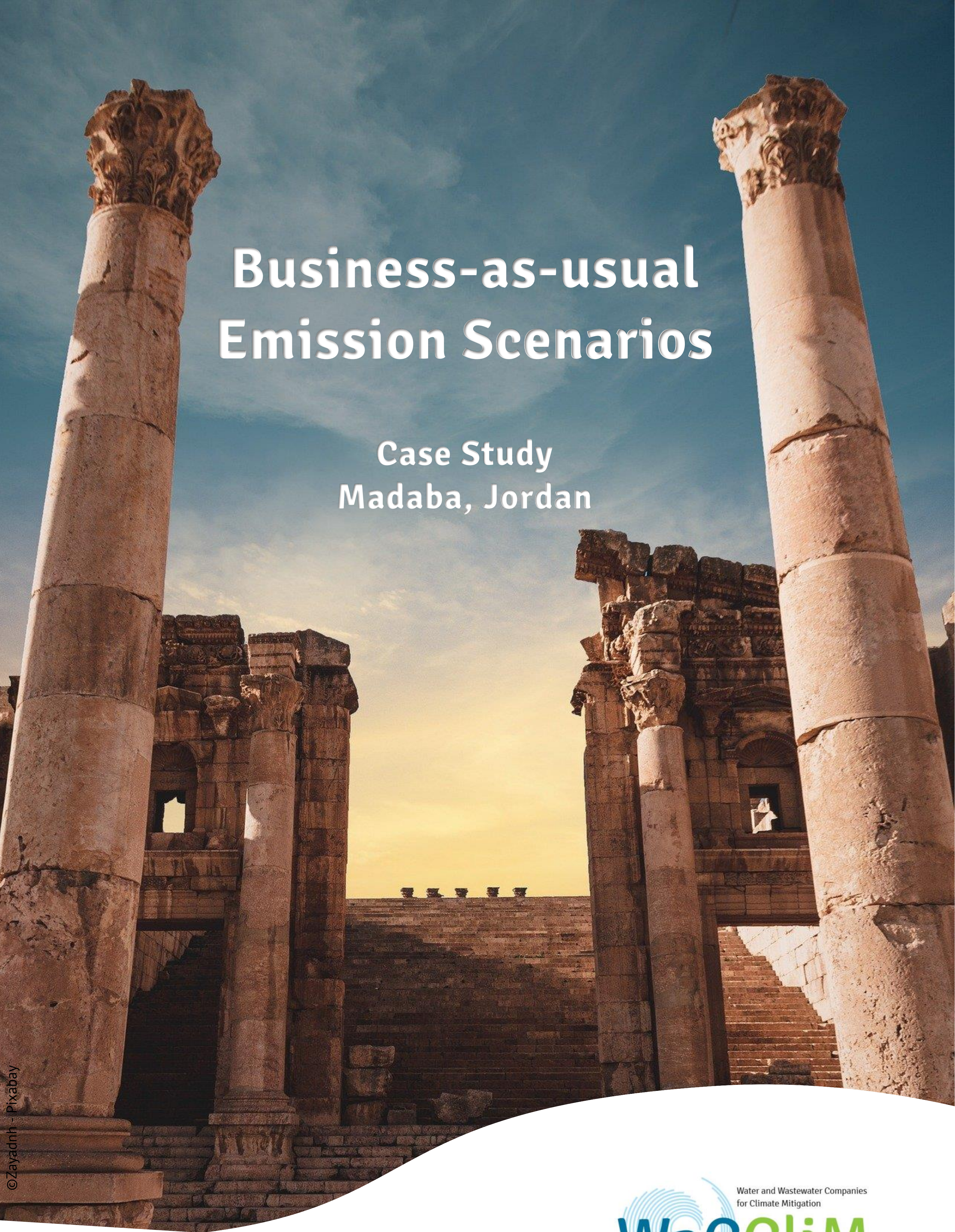
Business-as-usual Emission Scenarios

Case Study
Madaba, Jordan



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Water and Wastewater Companies for Climate Mitigation

WaCCliM

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Development of BAU emission scenarios for Madaba, Jordan

The Madaba Governorate is located in central Jordan, 35 km southwest of the capital Amman. It has an area of about 1 000 km² with an arid and semi-arid climate. Rainfall patterns are particularly low and have an uneven distribution and strong fluctuations terms of quantity and timing. Population and economic growth are exacerbating the gap between water supply and demand and this will be aggravated in the future due to refugee influx from neighbouring countries and challenges posed by climate change. Water needs for the different sectors of the population; deterioration of water quality and exhaustion of water supplies pose serious challenges on water sustainability and are putting pressure on water utilities. In addition, water and wastewater treatment processes also contribute to global greenhouse gas emissions. The urban water sector in Madaba is in need to implement measures to face such challenges and to reduce its carbon footprint.

The company Miyahuna operates the water supply and sanitation systems in the city of Madaba. Since 2016, the project Water and Wastewater Companies for Climate Mitigation - WaCCliM assists the water company by investigating opportunities for GHG reduction measures. Developing a business-as-usual (BAU) emission scenario for the utility by analysing the behaviour of future and past greenhouse gas emissions in the absence of mitigation efforts can help to understand the impacts of adopting a low carbon policy and can serve as a technical component to inform/decide strategic planning on climate change, emissions mitigation goal setting and long-term climate policy design.

The following case study analyses the GHG emissions of the utility Miyahuna under BAU conditions and applies the 'Methodology to establish BAU scenarios' developed by the WaCCliM project based on the Energy Performance and Carbon Emission Assessment tool- ECAM.

Water and wastewater services

Water is distributed weekly from the Madaba reservoir to eight main zones, supply hours are irregular due to the intermittent water supply [MWI et al, 2017]. Water shortage adds up to the irregularities in water supply and households receive water only once or twice a week. This situation forces the serviced population to look out for alternative sources of water to meet their demands, for example, storing water in tanks and buying water from private water providers [Aboelnga et al., 2020].

The total length of the existing distribution network is 1000 km from the wells to the customers' meters, with an average pressure of 0.6 MPa. Water is pumped from an altitude of 330 masl to elevations of 750–800 masl., which requires large amounts of energy [Aboelnga et al., 2018].

The wastewater is collected through the wastewater network and removed from the residential areas to the treatment station managed by Miyahuna Water Company. Wastewater is further treated using activated sludge processes. Handling sewage sludge is major challenge to the utility, which results in environmental and health hazards. Many Jordanian municipalities lack proper sludge management and infrastructure. Sludge is unutilised and improperly stored and disposed of. The treated wastewater is reclaimed to be reused for certain purposes such as irrigation for agriculture.

Building of the Miyahuna water company, Jordan ©Miyahuna

Methodology

The following steps are a summary of the 'Methodology to establish baseline emission scenarios in the urban water sector with ECAM' developed by the Project WaCCliM. A more complete overview of concepts and related theory can be found in the mentioned study.

Step 1: Definition of boundaries and time horizon

Developing a BAU scenario begins with defining the type of systems to be analysed, the limitations within the systems, and type of facilities and stages to which it applies. Additionally, it is important to define the time period over which the scenario will be projected.

Step 2: Identification of the key parameters and driving factors that affect the GHG emission trajectory

There are several factors to consider while developing a BAU scenario, such as the nature and composition of BAU activities, parameters and how this composition may change over time due to legal, economic, or physical factors. To establish a BAU scenario, it is important to identify the most relevant parameters or key parameters that drive the emissions of GHGs in the systems to be analysed.

Step 3: Data collection & projection

This step varies and adjusts according to each local context and the time frame decided for the scenario establishment. A robust and representative set of data must be collected for the year chosen as the starting point for the BAU scenarios. Preferably, the data must come directly from the utility. The initial data will then be projected considering the trends analysed in the previous step. To facilitate this, a tool to Project ECAM Inputs for GHG Emissions as BAU Scenarios (PEIGE) was developed, which projects the data based on fixed BAU trends, nevertheless, the tool need be adjusted and fit to local or utility BAU trends.

Step 4: Development of BAU scenarios using ECAM

One of the advantages of developing BAU emission scenarios in the urban water sector and in the context of the project WaCCliM is that the ECAM tool can be used to determine GHG emissions. Once the chosen data is properly projected, these will be the input source in ECAM to determine the GHG emissions in any desired time frame. This will then provide the past and future trajectory of GHG emissions to be considered as the BAU scenario.

Figure 1. *Steps to develop BAU scenarios*

Scope and time period

The project WaCCliM first began working with Miyahuna in 2016, therefore this will be the start point to develop BAU emission scenarios. The baseline scenario will be projected until the year 2040 and will analyse the following stages according to the characteristics of the utility:

- Water supply: Abstraction and Distribution
- Wastewater: Treatment and Discharge/reuse

Key parameters and data to adjust BAU trends

This section evaluates the historical development of the parameters based on reliable statistics and projection data. To have a robust comprehension of historical BAU trends, deep literature review should be conducted on the evolution of the parameters up to 15 years before the starting year of the BAU scenario. This analysis is used to obtain the Compound Annual Growth Rate (CAGR) which will be used in the next section to project the data. The CAGR values were adjusted accordingly in the PEIGE tool.

Resident population

The population of Jordan was analysed according to the report of 'Population Projections for the Kingdom's Residents during the Period 2015-2050' of the Jordan Department of Statistics[1]. The projections provided in the before-mentioned study analyse the population growth considering factors such as refugee movement and migration, relevant for this case study is the projection provided under BAU conditions. The calculated future growth rates show the increase of population until the end of the BAU scenario, a slight decrease from the year 2030 is observed. The figures are presented in Annex A and introduced in PEIGE.

Population with access to water and sanitation services

Data used for developing past trends are all from the Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) of the World Health Organisation (WHO database. Although there was a slight decline in the connection degree of drinking water supply, the situation can be seen as stable under the consideration of the additional pressure posed by Syrian migrants in recent years. Sanitation infrastructures have been improved moderately on the national scale, while the development in urban areas has been stagnant. Generally, the wastewater treatment in Jordan reaches a high level of quality due to the necessity for water reuse.

Jordan's Ministry of Water and Irrigation [MWI et al., 2017] reported insufficient funding as one of the primary challenges of its water industry, and added that private sector participation on a broader scale would be promoted. However, the new funding models still need to be employed intensively, especially taking into account the long amortisation period of investments and difficulty in cost recovery during operation which are typical for Jordan's water sector [MWI et al., 2017]. As such, the prospects of the new funding methods are still unclear. Consequently, this paper assumes that Jordan will continue making progress in both water and sanitation services over the coming two decades. The BAU change rate will follow that from the past and be at least 0.1 percentage point per year.

Table 1.*The future trend of the coverage of water and sanitation services in Jordan.*

Jordan	2000 (%)	2015 (%)	Past average ann. change 2000-2015 (percentage points)	BAU CAGR
% with improved drinking water [B]	99.8	98.9	-0.1	0.1%
% with improved sewer connection [B]	67.8	67.9	0.0	0.1%
% with wastewater safely treated [B]	67.8	67.9	0.0	0.1%

Sources and remarks:
[B] WHO/UNICEF [2017b]. WASH (JMP) database. Country files are available after typing the country name. Data in the worksheet "Estimates".

[1] http://www.dos.gov.jo/dos_home_e/main/Demograghy/2017/POP_PROJECTIONS(2015-2050).pdf.

Water and wastewater volume

The MWI [2013, 2017] publishes water statistics providing data on the total drinking water supply and treated wastewater. Based on data of population and the degree of connection from the sources presented the previous sections, it is possible to quantify the per capita water and wastewater volumes.

Energy consumption

In Jordan, water pumping is responsible for more than half of the total energy consumption in the water sector in 2013, implying an energy intensity in water abstraction of about 2.8 kWh/m³ [Busche & Hayek, 2015].

Table 2. *The BAU trend of per capita water supply and treated wastewater in Jordan*

	Units	2000	2015	CAGR 2000-2015 BAU CAGR (%)
Gross drinking water supply [E]	m m³/year	239	440	
Population with improved drinking water *	1 000 persons	5 083	9 031	
Per capita gross drinking water supply	m³/person/year	47.0	48.7	0.2%
Volume of collected/treated wastewater [E]	m m³/year	77	147	
Population serviced by WWTP *	1 000 persons	2 796	5 294	
Per capita collected/treated wastewater volume	m³/person/year	27.5	27.8	0.1%
Ratio of water reuse in the treated WW [E]	%		90	

Sources and remarks:
[E] MWI [2013, 2017]. Jordan water sector - facts and figures.
* Calculated from UNDESA and JMP data.

Billed authorised consumption volume

Jordan's MWI [2013, 2017] updates on non revenue water (NRW) based on gross and net drinking water supply statistics. The NRW level in 2015 is slightly lower than in 2000. At first, the trend in between could be seen to be continually declining to 42%, followed by a sudden surge to 47% in 2012. The reason behind this is probably related to a massive migration movement. It is expected that the development of water losses will soon take a positive turn. A higher rate than the past trend is thus suggested for the BAU scenarios (-0.2%).

Table 3. *The future trend of NRW ratio in Jordan.*

Year	Units	Value
2000	%	52 *
2015	%	51 *
Past annual percentage points	%	-0.1
BAU CAGR	%	-0.2

MWI [2013, 2017]. Jordan water sector – facts and figures.

Miyahuna had an energy intensity of almost 0.7 kWh/m³ for water distribution, which is taken as the average level of the country. Water treatment is thought to use 0.1 kWh per m³[MWI, 2015], has an energy intensity of around 1.0 kWh/m³.[2] The required nationwide electricity per volume wastewater is estimated at 0.6 kWh/m³. The collection and discharge are thought to require 0.1 kWh/m³ each González [2018].

According to González [2018], water abstraction from deeper aquifers will be economically unfeasible in 25 years, if the current practice continues. Thus, it is suggested to apply an annual growth rate of 0.8% for water abstraction and 0.5% for water distribution. The trend of other sub-stages is assumed to follow Table 3.

An important factor to consider in BAU trends related to energy intensity is the efficiency loss of pumping systems due to aging and deterioration. Although it is difficult to estimate the percentage of loss of pumping efficiency, old pumps are one of the major problems in Miyahuna. Several authors describe that the efficiency of pumping systems can be reduced from 10 to 15% after 10 years of use [UNIDO,2011; Eichhammer et al 2012]. For this specific case study, a value of 1.25% of increase in energy intensity was assumed in the stages with pumping equipment.

[2] Calculated based on data from MWI (2015) and González (2018).

Table 4. *Estimated energy intensity of the urban water sector in Jordan.*

Water Supply		
	Abstraction	Distribution
2015 (kWh/m³)	2.8	0.7
BAU CAGR	0.8%	0.5%
CAGR due to aging and deterioration of equipment	1.25%	1.25%
Total CAGR	2.1%	1.8%
Wastewater		
	Treatment	Discharge
2015 (kWh/m³)	0.6	0.1
BAU CAGR	0.6%	0.1%

Emission factors of grid electricity

From 2012 on, the IEA updated the country-specific electricity-only emission factors, providing a sound basis for the examination of the development path. Based on analyses of different IEA reports [2014, 2015, 2016a, 2017, 2018a, 2018b], the EF_{grid} in Jordan exhibited a declining trend due to the shift to natural gas as the fossil fuel with the lowest carbon intensity, although the fossil fuels' share in electricity generation remained steady at 100%.

Table 5. *The BAU trend of the grid emission factor*

	Unit	Value
2005 [M]	$kgCO_2/kWh$	0.665
2015 / National current states (2015) [M]	$kgCO_2/kWh$	0.588
CAGR 2005-2015	%	-1.2
BAU CAGR	%	-1.2

Per capita per year protein generation

In line with the ECAM tool, the national average protein intake is used for BAU projections without the consideration of regional divergence. Due to potential errors in the recording of stock variations [FAO, 2014], there is significant uncertainty in the data.

Table 6. *The BAU trend of the per capita protein generation quantity*

	Unit	Value
2000	g/capita/day	72.55
2013	g/capita/day	79.59
BAU CAGR	%	0.7

Per capita BOD_5 generation

The IPCC 2006 Guideline widely adopted the per capita BOD_5 values estimated by the US Environmental Protection Agency (EPA) [Doorn & Liles, 1999]. The typical value for this parameter 40 grams BOD_5 per capita per day for developing countries. As Jordan fits in this category this value is used in ECAM.

Due to the data gap the fact that the existing literature concentrates mainly on the contemporary situation rather than future development, a reliable projection is not applicable. As such, the current figure of 40 g BOD5 per capita per day will be used for the BAU estimations as a constant level towards. If regional or country-specific data are available to users, these are preferred.

CH_4 emission factors

The emission factor of the treatment can be assigned to the respective technology according to the recommendations of the IPCC 2006 Guideline, which is specified in detail in the ECAM tool and its methodology [WaCCliM, 2019]. In this BAU study, assuming the persistence of the existing technical systems, the emission factors will be regarded as fixed in the time evolution.

The Madaba WWTP uses activated sludge as the treatment type, therefore its emission factor of 0.06 kgCH4/kgBOD for the treatment system with "minor poorly aerated zones" will be used for the development of BAU scenarios.

BOD_5 loads

In BAU scenarios, BOD_5 loads are assumed not to exhibit endogenous variations and will be determined by the evolution of the serviced population and their per capita BOD_5 generation quantity (for more information about the calculations, please refer to the 'Methodology for establishing baseline scenarios in the urban water sector with ECAM').

Nitrogen concentration in the effluent

The nitrogen concentration in the effluent will be calculated based on the IPCC quantification standards and comprises loads in the collected but untreated sewage as well as the remaining nitrogen in the treated wastewater. Therefore, there is no specific BAU CAGR for this parameter. For a more detailed explanation please refer to the Methodology for Establishing Baseline Scenarios.

Sludge management

Disposal of sludge plays contributes significantly to the emission of greenhouse gases. The ECAM tool considers the different disposal pathways of dry sludge. In the specific case of the analysed Jordanian utility, the development of dry sludge is calculated in view of the sludge concentration and the amount of pumped sludge from the thickener. Since the total amount dry sludge was calculated in this particular manner for the utility, the same considerations and past utility data were taken to obtain the different average BAU CAGR values. The values and parameter were added to PEIGE and the total dry sludge was calculated on a yearly basis.

Table 7. *The BAU trend of the per capita sludge generation quantity*

	Unit	2016	2019	BAU CAGR %
Sludge concentration	g/ml	33	34.52	1.4
Sludge pumped	m^3	365	390	2.2

Data Collection and projection

The main pillar of establishing BAU scenarios having a robust set of data. The initial data for this case study was obtained directly from the operators in charge at the Miyahuna company. The data was later projected using the PEIGE tool which adds the respective CAGR value for each parameter to each year analysed under BAU conditions. Therefore, it is important to collect the most representative data possible.

Table 8 shows the initial and final values of the parameters that were projected with PEIGE and further inputted into ECAM to analyse the GHG emissions and establish the BAU scenarios.

Table 8. *Initial and final data to establish BAU scenarios*

Stages	Parameter	Unit	Initial value (2016)	BAU final value (2040)
General Information	Emission factor for electricity	kgCO2/kWh	0.6439	0.488
	Protein generation	kg/capita/year	27.74	33.03
	BOD_5 generation	kg/capita/year	0.04	0.04
Water Supply System				
Population	Resident population	persons	190 000	318 513
	Serviced population	persons	187 840	318 513
Abstraction	Electricity consumed for water abstraction	kWh	21 428 000	63 436 478
	Volume of abstracted water	m^3	8 744 483	15 587 136
Distribution	Electricity consumed for water distribution	kWh	5 821 549	16 011 470
	Volume of water injected to distribution	m^3	9 018 190	16075022
	Volume of billed authorised consumption	m^3	5 468 080	10 550 663
Wastewater system				
Population	Resident population	persons	190 000	318 513
	Population connected to sewers	persons	113 174	197 686
	Population serviced by WWTP	persons	113 174	197 686
Treatment	Electricity consumed for wastewater treatment	kWh	2 500 824	5 201 322
	Volume of treated wastewater	m^3	2 592 363	4 642 767
	Type of treatment	-	Activated Sludge - Minor poorly aerated zones	Activated Sludge - Minor poorly aerated zones
	Influent BOD_5 load	kg	2 066 113	3 608 970
	Effluent BOD_5 load	kg	62 127	112 861
	BOD removed as sludge	kg	1 342 973.45	2 345 830
	Annual Dry Sludge Production	kg	4 396 425	11 002 752
	Pumped Sludge	m^3	365	630
	Sludge concentration	mg/l	33	48
Discharge/Reuse	Energy consumed from the grid	kWh	625 206	1 148 038
	Total Nitrogen at discharge	mg/l	50	58.1
	Volume of reused effluent	m^3	2 389 500	4 279 452

BAU scenarios

GHG emission scenarios

In 2016, around 41 000 tons of CO_2e of GHG emissions were generated in the water supply and wastewater systems of Miyahuna. Figure 2 shows the possible development of GHG emissions until 2040, a clear tendency of increase in the emissions can be observed for both systems. The linear nature of the data can be directly attributed to the constant increase of the parameters due to the BAU CAGRS values. The steady population growth, higher per capita water consumption and increasing energy intensity are the main drivers behind the growing emissions, which are could be expected to double by the year 2040.

In BAU scenarios, total annual emissions from the urban water cycle will increase to around 110 000 tons CO_2e by 2040 (Figure 2). Both systems, water supply and wastewater management will show a similar rate of constant growth and as such the distribution of emissions among these sources will remain unchanged.

Within the operational boundary of the Miyahuna Water Utility, water supply abstraction and wastewater treatment contributed to most of the total emissions produced by the utility.

The indirect emissions from energy consumption in water supply system will increase significantly by the year 2040 under BAU conditions. In absolute numbers, however, water abstraction and distribution will generate 27 000 tons CO_2e and 6 500 tons CO_2e more GHGs, respectively, in 2040 compared to 2016, which are decisive for the high level of total emissions in the entire water supply system of Miyahuna (Figure 2). Maintaining BAU trends in the pumping system, which translate in the use of outdated pumps that lose their efficiency considerably over time, will drive the emissions of GHGs of the entire system.

The GHGs emitted directly and indirectly by the wastewater system are entirely dominated by the treatment of wastewater, which is more likely to increase circa 33 600 tons CO_2e (Figure 2) if BAU trends are to continue. Even if the type of wastewater treatment remains the same – which will contribute to the GHG emission of BAU trends, the disposal of sludge according to BAU practices will be responsible for the majority of GHG emissions by 2040, followed by the energy consumption. By comparing the emissions of the discharge/reuse stage to those emitted by the treatment stage, the differences are significant: the discharge/reuse of wastewater will show an increase of around 1 100 tons CO_2e in 2040 to the 402 tons CO_2e emitted in 2016. Most of the emissions in this component can be attributed to the energy consumption.

Various measures to mitigate climate risks can thus be considered, including the optimisation of energy efficiency – in particular the pumping system, the reduction of water losses and the valorisation of biogas, as well as further investments to improve sewer networks and the utility's treatment capacity.

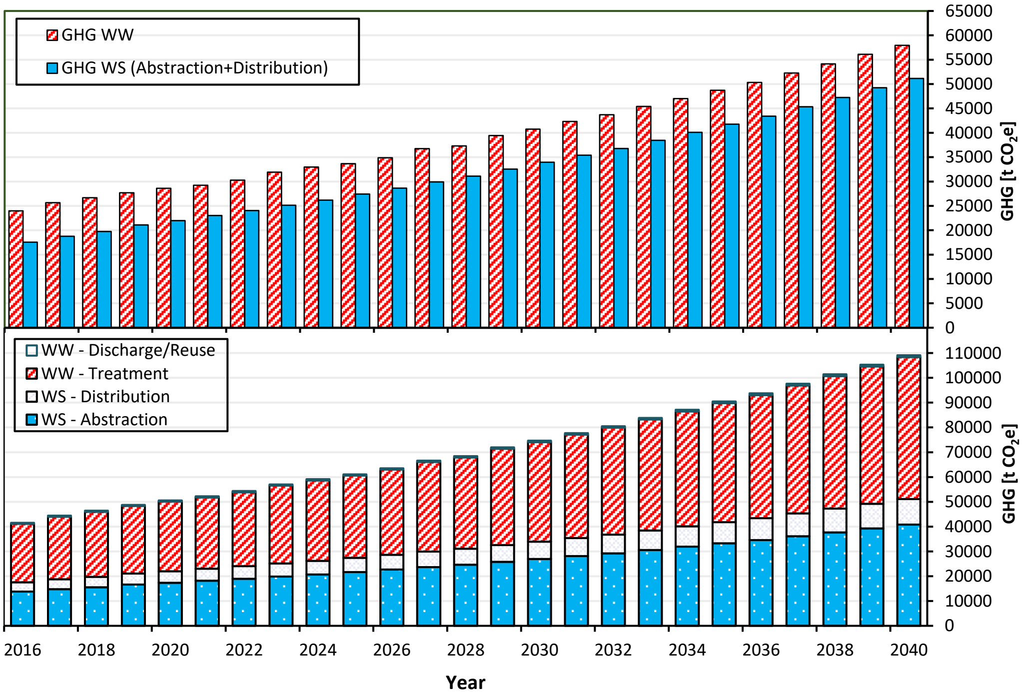

Figure 2. *GHG emissions as BAU scenarios for the wate supply (WS) and wastewater (WS) systems of Miyahuna. Top: Total GHG emissions per systems. Bottom: GHG emissions distributed per stage of each system*

Energy consumption

Energy consumption is one of the main parameters that drives GHG emissions in the BAU scenarios, as it was explained in the previous section. Figure 3 shows the possible development of energy consumption in MWh until 2040. What stands out from Figure 3 is its relation to the amount of GHGs predicted until the same year.

Energy demand in water supply will require to keep up with water demands which are more likely to increase due to population growth. Nevertheless, other factors such as pump aging, loss efficiency and increase in energy intensity will put pressure on the system if it remains the same as the start of the BAU scenario (2016). This translates in an increase of consumption of circa 33 650 MWh. Comparing both analysed stages, energy consumption for water abstraction is higher than for distribution and this is attributed to the type of water exploitation for water supply. In precise numbers, energy consumption is more likely to grow by 42 000 MWh and by 10 200 MWh for the stages abstraction and distribution respectively (Figure 3).

The wastewater system will undergo through the same behaviour as the water supply system. Energy consumption is higher for the treatment stage due to the massive energy consumption of aeration processes in activated sludge systems, this trend will continue the same and increase of 2 700 MWh in 2040. Discharge and/or reuse of wastewater have the least requirements of energy and will have an increase of around 520 MWh compared to 2016.

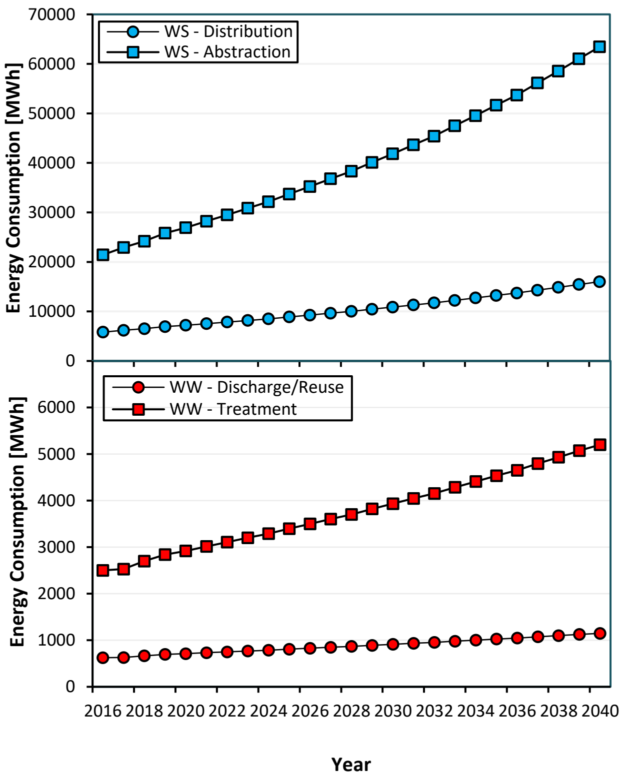

Figure 3. *The future trend of energy consumption per stage for the water supply (top) and wastewater (bottom) system*

Non-revenue water

Non-Revenue Water (NRW) can have a direct effect on water production costs and increased energy consumption which indirectly affects the pathways of GHG emission development. The BAU CAGR obtained in Step 2 of the current study analysed NRW since the year 2000 and a tendency of decrease was observed until 2015 (BAU CAGR of -0,2%). As it can be seen in Figure 4, NRW will slightly decrease towards 2040 (from 39% to 35%) under BAU conditions. Still, expecting to have almost one third of NWR up to 2040 can have a significant effect on costs, energy and GHG emissions.

Veryfing the data of the utiliy showed that the values of NRW also decreased slightly from 2016 to 2019. Nevertheless, the CAGR figures obtained to account for NRW reflect those of a country-wide level and may not be applicable to Madaba or Miyahuna Water Company for the mid-term future. A study on NRW and water losses conducted by Aboelnga et al., 2018 reported up to 40% of losses in the water supply system of Madaba. This leads up to uncertainities related to the CAGR values used for this case study and the results should be approached with some caution.

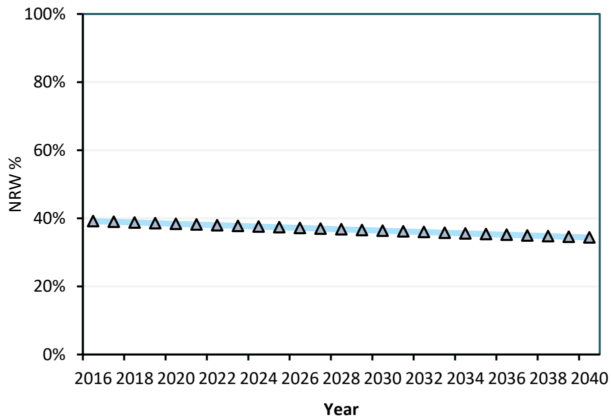

Figure 4. *The future trend of NRW for the water supply system of Miyahuna*

Mitigation impacts – the WaCCliM project

The project Water and Wastewater Companies for Climate Mitigation (WaCCliM) supports the Miyahuna water utility to reduce its carbon footprint and improve energy efficiency since 2016. An initial baseline was conducted to analyse the GHG emissions of the utility and the possible measures that could reduce them. Replacing the water pumping system and installing Variable Frequency Drives (VFD) resulted in one of the most promising measures that would significatively reduce the utility's footprint.

Up to this point in time, WaCCliM has been using and monitoring the results of their approach and the implemented measures considering the initial baseline as static in time. Nevertheless, developing BAU scenarios can help understand the real impact of the utility´s mitigation efforts and avoid its underestimation.

The comparison between the results of the project (in this case the mitigation scenario) and the BAU scenario can be seen in Figure 6, which shows the amount of GHGs in tons of CO_2e along years. The initial GHG assessment for both systems can be seen in year 2016.

The **water supply system** shows a major impact of the mitigation measures than the wastewater system. It is important to mention that for this comparison, only the data for the stage of water distribution was considered due to data availability for the mitigation scenario. Replacing the outdated pumps and installing Variable-Frequency Drive (VFD) in the system are measures that were first implemented in 2018, as it can be clearly seen in Figure 6, this had a significant impact that can be

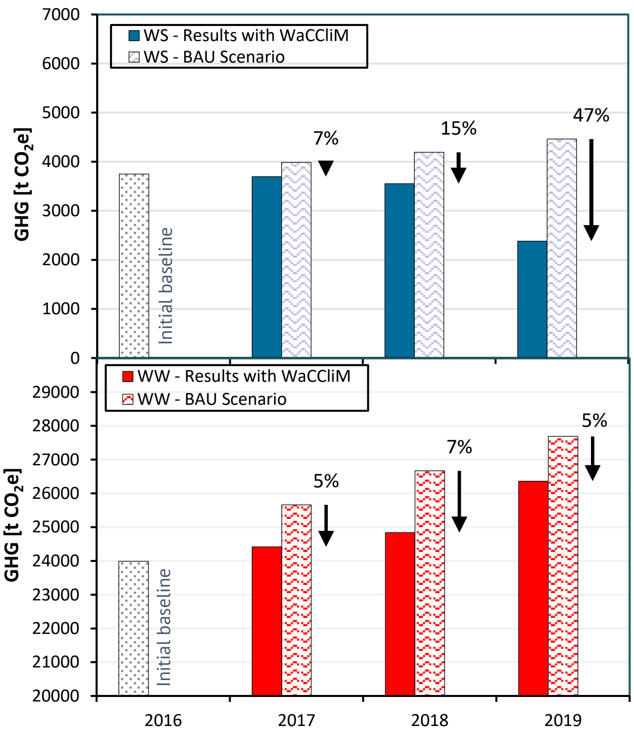

Figure 6. *Comparison of GHG emissions between the BAU scenarios and mitigation results achieved by WaCCliM*

appreciated in 2019, leading to a reduction of emissions up to 47% compared to 2016 (Figure 6), corroborating the fact that inefficient energy systems can result in higher carbon footprints if BAU conditions continue (energy mix coming from fossil fuels and outdated equipment).

Interestingly, a reduction in emissions was observed in 2017 and 2018 even though main mitigation efforts started in 2019. By observing and analysing the data with the company's operators, a decrease in the energy consumption was observed in the mentioned years. These fluctuations can be attributed to the interference of other projects aiming at improving the system but had a positive result in GHG mitigation:

- a new zoning and pressure management system for the Madaba water network was implemented.
- the construction of two Main Transmission Lines (North and South) of Madaba.

This outcome only proves that the improvement of different areas, processes and services in water utilities can lead to significant reduction of GHGs.

Based on figure 5, the GHG emissions of wastewater system increased rather than decreased, however, comparing the results with the BAU scenario the GHG emissions remain below the forecasted BAU trends if these were to continue as it was until 2016. Even though there was not a specific area in which mitigation measures were implemented, the efforts to improve the processes at system wide level resulted in GHG reduction, for example, the utility put efforts on increasing the number of sludge drying beds along the years. Additionally, it is important to consider that population growth and urbanization under BAU conditions increase the amount of wastewater conveyed to the utility and can change the wastewater composition, which could result in higher estimated emissions for the BAU scenario.

Regarding the difference between considering a static baseline and BAU emission scenarios, a clear explanation can be seen in Figure 5. Using the starting point to compare the results of the project led to underestimating the project's results by up to 16% in 2019.

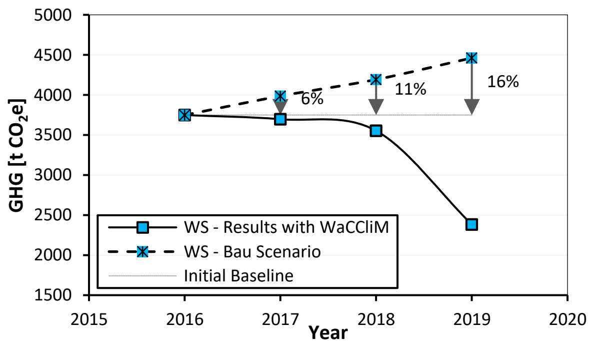

Figure 5. Difference between using the initial baseline and the BAU scenario to estimate results. Miyahuna water supply system.

Conclusions

This case study aimed at understanding the possible trajectory of GHG emissions of the utility Miyahuna under BAU conditions. The results obtained are an important step towards estimating the reduction of the utility's carbon footprint, the status of achievement of mitigation efforts and are a strong technical component for further implementation of climate policies not only at the level of the utility but also at regional and national scales. The scenarios show that the direct and indirect GHGs emitted by the utility can increase up to around 52 000 and 59 000 tons of CO_2e in 2040 for the water supply and wastewater systems respectively, if the utility continues with the same BAU trends as it was until 2016. The energy consumption shows the same constant growth along the years with an increment of almost 34 000 tons CO_2e compared to start of the study.

Additionally, this case study analysed the results of the mitigation measures implemented by the utility with support of the WaCCliM project. A reduction of 47% in the emissions coming from the distribution stage of water supply was recorded if we compare the project´s results with the BAU scenario. This comparison also highlighted some underestimation of the results, which have shown that reduction of GHGs can be up to 16% more than it was initially considered.

Considering uncertainties

Although this document attempts to deliver a reliable pattern of the evolution of GHG emissions as BAU scenarios, the approach presented in this guideline contains uncertainty resulting from different sources.

The GHG inventory method of the IPCC entails uncertainty related to default parameters, emission factors, and other metrics used, as explained in detail in the ECAM methodology [WaCCliM, 2019]. Since the IPCC guideline and ECAM lays the groundwork for the BAU scenario studies, this uncertainty is also inherent to the approach developed in this document.

The second aspect is linked to the methodology itself, which was addressed in part in the previous chapters. A major point is the application of a country-wide development trend on single utilities, which can exhibit individual performance in multiple aspects.

The third point is the statistical method used to determine the past trend. All the growth patterns applied only consider the start and end values of the reference period. The calculated result is thus very sensitive to the choice of the two data points.

In this context, the question of data quality also arises, as the last aspect leading to uncertainty. The data quality issue is also partly covered under the first point related to parameters used in the IPCC inventory method. However, three additional parameter groups, including the coverage of water and sanitation access, the per capita water and wastewater volume and the energy intensity are significant sources of uncertainty with BAU scenarios. Data sources for the connection degree in wastewater services show a significantly higher level of discrepancy than in the water supply. The per capita water and wastewater volumes are calculated based on the total quantity, which according to the UN [2014] often entails errors. The values presented as energy intensity in this methodology are estimations based on typical values of techniques and processes as well as analyses of the specific stress points faced by the respective country. Since the electricity consumption of the public water sector is often summarised under the same position as public lighting, it is hardly possible to calibrate the calculated energy consumption values with real statistics. The uncertainty range of these parameters is estimated as follows:

Table 9. *Uncertainty ranges for connection degree, per capita water/wastewater volume, and energy intensity.*

Parameter name	Uncertainty range
Connection degree water services	± 5%
Connection degree wastewater services	± 20%
Per capita water and wastewater volume	± 20%
Energy intensity	± 50%

Bibliography

Aboelnga, H.T.& El-Naser, H.& Ribbe, L. & Frechen, F.-B. (2020). Assessing Water Security in Water-Scarce Cities: Applying the Integrated Urban Water Security Index (IUWSI) in Madaba, Jordan. Water 2020, 12, 1299**.**

Aboelnga, H.T.& Saidan, M. & Al-Weshah, D. & Sturm, Michael & Ribbe, L. & Frechen, F.-B. (2018). Component analysis for optimal leakage management in Madaba, Jordan. Journal of Water Supply: Research and Technology - Aqua. 67. jws2018180. 10.2166/aqua.2018.180.

Busche, D. & Hayek, B. (2015). Energy efficiency in water pumping in Jordan. *Energy efficiency in the MENA water sector: Pumping water*. Available: *http://www.mena-water.net/energy-efficiency/good-practices/a-approaches-to-the-water-sector-5-papers.html?jumpurl=uploads%2Fmedia%2FA4-sukkar-reader-112015.pdf&juSecure=1&mimeType=application%2Fpdf&locationData=2960%3Att_content%3A16273&juHash=2a2820523b994a2c8d4940dd4ad94caae375976c* [Accessed 22 January 2019].

Doorn, M. J. & Liles, D. (1999). Quantification of methane emissions and discussion of nitrous oxide, and ammonia emissions from septic tanks, latrines, and stagnant open sewers of the world. No. EPA/600/R-99/089 (NTIS PB2000-101018). U.S. Environmental Protection Agency (EPA). Washington, DC.

FAO (Food and Agriculture Organisation). (2010). Food Balance Sheets. Available: *http://www.fao.org/fileadmin/templates/ess/documents/food_security_statistics/FoodConsumptionNutrients_en.xls* [Accessed 11 December 2018].

(2014). *FAO Statistical Yearbook 2014: Asia and the Pacific food and agriculture*. Available: *http://www.fao.org/3/a-i3590e.pdf* [Accessed 19 February 2019].

González, A. B. (2018). *The water-energy-agriculture nexus in Jordan – A case study on As-Samra wastewater treatment plant in the lower Jordan River basin*. Retrieved from *http://kth.diva-portal.org/smash/record.jsf?pid=diva2%3A1236635&dswid=-9521*

IEA (International Energy Agency). (2014). *CO_2 emissions from fuel combustion 2014*. Paris: OECD / IEA. DOI: 10.1787/co2_fuel-2014-en.

(2015). *CO_2 emissions from fuel combustion 2015*. Paris: OECD / IEA. DOI: 10.1787/co2_fuel-2015-en.

(2016a). *CO_2 emissions from fuel combustion 2016*. Paris: OECD / IEA. DOI: 10.1787/co2_fuel-2016-en.

(2016b). *Mexico energy outlook*. Paris: OECD / IEA. DOI: 10.1787/9789264266896-en.

(2016c). *World energy outlook 2016*. Paris: OECD / IEA. DOI: 10.1787/weo-2016-en.

(2017). *CO_2 emissions from fuel combustion 2017*. Paris: OECD / IEA. DOI: 10.1787/co2_fuel-2017-en.

(2018a). *CO_2 emissions from fuel combustion 2018*. Paris: OECD / IEA. DOI: 10.1787/22199446.

(2018b). *Electricity Information 2018*. Paris: OECD / IEA. DOI: 10.1787/electricity-2018-en.

IPCC (Intergovernmental Panel on Climate Change). (2001). *Climate change 2001: mitigation*. Contribution of Working Group III to the Third Assessment Report of the IPCC. Cambridge, New York: Cambridge University Press.

(2006). *2006 IPCC Guidelines for national greenhouse gas inventories*. [Eggleston H.S., B. L., Miwa K., Ngara T. and Tanabe K. (Ed.)]. Japan: IGES.

(2014a). *Climate change 2013: the physical science basis*. Contribution of Working Group I to the Fifth Assessment Report of the IPCC. [Stocker, T. F., Qin, D., Plattner, G.-K., Tignor, M. M. B., Allen, S. K., Boschung, J.*, et al.* (Eds.)]. Cambridge: Cambridge University Press. DOI: 10.1017/CBO9781107415324.

(2014b). *Climate change 2014: impacts, adaptation, and vulnerability. Part A: Global and sectoral aspects*. Contribution of Working Group II to the Fifth Assessment Report of the IPCC. [Field, C. B., Barros, V. R., Dokken, D. J., Mach, K. J., Mastrandrea, M. D., Bilir, T. E.*, et al.* (Eds.)]. Cambridge: Cambridge University Press. DOI: 10.1017/CBO9781107415379.

MWI (Ministry of Water and Irrigation). (2013). Jordan water sector – facts and figures. Available: *http://www.mwi.gov.jo/sites/en-us/Documents/W.%20in%20Fig.E%20FINAL%20E.pdf* [Accessed 20 October 2018].

(2015). Jordan water sector – facts and figures. Available: *http://www.mwi.gov.jo/sites/en-us/Hot%20Issues/Jordan%20Water%20Sector%20Facts%20and%20%20Figures%202015.pdf* [Accessed 20 October 2018].

(2017). Jordan water sector – facts and figures. Available: *http://www.mwi.gov.jo/sites/en-us/Hot%20Issues/Jordan%20Water%20Sector%20Facts%20and%20Figures%202017.PDF* [Accessed 20 October 2018].

MWI (Ministry of Water and Irrigation), GWP (German Water Partnership), & GIZ (Gesellschaft für Internationale Zusammenarbeit). (2017). Jordan's water challenges – Prospects for the private sector and opportunities for the German water industry. Berlin. Available: *https://www.germanwaterpartnership.de/fileadmin/pdfs/gwp-veranstaltungen/jahreskonferenz_2017/Whitepaper_Jordans-Water-Challenges_GWP.pdf* [Accessed 20 January 2019].

UNDESA (United Nations Department of Economic and Social Affairs). (2017a). World Population Prospects 2017. Available: *https://population.un.org/wpp/* [Accessed 25 December 2018].

(2017b). World Population Prospects: the 2017 revision, methodology of the United Nations population estimates and projections. UN. New York. Available: *https://population.un.org/wpp/Publications/Files/WPP2017_Methodology.pdf* [Accessed 1 March 2019].

(2018). World Urbanisation Prospects 2018. Available: *https://population.un.org/wup/* [Accessed 25 December 2018].

UNSD (United Nations Statistics Division). (2016). Environment Statistics (ENVSTAT). Available: *https://unstats.un.org/unsd/envstats* [Accessed 1 March 2019].

WaCCliM (Water and Wastewater Companies for Climate Migitation). (2019). ECAM 2.2 Methodology. Available: *http://wacclim.org/library/ecam-methodology-guide/* [Accessed 20 March 2019].

WHO (World Health Organisation) & UNICEF (United Nations International Children's Emergency Fund). (2017a). Progress on Drinking water, Sanitation and Hygiene – 2017 update and SDG baselines. Available: *https://washdata.org/report/jmp-2017-report-final* [Accessed 1 February 2019].

(2017b). The WHO/UNICEF Joint Monitoring Programme for Water Supply, Sanitation and Hygiene (JMP) database. Available: *https://washdata.org/* [Accessed 1 February 2019].

(2018). JMP Methodology: 2017 update & SDG baselines. Available: *https://washdata.org/report/jmp-methodology-2017-update* [Accessed 1 February 2019].

Annex A
BAU CAGR for resident population growth

Year	Initial value (2016)	BAU final value (2040)
2015	9401993	2,1%
2016	9 637 780	2,1%
2017	9 838 544	2,1%
2018	10 043 491	2,1%
2019	10 252 707	2,1%
2020	10 466 281	2,1%
2021	10 684 304	2,1%
2022	10 906 868	2,1%
2023	11 134 069	2,1%
2024	11 366 002	2,1%
2025	11 602 767	2,1%
2026	11 844 465	2,1%
2027	12 091 196	2,1%
2028	12 343 068	2,1%
2029	12 600 186	2,0%
2030	12 862 660	2,0%
2031	13 130 602	2,0%
2032	13 404 125	2,0%
2033	13 683 347	2,0%
2034	13 968 384	1,9%
2035	14 259 359	1,9%
2036	14 556 396	1,9%
2037	14 859 620	1,9%
2038	15 169 160	1,9%
2039	15 485 149	1,9%
2040	15 807 720	1,9%

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