A Fast Track Analysis of infrastructure provision in Palestine

Outcomes from the ITRC/UNOPS collaboration

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Executive Summary

Infrastructure is the basic physical and organisational structures, facilities and services that provide the foundation for economic productivity and human welfare. It is the physical fabric of modern society that connects humans and their environment, allowing cities and countries to function; it augments human endeavour through the provision of basic needs such as water, energy and waste management, and provides trade, mobility and participation services through transport and digital communications.

The occupied Palestinian territories of West Bank and Gaza Strip are distinct geographic entities, which are currently experiencing many different challenges in the provision of infrastructure services. Although regarded as a post-conflict region, Palestine has experienced such a protracted state of crises that relatively short-term characteristics common to post-conflict environments, such as refugee camps, or energy and water shortages resulting from damaged or disabled infrastructure assets, have become a part of everyday life. Just as the provision of infrastructure can enhance social wellbeing, the lack of infrastructure services can conversely lead to declining health and wellbeing, diminishing economic productivity and social freedom.

In order to understand and potentially address these challenges the Infrastructure Transitions Research Consortium (ITRC) has collaborated with the United Nations Office for Project Services (UNOPS) to develop a preliminary or 'Fast Track' systems-based analysis of infrastructure provision in Palestine. This process involves four key steps including: 1) defining and assessing the current system; 2) assessing future needs for infrastructure services; 3) identifying strategic alternatives for delivering a vision for future provision; and 4) analysing the scale and timing of alternative investments required. Due to the fact that infrastructure assets require significant capital investments and have long lead-times and life-times the timescale of the analysis must also be long. Accordingly, the timescale for this analysis is from 2015 to 2050.

Such an analysis involves rapidly assimilating information on Palestine's current infrastructure, and applies scenarios of future needs for infrastructure services and policy/investment strategies for addressing those needs. This report provides only a broad understanding of issues particular to Palestine and as such is not intended to provide definitive solutions to Palestine's infrastructure provision problems. Instead it is intended as a tool to facilitate a cross-sectoral analysis of Palestine that will mark the beginning of an iterative process of engagement with stakeholders and decision-makers, based on the application of the ITRC methodology of a systems-of-systems analysis of infrastructure provision.

The analysis begins with an assessment of current infrastructure services and their ability to meet current demand for services; identifying key challenges and interdependencies between each of the major infrastructure sectors (water, energy, waste, transport and digital communications). To demonstrate an assessment of the vulnerability of these existing systems to natural and man-made hazards an example application is provided for assessing the electricity network as an interdependent infrastructure system connected to infrastructure assets across all sectors in the Gaza Strip. We present the concepts and methods used in vulnerability characterisation, and offer insight into the vulnerability 'hotspots' in Gaza, providing a means for informing decisions around where new electricity infrastructure assets might best be located to reduce future risk.

Following the development of socio-economic scenarios that represent a characterisation of future uncertainty, a diverse range of alternative strategies for infrastructure provision are assessed, in order to illustrate the potential impacts of alternative future decision pathways. First is the *No Build* strategy, which characterises the performance of a future system in which no new assets are built beyond 2015, and the *Pipeline* strategy, which includes the implementation of the current pipeline of planned investments for each sector. These are compared with two strategies offering different approaches to maintaining current trends in infrastructure service provision: *Status Quo* and *Efficiency with Scarcity*. The major differentiation between these being that services in the *Status Quo* strategy are delivered using technologies previously implemented, whereas the *Efficiency with Scarcity* strategy focuses on solutions that improve efficiency and security of supply. Finally, *Infrastructure-led Development* is a strategy that focuses on generating higher economic growth and provision of needs through higher investment in infrastructure. The cross-sectoral implications of these strategies and interdependencies are also discussed. These last two strategies are based on the aspirational vision provided in the Palestine National Spatial Plan (State of Palestine 2015) with the key differences between the two being the availability of investment funds and autonomy of resource use for the Palestinian government.

The analysis presented in this report identifies that Palestine is experiencing shortages in the provision of most infrastructure services. The demand for infrastructure services is not currently being met in all sectors, and this demand is expected to increase due to population growth, increasing urbanisation, economic growth and climate change. Serious impediments to infrastructure supply also exist due to external factors including occupation security measures, conflict, and restricted access to energy.

Most acute is the water crisis, particularly in the Gaza Strip, with average water consumption below World Health Organisation guidelines (100 litres/person/day), and water quality standards regularly not achieved. The need to reduce abstractions from the Gaza's Eastern Mediterranean coastal aquifer to sustainable levels of 65 MCM p.a. (PWA 2011) presents a notable challenge. The aquifer is additionally being impacted by contaminant intrusion from, amongst others, seawater, wastewater, agricultural products. Water contamination is a major problem where sanitation facilities are poor – resulting in vulnerability for the underlying aquifer.

A number of major infrastructure projects (referred to in this study as the "national infrastructure pipeline" or simply "pipeline") are underway or are being planned to deliver improved infrastructure services to the people of Palestine. Such measures appear to be well prioritised in water and energy, with emphasis appropriately given to the acute crisis in the Gaza Strip. The government of Israel has also recently announced increases in supplies of water and electricity to Palestine. Unfortunately, with current socio-economic trends and the spectre of climate change these measures will fall short of meeting even the most basic demands in the near future, even under an optimistic scenario of low population growth, high economic growth, and no natural or man-made disasters. In fact the analysis presented here submits that Gaza will require at least twice as much investment in water infrastructure than is currently in the pipeline over the coming decade if they are to meet World Health Organisation levels of water availability.

Wastewater re-use has been identified in this study as an underutilised resource in Palestine that might alleviate such water shortages. Current levels of wastewater collection are generally high. However, the amount of wastewater that is fully treated is quite low, below 20% in total, with the majority of wastewater dumped in porous and tight cesspits or sent mostly untreated into the sea, rivers and wadis (streams) with related implications for the limited existing water supplies and human health.

Underpinning such problems within the water and wastewater sectors are inadequacies in the energy sector that are restricting the capacity of water transfer, water treatment and wastewater management facilities. Solar-based renewable sources of energy provide possible solutions, but land availability and reliability of the distribution grid have hampered efforts beyond small-scale local energy generation. Presently, there are limited photovoltaic sites in Palestine, with a total PV capacity in the West Bank estimated at less than 10 MW, despite the enormous solar potential of the area. Solar energy for water heating is common and generally a cheaper alternative to electricity, with nearly 57% of households having access to a solar water heater. Thermoelectric energy sources such as Combine Cycle Gas Turbines (CCGT) may provide reliable and efficient sources of electricity but could prove problematic in their demand for cooling water. Add to this the fact that even significant investments, such as the Hebron CCGT and Jenin CCGT plants in the West Bank, will only maintain per-capita-energy above the current levels (approx. 5,100 kWh/person) for a decade. In Gaza the current pipeline projects, including the Gas 4 Gaza connection and the Gaza Power Plant upgrade to 540 MW, could maintain current per capita energy levels (approx. 2,500 kWh/person) beyond 2040. However, if the Gaza Power Plant is only upgraded to 140 MW a return to the current low levels of electricity provision will happen within a decade.

Good resource recovery has the potential to provide some respite in the form of energy from waste. However, despite high waste collection rates in urban environments, the opportunities to fully utilise this resource are being lost due to illegal dumping and a lack of waste recovery facilities. Some facilities exist for recycling materials and it is estimated that around 44% of solid waste is treated using sanitary landfills (D-Waste 2014). Plans are also underway for two new sanitary landfills, one in the West Bank and one in Gaza Strip, however these will only serve to replace facilities that will soon close. The percentage of waste treated is therefore expected to decline to below 30% by 2030 if additional investments are made into new waste treatment facilities. With such large amounts of waste untreated, coupled with the number of sites not being controlled in terms of leachate (D-Waste 2014), serious concerns exist around possibly contamination of Palestine's scarce water resources, particularly in the Gaza Strip.

Transport infrastructure in Palestine is all road-based with over 3,500 kilometres of paved road in the West Bank and Gaza and a further 445 kilometres of unpaved roads in the West Bank (PCBS 2014). Capacity levels appear to be quite good but the number of vehicles per person is low compared to neighbouring countries at around 63 people per 1000 vehicles in 2014 (PCBS 2014) (NationMaster 2014). Palestinians are severely restricted in terms of travel outside of the borders of the territories by either air or sea with no ports available for such travel in Palestine. Serious impediments to internal mobility are also imposed by security measures which affect not only internal movements and trade within Palestine, but also access to external markets. Such restrictions are estimated to have a significant cost to Palestinians – up to USD$185 million per year due to extra time and mileage (Isaac et al. 2015).

Digital communications can provide some substitute services for mobility and in 2014 more than half of all households in Palestine had access to a computer and almost half had access to the internet (PCBS 2014) which is high compared to other countries in the area (World Bank 2014). Fixed telephone connection was around 40% of households in 2014, which is similar to 2004 levels. Conversely, mobile phone connectivity jumped dramatically from 72.8% to nearly universal 97.8% in the decade from 2004 to 2014 (PCBS 2014). In 2015, Israel proposed a network deal with the Palestinian Authority that could enable a 3G mobile network in Palestine (Scheer et al. 2015). The roll-out of 3G technology in Palestine could enable the demand for high-bandwidth applications such as video streaming, access to news and social media sites and online retail to be addressed. For this to happen large-scale investments would be required to maintain the current 2G network and to build new digital communications assets (such as base stations and the fibre backbone) to provide coverage of the 3G technology. With digital communication services typically delivered by the private sector areas of low population density may require direct government investment or incentives.

The infrastructure systems analysis presented in this document is designed to enhance the Palestine Authority's institutional capacity to meet such challenges. The results suggest there is much to be gained by persisting with this approach. At such relatively low levels of provision Palestine has the potential to "leapfrog" to more efficient and resilient infrastructure systems as in other post-disaster and post-conflict environments. Renewable energy sources could provide new and affordable sources of primary energy production, reducing dependence on imports that drain the national accounts. Digital communications are improving in connectivity and bandwidth with the vast majority of houses and businesses gaining access to the Internet and mobile coverage, particularly in the larger cities. Improvements in water security can be gained through desalination technologies that continue to advance and through capitalising on positive interdependencies, in particular gains of additional water and energy resources through improved materials recovery in the waste sectors.

There are also insights and opportunities to be gained from looking across all sectors simultaneously. An interesting story emerges from a comparison of the estimated relative cumulative costs of each of the different strategies for infrastructure provision (including estimated capital and operational costs) presented in this study (Figure 1). The most striking feature of this graphic is the relative cost of providing adequate water supply to the Palestinian population compared to that of other sectors. Much of this is due to the cost of desalination and distribution, which could improve over time, however it is doubtful whether such costs would every fall below that of the other sectors – highlighting the primary importance of securing water resources in this region. Also of interest is the fact that the *Efficiency with Scarcity* strategy is able to achieve the additional benefits associated with this strategy, such as greater resource recovery and a lower reliance on imports, at little additional cost over the *Status Quo*. Finally, through concentrating on maximising the benefits from interdependencies and economies of scale, the *Infrastructure-led development* strategy achieves its higher levels of infrastructure service delivery at a much lower per unit cost. This strategy provides for levels of infrastructure services that are closer to those enjoyed in neighbouring countries, such as Jordan, but requires significantly higher levels of investment than is currently evident in the infrastructure pipeline.

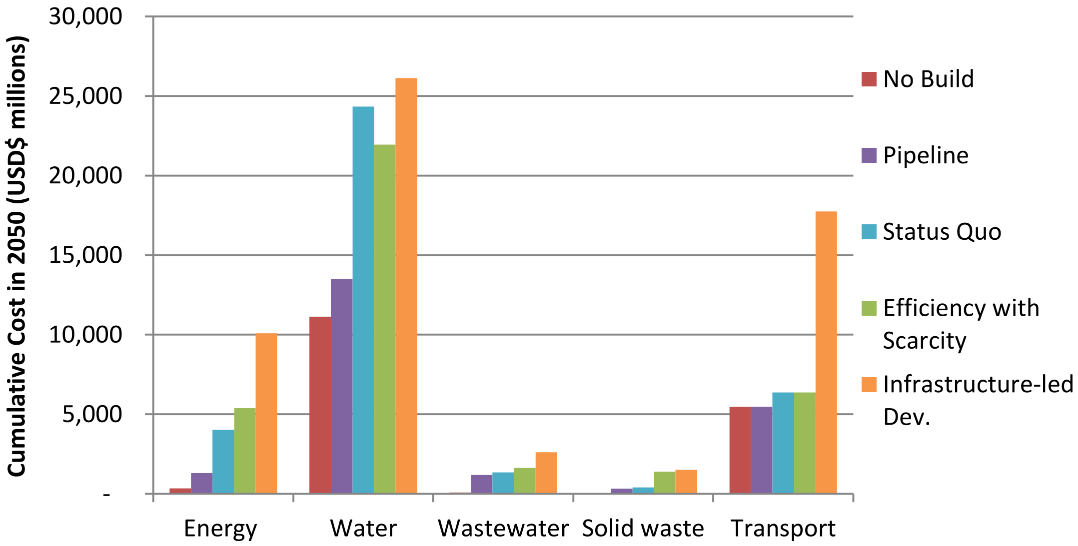


Figure 1: A comparison of relative cumulative costs by sector by strategy

The benefits to be gained through exploiting interdependencies can also be clearly seen in Figure 1, with energy and waste sectors employed to augment the most scarce resource, water supplies, at an advantages relative cost. The ITRC's system-of-systems based modelling methodology is designed to explore such potentially important cross-sectoral interdependencies. The tight coupling of many of Palestine's infrastructure systems, particularly energy and water (e.g. the need for large quantities of cooling water for thermoelectric power stations) require solutions that are cognisant of such complexities.

The decision to adopt any specific strategy will however depend on multiple factors and criteria. One additional factor relates to the current and future forecast performance of the national infrastructure systems. Within the subsections of this report we present the concept of service delivery to measure the performance of the different FTA strategies for the energy (kWh/person), water (litres/person/day), transport (passenger car units per lane kilometre), wastewater and solid waste sectors (% treated).

Comparing this to the relative cumulative costs presented above provides a means to explore one of the many trade-offs incorporated in real decisions. Such trade-offs can be explored both at the sectoral level and at the aggregate level (combining the performance of multiple sectors). Figure 2 presents the cross-sectoral cumulative costs for each strategy against the average percentage change in service delivery compared to the 2015 baseline. The plot shows that the least cost strategy, *No Build*, has unsurprisingly the lowest performance in terms of average service delivery, with a net negative average service delivery across all sectors. All other strategies result in a net positive average service delivery. For all strategies, there is a general positive correlation between the increased cumulative costs of a strategy and the benefits yielded through the average percentage change in service delivery. Despite the *Pipeline* strategy typically resulting in negative service delivery at 2050 (with respect to 2015 values), looking across the whole study reveals that this strategy has a net positive impact.

Both the *Status Quo* and *Efficiency with Scarcity* strategies are the closest to one another on the plot regarding performance. To further differentiate between these strategies, it is necessary to consider other important decision-making dimensions (for example, security of supply) which are not quantitatively calculated in this analysis but which are implicit in the design of the strategies. For example, the greater costs of the *Efficiency with Scarcity* strategy come with additional benefit of increased security of supply (through the adoption of more localised solutions within the strategy and moving away from a reliance on imports). The highest performing strategy, *Infrastructure-led Development*, is also the costliest in economic terms. Despite the increased service delivery, these costs may prove in practice to be prohibitive to the adoption of this strategy. As such, establishing hard constraints (in terms of budget, or any other performance metric) may help to inform any decision towards a specific strategy by reducing the overall strategy space being investigated – leading to the promotion of certain strategic approaches and specific investment decisions.

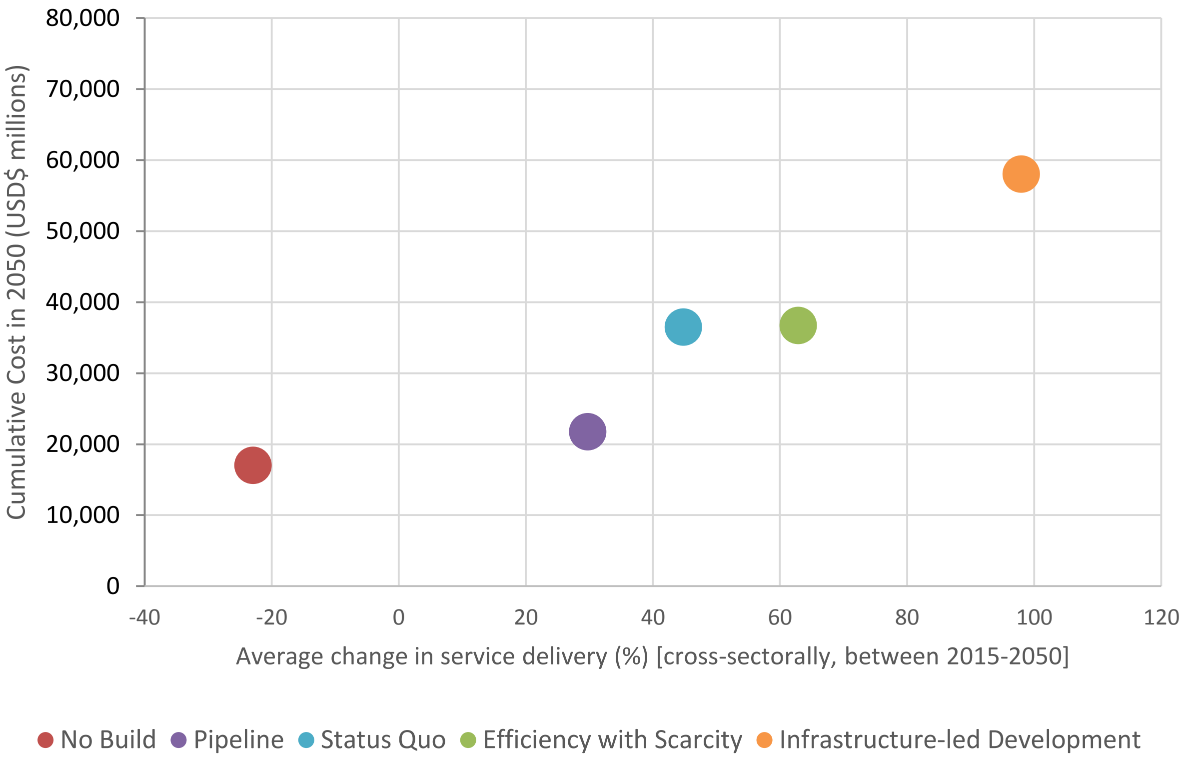


Figure 2: Relative cumulative cost plotted against the mean average percentage change in service delivery (2015-2050) for the no build, pipeline, status quo, energy with scarcity and infrastructure led development strategies in the central population scenario.

Based on ITRC's experience in delivering a systems-based infrastructure assessment capability to the UK government, the National Infrastructure Systems Modelling (NISMOD-International) platform and processes can provide governments, such as the Palestine Authority, with the ability to explore and understand their current infrastructure systems, including interdependencies, and assess alternative strategies for improving these systems' resilience and robustness to future uncertainties. Future work following this Fast Track Analysis will include working with stakeholders to further qualify and quantify Palestine's national vision and refining strategies for achieving this vision, analysing the scale and timing of alternative pathways of policy interventions and investments. Concurrent to these efforts will be much needed research into developing indicators capable of tracking the performance of such strategies and tying these to UN's sustainable development goals (SDG's). Developing such capabilities will enable system-wide evidence-based infrastructure planning to coordinate, prioritise and monitor future delivery of infrastructure services and provide confidence in the institutional capacity and consistency in decision-making necessary to attract further donor funding and much needed private investment in Palestinian infrastructure and the economy.

1 Introduction

National infrastructure systems form the basis for a society's economic and human wellbeing and environmental sustainability. These systems, which include energy, transport, digital communications, water supply, wastewater, flood protection and solid waste, require significant capital investments that have long lead-times and life-times, implying that near-term decisions have long-term implications.

Building infrastructure is a long-term commitment that is difficult to reverse, which means that infrastructure decisions have major implications for sustainability, notably the demand for energy and water from alternative infrastructure options and the mitigation of carbon emissions and adaptation to the impacts of climate change. Major infrastructure investments are taking place in emerging economies and post-conflict regions which will lock in patterns of development for decades to come. Fragile economies struggle with deficits in infrastructure provision, including basic energy, water and sanitation services and transport connectivity that would enable regrowth and trade.

This report focuses on the Palestinian territories of the Gaza Strip and West Bank, where such challenges are evident in most areas of everyday life and economic activity, and are often specific to each of the territories. For instance, an acute water crisis has developed particularly in the Gaza Strip, which is now among the areas of the world with the scarcest renewable water resources. The water that is available regularly fails to meet water quality standards, exacerbated by poor wastewater management practices (Eting 2015). Underpinning these problems are inadequacies in the energy sector which acts as the backbone to all such infrastructure systems, including water supply. Solar-based renewable energy provides a potential solution, but land availability and reliability of the distribution grid have hampered efforts in this direction (Evans 2015). Good solid waste management and increased resource recovery could provide some respite in the form of energy from waste. However, despite high waste collection rates in urban environments, the opportunities to fully utilise this resource are limited by illegal dumping and a lack of well managed waste facilities. Transport infrastructure is all road-based and there are serious impediments to mobility imposed by security measures which affects not only internal mobility and trade within Palestine, but also access to external markets.

Despite such problems there is cause for hope as infrastructure decisions being made now can do much to facilitate development pathways to more productive, secure and cleaner societies. Palestine has the potential to leapfrog to more efficient and resilient infrastructure systems as in other post-disaster and post-conflict environments (World Economic Forum 2014). Renewable energy sources could provide new and affordable sources of primary energy production. Digital communications are improving in connectivity and bandwidth with the vast majority of houses and businesses gaining access to the Internet and mobile coverage, particularly in the larger cities. Despite recent declines in donor funding sources (Office of the Quartet 2016), there exists a large and consistently generous donor community that has for many years been providing investment funding for infrastructure.

It is essential that key decision makers – governments, utility providers, designers, investors and insurers – have access to the best evidence to evaluate the performance and impact of short- and long term plans for such complex systems in an uncertain future. With a more rigorous systems-based approach to infrastructure investment, large gains are possible in the delivery of infrastructure services in Palestine (and other fragile economies), including the ability to increase system resilience, to alleviate infrastructure gaps that can lead to conflict, and to 'build back better' avoiding lock-in to costly, inefficient and unsustainable solutions.

It is to provide such capability that the Infrastructure Transitions Research Consortium (ITRC) began its research into models and decision support tools to enable analysis and planning of robust national infrastructure systems. The ITRC research addresses major challenges for the infrastructure sectors of energy, transport, digital communications, water, flood protection and waste, incorporating the critical interdependencies between these sectors. In its first research programme, running from 2011 to 2016, the ITRC developed the world's first national infrastructure system-of-systems model, NISMOD, which has been used to analyse long term investment strategies for energy, transport, digital communications, water, wastewater and solid waste (Hall, Tran et al. 2016). Crucially, NISMOD also provides insights into the vulnerability of infrastructure networks and the risks of cascading failure, in order to inform investment in improving resilience.

A major component of ITRC's second programme of work (MISTRAL) aims to apply the system-of-systems infrastructure assessment methods and tools developed during the first research program to other settings, including post-conflict and post-disaster contexts such as Palestine. In collaboration with the United Nations Office for Project Services (UNOPS) the ITRC consortium is developing both a platform and a process for the application of systems-based assessment of strategies for infrastructure provision to a wide range of international settings.

Part of this process is to undertake a 'Fast Track' national infrastructure assessment, rapidly assimilating information on the status of current infrastructure, scenarios of future needs for infrastructure services and policy/investment options for addressing those needs. The assessment helps develop a broad understanding of issues particular to the study site, focusing on how infrastructure systems are currently being utilised, and the capacity constraints within each of the key infrastructure sectors. There is an assessment of the drivers of future demand for infrastructure services, and an attempt to identify recent trends and future plans for infrastructure provision. A range of strategic options for infrastructure provision are presented, offering different approaches to maintaining or surpassing current per capita demands. Finally, this report is intended as a tool to facilitate the iterative process of engagement with stakeholders by presenting an overview of our methodology, in particular the systems-based approach to infrastructure provision.

This report introduces the assessment being undertaken for the occupied Palestinian territories (oPt) of the Gaza Strip and West Bank. This document aims to develop a broad understanding of issues particular to these territories, exploring how infrastructure systems are currently being utilised, and what are the current and future demands and capacity constraints within each of the key infrastructure sectors. It sets out to understand the challenges that the Palestinian Authority faces in infrastructure provision, assessing a range of potential future scenarios of socio-economic change, and develops a range of strategic pathways that will provide insight into the robustness of how different pathways decisions might affect the provision of solutions in such an uncertain future.

1.1 NISMOD-International: A framework for analysis of change in interdependent infrastructure systems

The NISMOD (National Infrastructure Systems MODel) International framework is both an assessment process and a structured platform based on the ITRC application to the UK which enabled a systems-based analysis of national infrastructure. As a platform it consists of a series of data layers and modelling tools that enable both short-term and long-term assessment of infrastructure strategies. The various components can be broken down as follows:

1. ***Geographical and socio-economic system definition***
   A series of spatial data layers (in GIS format) that set out the current infrastructure system and the contextual factors relevant to that system including (a) the infrastructure systems, their

asset and network layers, and characteristics of the assets (such as capacity, condition, age); (b) the geographical context, including maps, photos, topography, and geospatial environmental data e.g. natural hazards; and (c) socio-economic data including population (geographical), economic activities (including government and social).

2. ***Needs for infrastructure services***
   A set of tools and reporting capabilities that enable the analysis of current demands for infrastructure services including per capita and per unit demands from the economy. These tools are also used to assess different drivers of future needs in the form of scenarios of future population and economic status.
3. ***Infrastructure system functionality***
   Geographical Asset/network representation of system function, based on the data provided by the previous components, and enabling a definition of current capacity margins, locations of present and future capacity constraints, and an analysis of network vulnerabilities and infrastructure hotspots. Key components include (a) supply points i.e. energy, water, waste water, solid waste (b) connectivity capacity and current usage e.g. capacity and usage of highway network; (c) allocation of demand to assets (sink sites) and networks; and (d) source-sink connectivity.
4. ***Strategies for infrastructure provision***
   At the heart of NISMOD-International is an integrated set of models for each infrastructure sector that can be used to run strategies of infrastructure provision against a consistent (cross-sectoral) set of future national socio-economic and climate scenarios. Such modelling capability enables users to develop (a) visions and goals for the infrastructure system (based on different levels of ambition), (b) sector-specific targets, investment and policy options (supply and demand side); (c) analyse options to achieve goals/targets, including possible variants; and (d) estimate costs: capital, operation, environmental.

As mentioned above the NISMOD International framework is also a process designed to co-develop institutional capacity and systems knowledge and the data collection necessary to enable the use of the platform to undertake full national system-wide infrastructure assessments. There are six main steps in this process of implementation:

1. ***Define the current system***
   A systems-based analysis of national infrastructure must begin with a thorough review of the (i) the geographical context including topography, climate, natural hazards and the socio-economic situation; and (ii) the local infrastructure systems, including the asset and networks that make up the various infrastructure sectors: energy, transport, digital communications, water, waste, and the characteristics of each asset including capacity, condition, age, etc.; and finally (iii) the governance environment in which infrastructure decisions are made.
2. ***Assess possible future needs for infrastructure services***
   Once the context for the analysis is defined the future drivers of change must be assessed incorporating (i) an assessment of present day needs for infrastructure services including per capita demands and per unit demands from the economy; (ii) an assessment of drivers of future needs, through tools such as scenarios of future population and economic state, environmental change and historical mappings of human and natural hazards; (iii) the broad range of possible strategies for infrastructure provision including improving both infrastructure services and their resilience.
3. ***Develop the long term vision for national infrastructure***
   An understanding of the benefits of systems-based analysis can be grown within the host organisation through an iterative process where each new assessment of the system is presented to a representative group of stakeholders for validation of the representation of the

current system, and input into future scenarios of change, and possible future strategies for infrastructure provision. This process should also involve the development of metrics and performance indicators for evaluating the efficacy of the various strategies, including both sector-specific targets and cross-sectoral goals. Ultimately this process will lead to the defining of a national vision for infrastructure provision and the co-development of goals for assessing alternative pathways to this vision.

4. ***Identify strategic alternatives for delivering the vision***
   In most cases there will be more than one alternative pathway available for meeting the vision and goals identified in the previous step. Generally, such alternatives will include both demand and supply side solutions which can be categorised into a list of high-level options (e.g. for water supply this could include leakage reduction, demand management, surface water or groundwater enhancement, water reclamation/desalination).
5. ***Analyse the scale and timing of strategic alternatives required to address infrastructure needs***
   Once the high-level strategic alternatives have been identified their consequences and costs are explored through various investment and policy options and trade-offs. Major (keystone) investments are prioritised and key investment decision points identified.
6. ***Recommend adaptive pathways of policies and investments***
   Through a series of iterative workshops with stakeholders the intention is to develop a small selection of key adaptive pathways and the policies and investments required for each pathway. The adaptive pathways that are designed to be relevant to context (e.g. identified infrastructure related, country-specific sustainable development goals), and sensitive to the identified goals, acknowledging that such goals could be at multiple scales, involve multiple-actors and multiple criteria (not all of which are included in the model).

Collectively, the application of these six steps can greatly advance our understanding of infrastructure systems and focus the needs for the future assessment.

1.2 A Fast Track Analysis within the NISMOD process

A 'Fast Track' analysis (FTA) focuses on an expedited analysis of the earlier steps in this process, developing a broad understanding of issues particular to the study site (Palestine), exploring how infrastructure systems are being utilised, current and future demands and the capacity constraints within each of the key infrastructure sectors. It also provides an overview of any gaps in information and understanding, and attempts to identify any recent trends including future plans and challenges which are necessary for developing a comprehensive cross-sectoral vision. This report also sets out the methods used in the remaining steps in the process, and begins to develop a range of strategic pathways and their subsequent analysis. Importantly, this report is intended as a tool to facilitate the iterative process of engagement with potential stakeholders, both in Palestine and abroad, by presenting an overview of our methodology.

We use a simple assessment framework (Figure 3) in order to evaluate the effects of different strategy options on the performance of infrastructure provision given uncertain future demographic and economic change. For this report, there are three main aspects of the assessment framework:

Scenarios describe the main drivers of change - factors outside the direct control of infrastructure decision-makers which influence the future demand of infrastructure services, and will affect the impact and performance of strategies of infrastructure provision. The main drivers of change for this report are demographic and economic change, together with energy costs. We set out historical trends for these main drivers of change which are then used to derive distinct future scenarios of how demand for infrastructure services might change in the forthcoming years. Development of these scenarios is given in Section 5.

Strategies are sets of choices, or rationales for taking choices, about the provision of infrastructure services. There are many 'levers' which decision-makers can alter in order to change the current direction of infrastructure provision; however, for this report, we are focusing on the levels of investment available for infrastructure provision in the different sectors, and the ambition for change that any such investments are intended to bring. Focusing solely on these two decision variables, a framework can be derived within which alternative and diverse strategies can be positioned, as described further in Section 6, in which a range of diverse strategic options for infrastructure provision are presented, in order to illustrate the potential impacts of alternative future decision pathways.

Systems models are used to analyse the performance of strategies in the context of given scenarios. The system models take as inputs the current state of the infrastructure system and the demands placed upon it, strategies for each infrastructure sector and scenarios of exogenous changes. The models output projections of infrastructure performance, given those input conditions. For this report, relatively simplistic models are utilised, which will be developed more fully in the future. Results are given in Section 6.

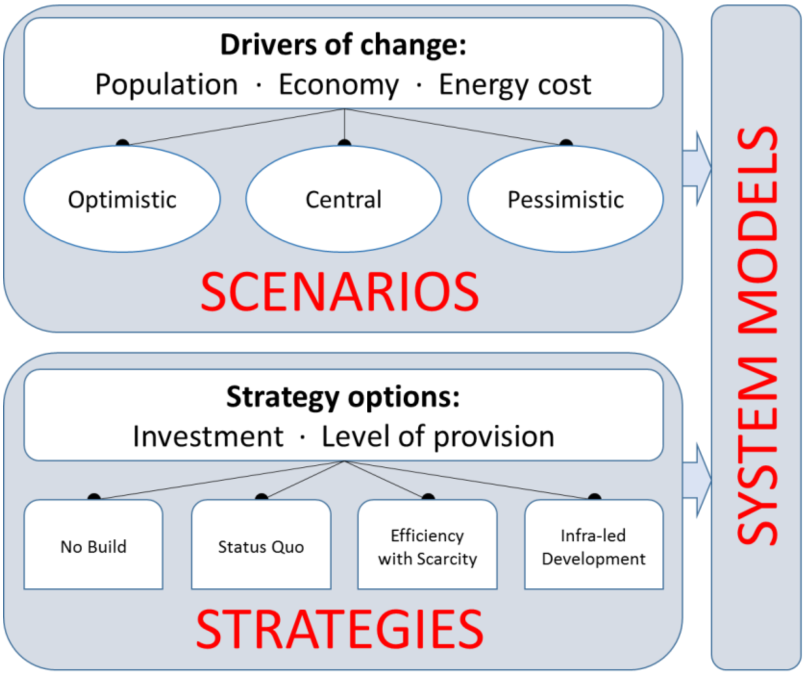


Figure 3: Simplified assessment framework utilised in this study

This document, including the outputs and results from this assessment, will provide a focal point in the ITRC assessment process, prompting discussion and enabling the co-generation of knowledge with stakeholders, both within Palestine and for supporters and donors across the world.

1.3 Introduction to Palestine

Palestine occupies parts of the western Levant region north of the Arabian Peninsula, and is comprised of two distinct territories separated by the State of Israel: the West Bank, a 5,655 km^2 territory bordering Israel to the north, west, and south and Jordan and the Dead Sea to the east; and the smaller Gaza Strip (365 km^2), located on the eastern coast of the Mediterranean sharing borders with Israel and Egypt (Figure 4).

Figure 4: A satellite image of the Levant region with the outlines of the occupied Palestinian territories of Gaza Strip and the West Bank shown in red. (Source: Google Earth, 2016)

Long a crossroads for many cultures and religions, the region was home to a majority-Arab population and a growing Jewish community during the first half of the twentieth century. In 1947, the passing of UN Resolution 181 partitioned Palestine into Jewish and Arab States, with Jerusalem to be separately governed under an international regime administered by the United Nations. Despite opposition by the Arab States, the founding of the State of Israel was declared the following year. In 1948 a coalition of Arab states declared war on Israel to prevent the partition of Palestine. By the conclusion of this conflict in 1949, Israel had acquired additional territory designated for the Arab state, with the remainder controlled by Jordan, known then as Transjordan (West Bank and East Jerusalem), and by Egypt (Gaza Strip). The Six Day war in 1967 led to Israel gaining control of further territory, including the Gaza Strip, Sinai Peninsula, the West Bank, East Jerusalem and the Golan Heights, some of which were returned as part of agreements signed in the aftermath of the 1973 Yom Kippur War.

Following years of Palestinian revolt to Israeli rule, known as the First Intifada, the Oslo Accords initiated a peace process in 1993 that would see Israeli withdrawal from certain occupied territories, as well as the establishment of the Palestinian Authority as the self-governing body of the Palestinian State. Strong opposition on both sides to these agreements resulted in continuing hostilities, and by 2000 a Second Intifada had begun. Partially in response to the deteriorating security situation, Israeli announced a unilateral withdrawal from the Gaza Strip in 2003, which was carried out two years later. The Islamist militant group Hamas, long-opposed to the two-state solution for Palestinian statehood, took control of the Gaza Strip after winning legislative elections in 2006, splintering the Palestinian Authority into two rival organisations (the other being Fatah, governing the West Bank) (BBC 2008).

Figure 5: The three administrative divisions dividing the West Bank as per the Oslo II Accord. Source: http://www.btselem.org/area_c/what_is_area_c

Since 2000, Israel has constructed a security barrier between its territory and the West Bank along the so-called 'Green Line' an armistice line established at the end of the 1948 war. This wall has been controversial as it often cuts deep into the West Bank, isolating Palestinian communities and restricting transport, most notably the ability to commute to work for many Palestinian residents. Furthermore, Palestinian control over the West Bank is limited by the classification of its territory into three divisions, established during the Oslo Accords: Areas A, B, and C (Figure 5). The Palestinian Authority has full civil and security control over Area A (approximately 18% of the West Bank and all of the Gaza Strip), while security control is carried out jointly by Israel and the Palestinians in Area B (22%); these areas are often isolated and have no territorial contiguity. The majority of the West Bank falls under the status of Area C, controlled fully by Israel, which limits the Palestinian Authority's attempts to develop national infrastructure to serve its population. As of 2013, some 300,000 Palestinians lived in Area C along with an estimated 350,000 Jewish settlers in 135 Israeli settlements and some 100 outposts (OCHA 2015).

In recent years, Palestinian leaders have made a drive for the recognition of Palestinian sovereignty, and in 2012 was granted non-member observer status to the United Nations General Assembly with the support of much of the international community (United Nations 2012). However, numerous questions must still be resolved before Palestine gains full membership in the organisation, not least of which are the many territory issues currently disputed with Israel. Today, Gaza remains effectively blockaded with heavy restrictions on all imports and no access to civilian air transport or sovereignty over its coast. In Jerusalem and the West Bank, continued Israeli settlement expansion threatens Palestine's hope for a stable and unified territory.

1.3.1 Geography and climate of oPt

The West Bank has quite a varied topography consisting of central highlands that are home to most of the population. The area consists of semi-arid rocky slopes, an arid rift valley and rich pastoral plains in the north and west. Ground surface elevations vary between 1,022 m above mean sea level in Hebron in the south, and 375 m below mean sea level near Jericho (adjacent to the Dead Sea). The Gaza Strip is a low-lying stretch of sand dunes along the coastline of the eastern Mediterranean Sea. It forms a foreshore plain that slopes gently up to an elevation of 90 metres at its western border. The sea water is warm and saline that can be affected by discharge from the river Nile (UNEP 2003).

The West Bank receives annual rainfall ranging between 100 mm near the Jordan River to 700 mm in the mountains extending across the central parts of the region (Shadeed and Almasri 2010). For the Gaza Strip the average annual rainfall varies from 450 mm/yr in the north to 200 mm/yr in the south with most of the rainfall occurring in the period from October to March. The average daily mean temperature ranges from 25°C in summer to 13°C in winter and daily relative humidity fluctuates between 60% to 85% (Ludwig 2016).

1.3.2 The governance of infrastructure provision in Palestine

Current governance structure in Palestine

The occupied Palestinian territories are governed by the Palestine Liberation Organization (PLO) which was officially recognized by the Arab League in 1974 as the "sole legitimate representative of the Palestinian people" in 1991. Its parliament, the Palestinian National Council, exists in exile with its members appointed by the leader of the PLO. The PLO is signatory to all agreements with Israel.

The Palestinian Authority (PA) was established in the West Bank and Gaza Strip after Israel and the PLO signed the interim Declaration of Principles (the Oslo agreement) in 1993. The Basic Law forms the foundation of Palestinian governance in the absence of a formal constitution. The Palestinian Authority is headed by a president, who is elected by the public through direct vote. The political structure of the PA is borrowed from the United States' system with three separate branches of government, namely the legislative branch, the executive authority, and the judiciary.

The executive branch or cabinet is the main governing authority of the PA and comprises of the prime minister and a maximum of 24 ministers, each accountable to the president. The ministers are nominated by the president but require parliamentary approval before taking office. The cabinet drafts budgets, which require approval from the legislative branch, run ministries, civil services and non-ministerial institutions and is responsible for administering and maintaining internal security.

The legislative branch, known as the Palestinian Legislative Council (PLC), is responsible for enacting laws. It is the Palestinian parliament and is responsible for drafting laws and overseeing the performance of the executive branch. The PLC has no powers in terms of foreign relations and all legislation must be approved by Israeli authorities. During the second PLC elections in 2006 Hamas participated and won a majority of the seats over Fatah (the majority party in the PLO), however the role of the PLC has since been reduced (JMCC 2009).

The judicial branch exists based on the Oslo agreement through the Palestinian Authority whose basic law stipulates the independence of the judiciary authority. The work of the council is affected by incomplete sovereignty and heavily influenced by involvement from the Israeli authorities (JMCC 2009). Since 1994, a consolidated system of legislation has been in effect in both the occupied West Bank and Gaza Strip. A total of 37 courts of law in the occupied Palestinian territories are divided into magistrate courts, courts of first instance, and three courts of appeal in Jerusalem, Ramallah and Gaza. Cases decided by these courts can be appealed at higher levels, namely at the high court of justice and the courts of appeal and cessation. The Higher Judicial Council, consisting of a group of senior judges, nominates new judges who are then appointed by the president. The attorney general is also appointed by the president after nomination by the minister of justice. A Supreme Court of Justice examines administrative disputes.

The occupied Palestinian territories are administrated by 379 local authorities made up of 124 municipalities, 10 local councils and 245 village councils (Juaidi, Montoya et al. 2016). Each of these authorities can be grouped into the 16 administrative divisions called governorates of which the Gaza Strip has five and the West Bank has eleven (including the East Jerusalem territory annexed by Israel), as shown in Figure 6. For the purposes of this analysis the majority of information will be provided at level of territories (West Bank and Gaza) and at the governorate level.

Figure 6: The 16 governorates of the occupied Palestinian territories

Governance of the provision of infrastructure services

Current governance arrangements by PA ministries are fairly clearly defined for each of the major infrastructure sectors (energy, water, transport, waste, wastewater and digital communications) with some overlap appearing across sectors, and at different scales (Table 1). There are also many foreign donor organisations that are heavily involved in investment decisions that can affect the delivery of infrastructure services in Palestine. With limited sources of primary energy, restrictions on use of available land, and an essentially landlocked country with no external ports, Palestine is extremely dependent on such external sources and resources. Unfortunately the organisation that has arguably the most influence and control over the provision of infrastructure services, the Coordinator of Government Activities in the Territories (COGAT), does not generally engage with the Palestinian Authority in the decision making process for future infrastructure development.

As in most countries a significant challenge in infrastructure planning involves being able to move away from government plans and decisions that are being made within the silos of each infrastructure sector. As is suggested in Table 1 the donor community, although a generous and consistent source of funding for infrastructure, is involved in similarly siloed investment decisions within individual sectors, exacerbating problems related to unaccounted interdependencies, and reducing the opportunity to harness technological synergies that might be available with the adoption of a whole-system perspective.

1.3.3 International comparison

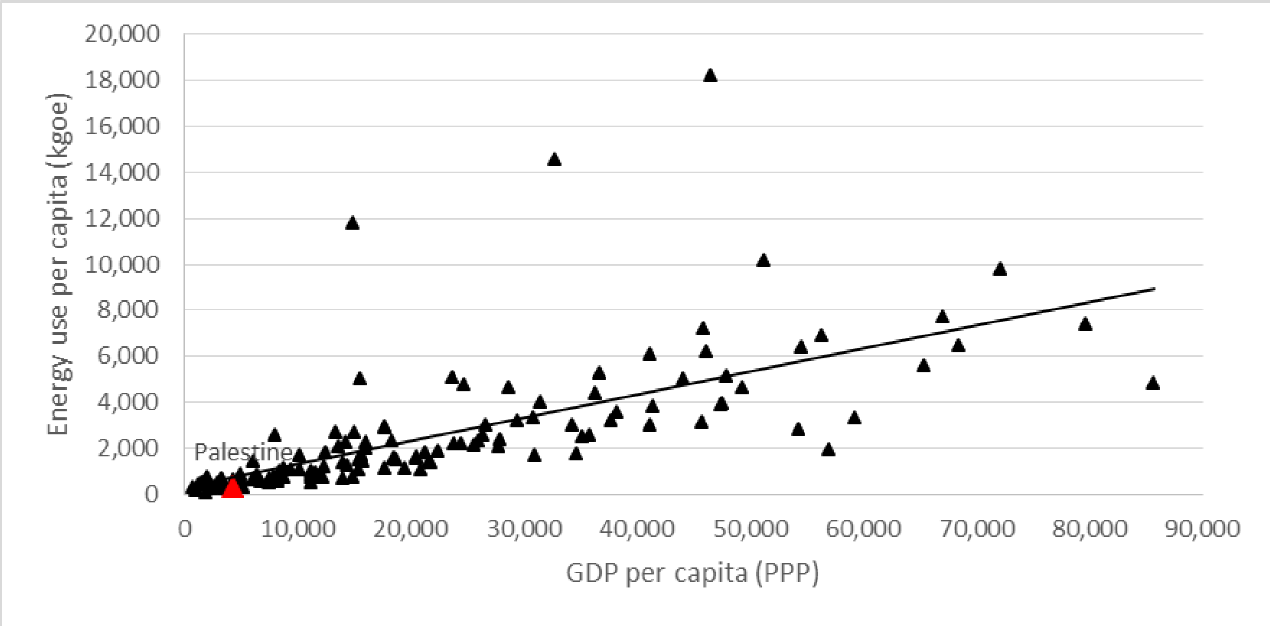
Palestine is somewhat of a conundrum in terms of international comparisons given its co-location with a modern industrialised nation in Israel, providing access to developed technologies and infrastructure services in juxtaposition with a protracted state of conflict. One reasonable means of comparison is through access to energy (or energy use) which is the enabler of modern standards of living and infrastructure services and, as asserted by the Office of the Quartet, "fundamental to economic growth" (Office of the Quartet 2016). In this respect Palestinians use a low amount of energy per person compared to the rest of the world (Figure 7a) even accounting for overall low income levels (Figure 7b and c), faring below the average of other countries with similar GDP per capita levels.

Table 1: A summary of the PA ministries and donor organisations that are involved in investment decisions in each of the infrastructure sectors

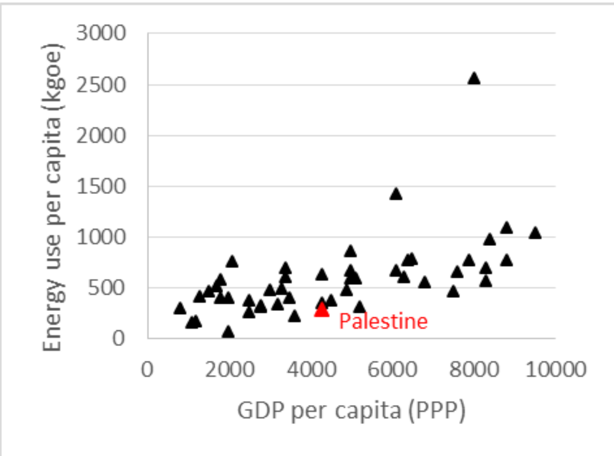
Organisation	Energy	Water	Transport	Wastewater	Solid Waste	Communications
Coordinator of Gov't Activities in the Territories	COGAT	COGAT	COGAT	COGAT	COGAT	COGAT
Prime Ministers Office	PMO	PMO	PMO	PMO	PMO	PMO
Israeli Civil Administration	ICA	ICA	ICA	ICA	ICA	ICA
Ministry of Local Government	MoLG	MoLG	MoLG	MoLG	MoLG	
Palestinian Environmental Quality Authority	PEQA	PEQA	PEQA	PEQA	PEQA	
Infrastructure Inter-ministerial Committee	IIMC	IIMC	IIMC		IIMC	IIMC
Land Authority	Land Authority	Land Authority	Land Authority	Land Authority		
Germany	BMZ/KFW	BMZ/KFW		BMZ/KFW	BMZ/KFW	
European Union	EC/EU	EC/EU		EC/EU	EC/EU	
US Agency for International Development	USAID	USAID	USAID	USAID	USAID	
World Bank	WB	WB	WB	WB	WB	
Dutch		Dutch	Dutch	Dutch		
Norway	Norway	Norway		Norway		
Japan		Japan		Japan	Japan	
French Agency of Development		AFD		AFD		AFD
Ministry of Finance	MoF	MoF	MoF			
Minsitry of Health		MoH		MoH	MoH	
Palestinean Water Authority		PWA		PWA	PWA	
Joint Water Committee		JWC		JWC		
Ministry of Agriculture		MoAG			MoAg	
Italy		Italy		Italy		
Australia		Australia		Australia		
Belgium		Belgium		Belgium		
UK Department for International Development	DFID					
Finland		Finland		Finland		
Qatar	Qatar		Qatar			
Sweden		Sweden		Sweden		
Islamic Development Bank	IsDB					
Canada					Canada	
Palestinian Energy Authority	PEA					
Palestinian Economic Council for Dev. & Recon.	PECDAR					
Palestinian Energy Regulatation Commission	PERC					
Palestinian Eectricity Transmission Company Ltd	PETL					
Palestinian Regulatory Commission for Water		PWRC				
High Council for Transport			HCFT			
Ministry of Public Works & Housing			MoPW&H			
Ministry of Transport			MOT			
Ministry of National Economy					MoNE	
Ministry of Telecom and Information Technology						MoC
High Judicial Council (Palestine)						

Government | Donors/Dev. Banks

a. International comparison



b. Countries <10,000 USD per capita



c. Within 4,000-6,000 USD per capita

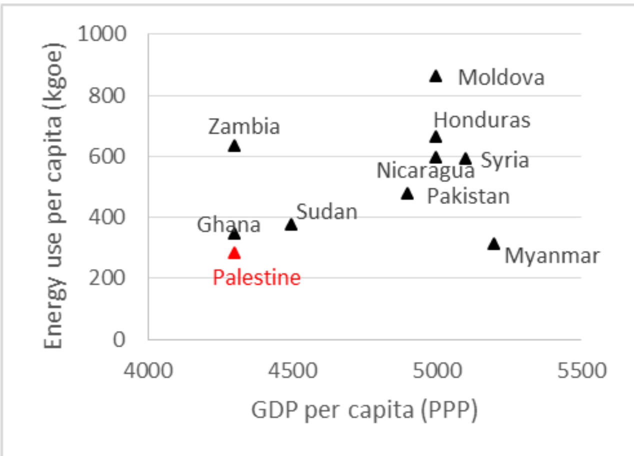


Figure 7: Energy use per capita (kg of oil equivalent) a) comparing Palestine to all countries, b) comparing Palestine to all countries with average incomes <10,000 USD per capita, and c) comparing Palestine to all countries with average incomes between 4,000 and 6,000 USD per capita (PCBS 2014, World Bank 2014, CIA 2016)

2. Infrastructure systems in Palestine

The following section describes the recent state of infrastructure systems in Palestine, including usage data where such information is available. Key challenges and interdependencies between systems are also discussed. How such systems might respond to meet these challenges and future demands are discussed in Section 7.

2.1 Energy

The provision of an efficient and resilient energy system is a key component of sustainable national development (Rogelj, Schaeffer et al. 2016). Energy supply plays a crucial role in economic growth through industry, transport, services and capital creation, and in social development through the provision of water, lighting, temperature control, medical services, educational facilities and waste management (Brown and Crawford 2009, IMF 2011). The occupied Palestinian territories are almost entirely reliant on external sources of energy, which historically has proved to be relatively unreliable and expensive. Improving Palestine's energy stability and self-reliance could unhinge much needed economic growth and greatly improve the lives of Palestinians.

2.1.1 Recent situation

Palestine consumed 19.43 TWh (69,950 TJ) of energy in 2015, which can be broken down into the following sources: 11.68 TWh (42,060 TJ) of fossil fuels (bitumen, oils and lubricants, LPG, fuel oil, kerosene, gasoline, diesel), 5.22 TWh (18,779 TJ) of electricity, 1.78 TWh (6,414 TJ) of biomass, and 0.75 TWh (2,670 TJ) of solar PV (PCBS 2015).

Energy consumption is led by the transport sector (46%), followed by households (40%), commerce and public services (8%), industry (5%) and agriculture (1%) (PCBS 2015). The majority of Palestine's primary energy supply (84.8%) is provided by imports, with the remaining energy supplied by solar PV and fuel wood. These latter sources, along with other renewables, and a currently unexploited gas field off Gaza's coast, are the only potential sources of local primary energy production. In terms of final energy supply mix these primary sources are consumed as 58.1% fossil fuels (diesel, gasoline, LPG, bitumen and kerosene), 26.1% electricity, and 15.8% renewables, including solar energy and biomass (PCBS 2015).

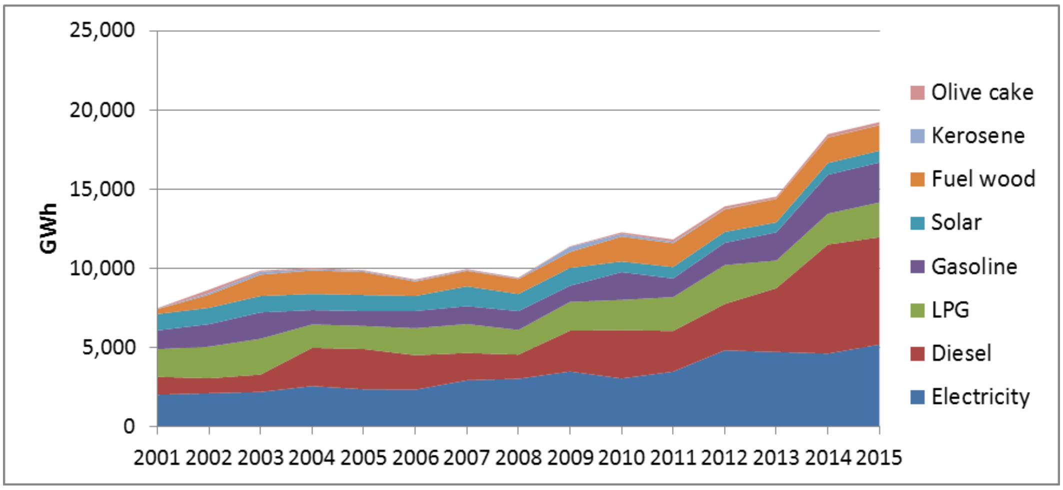


Figure 8: Change in energy consumption (GWh) in Palestine since 2001 (Source: PCBS Energy balance tables)

The patterns of energy use have varied over the last 15 years, as shown in Figure 8, which illustrates how energy use has risen quite substantially in the most recent four years, after a fairly steady period between 2003 and 2009.

The significant increase in energy use in 2014 and 2015 is largely due to the increased use of diesel for transport, which more than doubled between 2012 and 2014 in the official records however this is possibly due to recent corrections of accounting practices rather than a real change (PCBS, personal communication). Energy use by householders has remained relatively static, as has industry, with the largest increase in transport, as shown in Figure 9.

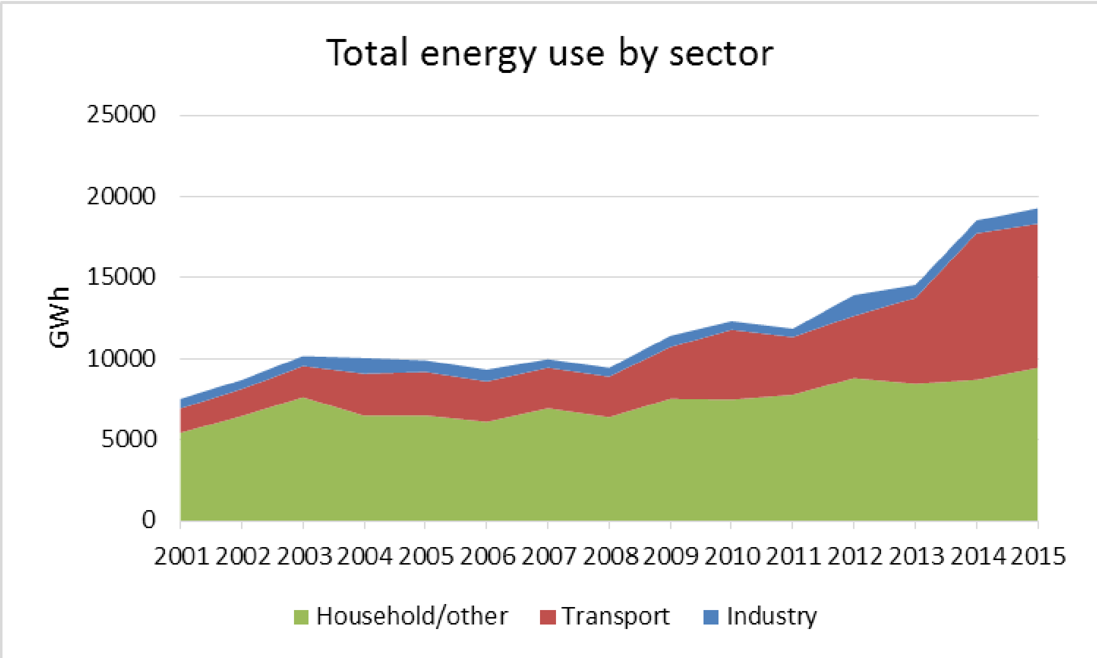


Figure 9: Energy consumption by sector, 2001-2015, Palestine (Source: PCBS Energy balance tables)

The supply of electricity in Palestine for the year of 2015 totalled 5.77 TWh, with the majority (5.41 TWh) imported from the Israeli Electric Corporation, and much smaller amounts from Egypt and Jordan. The remainder was generated by the Palestine Electric Company (0.35 TWh) or identified as 'self-generated' (0.15 TWh) (PCBS 2015). Electricity produced by the Palestine Electric Company in the Gaza strip is generated using imported diesel. Within Palestine, over 96% of localities (including all localities in the Gaza Strip) are served by an electricity network (Figure 10). While the majority of houses receive access to power most of Gaza's households receive at most 16 hours, typically only 6-8 (MAS 2014). In 2015 households consumed an average of 306.0 KWh of electricity, along with 22.0 kg of LPG and 21.0 litres of kerosene (PCBS 2015). At peak supply, around 200 MW of electricity is available, while current demand is estimated at around 450 MW (Office of the Quartet 2016). This shortage has a number of causes, primarily due to insufficient imports from Israel and Egypt and the Gaza Power Plant only producing around 60 MW of its full 140 MW capacity after being retrofitted to use diesel, which is expensive, and damage caused to the plant and distribution network during the 2014 conflict.

At present there are only a few large photovoltaic sites in oPt despite the enormous solar potential of the area. The total installed PV capacity in the West Bank is estimated at less than 10 MW (Office of the Quartet 2016). The opening of the first phase of a planned 1.5 MW Dead Sea Photovoltaic Generating Plant in 2015 has provided much needed local energy to residents of East Jerusalem. There is only limited but growing use of PV for electricity production at the household level. Solar energy for water heating is common (Figure 11) and generally a cheaper alternative to electricity, with nearly 57% of households having access to a solar water heater (PCBS 2015). Hospitals and hotels also use solar energy for a large portion of their water heating needs.

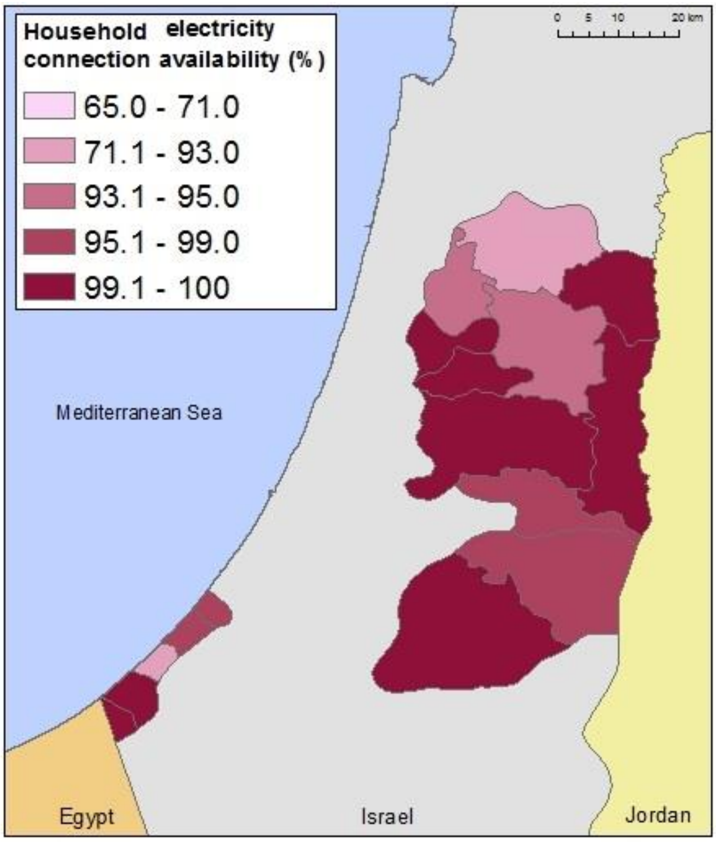


Figure 10: Availability of Electricity Network by Governorate (PCBS 2015)

The majority of electricity supplied in the West Bank and Gaza is based on a series of over one hundred 22 and 33 kV feeders from Israel and Egypt with internal distribution lines on lower voltage levels (UNISPAL 2007). Some of the main distribution feeders into oPt, particularly Gaza, are overloaded and have reached their thermal limit, unable to carry more supply to satisfy the increasing load (World Bank, 2007). These deficiencies have resulted in an increase in technical losses and system outages, and a poor quality of service, with total losses reaching up to 30% (Evans 2015). Israel currently has an installed generating capacity of around 13,500 MW, which is nearly 100 times the current Palestinian generating capacity (Henderson 2014).

Figure 11: Solar water heaters (stripped panels) on the rooftops of Palestinian flats in east Jerusalem

The UN Millennium Project highlighted the availability of energy services as a key factor in achieving the Millennium Development Goals (MDG) and defines a minimum annual per capita energy need of approximately 50 kilograms of oil equivalent (kgoe)[1], which equates to 580 kWh. This is based on a bare minimum need of 40 kgoe (465 kWh) per capita for cooking and an additional 10 kgoe (116 kWh) as fuel for electricity (Modi, McDade et al. 2006). The International Energy Agency suggest a minimum energy requirement of 250 kWh per household in rural areas to stay above the energy poverty line and 500 kWh for urban areas (IEA 2010). A comparison of energy usage in Palestinian households with the minimum suggested levels is shown in Figure 12.

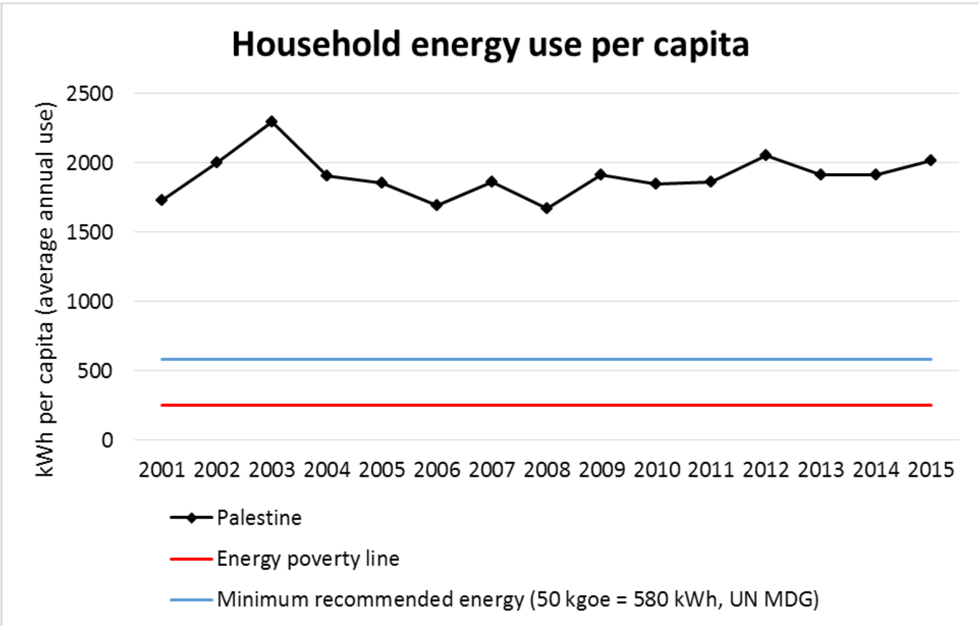


Figure 12: Average annual per capita household energy use in Palestine, compared with minimum recommended energy (50 kgoe) requirements stated in UN MDG (Source, PCBS Energy balance tables)

Despite exceeding this minimum, energy consumption in Palestine remains far below the rising Arab world average of 1,800 kgoe (20 MWh), and is roughly on par with Yemen (Figure 13). As energy

[1] kilograms of oil equivalent, abbreviated as kgoe, is a normalised unit of energy used to convert energy supplied by a variety of sources into equivalent units. It is assigned a standardised net calorific value of 41,868 kilojoules/kg.
1 kgoe = 11.63 kWh

consumption in the West Bank and Gaza is low by regional standards, the scope for achieving economies of scale is limited, and most energy demand (75%) is accounted for by the service and household sectors with little manufacturing activity. Despite high rates of connectivity, reliability of supply presents a major issue within Palestine, particularly for Gaza Strip, with daily electricity cuts of up to 18 hours impacting the majority of Gaza's population and 88.5 percent of Gaza businesses noting lack of reliable power as a serious obstacle to their operation (Office of the Quartet 2016).

Overall, the energy sector emitted 3.51 Mt of CO_2e in 2011, up from 1.81 a decade earlier, representing 81% of total emissions, with the agriculture and waste sectors emitting the remaining 15% and 4%, respectively (PCBS 2011).

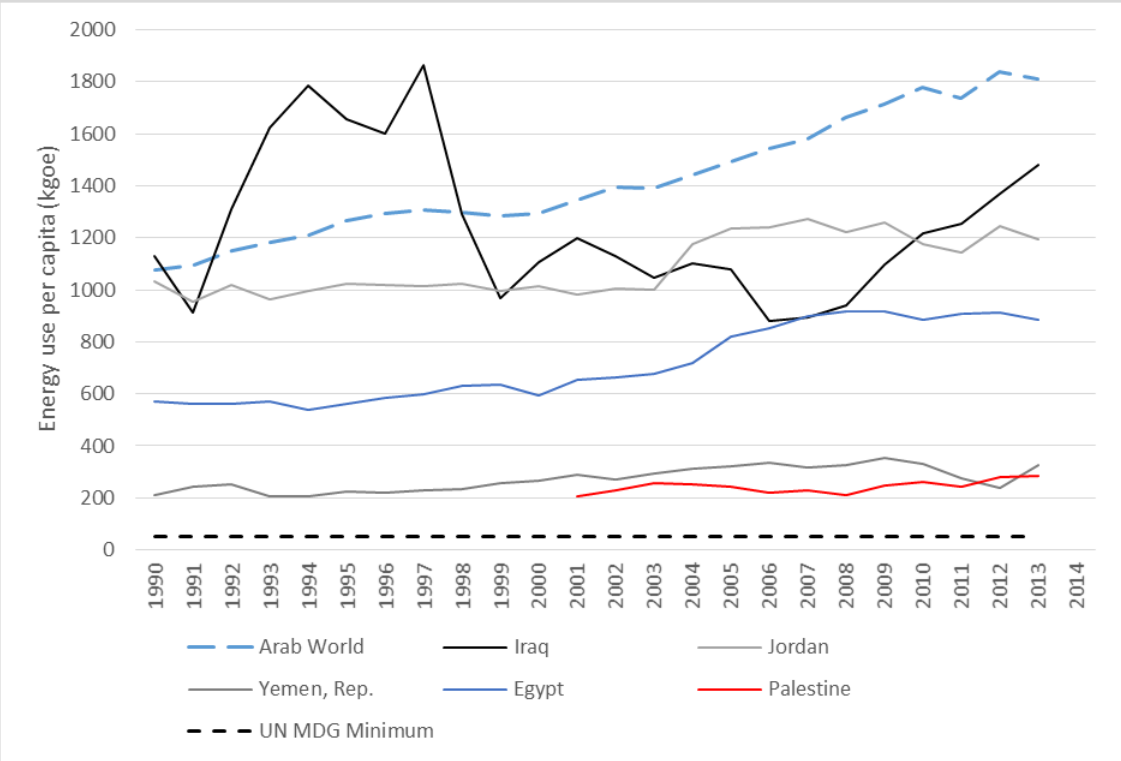


Figure 13: A time series of energy use per capita (kg of oil equivalent) of selected Arab countries. Source: (PCBS 2014, World Bank 2014, CIA 2016)

2.1.2 Key challenges

Gaza is experiencing a severe energy crisis that affects all areas of daily life for its citizens. Reliable energy supply is a prerequisite for the provision of basic services including access to clean water, management of waste water, functioning of schools, hospitals, security services and banks. Access to reliable and affordable energy is also fundamental to economic growth with recent studies showing businesses in the Gaza Strip lose an estimated 22 percent of production due to power outages (Assaf 2014).

Both Gaza and West Bank have an extremely high dependence on energy imports. The high level of power imports drives the imbalance of trade with electricity imports, accounting for 16-17% of the balance of payments annually (Office of the Quartet 2016), and making Palestinians vulnerable to Israeli pricing. According to the Paris Agreement, the Palestinians are allowed to sell fuel in West Bank and Gaza at a lower price than the price in Israel, at a rate which does not exceed 15% of excise tax on gasoline (UNISPAL 2007). However, when compared with other Middle Eastern countries, energy is lightly subsidized in Palestine. In Gaza, the high price of diesel used to run the central power plant substantially increases electricity generation costs and low bill collection rates are common even in the West Bank (World Bank 2014). Given that natural gas is about one quarter the price of diesel converting the Gaza Power Plant from diesel back to natural gas could provide considerable savings (Office of the Quartet 2016).

The electricity system in the West Bank has no generation capacity or regional transmission network and consists of isolated distribution systems not integrated into the network. The heavy reliance on external sources of energy also reduces available funding for strategic projects to develop local generation facilities and distribution networks (MAS 2014).

There exists a high rate of technical/non-technical loss in the electricity network. Part of the loss is likely the result of meter theft and direct hooking from the line (MAS 2014). This is further exacerbated by the poor performance of distribution companies in collecting dues (World Bank 2014), especially in Gaza, which hamper any efforts at demand management. The resultant poor financial health of the power sector is a key obstacle to its improvement and expansion, reducing the capacity of the electricity providers to conduct basic improvements and upgrades and limiting the opportunity for expansion (Evans 2015).

The Gaza Marine gas field is the only substantial domestic fossil fuel energy resource. The United States Geological Survey (USGS) has estimated the geological area known as the Levant Basin in the Eastern Mediterranean contains 122 trillion cubic feet (tcf) of natural gas. The Gaza Marine field has an estimated 1 tcf and a 25-year exploration license for this field was awarded to BG Group (formerly British Gas) by the Palestinian Authority in 1999. However this resource remains unexploited for political reasons and a failure to agree on commercial terms (Henderson 2014).

Given the daily average solar radiation of 5.4 kWh/m^2 in Palestine with around 3,000 hours of sunshine per year (Juaidi, Montoya et al. 2016), there is excellent solar potential in the region, particularly given limited alternative options for primary energy production and global concerns around greenhouse gas emissions and climate change (Evans 2015). However, the PA is unable to utilise large areas of Gaza along the Israeli border and might not have access land in Area C that could otherwise be used for power generation from PV. Moreover, any substantial power re-distribution would have to pass through Area C making energy re-distribution, management of intermittency and resilience planning problematic.

2.1.3 Interdependencies with other sectors

Energy is an essential input to all other infrastructure systems. Transport, which is currently dominated by diesel fuels, is particularly reliant on the energy sector. Changes in energy prices and technology will have implications for fuel spending and emissions in the transport sector.

The current water crises in Gaza and shortages in the West Bank are tightly coupled to energy shortages. Water transport, water treatment, and wastewater management all require energy. Reliable energy supplies are necessary if renewable supplies of water are to be increased. This problem is compounded by the fact that fuel demands are likely to rise as water shortages intensify and new water supply initiatives are undertaken, requiring more pumping from ground water sources, for transfers, and for even more fuel-intensive water sources such as desalination plants.

Any improvements in telecommunications will require reliable supplies of electricity. However, of all the other infrastructure sectors, waste actually has the potential to augment energy supplies through energy from waste (EfW). Energy from solid waste biogas is particularly efficient being one of the best sources of energy based on levelised costs of energy[2]. EfW is currently used as an energy input in rural areas, and has the potential to reduce dependence on diesel and gas imports if conversion to biodiesel and biogas is undertaken on a larger scale (Abu Hamed, Flamm et al. 2012).

2.2 Water supply

The Middle East is a semi-arid region characterized by deteriorating water resources and unsustainable development (Brown and Crawford 2009, Kanyoka and Eshtawi 2012). Accordingly, water supply is one of the most significant and urgent issues to be addressed in Palestine's infrastructure services, particularly in the Gaza Strip (Afifi 2006, Brown and Crawford 2009). The need for viable solutions is becoming increasingly urgent (Shomar 2011). However, given the Levant region's vulnerability to climate change (Christensen, Hewitson et al. 2007, Bergaoui, Mitchell et al. 2015) and the difficult political climate, any viable solutions must also be robust to these serious long-term uncertainties.

2.2.1 Recent situation

In 2014 the total water supply in Palestine was 342.7 million cubic metres (MCM), obtained from the following sources: pumping from Palestinian wells (72%), purchased from Israel (Mekorot) (19%), springs discharge (8%), desalination (1%) (PCBS 2014, PWA 2015). Rainfall varies by governorate, with quantities ranging from 700 mm (Tulkarm) to 200 mm (Jericho) in 2015, while evaporation levels are high, with Jericho recording the highest monthly average of 195 mm (PCBS 2015, PCBS 2015).

Although amounts vary by region, average household monthly water consumption is currently 623 litres per day (PCBS 2015), amounting to daily per capita consumption rates of roughly 79 litres/capita/day in both the West Bank and the Gaza Strip (PCBS 2014, PCBS 2014). Figure 14 plots per capita daily water allocation from domestic water supply in the West Bank and Gaza. While per capita consumption noticeably increased since 2001, particularly in Gaza, the past five years have seen levels drop below the WHO's recommended water requirements for assuring all consumption and hygiene needs are met (Howard and Bartram 2003), and are currently approximately equivalent in the West Bank and Gaza. They are above the basic short-term survival (consumption, hygiene, and cooking) level of 15 litres/capita/day outlined in the WHO (2013), but this level can only maintain human life temporarily. A list of minimum per capita water allocation according to a number of recent studies can be found in the appendix to this section.

In terms of total annual water allocation for domestic use (i.e. average daily allocation per capita * population * 365), Figure 15 shows a steady increase in domestic water supply from 2001 to 2008, with a recent decrease since 2009, when the amount allocated was around 180 MCM per year. In 2014 the amount of water allocated for domestic use in the West Bank was 80 MCM, compared with 51 MCM in Gaza.

[2] https://en.wikipedia.org/wiki/Cost_of_electricity_by_source

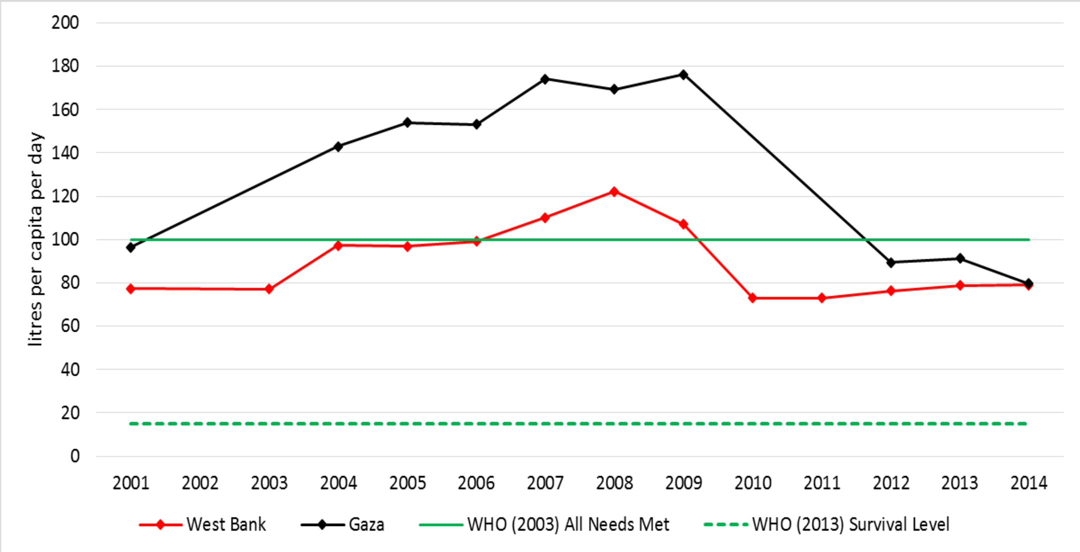


Figure 14: Daily allocation per capita (litres/capita/day), West Bank and Gaza (Howard and Bartram 2003, WHO 2013, PCBS 2014, PCBS 2014)

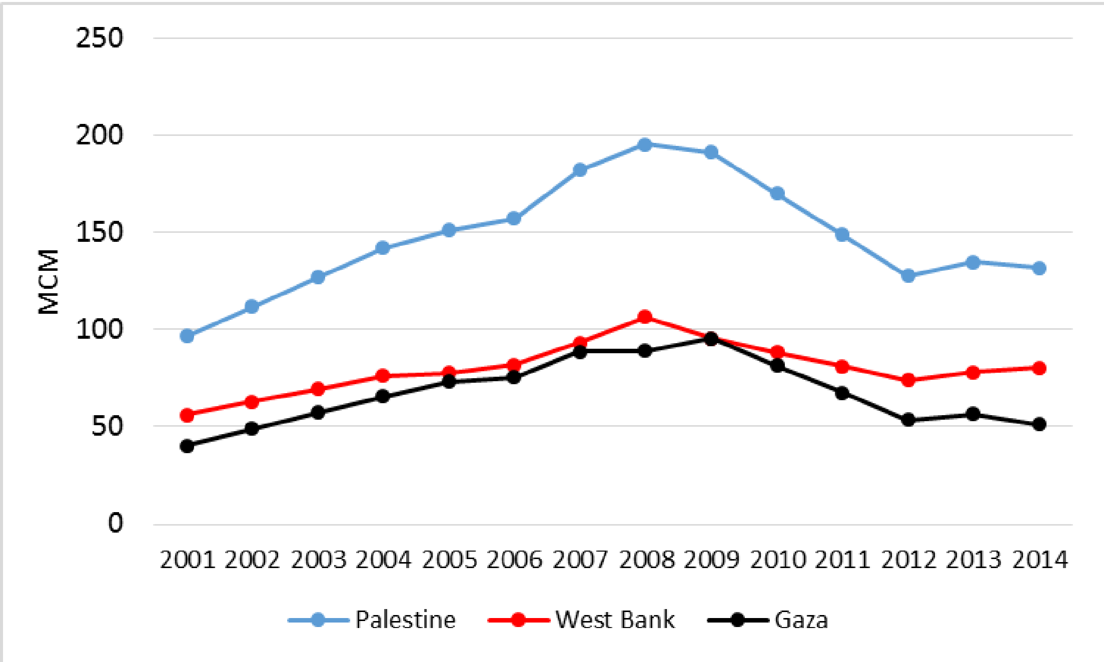


Figure 15: Annual water allocated for domestic use, West Bank, Gaza, Palestine, 2001-2014

Figure 16 presents the availability of water networks across governorates, with up to 40% of localities lacking water supply infrastructure. Overall, more than 90% of municipalities in Palestine are connected to the water supply network.

Common short-term solutions to water shortages in Palestine include the rapid expansion of unlicensed wells, small-scale desalination plants and imports of bottled water (Bohannon 2006). Gaza relies almost entirely on the Eastern Mediterranean coastal aquifer for agriculture and domestic uses. No other major water resources have been developed (PWA 2012), and only 2% of demand is met by water imports (PWA 2014).

With regard to agricultural water demand, there are currently 61,100 hectares of irrigable land in the West Bank (PWA 2014), with a minimum water requirement of 45 m^3/hectare/year as recommended by the Ministry of Agriculture. Agriculture is the main water consumer in the Gaza Strip, demanding approximately 60% of the total water supply (Afifi 2006, PWA 2014). Allocation of extracted freshwater for agricultural use in Palestine has dropped over 14 percent from 2002 to 2014 relative to total freshwater withdrawals, a pattern seen (although to a lesser extent) in some other industrialising countries in the same per capita income range (Figure 17). In part this is due to an increase in land productivity but also likely due to an increased reliance on imported food sources (Gilmont 2014, Gilmont 2015), involving a trade-off between water security and food security. The percent of water allocated for industrial use has also risen over the same period, emphasising the resulting decline in household consumption to their current low levels.

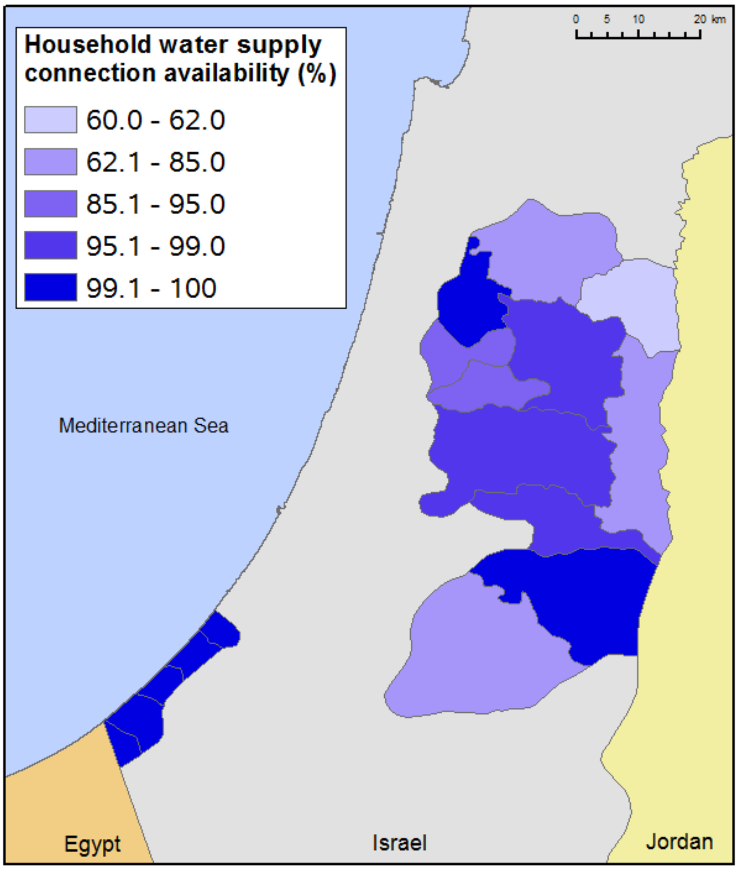


Figure 16: Availability of household water network connectivity by governorate (PCBS 2015)

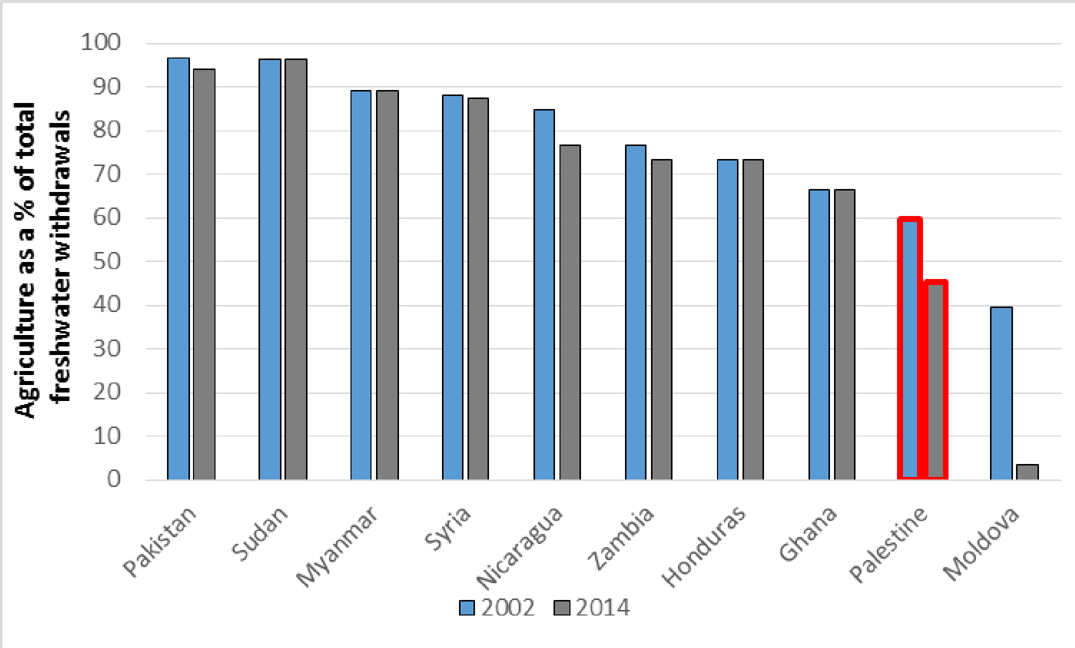


Figure 17: Annual freshwater withdrawals, agriculture (% of total freshwater withdrawal) (World Bank 2014)

2.2.2 Key challenges

As shown in Figure 14, the populations of both the West Bank and Gaza do not currently have sufficient water to meet WHO's recommended per capita residential water allocation of 100 litres/day. The only natural water resource available in Gaza, the Coastal Aquifer, is being depleted by more than 100 million cubic meters (MCM) per year more than is sustainable in the long term[3] (World Bank 2009). The aquifer is impacted by contaminants from seawater intrusion, wastewater, manure and natural occurrence. Water contamination is a major problem where poor sanitation facilities and aquifer vulnerability. All groundwater wells have at least one parameter exceeding the WHO standards, nitrate levels are increasing yearly (due both to sewage disposal and excessive fertilizer use), more than 90% of the water pumped from the aquifer have salinity exceeding the WHO standard (Shomar, Abu Fakher et al. 2010, UNRWA 2012), and four out of five Palestinians in Gaza buy their drinking water from unregulated, private vendors (Weibel and Elmughanni 2014). The consumption of contaminated water leads to high transmission rates for water-borne diseases (PWA 2012).

Tensions over trans-boundary water resources continue to limit water access to the Palestinian territories, and water sharing agreements have left Palestine with too little water. Two decades after the Oslo II Interim Accords gave Israel temporary control of most regional water resources, the Palestinian population has doubled, yet extraction levels have been capped at 1995 levels. In addition, Israeli permit regimes in the West Bank restrict the planning and development of Palestinian water, sanitation and hygiene infrastructure (EWASH 2015). Only 1.5% of Palestinian building permit applications in Area C were approved between 2010 and 2014, leaving many Palestinians no choice but to build without a permit and risking destruction or confiscation of water, sanitation and hygiene (WASH) structures including latrines, water networks, and cisterns (EWASH 2015). Only about 15 percent of the recharge capacity of the West Bank's water system is available to Palestinians (Haddad 2009, Isaac, Khalil et al. 2015), well below their allocated levels.

[3] The annual sustainable yield of the aquifer within the geographical boundary of Gaza is 55 million cubic metres (PWA, 2011).

The Israeli Water Authority as regulator has restricted aquifer drilling in West Bank towns. Estimates from the World Bank (World Bank 2009) suggest that Israel over-extracts 389 MCM per year relative to its Article 40 allocation, while total Palestinian aquifer extraction in 2012 was limited to 104 MCM (Isaac, Khalil et al. 2015). The Eastern Mediterranean coastal aquifer under Gaza is currently overexploited and is expected to soon become unusable for Gaza due to seawater inundation and wastewater contamination (Bohannon 2006, PWA 2012).

2.2.3 Interdependencies with other sectors

The water supply in Palestine is tightly coupled with energy supply. Energy is required to pump water from aquifers, transport water between areas, treat water and wastewater, and run desalination plants. Technological advances, such as desalination, have somewhat depoliticised water issues to some extent as water can be shared more effectively and fairly at a lower political cost (Bromberg 2016). However, such a technological solution requires access to the energy sources needed to power such facilities. The new desalination plant wastewater treatment plants planned for Gaza will not provide water unless their energy requirements are met. This is a particularly difficult problem for the Gaza Strip which is already unable to meet its domestic energy demands, importing the majority of its energy from Israel.

Underlying Palestine's future water supply strategy is also the increased role for treated wastewater (Eting 2015). The lack of suitable wastewater networks in many localities currently limits this potential, and improper disposal of contaminated water leads to further pollution of freshwater sources (a primary source of pollution for the troubled Eastern Mediterranean coastal aquifer under Gaza is unmanaged wastewater).

2.3 Wastewater

Given the extreme water stress faced in the region and per capita water consumption rates below recommended WHO levels (UN Human Rights, UN Habitat et al. 2010), solutions in the water sector will need to incorporate the treatment and reuse of collected wastewater in the Palestinian territories (Eting 2015). Management of wastewater is a crucial component in the health and wellbeing of any functioning society, and is particularly important for countries in the Levant, since they occupy one of the most arid regions in the world. In addition to offering water recovery, management of wastewater prevents health problems associated with untreated waste, reduces environmental degradation, and enables national self-sufficiency, which in turn can promote greater political and socio-economic stability (UN-ESCWA 2003).

2.3.1 Recent situation

Wastewater infrastructure in the Palestinian territories has been largely neglected since 1967 as capital investments have focused on the provision of safe drinking water (PWA 2012). While connection to wastewater collection networks, often old and poorly maintained, is available to the majority of localities in the Gaza Strip, it is limited to a few municipalities in much of the West Bank, mainly the large cities and refugee camps (Figure 18) (PWA 2012, PCBS 2015). The rest of the Palestinian population, amounting to over 1.5 million people (PCBS 2010) including 94.5% of the West Bank's rural residents, relies on porous and tight cesspits (in 59% and 22% of localities, respectively), exposed networks (2.5%) and channels (4%) for wastewater disposal (PCBS 2015).

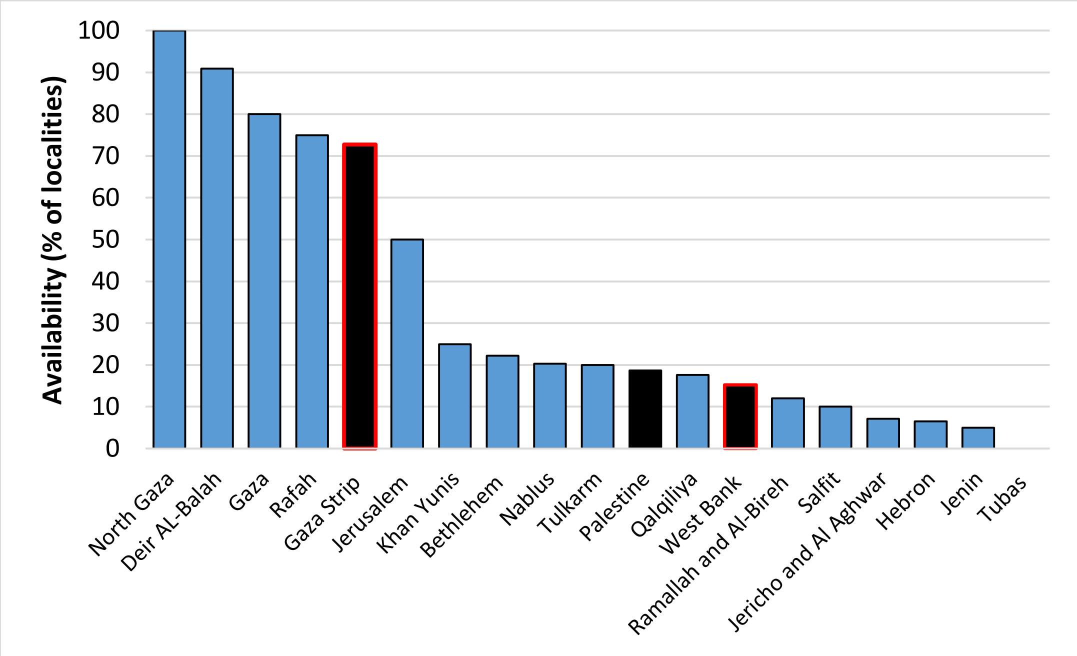


Figure 18: Availability of wastewater networks by governorate (PCBS 2015)

Given existing household connections to wastewater collection networks, the capacity for wastewater collection is estimated at around half of total wastewater produced (Figure 19). In 2015, over 114 million m^3 (MCM) of wastewater were produced in the Palestinian territories. Of this, an estimated 66 MCM were produced in the West Bank, including water discharged by settlements and industrial zones, with around 48 MCM produced in Gaza.

In the West Bank, around 41 MCM of wastewater is dumped annually into cesspits, and around 15 MCM is dumped straight into wadis (streams) untreated, then abstracted again and treated in Israeli wastewater treatment plants (WWTPs) inside the green line, to be reused by Israel, but paid for by Palestine. A further 6 MCM is dumped annually into local streams and not subsequently treated (Isaac and Rishmawi 2015). There are six operational WWTPs in the West Bank (Al-Teereh, Al-Bireh, Al-Taybeh, Jericho, Jenin, and West Nablus), in addition to a pre-treatment plant in Tulkarm. All treatment plants are considered to be overloaded and only account for around half of the wastewater produced (PWA, 2012).

In the Gaza Strip, around 37 MCM of the 41 MCM wastewater collected by sewage networks in 2015 were partially treated, and discharged into the Mediterranean. Both partially treated and untreated wastewater is discharged into open areas including wadis such as Wadi Gaza or into the Mediterranean Sea with many discharge points registered along the shoreline in the Gaza Strip (Isaac and Rishmawi, 2015, Auda & Shahin, 2005). In 2014 there were five treatment plants (four of them considered temporary, and all considered overloaded and inefficient (Nassar 2015)) with varying flow capacities already in operation (Beit Layhieh, Al Shiek Ejleen, Central district, Khan Younis, and Rafah), and three new plants scheduled for completion by 2018 (Nassar 2015).

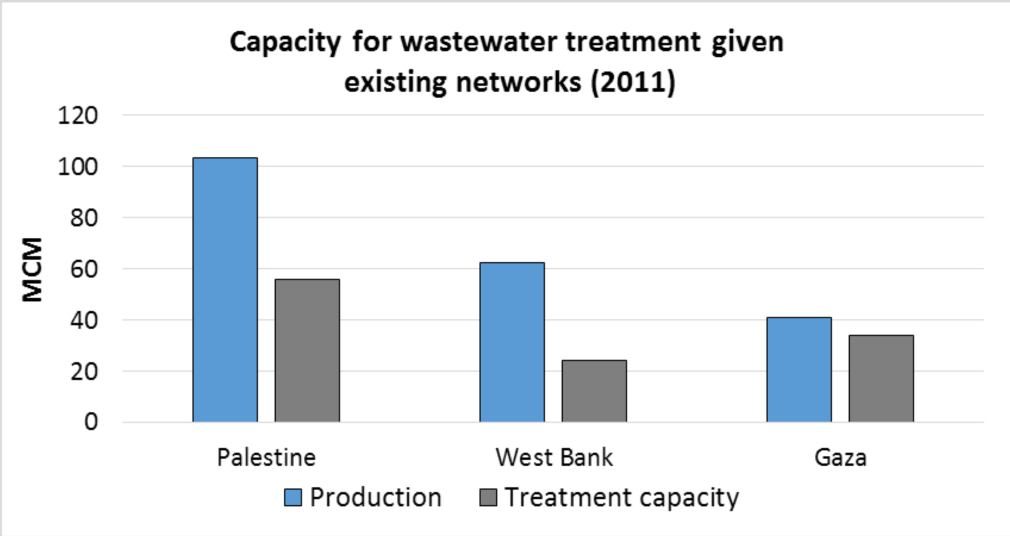


Figure 19: Estimated capacity in 2011 for wastewater collection given existing household connection to networks (PWA 2012, PCBS 2015)

2.3.2 Key challenges

Successful implementation of wastewater development projects in conflict-affected regions such as Palestine is challenging given high capital and operating costs as well as increased investment risk. As a result, large infrastructure components such as WWTPs remain under-developed or non-existent across much of the region. Of the five main West Bank WWTPs, only two are currently functioning at advanced levels, and generally perform secondary water treatment which limits the water's reuse to non-consumptive purposes such as aquifer recharge and irrigation. In comparison, Israel's 74 plants are increasingly employing tertiary treatment due to regulatory requirements (Dotan, Godinger et al. 2016). Given the trans-boundary nature of many West Bank streams, a large quantity of effluent produced in the Palestinian territories is treated by Israeli WWTPs and returned for Israeli reuse. Although Israel deducts treatment costs from the Palestinian clearance account, the resulting treated water does not benefit the Palestinian population (PWA 2012, Bromberg 2016).

Obstacles limiting the successful implementation of wastewater treatment and reuse in the Gaza Strip include a stagnant political situation that hinders any new development, a lack of required energy, as well as limited finances. Wastewater networks and facilities in the Strip have suffered years of degradation and collapse (Tal and Abu-Mayla 2013). The four existing WWTPs function mainly as transit stations for wastewater because they are overloaded by the growing population, and operate intermittently mainly because of energy shortages. With the sewerage network covering the needs of only 60-65% of the population, untreated sewage flows into the Mediterranean Sea, through open drainage areas like Wadi Gaza, and into lagoons, some of which were originally designed to collect fresh water. Much seeps straight into the aquifer, further contaminating Gaza's sole natural water supply source (UNEP 2009).

2.3.3 Interdependencies with other sectors

In the severely water-stressed oPt, recovered wastewater can substitute for future freshwater abstraction and be used for various purposes depending on the quality of the treated effluent: aquifer recharge, agricultural irrigation, ecosystem enhancement, industrial uses, and when highly treated, drinking water. Wastewater reuse offers not only the potential for fresh water recovery but also the recovery of nutrients and energy (GWI 2009). Reused wastewater can serve a number of vital purposes, including meeting water demand, maintaining natural environmental function, and improving health and well-being, and can serve as a less costly alternative to other water supply solutions such as desalination.

An interdependency between the water and wastewater systems that is particularly relevant in the developing context results from the fact that securing additional water resources for residents in oPt will likely also increase the amount of wastewater that must be managed. Any scenarios of future wastewater management requirements must take this possibility into account.

Finally, to ensure continued and increased expansion of wastewater treatment systems, energy sources will need to be secured, as most current wastewater facilities in the region (particularly Gaza) face energy deficits and power supply interruptions that limit them to partial operation (World Bank 2015).

2.4 Solid waste

Solid waste management in Gaza and the West Bank remains suboptimal due to political and institutional obstacles that have limited its effectiveness (D-Waste 2014). Dumping of most waste, including medical and hazardous substances, is widespread, and landfill and transfer sites do not yet have the capacity to manage the quantities of waste generated in the territories. The resulting contamination of the environment has significant health consequences for the Palestinian population (Isaac, Khair et al. 2011). Future strategies will require collaboration between local-level governments and numerous other ministries and organisations, as well as investment in large-scale facilities for waste treatment and storage.

2.4.1 Recent situation

Approximately 1.387 million tons of municipal waste is generated per year in Palestine, amounting to about 0.94 kg per capita per day. This amount ranges from 0.35 to 2.05 kg, with persons in urban areas producing higher amounts of waste, and places the West Bank and Gaza on the low end of per capita waste production compared to its counterparts in both the MENA (Middle East and North Africa) region and the wider international community (Figure 20). While overall municipal waste has increased by about 4% each year, 3% of this is due to high population growth, with the remaining 1% considered to be the result of increased per capita waste arisings. The dominant method of municipal waste management in Palestine is dumping in open, uncontrolled, and unmonitored sites (67%), while much of the rest is landfilled (33%), and marginal amounts (less than 0.5%) are composted and recycled, usually by private firms (D-Waste 2014). Given projected 2015 waste generation, this means that over a million tons is openly dumped, with only half a million tons landfilled (Figure 21), indicating a current lack of storage capacity and/or inadequate waste transport infrastructure, which will cause further problems with the rapidly growing Palestinian population.

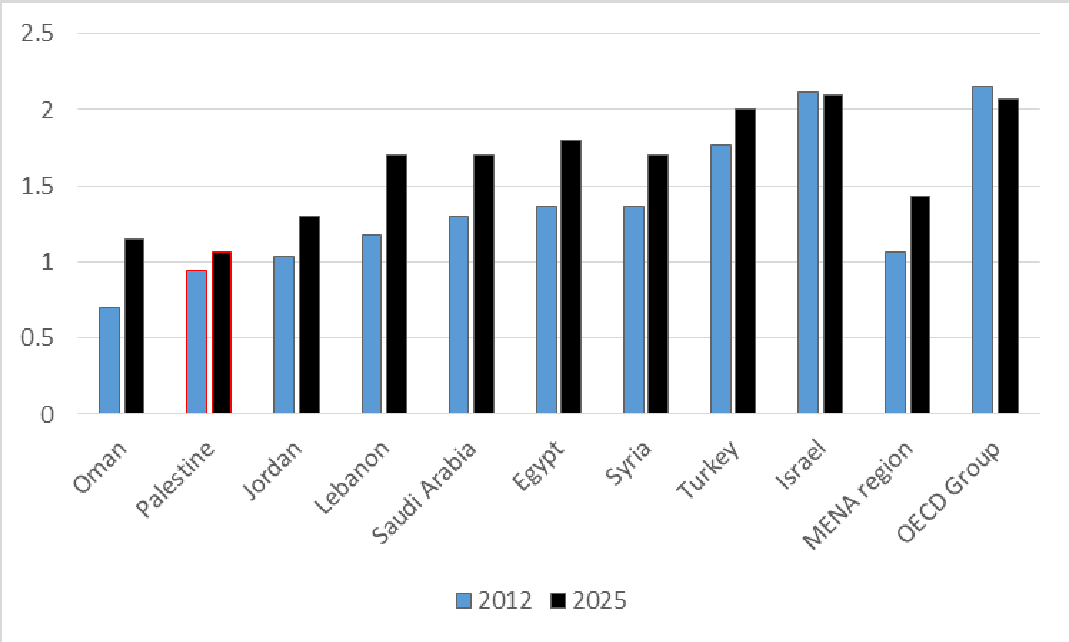


Figure 20: Per capita municipal waste generation, 2012 and 2025 projections (Hoornweg and Bhada-Tata 2012, D-Waste 2014)

The number of dump sites reached 183 in 2006, up from 137 in 2001 (Isaac, Khair et al. 2011). Around 242 thousand tons per year of solid waste is produced by economic establishments in Palestine, the majority (183,600) from the West Bank (PCBS 2015). This includes over 131 thousand tons of industrial waste, and 62 thousand tons of hazardous waste. Figure 22 shows the breakdown of waste composition in the Palestinian territories.

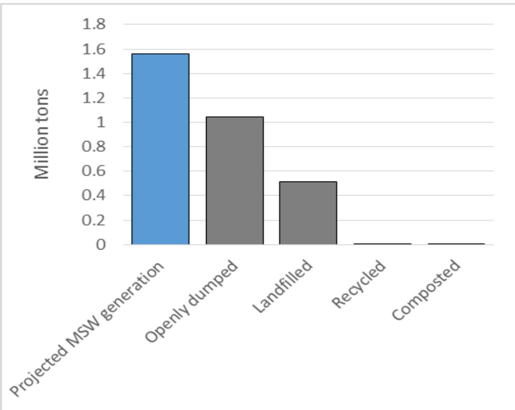


Figure 21: Waste disposal by destination, 2015 (D-Waste 2014, PCBS 2016)

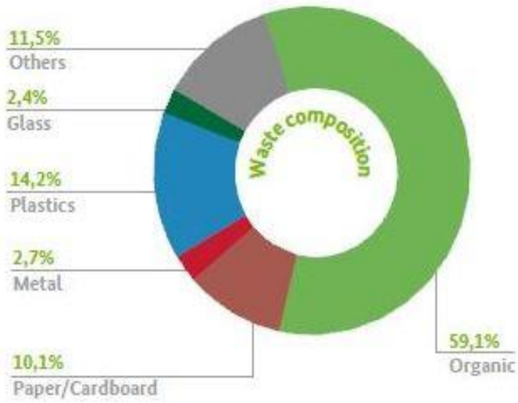


Figure 22: Waste composition in Palestine (D-Waste 2014)

According to the Household Environmental Survey (PCBS 2015), local authorities are largely responsible for the disposal of solid waste (78.8% of households), while UNRWA collected 9.4% (mostly in refugee camps), 0.3% of households had private waste collection. Overall, municipal solid waste collection levels are at 93% in urban areas and 88% in rural areas (D-Waste 2014), although collection frequency is often inadequate, leading to accumulation of waste in certain areas (Isaac, Khair et al. 2011).

Figure 23 shows solid waste collection availability by region, with approximately one-third of localities in some regions lacking service altogether. As of 2010, this affected nearly 40 thousand people in the West Bank (PCBS 2010).

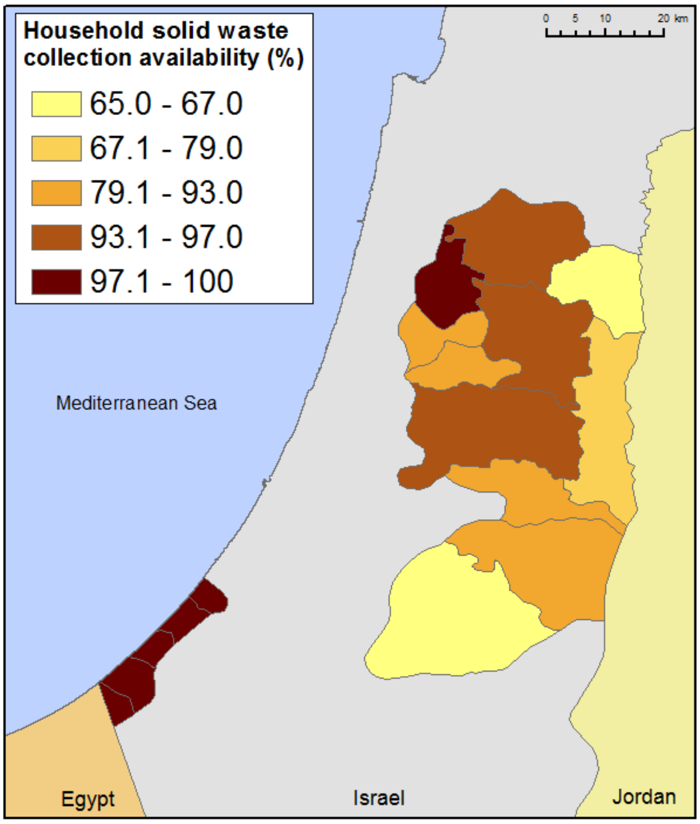


Figure 23: Availability of Solid Waste Collection Service by Governorate (PCBS 2015)

There are currently four landfill sites in the West Bank (D-Waste 2014) although recent reports suggest that only two of these are currently operational (Hattem 2014). Three landfill sites currently operate in Gaza (Figure 25) (El Baba, Kayastha et al. 2015), one of which is for hazardous materials and was built in 1998, although it is not operational due to feasibility and enforcement limitations. Controversy surrounds the management of these landfill sites with accusations of poor management and landfilling practices leading to pollution problems for nearby residents (Hattem 2014).

There are seven temporary storage areas in Gaza, and eight transfer stations in the West Bank: two in the south, and one each in Tubas, Jenin, Tulkarm, Qalqyilya, Nablus, and Ramallah (D-Waste 2014). According to UNEP, Israeli settlers in the West Bank generate approximately 2 kg of solid waste per capita per day, amounting to approximately 15 thousand tons per year, the large majority of which is disposed of in random dumpsites in the West Bank (UNEP 2003, D-Waste 2014). Periods of political tension and violence uprisings have had negative consequences for solid waste management in Palestine, as dumpsite maps of the West Bank prior to and during the Second Intifada (2000-2005) show a large increase in random dumping. Figure 24 shows the prevalence of dumping sites following this period of unrest.

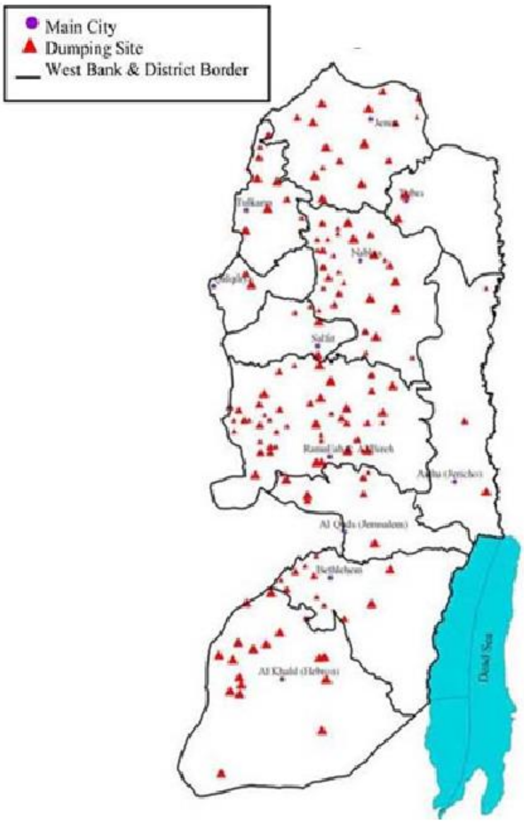


Figure 24: Location of solid waste dumping sites in the West Bank (Isaac, Safar et al. 2005)

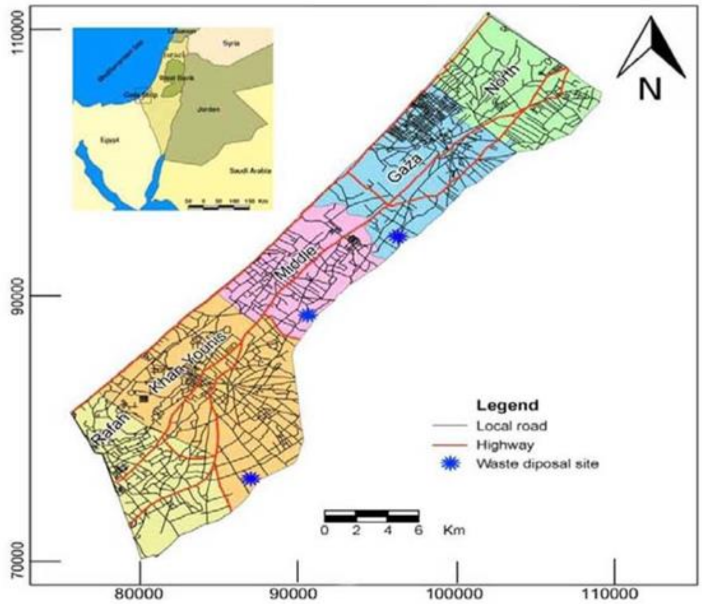


Figure 25: Present landfill sites, Gaza Strip (El Baba, Kayastha et al. 2015)

2.4.2 Key challenges

The management of solid waste faces political barriers that limit its effectiveness. A particular obstacle lies in obtaining approval for disposal facilities, as most waste treatment and disposal sites can only be located in "Area C" as classified by the Oslo Agreement. Since Israel has both civil and security control of these areas, approval is required for constructing these facilities, a process which often takes years and results in significant delays to improved waste management (D-Waste 2014).

Composting initiatives have been largely unsuccessful in Palestine, and recycling is minimal and largely limited to hard plastics – in Gaza, the limiting of imports of raw materials plays a role in the low recycling rate (D-Waste 2014). Of economic establishments that generate each type of waste, less than 10 percent undertake proper separation of paper and carton, plastic and rubber, soil and stones, organic, and glass and metal waste (Figure 26). Just over 30 percent separate sharp, infectious, and chemical waste, while over 50 percent of radioactive medical waste is separated (PCBS 2015, PCBS 2015).

Uncontrolled dumping and the resulting contamination has been shown to have serious health impacts for local residents, and the costs of diseases associated with improper waste management is expected to be high (Isaac, Khair et al. 2011, D-Waste 2014).

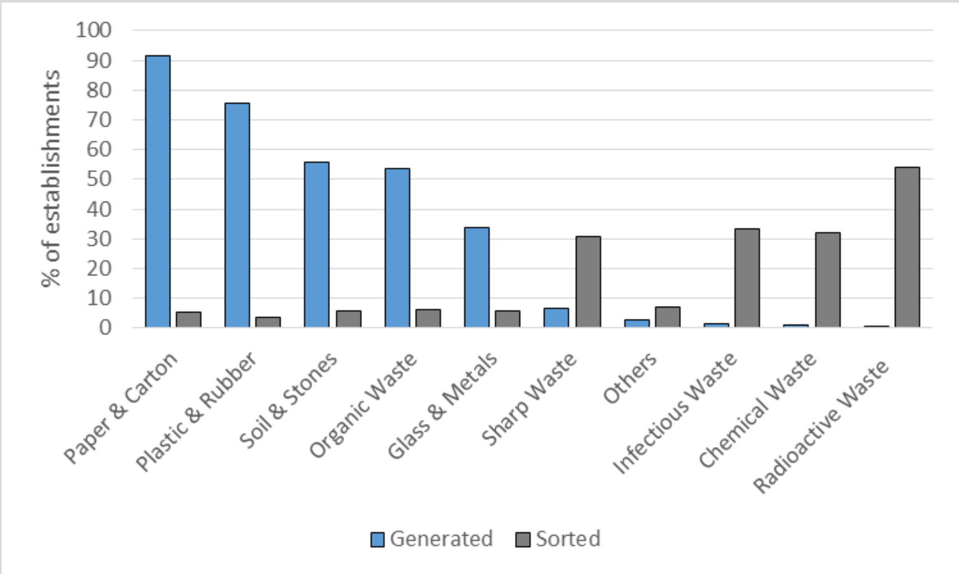


Figure 26: Waste generation vs. sorting, by type (PCBS 2015, PCBS 2015)

2.4.3 Interdependencies with other sectors

Joint Service Councils have begun studying the feasibility of collecting gas from solid waste to use as an input to energy generation (D-Waste 2014). A recent analysis of a proposed waste-to-energy (WTE) facility in the Gaza Strip showed the potential to develop up to 77.1 MW of electricity, which could help alleviate part of Gaza's chronic energy shortage (Ouda 2013). Given the amounts of waste that is being collected but unmanaged there appears good scope for also generating energy from WTE facilities in the West Bank.

Waste collection's use of transportation routes exists as a further interdependency between infrastructure sectors. However, as in most countries, this presents a relatively insignificant impact on transport capacity constraints.

2.5 Transport

The only major form of transport in Palestine is through roads and hence the road infrastructure network is a key component of development, allowing Palestinians access, among other things, to economic opportunities within both Palestine and Israel. However, tight security measures have considerably restricted movement in the territories, making the transport network highly inefficient to

Palestinian residents in the West Bank, while recent conflicts in Gaza have caused it extensive physical infrastructural damage. Measures important to growth in Palestine include the development of an improved road network, the resumption of civilian air transport, and the construction of a port in the Gaza Strip.

2.5.1 Recent situation

Palestine had around 63 vehicles per 1000 people in 2014 (PCBS 2014) which is relatively low compared to other nations and neighbouring countries (generally above 300 vehicles per 1000 people) (NationMaster 2014). The total paved road network length for the West Bank and Gaza is 3,544 kilometres, with a further 445 kilometres of unpaved roads in the West Bank (PCBS 2014). Figure 27 shows the road network in the West Bank and Gaza, with major trunk roads indicated in red and orange. In 2014, there were 121,675 private cars and 162,512 total vehicles licenced in the West Bank (PCBS 2015).

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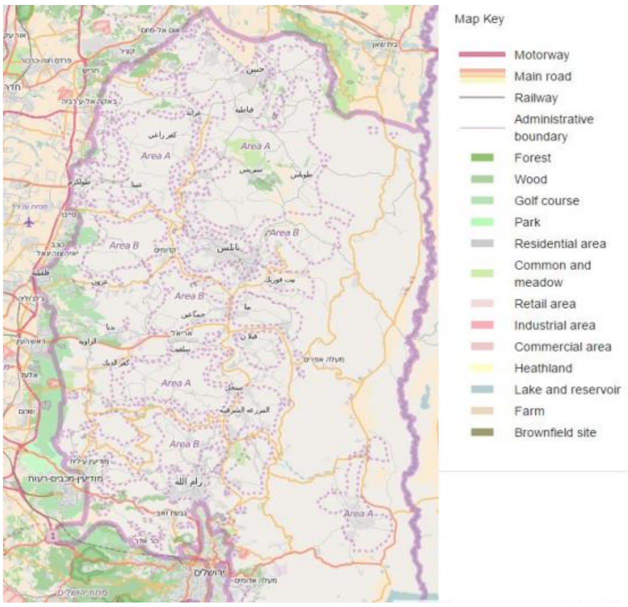

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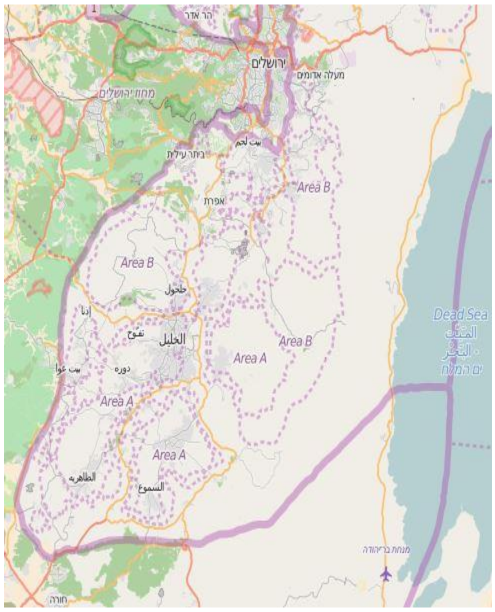

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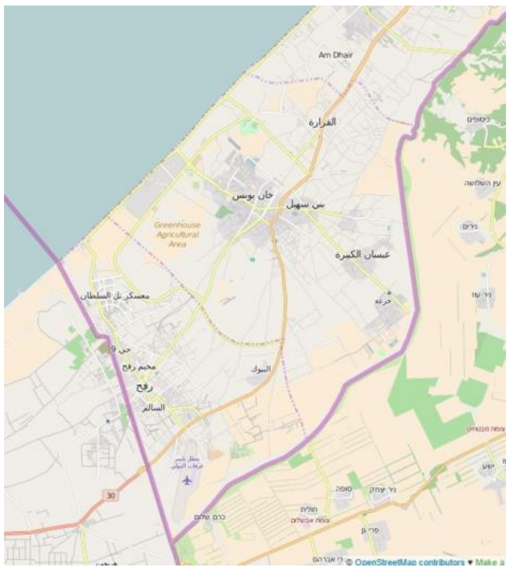

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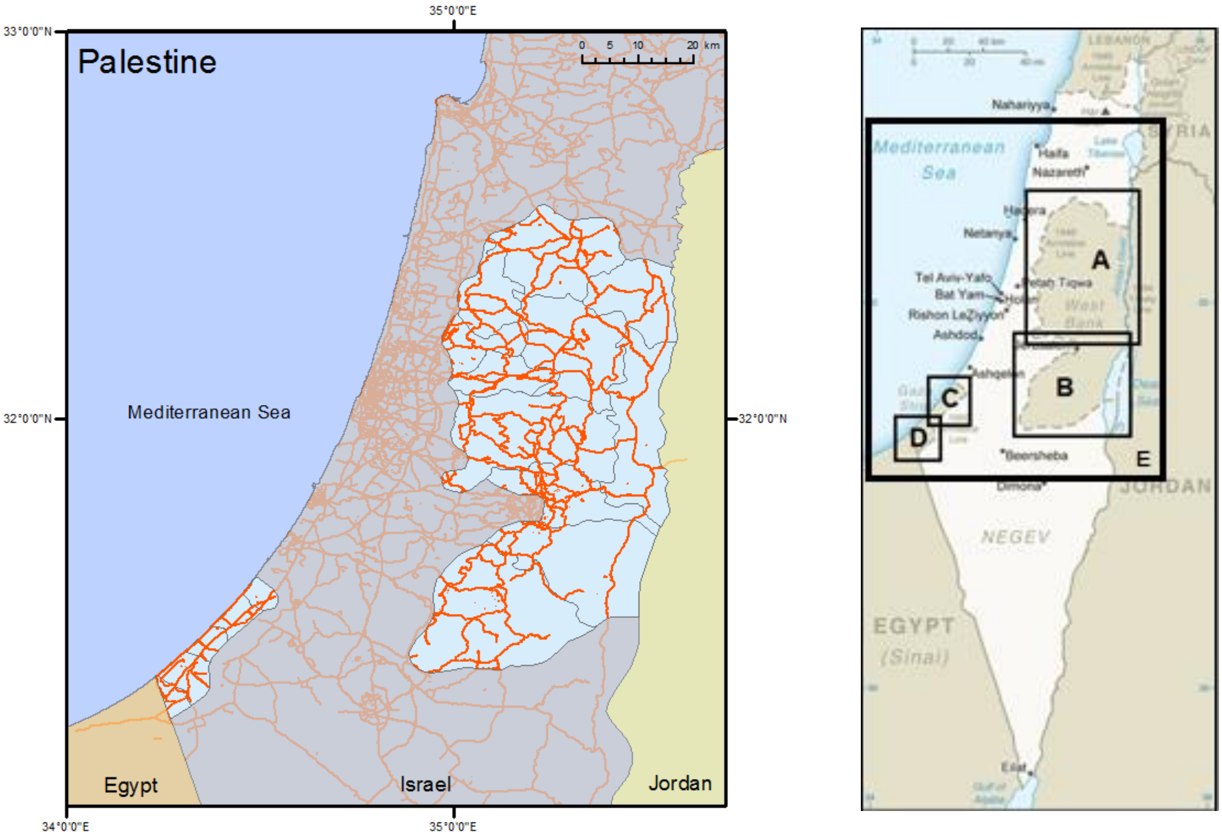

Figure 27: Road network, West Bank and Gaza: a) West Bank (North); b) West Bank (South); c) Gaza Strip (North); d) Gaza Strip (South), e) Major road network of Israel and the occupied Palestinian territories. Source: (CIA 2016, OpenStreetMap 2016)}

The estimated road network lengths for each governorate are presented in Figure 28. Figure 29 and Figure 30 show estimates of West Bank vehicle traffic based on vehicle density and traffic accidents by governorate (data not available for Gaza) as some form of proxy for traffic demand for which there is no data currently available.

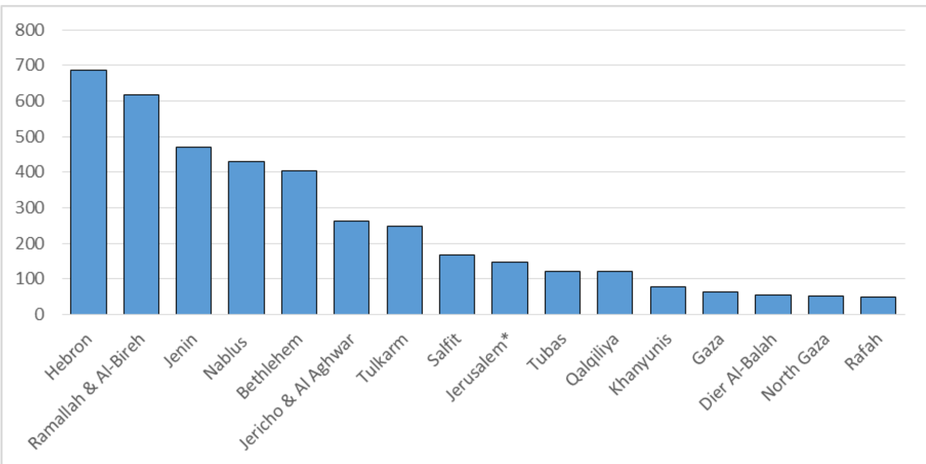

Figure 28: Road network length by governorate in the West Bank (2015) and Gaza Strip (2014). (PCBS 2014, PCBS 2015)

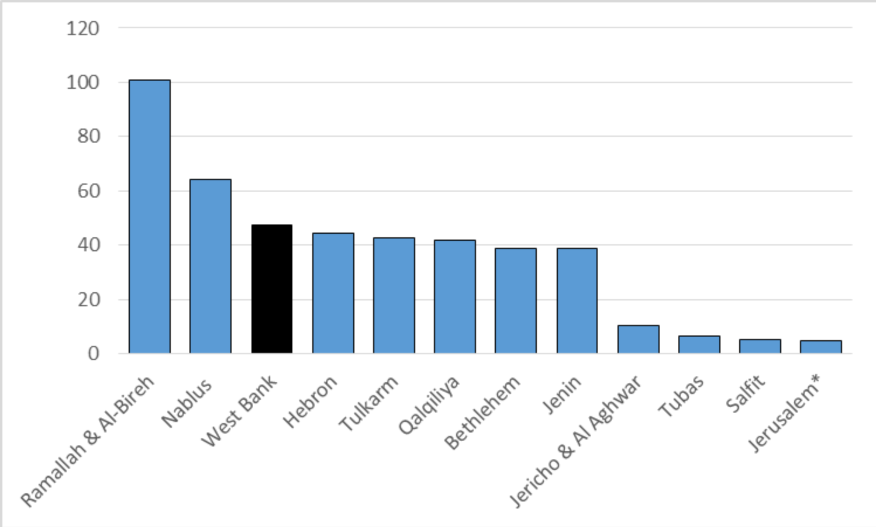

Figure 29: Vehicles per road length by governorate in the West Bank, 2015. (PCBS 2015, PCBS 2015)

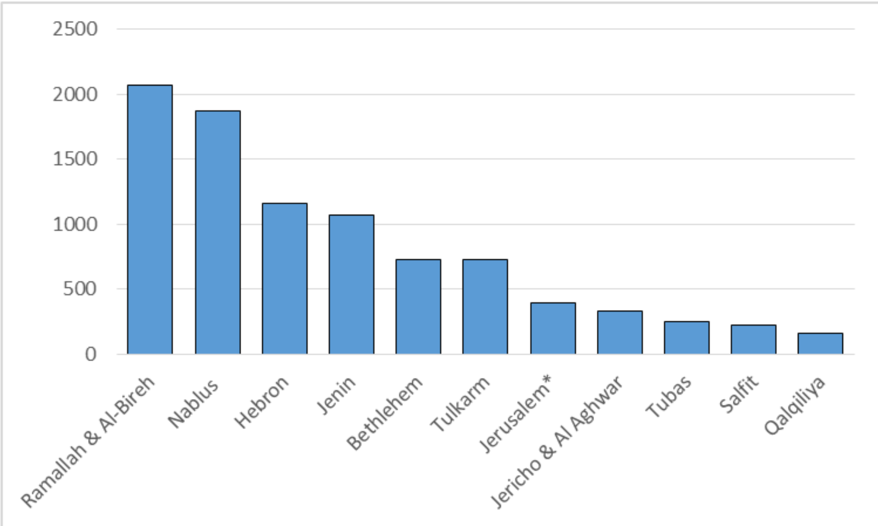

Figure 30: West Bank governorates total registered road traffic accidents, 2015 (PCBS 2015)

Figure 31 shows a map of the inter-governorate road capacity, which is calculated as the total number of roads that cross borders and hence connect governorates. Values are plotted as weighted lines on the map and are derived from 2014 open street-map data.

The port of Gaza serves as the primary seaport to the strip, although the Israeli naval blockade has severely limited its function and it now primarily receives fishing boats and the Palestinian naval police. Since the Oslo I Accord in 1993, a larger seaport has been planned for Gaza but has not materialized due to continued conflict between Israel and Palestine. There is no railway network in either the West Bank or Gaza, and all existing airports have been closed to civilian traffic.

The transport sector produced 2.8 million tons of CO_2 in 2014 (1.9 and 0.9 in the West Bank and Gaza, respectively), with 62.5% emitted by passenger vehicles and 35.7% by goods vehicles (PCBS 2014).

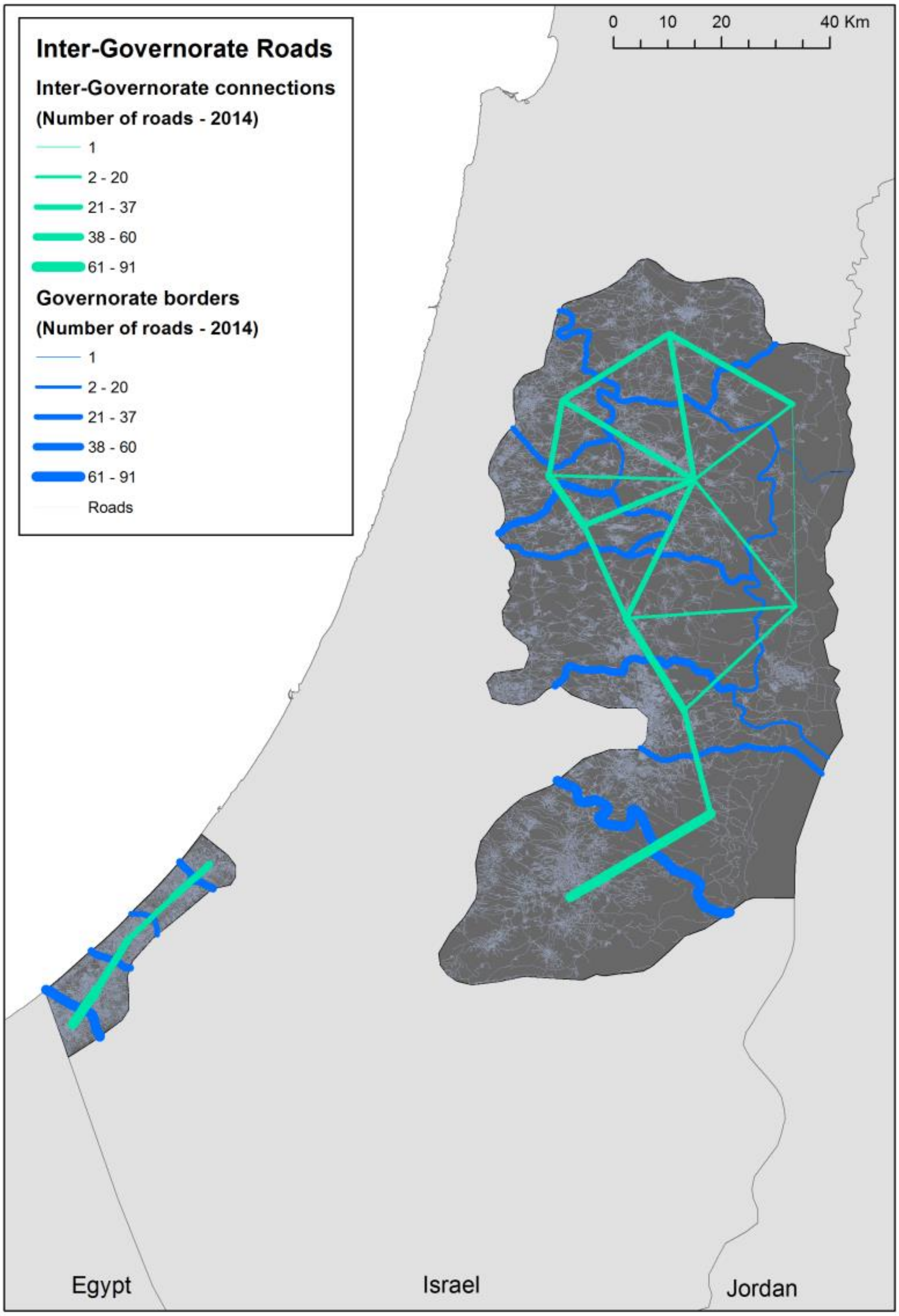

Figure 31: Palestine's inter-governorate road capacity, given as the total number of roads that cross the borders between individual sets of governorates 2014.

2.5.2 Key challenges

Palestine is subject to a strict closure and security regime from the Government of Israel. This affects transportation into and out of the Palestinian territories and within them. Palestinian producers are restricted in their access to potential markets outside Palestine, particularly from the Gaza Strip, for both work and trade (Balls and Cunliffe 2007). Transportation within Palestine faces barriers in the form of checkpoints, roadblocks, and limited-access roads that compartmentalize the West Bank, restricting the movement of people and goods and adding to commute times. The restrictions imposed by Israel on major routes affect traffic flows and result in huge transportation delays that affect the competitiveness of economic activity in Palestine (Isaac, Khalil et al. 2015). The access restrictions on several major thoroughfares, officially in place for security reasons, create somewhat of a dual infrastructure system in Palestine: while Israelis are permitted free access to high-quality roads serving Israeli settlements, Palestinians are often limited to using less-direct bypass roads, often in poorer condition. A recent report (Isaac, Khalil et al. 2015) estimates the annual cost to Palestinians of the main movement and access restrictions to be about USD$185 million per year due to extra time and mileage, identifying four major routes where Israeli restrictions are likely to affect traffic flows in the West Bank:

- Bethlehem to Ramallah (passage through Jerusalem is not permitted to West Bank residents)
- Jericho 90 (most direct route from northern West Bank to Jericho is restricted to permit-holders)
- Ramallah to Jerusalem (route through Qalandia checkpoint is not permitted to West Bank residents)
- Ramallah to Nablus (Route 60 closed by road blocks)

A summary of movement restrictions on West Bank roads, both staffed and non-staffed, is shown in Figure 32. Since the escalation of violence in October 2015, these restrictions have been tightened, with new closures directly impacting at least 850,000 Palestinians, the majority in Hebron governorate (OCHA 2016).

Transportation infrastructure in Gaza (e.g. roads, bridges) has been routinely damaged during recent conflicts with Israel. For example, the 2008-09 Gaza conflict resulted in over 220 impact craters and the damage of an estimated 167 kilometres of paved and unpaved roads (OCHA 2016).

Palestinians in oPt are severely restricted from leaving the country, particularly those in Gaza who must first be allowed to pass through Israel to leave. Also, most Palestinians must fly out of Jordanian airports and the Israeli managed border controls between oPt and Jordon mean that Palestinians must generally allow an extra day in their plans if they wish to fly to another country. Throughput at the Allenby/King Hussein border crossing into Jordan is increasingly becoming a bottleneck for trade and mobility. The crossing is currently having to process upwards of 10,000 passengers a day with long wait times and this is set to get much worse with traffic increasing by around 10% a year (Office of the Quartet 2016), with similar increases occurring in cargo movements. The crossing thus requires significantly improved facilities to cope with these traffic increases. Gaining visas to visit foreign countries can also be problematic for Palestinians further restricting their international mobility.

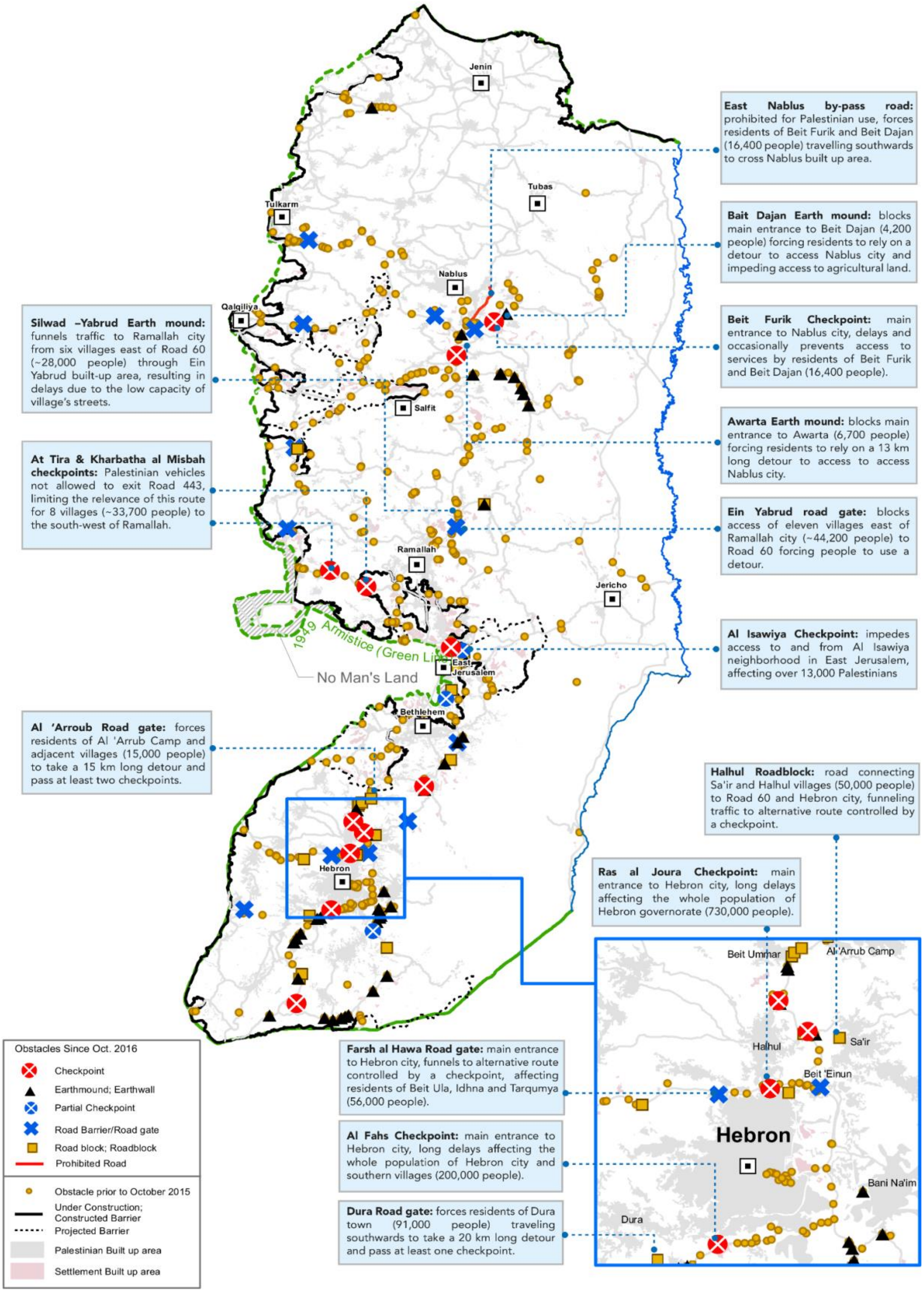

Figure 32: Movement obstacles in the West Bank with selected impacts (as of end 2015) (OCHA 2016)

2.5.3 Interdependencies with other sectors

Energy is a key component of the Palestinian transport sector, where diesel serves as the largest fuel source across Palestine (70%), the West Bank (74%), and Gaza (62%) and accounts for the most fuel spending and kilometres travelled in the sector (PCBS 2014, PCBS 2014). Regionally, total diesel consumption is concentrated in the West Bank (72%) with the remainder (28%) consumed in Gaza. For gasoline use, the same territorial breakdown is 60% to 40%, respectively.

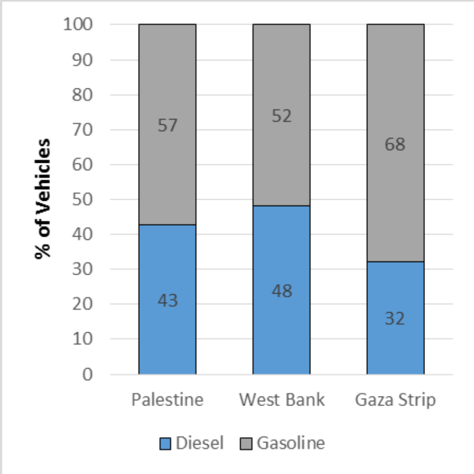

Figure 33: Registered vehicles by type of fuel, 2014 (PCBS 2014)

Diesel fuel accounted for 71% of CO_2 emissions in the transport sector in 2014 (PCBS 2014). However, only 43% of licenced road vehicles in Palestine run on diesel, with the majority (57%) using gasoline (Figure 33). This might result from the more prevalent use of diesel in large goods vehicles, while the vast majority of gasoline-powered vehicles are smaller passenger vehicles such as cars and motorcycles, although Figure 34 suggests that there has been a sudden upsurge in diesel transport since 2012 compared with previous years. However, conversations with PCBS officials have suggested the problems lie with the records of earlier years and that the more recent years of data is considered more accurate. It is these higher fuel usage levels that have been projected forward in the analysis of future energy demands in section 7 of this analysis.

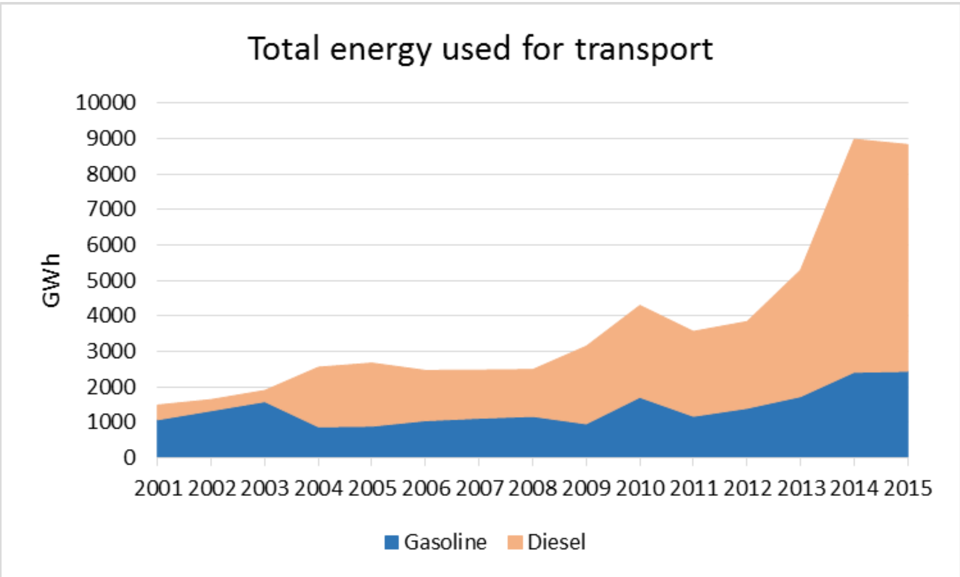

Figure 34: Energy used by transport in Palestine 2001-2015 (Source: PCBS Energy balance tables)

The transport network is also key to solid waste collection and provides an avenue by which water can be transported in times of localised shortfalls, particularly important for Gaza Strip.

2.6 Digital communications

Digital communications are a key enabling infrastructure sector that is fast-emerging in the Palestinian territories, with mobile phone, computer, and internet use increasing rapidly since the turn of the century among both individuals and businesses (PCBS 2012, PCBS 2014). However, development in this sector has stagnated in recent years due to the political situation and limitations imposed by Israel (Paltrade 2010, Office of the Quartet 2016). The removal of restrictions on Palestinian digital communications development, including on frequency allocation and the import of materials for infrastructure construction, can facilitate productivity and economic growth and bring Palestinian telecommunications standards in line with much of the rest of the world.

2.6.1 Recent situation

In 2014, 63.1% of households had access to a computer and 48.3% had access to the internet, up from 26.4% and 9.2% respectively in 2004 (PCBS 2014). Compared to other countries in the region, the Palestinian territories have a considerably high internet use rate, at about 53% of the population (Figure 35) (World Bank 2014).

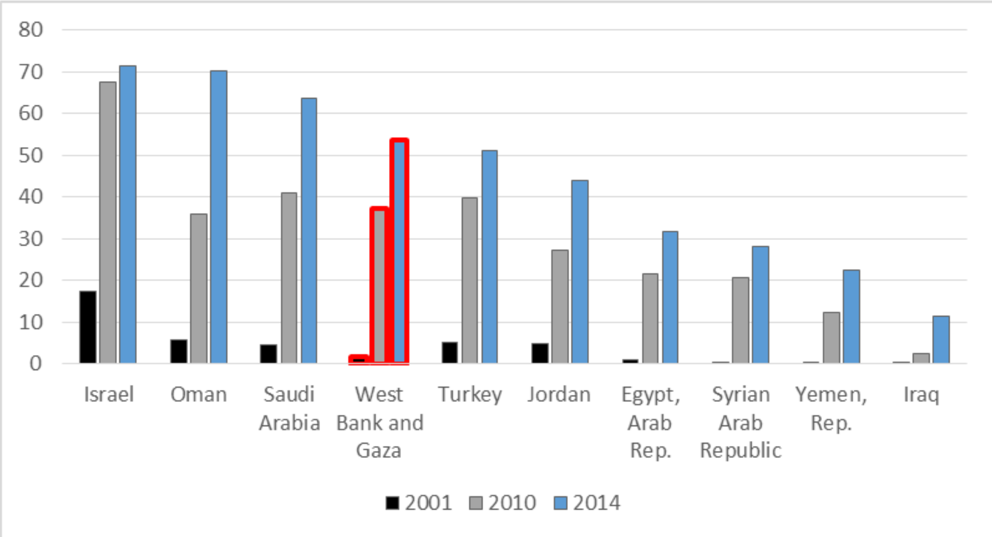

Figure 35: Internet users per 100 people (World Bank 2014)

Among businesses, 47.0% were using a computer by 2012, while 39.2% were using email (PCBS 2012). The percentage of individuals using email rose from 5.1% to 39.0% over the same period. Fixed telephone connection was 39.8% of households in 2014, down slightly from 40.8% in 2004. Conversely, mobile phone connectivity (households that own a mobile line) jumped from 72.8% to nearly universal (97.8%) take-up from 2004 to 2014 (PCBS 2014). The growth in numbers of subscribers to fixed telephone and mobile services have reflected these same trends (Figure 36) with the number of fixed telephone lines keeping pace with population while cellular phone subscriptions rose from 436,628 to 3,290,774 in the ten year period from 2004 to 2014 (PCBS 2014). Figure 37 shows the breakdown of telephone lines by subscription type.

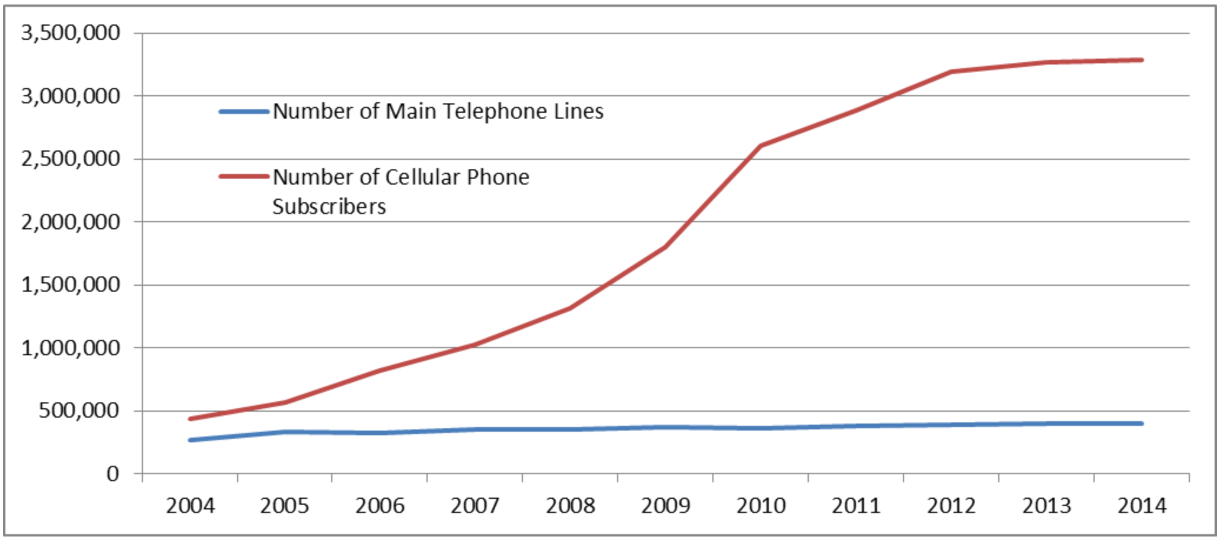

Figure 36: Number of fixed and cellular phone subscribers 2004-2014 (PCBS 2014)

The Joint Technical Committee (JTC) established by the Oslo Accords in 1995 regulates telecommunications within Palestine, with Israel given the power to decide on allocation of frequencies and infrastructure development.

Currently there are two mobile operators in the West Bank and Gaza, the Palestine Cellular Communications Company, Ltd, known as Jawwal, and the Wataniya Telecommunication, which must license their wireless spectrum from the Israeli government and route their traffic through Israel (Lichfield 2015). In 2015 Jawwal operated around 1000 towers in West Bank and 540 in Gaza Strip. The Wataniya Mobile company conversely operates around 520 towers in West Bank and 200 in Gaza Strip. Both systems are based on Global Systems for Mobile communications (GSM) technology (UNOPS, personal communication). These phone operators continue to use 2G wireless technology despite Israel having upgraded to 3G in 2006. Negotiations are underway for a switch to 3G in the West Bank, while Israel begins to move to 4G. Figure 38 and Figure 39 show 2G and 3G mobile coverage in the West Bank and Gaza, comparing coverage by Palestinian (Jawwal) and Israeli operators.

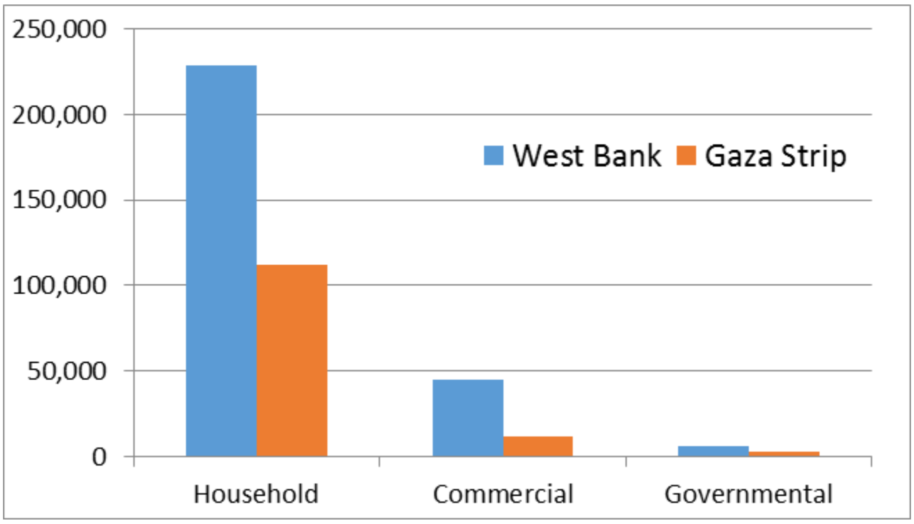

Figure 37: Number of main telephone lines in Palestine by subscription type, December 2015

a. 2G (Jawwal) **b. 3G (Jawwal)** **c. 3G (all mobile operators)**

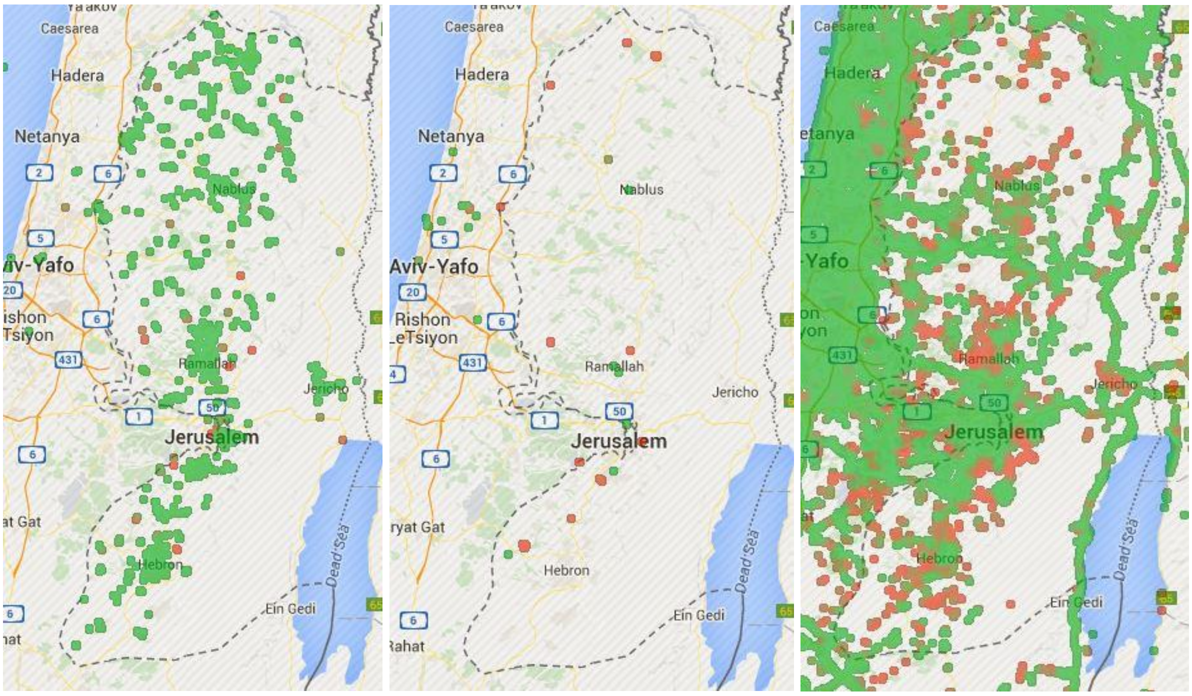

Figure 38: Mobile coverage in the West Bank as of May 2016 (Open Signal 2015)

a. 2G (Jawwal) **b. 3G (Jawwal)**

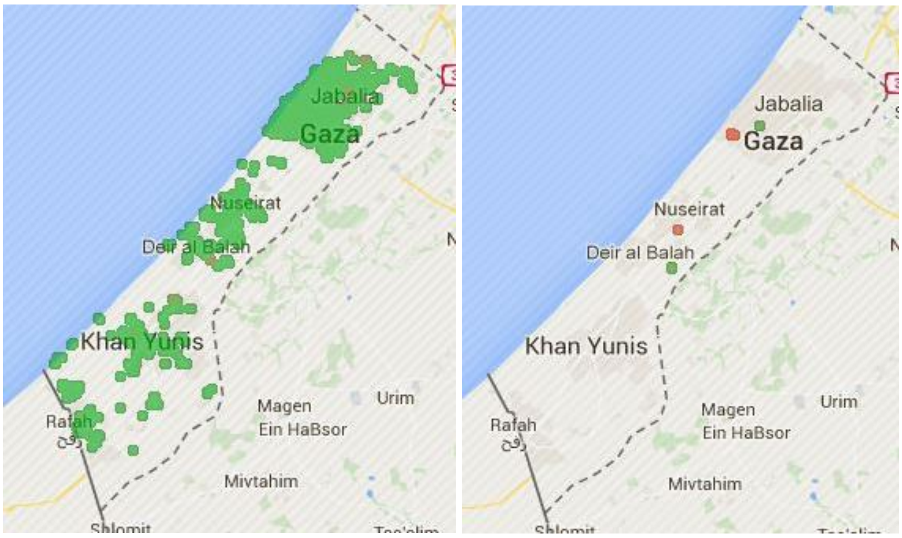

Figure 39: Mobile coverage in Gaza as of May 2016 (Open Signal 2015)

2.6.2 Key challenges

Local mobile operators rely on slow 2G technology. Surging demand for bandwidth due to increased use of social media applications will necessitate the launch of faster 3G technology. Additional spectrum is needed in the 2.1GHz range in order to implement 3G and mobile internet services, which the Government of Israel needs to release to local mobile operators along with a comprehensive telecommunications strategy for the area. Much also needs to be done to expedite entry of equipment to maintain and enhance 2G infrastructure and allow for construction of 3G networks. The Office of the Quartet (2016) suggests that such improvements should be implemented by 2017. It has been estimated that since 2013 the Palestinian mobile sector has lost between $400 million and $1.15 billion due to "years of delay in mobile broadband, the presence of unauthorized Israeli operators in the

Palestinian market, restrictions on importing equipment and absence of an independent regulator" (World Bank 2016). The implementation of 3G in the West Bank is expected to attract an additional $150 million in investment and provide around 10,000 indirect employment opportunities (Office of the Quartet 2016).

Providing wireless broadband at cost effective rates to consumers in Palestine must take into account socio-economic and political conditions in the region and will involve coordination between Israel and Palestine on development of the sector, particularly on efforts to build necessary infrastructure which are hampered by Israeli import restrictions. Regular permit request denials, particularly in Area C, has limited the reach of Palestinian operators and led to higher service fees for all customers (Isaac, Khalil et al. 2015). The JTC, composed of technical experts representing both sides as outlined in the Oslo Agreement, has failed to meet regularly since 2000, which has led to pending issues such as the release of frequencies to allow new companies into the market. While internet penetration per capita exceeds that of other post-conflict countries (e.g. Iraq and Afghanistan), there is only one service provider using copper wire connections and bandwidth is limited due to lack of investment in the broadband infrastructure (Paltrade 2010).

2.6.3 Interdependencies with other sectors

Like many other infrastructure sectors, the digital communications sector has a critical dependence on electrical power. Without a continuous supply of electricity, digital communication assets and systems (e.g. telecommunications networks) cease to function. To deal with intermittent electricity supplies, system owners may use batteries or generators to provide back-up. Such contingencies are however limited in the viable scale of deployment and are not seen as a sustainable alternative to the provision of reliable electricity grid.

Digital communications play a critical role in supporting the function of many other infrastructure types. More specifically good digital communication networks facilitate the operation of command and control systems required to efficiently operate individual infrastructure assets and interconnected infrastructure networks. This is for both 'hard' infrastructures (e.g. energy and water networks) and 'soft' infrastructures (e.g. the emergency services). As infrastructure systems become more sophisticated (both in terms of technology and interconnectivity), their dependence on digital communications infrastructure will also increase. Looking to the future, this will be important for a range of different infrastructure sectors, promoting further systems integration and efficiencies through automation and demand management solutions (e.g. the integration of intermittent renewables and storage in the energy sector and smart and autonomous systems in the transportation sector).

3 Vulnerability characterisation for interdependent infrastructure: Case study – Gaza Strip

3.1 Introduction

In subsequent sections a methodology will be presented for assessing the impact of long-term drivers of change, such as population and economic growth, on infrastructure provision and strategies for meeting future needs. In the short-term, more sporadically changes that have more immediate impacts on infrastructure planning, such as behavioural change, natural hazards and conflict require an alternative set of assessment methodologies – namely risk and resilience analysis. As an example application of such analysis this report introduces here a 'fast-track' vulnerability characterisation for interdependent infrastructure in the Gaza Strip. Here, we introduce the concepts and methods used in vulnerability characterisation, and offer insight into the vulnerability 'hotspots' in Gaza, resulting in an assessment of where new electricity infrastructure assets might best be located to reduce future risk.

This report focuses on the electricity network system within Gaza and its critical role in supporting not only direct consumers of electricity (i.e. domestic consumers), but also a range of indirect consumers from multiple critical infrastructure sectors (i.e. energy, water, waste water, health, banking and education).

The vulnerability of individual assets is characterised by calculating and comparing the potential direct and indirect disruptions that could result from their failure. The vulnerability of groups of assets is characterised by deriving geographic hotspots of critical assets and by intersecting critical assets with a historic conflict damage map and a synthetic natural hazard map.

A number of risk reduction interventions are proposed to address identified vulnerabilities. The report is concluded with the identification of next steps and future work.

3.2 Methods

Within this section of the report a set of steps is provided that defines the main components of the methodology for undertaking the vulnerability characterisation. For a detailed description of the methods see Thacker et al. (2016) and Thacker et al. (2016).

3.2.1 Data collection and systems definition

1. Collect data on the location and interconnectivity of assets within Gaza's electricity sector and classify via the following systems description:
    - In accordance with Figure 40, assets should be classified as either a source node (electricity generator), a sink node (distribution substation) or an intermediate node (intermediate substation between source and sink). Edges (overhead lines and cables) define the connectivity between nodes and are classified as intermediate in their functionality. Edges are directed to represent the direction of flow and therefore the functional dependence between assets.
2. Collect data on the location of assets within Gaza's critical infrastructure sectors that are not from the electricity sector, for example, from the energy, water, waste water, health, banking

and education sectors. Within the systems description, these are recorded as dependent nodes.

3. Collect data on the location and connectivity that defines the dependency edge that connects the dependent node and the supporting electricity sink node. These edges are also directed to represent their functional relationship.

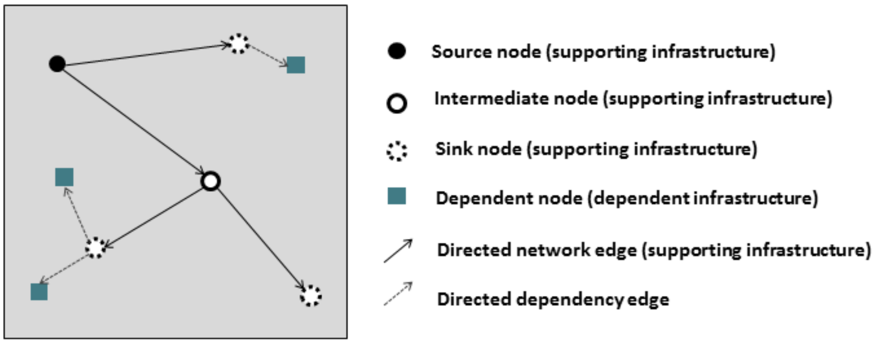

Figure 40: System description for mapping assets and interdependencies

3.2.2 Calculating the consequences of failure

4. Assign service demand attributes (number of consumers, amount of water etc.) to all assets based on the amount of service that that asset directly supports. Figure 41 shows how this can be completed for the previously introduced example system. As highlighted in the figure, service demands may in some instances be mapped geographically.
5. Following network assembly and service demand assignment (steps 1-4), the consequences of failure of individual assets are evaluated systematically for all nodes within the system. This is done by removing each node individually from the network and calculating the direct and indirect service demands that are lost as a result of the disconnection.

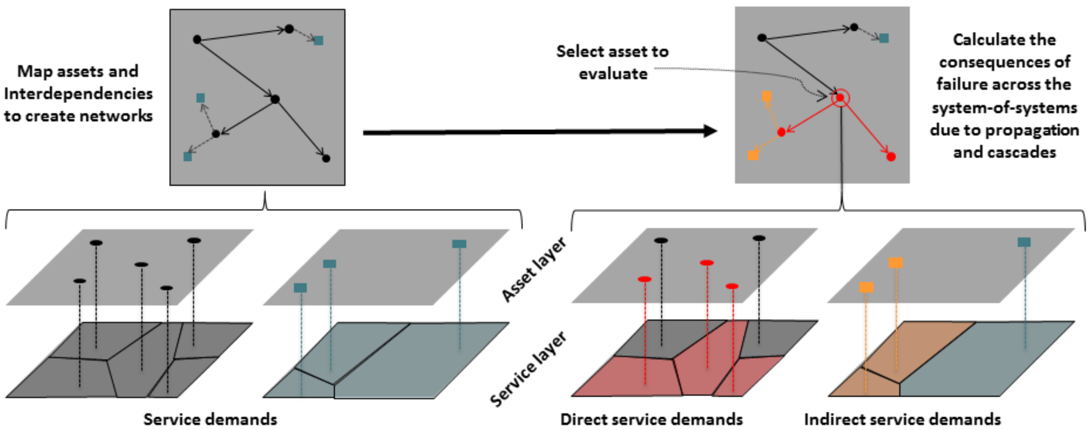

Figure 41: Framework for calculating direct and indirect failure impacts

3.2.3 Vulnerability characterisation

6. The vulnerability of oPt's infrastructure can then be evaluated at the asset level by comparing the consequences of failure of different assets. This comparison can highlight assets that are characterised as 'critical' to multiple consumers from different sectors.
7. The vulnerability of infrastructure can also be expressed above the level of individual assets – at the scale of multiple assets. One way this is achieved is by characterising the geographic

interdependence of different assets (where assets are geographic interdependent if through proximity, they can be exposed to similar environmental conditions – in this case, potential failure mechanisms). One means to characterise this is through the derivation of infrastructure hotspots, which denote geographic concentrations of critical infrastructure.

8. Identifying assets that are located within geographically bound areas where there is a well-defined failure mechanism can also highlight vulnerabilities. Examples of this would include: identifying asset/s located within previous conflict damage zones and identifying asset/s located within a known floodplain or flood prone area.

3.3 Application for Gaza

This section of the report provides details of the application of the fast-track vulnerability characterisation for Gaza. Following an initial description of the scope of the application, results from the analysis are presented. For a full description of the data used within the analysis, see (Thacker, Barr et al. 2016) and (Thacker, Pant et al. 2016).

3.3.1 Scope of application and data assembly

Table 2 gives a description of the data incorporated for Gaza; this includes the name, function and number of assets.

Table 2: Description of the datasets used in the analysis for Gaza

Sector	Function	No. of assets
Electricity	Supporting	Sources: 14 Sinks: 24 Edges: 24
Water treatment facilities	Dependent	7
Waste water treatment facilities	Dependent	3
Building	Dependent	167854
Schools	Dependent	59
Hospitals	Dependent	18
Banks	Dependent	31
Fuel sites	Dependent	28

Figure 42 shows a hierarchical representation of electricity network system in Gaza. The representation highlights the hierarchical nature of flows and therefore dependence that is established from the source asset layer (generation and interconnector assets) through lines to the sink asset layer (distribution substations). An example of dependence is shown on the figure by connecting buildings, through a dependency edge, to their supporting electricity distribution substation.

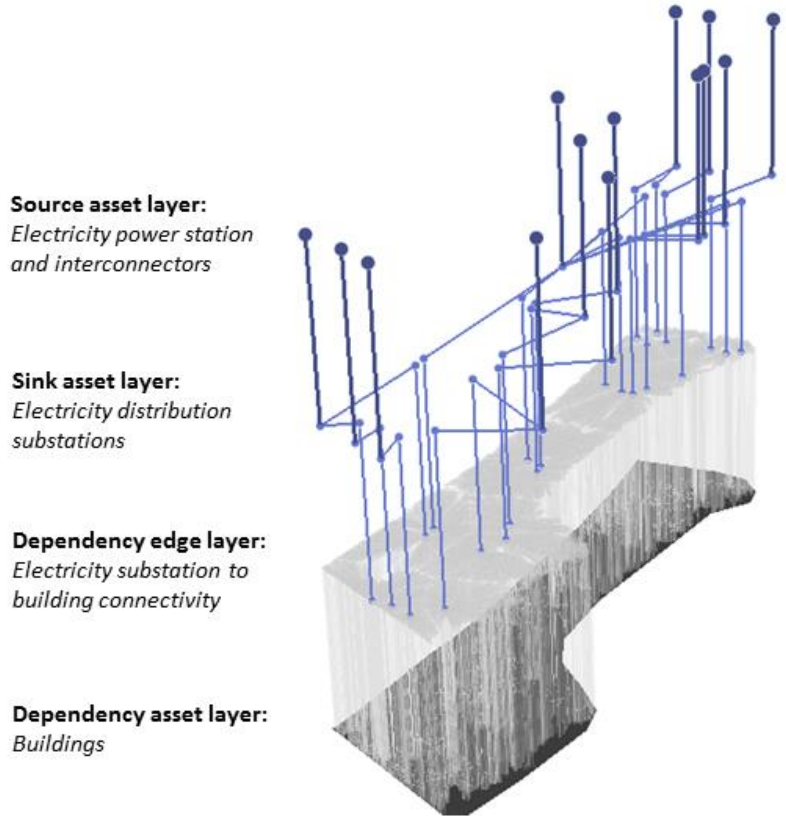

Figure 42: The electricity network hierarchy and dependent building assets for Gaza

Figure 43 maps the entire infrastructure asset data used within the study and shows the number of assets in the corresponding legend item. The figure highlights the dependency links that are established between the supporting and dependent infrastructure. In the absence of real data on the nature and location of these dependencies, an edge has been created between the dependent asset and its geographically closest supporting asset (electricity sink). This is based on the assumption that dependent assets will be connected to its closest possible supporting asset – this assumption is based on the fact that during installation the costs associated with installation, operation and maintenance would be sought to be minimized.

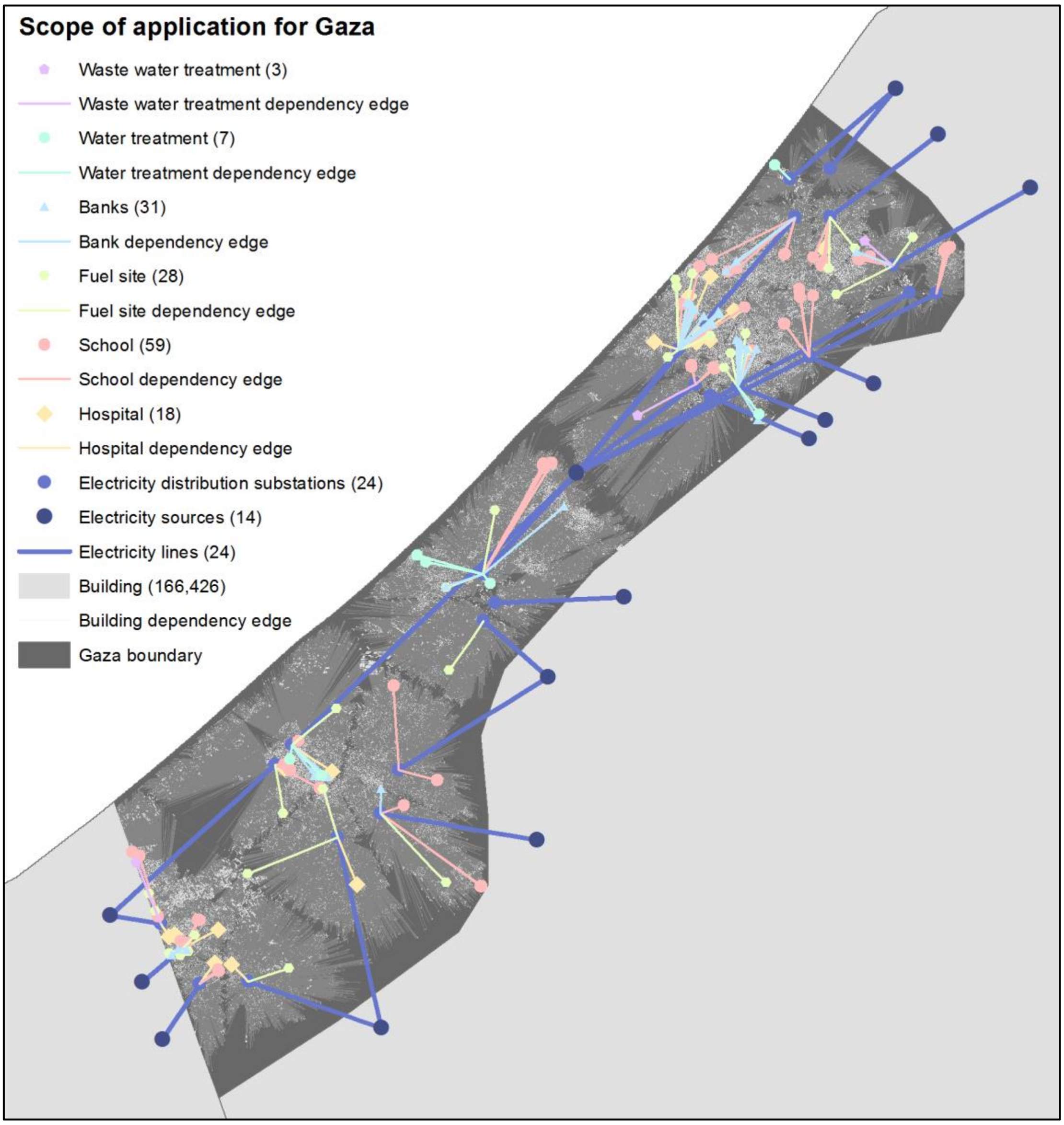

Figure 43: Scope of the application for Gaza, showing the electricity network and a range of dependent assets from the energy, water treatment, waste water treatment, health, banking and education sectors. The number of assets of each type is indicated in the figure legend

3.3.2 Direct and indirect failure impacts

Figure 44 highlights the magnitude of potential disruptions (across multiple sectors) that can occur due to the failure of the 24 individual electricity distribution substation assets within Gaza. Of these sink as substations assets, those with [ID's: 18, 22, 15 and 12] are shown to have relatively minor potential disruptions associated with their failure. The analysis shows that the range of impacts for all sectors is heterogeneously distributed across assets. A number of substations can be seen to particularly important for the provision of different sectors, for example, substations [ID's: 23, 16, 10 and 13] are particularly important for the water treatment sector and substations [ID's 14, 20 and 5] are particularly important for waste water treatment sector. Substation [ID: 25] shows very large potential impacts across multiple sectors and can be classified as highly critical.

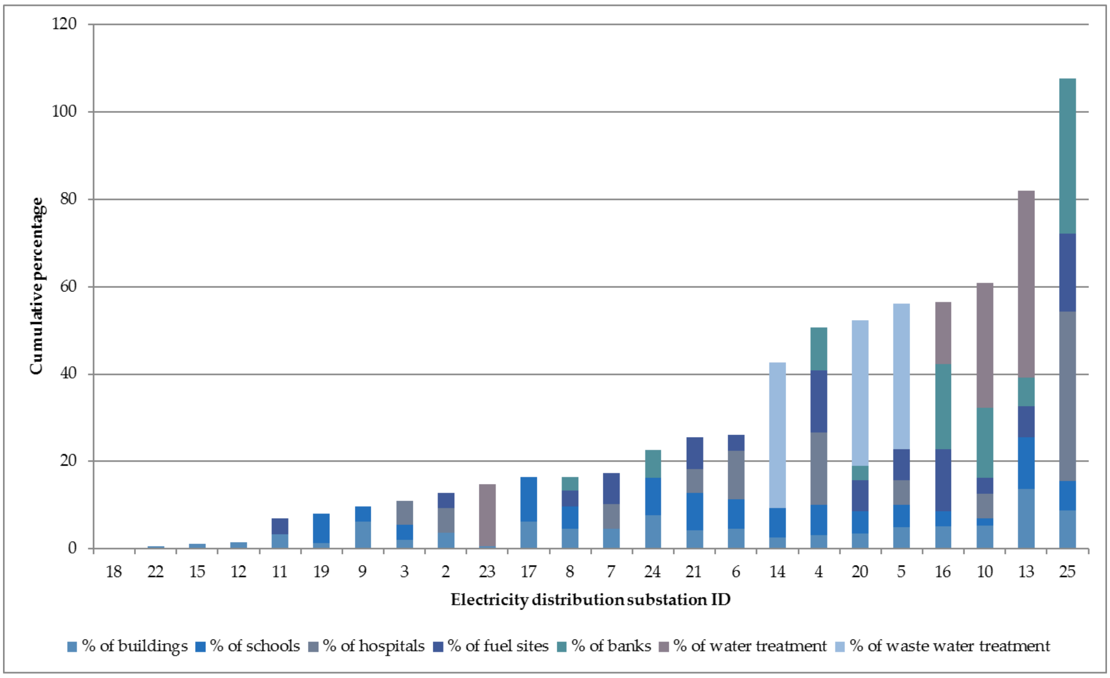

Figure 44: Vulnerability plot showing the magnitude of direct and indirect failure consequences for electricity distribution substation assets (sink assets)

Figure 45 highlights the magnitude of potential disruptions (across multiple sectors) that can occur due to the failure of the 14 individual electricity sources: these include Gaza power station [ID: 1] and 13 interconnector substations located within Israel and Egypt. The figure shows that interconnectors [ID: 36 and 34] have very small associated direct and indirect failure consequences. Conversely, asset [ID: 1] (Gaza power station) shows very large potential disruptions across multiple sectors. Other interconnector assets show an intermediate range of consequences associated with their failure. Like the electricity sink assets shown in Figure 5, the range of disruptions across sectors for source nodes is also heterogeneously distributed. The figures show the hierarchical nature of the electricity system and how the consequences of failure aggregate from sink nodes, up the hierarchy across dependencies to source nodes.

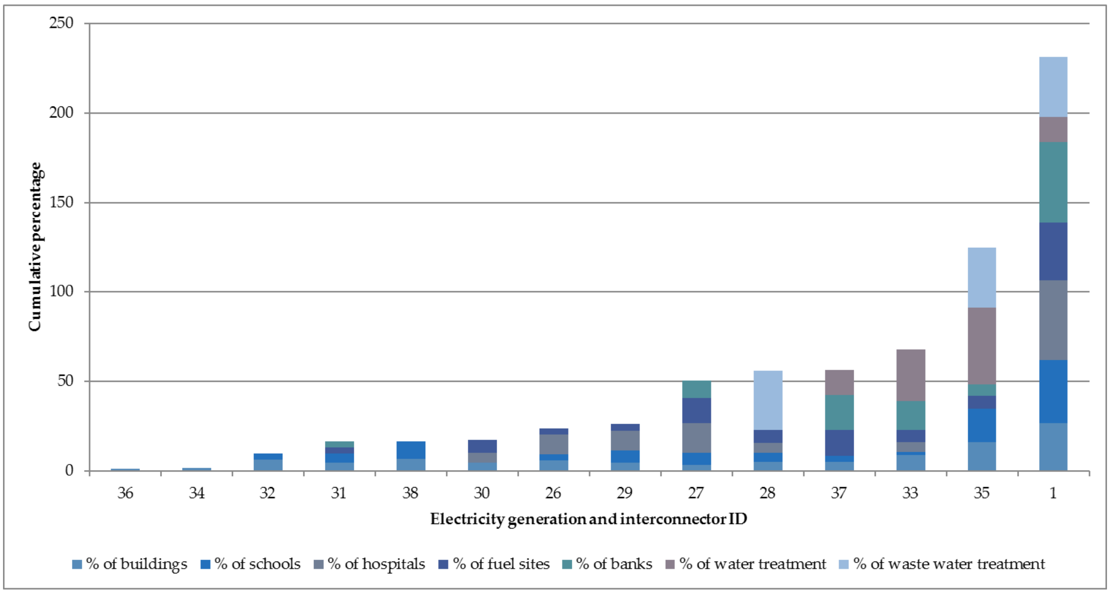

Figure 45: Vulnerability plot showing the magnitude of direct and indirect failure consequences for electricity power stations and interconnector substations (source assets)

3.3.3 Spatial vulnerability characterisation

Figure 46 shows kernel density hotspot maps for the infrastructures previously introduced in this report. The plots highlight geographic concentrations of the different infrastructures and provide a means to compare the spatial distribution of assets from multiple sectors. The plots highlight the wide range of densities and heterogeneity in spatial distribution. Despite this, clear centres of density intuitively correlate to the most urbanised areas; this is most clearly demonstrated for the buildings density plot. The figure highlights that despite there being three distribution substations in the centre of Gaza; there is very little other critical infrastructure in this area. Conversely, there is no substation located centrally to Gaza city, though there are multiple other critical infrastructures located there.

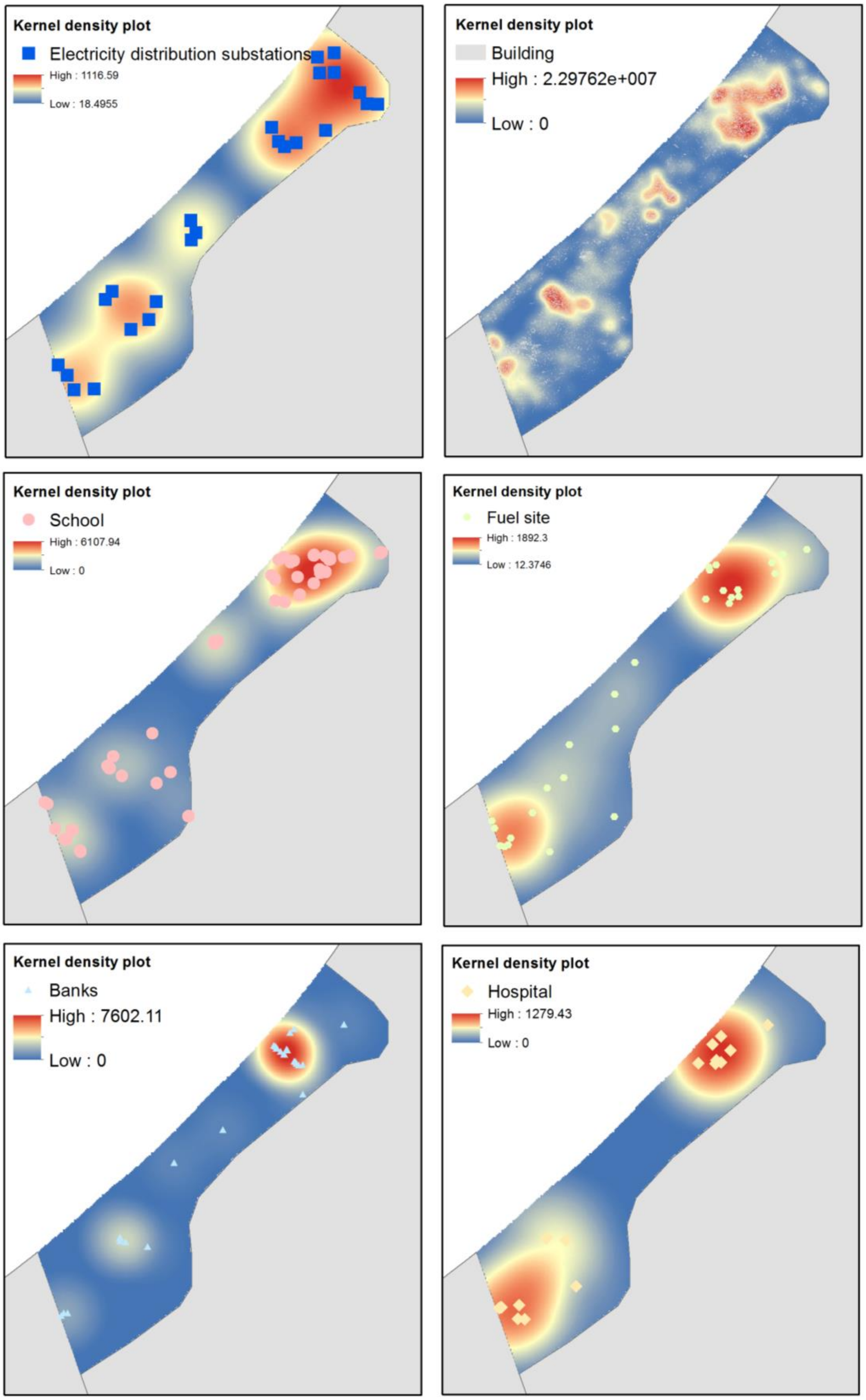

Figure 46: Kernel density plots showing relative geographic concentrations of critical infrastructure (classification of geographic co-location and interdependence)

Figure 47 shows a kernel density plot highlighting the damage hotspots sustained during the 2014 conflict in Gaza. Damage estimates are taken from the UN's UNOSAT data derived from Pleiades satellite. The map shows that hotspots are typically found along the north-east to south-east of Gaza and are typically away from urban centres. Though a number of substations are located within high-damage zones, a number of critical substations are not.

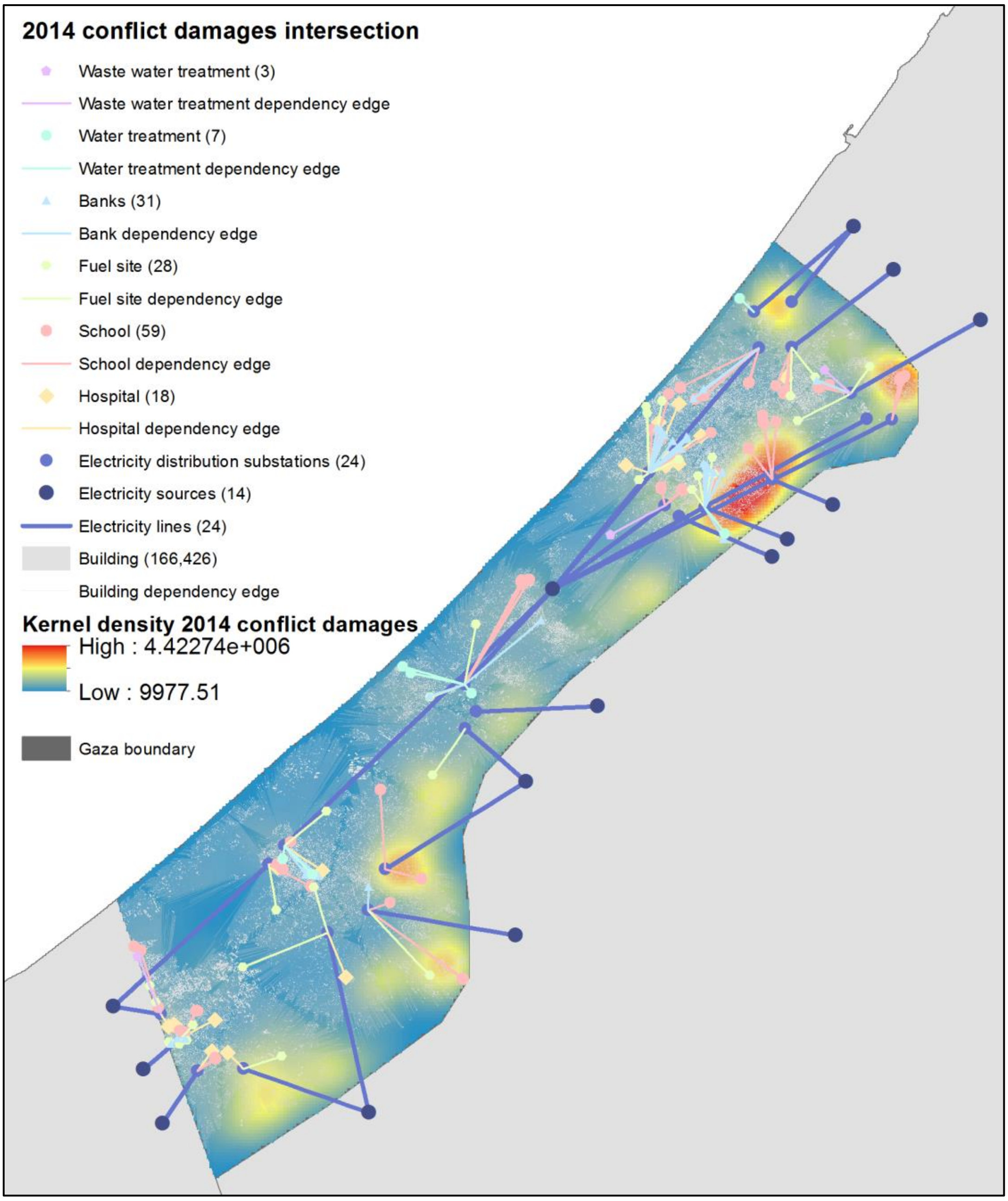

Figure 47: Kernel density map derived from satellite imagery representing damages sustained during the 2014 conflict in Gaza

Figure 48 highlights the infrastructure located within a synthetic flood inundation map. In the absence of real data, this synthetic flood map has been developed to represent three levels of flood likelihood – these levels correspond to elevation values extracted from a digital elevation map (DEM) of the region. Electricity substations [ID's: 13, 21 and 23] are located in the low likelihood flood zones and electricity source [ID: 1] is located in the significant likelihood flood zone of the synthetic flood map. Although substations [ID: 23 and 21] have relatively modest impacts associated with their failure, substation [ID: 13] has the second largest impacts of all distribution substations in Gaza. The direct and indirect consequences of flood-related failure of Gaza power station [ID: 1], are the greatest of any electricity asset in Gaza.

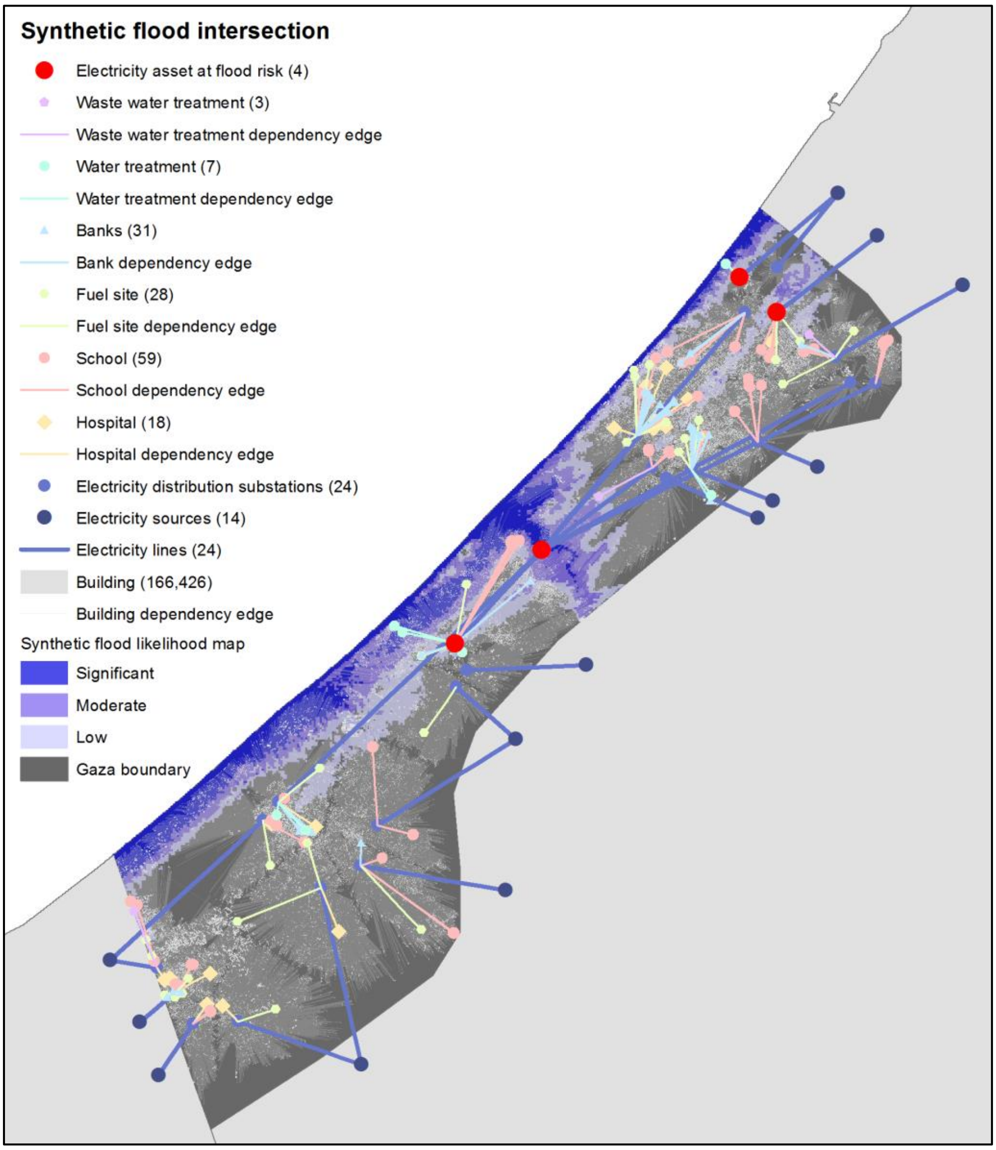

Figure 48: Synthetic flood inundation map for Gaza derived using a DEM for three likelihood bands: significant, moderate and low

3.3.4 Risk reduction interventions

Electricity is central to the functioning of multiple infrastructure sectors within the Gaza Strip. A small number of electricity distribution substations play a disproportionately large role in supporting large numbers of consumers from multiple sectors. A number of substations also play a relatively small role in supporting consumers from multiple sectors. The impacts of failure aggregate up layers of the electricity hierarchy from sink to source nodes.

Mapping assets and their associated density hotspots highlights the spatial heterogeneity of Gaza's infrastructure provision. Due this, the location of dependent assets does not necessarily correlate with the location of electricity assets - this is most noticeable in the centre of Gaza and in Gaza city.

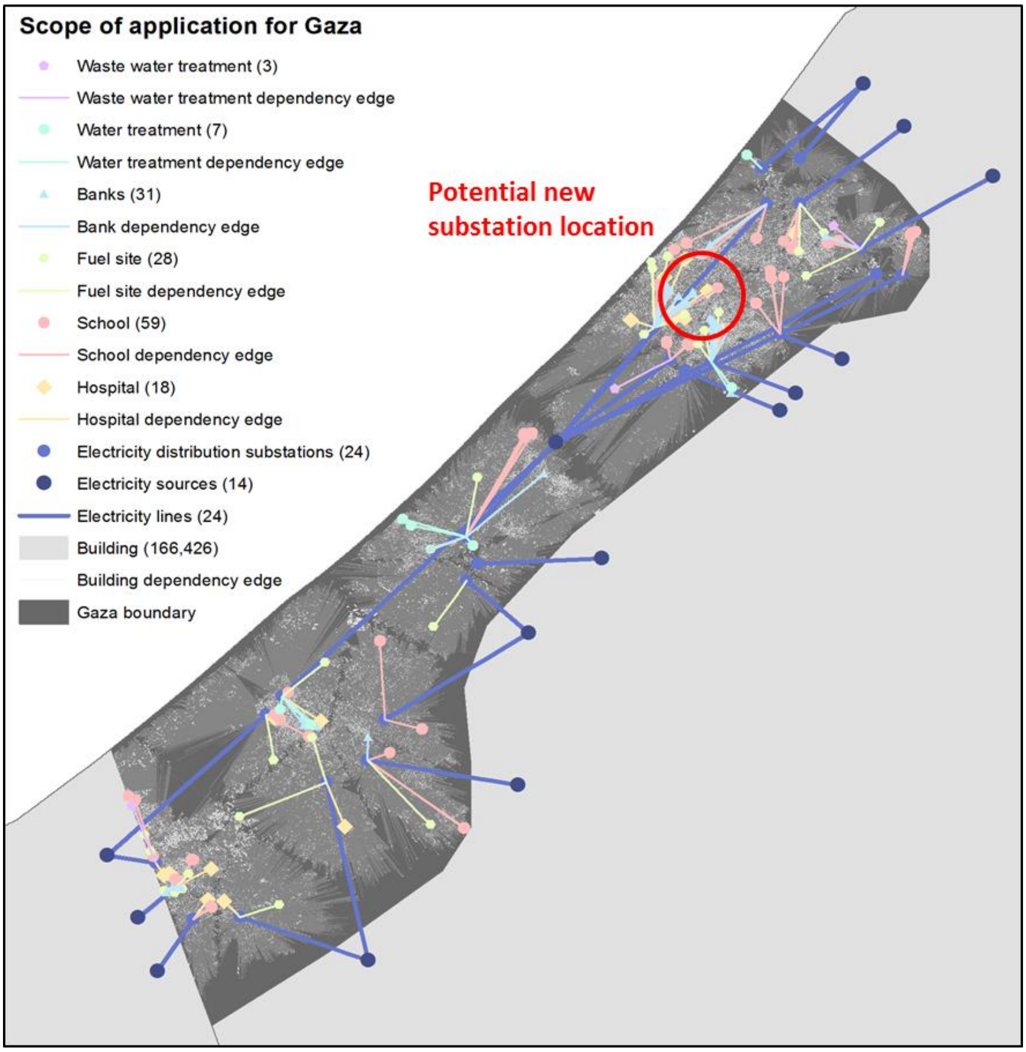

Figure 49: Map highlighting the potential location for a new electricity substation in Gaza city that would distribute the failure risks that currently emerge through the dependencies placed on substations located within the area. The location is also guided through knowledge derived from hazard and previous damage maps

Intersection with a synthetic flood likelihood map has shown three electricity distribution substations and one electricity source to be at risk of flood related failure. The failure of sink asset [ID: 13] and source asset [ID: 1] could result in large magnitude failures and as such, adequate provision should be assigned to protect against this failure mechanism in these locations.

Intersection with the 2014 conflict damage kernel density map shows that although a number of substations are located within high damage areas, a selection of critical substations are not. Locating new assets within areas which have not previously been damaged (or have suffered relatively less damage) may provide an option for reducing expected future failures. One area for consideration may be the centre of Gaza city.

Locating new supply infrastructure such as substations and associated sources or interconnectors within areas of high density demand (for example in Gaza city) can help to alleviate the disproportionate failure consequences associated with highly critical assets in that area. Figure 49 shows a candidate location for a new electricity substation in Gaza city that could help reduce risks that manifest through these mechanisms.

Although locating new assets such as substations is a complex task, locating them close to demand centres from multiple-sectors is not only beneficial to reduce installation costs, but also reduces losses (which are particularly high in Palestine systems) and also reduce the likelihood of failures that can occur due to electricity line failures (i.e. a greater cable length means a greater probability of failure due to increased risk of breakage due to natural or man-made events).

In addition to adding new substations, additional edges between different substations and substation and generation facilities and interconnectors can help build resilience by ensuring that, in the event of single asset failures, alternative supply options are available to maintain service delivery.

Distributed generation such as solar power installed on building roof tops can provide an alternative source of generation that not only supplements the overall generation portfolio, but is low carbon and is located geographically close to where demand is generated. The decentralised nature of this provision means that localised failures are likely to only have localised low-magnitude impacts.

Though in some instances back-up electricity generation may be available to provide support for assets, connection to a reliable grid infrastructure provides a more sustainable long-term alternative to support essential services and maintain social and economic wellbeing.

3.4 Future vulnerability work

Future work planned within ITRC's NISMOD-International programme will expand this definition of vulnerability to incorporate additional interdependencies and additional critical infrastructure types. Existing data will be checked and supplemented to ensure its validity.

Infrastructure risk will then be calculated by incorporating probabilistic information on the likelihood of asset failure. Finally, further options will be presented and explored to address vulnerabilities and reduce risks for the purpose of building systems-level resilience.

Sector	Type	Number	Source
Electricity	Network	1 source 24 sinks	Georeferenced from UN OCHA map
Water treatment facilities	Point assets	7	Georeferenced from UN OCHA map
Waste water treatment facilities	Point assets	3	Georeferenced from UN OCHA map
Building	Polygon	167854	Open street map: tag 'building'
Schools	Point assets	59	Open street map: tag 'school'
Hospitals	Point assets	18	Open street map: tag 'hospital'
Banks	Point assets	31	Open street map: tag 'bank'
Fuel sites	Point assets	28	Open street map: tag 'fuel site'
2014 conflict damages map	Polygon	-	Derived using kernel density analysis of UNOSAT data
Synthetic flood likelihood map	Polygon	-	Derived using kernel density analysis of an underlying regional DEM

4 Drivers of change

Infrastructure systems in Palestine must cope with the implications of long-term and highly uncertain future changes in population, the economy, society and the environment. Demographic trends are particularly important to development and planning in Palestine given the territories' limited natural resources and political options (PCBS 2015), while there are huge uncertainties concerning future economic growth in the region due to the ongoing political tension between Israel and the Palestinians.

Future investments in infrastructure will be challenged by a number of fundamental long-term trends including demographic developments (e.g. migration, ageing, and urbanisation), increasing constraints on public finances, environmental factors (e.g. climate change), technological progress (especially in the area of information and communication technology), trends in governance (particularly Israeli occupation), an expanding role for locally financed private sector as well as external donor aid, and an increasing need to maintain and upgrade existing infrastructures, or to rebuild where infrastructure has been damaged or destroyed as a result of conflict.

This section of the report provides an overview of these key drivers of demand for infrastructure services in Palestine. As identified in previous ITRC work (Hall, Henriques et al. 2012), the three major drivers of long-term change (demographic change, energy prices and economic growth) will be included in the development of scenarios of change to be used throughout this assessment (Section 3), while the short-term drivers of change (natural hazards and human conflict) dealt with through the use of vulnerability assessment (Section 6).

4.1 Demography

Trends of demographic change, particularly population growth, migration, and urbanisation, will pose challenges to infrastructure provision and affect infrastructure demand in the coming decades.

4.1.1 Population change

Demand for infrastructure services is highly correlated with population, and in Palestine, future demands are expected to be highly affected by demographic pressures caused by rapid population growth in both the West Bank and Gaza Strip. The population of Palestine has nearly doubled over the past two decades, rising from 2.7 million in 1997 to 4.8 million in 2016 (PCBS 2016), with a growth rate of nearly 3% in 2015, outpacing most of its regional counterparts (World Bank 2014). Table 3 presents the population for each of the sixteen Palestinian governorates over the last ten years, with the average annual growth rates over these years shown in the final column. Such growth is expected to remain stable due to a declining mortality rate and a high (though slowed) fertility rate (PCBS 2015). The 2016 populations are presented geographically in Figure 50. Significant uncertainty surrounds the possibility of the return of large portions of the estimated 6 million Palestinian diaspora currently living outside Palestine should conditions become favourable for them to return (Poppert 2017).

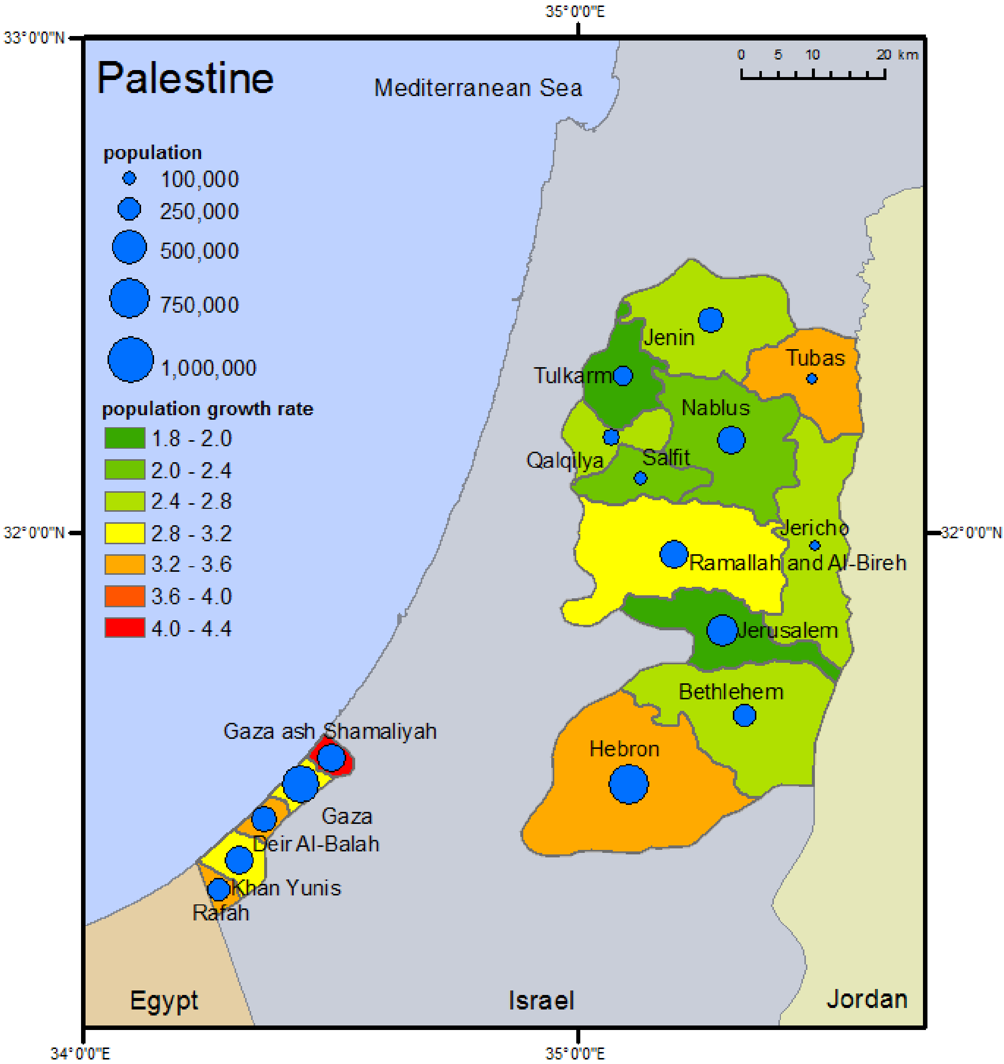

Figure 50: 2015 Population and growth rate (%) of the occupied Palestinian territories by governorate (PCBS 2016)

In 2016 the Palestinian population was split between the West Bank (61 percent) and Gaza (39 percent), although growth in Gaza has been slightly higher than West Bank (3.4% per annum on average between 2007 and 2016, compared with 2.6%). In both cases the age distribution is displayed as an expansive pyramid with a pronounced youth bulge (Figure 51), with roughly half of the population under the age of 20 (54.1 percent in Gaza and 48.0 percent in the West Bank) and nearly 40 percent younger than 15 years old. Although obviously symptomatic of the difficult social environment, such a population age profile contrasts starkly with that of developing countries which labour under the weight of an aging population that may not be well supported by the earning (and taxation generating) capacity of younger generations.

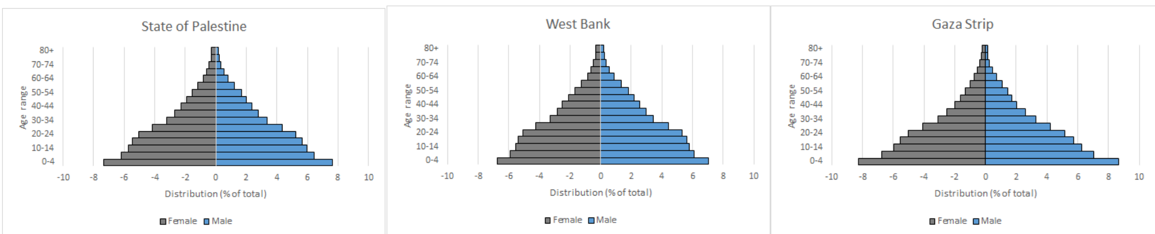

Figure 51: Population pyramids for Palestine, West Bank and Gaza in 2016 (PCBS 2015)

Table 3: Population figures for each of the sixteen Palestinian governorates 2007-2016 (PCBS 2016)

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	% change
Palestinian Territory	**3,719,189**	**3,825,512**	**3,935,249**	**4,048,403**	**4,168,860**	**4,293,313**	**4,420,549**	**4,550,368**	**4,682,467**	**4,816,503**	2.9%
West Bank	**2,323,469**	**2,385,180**	**2,448,433**	**2,513,283**	**2,580,168**	**2,649,020**	**2,719,112**	**2,790,331**	**2,862,485**	**2,935,368**	2.6%
Jenin	253,558	260,216	267,027	274,001	281,156	288,511	295,985	303,565	311,231	318,958	2.6%
Tubas	49,489	51,192	52,950	54,765	56,642	58,586	60,582	62,627	64,719	66,854	3.4%
Tulkarm	156,566	159,594	162,668	165,791	168,973	172,224	175,494	178,774	182,053	185,314	1.9%
Nablus	317,391	324,816	332,389	340,117	348,023	356,129	364,333	372,621	380,961	389,329	2.3%
Qalqiliya	90,120	92,506	94,947	97,447	100,012	102,649	105,330	108,049	110,800	113,574	2.6%
Salfit	58,932	60,309	61,714	63,148	64,615	66,119	67,641	69,179	70,727	72,279	2.3%
Ramallah & Al-Bireh	275,981	284,195	292,629	301,296	310,218	319,418	328,811	338,383	348,110	357,969	3.0%
Jericho & Al Aghwar	41,776	42,964	44,183	45,433	46,718	48,041	49,390	50,762	52,154	53,562	2.8%
Jerusalem	361,743	368,394	375,167	382,041	389,298	396,710	404,165	411,640	419,108	426,533	1.8%
Bethlehem	174,022	178,853	183,804	188,880	194,095	199,463	204,929	210,484	216,114	221,802	2.8%
Hebron	543,891	562,141	580,955	600,364	620,418	641,170	662,452	684,247	706,508	729,194	3.3%
Gaza Strip	**1,395,720**	**1,440,332**	**1,486,816**	**1,535,120**	**1,588,692**	**1,644,293**	**1,701,437**	**1,760,037**	**1,819,982**	**1,881,135**	3.4%
North Gaza	265,594	275,687	286,246	297,269	309,434	322,126	335,253	348,808	362,772	377,126	4.0%
Gaza	489,642	504,047	519,027	534,558	551,833	569,715	588,033	606,749	625,824	645,204	3.1%
Deir Al-Balah	202,493	209,014	215,808	222,866	230,689	238,807	247,150	255,705	264,455	273,381	3.4%
Khan Yunis	267,294	275,134	283,286	291,737	301,138	310,868	320,835	331,017	341,393	351,934	3.1%
Rafah	170,697	176,450	182,449	188,690	195,598	202,777	210,166	217,758	225,538	233,490	3.5%

The Palestinian Central Bureau of Statistics (PCBS 2015) has formulated a single baseline central projection of the Palestinian population (Figure 57) within the State of Palestine to 2020 based on the following assumptions:

- The decline of the total fertility rate by 30% during 2007-2025 in the West Bank and Gaza Strip.
- Decline of infant mortality rates by 50% during 2007-2025 in both the West Bank and Gaza Strip.
- The presumption of net international immigration equal to zero from 2007 to the end of the projection period in 2025.

For the purposes of this FTA we will adapt and extend this projection to 2050, and also develop low and high population growth projections for Gaza and West Bank, based on this baseline scenario but with alternative annual increases, based on the lowest and highest growth rates from the Palestinian governorates within each of the regions (Table 3). These population projections are described further in Section 4.

4.1.2 Population density and urbanisation

As can be seen in Figure 50, Gaza has a much higher population density than the West Bank. Population growth rates vary across the governorates and are not necessarily tied to population size. Population density is an increasing issue, since population is expected to increase, particularly in the Gaza Strip given that it is already one of the most densely populated areas on earth, and has had its effective land availability heavily reduced by conflict. The population density in Gaza is already among the highest in the region, with around 4,000 people per km^2.

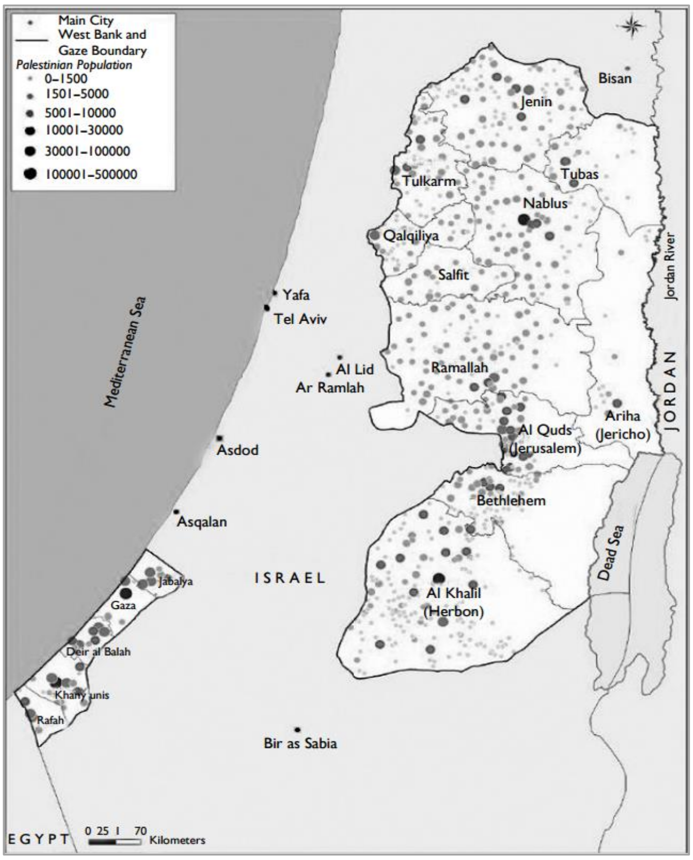

Figure 52: Detailed representation of Palestinian population density. Source: (Helu 2012)

Increased urbanisation is a global reality, with the increased numbers of world's population now living within an urban environment. Urbanisation can enable efficiencies in the delivery of infrastructure services but can also increase the risk of infrastructure failure without adequate planning (Helu 2012, UN Habitat 2016).

In the West Bank approximately 70% of the population live in urban areas, mostly in Bethlehem Hebron, Jerusalem, Nablus, and Ramallah (Figure 52). In Gaza it is around 80% of the population with few alternative options available. The rate of urbanisation in Palestine is around 3.3%, with approximately 9.4% of Palestinian's urban population living in refugee camps (UN Habitat 2016).

4.2 Economy

Gross domestic product has only risen modestly in real terms in Palestine over the last five years, with growth rates at 3.5 percent (total) and 0.5 percent (per capita) in 2015 (Figure 53). The largest contributors to GDP growth were services and construction, which was linked to a drop in unemployment from 27.5 to 26.6 percent (PCBS 2015). Investment in plant and machinery in the West Bank and Gaza as a proportion of GDP has fallen from 12.9% in 2000 to 4.8% in 2014 with the current annual level of underinvestment in plant and machinery estimated at around $1.4 billion a year (Office of the Quartet 2016).

Possibly the most significant source of uncertainty for economic growth in the region is the political tension between Israel and the Palestinians (IMF 2016). This factor features prominently in the three alternative short-term economic growth scenarios provided by The Palestinian Central Bureau of Statistics, which are based on a range of social, political and economic circumstances including factors relating to world energy prices, foreign aid, Israeli security and military measures, the Gaza blockade, and numbers of Palestinian workers in Israel (PCBS 2015). The three scenarios describe a continuation of current trends, together with optimistic and pessimistic future developments, and are described more fully in Section 4.

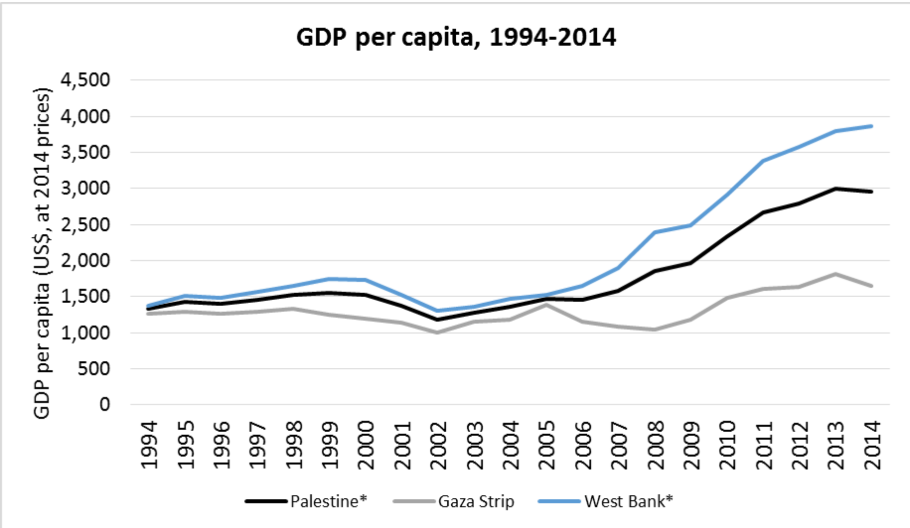

Figure 53: Gross domestic product per capita, by region, 1994-2014 (US$, 2014 prices)
*** data excludes those parts of Jerusalem which were annexed by Israel in 1967**

4.3 Energy prices

The cost of electricity in oPt is high compared with other Middle Eastern countries, particularly Israel (Salem, Hilal et al. 2007). Energy costs for industrial and commercial purposes are higher than for domestic use; according to the JDEC's tariff of 2007, the electricity cost for domestic use is about 14 US cents/kWh, while it is about 18 US cents/kWh for industrial and commercial uses (Brauch, Oswald-Spring et al. 2011). Fuel imports are a source of significant fiscal revenue to the PA as a result of the use of the Israeli excise structure in combination with a value-added tax (UNISPAL 2007). Excise taxes on gasoline are highest (Table 4), while kerosene and diesel, used primarily for vehicles and the Gaza Power Plant (heavily damaged in the 2014 conflict) are taxed at a lower rate.

Table 4: Structure of fuel excises, as of January 1, 2007 (UNISPAL 2007)

	NIS/1000 litre	US$/US gallon
Gasoline	2,246	1.90
Kerosene	1,331	1.12
Diesel (Gasoil)	1,331	1.12
Fuel oil (per tonne)	13	0.01
LPG (per tonne)	100	0.08

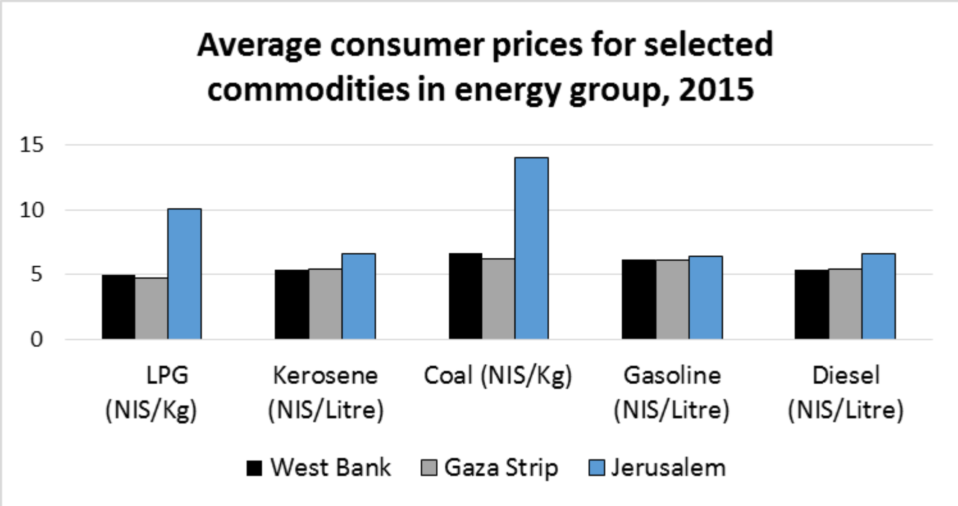

Figure 54: Average consumer prices for selected commodities in energy group, 2015. Source: PCBS

For the purposes of this FTA we will adopt the low, central and high global energy prices used in the ITRC analysis of the UK (Hall, Tran et al. 2016) using updated 2015 world energy prices (DECC 2015), adjusted to incorporate these premiums associated with importing energy into Palestine.

4.4 Technology

One of the most difficult drivers of demand to assess will be technological change. However, the precise impacts of technological advances on infrastructure demand and provision in Palestine cannot be given with a high degree of certainty, though they are expected to be significant. Technological change could lead to:

- greater *efficiency* in infrastructure provision (e.g. energy production), making certain technologies more feasible to produce on a large scale;
- reduced *costs* of production make certain technologies more affordable and widely-used (as has been the case with solar PV production);
- enhanced *resilience* of infrastructure systems as greater connectivity reduces single points of failure and enables faster rebounds from external shocks; and
- increased *risk of failure* of infrastructure systems as this greater connectivity between systems implies more risk of cascading failures and a higher reliance on information systems, creating an additional risk through cyber threats.

It is possible that the higher energy prices experienced by Palestinians, resulting from both exogenous market drivers and high Israeli tariffs, could serve to drive innovation and the development of alternate energy technologies (as was the case in Cuba during its economic embargo in the 1990s). This has been demonstrated through the opening of new decentralised solar PV generating plants, which have reduced dependence on Israeli energy imports in some regions.

As in other post-disaster and post-conflict environments Palestine also has the potential to leapfrog to more efficient technologies and more resilient infrastructure systems through infrastructure investment based on 'build back better' principles (World Economic Forum 2014).

Different impacts of technologies on infrastructure use and provision are embedded within the different strategies developed for this assessment, and further details are given in Sections 5 and 6.

4.5 Climate change

Palestine is located in a transitional climatic zone between the Mediterranean and arid tropical regions, with temperature patterns differing across its three distinct climate zones: coastal (hot and humid during summer, mild in winter); hilly (cold winter, mild summer); and Jordan Valley (hot and dry in summer, warm and humid in winter) (PEA 2016). Along with much of the rest of the Middle East and North Africa, climate change is projected to have major impacts in Palestine, leading to an overall decrease in average rainfall, warmer temperatures, and increased frequency of drought. Due to rapid population growth, urbanisation, and limited agricultural productivity, the region is already one of the most vulnerable in the world (Elasha 2010). According to the IPCC (IPCC 2013.), temperatures in the region are estimated to increase by 3 to 5 degrees over the next century, with water runoff dropping 20 to 30 percent by 2050.

Given the severe water scarcity present in Palestine, climate change is likely to have adverse consequences for water provision in the West Bank and Gaza, which may increase tensions between the Palestinian territories and its neighbours. Besides water provision, other infrastructure systems will face increased stress as a result of warmer and dryer climate conditions. For example, the failure of rural livelihoods as a result of desertification and changing rainfall patterns could drive rapid migration to cities, putting pressure on urban infrastructure. Increased heat can also increase costs of maintaining metals-based infrastructure, power generators and data centres which rely on cooling to maintain function. Increased frequency and intensity of storm events, already a major source of damages in Palestine (Table 8) can increase costs of maintaining the electricity networks, roads and buildings.

4.6 Behaviour

Decision-makers must take into account the results of exogenous behavioural change, including demographic and migration decisions, over which they have little control. Similarly, changing technology will affect lifestyle decisions as new developments (e.g. water reuse, new energy sources) reduce constraints on water and energy infrastructure. Instruments intended to influence infrastructure service demand may prove less effective in areas where incentives are lower or non-existent. For example, collection rates on electricity payments in Gaza are rarely above 40 percent and can drop as low as 10 percent (World Bank 2014).

As with technology, behaviour change in this assessment is embedded within some of the strategies for infrastructure use and provision set out in Section 5.

4.7 Conflict/security

Infrastructure may facilitate or hamper security: limits to road access may pose mobility and security risks in disaster or conflict situations or a loss of energy infrastructure services may limit security and emergency operations (hospitals, police, jails, court houses, etc.). Resilience in infrastructure systems speaks to the ability to overcome system fragility and instability including both how vulnerable a system is to shock or hazard and how well they can recover from a shock.

Conflicts between Israel and Gaza in 2008-09, 2012, and 2014 have inflicted major losses on a variety of infrastructure systems including roads, bridges, sewage treatment and power plants, and water lines, while damaging or destroying factories, businesses and workshops that employ thousands of Palestinians. Damages from the 2014 conflict have been estimated[4] at $34.43 million to water and sanitation infrastructure, $77.76 million to roads and vehicles, $55.84 million to electricity infrastructure, and $33.57 million in telecommunications and information technology (Isaac, Khalil et al. 2015), a total of around $200 million for these infrastructure sectors, representing 1.6% of 2014 Palestinian GDP (reported by World Bank as $12.73 billion). If other sectors are included (agriculture, housing, health, education, industry, banking), the overall loss incurred due to the 2014 assault on Gaza Strip is estimated at $2 billion, which accounts for 15.7% of 2014 GDP .

Table 5: Estimated direct damage caused by military operations in Gaza, 2012 and 2014 (USD$ millions) (UNCTAD 2015)

Type of damaged facility (totally or partially damaged)	November 2012		July 2014		Total	
	Number	Cost	Number	Cost	Number	Cost
Residential structures	8,298	73	56,000	1,304	64,298	1,377
Government, educational, religious and other structures	58	158	293	144	351	302
Infrastructure, roads, power station and utilities	--	74	--	119	--	193
Industrial and commercial establishments	--	213	1,000	360	1,000	573
Agricultural land and other related assets	--	120	--	138	--	258
Other losses	--	--	--	15	--	15
Total costs		638		2,080		2,718

While large-scale hostilities have not occurred in the West Bank since 2014, Israeli security measures continue to restrict infrastructure services, resulting in economic losses. Transport is particularly affected, as residents of the West Bank are restricted from using some of the most direct routes between urban centres. Isaac et al. (2015) calculates total annual costs of the main movement and access restrictions at around $185 million, while agricultural losses due to spoilage are estimated at 5-10%.

Tensions between Palestine Arabs and Israel has lasted for decades resulting in slowly increasing restrictions on land and access to basic services for the Palestinians (Smith 2013). It would be reasonable to assume that such conditions could persist for decades to come (Aly, Fieldman et al. 2013), and such a state of political stalemate is considered the basis for the baseline case of future socio-economic growth used in this report. The pessimistic scenario would involve increased hostility on both sides and the inevitable tightening of Israeli security control and restrictions on access to external funds, and the infrastructure services they control. An optimistic scenario would involve decreasing conflict and greater economic sovereignty which could result in quite high economic growth as Palestinian's enjoy access to safe access to restricted lands, improved health for civilians, increased primary energy production, improved mobility and access to clean drinking water and digital communications (Office of the Quartet 2016).

[4] Isaac et al. (2015) use an average exchange rate for 2015 throughout their report, where $1 = 3.85 NIS (New Israeli Shekel)

4.8 Natural hazards

In addition to longer-term trends of drought and desertification associated with climate change, natural hazards that threaten lives, livelihoods and infrastructure assets in the region through short-term events, such as: floods, storms, and forest fires. Despite its warm climate, recent winter storms have also led to massive power failures and road closures in the region, affecting thousands of Palestinians costing millions in losses to the Palestinian economy, particularly the agricultural sector (Acero 2013, International Middle East Media Center 2015, EM-DAT 2016). Seismic activity in the region poses a considerable threat to vulnerable infrastructure and buildings, particularly in dense urban areas, although no major losses due to earthquakes have been recorded in recent years. Nevertheless, due to its location near a fault line, Palestine remains at risk of a major earthquake and would likely be ill-equipped to deal with its consequences, meaning death tolls that could figure in the thousands (Melhem 2015). Efforts to reduce exposure to earthquake hazards are currently being pursued through the SASPARM-European FP7 project in collaboration with several international organisations (Melhem 2015).

In 2013, Palestine joined nine other Arab countries in establishing a disaster loss database in order to consolidate historical data and provide baseline information that will inform development planning policies and strengthen disaster resilience across Palestinian communities (Acero 2013). Over 400 events were recorded from 1980 to 2013, the vast majority of them classified as hydro-meteorological. Four geophysical events were also recorded, namely earthquakes and landslides. Overall losses directly related to these events included 63 deaths and over 800 damaged or destroyed houses (Table 7) (UNISDR 2015). The majority of these events occurred in the West Bank with consequently higher losses in this region (Table 6). Table 8 shows the types of hazards expected in Palestine with an approximate valuation of their cost over the last decade (Dabbeek 2010).

Table 6: Distribution of disasters, damage and losses in Palestine by region (1980 to 2013) (UNISDR 2015)

	Number of events	Deaths	Houses destroyed	Houses damaged
West Bank	344	53	42	526
Gaza	67	10	25	272
Total	**411**	**63**	**67**	**798**

Table 7: Distribution of disasters, damage and losses in Palestine by type (1980 to 2013) (UNISDR 2015)

Hazard	Number of events	Deaths	Houses destroyed	Houses damaged
Structure	18	18	2	0
Rains	25	16	0	26
Flood	82	15	37	555
Storm	46	5	27	191
Cold wave	7	3	0	10
Thunderstorm	9	3	0	10
Snowstorm	29	2	1	3
Forest fire	110	1	0	3
Avalanche	1	0	0	0
Drought	11	0	0	0
Earthquake	3	0	0	0
Fog	1	0	0	0
Frost	25	0	0	0
Heat wave	30	0	0	0
Landslide	1	0	0	0
Windstorm	13	0	0	0
Total	**411**	**63**	**67**	**798**

Table 8: Main types of hazards expected in Palestine (Dabbeek 2010)

Hazard type	Probability of occurrence	Probability of damage	Priority	Total damage in last 10 years	Last severe events
Floods	Low	Low – limited	Third	Millions	1963, 1966, 1987, 1991
Earthquakes	High	High	Third	--	1759, 1927
Droughts	Medium	High in the long run	First	Tens of millions	2007-2010
Land/mud slides, rock falls/avalanches	Medium	Medium – high	Second	Millions	1992, 1997, 2003, 2005
Epidemic outbreaks of disease	Low	Low	Second	Millions	1981
Industrial accidents	High	Medium – high	Third	Millions	1999, 2006
Population displacement	High	High	First	Tens of millions	2001-2006
Sea disasters	Medium	High in the long run	Second	Tens of millions	--
Pollution of underground water	High	High	Second	Tens of millions	2016
Desertification	High	High in the long run	Second	Tens of millions	--
Occupation, wars	High	High	First	Billions	2000-2014

5 Development of socio-economic scenarios

The drivers of change described above all have potential to impact on future requirements for infrastructure provision. However, some of these drivers of demand have a more consistent impact on long-term planning, such as demographic change, technology, economic growth and energy prices, while others occur more sporadically with more immediate impacts on short-term planning, such as behavioural change, natural hazards and conflict.

The impact on these latter, short-term drivers of change are dealt with using risk and vulnerability modelling as presented in Section 3. As documented in Section 2 these so-called “short-term” drivers can impact on long-term economic growth. This impact is assumed to be incorporated in the socio-economic scenarios used here. Within a full analysis, for which the FTA is a precursor, the aim will be to incorporate such short-term resilience planning into the long-term capacity planning by informing decisions around where new capacity should be built and how it should be connected to existing networks (see Section 3 for an example of this process).

To account for the impact of the long-term drivers we adopt a simplified approach involving plausible ranges of future change based on three primary scenario dimensions common to all infrastructure sectors: demographic change, economic growth and energy prices (Figure 55). Technological change is integral to each of the sectors and can both reduce and increase demand. For this FTA it will be assumed to be included in the range of scenarios generated by the other dimensions but will be more explicitly modelled in future work.

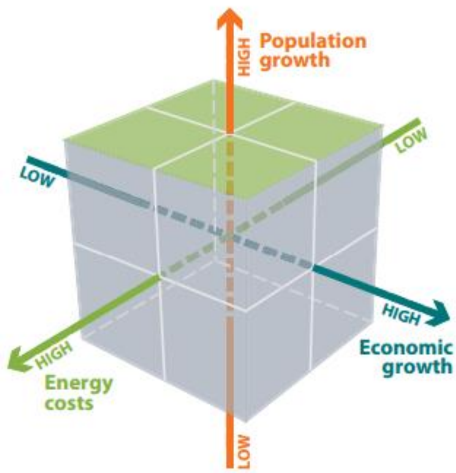

Figure 55: A stylised representation of the dimensions of drivers used to develop the scenarios of change of demand for infrastructure services

The range of future pathways within this dimension space is vast. In order to reduce the number of scenarios to a manageable number, a ‘central’ growth scenario is compared with a small number of scenarios created using extremes of the dimension space – high or low values for population change paired with optimistic and pessimistic futures for economic growth, which are each coupled with high or low energy prices (such that optimistic economic growth assumes a lower energy price, and pessimistic growth assumes high energy prices).

Guha-Sapir and D'Aoust (2010) suggest that fertility rates among conflict-affected populations is a complex issue, and describe situations where fertility rates have been observed to decrease due to conflict-related insecurity (the general increase in violence, psychological stress, wealth uncertainty, and poor health), but also note that conflicts and ensuing loss of life can also boost fertility through what is sometimes called an ‘insurance effect’ (where uncertainty about the future increases, having more children secures the preservation of a minimum level of income).

Since such uncertainty exists around post-conflict population change, we propose examining both high and low population change for each of the economic growth scenarios, as shown in Table 9.

Table 9: Scenario options – colour coded to show likely better (green) and worse (red) scenarios in terms of socio-economic conditions and availability of services per individual

		POPULATION GROWTH		
		High	**Central**	**Low**
ECONOMIC GROWTH	**Optimistic**	Opti-High	Opti-Cent	Opti-Low
	Baseline	Base-High	Base-Cent	Base-Low
	Pessimistic	Pess-High	Pess-Cent	Pess-Low

However, for this Fast Track assessment only the extremes of Opti-Low, Base-Cent and Pess-High will be examined. For the remainder of this report, these scenarios are referred to as the 'Balanced Prosperity', 'Central' and 'Unstable Adversity' scenarios, as shown in Table 10.

Table 10: Scenario options used in this report

		POPULATION GROWTH		
		High	**Central**	**Low**
ECONOMIC GROWTH	**Optimistic**			Balanced Prosperity
	Baseline		Central	
	Pessimistic	Unstable Adversity		

The following sub-sections describe how these ranges are developed.

5.1 Population change

The average growth rate between 2007 and 2016 is 2.6% in West Bank and 3.4% in Gaza (2.9% on average for all Palestine), and this is used to estimate future population numbers for the central population growth in each of the regions. The low and high population change figures assume an annual increase in population of 1.8% and 3.4% respectively in West Bank, and 3.1% and 4.0% respectively in Gaza (Figure 56), and the sum of these two projections give a range of between 10.7 and 16.3 million people living in Palestine in 2050 (equivalent to 2.3% and 3.6% annual growth) (Figure 57). These alternatives are based on the lowest and highest growth rates from the Palestinian governorates within each of the regions (Table 3).

Future population trajectories could also include the return of the Palestinian diaspora, which comprises nearly two million residing in Jordan, and nearly half a million in both Syria and Lebanon (PCBS 2010). Although the return of diaspora to Palestine is a real possibility, such a scenario is not included explicitly in any of the alternatives in this FTA. Although the Unstable Adversity scenario could be regarded as accommodating a slow rate of diaspora return, it should be noted that a sudden return of a large number of diaspora would represent a much steeper population growth rate than is used in this scenario. This issue may not be as problematic as it would seem according to Zimmerman et al.'s (2006) analysis of the PCBS methodology that argued that a significant number of the diaspora may already be included in the official PCBS population estimates.

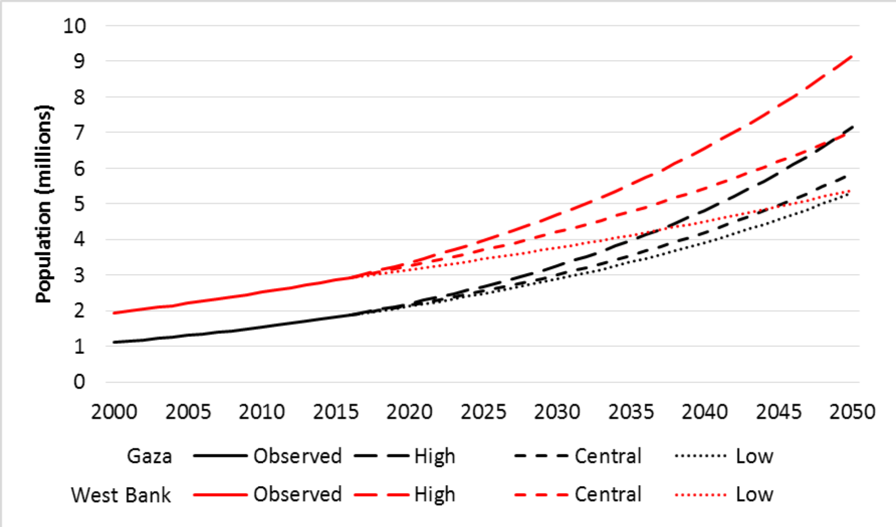

Figure 56: High, central and low population projections for Gaza and West Bank, to 2050 (PCBS 2016)

Gaza is relatively small in area (365 km^2), and has a population density of around 5,000 people per km^2 in 2016. Even at the lowest estimated growth rate, this becomes 8,000 per km^2 in 2030 and 14,500 per km^2 in 2050. For comparison with similar sized regions, in 2016 Addis Ababa (Ethiopia) has population density of 5,800 per km^2, Casablanca (Morocco) has 8,600 people per km^2 and Giza (Egypt) 14,600 per km^2. At the highest growth rate, the population density of Gaza in 2050 is nearly 20,000 per km^2, which is commensurate with that of present-day Mumbai (India). It should be noted that given the limits on water availability in Gaza such a scenario seems unlikely without a significant technological breakthroughs such as cheap reliable sources of energy (e.g. fusion power). As such some sort of population tapering would be expected in this Unstable Adversity scenario.

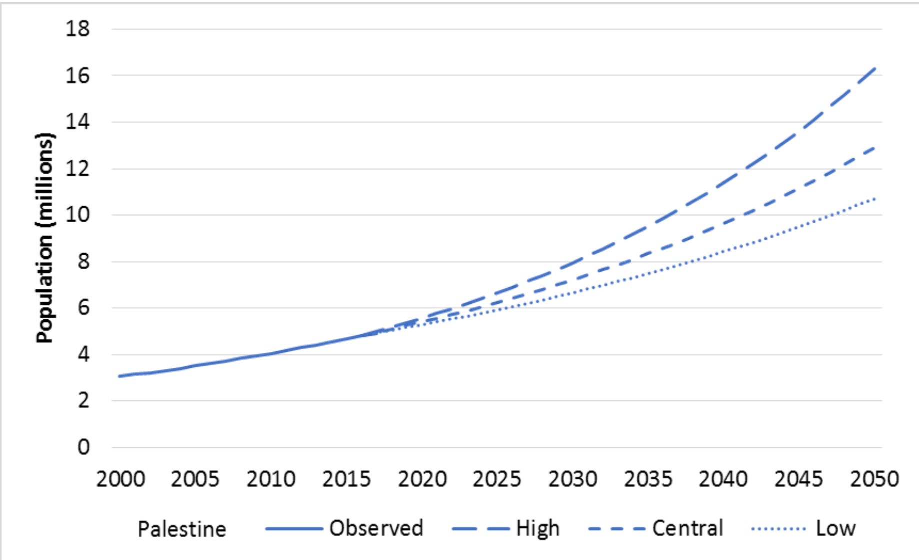

Figure 57: High, central and low population projections for Palestine, to 2050 (PCBS 2016)

5.2 Economic forecasts

Economic forecasts for 2016 have been developed by the Palestine government in consultation with local economists, the Ministry of Finance and the Palestinian Monetary Authority. Each scenario considers political and economic circumstances, the blockade imposed upon the Gaza Strip, foreign aid, Israeli measures in Palestine, the number of Palestinian workers in Israel, and other economic and social variables[5].

The **baseline** economic scenario assumes the same conditions as 2015, a maintenance of current energy prices, and economic and political conditions including continuing financial support from donor countries for the budget of the State of Palestine; a continuation of transfer of clearance revenues from Israel; tax collection levels and government transfers are maintained; numbers of public sector employees will remain constant; and obstacles on the intra-regional or international movement of people and goods will remain unchanged.

The **optimistic** economic scenario is based on an improved political and economic situation due to greater political reconciliation between the West Bank and the Gaza Strip, the reconstruction of Gaza, and increased international assistance to finance the budget of the State of Palestine; uninterrupted transfer of clearance revenues and improved tax collection efficiency; and reduced obstacles imposed by Israel on the movement of goods both within Palestine and with neighbouring countries.

The **pessimistic** socio-economic scenario accounts for the deterioration both in the volatile political and economic situation and in the political reconciliation between the West Bank and the Gaza Strip. It assumes reduced aid from donor countries to fund the Palestinian budget; an increase in tax evasion and fluctuation in the transfer of clearance revenues; and increased obstacles imposed on the movement of Palestinian goods and people, with a particular drop in the numbers of workers in Israel due to closures and a halt in negotiations.

According to a recent study by the Applied Research Institute (Isaac, Khalil et al. 2015) the overall economic losses in Palestine due to the Israeli occupation could be valued at around USD$9.5 billion in 2014, or 74 percent of Palestinian nominal GDP (Isaac, Khalil et al. 2015). These estimates are roughly in line with the difference between GDP growth shown in the optimistic and pessimistic economic scenarios used in this assessment. Figure 58 compares the three scenarios across the major economic sectors (real, fiscal and external) of the Palestinian economy, and provides an indication of what each scenario could mean in terms of real incomes, employment and public funds available for investment in maintenance and improvement of infrastructure services.

[5] Further details available from PCBS (2015). Press report of economic forecasting for 2016.

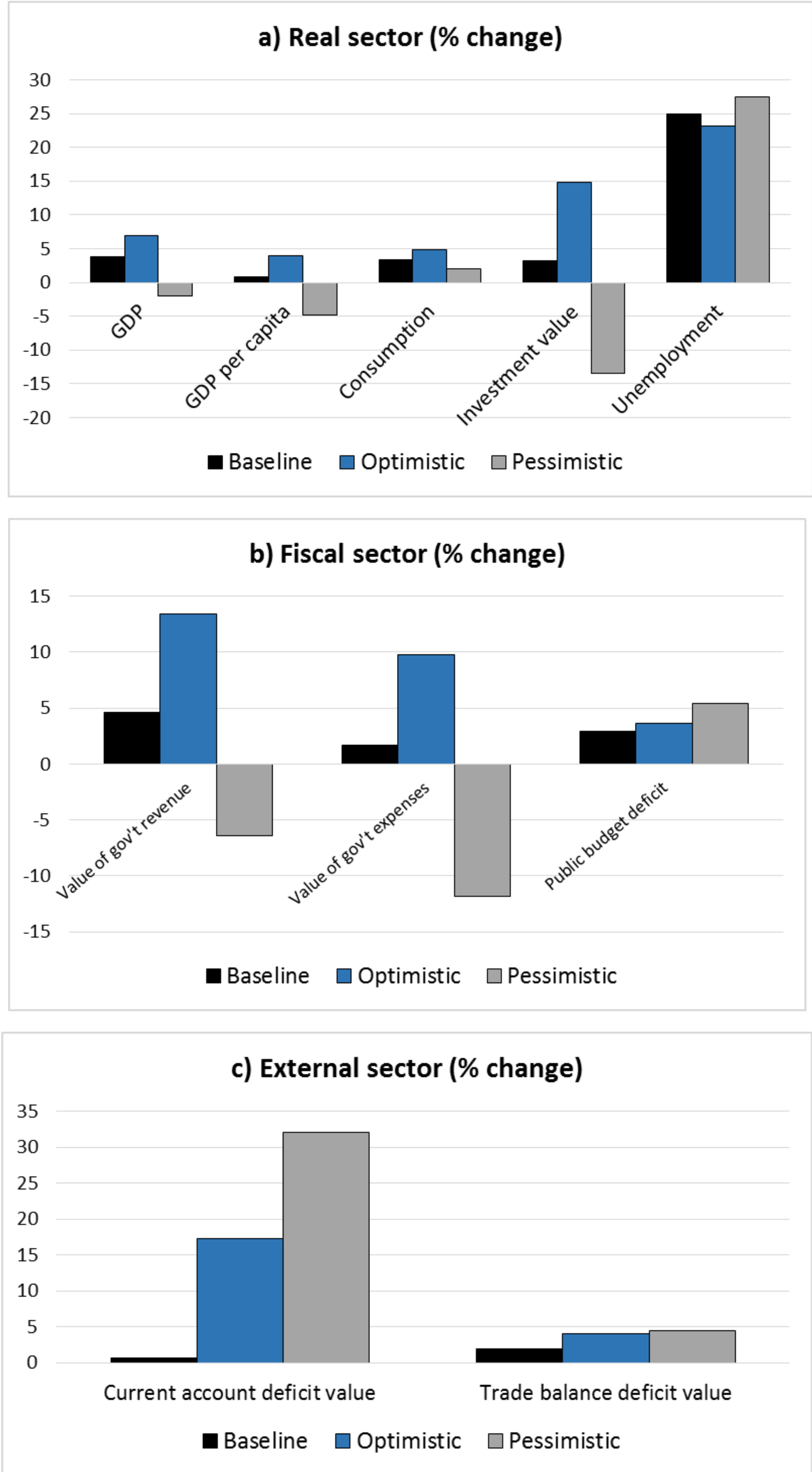

Figure 58: Percentage change associated with each economic scenario broken down by a) the real sector b) the financial sector, and c) the external sector (PCBS 2015)

Recent PCBS data of production by economic sector have shown that services are a major source of growth and employment, as shown in Figure 59. For simplicity the split in economic activity by sector is expected to remain constant in each of the three scenarios along with its associated impacts on business and industry demand for infrastructure services such as energy, water, and wastewater.

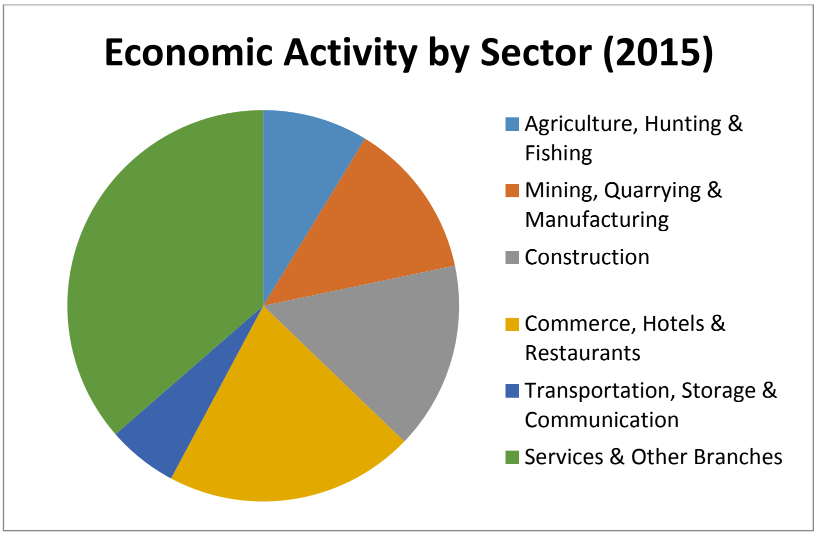

Figure 59: Estimates of economic activity attributable to each economic sector for the economic scenarios (PCBS 2016)

Employment levels among Palestinians are shown by governorate in Figure 60, tracking changes over the past 15 years. While growth in labour force participation is evident across many regions since 2010, a particularly large decrease is noted in Jerusalem, where workers have faced increased employment barriers.

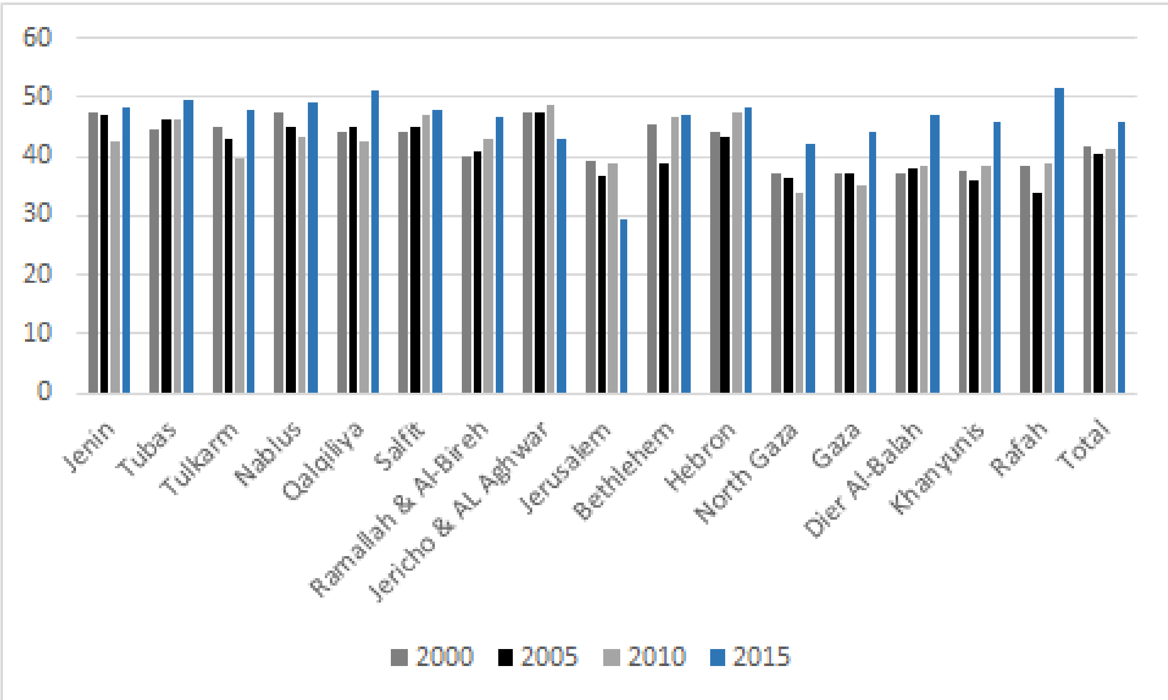

Figure 60: Labour force participation (over 15) rates by governorate (%) (PCBS 2015)

For the purposes of this fast track assessment these scenarios are used to bound a likely trajectory of infrastructure growth in Palestine, where greater demand for infrastructure in all sectors is linked positively to socio-economic growth, foreign investment, a reduction of Israeli barriers to the movement of goods and people, and the protection of existing infrastructure systems from destruction due to conflict. For this assessment, we assume a continuation of these forecasts in the longer term. We thus will generate three economic growth scenarios with similar names and assumptions as follows:

The **baseline** economic scenario assumes an annual GDP growth of 3.5%.

The **optimistic** economic scenario assumes an annual GDP growth of 5.5%.

The **pessimistic** economic scenario assumes an annual GDP growth of 1.5%.

Most estimates of Palestine GDP growth do not extend beyond more than one to five years (PCBS 2015, IMF 2016, Office of the Quartet 2016). The GDP growth estimates provided sit at the low-end of the range of estimates that have been proposed (3 to 5.5%). Such conservative estimates were deemed credible given that this assessment must project growth to 2050 in order to capture investment risks in long-lived infrastructure investments, and that Palestine has for decades has been regarded as a fragile economy, without economic sovereignty (Office of the Quartet 2016).

Pairing each of these estimates of GDP growth with an appropriate population scenario (pessimistic economic change with high population growth, for the worst case, optimistic economic change with low population growth for the best case option), it is possible to develop estimates of GDP/per capita change, and the resultant GDP per capita projections to 2050 for West Bank and Gaza are shown in Figure 61, and for Palestine in Figure 62. Only in West Bank for the Balanced Prosperity (optimistic/low population) scenario does the projected GDP per capita grow significantly (at an average of 3.6% per annum). Note that GDP per capita decreases for the pessimistic scenarios, since population grows at a higher rate than GDP growth.

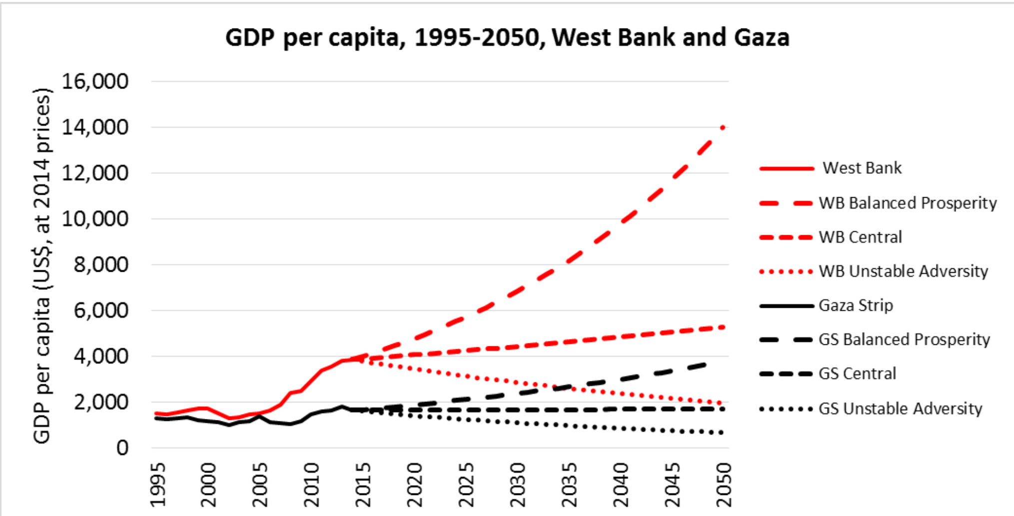

Figure 61: Historical and projected GDP per capita for West Bank and Gaza, for three scenario options

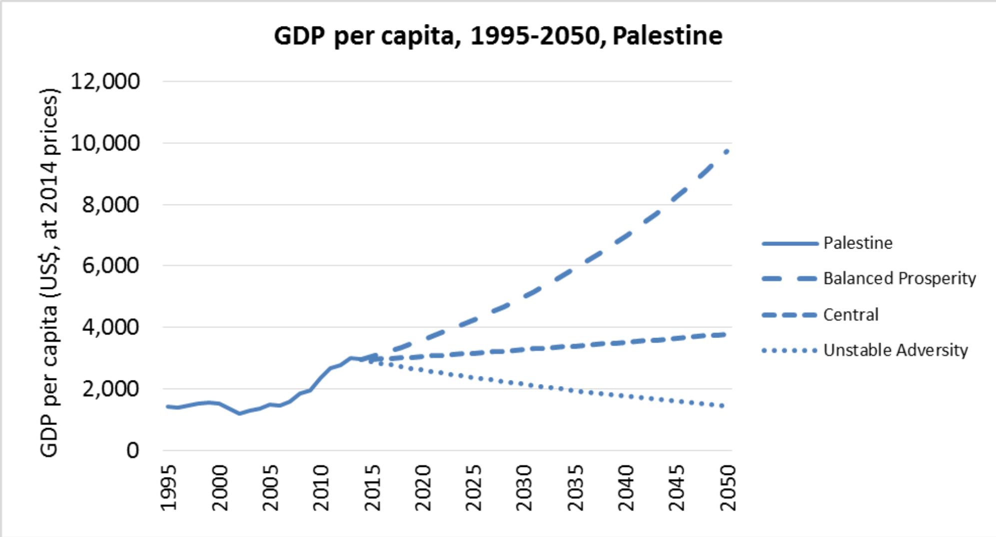

Figure 62: Historical and projected GDP per capita for Palestine, for three scenario options

An additional point of note in regards to the economic situation in Palestine is that an estimated 42.8 percent of Palestinians are still considered refugees, a legacy of the 1948 Arab-Israeli War. Such refugees comprise some 27 percent and 67 percent of the populations of the West Bank and Gaza respectively (PCBS 2015), and are sheltered in designated UNWRA[6] refugee camps, which have developed from tented cities to rows of concrete blockhouses to urban areas indistinguishable from their surroundings. Such camps represent a complexity to the management of infrastructure in that they generally consist of non-paying customers of infrastructure services. This complexity will have an impact on affordability of infrastructure solutions for the government and also on the efficacy of any demand management measures that are attempted. As this research does not assess the financing of infrastructure capacity provision the demand for infrastructure services by refugees will be considered as the same as that of other Palestinians.

[6] UNRWA - United Nations Relief and Works Agency for Palestine Refugees in the Near East

6 Development of strategies for infrastructure provision

There are many ‘levers’ which decision-makers can affect to change the current direction of infrastructure provision. In developing countries and post-conflict situations, the most important are the levels of investment available for infrastructure provision in the different sectors, and the ability or ambition of governing bodies to apply the changes such investments bring in a post- or ongoing-conflict situation. Focusing solely on these two areas of influence, a framework can be derived within which alternative and diverse strategies can be positioned (Figure 63). No single strategy under such a simple framework can fully describe the wide range of decisions which must be made by government and others, but for this assessment, we are focusing on four diverse strategies with different levels of investment requirement and different levels of ambition or restrictions, in order to illustrate the potential impacts of alternative future decision pathways. None of these strategies will necessarily give the optimal approach to future decisions, but the intent is to provide an insight into the implications of the different approaches. Thus, these strategies are designed to range from an investment, heuristic no-build strategy (No Build), to a ‘neutral’ strategy in which current trends in infrastructure service provision are extended into the future (Status Quo), to a strategy that provides an example of how infrastructure needs can be addressed through efficiencies given the scarcity of available resources (Efficiency with Scarcity), and finally to a strategy that focuses on generating higher economic growth and provision of needs through higher investment in infrastructure (Infrastructure-led Development).

Each of the strategies, depicted in Figure 63, will result in a range of investment costs and outcomes dependant on the future conditions (scenario). For instance, higher population growth will result in higher demand, and hence require higher levels of investment for a strategy to be effective. Similarly, provision of infrastructure service can be affected by a range of demand management strategies (including behaviour change and impact of technology).

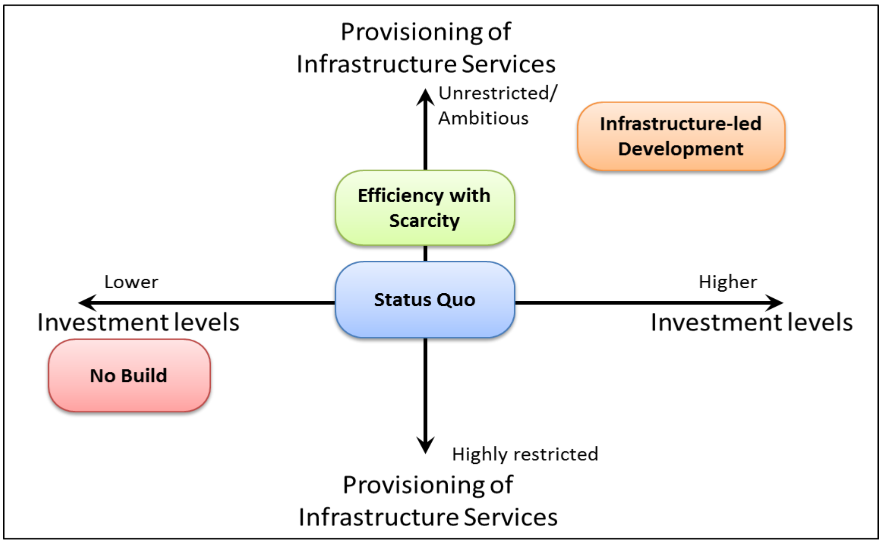

Figure 63: Framework for positioning strategies of infrastructure provision

6.1 Strategy descriptions

There are numerous situations and decisions which could lead to each of the strategies described here, as well as very many other strategies which could fit into this framework. For simplicity, we have restricted this assessment to only four fairly simple examples of future strategies. Components within a strategy include a strategy narrative, or policy approach, that guides the choice of investments and technologies in each sector, and the timing and amounts of investment in new infrastructure, including projects that are included from the current infrastructure pipeline (listed below). The narrative for each of these strategies is provided here, with further discussion on investments provided in each of the sector reviews in Section 6.

6.1.1 Infrastructure Pipeline of Planned Investment

The Infrastructure pipeline is the list of projects that have been identified by the Palestinian Authority as currently under construction or planned for construction in the next 5 to 10 years (Table 11). The differing levels of regional stability, investment ambition and technology preference represented by each of the strategies will be reflected in which of these pipeline projects are included in the range of strategies detailed below, from none in the No Build strategy to all pipeline projects in the Infrastructure-led Development strategy (Table 12).

6.1.2 No Build (NB)

The No Build strategy is strictly speaking not a realistic government ‘strategy’ as it involves no future investment in infrastructure services beyond the base year of 2015. This strategy is used primarily as a heuristic tool used to highlight the rate at which existing assets are retiring and to provide a counter-factual for comparison against the more realistic strategies following. Thus, in this strategy infrastructure services will dwindle through time as demands grow (i.e. socio-economic growth), and as supplies decrease either due to existing capacity expiring or due to changing environmental conditions.

Key features:

- Involves no future investment in new infrastructure beyond the base year (2015).
- Maintenance occurs on existing infrastructure but existing assets that expire are not replaced.

Table 11: Planned infrastructure 'pipeline' projects

Project type	Project name	Impact	Completion	Estimated cost
ENERGY				
Energy generation: Imported electricity	GS - Gas for Gaza sub-project: 161KV line	100 MW extra electricity imported	2020	
Energy generation: Gas	WB - Jenin Power Plant	450 MW gas power plant	2020	$600m
	GS - Gas for Gaza pipeline and GPP conversion	80 MW extra electricity, reduced energy costs	2020	$93m
	GS - Gas for Gaza sub-project: Power station Phase I	150 MW extra electricity generated	2023	$155m
	GS - Gas for Gaza sub-project: Power station Phase II	300 MW extra electricity generated	2027	$320m
	GS - Gaza Marine gas field	Supply of gas owned by Palestine	2025	~$1 billion
	WB - Hebron Power Plant	200 MW CCGT power plant	2025	
Energy generation: Wind	NONE			
Energy generation: Solar	GS - Gaza Solar Cells	30 MW	2016	
	WB - Solar PV expansion phase 1	5.7 MW	2020	
	PAL - Solar PV expansion phase 2	35 MW	2023	
	PAL - Solar PV expansion phase 3	110 MW	2025	
Energy distribution: Electricity network	GS - Gaza Electricity Network Rehabilitation	Improve reliability and performance	2020	$133m
	WB - Transmission network enhancement	Improve reliability and performance	2025	$45m
WATER				
Water supply: Desalination	GS - STLV desalination projects	7.3 MCM per year	2017	?
	GS - Gas for Gaza (G4G) Desalination plant Phase 1	55 MCM extra water per year	2025	$500m
	GS - Gas for Gaza (G4G) Desalination plant Phase 2	30 MCM extra per year	2030	?
Water supply: Imports	GS – Imports from Israel Phase 1	5 MCM per year	2017	?
	GS – Imports from Israel Phase 2	10 MCM per year	2020	?
	PAL - Red Sea-Dead Sea Water Conveyor Project	16 MCM to WB	2030	?
WASTEWATER				
Water treatment: New plants	GS - Northern WWTP	9-18 MCM/yr	2018	?
	GS - Southern WWTP	16 MCM/yr	2020	?
	GS - Central WWTP	65 MCM/yr	2030?	?
	WB - Hebron Regional Wastewater Management Project - Phase 1	5.5 MCM/yr	2023	$62m
TRANSPORT				
Rail	WB - 36km railway between Nablus and Ramallah	Increased mobility	2025	$150m
Air & Sea	Gaza Sea & Airport	WB – Single runway airport	2025	~$5bn
Air	West Bank Airport	WB – Single runway airport	2030	~$3bn
SOLID WASTE				
New waste management facilities	GS - Solid Waste Management Project	300,000 tons per year	2020	$35m
	WB - Southern West Bank Solid Waste Management	100% of municipal waste from 700,000 people	2016	$20m
	WB – Jericho – Cell 1 expansion	Mgmt of municipal waste from 50,000 people	2017	$3.1m
	WB - Solid waste management Ramallah/Al Bireh	New sanitary landfill replacing 83 dumpsites	2020	$12m
DIGITAL COMMUNCATIONS				
Wireless spectrum allocation	GS - 2G rollout	Attract investment and revenue	2017	?
	GS - 3G rollout	Attract investment and revenue	2020	?
	WB - 3G rollout	Attract investment and revenue	2020	?

6.1.3 Status Quo (SQ)

The Status Quo strategy presents a ‘baseline’ future, giving levels of investment determined by past trends. The future political environment is seen as reflecting the current state, with restrictions on the ability of the government to effect and coordinate change, particularly in Gaza. Thus, the investments included in future years are kept in line with historic levels, in that *per capita* supply of infrastructure services are maintained under scenarios of central population growth. Current inefficiencies in the delivery of infrastructure services in terms of costs, energy and water usage will also continue through time. This strategy will include the most likely projects in the current infrastructure pipeline although their fulfilment may be constrained to keep in line with past achievements.

Although this strategy aims to maintain current levels of supply in response to per capita demand there will naturally be an increase in overall infrastructure demand with population growth which will require additional investments in new infrastructure. Such investments will replace or supplement infrastructure that is already available only up to the extent of maintaining current levels of service, with limited technological advances or targeted behavioural change (i.e. demand management). The current proportion of individual economic sectors (industry, construction, agriculture and services, etc.) will be assumed to be maintained through time (as per Figure 59).

Intermittent electricity provision problems will continue into the future, so that users are supplied with limited hours of electricity per day (e.g. currently 6-8 hours per day of electricity provision in Gaza). The current levels of connectivity to electricity and water/wastewater networks may deteriorate in scenarios of high population increases. Current trends in technology choices and fuel types will be used as the basis for determining the technology choices for future investment. Communities may seek newer, alternative means of power supply, such as renewables, but will still receive only intermittent electricity provision in line with hours of sunlight/wind. Abstraction of water from aquifers will have to be reduced to sustainable levels with consequential impact on water availability, particularly in Gaza. The current road network is maintained to allow movement, but few new roads will be constructed.

Key features:

- Maintains current trends of infrastructure services provision into the future – e.g. maintaining into the future the current service levels i.e. maintaining litres per person per day of water, kWh energy per person per annum, and seeking to increase the percentage of waste treated to above 50%. However priority among the sectors is given to the provision of water and so aquifer abstractions must be reduced to sustainable levels by 2020 even at the cost of additional energy demands.
- Continues ‘business-as-usual’ investments in regards to asset types, timing and investment amounts to maintain current service levels. Technological growth is completely exogenous i.e. market driven.
- Complies with the ‘PENRA vision’ in limiting dependence on any one source of energy to no more than 50 percent (World Bank 2017).
- Electricity provision will continue to be intermittent with a possibility of even lower domestic supply levels to provide more energy for water management.
- Imports will increase for energy and water sectors to fill in any gaps in maintaining per capita infrastructure services not provided by local assets.

6.1.4 Efficiency with Scarcity (ES)

The Efficiency with Scarcity strategy is based on the identified priorities in the recently released Envisioning Palestine report (State of Palestine 2015) involving empowering Palestine with greater autonomy of resource production, increased efficiency in service delivery and improved waste management. Such a strategy would likely require an improved political environment, higher levels of donor support and better access to overseas markets for import and export including access the latest materials and technologies. Despite such a positive environment there are still constraints in terms of investments and so the majority of improvements will arise through efficiency improvements. This strategy will not include all the projects in the pipeline and will focus on maintaining current levels of service in the face of growing socio-economic growth and demand (as is the case in the Status Quo strategy).

To differentiate this strategy from the Status Quo there will be a focus on choosing local solutions, i.e. reducing imports, maximising waste recovery and re-use, and increasing efficiency of existing assets with some attempts to change user demand through behavioural change to overcome resource constraints and release additional capacity. There will also be a focus on developing locally produced renewable energy, particularly solar, as per the recently released National Spatial Plan envisioning report (State of Palestine 2015), with some reliance on external countries to keep costs at a reasonable level. Water shortages will be a high priority issue, particularly in Gaza, and so additional electricity resources will be sought to enable water and wastewater management to prevent unsustainable abstraction from aquifers whilst maintaining current per capita water consumption levels. Technological choices will be based on those identified as most viable by the Palestinian Water Authority (PWA 2011, PWA 2012, PWA 2014). There will be no major road programme and so limited growth in transport, rather this strategy will rely on technological solutions, coordinated investments and efficiency improvements to alleviate any problems within infrastructure networks. Solid waste and wastewater will be treated locally as much as possible, with a focus on energy and materials recovery and reuse (State of Palestine 2015) rather than using official and unofficial waste disposal sites. The current proportion of individual economic sectors (industry, construction, agriculture and services, etc.) will be assumed to be maintained through time (as per Figure 59).

Key features:

- Maintains current trends of infrastructure services provision into the future – e.g. maintaining into the future the current service levels i.e. maintaining litres per person per day of water, kWh energy per person per annum, and seeking to increase the percentage of waste treated to above 50%. Priority among the sectors is given to the provision of water and so aquifer abstractions must be reduced to sustainable levels by 2020 even at the cost of additional energy demands.
- Complies with the 'PENRA vision' in limiting dependence on any one source of energy to no more than 50 percent (World Bank 2017).
- If any cost savings are achieved through efficiency measures and smart infrastructure planning these are used to achieve higher supply of infrastructure services than Status Quo strategy.
- Asset types are chosen specifically to reduce reliance on imports and improving local production of services such as energy, water and treatment. Specifically renewable energy sources are chosen over those dependent on imported fuels.
- Technological growth is somewhat exogenous although certain options are promoted that are more likely to reduce demand and not create new demands in other sectors that are also suffering from scarcity.

6.1.5 Infrastructure-led Development (ID)

The Infrastructure-led Development is similar to the Efficiency with Scarcity strategy in that it is based on the identified priorities of the Envisioning Palestine report (State of Palestine 2015) but with greater access to financial resources and an improved political environment. The emphasis in this strategy is to meet higher national targets of infrastructure provision by 2050 and thereby enable economic growth through infrastructure provision, with a focus on capturing any gains to be made through national solutions and economies of scale. Essentially this will involve investing in new infrastructure in places where there is a lack in supply, and meeting future growing demands through a large-scale infrastructure building and expansion programme. This strategy must assume greater interactions with regional neighbours and the wider global community and donors, large increases in private investment, and sustained internal economic growth. The infrastructure pipeline will be implemented in full using the most ambitious timeline.

This strategy will incorporate the latest technological solutions when new capacity is required to gain efficiencies with an emphasis on larger capacity solutions in order to gain from economies of scale in the long term. The road network will be expanded where needed, in particularly to create greater linkages between northern and southern governorates (State of Palestine 2015), and imposed restrictions on movement are assumed to be removed through political progress. Energy supply will become more reliable and widespread through improvements to the transmission and distribution networks and the introduction of a wider range of energy generation solutions such as CCGT and industrial scale solar. Alternative energy sources, such as renewables, will be given some priority (State of Palestine 2015), however availability of land, particularly in Gaza, will limit the amount of energy that can be provided by renewable energy sources. Water availability will be secured through large scale desalination projects supplemented by negotiated water transfers from Israel if local resources are insufficient. Leakages in the water and wastewater distribution systems will be reduced, together with an expansion of centralised wastewater treatment capacity across both Gaza and the West Bank. Water gained from wastewater reuse and energy from waste will maximised as per the Palestine envisioning report (State of Palestine 2015). The focus in wastewater treatment will be on increasing collection and connectivity to centralised solutions to realise gains from economies of scale and water reuse. Solid waste management will focus on improved collection and disposal as well as resource recovery including energy from waste (State of Palestine 2015). For the purpose of simplification the current proportion of individual economic sectors (industry, construction, agriculture and services, etc.) will be assumed to be maintained through time (as per Figure 59).

Key features:

- Promotes growth through increases in the provision of infrastructure services.
- Meets an ambitious vision for national provision through least cost solutions by meeting high infrastructure service targets – e.g. achieving higher service levels e.g. 100 litres per person per day of water, 9,000 kWh per person per annum, 100% of waste treated.
- Increase in imports are kept equal or below those of the Status Quo Strategy.
- Promotion of national-scale solutions and economies of scale by building bigger assets to provide for all areas. Choosing larger projects will also inherently mean that such assets will be built less often.
- Water gained from wastewater reuse and energy from waste will be maximised.
- Technological growth is promoted regardless of whether it will reduce demand or create new demands in other sectors.

6.1.6 Assignment of Pipeline Projects for each Strategy

Table 12: Assignment of 'pipeline' projects to particular strategies

Project type	Project name	Strategy			
ENERGY		NB	SQ	ES	ID
Energy generation: Imported electricity	GS - Gas for Gaza sub-project: 161KV line			✓	✓
Energy generation: Gas	WB - Jenin Power Plant		✓	✓	✓
	GS – Gas4Gaza pipeline		✓	✓	✓
	GS – Gas4Gaza sub-project: Power station convert		✓	✓	✓
	GS – Gas4Gaza sub-project: Power station Phase I			✓	✓
	GS – Gas4Gaza sub-project: Power station Phase II				✓
	GS - Gaza Marine gas field				✓
	WB - Hebron Power Plant				✓
Energy generation: Wind	NONE				
Energy generation: Solar	GS - Gaza Solar Cells		✓	✓	✓
	WB - Solar PV expansion phase 1		✓	✓	✓
	PAL - Solar PV expansion phase 2			✓	✓
	PAL - Solar PV expansion phase 3				✓
Energy distribution: Electricity network	GS - Gaza Electricity Network Rehabilitation		✓	✓	✓
	WB - Transmission network enhancement				✓
WATER					
Water supply: Desalination	GS - STLV desalination projects		✓	✓	✓
	GS - Gas for Gaza (G4G) Desalination plant Phase 1			✓	✓
	GS - Gas for Gaza (G4G) Desalination plant Phase 2				✓
Water supply: Imports	GS - Imports from Israel Phase 1		✓	✓	✓
	GS - Imports from Israel Phase 2		✓	✓	✓
	PAL - Red Sea-Dead Sea Water Conveyance Project				✓
WASTEWATER					
Water treatment: New plants	GS - Northern WWTP		✓	✓	✓
	GS - Southern WWTP			✓	✓
	GS - Central WWTP				✓
	WB - Hebron WWTP Phase 1				✓
TRANSPORT					
Rail	West Bank to Gaza railroad				✓
SOLID WASTE					
Major projects	GS - Gaza Solid Waste Management Project			✓	✓
	WB - Southern West Bank Waste Management		✓	✓	✓
	WB – Jericho – Cell 1 expansion		✓	✓	✓
	WB - Solid waste management Ramallah / Al Bireh				✓
TELECOMS					
Wireless spectrum allocation	GS - 2G rollout		✓	✓	✓
	GS - 3G rollout				✓
	WB - 3G rollout				✓

7 Results from the Fast Track Assessment

7.1 Energy sector

The current situation for the energy sector in Palestine is described in Section 2.1. This section gives examples of future challenges, details of planned investments and modelled strategies of future infrastructure provision given scenarios of socio-economic change, and resultant changes in demand.

7.1.1 Future challenges

Assuming similar levels of per capita energy supply for Palestine at current prices the total demand for energy in the West Bank and Gaza is still expected to increase with increasing population and economic growth.

Figure 64 and Figure 65 below provide historical energy supply and estimates for the growth of total energy demand in the identified low (Balanced Prosperity), medium (Central) and high (Unstable Adversity) population growth scenarios based purely on *current* per capita energy usage remaining constant, which is regarded as well below *actual* per capita demand. A more complex representation of energy growth is possible, particularly in respect to use of *potential per capita energy demand*, and the inclusion of future economic growth and global fuel prices. The growth estimates provided in other more sophisticated analyses (UNISPAL 2007) have produced higher demand figures. However, we chose here to represent future energy demand based on current supply and population growth for consistency with the estimates of future demand generated for the other infrastructure sectors in this assessment.

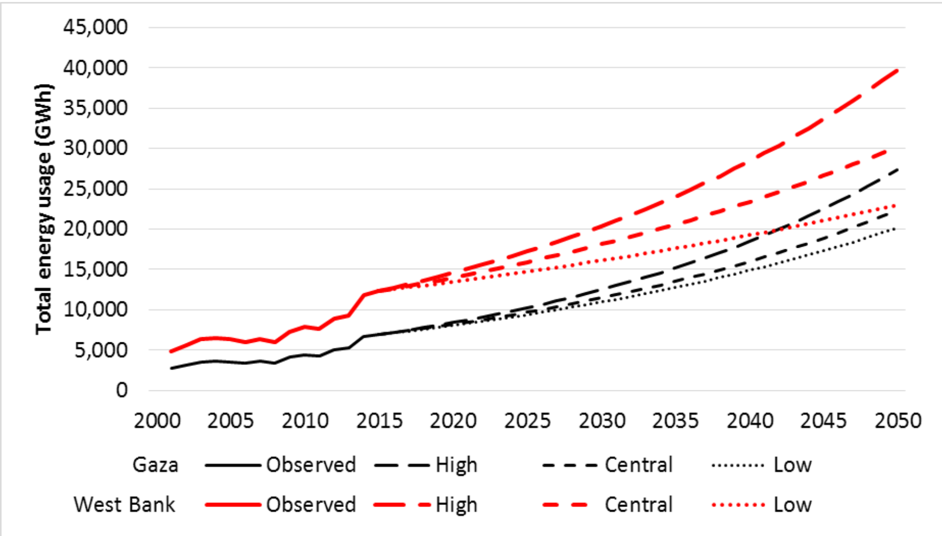

Figure 64: Total energy demand scenarios for the West Bank and Gaza (PCBS Energy balance tables, ITRC Population projections)

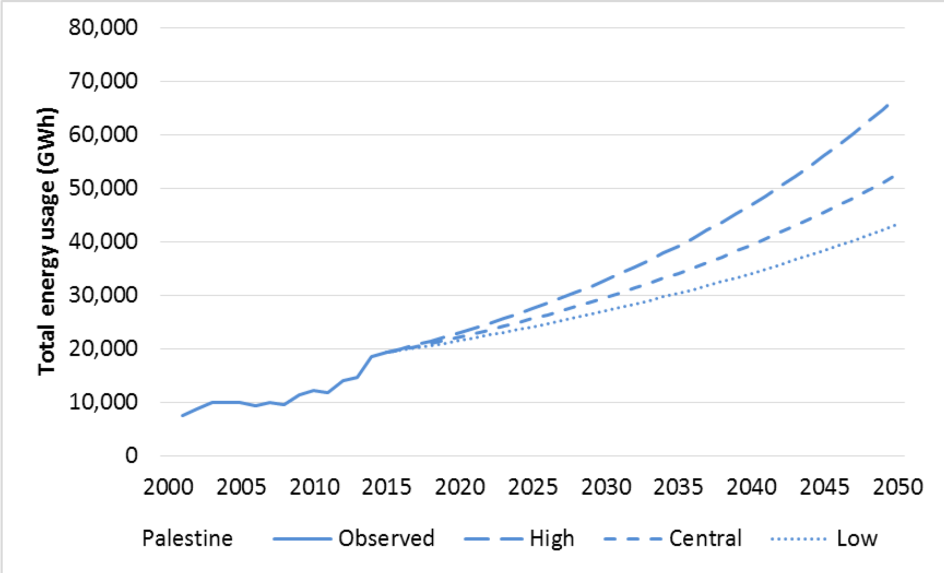

Figure 65: Total energy demand scenarios for Palestine (PCBS Energy balance tables, ITRC Population projections)

7.1.2 Planned 'infrastructure pipeline' investments

The Palestinian Energy Authority (PEA), an independent institution established in 1994, has recently a stated commitment to several objectives as part of its medium term strategy (PEA 2016):

- Providing Palestinians with reliable and affordable electricity;
- Ensuring efficiency in the legal, institutional, economic, financial, and technical aspects of energy sector development;
- Reforming the institutional framework, including overall sector coordination, policy formation, and other functions;
- Remedying system deficiencies and improving service delivery;
- Supervising new project design and implementation; and
- Conducting research in the sector.

A number of priorities have been identified for the Palestinian energy sector to meet these objectives (UNISPAL 2007). These include technical, financial, and institutional capacity development of power utilities, such as opening its power and natural gas markets to private investors and operators, and specific infrastructure projects. One major project currently being led by the Office of the Quartet is the Gas for Gaza (G4G) pipeline aimed at providing a consistent supply of gas between Gaza and Israel's existing gas infrastructure (Office of the Quartet 2016). This project will be implemented in conjunction with the conversion of the Gaza Power Plant to burn natural gas instead of diesel and together they are expected to increase the Gaza Power Plant capacity to 140 MW from its current capacity of 60 MW by 2020. Following this are two additional upgrades taking the plant total generation capacity to first 290 MW by 2023 and then to 540 MW by 2027. Plans also include a desalination component with a capacity of a further 30 MCM of water for Gaza. The G4G project is backed by the governments of the Netherlands and Qatar and is officially supported by the government of Israel. A Technical Feasibility Study was launched in 2015 and a possible pipeline route identified. If all goes according to plan the gas could be flowing into Gaza by 2019-20 (Office of the Quartet 2016). There is hope also that at some point gas supplies in Gaza will also be enhanced by the development of the Gaza Marine gas field of the coast of Gaza Strip.

A similar project to provide gas to the West Bank is currently under planning along with the first conventional power station in the West Bank, a 450 MW gas power plant to be built in the north town of Jenin. The Jenin Power Plant project is approved in principle by the government of Israel and is currently underway, with power generation expected to commence at the beginning of 2020 (Office of the Quartet 2016).

The Gaza Electricity Network Rehabilitation Project aims to expand electricity networks in Gaza to improve reliability and performance, with the objectives of rehabilitating medium and low voltage networks, improving network supply, and increasing collection (World Bank 2016). Additionally, plans to construct a 220kV transmission network in Gaza with two substations in addition to the substation in the Gaza Power Plant would alleviate the Israel Electric Corporation constraint on supplying sufficient electricity for potential demand (UNISPAL 2007, PEA 2016). Section 3 presents an analysis of the vulnerability of the current Gaza Strip electricity distribution network, provided as a case study of a methodology capable of providing evidence for where to locate such substations in order to increase the resilience of the system.

A similar plan to improve the electricity network in the West Bank, a €45 million 161 kV transmission network with four associated substations was approved for finance by the European Investment Bank in 2005, however little information is available on the progress of this project. Figure 66 shows existing substations and distribution lines in the West Bank and Gaza in relation to population centres, along with proposed transmission line improvements and additional substations.

A recently completed 470 kW photovoltaic solar system in Tubas and a 300 kW system under construction in Jericho should add to energy supplies in these areas. Potential for solar energy production from more future projects is good, particularly in the West Bank, which has greater availability of land for large PV farms, and the use of rooftops for PV installations could in the future efficiently cover a portion of Palestine’s electricity needs (Abu Hamed, Flamm et al. 2012). The Office of the Quartet (2016) has identified approximately fourteen sites potentially suitable for developing commercial-large scale solar PV, amounting to roughly 6.5 km^2. A large solar array to help power the new desalination plant in the Gaza Strip is also under consideration, however land for such an installation in the area is at a premium (Evans 2015).

While solar energy offers the most potential among the renewable energy sectors in Palestine, wind energy generation in the region has also been explored in numerous studies (Shawon, El Chaar et al. 2013, De Meij, Vinuesa et al. 2016, Juaidi, Montoya et al. 2016), with Hebron identified as the most suitable area in the West Bank. Such energy could effectively power small-scale operations such as water pumping from shallow wells (Ibrik 2009).

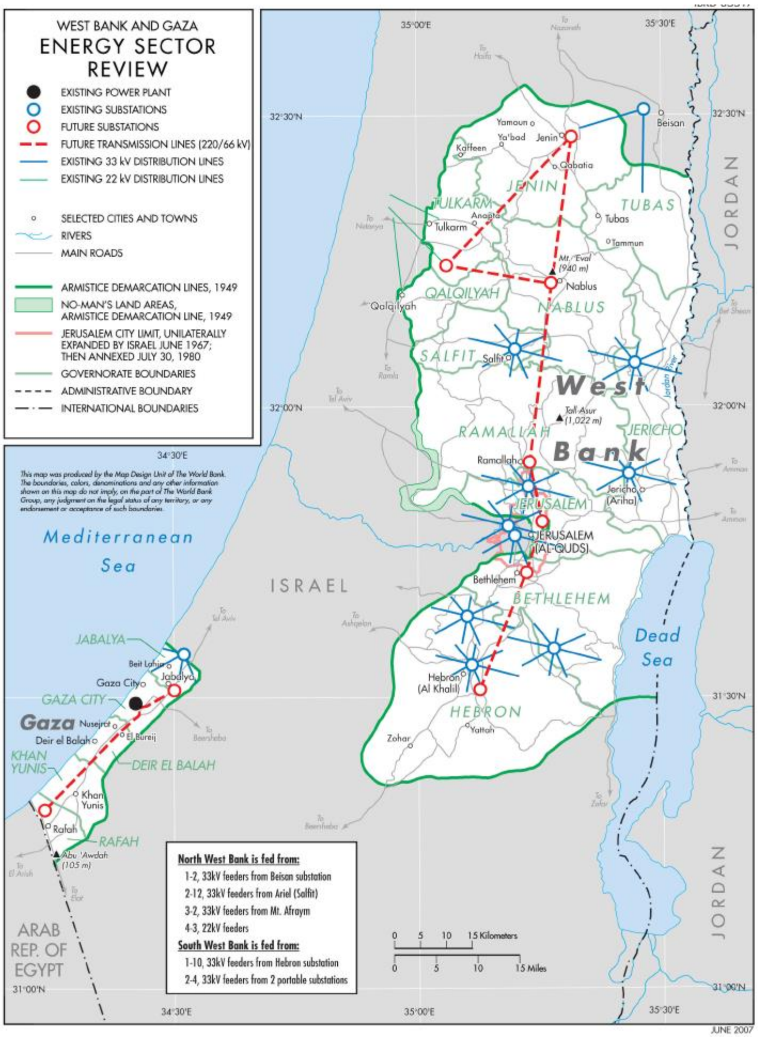

Figure 66: Current and proposed electricity supply system in the West Bank and Gaza (UNISPAL 2007)

7.1.3 Model implementation and assumptions

As outlined in Section 5.1, there are three distinct strategies for future infrastructure provision: 'Status Quo' (SQ), 'Efficiency with Scarcity' (ES) and 'Infrastructure-led Development' (ID). In addition, there are two strategies for comparison: 'No Investment', in which no further infrastructure is added to the current system, and 'Pipeline', in which only those projects identified as currently in progress or with plans in place for construction are completed. These distinct strategies are likely to have a range of effects on infrastructure provision in West Bank and Gaza. The following section gives outputs from a bespoke simplified energy model to provide comparisons between these strategies for energy generation and use, together with associated costs of implementation.

The model estimates changes in demand according to the population growth scenario, and infrastructure assets added to the system according to the strategy being implemented. Initially, these new infrastructure assets are selected from the 'pipeline' of projects. All such projects are included in the ID strategy, as shown in Table 12, while other strategies have a subset of these projects, depending on assumptions of regional stability, investment ambition and technology preference represented in each of the strategies.

Subsequent asset building is regulated within the model by further assumptions on technological change and investment opportunities which differ for each strategy, and which influence the type of infrastructure assets to be added, and at what time intervals new infrastructure becomes available.

As shown in Figure 13, Palestine is far below the average of neighbouring countries in terms of energy per capita usage, and one of the aims of future energy infrastructure provision is to provide enough energy for households and industry to have constant and robust access to energy. The strategies aim to fulfil different aims – for SQ and ES, it is to maintain current (relatively low) levels of per capita energy provision, while for ID the aim is to raise the per capita energy generated to 9000 kWh per year, similar to neighbouring countries. To achieve these aims, different rates and impacts of infrastructure provision are implemented. For simplicity, additional CCGT and Solar PV generation is added to the infrastructure system, and the timings and amount of power added to the system is shown in Table 13. Growth in transport energy and ICT is assumed to increase linearly with population growth.

Table 13: Amount of energy generation added for each alternate strategy (GWh per year) – central growth scenario. Pipe=Infrastructure pipeline, SQ=Status Quo, ES=Efficiency with Scarcity, ID=Infrastructure-led Development

			2020	2025	2030	2035	2040	2045	Total (GWh)
Gaza Strip	Pipe	CCGT	2020	1260	2520				**5800**
		Solar PV	130						**130**
		Imports							
	SQ	CCGT			840			840	**1680**
		Solar PV	130			880			**1010**
		Imports	660	660	660	660	660	660	**3960**
	ES	CCGT	1180	840	840			840	**3700**
		Solar PV	130			880			**1010**
		Imports	330	330	330	330	330	330	**1980**
	ID	CCGT	1180	8220	11340		7560		**28300**
		Solar PV	845	750			1930		**3525**
		Imports	330	330	330	330	330	330	**1980**
West Bank	Pipe	CCGT	3780	1680					**5460**
		Solar PV	200	550					**750**
		Imports							
	SQ	CCGT	3780		840	840	840	2520	**8820**
		Solar PV	30			1740	1740	1740	**5250**
		Imports	790	790	790	790	790	790	**4740**
	ES	CCGT	3780						**3780**
		Solar PV	200		1690	3550	1970	4130	**11540**
		Imports	525	525	525	525	525	525	**3150**
	ID	CCGT	3780	1680	15120		7560		**28140**
		Solar PV		550	1750		7585		**9885**
		Imports	660	660	660	660	660	660	**3960**

In the baseline year (2015), the energy generation mix is determined by official figures (PCBS 2015) to be broken up as follows: electricity derived from fossil fuels 25%; fossil fuels 62%; solar PV 4%; other 10%. In future years the quantity of energy imported is used to match any shortfall in energy requirements for meeting the general goals of each strategy (i.e. maintaining current energy use per capita for SQ and ES and meeting the 9,000 kWh/person/day target for ID). The resultant annual increase in electricity imports for each of the regions and strategies are shown in Table 13. The most important differences shown are the higher requirements for imports in Gaza Strip for the Status Quo and the higher reliance on import for the Status Quo strategy in general over the other two strategies.

As discussed in Section 2.2.2, Gaza's Eastern Mediterranean coastal aquifer is currently being used at an unsustainably high level. One of the restrictions on this energy model is that the Coastal Aquifer is brought within 10 years to sustainable use (65 MCM p.a. (PWA 2011)); any additional water requirements for population growth or interdependences, such as cooling water for newly built CCGT plants, are assumed to come from other sources, such as desalination, which have additional energy demands. Restrictions were placed on the amount of land available for Solar PV in Gaza Strip (Evans 2015).

Obtaining energy from the conversion and treatment of solid waste and biomass by-products of wastewater treatment is also assumed to contribute to ES and ID strategies, although the amount of energy derived from such treatment is limited compared with other conventional sources.

7.1.4 Model results

Figure 67 and Figure 68 show the resultant energy supplied for each of the strategies in Gaza Strip and West Bank, together with the expected demand (central growth scenario) if per capita demand is unchanged. Both Status Quo and Efficiency with Scarcity strategies continue to provide enough energy to maintain current demand profiles. Limiting energy generation to only those projects identified in the 'pipeline' would result in energy supplies falling below current per capita levels as population increases. The decline in energy generation in the pipeline for Gaza in 2042 is due to the original Gaza Power Plant reaching its expected 40 year expiry having been built originally in 2002.

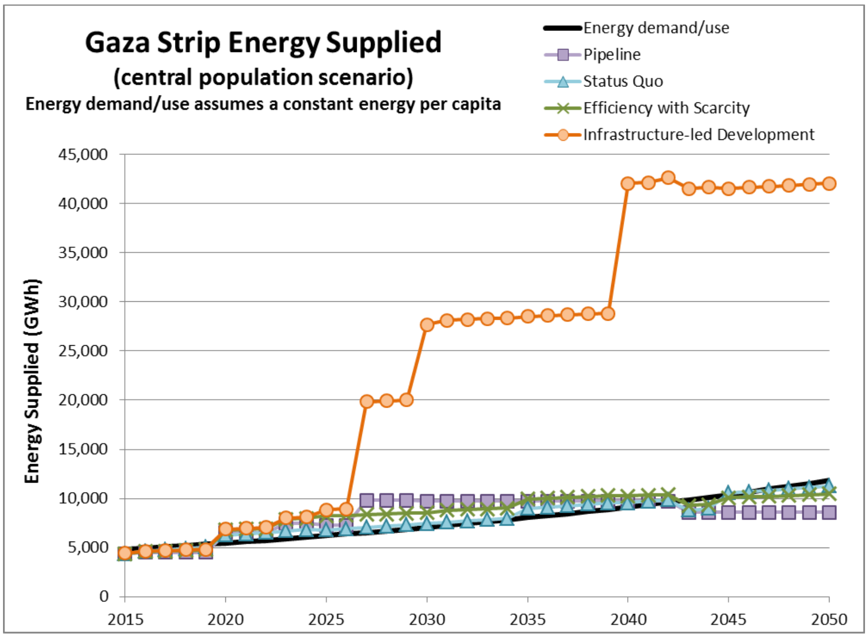

Figure 67: Energy supply (GWh), Gaza Strip (2015-2050, central growth, all strategies)

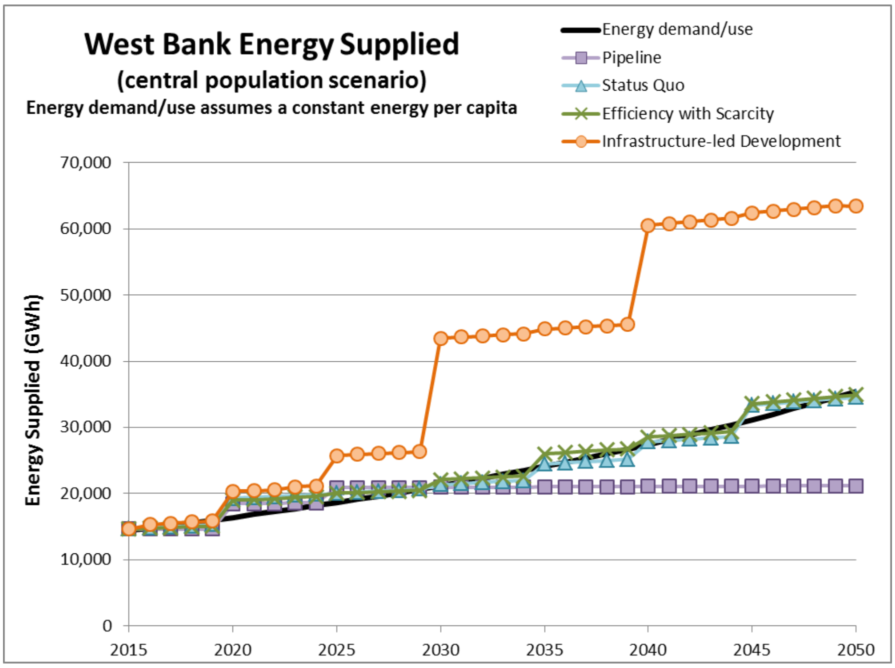

Figure 68: Energy supply (GWh), West Bank (2015-2050, central growth, all strategies)

In terms of per capita energy provision, the resultant energy supplied only increases for the Infrastructure-led Development strategy; extra demands resulting from population growth eventually outweigh any additional energy generation for all other strategies, as shown in Figure 69 and Figure 70. For the ID strategy with central growth, the average per capita energy increases in Gaza Strip substantially in 2025, as 8220 GWh of CCGT energy is added to the system. The 9000 kWh target per capita energy supply is initially met in 2030 in Gaza and West Bank, but population increase means that it soon falls below the target, until the next investment in infrastructure is implemented.

For the Balanced Prosperity (low population growth) scenario, assuming the same level of infrastructure investments for each strategy, the per capita targets are exceeded for the ID strategy in 2030 for both Gaza and West Bank, and there a fewer investments needed beyond these dates to maintain that level. Conversely, for the Unstable Adversity (high population growth) scenario, the same level of investment provides around 7,000 kWh per capita rather than reaching the 9,000 kWh target. To achieve that target by 2050 requires the provision of an extra 12,000 GWh in Gaza, and 19,000 GWh in West Bank. To achieve such outputs would require significantly higher investments as well as more land and water than the Gaza Strip might be able to provide.

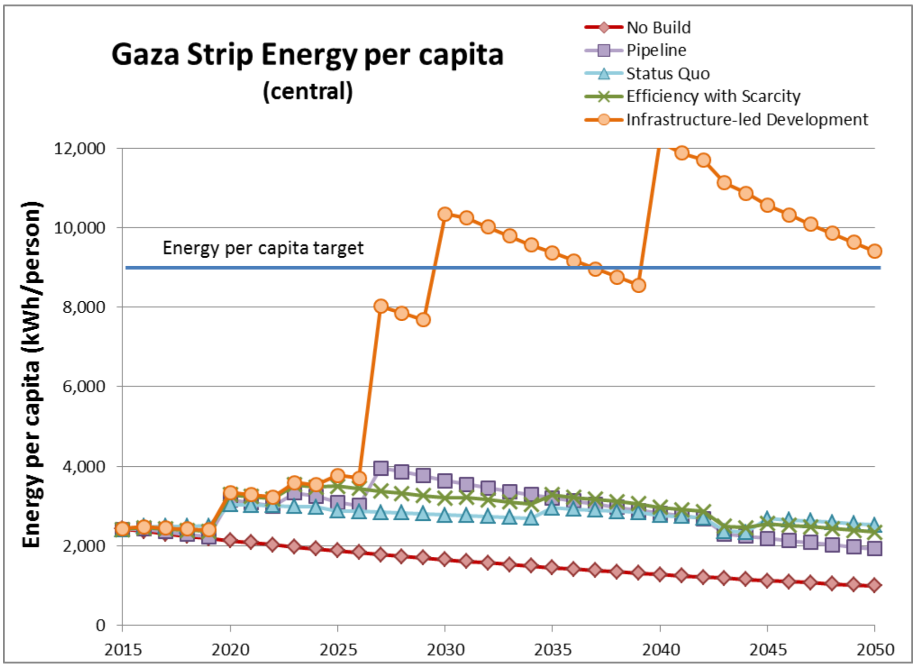

Figure 69: Energy supplied per capita (kWh/person), Gaza Strip (2015-2050, central growth, all strategies)

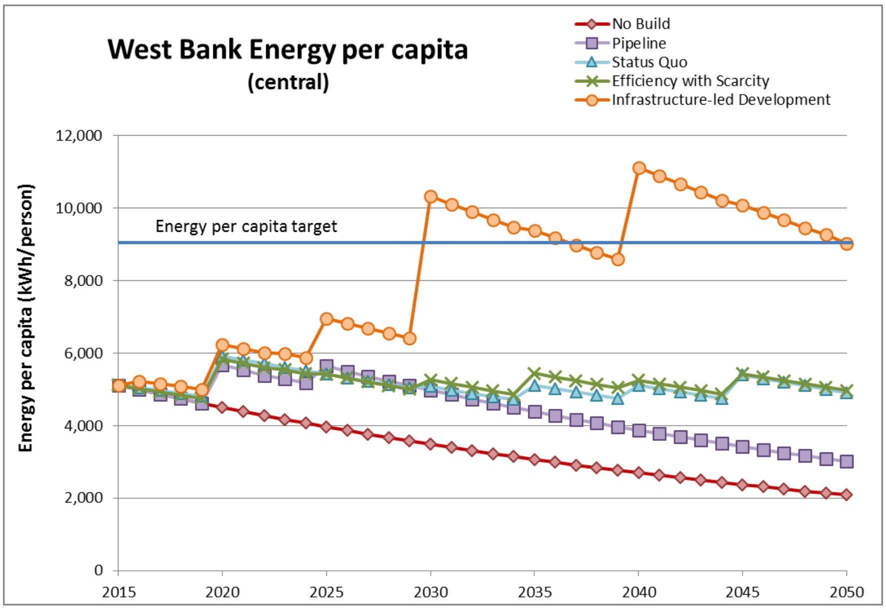

Figure 70: Energy supplied per capita (kWh/person), West Bank (2015-2050, central growth, all strategies)

The resultant energy mix for Gaza Strip and West Bank for each of the strategies is shown in Figure 71. The ID strategy has the most growth in electricity from fossil fuel sources, as CCGT plants are built and imports increase, although there is also large growth in local solar PV, particularly in West Bank. While ES and SQ strategies result in similar amounts of energy generated, there is more solar PV in West Bank for the ES strategy, as the focus is on more efficient local solutions reducing reliance on imports of electricity and fuels.

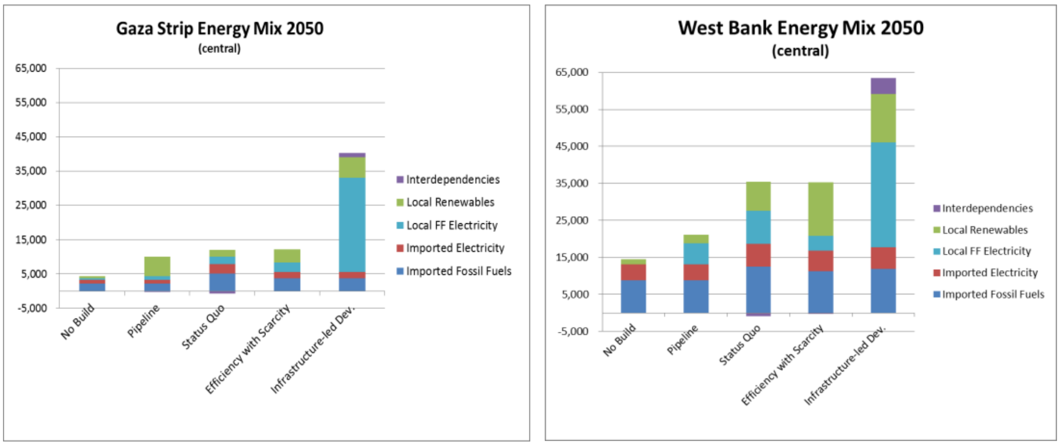

Figure 71: Energy generation mix (GWh), for Gaza and West Bank in 2050 (central scenario)

There are obviously cost implications of building more infrastructure, as shown in Figure 72; the extra energy generated in the ID strategy costs approximately twice as much as the ES and SQ strategies for central growth[7].

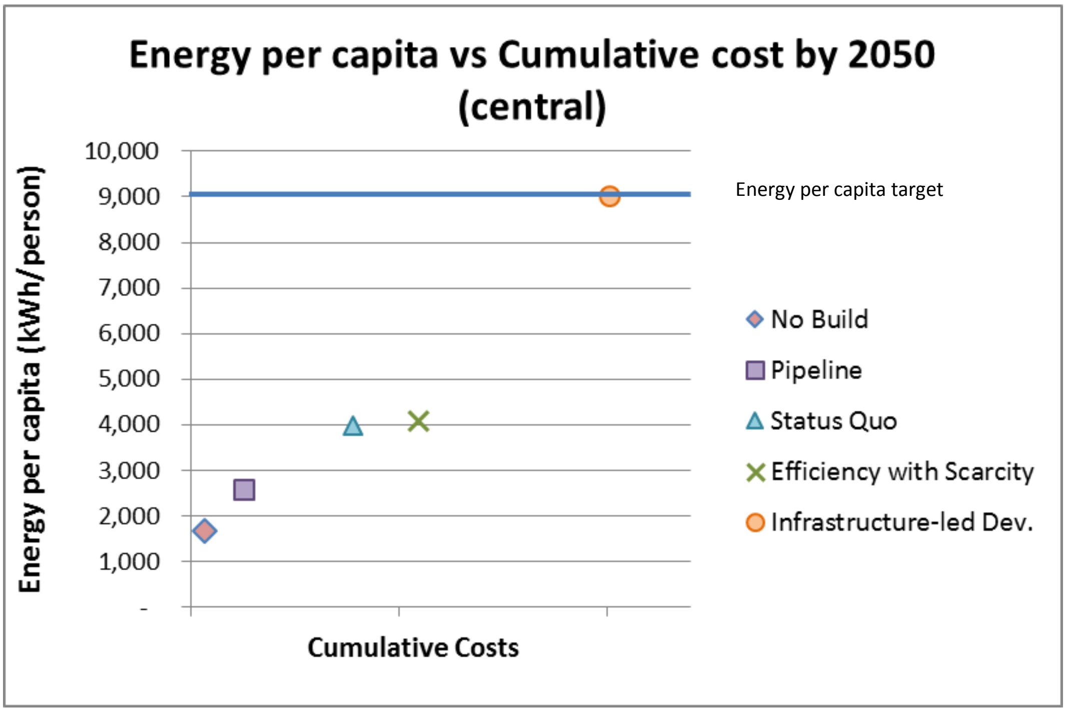

Figure 72: Relative cumulative costs by 2050 of the range of energy per capita provision strategies (kWh/person)

One noteworthy problem associated with each of the large thermoelectric gas turbine projects in the pipeline for both Gaza and the West Bank is the need for large quantities of cooling water in their electricity generation. A gas turbine plant requires around 2.27 CM of water for each MWh of electricity it generates. If we assume that only 25% of this water demand is effectively consumptive (i.e. it directly effects water availability) the completed Gas 4 Gaza 540 MW of electricity generation will remove at least

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[7] No actual cost figures are given in this report. It should be noted that costs in the model are based on estimated pipeline project costs where data is available, or estimated from the U.K. Institution of Civil Engineering infrastructure cost data. Not all operating costs could be estimated. Thus any estimated costs are likely to be indicatory only.

3 MCM of water each year from the water available in the Gaza Strip. With all the thermoelectric power plants included in the ID strategy the demand for cooling water rises to around 30 MCM per year by 2050. Such amounts present serious limits to such solutions and are thus included as part of the calculated interdependencies in the Water supply sector modelling in Section 7.2 below.

7.2 Water supply sector

7.2.1 Future challenges

In the West Bank, the Palestinian Water Authority (PWA 2014) estimates that public water demand (including domestic, municipal, and industrial) will nearly triple from 2012 to 2032, increasing from 105 to 394 million m^3. This is based on a number of assumptions, including a high but slowed population growth rate of 3.5%, a rise in per capita demand to 120 litres/capita/day by 2032, and an increase in water demand by industry from 3 to 10%. These increases are expected to be tempered somewhat by a planned reduction in unaccounted-for water to 20% through investment in transmission and distribution networks, and increases in treated wastewater use and reliability of supply.

Figure 73 plots projected water demand for Palestine to 2050 under our three scenarios, using a) per capita demand based on current provision levels; and b) per capita demand using the upper boundary of the WHO’s recommended per capita water allocation (100 litres/day) for domestic consumption as a minimum provision. Domestic allocation includes commercial and industrial uses, while a fixed agricultural water allocation of 150 MCM is included in the figures (based on 2014 levels). The estimates presented for water requirements in 2050 under the minimum WHO requirements vary widely, ranging from 540 million (low population) to 755 million m^3 (high population). Of note is that the PWA estimates for public water demand given above are higher than even our highest population and per capita water demand projections, which our modelling results below suggest will be an extremely difficult and expensive target to achieve.

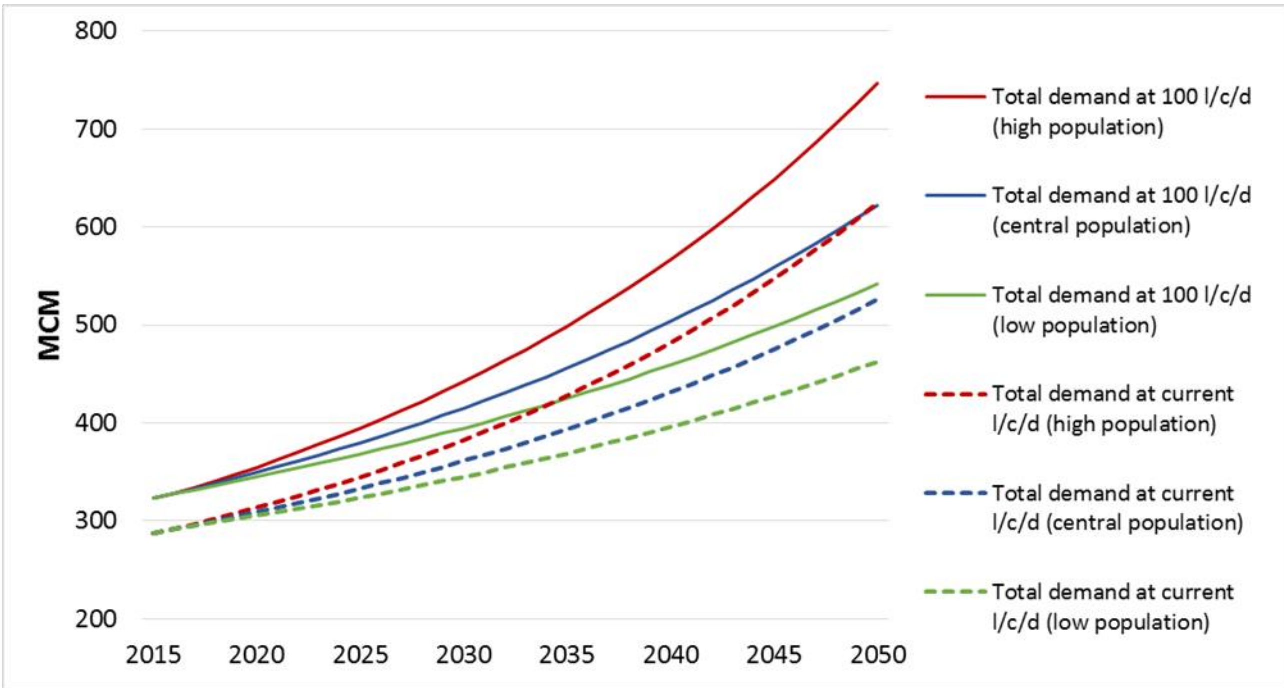

Figure 73: Total water demand (incl. fixed agricultural abstraction) at current and WHO-recommended per capita allocation for three population scenarios, Palestine (UN Human Rights, UN Habitat et al. 2010, PCBS 2014, PCBS 2014, PCBS 2014, PCBS 2016)

7.2.2 Planned 'infrastructure pipeline' investments

In 2011 the Palestinian Water Authority outlined a set of nine interventions to deal with the most immediate crisis in Gaza including the establishment of a specialist coordination unit, a water and health monitoring program, accelerated upgrading of the water distribution and supply network, the introduction of several short-term low-volume desalination units, the introduction of long-term high-volume desalination projects, extension of pilot schemes to reuse treated wastewater, the accelerated completion of wastewater treatment plants in construction and a review of the water use of the agricultural sector in Gaza.

A number of these measures are underway including the deployment of several short-term low-volume desalination units, along with a securement from the government of Israel in 2015 to increase the export of water into Gaza to 10 MCM with possibly a further 10 MCM following this (Office of the Quartet 2016). Plans for a long-awaited 55 MCM/y desalination plant in the north of Gaza are apparently in motion (PWA 2015). This initiative, emphasized as a priority infrastructure project by the PWA, is expected to alleviate the water crises to some degree as well as provide for the rehabilitation of the coastal aquifer through reduced pumping rates, and job creation opportunities for local residents. A strategy also exists to increase and deliver water resources to population centres across the Gaza Strip as part of the desalination project. However, there are concerns as to whether this facility will be built in time to save the aquifer from seawater inundation and whether an energy source can be secured given the energy problems already present in the region. The desalination plant will need around 25 MW installed power, about 10% of which could possibly be generated by on-site Photovoltaic cells (peak load) (PWA 2015).

The Strategic Water Resources and Transmission Plan (PWA 2014) examines the implementation of water reallocation and transmission within the West Bank that has been proposed by the PWA as part of their long-term national plan (2017-2032). Given the water quantities available for reallocation or conveyance between governorates (Table 14), three solutions for water delivery infrastructure are outlined: 1) reallocation, 2) full conveyance, or 3) combination alternatives.

Table 14: Quantities available for reallocation or conveyance between governorates (MCM/year) (PWA 2014)

Year	From	To	Quantity (MCM/year)
2017	Bethlehem	Jerusalem	3.5
2022			23.5
2027			15
2032			14
2017	Ramallah	Jerusalem	4
2017	Qalqilla	Salfit	1.5
2027	Qalqilla	Nablus	9
2032			9
2027	Jericho	Ramallah	9
2032			9
2027	Tubas	Jenin	8
2032	Salfit	Nablus	3
2017	Tulkarm	Jenin	3.9
2032	Jericho	Hebron	20
2027	Jenin (J.R.B.)	Tubas, Nablus, Tulkarm, Salfit	50 from source
2032			

Alternative 1 suggests reallocation whenever possible between water resources while minimizing conveyance between governorates. The concept of reallocation involves reallocating abstraction from one sector, such as agriculture to another, or reallocating water abstraction licences from one governorate to another e.g. drilling a 2 MCM/year well in Nablus Governorate instead of a planned 2 MCM/year groundwater well in the Western Aquifer in the Tulkarm governorate. This will obviously depend on the existing hydro-geological conditions but it is the most cost effective option, and would minimize water transmission losses, pumping, and the potential for pollution. This option is however considered the least flexible option and would rely on uncertain groundwater resource development in certain locations, Israeli approval for basin reallocation, and the need for new well drilling. The options available in alternative 2 are estimated to be the most costly as they involve the construction of conveyance infrastructure between water resources in the West Bank to maximize the potential for movement of water between governorates. This option would involve less uncertainty in groundwater resources while offering a flexible option to allocate water between governorates in case of changes in planning options. On the other hand, it would require construction of conveyance systems in Israel-administered Area C, and would involve large transmission distances, which increase physical losses and potential pollution. Alternative 3 forms the basis of the PWA's transmission plan, and requires the development of a combination of systems to allow for both water conveyance and reallocation where it is reasonable to do so. This would provide the most practical solution by balancing the trade-offs of the other two options (PWA 2014).

A map of the demands for water and quantities available for movement between the various governorates is presented in Figure 74 showing the potential for solutions through the above alternative abstraction options.

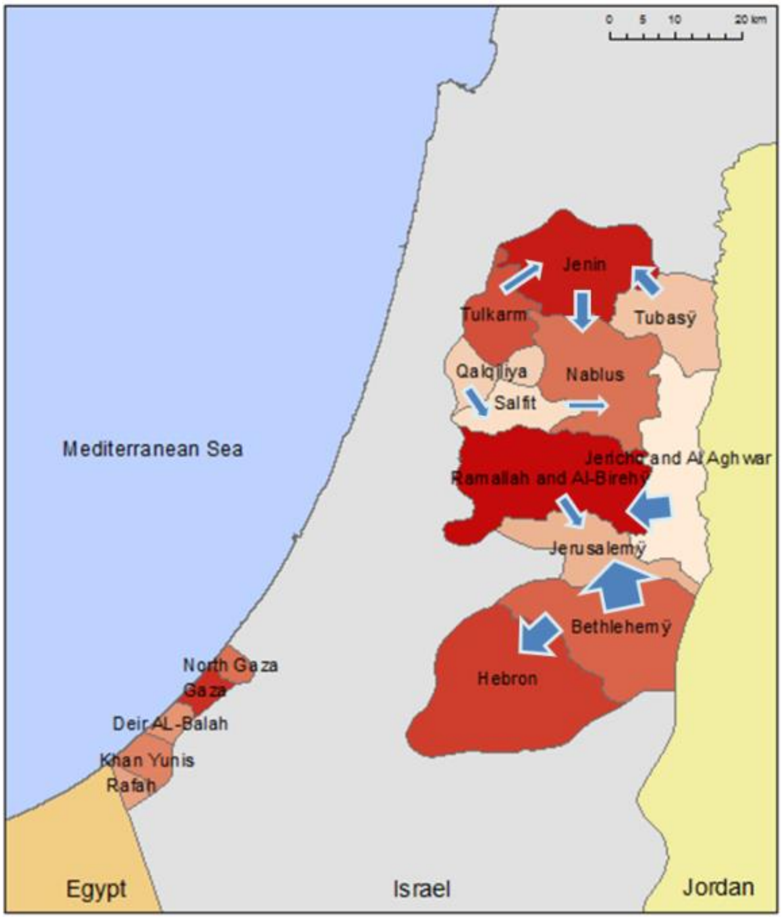

Figure 74: A geographical representation of the water quantities available for movement/shifting between governorates (blue arrows) against a background of relative water demand with darker red representing higher demand for water

7.2.3 Model implementation and assumptions

A similar model is used for assessing future strategies for water supply as described for energy in Section 7.1.3, with a 2015 baseline for demand and supply, a demand profile changing dependent on the socio-economic scenario, and water supply options either already in the pipeline or included in one of the 3 alternative strategies. For this simplified model, the options for increasing the supply of water within Palestine are limited to increasing imports, building new desalination capacity and reducing leakage. A common constraint on all strategies is to restrict the abstractions of water from the Coastal Aquifer under the Gaza Strip to a sustainable level (i.e. 65 MCM per year) by 2025 in order to avoid complete collapse of the aquifer.

Table 15 shows the resultant additional water supply added for each of the strategies in Gaza and the West Bank by source. Once again the pipeline projects are added depending on the assumptions for each of the strategies (Table 12), such that all pipeline projects are included in the ID strategy, while only a subset of the projects are included in ES and SQ strategies.

Table 15: Water supply provision added within each strategy by source (MCM per year) – central growth scenario. Pipe=Infrastructure pipeline, SQ=Status Quo, ES=Efficiency with Scarcity, ID=Infrastructure-led Development

			2020	2025	2030	2035	2040	2045	Total (MCM)
Gaza Strip	Pipe	Desalination	7	55	30				**92**
		Leakage reduction							
		Imports	15						**15**
	SQ	Desalination	27	60	40	60	40	80	**307**
		Leakage reduction	10						**10**
		Imports	18	14	14	14	14	14	**88**
	ES	Desalination	27	155		40	40	80	**342**
		Leakage reduction	10		5		5		**20**
		Imports	20	9	9	9	9	9	**65**
	ID	Desalination	40	175	40	40	100	60	**455**
		Leakage reduction	10		5		5	10	**30**
		Imports	20	9	9	9	9	9	**65**
West Bank	Pipe	Desalination							
		Leakage reduction							
		Imports				16			**16**
	SQ	Desalination		20	20	40	40	60	**180**
		Leakage reduction	10						**10**
		Imports	4	4	4	4	4	4	**24**
	ES	Desalination		20	20	20	20	40	**120**
		Leakage reduction	10		5		5		**20**
		Imports	3	3	3	3	3	3	**18**
	ID	Desalination		20	20	40	60		**140**
		Leakage reduction	10	5			5	5	**25**
		Imports	3	3	3	3	3	3	**18**

Water demand assumptions in the baseline year (2015) are as follows in Gaza: industrial use is set at 1 MCM per year; use for agriculture is 95 MCM per year, increasing at the same rate as population growth; domestic use is 66 MCM per year given an average 100 litres per person per day. For West Bank, these assumptions are as follows: industrial use is set at 1 MCM per year; agriculture requires 57 MCM per year, increasing at the same rate as population growth; and domestic use is 104 MCM per year. Note that while domestic use of water is lower in total for Gaza than West Bank, there is a higher demand for water in agricultural use in Gaza Strip, as set out in the PCBS water balance tables for use of water abstracted from wells, resulting in similar annual water demand in both Gaza Strip and West Bank.

7.2.4 Model results

How the different strategies are assumed to affect water supply is shown in Figure 75 and Figure 76, compared with the estimated demand profile for the central growth scenario (with an assumed constant 100 litres per capita per day for domestic consumption).

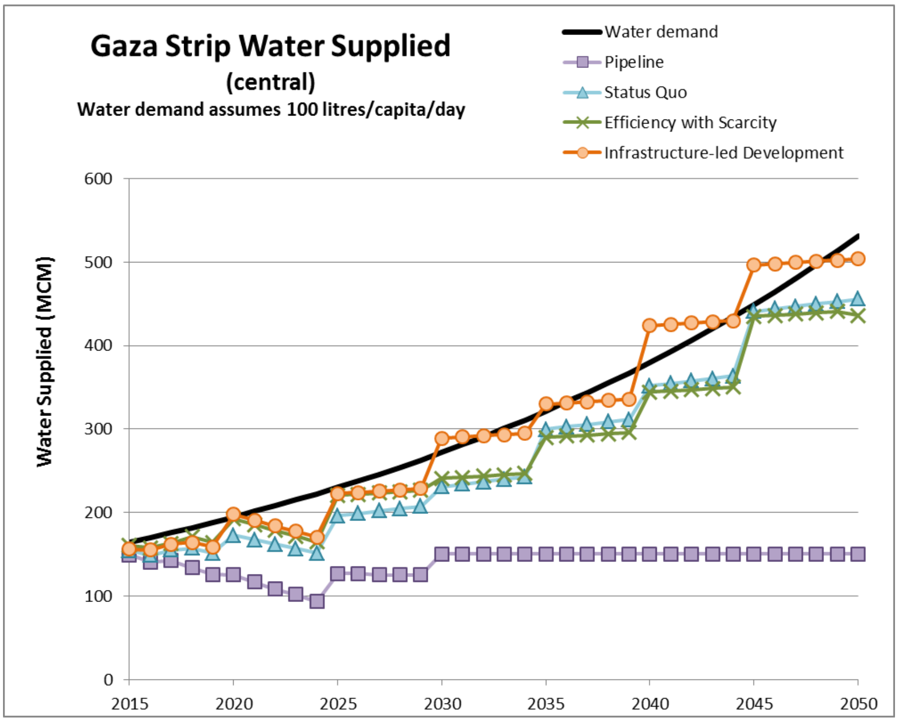

Figure 75: Water supply (MCM), Gaza Strip (2015-2050, central growth, all strategies)

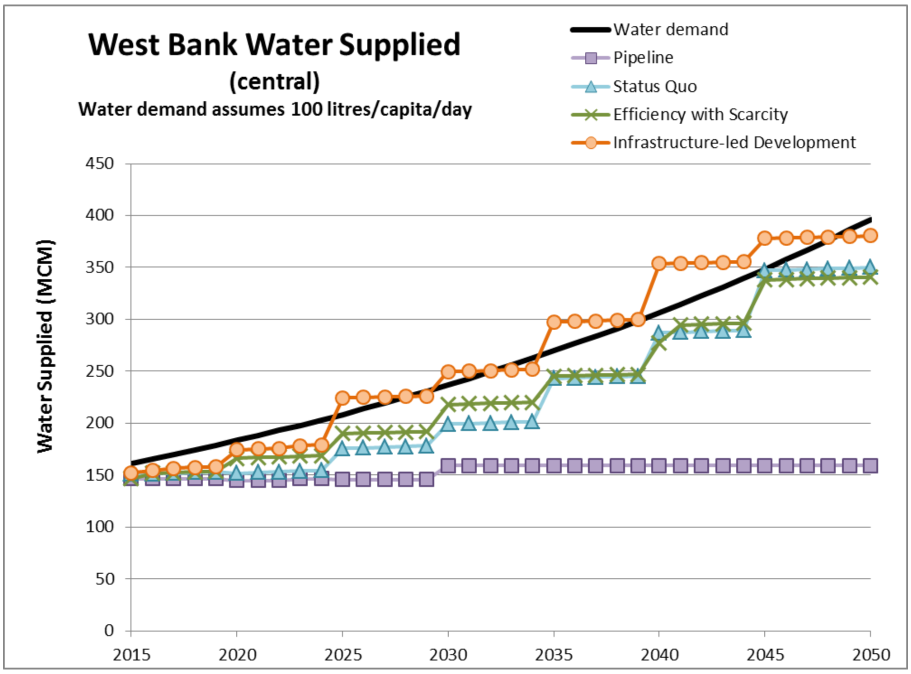

Figure 76: Water supply (MCM), West Bank (2015-2050, central growth, all strategies)

In terms of per capita water provision, the ID strategy provides the higher quantities of water, while meeting the 100 l/c/d target. In Gaza Strip particularly, there are ongoing problems of water supply, as population growth continues to place higher demand than can be supplied through additional desalination plants as shown in Figure 78. There are few differences between the alternate strategies in Gaza, as the options are limited for additional supply. In West Bank, however, the ID strategy does achieve the 100 l/c/d target by 2050 when new infrastructure is added to the system. For this study we assume that no more abstractions can be made from West Bank aquifers but this is not necessarily accurate.

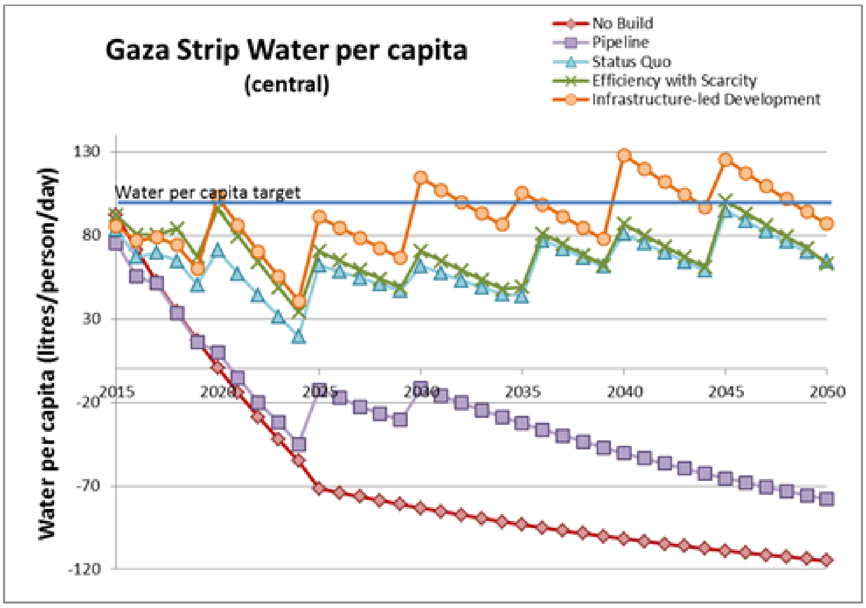

Figure 77: Water supplied per capita (litres/person/day), Gaza Strip (2015-2050, central growth, all strategies)

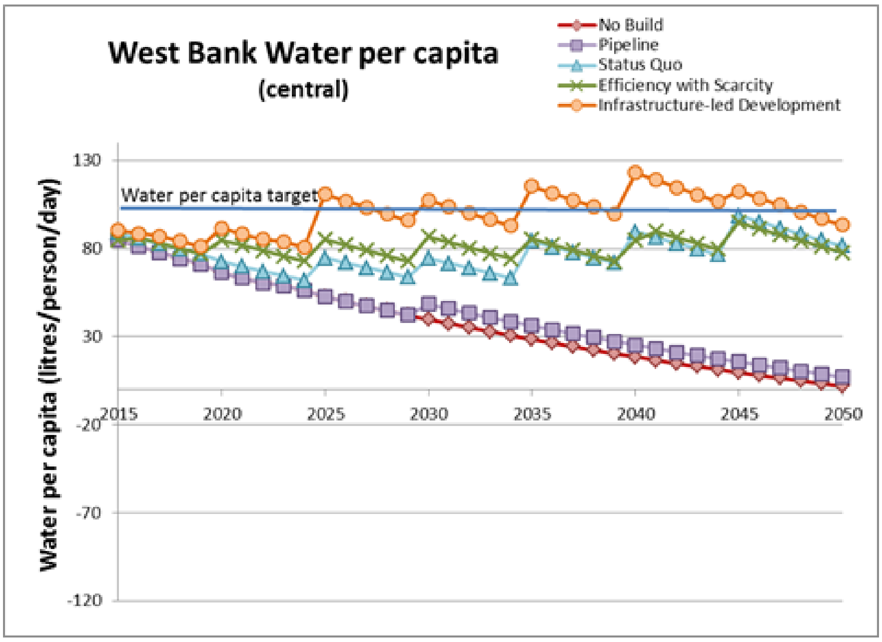

Figure 78: Water supplied per capita (litres/person/day), West Bank (2015-2050, central growth, all strategies)

For the Balanced Prosperity (low population growth) scenario, water supply per capita in Gaza exceeds the 100 l/c/d WHO minimum for each of the three strategies by 2040. For the Unstable Adversity (high population growth) scenario, water supply levels in Gaza fall to less than 30 l/c/d by 2050 for all strategies, and so continued pressures of population growth would imply much more investment would be required.

As shown in Figure 79, there is substantial reliance on desalination to provide future water supplies, which may not be feasible in the current political environment. However, it is important to recognise the limitations that will be imposed on aquifers and rivers if such sources are not supplied. Further reliance on imports may be required to meet higher per capita demands. The Efficiency with Scarcity strategy gains more water from wastewater re-use. These gains are lost to some degree in the Infrastructure-led development strategy due to interdependencies with energy, demands for CCGT cooling water, which creates additional strain on the water supply network.

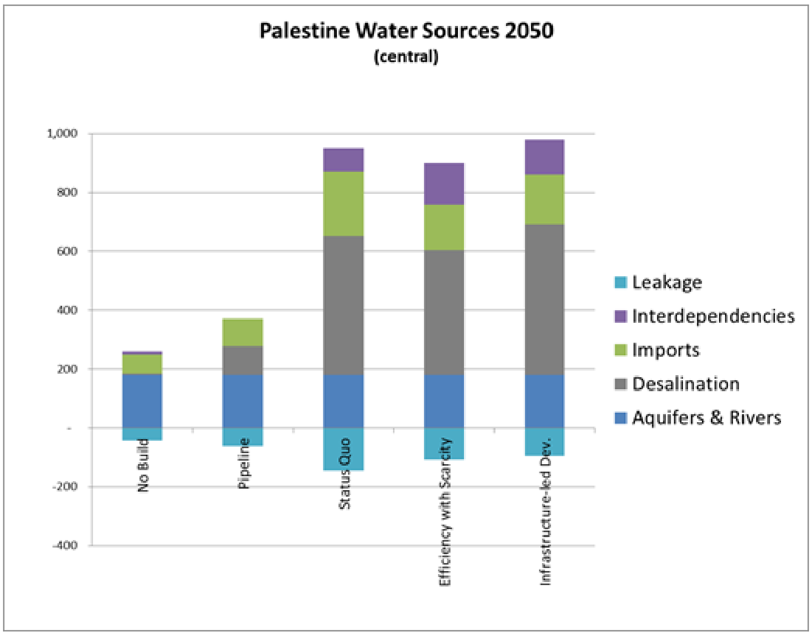

Figure 79: Water sources and losses for Palestine (MCM), 2050 (all strategies)

7.3 Wastewater sector

7.3.1 Future challenges

The need for wastewater treatment and disposal will increase with the growth of the Palestinian population and improved network connection. With annual per capita wastewater production currently estimated at around 27 m^3 (PWA 2012), Figure 80 projects future levels based on the high, central, and low population growth scenarios, with results ranging from 285 to around 435 million m^3 of wastewater produced annually.

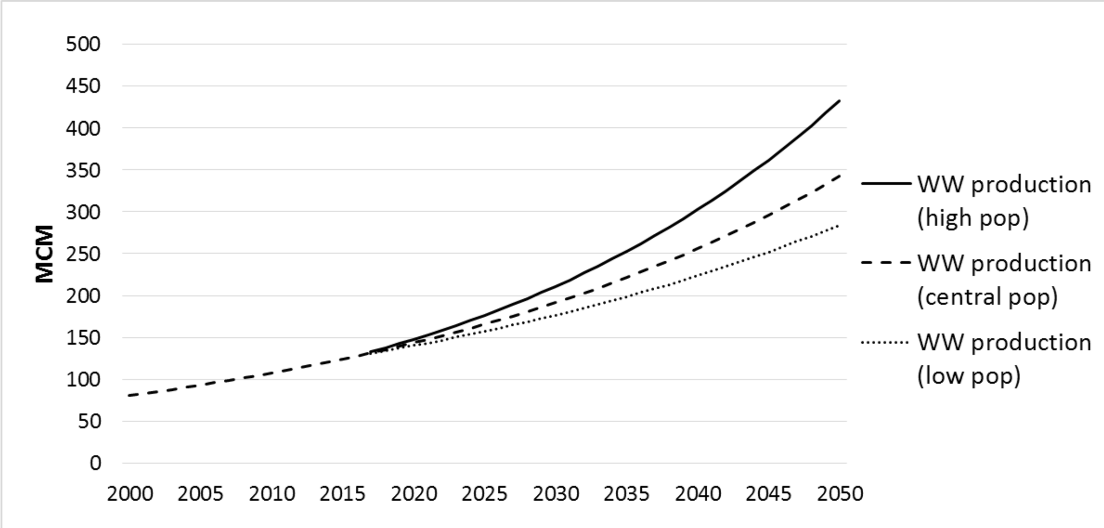

Figure 80: Projected wastewater production (MCM) based on current levels of production per capita (PWA 2012)

7.3.2 Planned 'infrastructure pipeline' investments

The process of wastewater reuse is less energy intensive and requires fewer resources than other costly processes such as desalination or even water abstraction given the water scarcity of the region (Siddiqi and Anadon 2011). Increased wastewater treatment and reuse capacity will provide a host of benefits to the region and have the potential to address multiple issues related to water security in the Palestinian territories (Eting 2015). These include increased water supply for multiple uses, decreased demand for fresh water, reduced environmental impacts, improved health, and less reliance on imported water sources, including 'virtual water' as an input to food (Gilmont 2015). This increased self-sufficiency could form part of the solution towards greater political and economic stability, and contribute to regional water security.

As of 2011, there were 27 projects with committed funding by external donors, both public and private, to improve wastewater collection, reuse, treatment, and capacity building. These projects, both in the West Bank and Gaza, were at varying stages of design and implementation (PWA 2012).

Figure 81 shows the status of connections to the sewage network in the West Bank, including existing central and collective WWTPs and wadis. Additional water treatment plants are planned in Jericho, Hebron, and Nablus East.

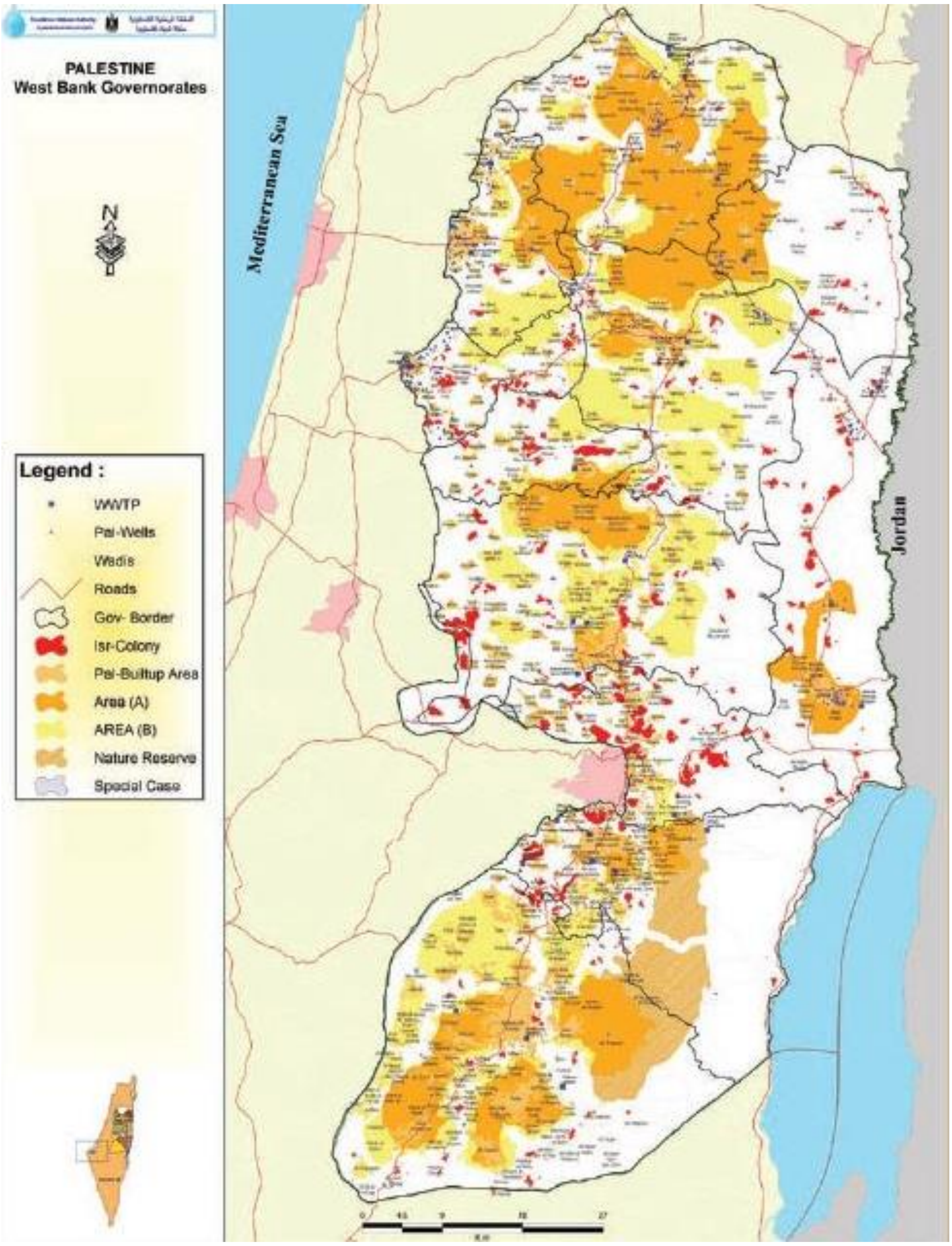

Figure 81: Status of Connections to Sewage Network in the West Bank (PWA 2012)

Figure 82 below provides a map of the existing and planned wastewater treatment plants in Gaza.

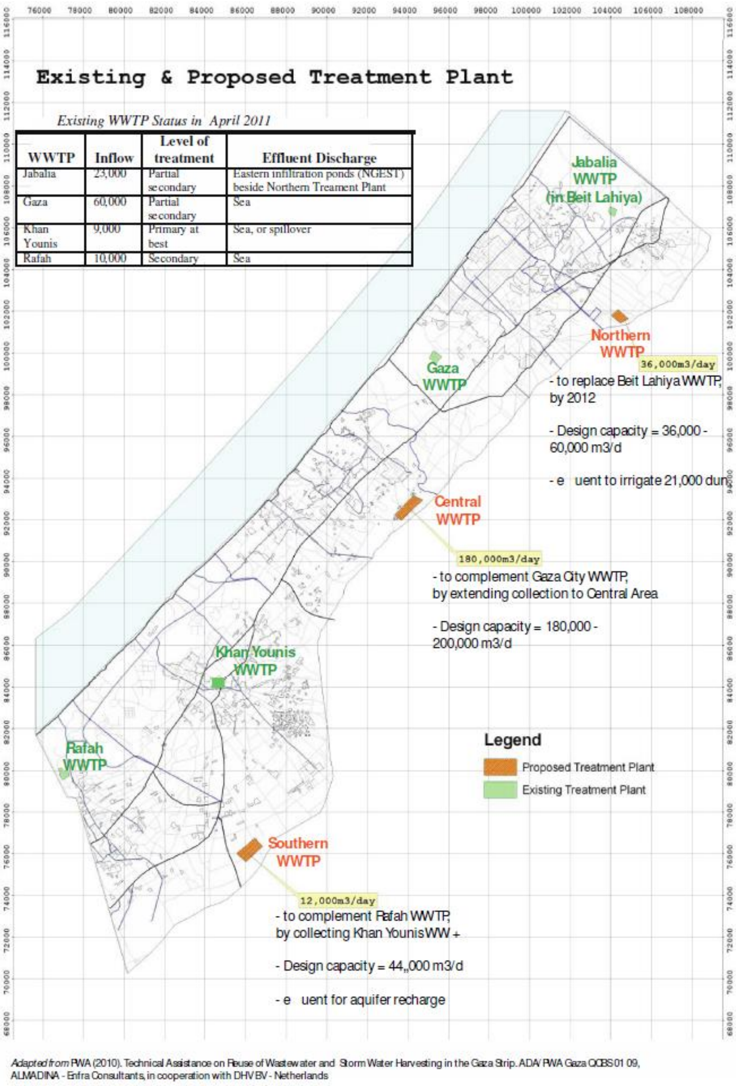

Figure 82: Existing and future WWTPs in the Gaza Strip (PWA 2011)

7.3.3 Model implementation and assumptions

Once again a similar model is used for assessing future strategies for wastewater supply as described above for the energy and water sectors. The model uses a 2015 baseline for the amount of wastewater generated, and the treatment capacity, with the profile of both metrics changing dependent on the socio-economic scenario, and wastewater treatment options either already in the pipeline or included in one of the 3 alternative strategies as stipulated in Table 12. For this model, the options for increasing the wastewater treatment capability within Palestine is limited to increasing the efficiency of current treatment plants which are overburdened (i.e. WWTP Repairs), and building new Anaerobic Digestion capacity (New WWTPs). These additional treatment capacities are shown in Table 16. Given the documented need for upgrades and repairs to existing WWTP facilities (Isaac and Rishmawi 2015) it was decided that the two more progressive strategies (ES and ID) should include an attempt to repair these facilities with the ID strategy repairing the facilities at the faster rate.

Table 16: Wastewater treatment capacity provision added within each strategy (MCM per year) – central growth scenario. Pipe=Infrastructure pipeline, SQ=Status Quo, ES=Efficiency with Scarcity, ID=Infrastructure-led Development

			2020	2025	2030	2035	2040	2045	Total (MCM)
Gaza Strip	Pipe	WWTP Repairs							
		New WWTPs	34		65				**99**
	SQ	WWTP Repairs							**0**
		New WWTPs	18	10	10	10	20	30	**98**
	ES	WWTP Repairs	12	12					**24**
		New WWTPs	34		10	10	20	20	**94**
	ID	WWTP Repairs	24						**24**
		New WWTPs	34	20	65			20	**139**
West Bank	Pipe	WWTP Repairs							
		New WWTPs		6					**6**
	SQ	WWTP Repairs							**0**
		New WWTPs		10	10	20	20	20	**80**
	ES	WWTP Repairs	12	1					**13**
		New WWTPs		10	10	20	20	20	**80**
	ID	WWTP Repairs	13						**13**
		New WWTPs	20	60		30		30	**140**

7.3.4 Model results

How the different strategies are assumed to affect wastewater treatment capacity is shown in Figure 83 and Figure 84. As shown in Table 16, there are three proposed new treatment plants in Gaza Strip, including a Central WWTP with a design capacity of 65 MCM, which is assumed to become available in 2030 (Figure 83). This WWTP has a significant effect on the treatment capacity in Gaza Strip, such that the pipeline projects supply enough extra treatment capacity for the extra wastewater expected to be generated as a result of central population growth. If this large treatment plant is not constructed, additional smaller treatment capacity needs to be added to the system. Note that this simplistic model assumes that new WWTP facilities will work at design capacity, and does not account for deterioration and decommissioning of WWTPs in the future, so in reality, there would be a general decrease in treatment capacity over time.

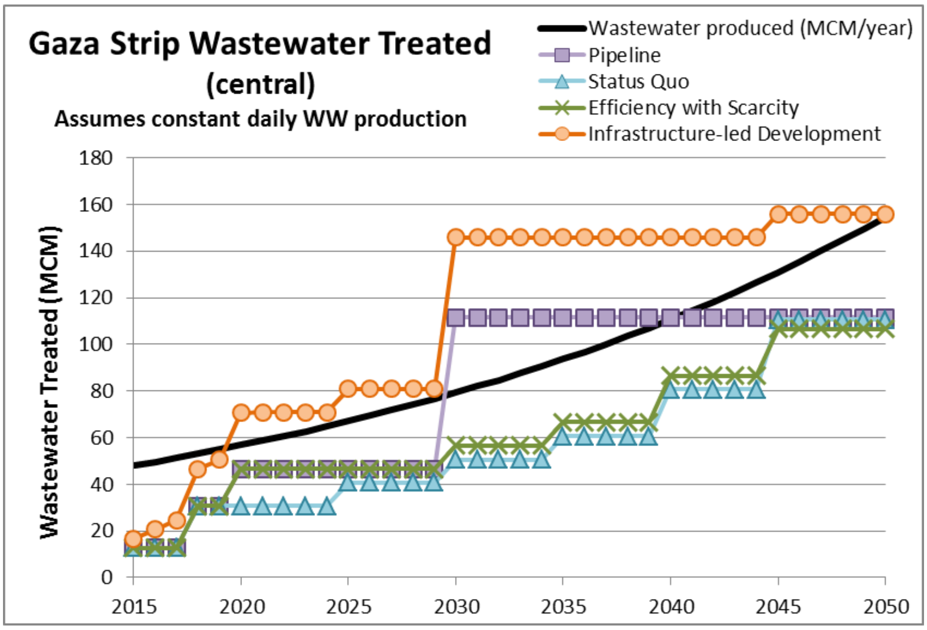

Figure 83: Wastewater treated (MCM), Gaza Strip 2015-2050 (central growth, all strategies)

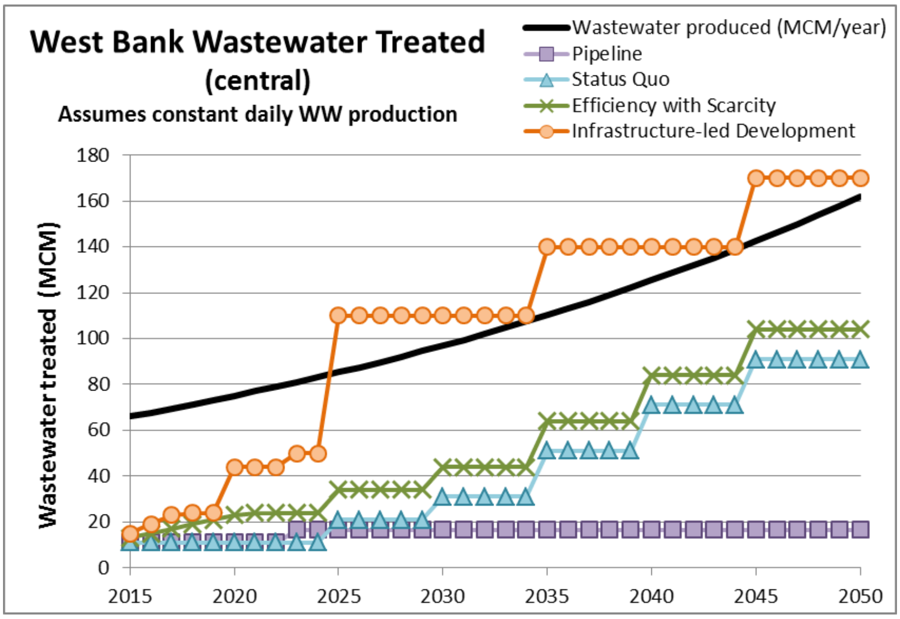

Figure 84: Wastewater treated (MCM), West Bank, 2015-2050 (central growth, all strategies)

The pipeline project proposed for the West Bank, however, only adds an additional 6 MCM treatment capacity to a system which is already failing to meet demand significantly, with only 11 MCM of the 66 MCM generated wastewater being effectively treated. In order to meet future demand for treatment capacity, WWTPs which are currently working far below capacity must be regenerated, and additional WWTP treatment capacity added to the system.

Figure 85 shows the effectiveness of each of the strategies in 2050, for central population growth.

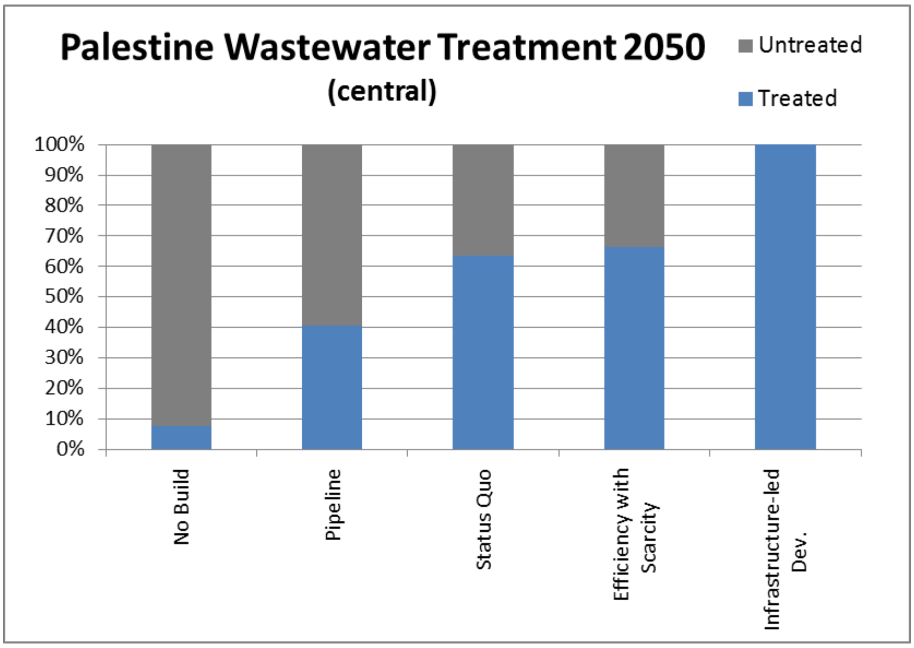

Figure 85: Percentage of wastewater treated in 2050 (central growth, all strategies)

These figures again show how the proposed additional WWTP facilities in the 'pipeline' built in Gaza help to meet additional demand, while such extra treatment capacity is lacking in West Bank. Without the 65 MCM WWTP built in 2030, the pipeline projects in Gaza would exhibit a shortfall of 70 MCM per year.

For the low population growth scenario, all strategies meet the additional demand by 2050 in Gaza, but there is still a deficit in West Bank of 20 MCM per year for ES, and 32 MCM for SQ. For the high growth scenario, these deficits are 109 and 122 MCM respectively, with a deficit of 53 MCM for ID, assuming the same construction profile in West Bank. In Gaza, the high growth scenario results in a treatment capacity shortfall of 19 MCM for ID, 58 MCM for ES, and 64 MCM per year for SQ.

7.4 Solid waste sector

7.4.1 Future challenges

Municipal waste generation is expected to increase substantially due to population growth and urbanisation trends. Figure 86 projects growth in municipal solid waste arisings, including medical, institutional, commercial, and industrial wastes, based on 2012 per capita rates and an annual one percent increase in per capita generation as estimated in (D-Waste 2014), solid waste levels ranging from 3.4 to 5.3 million tons by 2050.

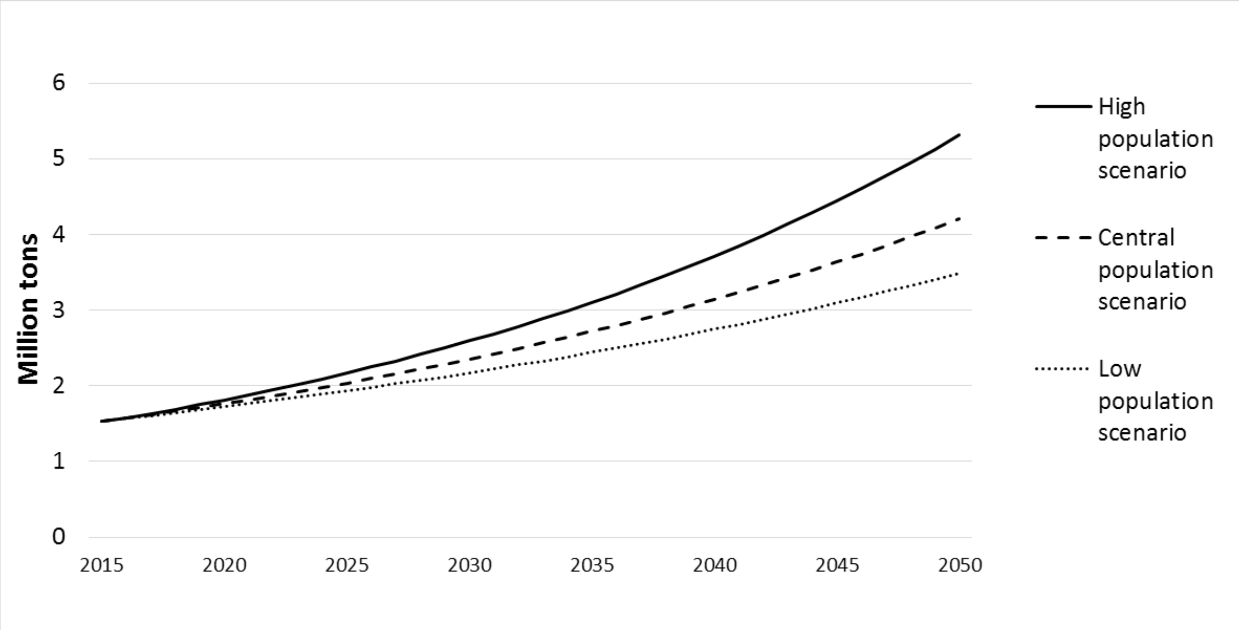

Figure 86: Municipal solid waste generation growth (Mt), 2015-2050 (D-Waste 2014, PCBS 2016)

7.4.2 Planned 'infrastructure pipeline' investments

Responsibilities in the solid waste sector are shared across institutions. While the Ministry of Local Government (MoLG) is the main coordinating agency for solid waste management across Palestine (UNEP 2003) future planning will require the involvement of other institutions: Ministry of Planning, Environmental Quality Authority, Ministry of Health, Palestinian Standards Institute, Palestinian Central Bureau of Statistics, Municipal Development and Lending Fund, Joint Service Councils, and Local Authorities. As of 2014, there were several major projects ongoing, including three major sanitary landfill sites with a combined capacity of 18.8 million cubic meters, closure of dumpsites, and recycling infrastructure at Ramallah/Al-Bireh, Rafah, and the South West Bank. These developments are expected to reduce the overall amount of waste that is openly dumped in Palestine (D-Waste 2014).

Two additional transfer stations are planned to be built in the West Bank, while in the future Gaza is expected to have six operational official transfer stations (D-Waste 2014).

7.4.3 Model implementation and assumptions

The simple model for waste management focuses entirely on municipal solid waste. It uses a 2015 baseline for the amount of waste arisings and an estimated per capita waste production of around 1.2kg per person per day (D-Waste 2014). Treatment capacity requirements change depending on the socio-economic scenario examined, and wastewater treatment options either already in the pipeline or included in one of the 3 alternative strategies as stipulated in Table 12. For this model, the options for increasing the municipal waste treatment capability within Palestine is limited to increasing the building of new sanitary landfill capacity or energy from waste facilities. These additional treatment capacities are shown in Table 17 for each of the strategies and the pipeline. Note that the expiration of landfills necessitates new infrastructure builds which in part explain the increases in investments required after 2035 in all strategies.

Table 17: Municipal waste treatment capacity added within each strategy (Mt per year) – central growth scenario. Pipe=Infrastructure pipeline, SQ=Status Quo, ES=Efficiency with Scarcity, ID=Infrastructure-led Development

			2020	2025	2030	2035	2040	2045	Total (Mt)
Gaza Strip	Pipe	Sanitary Landfill	0.3						**0.3**
		Energy from Waste							
	SQ	Sanitary Landfill		0.4	0.4		0.8	0.8	**2.4**
		Energy from Waste							
	ES	Sanitary Landfill	0.3				1.2		**1.5**
		Energy from Waste		0.6	0.3			0.3	**1.2**
	ID	Sanitary Landfill	0.3						**0.3**
		Energy from Waste		1.2	0.9		0.9		**3**
West Bank	Pipe	Sanitary Landfill	0.5						**0.5**
		Energy from Waste							
	SQ	Sanitary Landfill	0.4	0.4	0.4	0.8	0.4	0.4	**2.8**
		Energy from Waste							
	ES	Sanitary Landfill	0.4	0.4			0.8	0.4	**2**
		Energy from Waste		0.6	0.3				**0.9**
	ID	Sanitary Landfill		0.8		0.8		1.2	**2.8**
		Energy from Waste		0.9	0.9				**1.8**

7.4.4 Model results

The effects of each of the different strategies investments in municipal waste treatment capacity are shown in Figure 83 and Figure 84. There is one major new municipal landfill site in Gaza Strip, with a design capacity of 300,000 tons per year, which is assumed to become available by 2020 (Figure 83). Despite its size this landfill has only limited effect on the treatment capacity in Gaza Strip, as services are already well below requirements. All strategies therefore require significant investments in additional capacity to treat the amounts expected to be generated as a result of central population growth. If this large landfill is not constructed, as shown in the Status Quo strategy, treatment capacity essentially declines to zero by 2025. Note that this simplistic model assumes that all landfill facilities will work at design capacity, and have a 20 year lifetime unless otherwise stated.

Planned investment in solid waste management in West Bank is more in line with future demand requirements but additional investment is each strategy to maintain current levels of percentage of municipal waste treated (SQ and ES) and a 3 fold increase in investment is required by 2030 to treat all waste (ID strategy). Both the ES and ID strategies make use of energy from waste technologies to treat waste. This leads to these two strategies having significantly higher treatment costs but allows for the generation of an additional 1,100 and 2,500 GWh of additional energy in the ES and ID strategies respectively, with the latter amounting to around 2.5% of total energy demand by 2050. Even higher levels of energy from waste are viable under certain assumptions of the wastes' average calorific value.

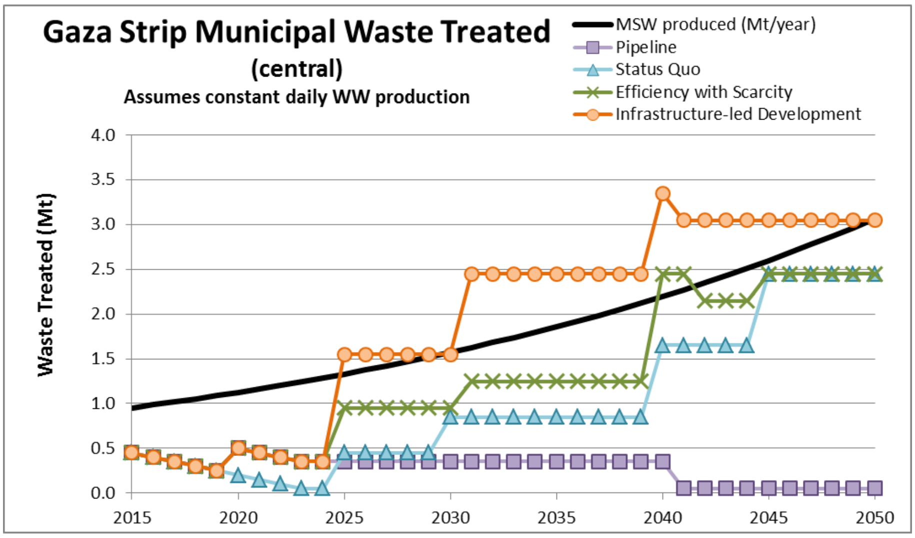

Figure 87: Municipal waste treated (Mt), Gaza Strip 2015-2050 (central growth, all strategies)

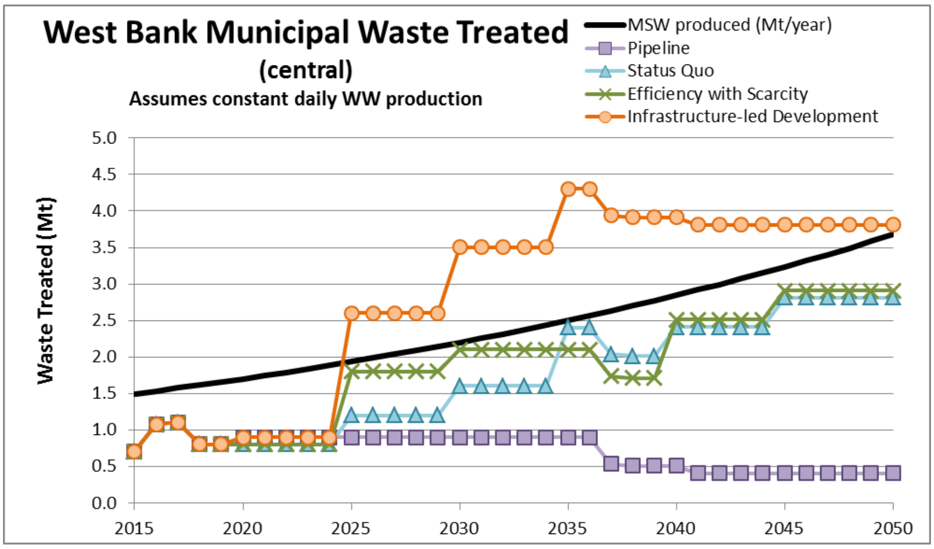

Figure 88: Municipal waste treated (Mt), West Bank, 2015-2050 (central growth, all strategies)

Figure 89 shows the levels of treatment achieved by each of the strategies in 2050. These figures again show how the levels of waste treatment are achieved by the proposed additional waste treatment facilities in each strategy. The pipeline projects do not achieve greater treatment than the No Build strategy by 2050 because the new landfill capacity in the pipeline is filled before 2050 resulting in no long-term improvement.

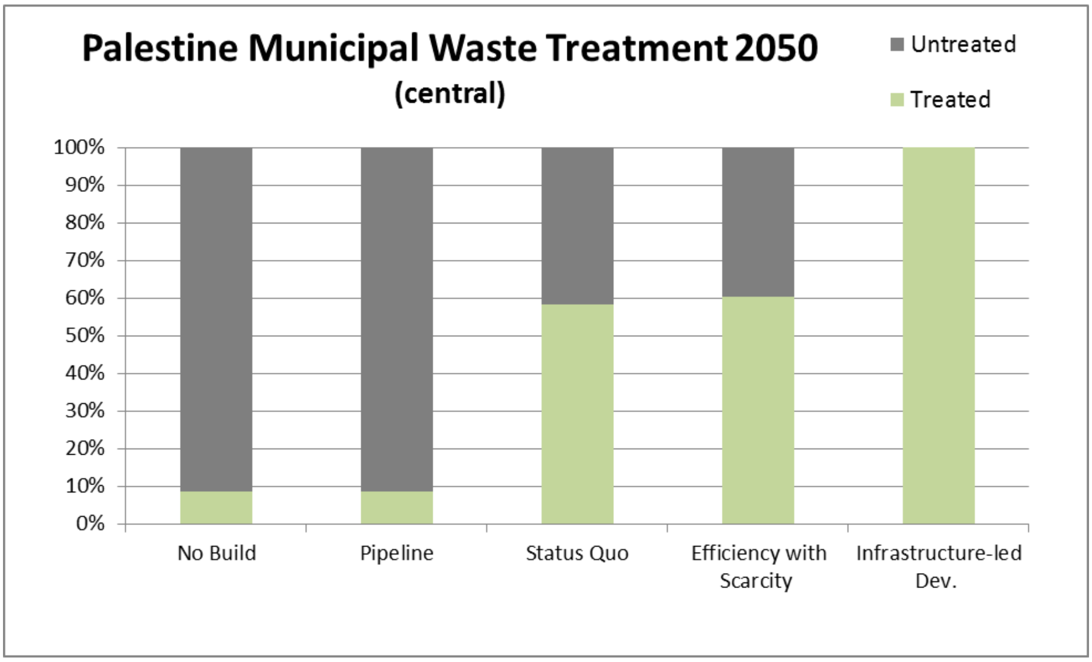

Figure 89: Percentage of municipal waste treated in 2050 (central growth, all strategies)

For the Balanced Prosperity (low population growth) scenario, all strategies meet the additional demand by 2035 in West Bank and 2045 in Gaza. For the Unstable Adversity (high population growth) scenario, each strategy experiences a shortfall in treatment capacity by 2050, with a deficit in Gaza of 1.2 Mt for SQ and ES, and 0.5 Mt for ID, and 2 Mt for SQ and ES, and 1 Mt for ID in West Bank, assuming the same construction profiles as used for the central scenarios.

7.5 Transport sector

7.5.1 Future challenges

The Palestinian Ministry of Transport has a stated aim to meet standards of excellence in organisation of the transport sector in providing high quality services that contribute to the development and sustainability of the Palestinian economy (Ministry of Transport Palestine 2016). However, transport planning in Palestine is hampered by political constraints and questions of mobility among Israelis and Palestinians in Palestine remain unresolved (Garb 1998). Movements of Palestinians are regularly restricted during periods of conflict. While peace negotiations have outlined mobility conditions for Palestinians such as safe passage between the West Bank and Gaza and plans for an airport and sea port, there remains uncertainty regarding the implementation of these measures.

A number of road expansion projects are proposed or underway for Palestine, with several funded by external governments or aid organisations. The projects completed between 2009 and 2011 are shown in Figure 90.

7.5.2 Planned 'infrastructure pipeline' investments

In 2015 the Minister of Transport and Communications, m. Samih Tubeileh, announced the development of comprehensive plans for transportation in Palestine, including linking the cities of the West and Gaza through land routes between Palestine, Egypt and Israel. The project will begin with a rail line between

Ramallah and Nablus with initial approval from the French government and will cost an estimated USD$150 million (Maan News Agency 2015).

Limited information was found on future road projects that are being planned. It appears most expenditure in transport is being funnelled into maintenance of the existing road network.

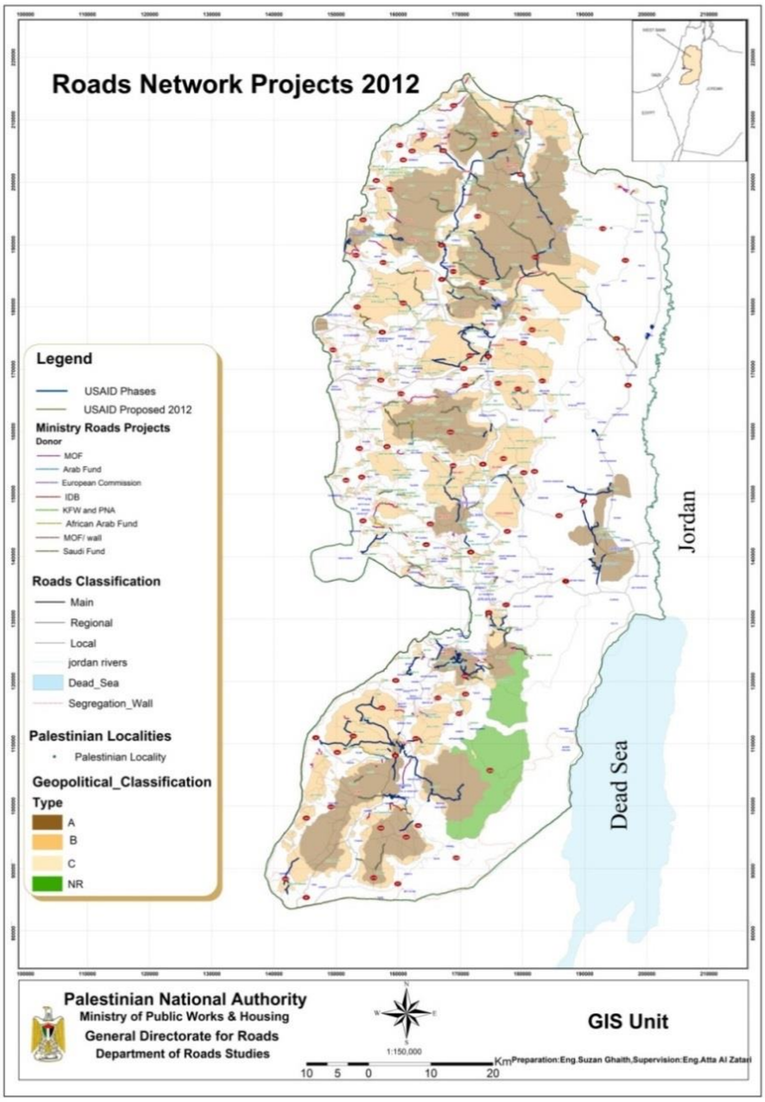

Figure 90: Completed road network projects 2009-11, West Bank (MoPWH 2012)

7.5.3 Model implementation and results

The assessment of spatially-disaggregated forecasts of transport demand and capacity utilisation requires sophisticated long-term transport models and an enormous amount of data including origin/destination matrixes of past travel behaviour by travel mode, congestion on the transport networks and estimates of elasticities of transport demand (Hall, Tran et al. 2016). For this study we did not have access to such sophisticated modelling and data. However, reasonably credible estimates for future road transport infrastructure requirements can be provided by assessing current trends.

Passenger Car Units (PCU) is a measure designed to equilibrate transport across different vehicle types based on their impact on capacity of transport networks (Hall, Tran et al. 2016). For the purposes of this study vehicles were rated as follows: passenger cars and motorcycles (Cars)=1 PCU, light good vehicles (LGV)=1.9 PCU, heavy good vehicles (HGV)=2.9, public service vehicles (PSV)=2.5. Figure 92 presents estimates of growth in passenger car units that might result in the central population growth scenario based on trends in vehicle ownership and usage in other countries. Such projections suggest that even under only medium population growth vehicle numbers could be up to 10 times current levels by 2050. Such growth can be expected to increase the strain on road networks, particularly around access points which are restricted by Israel security services, and the strain on the energy sector with transport already making up half of current energy demand (see section 2.1.3).

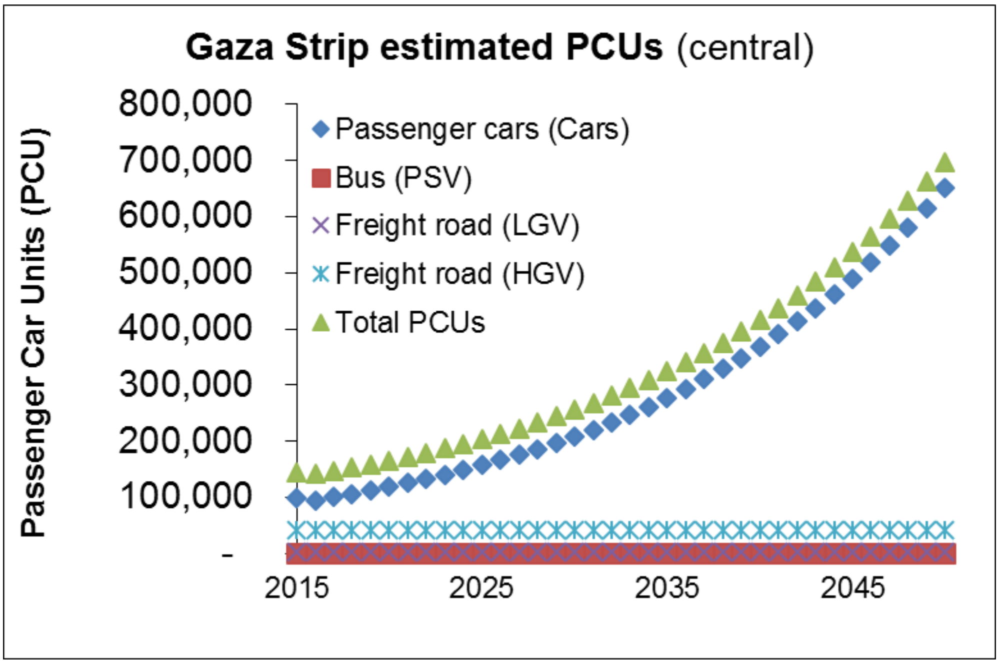

Figure 91: Estimated growth in passenger car units in Gaza Strip for the central scenario based on trends shown in other countries.

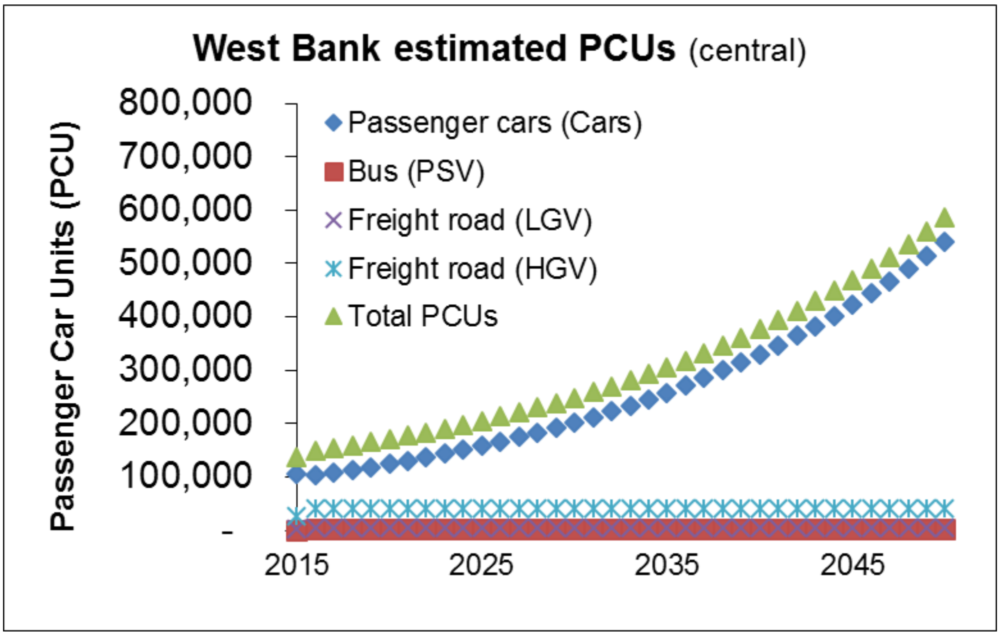

Figure 92: Estimated growth in passenger car units in West Bank for the central scenario based on trends shown in other countries.

A reasonable method for providing some estimates for future road network construction requirements in Palestine is to take the current transport network (paved roads) and increases in passenger car unit demands into the future, including socio-economic growth between governorates. Figure 94 presents the recorded paved road kilometres by governorate and (PCBS 2015) and Figure 93 presents a count of roads connecting each governorate (Ministry of Local Government 2016).

This data was projected into the future to provide estimates of possible construction requirements for each of the strategies. The No Build (NB) and Pipeline (Pipe) both include no increase in road kilometres as no information could be found around any new road projects in planning. The Status Quo (SQ) and Efficiency with Scarcity (ES) strategies both use the current rate of construction which is an approximate increase in new road kilometres per year of 0.7% (PCBS 2015, PCBS 2016)).

Without any information on congestion the Infrastructure-led Development strategy (ID) aims to provide a more even distribution of lane kilometre between Gaza Strip and the West Bank. For the West Bank the rate of new lane construction is set at current construction rates. Given that West Bank already has an extensive road network and limited evidence of serious congestion that is not related to security access points, the current rate of construction appears to be adequate. For Gaza Strip the construction is set to 150% of the current population growth (3.4%) in an attempt to bring the Gaza Strip more in line with the West Bank by 2050. Note that no account was taken of land-use requirements or area security restrictions on road construction. Any additional inter-governorate roads built were costed as an extra 5 kilometres of paved road under the assumption that the majority of their road construction is included in the intra-governorate estimates. The demand for road construction between governorates is higher in the West Bank due to more interconnected governorates.

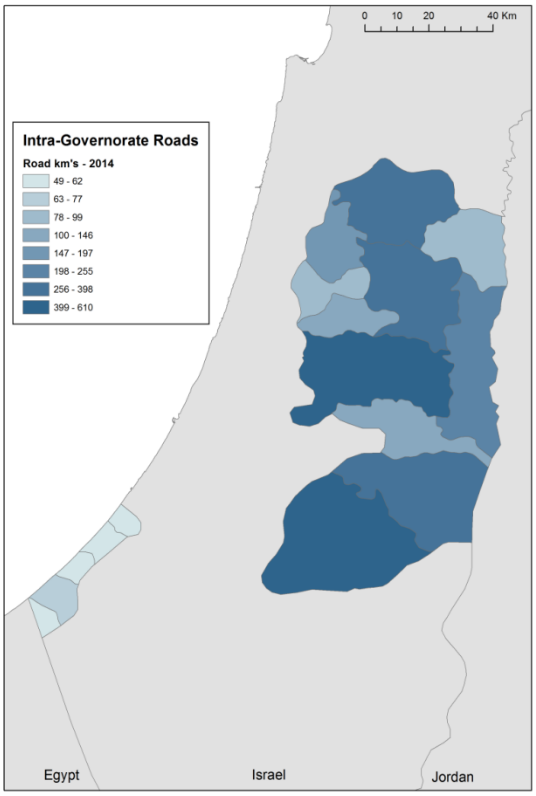

Figure 94: Total paved roads in Palestine by Governorate, 2014 (PCBS 2015)

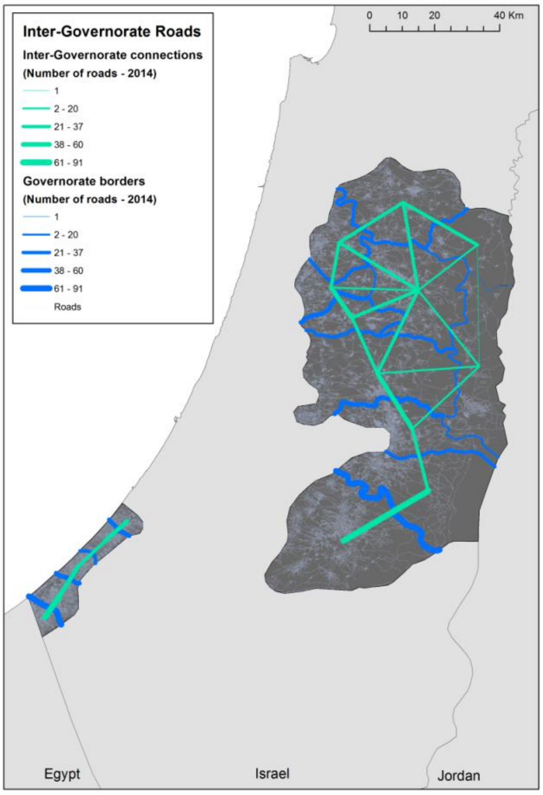

Figure 93: Counts of road connections between governorates in Palestine (Ministry of Local Government 2016)

The results from these road construction strategies are presented in Figure 95 and Figure 96 for Gaza Strip and West Bank respectively. To bring the Gaza Strip in line with West Bank's level of PCUs per lane kilometres by 2050 in the *Infrastructure-led development* strategy the rate of road construction in the Gaza Strip must increase to 6.2%. Such a construction rate is almost nine times the current estimated construction rates for Palestine.

For the Balanced Prosperity (low population growth) scenario we see around a 13% decrease in passenger car units per road kilometre (PCU/km) across all of Palestine given the same investments. However this decrease does little to improve the situation in Gaza for all strategies except the ID strategy. For the Unbalanced Adversity scenario we see an 18% increase in PCU/km across all of Palestine with the same investments requiring the construction rate to increase nine fold over current levels to achieve the ID goals.

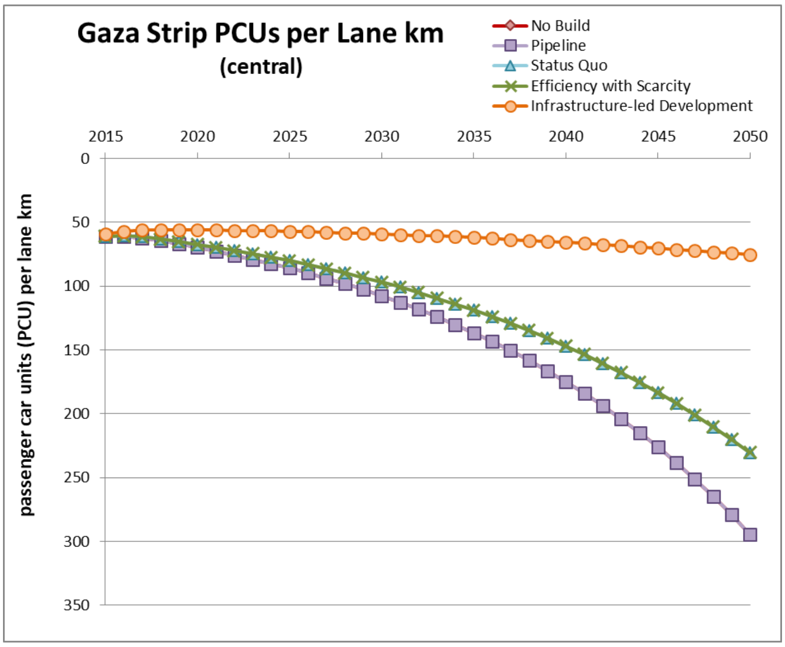

Figure 95: Estimates of passenger car units per road kilometres for the Gaza Strip 2015-2050 (central growth, all strategies)

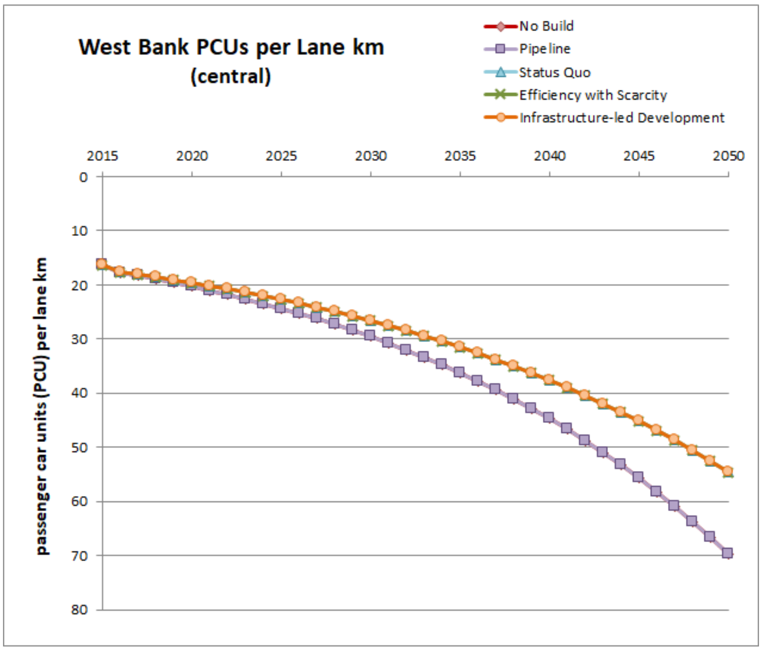

Figure 96: Estimates of passenger car units per road kilometre for the West Bank 2015-2050 (central growth, all strategies)

To examine the implication of the Palestinian Authority's proposed plans for airports in the West Bank and Gaza and a larger seaport in Gaza these investments were included in the *ID* strategy. Costs for each will depend on their capacity which has yet to be defined. The original Yasser Arafat airport was built for Gaza in 1996 at a cost of 75 million USD. It had a single runway that could handle most airliner types including the Boeing 747 with the airport designed to handle up to 700,000 passengers yearly (Chemaitelli 2008). Equivalent airports in West Bank and Gaza would likely cost close to USD$3bn in today's dollars meeting modern standards. A combined airport and seaport island terminal off the Gaza coastline has been proposed at an estimated cost of USD$5 billion. This man-made island would include a single runway, cargo port, gas-fired power generator and a desalination plant (Sanchez 2017).

7.6 Digital communications sector

7.6.1 Future challenges

The most obvious challenges for the digital communications sector is access to technology and markets for the various network providers that are hoping to provide telecommunications coverage to the West Bank and Gaza. There appears sufficient appetite within the investment community to provide telecommunications services albeit at a risk that requires a consummate higher return.

7.6.2 Planned 'infrastructure pipeline' investments

In 2015, Israel proposed a network deal to the Palestinian Authority that could enable a 3G mobile network in Palestine (Scheer, Almughrabi et al. 2015). The Palestinian Trade Centre (Paltrade), under the supervision of the World Bank, released a number of recommendations on the telecommunications sector in its 2010 report (Paltrade 2010) including:

- Palestinian and Israeli officials should work on activating the Joint Technical Committee and encouraging a permanent regular meeting schedule to address challenges and issues related to digital communication in Palestine;
- Palestinian and Israeli officials should address the release of needed frequencies through the activation of relevant Oslo agreement articles, or review the agreement as a whole;
- The Israeli government should adopt and implement clear and transparent policy regarding the release of frequencies, the import of equipment through Israeli ports, and infrastructure development in Area C.
- The Palestinian National Authority should establish a regulator to manage issues such as local competition and illegal Israeli Competition in the telecommunications sector.

According to the Office of the Quartet the government of Israel has allowed two Israeli operators and increase in market share to 7.95% and for 66% of the growth in Palestinian subscribers to go to Israeli operators in the first half of 2016. The government of Israel has also introduced a new proposal to allow another Israeli operator to share the spectrum with Palestinian operators. This has been welcomed by Palestinian parties as the company selected has no existing infrastructure in the West Bank. Although delays will prevent the launch of 3G services by the end of 2016 there is hope that commercial services could still be launched in 2017 (Office of the Quartet 2016).

7.6.3 Model implementation and results

At the time of writing there was insufficient information available on digital communications infrastructure assets within Palestine to be able to model future requirements within the sector. Despite this, we provide an indication of the potential strategic development of the sector based on similar development trajectories within other countries.

At the heart of this strategic development is the evolution of the core technology that is being used to deliver the digital communications service. Currently, mobile internet services are provided using aging 2G infrastructure. This technology provides access to only basic end-use services (email etc.) that are enabled through the internet. The proposed roll-out of 3G technology in Palestine could enable the demand for high-bandwidth applications such as video streaming, access to news and social media sites and online retail to be addressed. For this to happen Israel is required to allocate 3G frequencies to companies that provide services in the area – this includes Jawal, Wataniya and Cellcom and Pelephone.

Additionally, large-scale investments would be required to maintain the current 2G network and to build new digital communications assets (such as base stations and the fibre backbone) to provide coverage of the technology. Digital communication services are typically delivered by the private sector. This mechanism is effective at deploying a technology at a fast pace and to areas of high-population density (where economies of scale are in effect); in areas of low population density, direct government investment or incentives may be required.

4G provides an even greater bandwidth potential than 3G and has been developed as its natural successor. Its roll-out in multiple countries globally has led to the development of new 'data-heavy' end-use services and applications. Operating at higher frequencies than both 2G and 3G, the spatial coverage provided by existing telecommunications masts is reduced. To account for this reduction, maintaining the same level of service delivery within a given region requires the networks to be densified – resulting in large capital investment implications. The deployment of these technologies not only comes with an increased financial cost, but also with a cost of requiring large amounts of electrical power. As conveyed in other areas of this report, electrical power in a scarce resource throughout Palestine. This critical dependence on electricity should be considered when developing Palestine's future digital communications infrastructure.

Due to rapid innovation within the sector, it is challenging to forecast future needs for digital communications and the technological solutions that can address those needs. Currently a number of countries around the world are seeking to develop and finalise the 5G standard. Like the generations before it, 5G will provide an even greater bandwidth potential and will open up an extended range of end-use applications. Amongst others, this includes the data requirements to support the internet of things and to support autonomous vehicles. Despite the opportunities that are provided by these future innovations (efficiency improvements and demand management etc.), the increased reliance on other infrastructure sectors of digital communications for command and control will create an important interdependence that may increase the risks of cascading failure. Palestine's relatively late adoption of such technologies comes with the advantage of the reduced costs and risks of not being an early adopter and the ability to leapfrog certain transitional technologies to ones that better meet the needs of the economy and populace.

8 Cross-sectoral synthesis

8.1 Appraisal of cross-sectoral strategies

Within preceding sections of this report we have presented a sector-level fast-track analysis for national infrastructure systems in Palestine. Where data have permitted, this has included the analysis of the performance of a range of different future infrastructure strategies for each sector. More specifically, strategy-based analysis has been completed for the energy, water, wastewater and solid waste sectors and omitted for the transport and digital communications sectors.

For each of the sectors included in this analysis the performance of the system has been tested for a set of pre-defined strategies. The first of these strategies, '*No Build'*, characterises the performance of a future system in which no new assets are built beyond 2015. The forecast growth in demand across all sectors results in a decrease in per capita service delivery. In the energy and wastewater sectors this decrease is proportional to the increase in population growth in Palestine. Externally imposed restrictions of withdrawals within the water sector result in a sharp reduction in per capita water availability before 2025, with a reduced rate of decrease following that time. An additional large decrease in per capita solid waste treatment is also observed between 2015 and 2020, due to the Zahrat Alfinjan landfill site reaching the end of its asset life in 2017 (D-Waste 2014).

The second strategy, '*Pipeline*', characterises the performance of a future system in which the current pipeline of planned investments for each sector are implemented as planned. The data available to this study indicates that there are 13 projects in the energy sector, 6 in the water sector, 4 in the wastewater sector and 4 in the solid waste sector. In all sectors the pipeline investments increase per capita service delivery when compared to the No Build case. However, due to the increased demand for infrastructure services, these investments do not maintain 2015 levels of service provision across the whole time-frame of the study (2015-2050). Without further investment than specified in the pipeline the per capita service delivery for the energy sector is forecast to fall below 2015 levels by 2030. Within the solid waste sector, the benefits of the pipeline in terms of increased per capita service delivery are lost beyond 2020. Pipeline investments within the water sector are not sufficient to counter the per capita water availability that is reduced extensively to 2025 due to external withdrawal restrictions. The wastewater pipeline of investments is sufficient to elevate per capita wastewater treatment from 2015 values beyond the time of the study, past 2050.

Two additional strategies, '*Status Quo'* and '*Efficiency with Scarcity'*, have been developed to extend the levels of investment beyond the pipeline, maintaining 2015 levels of service delivery to the end of the study horizon 2050. The major differentiation between the two strategies is that future services delivered within the Status Quo strategy are delivered using technologies previously implemented, whereas in the Efficiency with Scarcity strategy, local technological solutions are preferred. For the energy sector, the per capita service delivery in 2015 is continued for both strategies until 2050. In the water sector, both strategies also maintain a similar per capita service delivery, though these levels fluctuate due to long planning horizons and the scale of the assets within these strategies to meet future socio-economic growth. Within the wastewater and solid waste sectors, the service delivery for both strategies follows the investment trends they have achieved in the pipeline strategy. Thus, for the Status Quo strategy, the level of service delivery is reduced based on the confidence in delivering on this investment trend in waste management assets within the region.

Within the final FTA strategy '*Infrastructure-led Development'*, an aspirational future (2050) service delivery has been set which is considerably higher than the 2015 values. For the energy sector, this is set at 9000 kWh/person/year, for the water sector this is the WHO recommended 100 litres/person/day, for transport the road lane kilometres per vehicle in Gaza Strip are brought up to the level of the West Bank, and for the wastewater and solid waste sectors all wastes are treated. Across all sectors, this strategy seeks to deploy investments to increase service delivery to these aspired-to levels by 2030.

All the strategies introduced within the FTA represent candidate sets of future portfolios of investments that could be implemented. Analysing the cross-sectoral performance of these strategies, alongside other strategies (as defined by decision-makers), provides the basis for the generation of evidence that can underpin Palestine's infrastructure future.

Figure 97 and Figure 98 present relative cumulative cost for each of the strategies in 2050. These estimated costs include capital expenditure on new infrastructure assets as well as operational costs of existing assets based on published records and pipeline project costs where data is available, or estimated from the U.K. Institution of Civil Engineering infrastructure cost data and other sources. Not all operating costs could be estimated and no discount rate was applied to future costs. Thus, only relative costs are presented as the numbers were pulled from many available sources and are not considered to be accurate enough to be able to present actual values.

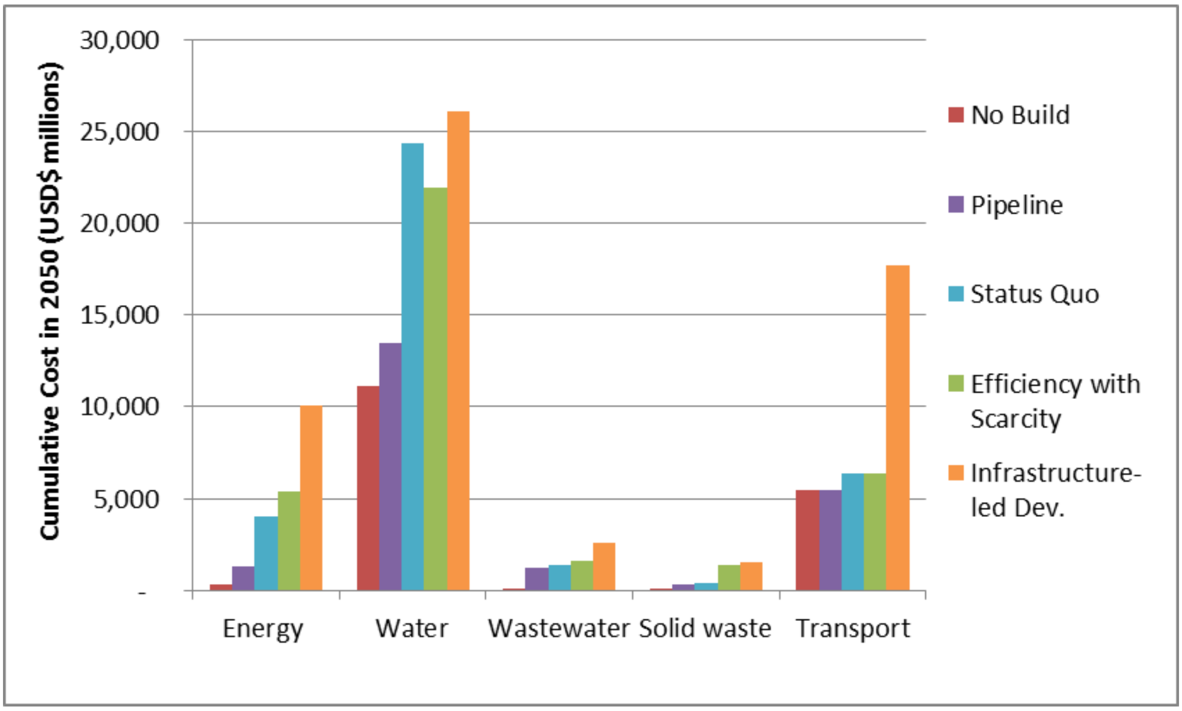

Figure 97: A comparison of relative cumulative costs by sector

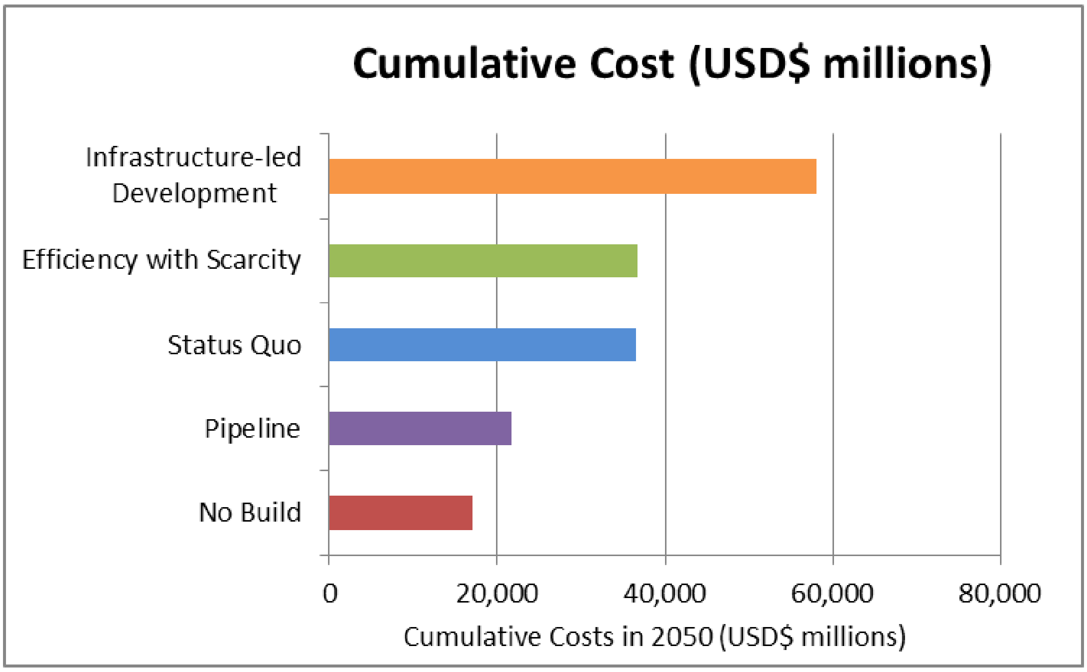

Figure 98: A comparison of total relative cumulative costs across all sectors

Keeping such caveats in mind an interesting picture emerges from attempting such a comparison. Most striking is the relative cost of providing adequate water supply to the Palestinian population compared to other sectors, as shown in Figure 97. Much of this is due to the cost of desalination and distribution which could improve over time but it is doubtful whether it would become lower than other sectors. Also of interest is that the *Efficiency with Scarcity* strategy is able to achieve the additional benefits associated with this strategy at little additional cost over the *Status Quo* strategy (Figure 98). Finally, through concentrating on maximising the benefits from interdependencies and economies of scale, it appears the *Infrastructure-led development* strategy is able to achieve its higher levels of infrastructure service delivery at a much lower per unit cost. The advantages trade-offs can be clearly seen in Figure 97, with energy and waste sectors employed to augment the most scarce resource, water supplies, at an advantages relative cost. Such trade-offs are explored in more detail in the following section.

8.2 Cross-sectoral performance, trade-offs and decisions

The decision taken to adopt any specific strategy (portfolio of interventions) will however depend on multiple factors and criteria. One set of important factors relates to the current and future forecast performance of the national infrastructure systems. Within the previous subsection of this report we presented one dimension of the performance of the different FTA strategies for the energy, water, wastewater and solid waste sectors. The performance in this case was defined in terms of service delivery, often presented and discussed in relative terms to current levels. For the FTA, an additional performance metric ‘cumulative cost’ was also calculated – this includes the capital and operational costs for each strategy between the time periods of the study 2015-2050. The comparison of performance metrics (in the case of the FTA: service delivery and cost) provides a means to explore one of the multiple trade-offs that are incorporated in a real decision. Such trade-offs can be explored both at the sectoral level and at the aggregate level (combining the performance of multiple sectors).

Figure 99 presents one such trade-off: this is achieved by plotting the cross-sectoral cumulative costs for each strategy against the average percentage change in service delivery compared to the 2015 baseline (using the mean average for each strategy across sectors and across the time period 2015-2050). The plot shows that the least cost strategy, *No Build*, has unsurprisingly the lowest performance in terms of average service delivery, with a net negative delivery average service delivery across all sectors. All other strategies result in a net positive average service delivery. For all strategies, there is a general positive correlation between the increased cumulative costs of a strategy and the benefits yielded through the average percentage change in service delivery. Despite the *Pipeline* strategy typically resulting in negative service delivery at 2050 (with respect to 2015 values), looking across the whole study reveals that this strategy has a net positive impact.

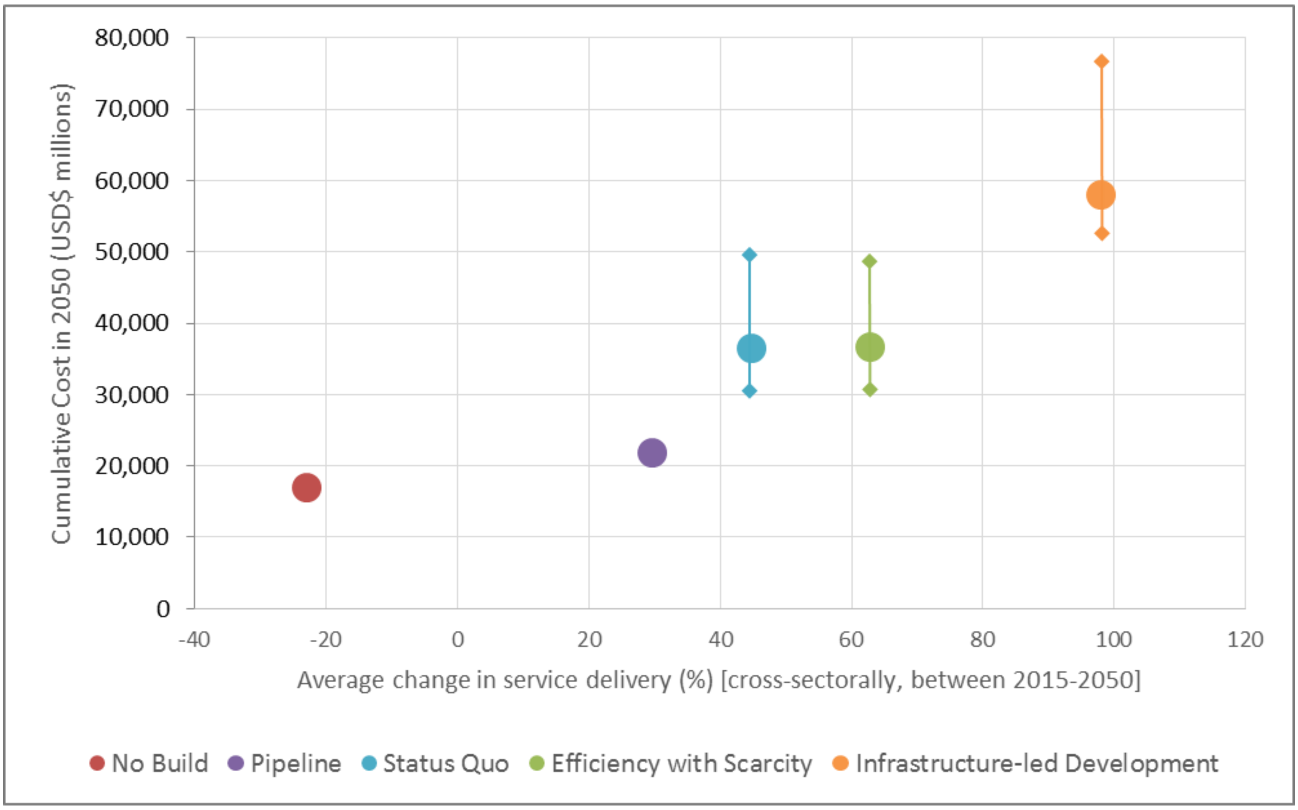

Figure 99: Relative cumulative cost plotted against the mean average percentage change in service delivery (2015-2050) for the No Build, Pipeline, Status Quo, Energy with Scarcity and Infrastructure-led Development strategies in the central population scenario. The bars attached to the latter three strategies show an estimated range of costs between the Balanced Prosperity to the Unbalanced Adversity scenarios for these strategies.

Both the *Status Quo* and *Efficiency with Scarcity* strategies are the closest strategies to one another on the plot regarding performance. To further differentiate between these strategies, it is necessary to consider other important decision-making dimensions (for example, security of supply) which are not quantitatively calculated in this analysis but which are implicit in the description of the strategies. For example, when compared to the *Status Quo* strategy, the greater costs of the *Efficiency with Scarcity* strategy also come with additional benefit of increased security of supply (through the adoption of more localised solutions within the strategy – moving away from a reliance on imports). The highest performing strategy, *Infrastructure-led Development*, is also the costliest in economic terms. Despite the increased service delivery, these costs may prove in practice to be prohibitive to the adoption of this strategy. As such, establishing hard constraints (in terms of budget, or any other performance metric) may help to inform any decision towards a specific strategy by reducing the overall strategy space being investigated – leading to the promotion of certain strategic approaches and specific investment decisions.

It is worthy of note that the cost uncertainty represented by the vertical bars in Figure 11, produced from applying the Unbalanced Adversity and Balanced Prosperity scenarios, is that the cost uncertainty for the *Status Quo* and *Efficiency with Scarcity* strategies do not overlap with that of the *Infrastructure-led Development* strategy. This suggests firstly that the risk from uncertainty represented by alternative socio-economic scenarios are reasonably well contained, and secondly that the bounds of uncertainty are not so great as to prevent comparison between these strategies in terms of costs.

Further work beyond this FTA assessment could aspire to integrate a broader range of infrastructure system performance metrics that expand this trade-off space. As indicated earlier, this could include the security of supply and other metrics that relate to systems vulnerability, risk and resilience. A further set of metrics could also relate to environmental performance and include metrics around net greenhouse gas emissions and other forms of pollution.

8.3 The importance of interdependence

Within this study, the ITRC's system-of-systems based modelling capability has been utilised to incorporate a number of important cross-sectoral interdependencies between different infrastructure sectors. The following subsection describes the different forms of interdependence and how these interdependencies create both risks and opportunities for the current and future infrastructure systems in Palestine.

One form of interdependence emerges as a cross-sectoral demand between different infrastructure sectors. Figure 100 presents a stylised representation of the interdependencies between each of the modelled infrastructure sectors including estimated volumes of potential annual flows in 2050 in the Infrastructure-led Development strategy. Arguably the strongest of these cross-sectoral demands is the demand that all sectors have on energy. Although all sectors demand energy (in one form or another), a number of different technologies from a variety of Infrastructure sectors have a very high energy intensity. Examples include desalination plants from the water sector and data centres from the digital communications sectors. Choices towards these technologies should reflect the underlying availability of energy to service the assets needs both in the current and future energy system. Two other sectors provide services that span all sectors; the first of those is transport, which delivers staff and personnel who are required to operate assets and facilities, the second is digital communications, which is the basis for the digital control infrastructure used to operate technical systems and facilitate communication in the human systems. The expansive and pervasive nature of these services means that minor changes in their function and operation can have broad and unexpected consequences in different sectors.

The analysis also reveals a number of other specific interdependencies that are important for Palestine, as shown in Figure 100. The first of these is the dependence of energy on water, specifically the requirement of large quantities of water required to cool thermoelectric power stations. In assessing the technology options and location of any power station it is also necessary to understand the local and system-wide capability of the water system to deliver cooling water across its lifetime. One opportunity for recovering water is by making better use of wastewater, this could be directly in processes where potable water is not required or as a raw material for a direct reuse process in which potable water is produced from waste water. The recycling and reuse of waste is not only confined to wastewater, but can also be implemented in the solid waste sector. This step towards the 'circular economy' not only reduces the waste arising's that need to be processed, but also provides materials that can be repurposed. One example of this would be the derivation of energy from waste – a strategic option that would not only help Palestine address long-standing issues of solid waste management but also provide much needed energy to help support Palestine's other infrastructure sectors.

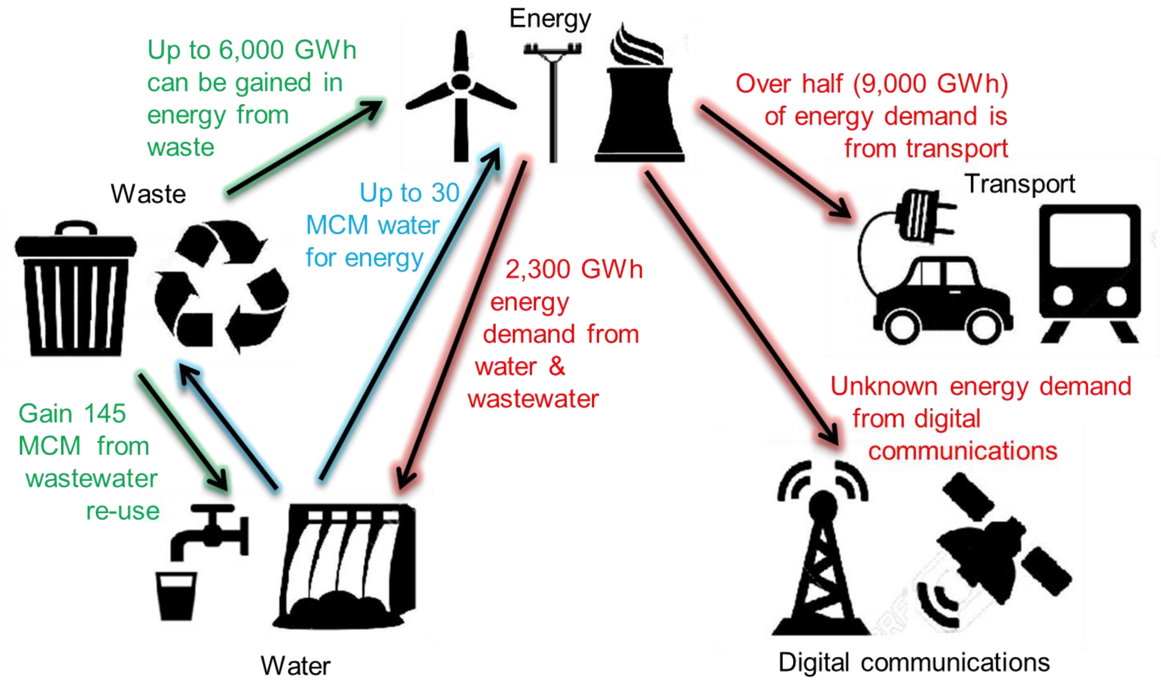

Figure 100: A stylised representation of the interdependencies between each of the major infrastructure sectors including estimated volumes based on the Infrastructure-led Development strategy in 2050 under the central growth scenario

Throughout this report, we have shown that an increasing demand for infrastructure services will place a significant strain on both the current infrastructure systems and the natural resources on which many infrastructures fundamentally depend. With a greater scarcity of resources in the natural environment, it becomes increasingly important to consider the opportunities that exist through the positive exploitation of interdependencies within and between sectors. This is particularly important for Palestine, a country which already faces chronic resource constraints. The reuse of water, the extraction of energy from waste and the selection of energy generation technologies that do not overwork already overstressed water resources provide just a selection of a practical set of interventions that would harness this opportunity.

One additional perspective of interdependence relates to the risks of infrastructure failure. As shown in Section 3, electricity occupies a central role in the national infrastructure, providing electricity to a number of other hard and soft infrastructures that would cease to function without it. The analysis shows the importance of electricity assets and reveals the magnitude of potential disruptions, across a broad range of sectors, which could result from their failure. Due to heterogeneities within the system, a small number of assets have potentially large failure impacts. These are particularly important to consider with respect to risks that manifest through exposure to natural or manmade hazards. Adaptation measures (such as the installation of flood defences) applied to existing assets at risk provides a means to enhance systemic resilience. The decision of where to place new assets should also reflect these interdependency-related risks: this is not only by locating them outside of hazard prone areas, but also by using their installation as an opportunity to reduce the cascading risks of other assets: (i) either by introducing additional redundancy and back-up to network systems, and (ii) or by shifting the number of dependent infrastructures (and related customers) away from assets with high individual consequences to effectively distribute the potential failure impacts.

Electricity networks forms the backbone of many of today’s national infrastructure systems. In many countries around the world, digital communications systems are joining electricity in this role. New technologies in this area are facilitating the operational control of various infrastructure systems at the national scale. Despite offering improvements in efficiencies, the centralised nature of this control can create systemic vulnerabilities that can manifest in risks to customers across multiple sectors. As Palestine develops its digital future, considerations as to the structure of its underlying digital communications systems should be a key priority so as to reduce potential cascading failure risks. This is particularly important when considering a potentially advanced technical future in which high-bandwidth networks (i.e. 5G) are directly supporting automated services across multiple sectors (for example, autonomous vehicles or automated energy demand management systems).

9 Conclusions

There are many challenges facing the people of Palestine including limited access to infrastructure services that provide basic needs, such as water, energy and waste treatment, transportation and communications. Providing secure and resilient infrastructure services in these sectors can enhance future economic productivity and social welfare, while the lack of such services can conversely lead to declining wellbeing, and diminishing economic productivity and social freedom.

The ITRC, together with UNOPS have reviewed the recent situation in Palestine, and identified a number of key challenges in the provision of infrastructure services. The analysis presented in this report identifies that Palestine is experiencing shortages in the provision of most infrastructure services. The demand for infrastructure services is currently not being met in all infrastructure sectors, and this demand is expected to increase due to population growth, increasing urbanisation, economic growth and climate change. Serious impediments to infrastructure supply also exist due to external factors including occupation security measures, conflict, and insufficient asset utilisation.

This report presents the ITRC's findings from the first stages of this assessment (the FTA), which focuses on an expedited analysis of the earlier steps in this process, developing a broad understanding of issues particular to the study site (Palestine), exploring how infrastructure systems are being utilised, current and future demands and the capacity constraints within each of the key sectors. It also provides an overview gaps in information and understanding, and attempts to identify trends including future plans and challenges. This report also sets out the methods used in the remaining steps in the process, and begins to develop a range of strategic pathways and their subsequent analysis. Importantly, this report is intended as a tool to facilitate the iterative process of engagement with potential stakeholders, both in Palestine and abroad, by presenting an overview of our methodology.

Palestine is currently experiencing deficiencies in the provision of most infrastructure services. The availability of water networks varies across governorates, with up to 40% of localities lacking water supply infrastructure. An acute water crisis exists in the Gaza Strip, with average water consumption below World Health Organisation recommended water requirements for assuring all consumption and hygiene needs are met (100 litres per capita per day). The need to reduce abstractions from the Gaza's Eastern Mediterranean coastal aquifer to sustainable levels of 65 MCM p.a. (PWA 2011) presents a notable challenge. The aquifer is additionally being impacted by contaminant intrusion from, amongst others, seawater, wastewater, agricultural products. Water contamination is a major problem where sanitation facilities are poor – resulting in vulnerability for the underlying aquifer.

Wastewater re-use is an underutilised resource in Palestine that might alleviate such water shortages. Current levels of wastewater collection are generally high. However, the wastewater sector has been largely neglected in the Palestinian territories since 1967 as capital investments have focused on the provision of safe drinking water. The amount of wastewater that is fully treated is quite low, below 20% in total, with the majority of wastewater dumped in porous and tight cesspits or sent mostly untreated into the sea, rivers and wadis (streams) with related implications for the limited existing water supplies and human health.

Underpinning these problems are inadequacies in the energy sector which restrict the capacity of water transfer, water treatment and wastewater management facilities. These problems in energy supply also impact on households: while the majority of houses receive access to power most of Gaza's households receive at most 16 hours of electricity each day, and typically as low as 6 to 8 hours/day. At peak supply, around 200 MW of electricity is available, while current demand is estimated at around 450 MW.

Hospitals and hotels also use solar energy for a large portion of their water heating needs. This shortage has a number of causes, primarily due to insufficient imports from Israel and Egypt and the Gaza Power Plant only producing around 60 MW of its full 140 MW capacity.

Solar-based renewable sources of energy provide possible solutions, but land availability and reliability of the distribution grid have hampered efforts beyond small-scale local energy generation. Thermoelectric energy sources such as Combine Cycle Gas Turbines (CCGT) may provide reliable and efficient sources of electricity but could prove problematic in their demand for cooling water. Add to this the fact that even significant investments, such as the Hebron CCGT and Jenin CCGT plants in the West Bank, will only maintain current per capita energy above the current levels (approx.. 5,100 kWh/person) for a decade. In Gaza the current pipeline projects, including the Gas 4 Gaza connection and the Gaza Power Plant upgrade to 540 MW, could maintain current per capita energy levels (approx.2,500 kWh/person) beyond 2040. However, if the Gaza Power Plant is only upgraded to 140 MW a return to the current low levels of electricity provision will also happen within a decade.

Good resource recovery has the potential to provide some respite in the form of energy from waste. However, despite high waste collection rates in urban environments, the opportunities to fully utilise this resource are being lost due to illegal dumping and a lack of waste recovery facilities. Some facilities exist for recycling materials and it is estimated that around 44% of solid waste is treated using sanitary landfills (D-Waste 2014). Plans are also underway for two new sanitary landfills, one each in the West Bank and Gaza. However these will only serve to replace facilities that are soon to close. The percentage of waste treated is therefore expected to decline to below 30% by 2030 if additional waste treatment facilities are not commissioned. With such large amounts of waste untreated, coupled with the number of sites not being controlled in terms of leachate (D-Waste 2014), serious concerns exist around impacts to scarce water resources, particularly in the Gaza Strip.

Transport infrastructure in Palestine is all road-based with no access to ports for travel outside of the borders of the territories by either air or sea. Serious impediments to internal mobility are also imposed by security measures which affect not only internal movements and trade within Palestine, but also access to external markets. Such restrictions are estimated to have a significant cost to Palestinians – up to USD$185 million per year due to extra time and mileage (Isaac et al. 2015).

Digital communications can provide some substitute services for mobility and more than half of all households in Palestine have access to a computer and almost half have access to the internet (PCBS 2014). Although fixed telephone connection of households is low mobile phone connectivity is nearly universal 97.8% (PCBS 2014). In 2015, Israel proposed a network deal to the Palestinian Authority that could enable a 3G mobile network in Palestine (Scheer et al. 2015). The roll-out of 3G technology in Palestine could enable the demand for high-bandwidth applications such as video streaming, access to news and social media sites and online retail to be addressed. For this to happen large-scale investments would be required to maintain the current 2G network and to build new digital communications assets (such as base stations and the fibre backbone) to provide coverage of the 3G technology. With digital communication services typically delivered by the private sector areas of low population density may require direct government investment or incentives.

A number of major infrastructure projects (referred to in this study as the "national infrastructure pipeline" or simply "pipeline") are planned to deliver improved infrastructure services to the people of Palestine. Current measures appear to be well prioritised in water and energy, with emphasis appropriately given to the acute resource shortages in the Gaza Strip. The government of Israel has also recently announced increases in supplies of water and electricity to Palestine. Unfortunately, with current socio-economic trends and the spectre of climate change these measures will fall short of meeting even the most basic demands in the near future, even under an optimistic scenario of low population growth, high economic growth, and no natural or man-made disasters. In fact the analysis presented here submits that Gaza will require at least twice as much investment in water infrastructure than is currently in the pipeline over the coming decade if they are to meet World Health Organisation levels of water availability.

The assembly and testing of a set of cross-sectoral strategies for infrastructure provision in Palestine is one of the major outputs of this report. In developing countries and post-conflict situations, two of the most important factors for decision makers are the levels of investment available for infrastructure provision in different sectors, and the ability or ambition of governing bodies to apply such investments in tune with future needs and demands and supplies in related sectors. Focusing solely on these two areas of influence, a framework was derived within which alternative and diverse strategies can be positioned. Five strategies were devised to carry out this assessment: (1) No Build – a minimal investment, highly restricted strategy; (2) Pipeline – where infrastructure projects in the current investment pipeline are implemented; (3) Status Quo – a 'neutral' strategy in which current levels of infrastructure services provision continue; (4) Efficiency with Scarcity – where infrastructure provision needs are addressed through efficiencies under scarcity of available resources; and (5) Infrastructure-Led Development – which requires higher investment, but with a focus on higher levels of infrastructure provision.

These strategies are designed to provide the Palestine Authority's with an overview of the considerable challenges they face in providing for the Palestinian people. The results suggest there is much to be gained by persisting with this approach. The *Efficiency with Scarcity* was shown to be capable of providing equivalent infrastructure services to the *Status Quo* strategy for similar costs but with greater resource recovery and a lower reliance on imports. Finally, the *Infrastructure-led Development* strategy demonstrated that meeting higher levels of infrastructure services can be achieved at lower unit cost through exploiting positive interdependencies and economies of scale. This strategy provides for levels of infrastructure services that are closer to those enjoyed in neighbouring countries, such as Jordan, but require significantly higher levels of investment than is evident in the current national infrastructure pipeline.

The tight coupling of many of Palestine's infrastructure systems, particularly energy and water, and energy and transport, require solutions that are cognisant of these interdependencies. Gains are clear when the energy and waste sectors are employed to augment water supplies at an advantageous relative cost. The multitude of government, private and donor community actors involved in infrastructure-decisions creates additional complexity that requires an integrated approach and transparency to the decision-making process.

The aim of the ITRC/UNOPS collaboration that produced this research was to develop a systems-based assessment of alternative future strategies for infrastructure provision in Palestine that can be used to build the evidence base to support decision-makers in addressing its key infrastructure challenges. This FTA report has presented a number of initial insights for the current and future performance of Palestine's infrastructure systems. The limitations of the FTA (as an analytical exercise) manifest due to time constraints and access to underlying information. Such limitations introduce uncertainty, which should be fully considered when deriving insights and conclusion from this analysis. In addition to limitations in the sophistication of the underlying models, limitations also exist within the number of strategies that have been developed. As discussed within the report, these initial strategies have been developed and presented to draw-out particular issues inherent within Palestine's circumstances and should be considered as a start to a much more in-depth evaluation of infrastructure strategies for the future of Palestine.

It is therefore hoped that this study forms, not only an important resource, but also the basis for the Palestinian authority and other stakeholder to develop a deeper understanding of their infrastructure and future infrastructure decisions. Future work, in collaboration with ITRC and UNOPS could develop this initial FTA further, adding more sophistication to the underlying analysis and providing the opportunity to develop and test further infrastructure strategies including developing a complete "vision" applied across all sectors. It is expected that such an analysis would help Palestine's infrastructure decision-makers to better understand their current infrastructure system-of-systems, including interdependencies, and assess alternative management strategies for improving the systems' resilience and robustness to future uncertainties. Included within future work could be research into developing indicators capable of tracking the performance of alternative strategies and linking these to a vision for Palestine's future (State of Palestine 2015) and the UN's Sustainable Development Goals. Developing such capabilities will enable system-wide evidence-based infrastructure planning to coordinate, prioritise and monitor future delivery of infrastructure services and assess their impact in a highly uncertain future. It will provide confidence in the institutional capacity and consistency in decision-making necessary to attract further donor funding and much needed private investment into the economy.

Appendix A: List of acronyms and abbreviations

CCGT	Combined Cycle Gas Turbine
CO2	carbon dioxide
CO2e	carbon dioxide equivalent
COGAT	Coordinator of Government Activities in the Territories
DEM	digital elevation map
ES	Efficiency with Scarcity strategy
FTA	Fast Track Assessment
G4G	Gas for Gaza
GDP	Gross Domestic Product
GHz	gigahertz
GIS	Geographic Information System
GWh	gigawatt hours
ICT	Information and Communication Technologies
ID	Infrastructure-led Development strategy
IPCC	Intergovernmental Panel on Climate Change
ITRC	Infrastructure Transitions Research Consortium
JTC	Joint Technical Committee
kgoe	kilograms of oil equivalent
kWh	kilowatt hours
LPG	Liquefied Petroleum Gas
MCM	million cubic metres
MDG	Millennium Development Goals
MENA	Middle East and North Africa
mm	millimetres
MoLG	Ministry of Local Government
Mt	mega-tonnes (1 million tonnes)
MW	mega-watts (1 million Watts)
MWh	mega-watt-hours
NB	No Build strategy
NIS	New Israeli Shekel
NISMOD	National Infrastructure Systems Model
NPC	Net Present Cost
oPt	Occupied Palestine territories
PA	Palestinian Authority
PCBS	Palestinian Central Bureau of Statistics

PEA	Palestinian Energy Authority
PLC	Palestinian Legislative Council
PLO	Palestine Liberation Organization
PV	photovoltaic
PWA	Palestinian Water Authority
SQ	Status Quo strategy
tcf	trillion cubic feet
TJ	Tera joules
TWh	terawatt hours
UK	United Kingdom
UN	United Nations
UNOPS	United Nations Office for Project Services
UNRWA	United Nations Relief and Works Agency
USD	United States Dollars
WASH	water, sanitation and hygiene
WHO	World Health Organisation
WTE	waste to energy
WWTP	wastewater treatment plant

Appendix B: Minimum per capita water allocation according to recent studies

Study	Minimum (l/c/d)	Notes	Source
WHO - Technical Notes on Drinking Water, Sanitation and Hygiene in Emergencies (2013)	7.5 to 15	Survival (2.5 to 3), hygiene (2 to 6), cooking (3 to 6). "Based on estimates of requirements of lactating women who engage in moderate physical activity in above-average temperatures, a minimum of 7.5 litres per capita per day will meet the requirements of most people under most conditions. This water needs to be of a quality that represents a tolerable level of risk. However, in an emergency situation, a minimum of 15 litres is required. A higher quantity of about 20 litres per capita per day should be assured to take care of basic hygiene needs and basic food hygiene. Laundry/bathing might require higher amounts unless carried out at source."	WHO (2013). Technical Notes on Drinking-Water, Sanitation and Hygiene in Emergencies, World Health Organization, Accessed from http://www.who.int/water_sanitation_health/publications/2011/WHO_TN_09_How_much_water_is_needed.pdf?ua=1 on 4/7/2016 and WHO (2011). Guidelines for drinking-water quality - 4th ed. Malta, Gutenberg, Accessed from http://apps.who.int/iris/bitstream/10665/44584/1/9789241548151_eng.pdf on 3/8/2016.
WHO / UNICEF (2000)	20	"Reasonable access" was broadly defined as the availability of at least 20 litres per person per day from a source within one kilometre of the user's dwelling. (p. 77)	WHO/UNICEF (2000). Global Water Supply and Sanitation Assessment 2000 Report, World Health Organization / UNICEF. Accessed from http://www.who.int/water_sanitation_health/monitoring/jmp2000.pdf on 5/7/2016.
Gleick (1996)	50	Drinking (5), sanitation (20), bathing (15), food prep (10)	P.H. Gleick, Basic water requirements for human activities: Meeting basic needs, Water International, 21 (1996) 83-92.
Howard and Batram (WHO) (2003)	100	Optimal access: all consumption and hygiene needs met.	Howard, G. and J. Bartram (2003). Domestic Water Quantity, Service Level and Health. Geneva, World Health Organization. Accessed from http://www.who.int/water_sanitation_health/diseases/en/WSH0302.pdf on 3/7/2016.
PWA (2011)	100	"The degree to which prices for consumption above basic levels (taken as 100 litres per capita/day) will need to be increased in order to maintain affordability to the poor will probably be quite significant."	PWA (2011) "The Gaza Emergency Technical Assistance Programme (GETAP) on water supply to the Gaza Strip, Component 1 – The comparative study of options for an additional supply of water for the Gaza Strip (CSO-G)." Palestinian Water Authority, accessed from

Study	Minimum (l/c/d)	Notes	Source
			https://www.humanitarianresponse.info/system/files/documents/files/PWA%20-%20CSO-G%20updated%20Final.pdf on 18/10/2016.
Chenoweth (2008)	135	"The preceding analysis suggests that a country could meet its domestic water requirements together with its water requirements for maintaining a water efficient non-agricultural economy capable of sustaining a high level of human development with as little as 120 l/c/d. Low (but not exceptionally low) water distribution losses of approximately ten percent suggest that another 10 to 15 l/c/d of water would be required. Therefore, a minimum of 135 l/c/d is required for social and economic development that would permit the achievement of high human development."	Chenoweth, J. (2008). Minimum water requirement for social and economic development. Accessed from http://epubs.surrey.ac.uk/7676/49/minimum_water_requirement7.pdf on 10/7/2014.
Shuval (1992)	274	For non-agricultural water demands. **68** l/c/d for essential fresh food production (can be recycled). Israel-based study.	H. Shuval, Approaches to Resolving the Water Conflicts Between Israel and her Neighbours - A Regional Water-for-Peace Plan, Water International, 17 (1992) 122-143.
Falkenmark (1986)	1,369	Modern society in semi-arid conditions. **1095** for irrigation and **274** for domestic and industrial needs. Israel-based study.	M. Falkenmark, Fresh water - time for a modified approach, Ambio, 15(1986) 192-200.
World Water Programme (2003)	4,654	"At present many developing countries have difficulty in supplying the minimum annual per capita water requirement of 1,700 cubic metres (m3) [4,654 l/c/d] of drinking water necessary for active and healthy life for their people (see map 1.1)" (p.10)	World Water Assessment Programme (2003). Water for People, Water for Life: the United Nations World Water Development Report. United Nations, UNESCO/Berghahn Books. Accessed from http://unesdoc.unesco.org/images/0012/001297/129726e.pdf on 29/6/2016.

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