount of land predicted to change from natural habitats or agricultural uses into human settlements. Land consumption is measured in square kilometres (km^2). It is estimated using artificial neural networks based on orography, roads, built-up area, population, and employment from historical data. For example, for the BAU Scenario, the indicator assesses the land consumption from 2000 to 2020 and this period determines the accuracy for future predictions.

Image 10 shows the changes in the city's urban footprint and land consumption according to historical data, the planned expansion of GAM, or enforcing a compact growth scheme. The results depict the implementation of the urban form policy lever. Thus, the BAU Scenario has the most extensive land consumption of all scenarios, with an increase of 59.6% (339.9 km^2). Historical land consumption has increased at a rapid pace and surpasses the increase in population. The land consumption planned by the municipality is supporting urban expansion by 37.5% (214.0 km). The Ambitious Scenario assumes strict policies to limit land consumption by 7.9%, while the Net Zero scenario maintains the current urban footprint (569.9 km^2).

Image 10. Land consumption for each scenario.

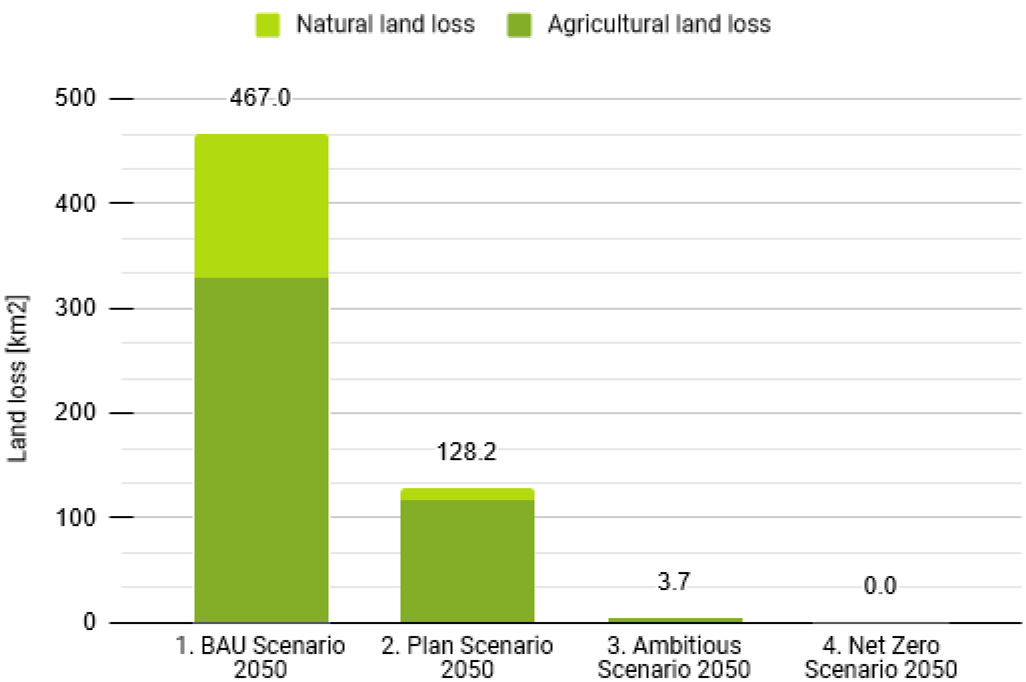


Source: Urban Planning Scenarios for Amman, 2022.

Land consumption has a direct relation with agricultural and natural land loss, as it accelerates the land loss rate. Image 11 identifies the change in natural and agricultural land in the urban footprint of 2050. For example, in the 909.8 km^2 urban footprint of the BAU Scenario, there are 467km^2 of natural and agricultural land loss. The land loss decreases significantly in the Plan and Ambitious Scenarios, to reach 128.2 km^2 and 3.7km^2, respectively.

The agricultural and natural land loss affects the overall performance of the city. The BAU, Plan and Ambitious scenarios have a higher percentage of agricultural land loss, which could produce more stress over the food supply in the city. Also, it impacts the economic sector as agricultural activities represent 28% of the national GDP (The Hashemite Kingdom of Jordan, 2020). The land loss will affect the infiltration capacity of the city soil and enhance the occurrence of flash floods. From the total land loss, the BAU Scenario will suffer from a 30% loss of natural land and 70% of agricultural land. From the land loss in the Plan Scenario, around 91% will be agricultural land and 9% from natural land. The Ambitious Scenario has the lowest land loss of the aforementioned scenarios, with 3.7 km^2 of agricultural land loss as shown in Image 11.

Image 11. Land loss characteristics for each scenario.

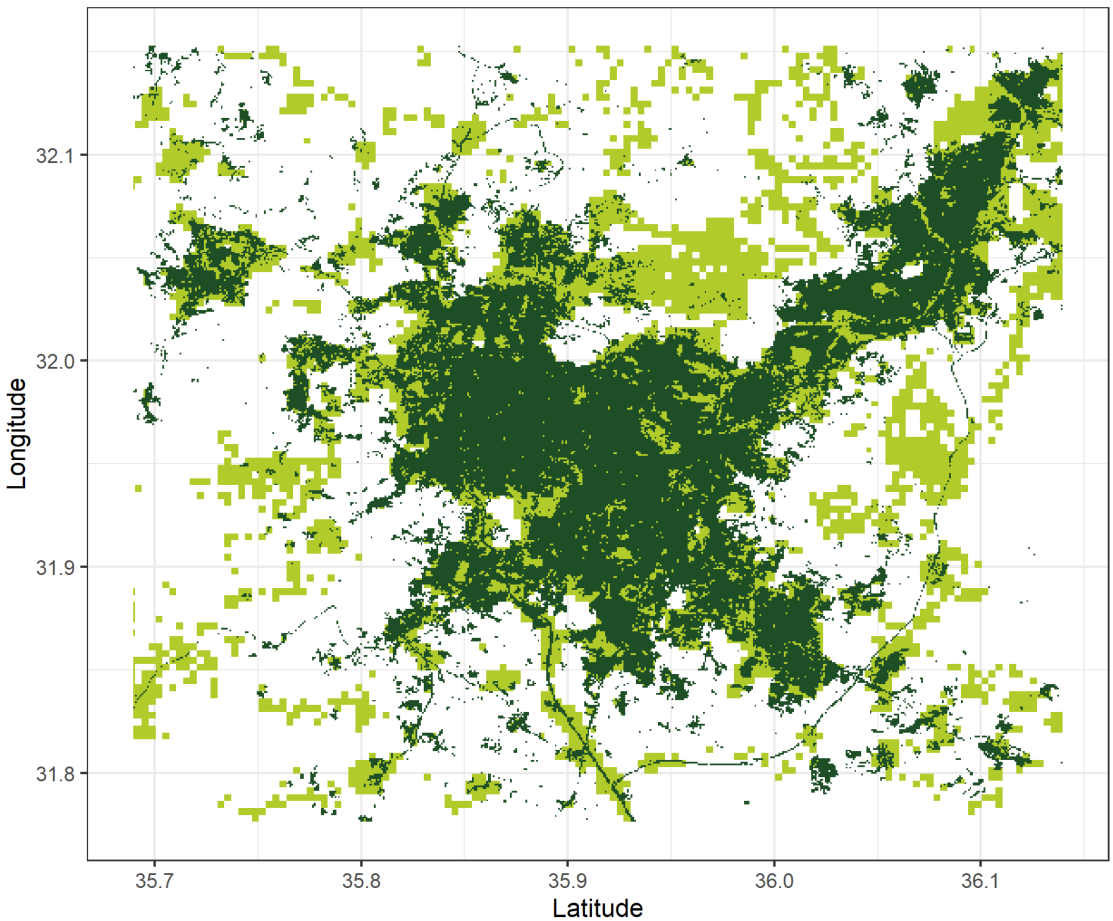


Source: GAM, 2022 and Urban Planning Scenarios for Amman, 2022.

The urban footprint is also related to GHG emissions and additional characteristics of the city. In the BAU Scenario, land consumption adds up to 5% of GHG emissions. Also, it is related to electricity consumption and commuting energy. Image 12 to Image 13 present, through maps, the new urban areas according to each of the future scenarios.

Image 12 presents the expected urban expansion between 2020 and the BAU Scenario for 2050. The dark green in the map represents the current urban footprint and the light green represents the urban expansion according to the historical analysis from 2000 and 2020. The expected expansion reaches an area of 909.8 km^2. Under this scenario, scattered areas increase and the urban footprint boosts in the north-eastern parts of the city towards Russeifa, Zarqa, and the industrial area of the city.

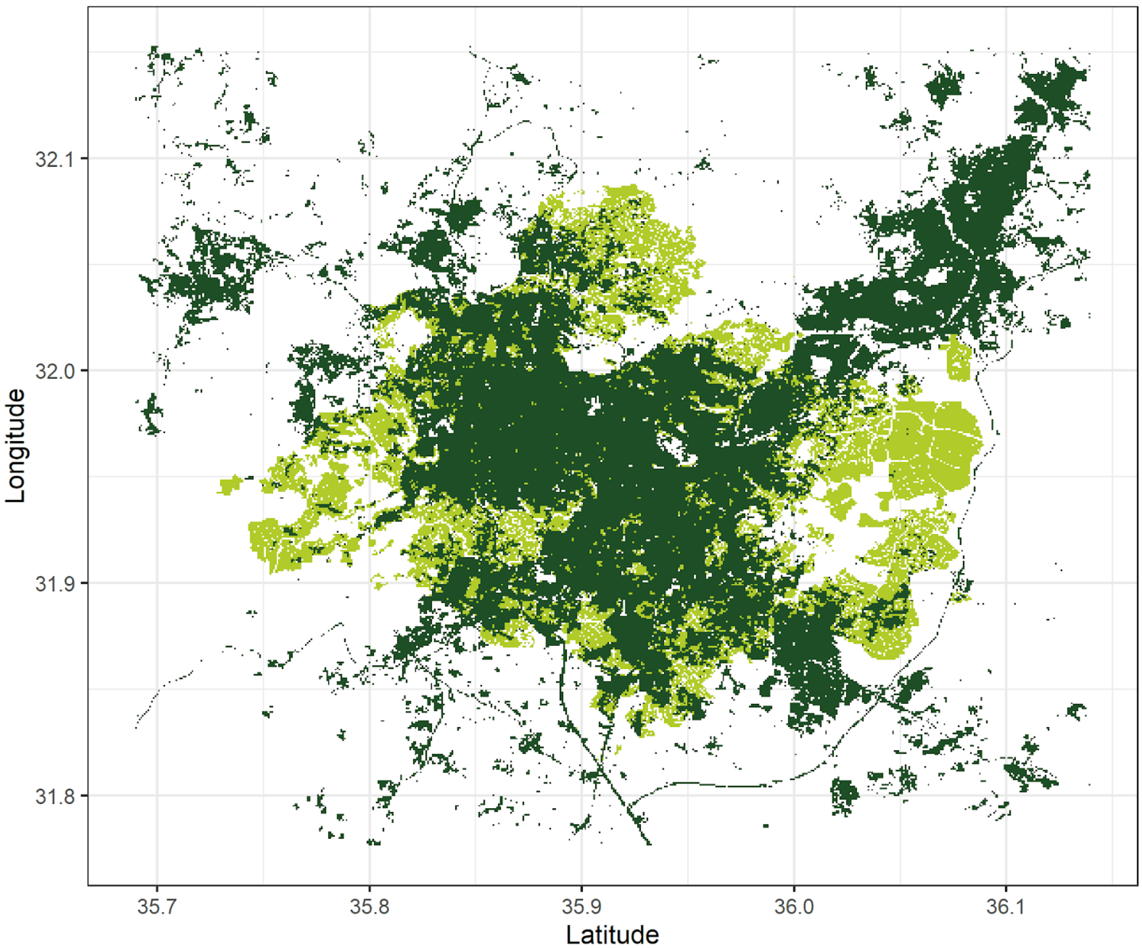
Image 12. Urban expansion for the Business As Usual Scenario – 2050.



Source: GAM, 2022 and Urban Planning Scenarios for Amman, 2022.

Image 13 presents the expected urban expansion between 2020 and the Plan Scenario for 2050. The dark green in the map represents the current urban footprint and the light green represents the urban expansion forecasted by GAM. The expected expansion reaches an area of 783.9 km^2. This scenario reduces the scattered areas presented in the BAU scenario and promotes urban sprawl from the centre to the nearest areas, which is limited in the north-eastern area towards Zarqa and scattered areas.

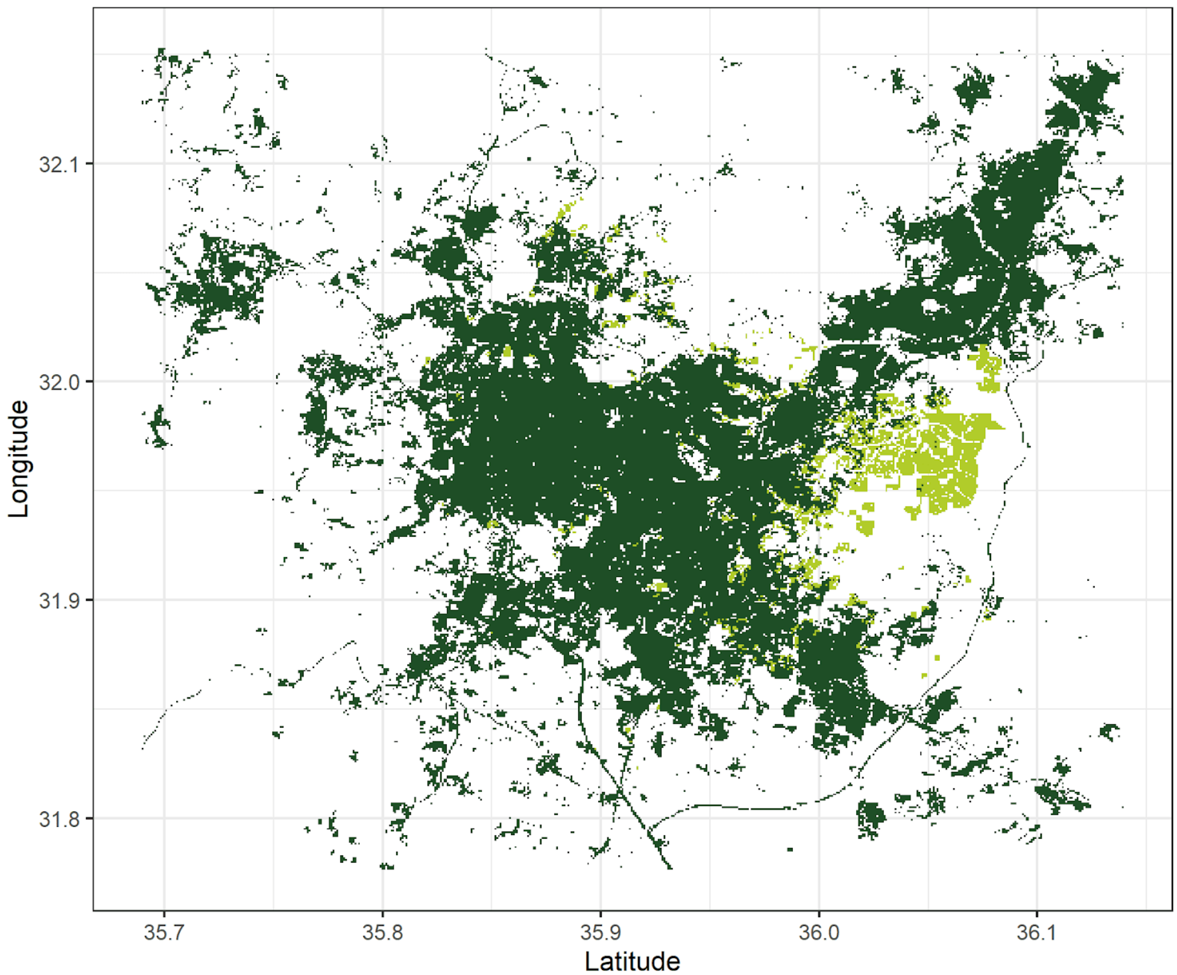
Image 13. Urban expansion for the Plan Scenario – 2050.



Source: GAM, 2022 and Urban Planning Scenarios for Amman, 2022.

Image 14 presents the expected urban expansion between 2020 and the Ambitious Scenario for 2050. The dark green in the map represents the current urban footprint and the light green represents the urban expansion according to the control measures recommended for the Ambitious Scenario. The expected expansion reaches an area of 615 km^2. Strict measures are implemented in this scenario to inhabit bare[17] land and annex suburban areas within a buffer zone of 2.5 kilometres around the 2020 city boundaries. Hence, land consumption occurs near the Western part of Amman.

Image 14. Urban expansion for Ambitious Scenario - 2050.

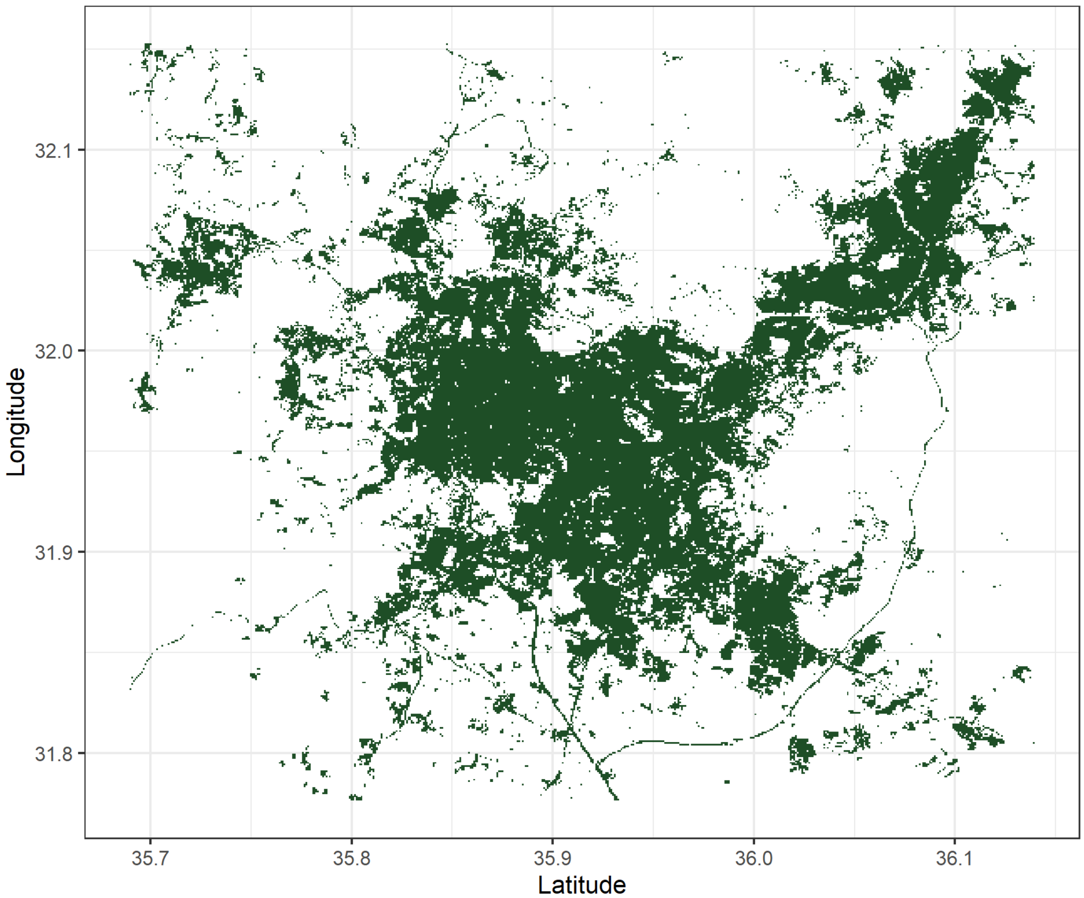


Source: GAM, 2022 and Urban Planning Scenarios for Amman, 2022.

[17] Further analysis should be considered to modify the land use and vacant land depicted by the municipality. The measures include the occupation of agricultural, natural and bare areas.

Image 15 presents the expected urban footprint for the Net Zero Scenario 2050. This scenario assumes zero land consumption to avoid GHG emissions and increase resource efficiency in Amman. The scenario encourages strengthening the control measures for urban expansion to achieve zero land consumption.

Image 15. Urban expansion for the Net Zero Scenario - 2050.



Source: GAM, 2022 and Urban Planning Scenarios for Amman, 2022.

2050 Forecast for population density

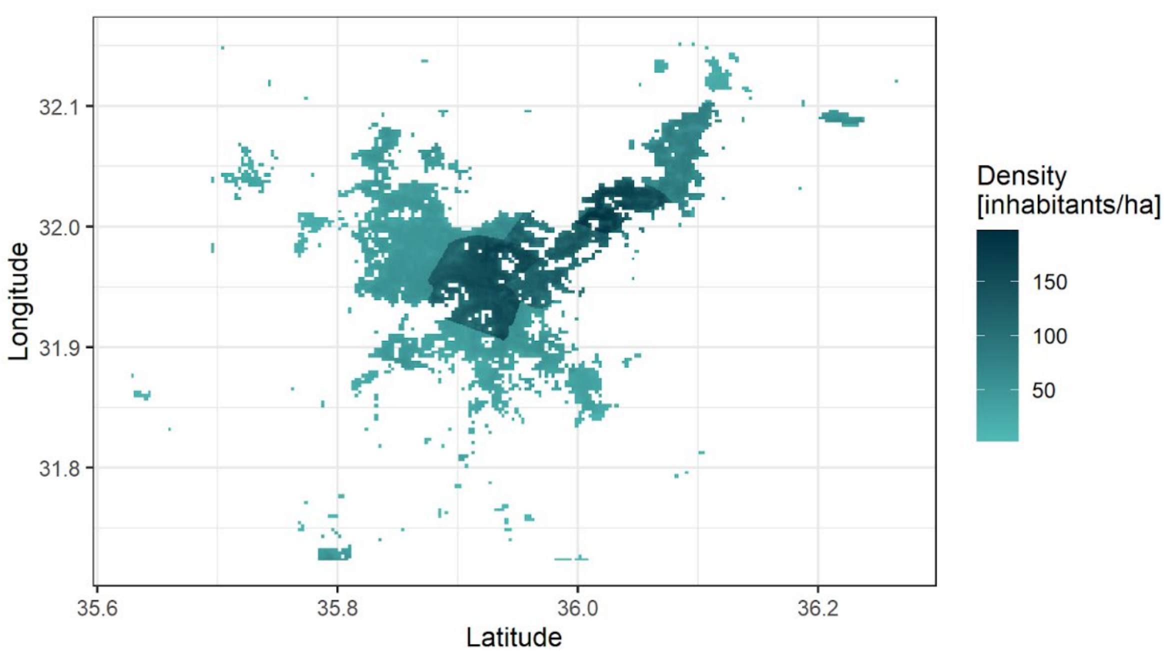
Population density is related to the increase of inhabitants in Amman and the percentage of land consumption. It is a complex concept that has inter-related dimensions and can provide spatially based measures, or it could be a social interpretation from each person's perspective (Dempsy et al., 2010). Land use planning and urban policies shape population density in the city, and it can arrange development to avoid prone risk areas or increase accessibility to infrastructure. Also, it is a tool to measure the viability of densification measures to shape a more efficient city.

Morphological densification is different from overcrowding cities. This type of density refers to the built environment with compact urban land cover, demarcated limits, street connectivity, impervious surface coverage, and a high building footprint to parcel size ratio (OECD, 2017). On the other hand, overcrowding is defined as places that contain too many people or things (Cambridge University Press, 2022). The density factor provides accessibility and incorporates efficient resource management, while overcrowding prone vulnerabilities as COVID-19 infections or face privacy and quality-of-life challenges (OECD, 2017; Global Development Institute, 2020).

This indicator accounts for the number of people living in each unit of area according to the base year (2020) and every future scenario (2050). Population density is measured in inhabitants per hectare. It is calculated as the total population of the city divided by the city footprint (built-up area footprint). Density is key to shortening distances to infrastructure and developing resource-efficient cities. For example, the Net Zero Scenario accommodates all the new inhabitants (976,309) in the existing land and implements mobility-efficient measures to distribute population close to public transport. Noteworthy, the population forecast considers the annual population growth rate from the last 20 years.

Image 16 shows the population density in the city by 2020. Densely populated areas settle in the centre and north-eastern part of the city. Commercial activities, the industrial zone of Marqa, and the road towards Zarqa are located in these areas. On the other hand, most of the urban footprint of Amman has a medium to low density, reaching a city average of 59.4 inhabitants per hectare. The population density is higher than the national average (1.15 inhabitants per hectare: The World Bank, 2022) but lower than most populated cities in the MENA region. For example, Istanbul has approximately 290 inhabitants per hectare, and Cairo has 208 inhabitants per hectare (European Commission, 2021; Ahram Online, 2021).

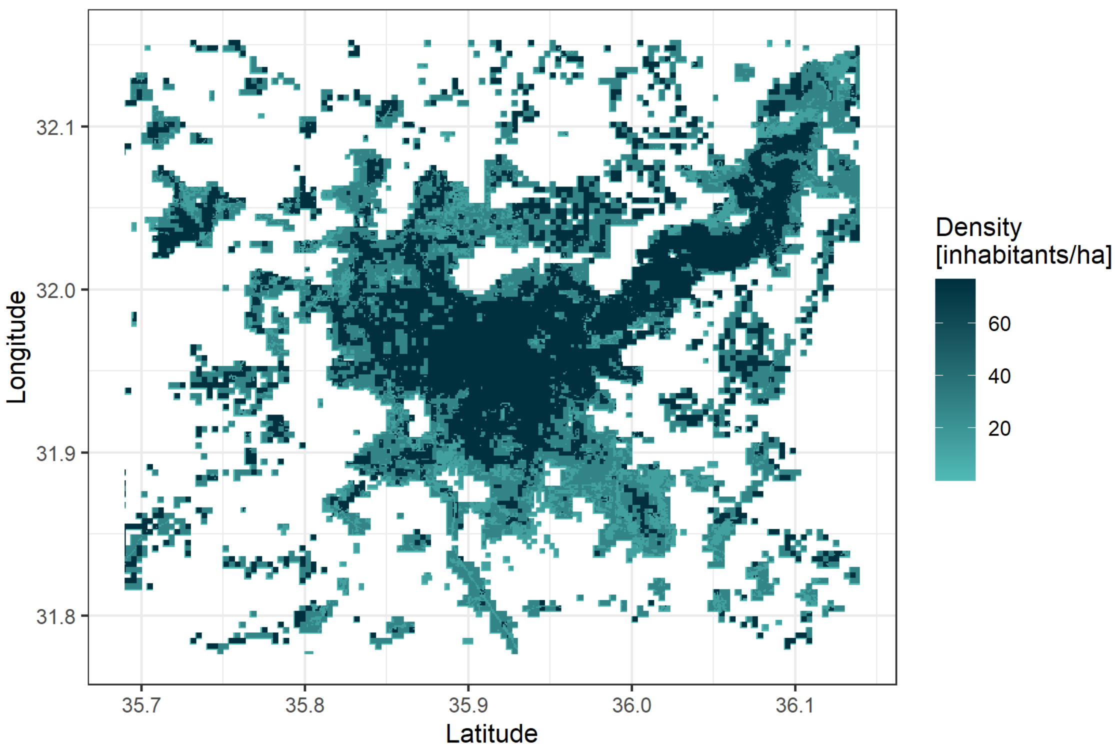
Image 16. Population density distribution in 2020.



Source: The Greater Amman Municipality, 2022.

Image 17 presents the distribution of population density in Amman for the BAU Scenario. According to the population increase and land consumption, population density decreases overall in the area of the city in comparison to previous years. Medium and low-density areas are located in the new urban areas. However, the population is evenly distributed throughout the urban footprint, without significant densely populated areas, resulting in an average of 47.9 inhabitants per hectare. The low density creates a challenging environment for infrastructure investment, as areas of prioritisation become less clear and proper access to amenities and public services require a significant municipal contribution. The BAU scenario has the lowest population density compared to other future forecasts.

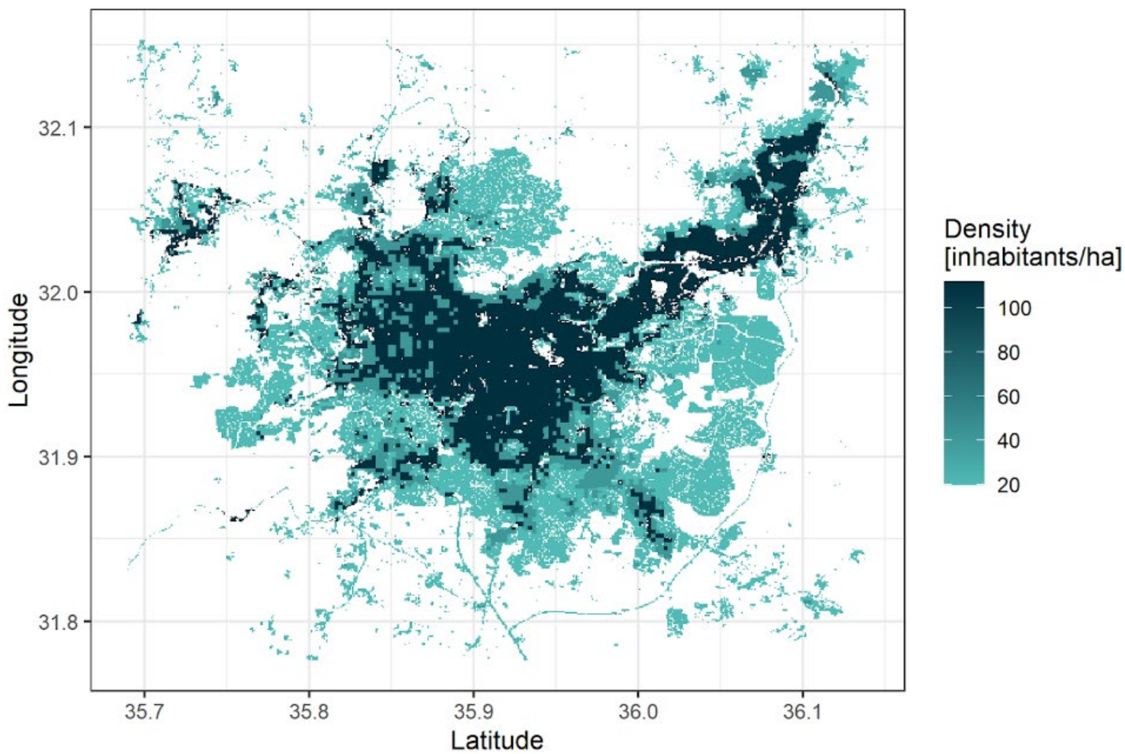
Image 17. Population density distribution in the Business As Usual Scenario - 2050.



Source: Urban Planning Scenarios for Amman, 2022.

Image 18 shows that the population density will decrease despite the urban policies from GAM. According to the Municipality forecast for 2050, the population density will decline by 6.3% to reach an average of 55.6 inhabitants per hectare. Under the Plan Scenario, the west and southern parts will have new highly dense population areas. The newly developed zones will have the lowest population density, increasing the necessity to invest in amenities and social infrastructure.

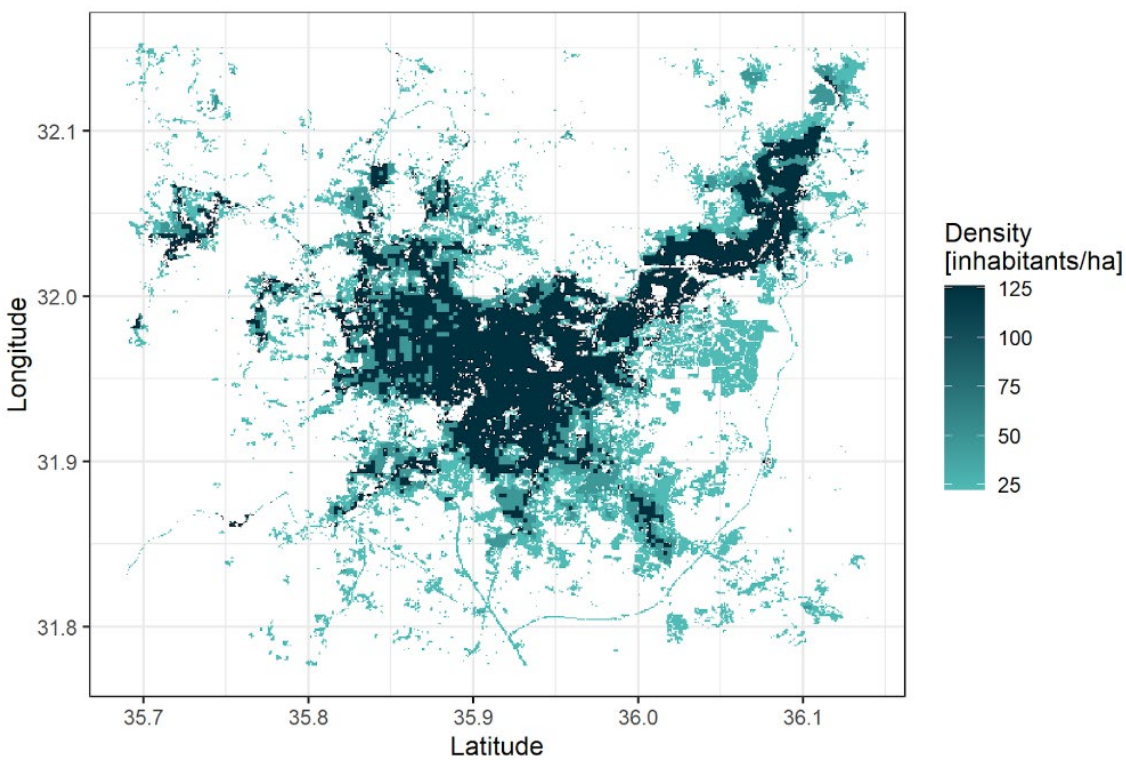
Image 18. Population density distribution in the Plan Scenario - 2050.



Source: Urban Planning Scenarios for Amman, 2022.

As shown in Image 19, the Ambitious Scenario shows a different pattern. This scenario portrays strict measures for compact growth and promotes densification measures, reaching 70.9 inhabitants per square hectare (19.4% increase in population density compared to 2020). The low-density areas have a similar distribution to the Plan Scenario, as the consumed land has the lowest density in the urban footprint. On the other hand, high-density areas cover the majority of the city, including the scattered areas. The municipality could regulate land use to enhance the benefits from planned infrastructure investments and densify areas with accessibility to amenities and social infrastructure.

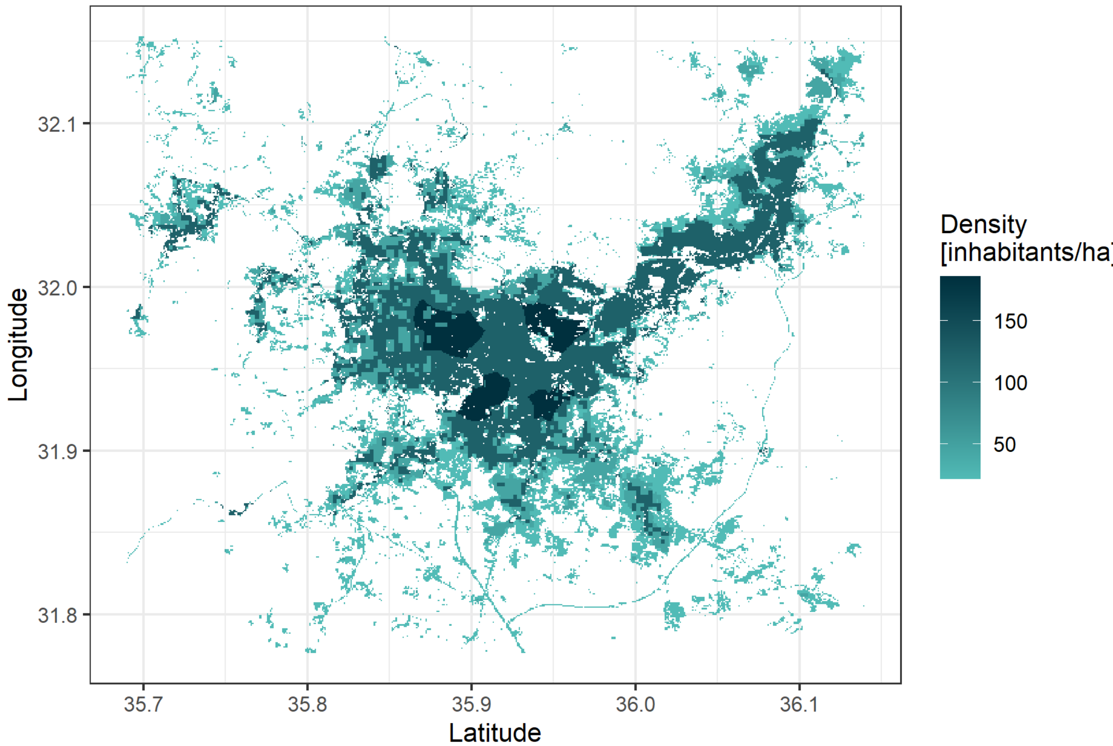
Image 19. Population density distribution in the Ambitious Scenario - 2050.



Source: Urban Planning Scenarios for Amman, 2022.

Image 20 presents the population density for the Net Zero Scenario. This scenario allocates the population to increase accessibility to transportation and promote more active mobility. Therefore, the four high-density population areas are settled near existing and planned BRT routes. Middle and low-density areas are dispersed, and low-density areas are settled the furthest from the city centre. This shows a radial distribution, where the core activities are centred in the commercial areas and near the public transport routes. The average population density in the Net Zero Scenario increases approximately 30% (76.5 inhabitants per hectare).

Image 20. Population density distribution in the Net Zero Scenario - 2050.



Source: Urban Planning Scenarios for Amman, 2022.

2050 Forecast for green areas per capita

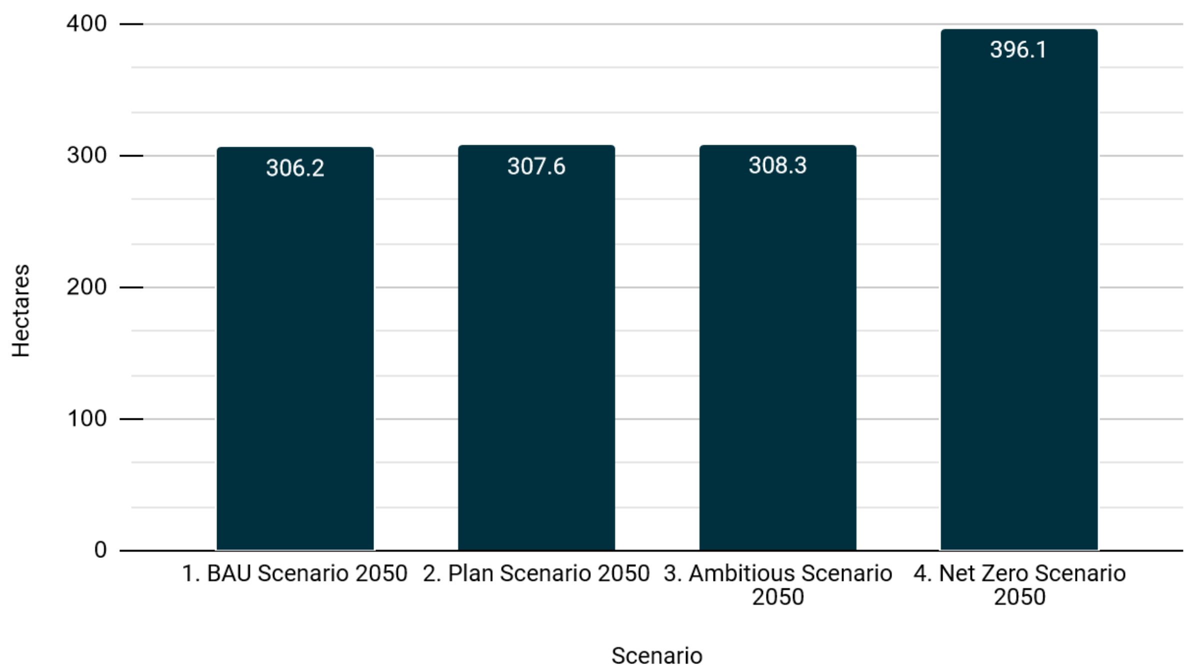
Green areas support sustainability and the importance of ecosystem services. The benefits include carbon sequestration, reduction of severity of environmental hazards and heat island effect. Also, green areas integrated with agricultural activities promote food security and economic activities. However, these areas are in constant threat from various factors, being the most important land consumption. To contrast the environmental hazards and provide ecosystem services, sufficient and high-quality green areas should be readily made available to city inhabitants. Improving public health through urban development and green area renewal of compact cities (Russo and Cirella, 2018; Brennan 2020).

This indicator accounts for the total green area within the city (forests, parks, gardens, among other green areas) per inhabitant. It is measured in square kilometres (m^2) per person.

They are calculated through spatial information from parks, public spaces, and areas with vegetation. The total square metres of green areas are divided by the city population.

Images 21 and 22 show a significant area of opportunity in the number of green areas per capita. Although the policy L. Green spaces and parks, and M. Grey and green infrastructure, the BAU, Plan and Ambitious Scenario suffer a decrease in the availability of green areas, as in 2020 the area per capita is 0.9 m^2 per inhabitant. According to GAM, limited efforts regarding green areas are related to the availability of land in the city, water shortages and infrequent maintenance. Thus, the Plan and Ambitious increase the green areas by 1.5 ha and 2.1 ha, respectively. Under both scenarios, Amman does not have a significant increase in green areas per capita. By contrast, Net Zero strategies reach 89.9 ha with more ambitious efforts regarding green permeable areas. New parks are located within the city centre and near public transport routes that do not have buildings[18]. The green infrastructure is located along the Zarqa river area, in a buffer zone between 100 and 200 m.

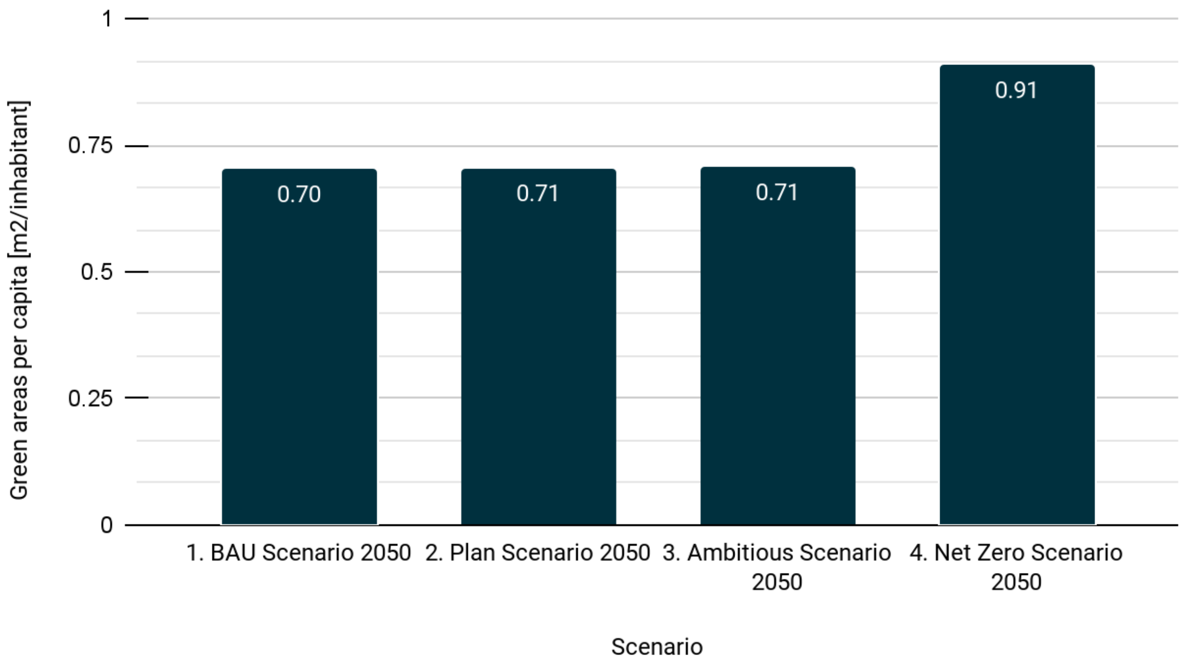
Image 21. Green areas in Amman.



Source: Urban Planning Scenarios for Amman, 2022.

[18] Further analysis should take place according to the identified available land and land use plans of GAM.

Image 22. Green areas per capita



Source: Urban Planning Scenarios for Amman, 2022.

Results show that the densification efforts require more ambitious goals to reach a compact growth for the future scenarios. GAM's containment measures for the Plan Scenario are not strong enough to densify the city, thus the urban expansion will be more rapid than the population growth and express a lower population density than the current situation. This means that new buildings will be built outside the 2020 city boundaries and limited infill measures will be applied. The urban footprint depicts the impacts of implementing the urban expansion policy lever. These includes the historical urban expansion for the BAU Scenario, the expansion areas forecasted by GAM for the Plan Scenario, compact growth and densification for the Ambitious Scenario, and a policy of zero urban growth for the Net Zero Scenario.

Table 2. Integrated results for land consumption and population density.

Indicator	BAU Scenario 2050	Plan Scenario 2050	Ambitious Scenario 2050	Net Zero Scenario 2050
Total population [inhabitants]	**4,360,676.0**			
Projected population growth by 2050[inhabitants]	**976,309.0**			
Urban footprint [km^2]	**909.8**	**783.9**	**615.0**	**569.9**

Indicator	BAU Scenario 2050	Plan Scenario 2050	Ambitious Scenario 2050	Net Zero Scenario 2050
Land consumption [km^2]	**339.9**	**214.0**	**45.1**	**0.0**
Natural land loss [km^2]	**137.9**	**11.1**	**0.0**	**0.0**
Productive land loss [km^2]	**329.1**	**117.0**	**3.7**	**0.0**
Population density [inhabitants/ha]	**47.9**	**55.6**	**70.9**	**76.5**
Green areas [ha]	**306.2**	**307.6**	**308.3**	**396.1**
Green areas per capita [inhabitant/m^2]	**0.7**	**0.7**	**0.7**	**0.9**

Source: Urban Planning Scenarios for Amman, 2022.

2050 Forecast for proximity to transport

City mobility trends portray an increase in the private vehicle fleet. For example, the private car fleet doubled from 40 to 178 cars per thousand inhabitants between 1996 and 2008. The TMMP mentions that it is related to the perception that public transport is relevant to the low-income population. The main modes of transport are private cars (33%), followed by walking (26%), public transport (between 13 and 14%) and taxis (9%). The trend is also related to the average journey time since the average duration travelling by car is under 30 minutes and by bus is over 50 minutes (Greater Amman Municipality, 2010).

The proximity to transportation and cycling lanes account for a percentage of proximity related to transport infrastructure. It is divided into two indicators: proximity to public transport and proximity to public routes. Proximity to public transportation accounts for the percentage of the population that lives within an 800 m radius from BRT routes and 300 m from bus routes. By contrast, proximity to cycling routes accounts for the percentage of the population that lives within a 700 m radius from cycling lanes. Both indicators are calculated through spatial information and are measured in percentages.

The 2050 forecast of proximity to transport is erratic due to the relation of population distribution and future investments. Image 22 shows the existing and proposed routes for the Light Rapid Transit (LRT) or Bus Rapid Transit (BRT) included in the lever G. Mass public transit and H. pedestrianisation. The BRT system is expected to improve conditions, but it does not provide enough coverage to the new urban areas. The Plan Scenario considers 60 km of new routes to connect the city centre with the western area. The Ambitious and Net Zero Scenario proposes a total of 110 km of new BRT routes, with a metropolitan scope. The new routes connect suburban areas and neighbouring cities to promote mobility to the commercial and industrial areas in the municipality. Both scenarios consider connecting Zarqa, Madaba, and Alt-Salt and inner connections between the existing routes. Additionally, the Ambitious and Net Zero Scenarios integrate 110 km of complete corridors with proper sidewalks and cycling lanes to promote active mobility in the city and decrease GHG emissions produced by motorised vehicles.

Proximity to public transportation decreases as the population is more dispersed and has less accessibility to the BRT system. For example, the BAU Scenario has the lowest percentage of proximity to transportation due to the rapid urban expansion and the limited investment. The other three scenarios have proximity to transportation of at least 80%. These percentages are closer to the 2020 situation. By contrast, the best-case scenario is the Net Zero, where population density characteristics promote a more efficient mobility system with 89.7% of proximity to public transportation.

Active mobility planning is limited to more ambitious scenarios. The BAU and Plan Scenario does not include cycling lanes projects and the proximity to this infrastructure is zero. On the other hand, the Ambitious and Net Zero Scenarios include a complete corridor that provides active mobility systems in the city. Similar to proximity to transportation, the best-case scenario for the proximity to cycling lanes is the Net Zero Scenario. The population is distributed close to the new transport infrastructure, resulting in proximity to cycling lanes of 21%.

Additionally, the GAM has listed some strategic measures to provide a better-quality service of public transport and the development of key routes (Greater Amman Municipality, 2010). Both strategies could help the connectivity and mobility infrastructure within the city and the metropolitan area. It may also decrease the duration of the trips and increase the service quality as GAM is planning to increase the efficiency of public transport and active mobility measures. Proper urban policies may enhance the benefits of the planned infrastructure and generate more interest in more clean means of transportation in the city. For example, compact growth supports mass transit and a wider array of non-motorized transportation options to promote active mobility or prevent potential traffic congestion (Transportation Efficient Communities, 2022).

Table 3. Integrated results for proximity to public transport.

Indicator	BAU Scenario 2050	Plan Scenario 2050	Ambitious Scenario 2050	Net Zero Scenario 2050
Proximity to public transportation	**65.7%**	**84.3%**	**87.9%**	**89.7%**
Proximity to cycling routes	**0.0%**	**0.0%**	**19.9%**	**21.0%**

Source: Urban Planning Scenarios for Amman, 2022.

2050 Forecast for energy consumption

The analysis comprises energy consumption associated with the urban form. This indicator is mainly related to three city characteristics, urban expansion, vehicle kilometres travelled, and technology used by inhabitants. The increase in the urban footprint affects energy consumption as networks from public lights, water supply, and wastewater treatment expand. Also, the expansion of distances within the city boosts the required kilometres to travel from one point to another. Finally, energy consumption changes according to the technology that prevails in the city, for example, LED technology.

The energy consumption indicator accounts for the total average energy consumed for public lighting, municipal water supply, solid waste management, energy in dwellings, commuting by public transport and private cars, and wastewater treatment. The energy consumption is measured in megajoules that an inhabitant consumes in a year. It is calculated as the sum of each category of energy and electricity consumption. The components of the energy consumption indicator are described as follows:

Energy-related to buildings

This indicator accounts for the energy consumed by heating, lights, space cooling, cooking, electrical appliances, and water heating. The energy-related to buildings is measured in megajoules that an inhabitant consumes in a year. It is calculated by multiplying the number of buildings by the energy consumption per household sector. The energy-related to buildings was calculated based on the report named "Development of an energy benchmark for residential apartments in Amman" published in 2019[19].

Commuting energy

This indicator accounts for the energy consumed by private vehicles and public transportation. The commuting energy is measured in megajoules that an inhabitant consumes in a year. Energy consumption associated with transportation is calculated by adding the energy consumed per type of fuel and transport in the city. The energy conversion factor combines the calorific value and the density of diesel or gasoline. Commuting is obtained by multiplying the vehicle kilometres travelled per means of transport, by the percentage of motorised vehicles that use either diesel or gasoline, the fuel calorific value and density. The result is divided by the fuel consumption rate of the motorised vehicle[20].

The energy consumption by electric transport is obtained by multiplying the vehicle kilometres travelled per means of transport, by the percentage of electric vehicles. The result is divided by the energy economy in kilometres per kilowatt-hour[21]. The result is presented in kilowatt-hours per year and transformed according to the unit transformation.

Electricity related to public lighting

This indicator accounts for the electricity consumed by streetlights. The electricity is measured in megajoules that an inhabitant consumes in a year. It is calculated by multiplying the total bulbs for street lighting required for the urban footprint, the energy consumption, and the penetration of LED technology or other efficiency measures[22].

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[19] The energy unit transformation considered that 1 kWh is equivalent to 3.6 MJ, recognizing that a Watt is a J/s (Bureau International des Poids et Mesures, 2019).

[20] *Commuting energy from motorised vehicles* = $(VKT_i * \%MV_i * CV_i * d_i) / (Fuel\ economy_i)$. Where VKT_i is vehicle kilometres travelled per means of transport, $\%MV_i$ is the percentage of motorised vehicles that use either diesel or gasoline, CV_i is the fuel calorific value, d_i density, and $Fuel\ consumption_i$ the fuel consumption rate of the motorised vehicle.

[21] *Commuting energy from electric vehicles* = $(VKT_e * \%MV_e) / (Energy\ economy_e)$. Where VKT_e is vehicle kilometres travelled per bus or car, $\%MV_e$ is the percentage of electric buses or cars, and $Fuel\ consumption_e$ the fuel consumption rate of the electric vehicle. The energy unit transformation considered that 1 kWh is equivalent to 3.6 MJ, recognizing that a Watt is a J/s (Bureau International des Poids et Mesures, 2019).

[22] The energy unit transformation considered that 1 kWh is equivalent to 3.6 MJ, recognizing that a Watt is a J/s (Bureau International des Poids et Mesures, 2019)

Electricity related to water and wastewater

This indicator accounts for the electricity consumed to supply water through the city network and the electricity consumed in the wastewater treatment plant. The electricity related to buildings is measured in megajoules that an inhabitant consumes in a year. It is calculated by multiplying the electricity requirements to supply a cubic metre of water, the water distribution loss, and the water network length (calculated according to the urban footprint and length of roads)[23].

Image 23 and Table 4 show the energy-related to buildings according to each scenario. The results depict the implementation of levers: C. Demand-side management and D. Green building codes which benefit the overall energy and electricity consumption in buildings. On average, 15% of energy and electricity consumption in the city buildings are related to lighting and electric appliances, 66% is related to heating, space cooling and heating water. The remaining 19% is related to the energy required for cooking. The BAU and Plan Scenarios have a minor difference in energy reduction, as the penetration of policies is null or low (15%). By contrast, the Ambitious and Net Zero Scenario have a significant reduction in energy consumption. From the six categories of energy consumption, heating activities have the highest energy consumption. Therefore, policies related to heating technology and behavioural change have the highest benefits.

[23] The energy unit transformation considered that 1 kWh is equivalent to 3.6 MJ, recognizing that a Watt is a J/s (Bureau International des Poids et Mesures, 2019).

Image 23. Energy* related to buildings.

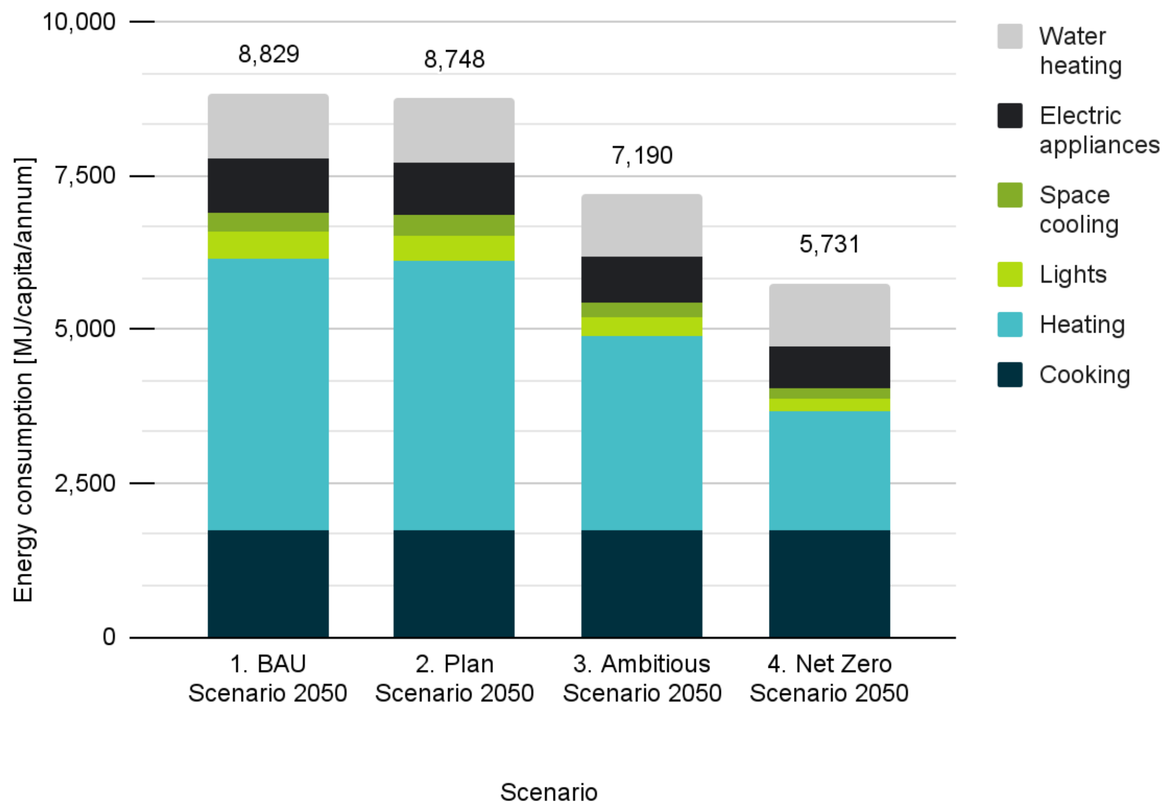


Table 4. Integrated results for energy consumption.

Indicator	BAU Scenario 2050	Plan Scenario 2050	Ambitious Scenario 2050	Net Zero Scenario 2050
Energy related to cooking [MJ/capita/annum]	1,715.9	1,715.9	1,715.9	1,715.9
Energy related to heating [MJ/capita/annum]	4,440.4	4,387.1	3,161.6	1,953.8
Energy related to lights [MJ/capita/annum]	424.7	418.3	310.0	212.3
Energy related to space cooling [MJ/capita/annum]	326.6	324.2	235.5	143.7
Energy related to electric appliances [MJ/capita/annum]	870.0	863.5	772.1	696.0

Energy related to water heating [MJ/capita/annum]	1,051.1	1,038.5	994.4	1,009.1
Energy related to buildings [MJ/capita/annum]	**8,828.8**	**8,747.6**	**7,189.5**	**5,730.9**

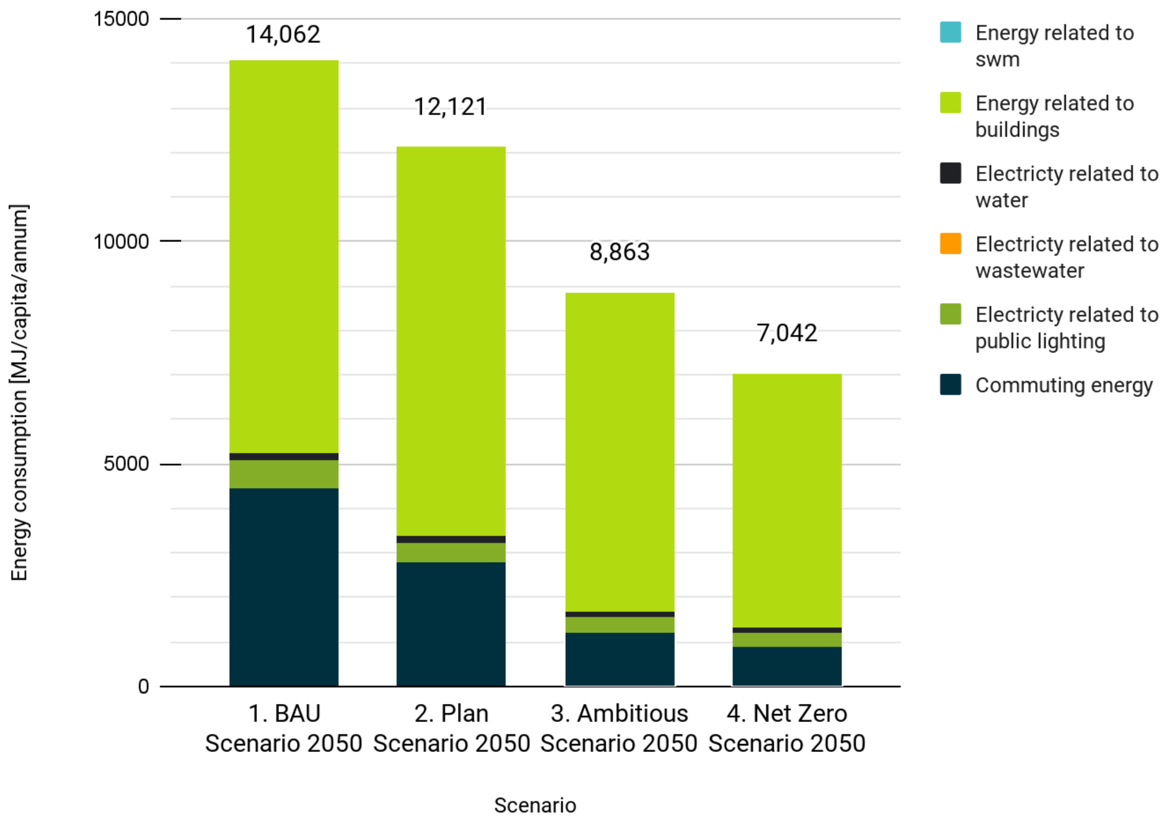
*Note: the energy consumption related to buildings include electricity consumed from the electric grid, energy consumed from diesel, liquefied petroleum gas and solar water heating.

Source: Urban Planning Scenarios for Amman, 2022.

Image 24 shows the energy consumption of the city according to various levers. The results depict the implementation of several levers, including levers: C. Demand-side management, D. Green building codes, E. electricity consumption in public lighting, F. Electrification of transport, G. Mass public transit, K. Water management. Additionally, the elasticity related to the kilometres travelled by private vehicles or public transport is affected by active mobility measures, such as H. Pedestrianisation and I. Controlled Parking.

Energy consumption decreases in all five categories for the Plan, Ambitious and Net Zero Scenarios. The highest energy consumption occurs in the BAU Scenario, as it has no policies related to energy efficiency and the urban footprint is the largest of all the future scenarios. Also, the commuting energy consumption is higher than the other scenarios, as distances are more likely to extend. By contrast, the Net Zero scenario is the most efficient in energy terms, as it has the topmost penetration of energy saving and efficiency measures. Also, the urban footprint facilitates more efficient resource management. The Plan Scenario has an important energy reduction in commuting activities as there are significant investments for public transport systems and electrification of transport. Though the energy-related to buildings is similar to the BAU scenario, which indicates areas of opportunities for the planned policies. Finally, the Ambitious Scenario promotes more aggressive measures to enhance energy efficiency in buildings.

Image 24. Energy consumption of Amman.



Source: Urban Planning Scenarios for Amman, 2022.

Results show that the combined effect of policy levers reduces energy consumption for future scenarios. The integration of mass transit, pedestrianisation measures, and changing fuel technology to electric vehicles produces a significant decrease in the energy consumption related to mobility. By contrast, the reduction of electricity consumption related to buildings is minimal for the Plan Scenario due to the penetration objective. Despite the ambitious goals set for electricity reduction, the number of buildings that integrate efficiency measures is highly important. The percentage of penetration creates a significant reduction in electricity consumption, as shown in the Ambitious scenario. Noteworthy, the Green Building Code measures might lead to savings in oil, gas, or wood consumption used in buildings for various purposes such as heating.

In addition, results show that the urban footprint strongly affects electricity consumption because the city requires more electricity to provide proper street lighting. The bigger the urban footprint, the bigger the demand for electricity related to this service. The electricity-related wastewater does not change due to the actual capacity of the water treatment plant.

The green building codes and water efficiency measures decrease the water demand and the electricity required to supply potable water. The number of buildings that integrate efficiency measures and reduction in water losses highly benefit the overall potable water management system. Noteworthy, the city is planning to create a new wastewater treatment plant to support the regional production of wastewater and energy consumption might increase.

Table 5. Integrated results for energy consumption.

Indicator	BAU Scenario 2050	Plan Scenario 2050	Ambitious Scenario 2050	Net Zero Scenario 2050
Electricity related to public lighting [MJ/capita/annum]	636.0	456.7	358.8	332.6
Energy related to buildings [MJ/capita/annum]	8,828.8	8,747.6	7,189.5	5,730.9
Energy related to solid waste management [MJ/capita/annum]	1.1	1.0	0.6	0.3
Electricity related to water [MJ/capita/annum]	142.3	135.5	100.2	89.6
Electricity related to wastewater [MJ/capita/annum]	9.1	9.1	8.6	8.3
Commuting energy [MJ/capita/annum]	4,445.0	2,771.6	1,204.9	880.7
Energy consumption [MJ/capita/annum]	**14,062.3**	**12,121.4**	**8,862.6**	**7,042.4**

Source: Urban Planning Scenarios for Amman, 2022.

Renewable energy generation

Currently, national measures are focused on increasing renewable generation in the energy mix. The major energy investments seek to decrease the number of energy imports through new natural gas power plants (National Electric Power Company, 2020). The Jordan Energy Strategy 2020-2030 has the objective to provide a secure, affordable and sustainable system and achieve optimal investments which provide social and economic benefits. For a medium- and long-term objective, the national strategy is seeking to increase the energy mix with solar and wind parks, as they continue investing in both energy sources[24].

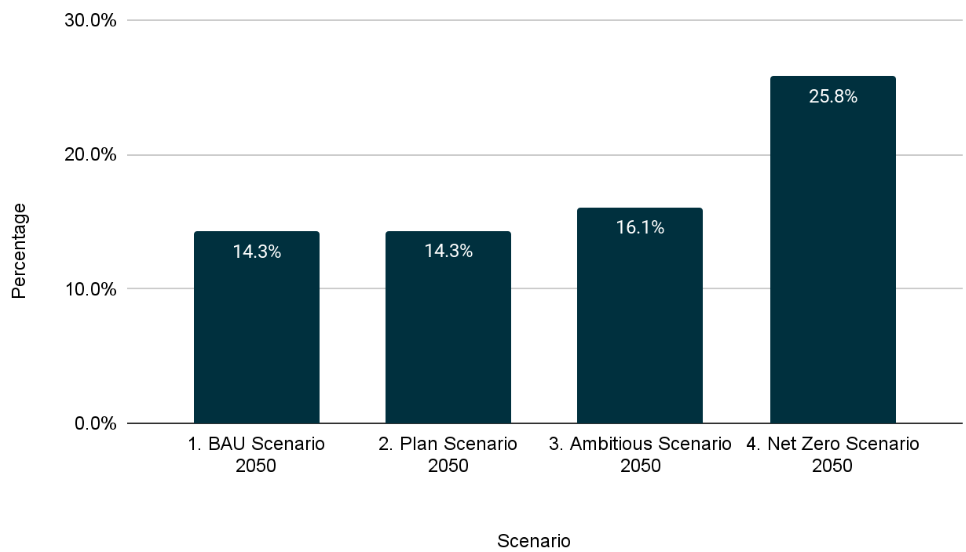
The renewable energy indicator accounts for the percentage of renewable energy contribution. The approximation was based on the anticipated demand for energy and the renewable contribution determined in climate plans and net zero goals. Renewable energy

[24] The concluded projects for 2020 included two solar projects with a total capacity of 211MW, two wind projects with a total capacity of 145 MW, and an additional wheeling solar electrical distribution system between different grid or network service areas of 56MW.

generation is measured in percentages. It is calculated by adding the annual generation of solar photovoltaic, wind, biogas, and hydroelectric sources.

Image 25 presents the increase in energy generation for the different scenarios. It depicts results from the lever B. Renewable energy. The BAU Scenario assumes that there are no investments within the city, limiting the renewable energy contribution to 14.3% of the required energy to supply the city activities (IRENA, 2019). The Plan and Ambitious Scenarios have a slight increase in renewable energy generation. Noteworthy, the Ambitious Scenario has an important increase in distributed energy with solar street lighting. The Net Zero Scenario brings significant changes in the energy sector, as it assumes that all energy in the city will be supplied from renewable sources[25]. This assumption requires creative policy changes and investments as the electricity system would require decommissioning the non-renewable energy power plants, greening the national grid, or creating distributed renewable energy systems to maintain the energy security of Amman and the country.

Image 25. Renewable energy generation.



Source: Urban Planning Scenarios for Amman, 2022.

2050 Forecast for greenhouse gas emissions

Cities are major contributors to GHG emissions. Those emissions are related to the high dependency on fossil fuels for energy generation and they are associated as a by-product of urban landscapes. These CO_2 emissions exacerbate global warming, which further aggravates climate change and pollution's negative impacts. Climate change increases the severity and frequency of floods, landslides, and other events (UN, 2022). To prevent and build more resilient cities, Jordan's government and GAM agreed on international commitments to encourage green policies and had already begun to take measures to reduce GHG emissions.

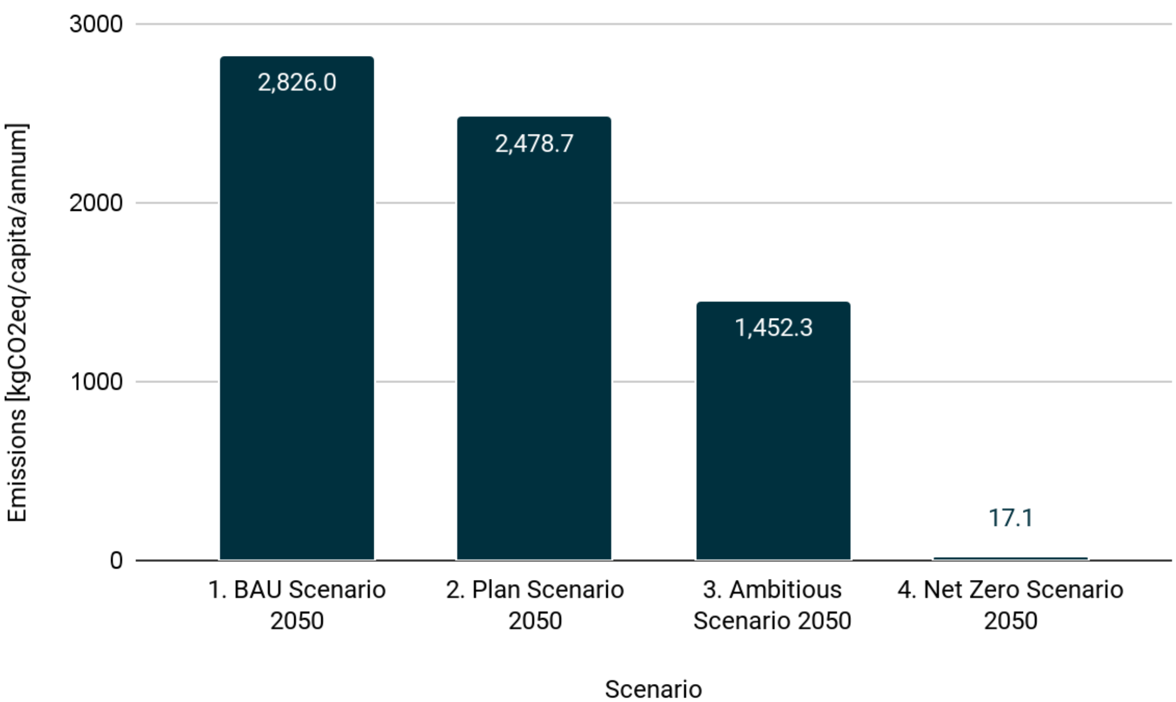
This indicator accounts for the average GHG emissions released annually. It depicts the GHG of energy consumption, land consumption, public lighting, municipal water supply, solid

[25] Scenarios do not differentiate between local and national renewable energy generation.

waste collection, energy in dwellings, and commuting for public transport and private vehicles. Greenhouse gas emissions are measured in kilograms of CO_2eq per capita per year. Emissions are calculated using the energy and electricity consumption of each category and the emission factor of the energy source.

Image 26 shows that the combined effect of policy levers create a cleaner electricity mix and reduce energy consumption. The graph depicts the results of the integration of most policy levers related to energy consumption, renewable energy and transport. GHG emissions decreased in the Plan, Ambitious and Net Zero Scenario. Key variables related to the reduction of GHG emissions were renewable energy contributions. The reduction of GHG emissions by the Plan Scenario is 12% compared to the BAU, the Ambitious 49%, and the Net Zero Scenario 99%. However, this is an optimistic view as the amount of GHG released to the atmosphere compared to 2020 is different. The GHG emissions increase in the Plan Scenario by 14% compared to the actual emissions, and they only decrease in the Ambitious and Net Zero Scenario by 33% and 99%, respectively.

Image 26. GHG emissions results.



Source: Urban Planning Scenarios for Amman, 2022.

2050 Forecast for economic costs

Economic costs of cities and their urban form include transportation, greenhouse gas emissions per capita, productivity, distribution costs for utility services, access costs to facilities, among others. These costs are defined by density, centricity and city size (UN-Habitat, 2014). Consequently, lower density cities are likely to have higher distribution costs and high-density forms are likely to offer the best balance of low transportation and infrastructure costs, low environmental impact, and high income-generation abilities (UN-Habitat, 2014; Wenban, 2011). However, the high-density levels might also include congestion and high land prices. Policy development and investments in infrastructure require a broad approach to assess the potential benefits and necessities for Amman.

Costs for new infrastructure and local policies

The indicator is disaggregated in 14 costs for municipal investments required to reach the potential of GHG reduction according to each scenario. Expenditures are calculated by multiplying the parametric cost of the new infrastructure or the economic measure.

Table 6 shows key sources for expenditure estimation related to new infrastructure and policy levers. The different investments for each scenario were based on the different phases detailed in the documents or parametric costs per kilometre of new infrastructure. Exchange rates for the different currencies were:

A. Euro to US Dollar: $1.10,
B. Dinar to US Dollar $1.40, and
C. Pound sterling to US Dollar $1.30.

Urban expansion

This indicator accounts for the enforcement of urban planning measures and management of spatial information for real estate activities. The estimation added the sum of the following costs:

- Improve public realm € 80,000.00 – € 120,000.00
- GIS database updates € 50,000.00 per year,
- Development of an up-to-date land use plan € 3,000,000.00 – € 4,000,000.00

The Plan Scenario comprises the minimal costs for the public realm and land use plan (€ 80,000.00 and € 3,000,000.00 respectively). The Ambitious and Net Zero Scenarios consider the topmost cost (€120,000.00 for the public realm and € 4.00 million for a land use plan). The cost estimation was based on the "Development of a servicing and implementation plan for East Amman" from the Amman Green City Action Plan published in 2021 by AECOM.

Renewable energy contribution

This indicator accounts for the new installed capacity of renewable energy. It comprises the cost per megawatt in Amman and the new installed capacity of renewable energy. The investment in large grid-scale solar projects is € 26,000,000.00 – € 65,000,000.00 according to the strategy of "Efficient and resilient energy systems and buildings" from the Amman Green City Action Plan published in 2021 by AECOM. The cost estimation per megawatt of installed capacity was € 1.30 million.

Demand-side management

This indicator accounts for the financial benefits implemented to promote behavioural and technology changes. It was calculated by multiplying the financial benefit and the number of buildings implementing this intervention. The analysis estimated $ 220.00 USD per engaged household. The cost assumption was based on the document "Monetising behavioural change as a policy measure to support energy management in the residential sector: A case study in Greece" (Koasidisa, et al., 2022).

Green buildings codes

This indicator accounts for the cost of the enforcement of building codes in the city. It was calculated by multiplying the cost of increasing awareness of green building design per building and the number of buildings implementing this intervention. The expenditure was based on the Amman Green City Action Plan strategy (€ 90,000.00 – € 130,000.00).

Electricity consumption in public lighting

This indicator accounts for the cost of installation and LED or solar street light technology. It was calculated by multiplying the cost of these technologies per lamp and the number of streetlights that would be replaced. The cost of LED bulbs and their installation was based on the description of the "Integration of LED systems into municipal street lighting" from the Amman Green City Action Plan published in 2021 by AECOM. The cost of solar lamps was based on costs published by Alibaba, in 2022. The assumptions were:

- LED technology: $ 814.00 USD per lamp
- LED solar lamp: $ 2,279.00 USD per solar lamp.

Electrification of transport

This indicator accounts for the electrification of public buses. It was calculated by multiplying the average cost of battery-electric buses, the percentage of penetration of the policy and the bus fleet of the city. The average cost of battery-electric buses is $56,437.00 USD, based on the average price published by Nunno, 2018.

Mass public transit

This indicator accounts for the implementation of new BRT routes. It was calculated by multiplying the parametric cost of BRT systems and the proposed kilometres of mass public transit. The average cost analysed was $11,504,575.00 USD per kilometre, published by the Institute for Transportation & Development Policy (ITDP, 2006).

Pedestrianisation

This indicator accounts for the implementation of new cycling lanes and sidewalks. It was calculated by multiplying the parametric cost of cycling lanes and sidewalks and the proposed kilometres for a complete street corridor. The investment was based on the report of Taylor and Hiblin, 2017; and Purnell, 2021:

- $1,248,000.00 USD per kilometre of bike lanes.
- $258,500.00 USD per kilometre of sidewalks.

Controlled parking

This indicator accounts for the implementation of parking metres. It was calculated by multiplying the amount of parking metres and the cost per unit. The cost published by ITS, 2020 was $250.00 USD per parking metre. The estimation considered that each hectare would require 2 parking metres.

Waste management

This indicator accounts for the cost of dumpster containers, expenditure for material recovery facilities and transfer stations. The estimation added the following costs:

- New dumpster containers $380.00 USD (Alibaba, 2022).
- Improvement of Al-Shaer waste transfer station € 6,500,000.00 (AECOM, 2021)
- Transfer Facility of waste from electrical and electronic equipment (WEEE) € 400,000.00 – € 410,000.00 (AECOM, 2021)

The Plan Scenario comprised changing 20,000 containers. The Ambitious Scenario included changing 20,000 waste containers, improving the transfer station and the development of WEEE recovery facility. The Net Zero Scenario sums the change of 20,000 waste containers, improving two transfer stations and constructing a WEEE material recovery facility.

Water management

This indicator accounts for the cost of water efficiency packages for the city, and expenditure for a sound maintenance program based on the parametric cost of water network maintenance per kilometre. The cost was based on the green building code design cost (€ 90,000.00 – € 130,000.00) and the parametric cost of water network maintenance ($741.18 USD per kilometre). Costs were obtained in the Amman Green City Action Plan published in 2021 by AECOM and the report published by Pitman, 2004 for water network maintenance.

Green spaces and parks

This indicator accounts for the creation of parks and their comprehensive maintenance. It was calculated by multiplying the number of parks and the cost of expanding green spaces (€ 350,000.00 – € 530,000.00) detailed in the strategy of "Comprehensive and reflective land use planning" from the Amman Green City Action Plan published in 2021 by AECOM.

Grey infrastructure

This indicator accounts for the infill cost of upgrading the water, sewage, and electric networks in the existing areas of the city with a two-fold increase in their population. The parametric costs for renewal and maintenance of public utilities detailed by the Greater Amman Municipality in 2017 were:

- $ 63,000.00 USD/km for electricity network.
- $ 31,500.00 USD/km for sewer network.
- $ 76,380.00 USD/km for the water network.

This indicator also accounts for the expansion costs including building roads, water, sewage, public lighting, and electric networks in the new areas of the city by adding the parametric costs of infrastructure per kilometre that is built in the new urban areas. The parametric costs are then multiplied by the number of kilometres of primary, secondary, and tertiary roads, and by the amount of total land designated for expansion. The cost or construction of public utilities detailed by the Greater Amman Municipality in 2017 were:

- $ 413,000.00 USD/km for primary roads.

- $ 320,600.00 USD/km for secondary roads.
- $ 294,000.00 USD/km for tertiary roads.
- $ 42,000.00 USD/km for electricity network.
- $ 21,000.00 USD/km for public lighting.
- $ 21,000.00 USD/km for sewer network.
- $ 42,000.00 USD/km for the water network.

Infrastructure for flood prevention

This indicator accounts for the water drainage infrastructure (for example, micro-tunnelling) connecting the pond area to the Zarqa River and implementing nature-based solutions. The estimation for the micro-tunnelling considered the following:

- Developing the feasibility study of water conveyance and/or storage to reduce flood risk: € 700,000.00 – € 740,000.00
- Implement drainage infrastructure for Ruseiffa natural lagoon Phase 1: € 5,200,000.00

The Plan Scenario included the minimal economic effort for water conveyance, while the Ambitious Scenario considered the topmost cost.

The estimation for the nature-based solution in the Net Zero Scenario included the following:

- Implement nature-based solutions for Ruseiffa natural lagoon Phases 1 and 2: € 13,320,000.00
- Pilot sustainable drainage systems principles: € 13,710,000.00

These costs are based on the "Integration of water resources management" from the Amman Green City Action Plan published in 2021 by AECOM.

Table 6 shows the total cost of municipal investments. Expenditures are presented in millions of US dollars for each scenario. The analysis under the BAU Scenario excludes public policies and interventions that support the city's sustainability, for example, renewable energy generation, water and energy efficiency in buildings, among others. However, the BAU Scenario includes the development of public utilities required to supply new urban areas, for example, new roads, street lighting, electricity, water and sewage networks. By contrast, the Net Zero Scenario depicts the investment to endorse roughly net zero emissions from the urban, energy and transport sectors. For example, renewable energy capacity increases significantly to support the city's electric demand (see policy lever descriptions in the Methodology section). The Plan and Ambitious Scenario have urban policy measures that promote compact growth. These scenarios require grey infrastructure to supply public services to the new urban areas while implementing new sustainable investments.

Table 6. Capital expenditures of new infrastructure and local policies.

Expenditures [Millions of USD]	**BAU Scenario 2050**	**Plan Scenario 2050**	**Ambitious Scenario 2050**	**Net Zero Scenario 2050**
Urban planning: Enforcement of urban planning measures and management of spatial information for real estate activities.	$0.0	$5.0	$6.2	$6.2

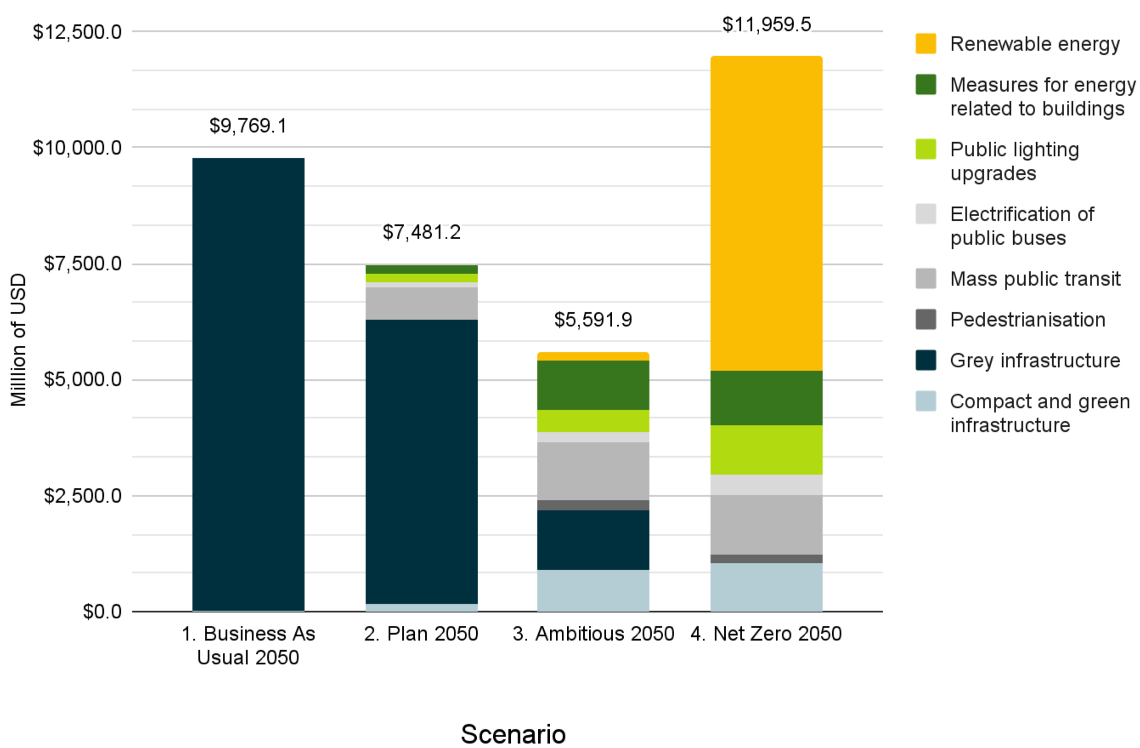
Expenditures [Millions of USD]	**BAU Scenario 2050**	**Plan Scenario 2050**	**Ambitious Scenario 2050**	**Net Zero Scenario 2050**
Renewable energy: Expenditure of installed capacity of renewable energy in megawatts.	$0.0	$20.2	$196.8	$6,775.5
Demand side management: Financial benefits implemented to promote behavioural and technology changes.	$0.0	$31.3	$187.7	$208.6
Enforcement of buildings codes: Cost of the enforcement of building codes in the city.	$0.0	$143.1	$858.3	$953.7
Public lighting upgrades: Cost of the street light installation and LED technology or solar street light technology.	$0.0	$189.6	$462.5	$1,061.6
Electrification of public buses: Average cost of battery-electric buses.	$0.0	$115.5	$231.0	$462.0
Mass public transit: Cost of implementing the new BRT routes based on the parametric cost of BRT systems per kilometre.	$0.0	$690.3	$1,265.5	$1,265.5
Pedestrianisation infrastructure: Cost of implementing the new cycling lanes and sidewalks based on their parametric cost per kilometre.	$0.0	$0.0	$165.7	$165.7
Controlled parking: Cost of implementing parking metres.	$0.0	$2.5	$37.5	$37.5
Waste management: Cost of dumpster containers. Expenditure for material recovery facilities and transfer station.	$0.0	$7.6	$21.8	$35.6
Water management: Cost of water efficiency packages for the city, and expenditure for a sound maintenance program based on parametric cost of water network maintenance per kilometre.	$0.0	$143.1	$862.1	$957.4
Green spaces and parks: Expenditure for the creation of parks and comprehensive maintenance systems.	$0.0	$0.4	$0.4	$0.6
Grey infrastructure*: Expenditure for building roads, water, sewage, public lighting, and electric networks in the new areas of the city or upgrading to support densification.	$9,769.1	$6,126.3	$1,289.9	$0.0
Infrastructure for flood prevention: Expenditure for the water drainage infrastructure (i.e., micro-tunnelling) connecting the pond area to the Zarqa River, and expenditure for a green water drainage infrastructure.	$0.0	$6.5	$6.5	$29.7
Total	**$9,769.1**	**$7,481.2**	**$5,591.9**	**$11,959.5**

Source: Urban Planning Scenarios for Amman, 2022.

These expenditures are based on the previous analysis and plans depicted by GAM or according to international sources. In Table 6, grey infrastructure includes expenditures related to infill retrofit and expansion investments. In the BAU Scenario, the infill cost is $38 million USD (0.4% of the total cost of the BAU Scenario) and the expansion cost is $9,731 million USD. The Plan, Ambitious and Net Zero Scenario will not hold areas with a two-fold increase in population, which result in zero infill costs.

Image 27 shows the total cost for the policy levers implemented per scenario. The recommended investment is $11.9 Billion US dollars to reach a Net Zero Scenario. These costs are related to renewable energy generation, public lighting upgrades and mass public transit. By contrast, if GAM does not intervene with resilient infrastructure and GHG emission reduction policies, the municipality will require $9.8 Billion US dollars to upgrade and expand the water, sewage, and electric networks. Regarding the Plan Scenario, GAM will likely invest $7.5 Billion US dollars in developing the planned interventions and policies. Under this scenario, the investment in public utilities sums 82% of the total expenditure. Finally, the Ambitious Scenario has the lowest forecasted cost, with $5.6 Billion US dollars. It reduces up to 50% of GHG emissions compared to the BAU Scenario. Noteworthy, the new infrastructure and policies could provide co-benefits such as proximity to facilities or more efficient public services.

Image 27. Total capital expenditure of new infrastructure and local policies.



Source: Urban Planning Scenarios for Amman, 2022.

Private sector costs

This section presents three indicators related to private costs. The results are related to the potential costs that citizens would pay from energy-related to buildings, fuel costs for transportation from private cars and productivity loss related to commuting. The exchange rate was assumed as $1.4 from Dinar to US Dollar.

Cost of energy-related to buildings

This indicator accounts for the expenditure required to provide electricity and thermal energy in buildings. The cost measures the expenditure that citizens would require to pay for electricity. It comprises the expenditure from using the electric grid to provide electricity, also the cost of gas and diesel used for heating and water heating. Cost assumption considered a $0.1115 USD/kWh for electricity, $0.87 USD/L for diesel and $0.2 USD/L for gas, based on information presented by Global Petrol Prices, 2022a; 2022b; 2022c; and the energy statistics from Nazer, 2019.

Fuel cost

This indicator accounts for the fuel required to travel within the city. It is calculated by multiplying the diesel and gasoline needed for private cars and the price of each fossil fuel. Cost assumptions considered $0.87 USD/L for diesel and $1.53 USD/L for gasoline, based on information presented by Global Petrol Prices, 2022a; 2022b; 2022c; and the energy statistics from Nazer, 2019.

Productivity loss by commuting

This indicator accounts for all the hours spent commuting. It assumes that the time lost by commuting would be used for work or productive activities accordingly and it is calculated by multiplying the hours spent commuting by the average income in Amman. The commuting time considers the daily vehicle travelled in the city, which includes mobility by cars and buses. Cost assumptions considered $1.85 USD/hour as the average salary in Jordan, based on information published in the Household Expenditures and Income Survey from the Department of Statistics, 2017.

Figure 28 shows the total cost for citizens has a steady decrease related to more ambitious GHG reduction goals. The Net Scenario has the lowest expenditures for all three indicators. It is 28% lower than the BAU Scenario, which has the highest cost for the citizens. The worst-case scenario is under the costs forecast for Business As Usual, as costs for citizens are high. The private costs are **$385** US Dollars per capita for the BAU Scenario; **$317** US Dollars per capita for the Plan Scenario; **$253** US Dollars per capita for the Ambitious Scenario; and **$183** US Dollars per capita for Net Zero Scenario. Productivity loss by commuting has approximately 1% change between the BAU and Net Zero Scenarios. The urban and transport sector will likely have a significant improvement in active mobility and a reduction of urban expansion. Though, people might change their means of transportation and change mobility patterns, while spending similar commuting time. For example, citizens will likely use mass transit transport to have more resource efficient transportation.

Image 28. Cost for energy, fuel and commuting time per capita.

Source: Urban Planning Scenarios for Amman, 2022.

Municipal service cost

This indicator accounts for public lighting, water, wastewater treatment, waste management, and maintenance of the city's roads. The cost is an annual estimation of the average expenditure[26] for the maintenance of roads. It also considers the operating cost[27] for public lighting, waste collection system, water and wastewater usage. The annual municipal expenditure in public services is estimated from:

- The energy needed to provide public lighting in all the streets of the city multiplied by the cost the municipality pays per each kWh of electricity consumed for public lighting,
- Plus, the average cost of replacing light bulbs in the city, plus the energy needed to provide potable water multiplied by the cost the municipality pays per each kWh of electricity consumed for provision of potable water,
- Plus, the average annual expenditure to run the solid waste management and collection services in the city,
- Plus, the average annual expenditure to maintain all the city's roads,

[26] Average expenditure for maintenance of primary roads is $220,000.00 USD/km, secondary roads are $116,000.00 USD/km, and tertiary roads are $81,200.00 USD/km. Costs were detailed by the Greater Amman Municipality in 2017.

[27] Cost that the municipality pays per kWh of electricity consumed for public lighting $0.1596 USD/kWh, to provide potable water $0.1316 USD/kWh, and for wastewater treatment 1 USD/kWh. Costs were detailed by the Greater Amman Municipality in 2017.

- Plus, the running cost of the construction waste management system and the wastewater treatment running cost.

The running cost of water and wastewater is around 6% and 13% of the total municipal service cost according to each scenario. Table 8 shows that a more efficient urban form lowers municipal costs, as the Net Zero Scenario has the lowest municipal expenditure of all scenarios. The reduction between the BAU and the Net Zero Scenario is around 30%. Notably, the exchange rate was assumed as $1.4 from Dinar to US Dollar.

Table 7. Annual costs for municipal service per scenario.

Expenditure [Million USD]	BAU Scenario 2050	Plan Scenario 2050	Ambitious Scenario 2050	Net Zero Scenario 2050
Municipal service	$2,955.1	$2,537.5	$2,131.5	$1,987.8

Source: Urban Planning Scenarios for Amman, 2022.

Costs for extreme events

This section presents two indicators related to climate change economic impacts. The results are related to the potential costs for the productivity loss caused by extreme events and temporary relocation caused by these extreme events.

Productivity loss caused by extreme events

This indicator accounts for the working hours lost related to extreme events. The analysis assumed a day event caused by pluvial or fluvial flooding or landslides. The cost is measured in millions of dollars. Calculations are based on return periods for each hazard from hazards data (GFDRR, 2022), night-time lights data (NOAA via WorldPop, 2020), and GDP data (World Bank Group, Development Indicators, 2022).

Temporary relocation caused by extreme events

The cost of temporary relocation or change of residence assumes a one-day event caused by extreme events. The estimation is based on return periods for each hazard from the report "Unveiling the cost of internal displacement: 2020" (Cazabat and Yasukawa, 2020), hazards data (GFDRR, 2022), and population data (WorldPop, 2020). IDMC published the global estimates of the costs and losses from impacts associated with internal displacement. The assessment includes the impact metrics on housing, livelihoods, education, health and security. For example, the housing dimension includes costs associated with providing shelter, non-food items, water, sanitation and hygiene services, and camp coordination and camp management. The health dimension includes costs associated with providing food security, nutrition and primary healthcare. For each metric, the average costs are assessed for a year of displacement (Cazabat and Yasukawa, 2020). According to the report, costs are likely to be underestimated, but in some cases, it holds a substantial GDP share (Cazabat and Yasukawa, 2020).

Table 8 shows the potential cost attributed to three-day extreme events. Landslides, pluvial or fluvial flooding prevention and adaptation measures are related to the urban form and the city infrastructure. For example, grey and green infrastructure for water conveyance and storage to reduce flood risk or compact growth efforts reduce the potential cost of extreme events. In Amman, the expenditures for urban planning measures and flooding prevention infrastructure cost approximately $20 Million US Dollars (see urban planning, grey infrastructure for flood prevention and green infrastructure in Table 6). However, this investment will likely reduce the city costs for extreme events by 87%. Contrary, if GAM does not invest in proper infrastructure and measures, the municipality would spend $106.7 Million US Dollars from loss of productivity and temporary relocation.

Table 8. Costs for extreme events.

Expenditure [Million USD]	BAU Scenario 2050	Plan Scenario 2050	Ambitious Scenario 2050	Net Zero Scenario 2050
Productivity loss caused by extreme events	$8.3	$2.1	$1.7	$1.0
Temporary relocation	$98.4	$24.2	$19.5	$12.2
Total	**$106.7**	**$26.3**	**$21.2**	**$13.2**

Source: Urban Planning Scenarios for Amman, 2022.

Costs for GHG emissions

This section presents two indicators related to GHG emission. The results are related to the potential costs from land consumption and carbon market benefits.

Emissions from land consumption

This indicator accounts for the cost of emissions produced by the land-use change from agricultural or natural land to build-up areas. The cost was measured in millions of dollars spent in the carbon market. It is calculated by multiplying the tonnes of carbon dioxide emitted for land consumption and the prices in the carbon market. Cost assumptions for carbon dioxide emissions were $50.00 USD/ton, based on EDF, 2022.

Carbon market benefits

The cost is measured in millions of dollars acquired in the carbon market, based on the cumulative impact of GHG reduction in the 30 years (2020 and 2050). The CO2 emissions depicted in the analysis of 2020 status and 2050 scenarios, are multiplied by the cost. The economic benefit considers a linear reduction of GHG emissions between 2020 and 2050, thus if the cost reaches a reduction below the baseline emissions the carbon benefit is included in the analysis. Cost assumptions for carbon dioxide emissions were $50.00 USD/ton, based on EDF, 2022.

Table 9 shows the potential cost of GHG emissions reduction. Expenditures related to land cover change (LCC) are related to urban expansion, urban footprint, and green areas. The costs related to LCC decrease if more ambitious measures are applied to urban form. Additionally, carbon markets provide economic benefits if carbon sequestration is promoted.

Table 9. Costs for GHG emissions.

Expenditures [kWh/capita/annum]	**BAU Scenario 2050**	**Plan Scenario 2050**	**Ambitious Scenario 2050**	**Net Zero Scenario 2050**
Emissions from LCC	$50.7	$13.9	$0.4	$0.0
Carbon market benefits	$3,350.3	$0.0	-$848.6	-$6,017.6

Source: Urban Planning Scenarios for Amman, 2022.

Results for the economic cost analysis show that, in the long run, the Net Zero scenario performs better than other scenarios. This indicates that budget allocation for more ambitious goals have significant trade-offs and yield savings in the long term. Under the Net-Zero scenario, a quarter of the expenses could be managed through national or international financial mechanisms to support the municipality's expenses. These could promote more efficient municipal financial management and relieve financial stress over GAM. Noteworthy, the BAU and the Plan Scenarios have the highest strain over municipal expenses.

Climate investments co-benefits.

2050 Forecast for proximity to facilities

The location and availability of infrastructure encourage tendencies for urban expansion (Song, 2013). The location of social and public services, such as health, education, and recreation are key factors to plan the urban expansion. For example, if services are in the outskirts, the city tends to expand, while if they are concentrated in different areas within the city boundaries it helps densification programs. In addition, the planned location of the social infrastructure, such as health centres, economic hubs, schools, and recreational facilities needs to be transit-oriented to ease accessibility. The same condition occurs with economic hubs, to enhance economic development, hubs need to be accessible to people, as it provides more efficiency and economic stability (Brueckner, 2000; Song, 2013).

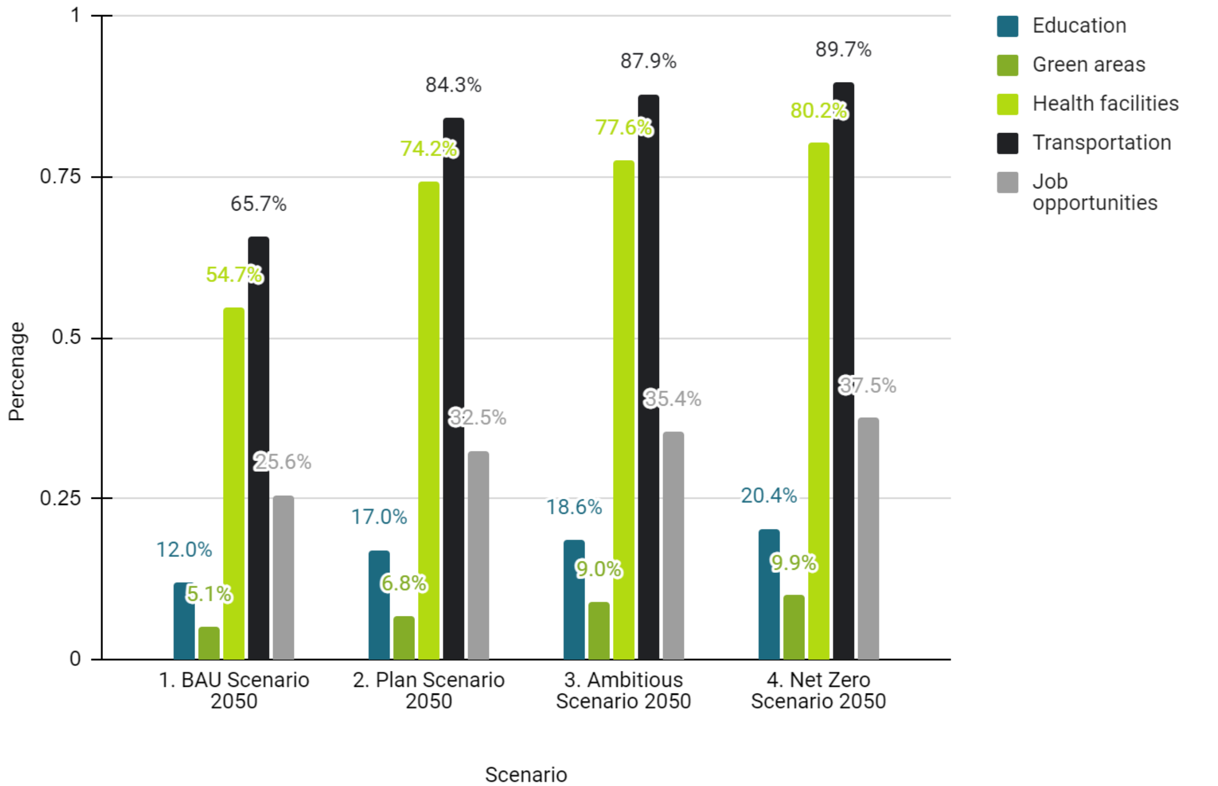
Proximity to facilities accounts for a percentage of proximity related to social and economic infrastructure. It is divided into the following indicators:

- Proximity to education accounts for the percentage of the population that lives within 800 m walking distance (isodistance) from a school.
- Proximity to health facilities accounts for the percentage of the population that lives within a 3,000 m walking distance (isodistance) from the nearest health centre.
- Proximity to job opportunities accounts for the percentage of the population that lives within a 1,000 m radius from an economic cluster.
- Proximity to public transportation accounts for the percentage of the population that lives within an 800 m radius from BRT routes and 300 m from bus routes.
- Proximity to cycling routes accounts for the percentage of the population that lives within a 500 m radius from cycling lanes.
- Proximity to green areas accounts for the percentage of the population that lives within a 700 m walking distance (isodistance) from green areas.
- Proximity to infrastructure is relevant for low carbon development, mainly because it increases productivity by reducing commuting time, reducing carbon emissions by shortening vehicle kilometres travelled, motivating active mobility, benefiting people's health, and reducing the dependency on motorised vehicles.

In addition, the proximity to health facilities holds a direct relationship with post-pandemic health system management and efficiency in health service provision as it supports the increasing demand of these services.

Image 29 shows that the proximity and location of the social infrastructure are variable. The graph depicts that the proximity to public transport is above 80% in all scenarios, and 75% for health centres. The new BRT routes enhance these percentages as the proximity to mass public transit increases significantly in the Plan, Ambitious and Net Zero Scenario. By contrast, the quantity and location of green areas have the biggest area of opportunity. Inhabitants have a proximity percentage of less than 10% in all scenarios, which depicts a strong necessity to increase these types of public spaces into investments.

Image 29. Potential proximity to infrastructure by 2050.



Source: Urban Planning Scenarios for Amman, 2022.

Results show that proximity to facilities are related to new investments and urban planning policies. Also, it is strongly related to the urban footprint and the distribution of population, as the amount of infrastructure and the location of inhabitants change the final percentage. Proximity to infrastructure is relevant for low carbon development, as it reduces commuting time, carbon emissions, promotes active mobility, benefits people's health, and reduces dependency on motorised vehicles.

Table 10. Integrated results for proximity to infrastructure.

Indicator	BAU Scenario 2050	Plan Scenario 2050	Ambitious Scenario 2050	Net Zero Scenario 2050
Proximity to education facilities	12.0%	17.0%	18.6%	20.4%
Proximity to health facilities	54.7%	74.2%	77.6%	80.2%
Proximity to green	5.1%	6.8%	9.0%	9.9%

Indicator	BAU Scenario 2050	Plan Scenario 2050	Ambitious Scenario 2050	Net Zero Scenario 2050
areas				
Proximity to job opportunities	25.6%	32.5%	35.4%	37.5%
Proximity to transportation	65.7%	84.3%	87.9%	89.7%
Proximity to cycling routes	0.0%	0.0%	19.9%	21.0%

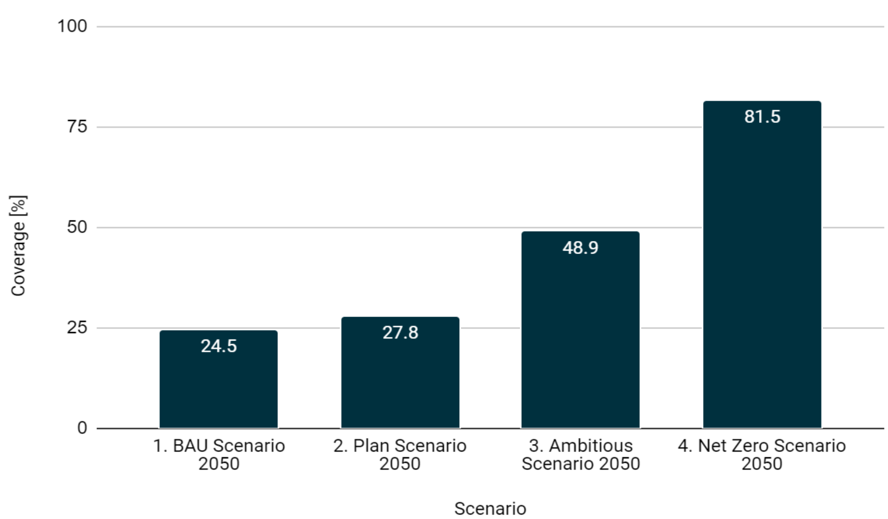
Source: Urban Planning Scenarios for Amman, 2022.

2050 Forecast for solid waste coverage

This indicator accounts for the coverage of the waste collection system. It is calculated by using the number and average capacity of solid waste containers, the number of collection trucks, the times that solid waste is collected, the capacity of the landfill, the capacity of the collection trucks, and the waste generated per person per day.

Image 30 shows that urban expansion strongly affects the waste collection service coverage, as trucks are required to travel further. This indicator rapidly decreases when the land consumption increases, and the urban footprint expands. Also, the daily amount of waste generated by the inhabitants allows longer collection routes. The Net Zero Scenario has the best solid waste collection service, as it will be able to cover approximately 81.5% of the city. While the BAU Scenario will likely have less than 25% service coverage. The other scenarios have less than 50% of the public service coverage.

Image 30. Solid waste coverage.



Source: Urban Planning Scenarios for Amman, 2022.

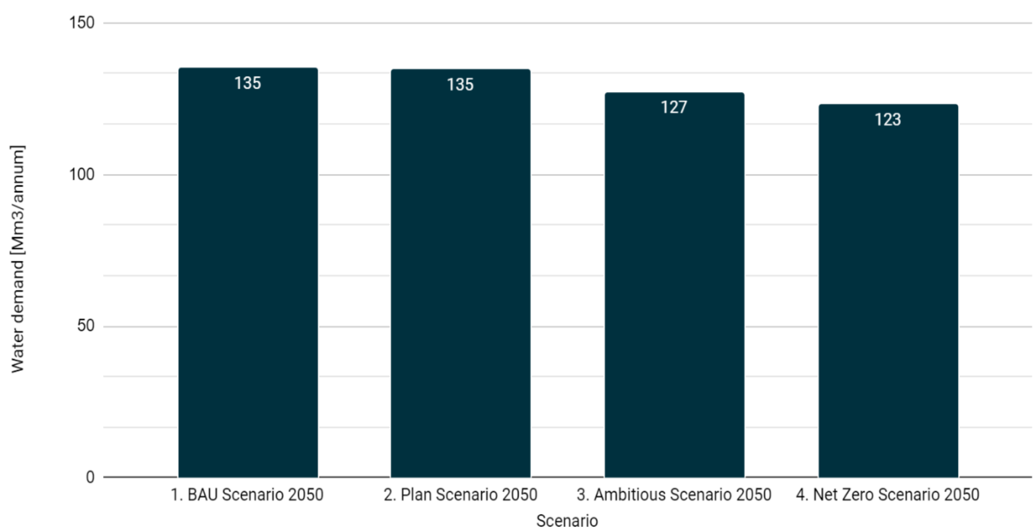
2050 Forecast for water demand

The water and sewage network has extensive coverage in the city. Around 97% of Amman's population is connected to the potable water network and 79.4% to the sewage system (AECOM, 2021). Noteworthy, all collected wastewater is treated. The less developed areas of the city are not connected to both networks and 50% of drinking water is lost by technical losses and illegal connections (around 2,914,420 m^3 of non-revenue water loss). Additionally, the city manages the resource from water bodies outside of the municipal boundaries. This infrastructure provides a description of the carrying capacity of the resources in the city and indicates potential challenges for climate change mitigation measures and resilience.

This indicator accounts for the total cubic metres of water consumed per year in the city. The water demand is calculated by using the water demand per housing unit, the penetration of water efficiency measures, the target water demand, and the total housing units. The approximation to the indicator excludes renewable water that is obtained through rainwater harvesting.

Image 31 shows that the Green Building and water efficiency measures decrease water demand. The difference of water demand between the BAU and the Net Zero Scenario will likely be 12 million cubic metres per year. On the other hand, there is a negligible change in water demand between the BAU and the Plan Scenario, as the penetration for the water efficiency measures in the second scenario is low (15%). A decrease in the city water demand will most likely reduce the risk of water shortages.

Image 31. Water demand.



Source: Urban Planning Scenarios for Amman, 2022.

2050 Forecast for exposure to hazards

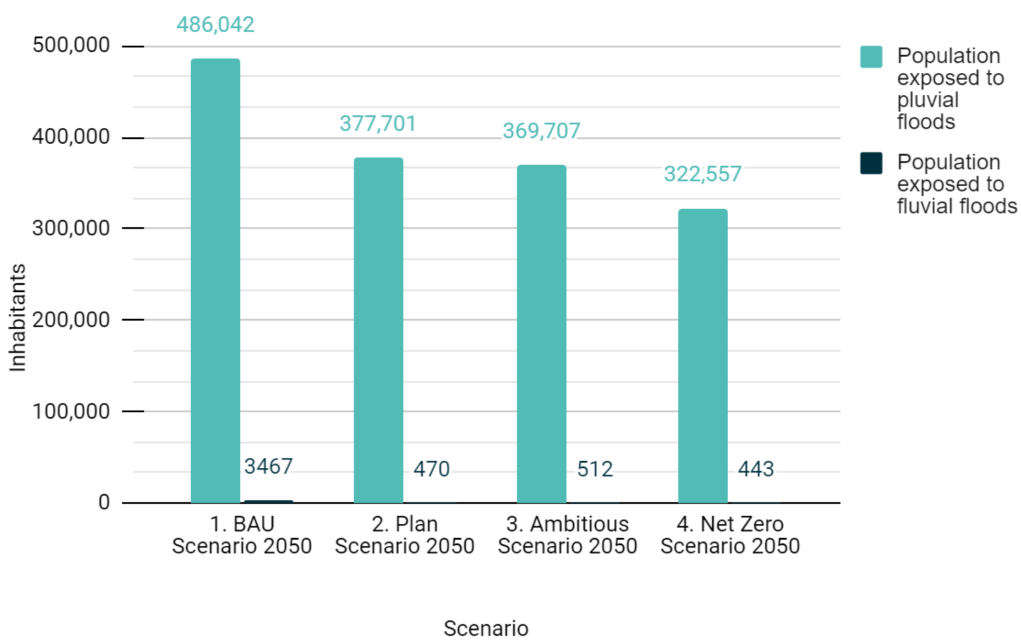
Exposure to hazards accounts for a percentage of proximity related to social and economic infrastructure. It is divided into the following indicators:

- Exposure to landslides accounts for the population exposed to landslide hazards in the city.
- Exposure to pluvial hazards accounts for the population exposed to pluvial hazards in the city.
- Exposure to fluvial hazards accounts for the population exposed to fluvial hazards in the city.

The three indicators are measured by the number of inhabitants. These indicators are calculated by dividing the number of inhabitants that live within the hazard area by the total population. The population exposed to hazards is obtained through spatial analysis.

Image 32 shows that exposure to pluvial and fluvial hazards has a highly relevant trade-off of densification. The distribution of the population in the urban footprint has a strong relationship with the exposure of hazards. Thus, the affected population is variable in the different scenarios. For example, between the Plan and Ambitious Scenario the population exposed to fluvial floods has a slight increase, while the population exposed to pluvial floods decreases.

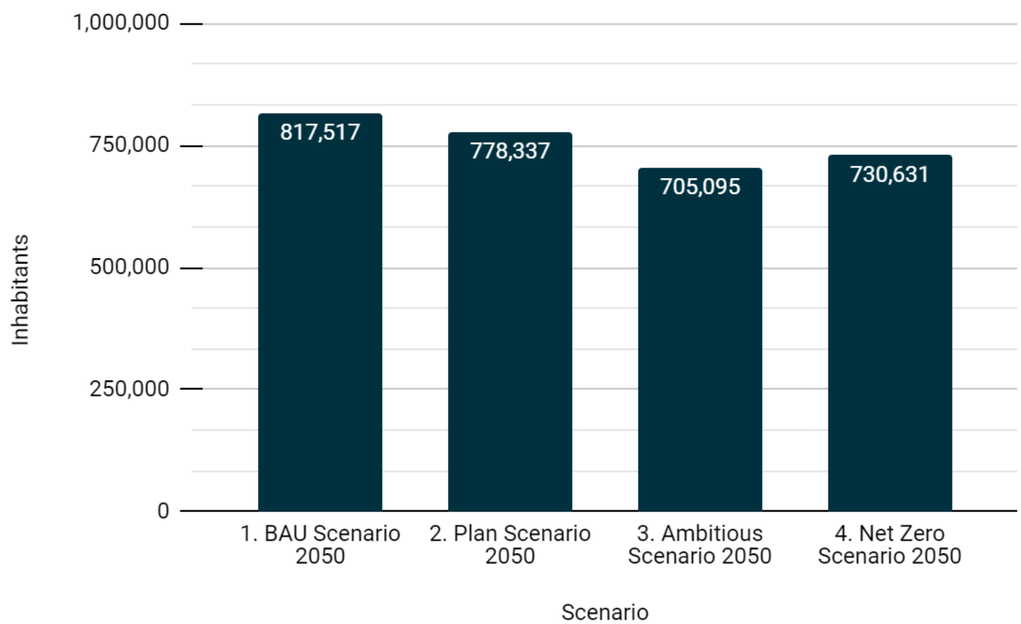
Image 32. Potential population exposed to pluvial and fluvial floods by 2050.



Source: Urban Planning Scenarios for Amman, 2022.

Image 33 shows the potential population exposed to landslides. This indicator has direct relation with urban expansion, densification and population distribution. The scenario with the least population exposed to landslides is the Ambitious. Under the Net Zero Scenario, the exposed population increases as they are located within the current city boundaries. To decrease the exposure to landslides, it would be necessary to integrate this hazard in the urban planning policies of Amman. The database analyses landslides triggered by rainfall. Earthquake-triggered landslides may present a greater risk, but they are not included due to this analysis's focus on climate change. Across the whole city, the average value of the median annual frequency is just 0.0014, roughly corresponding to a 700-year return period (GFDRR, 2021).

Image 33. Potential population exposed to landslides by 2050.



Source: Urban Planning Scenarios for Amman, 2022.

Table 11. Integrated results for exposure to hazards.

Indicator	BAU Scenario 2050	Plan Scenario 2050	Ambitious Scenario 2050	Net Zero Scenario 2050
Population exposed to drought	0	0	0	0
Population exposed to earthquake	0	0	0	0
Population exposed to volcanic eruption	0	0	0	0
Population exposed to fluvial floods	3,467	470	512	443
Population exposed to pluvial floods	486,042	377,701	369,707	322,557

Population exposed to landslide	817,517	778,337	705,095	730,631

Source: Urban Planning Scenarios for Amman, 2022.

Discussion.

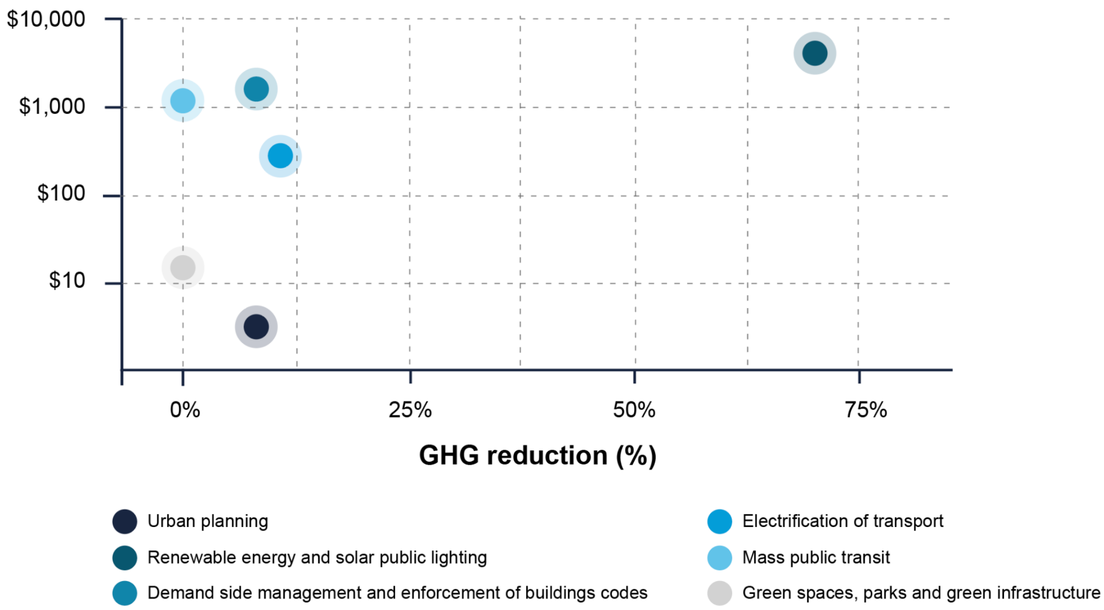
The project provided analytical insights to the Jordan Climate Change Development Report (CCDR) focusing on the urban, transport, and energy sectors. Also, it undertook the analysis of indicators related to these sectors to identify the potential for GHG emission reduction from policies and investment in the city. Results provided an insight into the potential benefits of four scenarios: the BAU, Plan, Ambitious and Net Zero Scenario. They included the implementation of 13 policy levers and their integrated impacts. The results were compared through different indicators to identify the most resource-efficient scenario. Related co-benefits of these policies and interventions were also determined to prioritise future actions and investments for a greener and more resilient Amman.

The analysis shows that the Net Zero Scenario requires important investments but it brings a significant GHG reduction and associated co-benefits. Cost distribution for more ambitious goals have significant trade-offs and provide savings in the long term. For example, the costs related to municipal service and hazard exposure in the Net Zero decreased significantly (up to 87%) compared to the other scenarios with an investment of $11.9 Billion US dollars. Also, under the Net Zero Scenario the GHG reduction is approximately 50% compared to the BAU Scenario. The investment in new infrastructure and policies boost proximity to facilities and promote more efficient public services. By contrast, the BAU Scenario has no green and sustainable capital investment, thus it does not take actions to reduce and mitigate GHG emissions. This scenario will likely cost more than implementing investments to improve the sustainability of the city. Similarly, the Plan Scenario, which was based on GAM goals, has significant areas of opportunity in GHG and the economic costs. The Ambitious Scenario has notable improvements in all indicators and benefits from the carbon market.

To promote a green and resilient Amman, policy levers costs could be financed through different local and international financial mechanisms. Under the Net Zero Scenario a significant economic cost could be financed through private or international mechanisms. For example, donations via international development cooperation, international sources, or concessional or non-concessional credit through private banking. In comparison, the BAU, Plan and Ambitious Scenarios have a lower percentage of economic costs that could be financed through these financial mechanisms. These last three scenarios strain GAM's budget management.

To determine future actions and investments for a greener and more resilient Amman, the potential for reduction should be considered. Each lever provides reductions in energy consumption, GHG emissions or economic costs. Key levers to reduce GHG are urban planning, renewable energy generation and solar public lighting, demand-side management and enforcement of building codes, electrification of transport, mass public transit, green spaces, parks and green infrastructure. Levers that enhance the co-benefits or have GHG reduction of a lesser magnitude are waste and water management. Image 34 depicts the potential of GHG emission reduction and the approximate cost for the main policies and interventions. Benefits and costs are based on the Net Zero goals.

Image 34. GHG reduction and costs.



Source: Urban Planning Scenarios for Amman, 2022.

Urban policies for land use will be key for a resource-efficient and resilient city as land consumption is related to municipal service costs and GHG emissions. The potential for reduction is up to 7-8% (212 $kgCO_2eq$ per capita per annum) for land consumption and up to 11% related to municipal service costs and infill costs. There is a 25% decrease in consumption of electricity-related to public services and a decrease of 37% in electricity consumption from public lighting. The reduction from electricity-related to the water supply is 12%. There is an additional reduction of the vehicle kilometres travelled which has a negligible impact on commuting energy. Land consumption has additional relation with spatial information, for example, proximity to infrastructure, exposure to hazards and population density. The distribution of population within the city is important to facilitate mobility, provide access to social infrastructure and public utilities. Also, the selection of areas of densification and investment areas within the city reduces or enhances exposure to hazards.

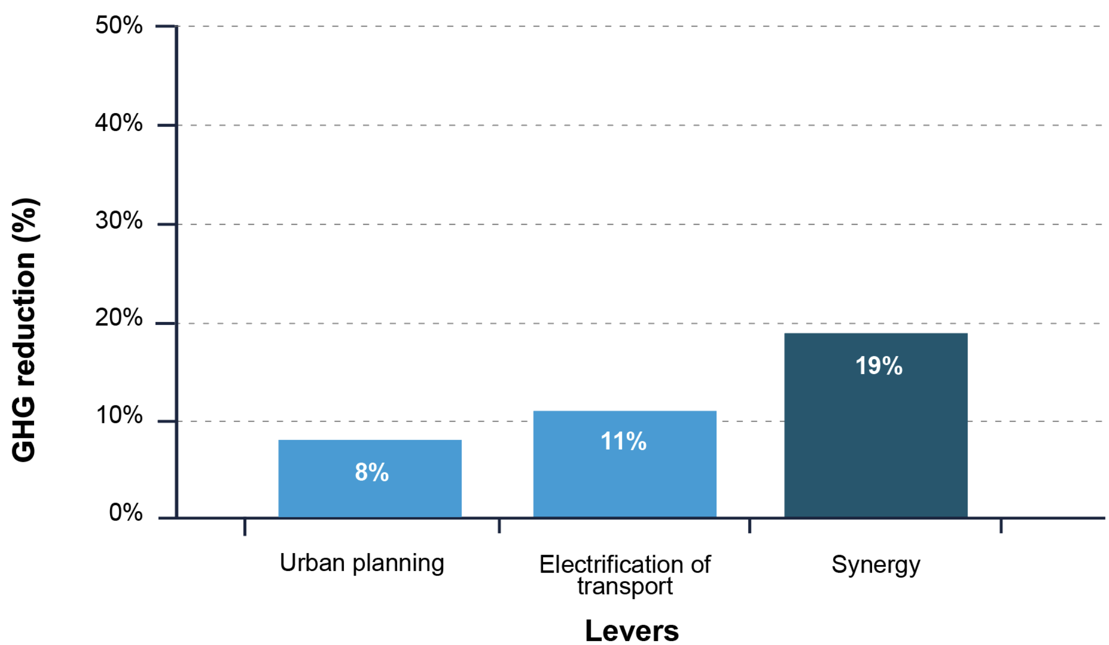
Renewable energy generation is key for GHG emission reduction. The implementation of renewable technologies in streetlights will reduce GHG emissions by 20%. The benefits are exponentially enhanced if non-locally generated energy is supplied by renewable energy sources. The implementation of supplementary sources avoids the decommission of existing power plants and the potential reduction of GHG emissions by approximately 70%. However, cost reduction would not cope with the required investment for renewable energy. The rapid transition to renewable energy might only benefit costs through carbon market bonuses. Also, the private sector and other financial mechanisms could participate in the implementation of these technologies.

Other levers depict a high cost for GHG reduction, but they bring co-benefits to other economic sectors of Amman. Demand-side management and energy efficiency measures could save up to 20% of energy consumption related to buildings by 2050. This lever promotes the change in technology and behavioural changes, including major updates in the characteristics and quality of buildings. Due to the significant decrease in energy demand from the grid, GHG emissions could be reduced and provide carbon benefits. Electrification of the motorised fleet could reduce up to a quarter of the energy consumption from the city. This lever is related to the consumption of diesel and gasoline. However, it requires a major investment of private and public sectors. Mass public transit has a minimal impact on fuel cost, commuting time, and GHG emissions but it benefits the proximity to transportation systems by more than 15%.

Synergies provide cumulative effects and boost green and sustainable strategies. Isolated measures could provide significant changes, but the integration of different policy levers produce rapid benefits to the climate change challenges in Amman. Green areas, parks and green infrastructure reduce hazards exposure and bring significant cost benefits. The cost benefits are related to the most expensive expenditures for Amman, loss of productivity related to extreme events and temporary relocation. In addition, green areas, parks and green infrastructure could reduce the frequency and intensity of hazards, they bring co-benefits such as life quality, encourage water natural infiltration, and reduce the heat island effect. Other levers, such as pedestrianisation, water and waste management enhance the benefits of other levers. Although individually, they have a negligible change in GHG emissions.

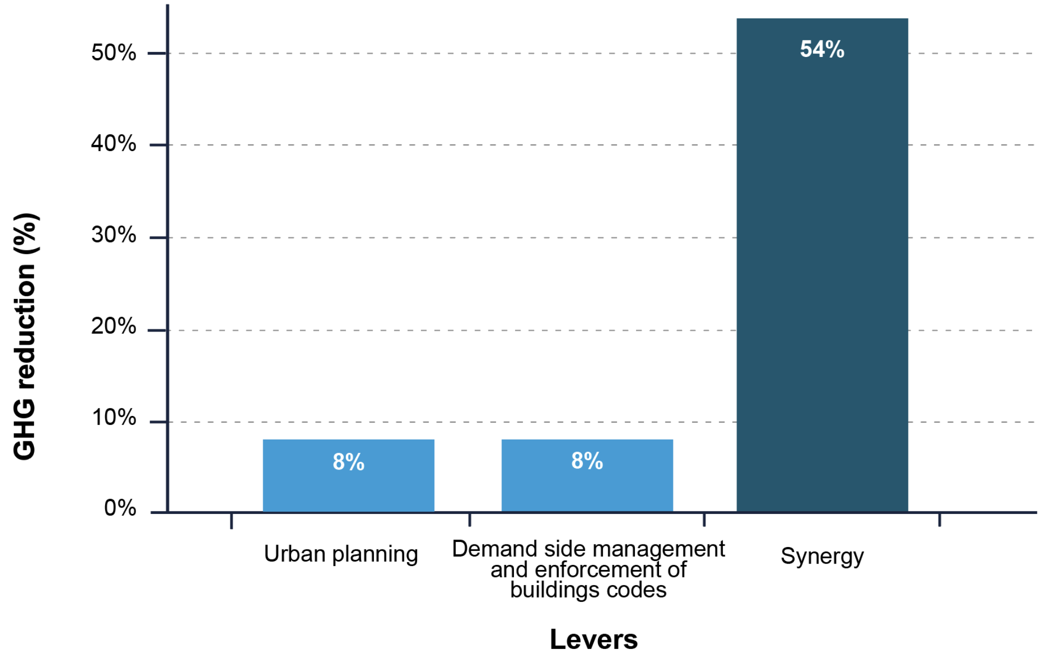
Images 35 and 36 show the GHG reduction potential from the combination of several policy levers. Image 34 shows the potential of GHG reduction based on the Net Zero goals for urban planning and electrification of transport. The image presents the GHG reduction by implementing each measure and the synergy of both levers, which sum a total of 19%. The analysis considered isolating the potential GHG reduction of policy levers. Net Zero scopes were implemented into the BAU Scenario parameters. After assessing each potential impact, policy levers were coupled into the BAU scenario to identify the GHG reduction of specific synergies. Image 35 shows the potential of GHG reduction based on the Net Zero goals for urban planning, demand side management and enforcement of building codes. The individual GHG reduction of each lever is 8%, but by creating synergies between both levers' emissions decrease by 54%.

Image 35. Cumulative GHG emission reduction of urban planning and electrification of transport.



Source: Urban Planning Scenarios for Amman, 2022.

Image 36. Cumulative GHG emission reduction of urban planning, demand side management and enforcement of buildings codes.



Source: Urban Planning Scenarios for Amman, 2022.

Amman has endorsed efforts to reduce GHG emissions. However, it is necessary to enforce action plans to achieve the climate change goals. For example, the Amman Climate Action Plan is a strategy that outlines a collection of measures and policies that reduce GHG emissions. It defines GHG reduction goals based on local priorities for reducing emissions and provides the guiding framework for achieving those goals. However, the goal set under the Action Plan does not achieve net zero emissions. Another example is the Green City Action Plan, which identifies, and shapes projects, programmes, and policy actions tailored to address the most significant environmental issues in a city. However, integrated measures are not assessed, and costs pressure the municipality budget. Amman could reach GHG reduction by 2050, but more ambitious goals could benefit the overall results of these efforts.

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