Participatory creation of integrative scenarios for the Jordanian power and water sector

Background report

For participatory workshop in Amman
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Content

1. Introduction

Jordan ranks as the fourth water-scarcest country in the world since the majority of its territory is desert where only 50 millimetres of rain falls every year. Jordan gets most of its water from the groundwater basins which are already partly exhausted because of unsustainable usage when groundwater is extracted at twice the rate as it is being replenished. The climate change with unpredictable intensity, duration, and frequency of precipitations, rising temperatures and evaporation increases water scarcity in Jordan. The growing water demand due to growing standards of life and increase in the number of population, inefficient agriculture, which depends on overexploiting of groundwater, regional instability and migration with sharp increase in the number of refugees increases pressure on available water resources.

At the same time, Jordan has settled targets to reach its goals of climate-change mitigation and energy security policies, namely, to satisfy the growing Jordanian energy demand with sustainable energy supply as well as to reduce its import dependency from volatile energy imports that are prone to political risks. Jordan also has to address the intermittency and storage options for volatile sources such as renewable energy sources. At the same time, energy supply options should correspond to the requirements of environmental sustainability regarding the possible impacts on land and water resources as well as safety concerns in terms of impacts on human health and pollution of soil, water, and other environmental resources. Expectations also exist that further deployment of energy supply technologies will create multiplier effects on local economies as well as a number of direct, indirect and induced employment opportunities.

The energy and water sectors in Jordan are interconnected. However, there are currently only a few synergies in their activities and cooperation. Both sectors have to address challenges and cooperation would have been beneficial for both. The water sector is facing high power costs which are caused by the operation of wells and pumps, high water and energy losses and growing water demand. The power sector is facing challenges regarding the stability of the grids, the costs of electricity, and temporary overcapacities. The aim of this project is to identify possible areas for collaboration and potential areas of conflict in an integrated participatory governance and science-based approach.

During an initial two-day on-site workshop, stakeholders in particular from the Jordanian power and water sectors will on the first day be invited to identify parameters and settings for further scenario development based on their views about important criteria for the water and energy sectors as well as perceptions of risks and challenges faced by the water and energy sectors. On the second day, the participants will develop different future scenarios for the Jordanian power and freshwater systems in more detail. This might include a business-as-usual scenario and up to five additional scenarios that consider aspects such as pump-storage options, load-shifting, desalination, renewable energies, and energy efficiency measures.

2. Background

Water scarcity is the most acute environmental challenge in Jordan, which is already the fourth water-scarcest country in the world, suffering from erratic precipitations. The risk of water unsafety in the country is very high and Jordan is among the 18 countries in the world with the highest risk of water unsafety with an annual 150m^3 availability per capita per annum. The probability exists that the rate of precipitation necessary to refill the Jordanian aquifers will decline to 15% by the year 2100. There is also the risk that the existing country aquifers will completely deplete by 2030 because of the impacts of climate change and unsustainable water usage[9].

Despite the water scarcity, the availability and coverage of water services are nearly universal and indiscriminative of the place of residence or income. Jordan is the world leader in wastewater treatment for irrigation and urban water supply. However, up to 51% of the country's water is wasted due to the inefficient use of water resources such as illegal wells, which exploit groundwater twice as fast as it is recharged[10].

The water sector is Jordan's largest single energy consumer, with a share of 15% of the electricity generated in the country. Given that the water sector is highly subsidised, the total energy bill paid by the Ministry of Water and Irrigation of Jordan in 2017 amounted to JOD 161 million based on the energy cost of 0.094 JD/kWh. Energy costs constitute 43% of the total operation and maintenance costs of the water sector. Assuming that current operational patterns will remain the same, real power costs for water pumping are estimated to amount to JD640 million by the year 2025[11].

There are three major policy-making stakeholders in the energy and water sectors: the Ministry of Energy and Mineral Resources, Ministry of Environment, and Ministry of Water and Irrigation. The Ministry of Energy and Mineral Resources (MEMR) is the overarching legislative authority on energy-related issues in Jordan. It establishes political conditions for the development of the energy markets. It is responsible for the energy security of the country, namely, for adequate energy supply at the lowest possible costs. In this responsibility, the ministry defines energy policies and proposes them to the Council of Ministers for approval, fixes energy tariffs, and regulates all activities impacting the energy sector. It is also responsible for all activities connected with the exploration and development of minerals and hydrocarbons. The Ministry of Environment is in charge of designing and implementing environmental policies in Jordan as well as for the implementation of environmental standards in accordance with international norms. It also has a strong focus on the water sector due to its energy consumption and in questions of water pollution and industrial water treatment. The Ministry of Water and Irrigation is responsible for water protection and the prevention of pollution; modernizing and implementing water policies; execution of water projects; and caring for and defending Jordan's water rights in the region.

The energy and water sectors are suffering from the low level of cooperation at the level of the ministries. This leads to challenges in the implementation of new projects which require water-energy nexus. For instance, the Ministry of Water and Irrigation is striving to implement more renewable energy projects with the expectation that these projects will help to lower the energy

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[9] According to Falkenmark Indicator of the Water Stress Index and Aquastat data of the Food and Agriculture Organization, World Resources Institute and UNDP, 2014

[10] Ministry of Water and Irrigation of Jordan, 2017

[11] Water Authority of Jordan, 2017; Energy Efficiency and Renewable Energy in the Water Sector, 2016

bills paid for the operation of water piping and for water supply. Such projects require cooperation from the side of the Ministry of Energy and Mineral Resources of Jordan. The need to implement renewable energy sources (RES) projects for water pumping operations has created awareness at the government level about the necessity to cooperate and to coordinate actions for the deployment of RES projects. The first steps in this direction were taken by the formation of the steering committee which represents communities, water, and energy. This committee is responsible for further planning of the water-energy nexus efforts.

3. Energy security in Jordan

3.1. Electricity supply

Currently, fossil fuels, such as oil and gas, remain the main sources of electricity supply in Jordan. Over 82% of the Jordanian electricity is supplied by imported oil and 12% by imported natural gas. Energy imports from other countries of the region become volatile due to growing energy needs in these countries and existing political risks in the region. Jordan's own oil and gas reserves are negligible however this situation might change with the discovery and exploration of the gas reservoir in the Mediterranean Sea and from the Risha field. Another hope is on natural gas imports from Israeli offshore fields Tamar and Leviathan through the Arish-Ashkelon pipeline. However, this remains a contested option for political reasons. To diversify its energy supply, the Jordanian government is proceeding with the construction of infrastructure for liquefied gas and shale oil. There are a couple of projects throughout the country for oil shale electricity generation and for LNG terminals, however, concerns exist about the costs and security of these electricity generation options.

Jordan also follows the option of deployment of nuclear power with policy targets to provide a significant share of electricity from nuclear for domestic consumption and even for electricity by 2030. The institutional structure for nuclear energy deployment was established with the Jordan Atomic Energy Commission as well as a number of other organisations. Also, the Jordan University of Science and Technology has its first nuclear engineering program. However, plans for the deployment of nuclear power are affected by public protests against nuclear power, difficulties in finding a suitable project site, and a constant change of international partners for the realisation of the nuclear power stations.

Only 2% of all electricity is currently coming from RES despite favourable geographic conditions. The majority of the regions in Jordan offer direct normal irradiance (DNI) above 2,000 KWh/m^2/yr. The annual solar influx is around 3,602 hours, and the daily average sunshine duration is 9.9 hours. The areas of Ma'an and Aqaba have the highest levels of solar irradiance in the country and in some places the solar intensity reaches 2.600 kWh/m^2.
Jordan has favourable conditions for wind-power generation in terms of wind speed and long periods of windy weather. The diversity of the topography of Jordan is favourable for high wind speed, as Jordan lies 400 m below sea level at the Dead Sea and up to 1,700 m above sea level in the north and the south. Wind speeds in Jordan can reach 7.5 meters/second and up to 11.5m/second in hilly areas. The Jordanian government set the target to reach a 10% share from RES in the energy mix of the country by 2020, however, this target is now in question due to the decision of the government to postpone further deployment of RES projects.

3.2. Electricity grids

The transmission grids in Jordan, mainly of 132 kV, are located along the north-south axis of the country. There is also one 400 kV grid that crosses the entire country. In terms of regional interconnections, Jordan has 230 kV and 400 kV lines with Syria and Egypt. The system is operated by NEPCO, the company owned by the government of Jordan. The electricity grids coverage is almost universal with 99% of the population being connected to distribution grids. The current capacity of electricity grids stands at 3,200 MW and can only accept another 500 MW. The capacity of the electricity grids is a major bottleneck for the further deployment of RES. Even though the Ministry of Energy and Mineral Resources announced the plan to construct additional power grids, considering the need for renovation of existing infrastructure as well as the speed of construction.

3.3. Water demand by the energy sector

In 2015, the energy sector water need in Jordan was 14 million m^3. It is projected that this water demand will rise to 150 million m^3 by 2030. The Jordanian energy sector could significantly decrease its water consumption by integrating solar and wind energy options. Currently, in terms of water consumption, the fossil fuel-dependent energy sector in the MENA region consumes 0.05 billion m^3/year for coal, 0.4 billion m^3/year for oil, and 0.8 billion m^3/year for natural gas. Nuclear power plants, depending on the cooling technology applied, use approximately 1.5 to 2.7 m^3 of water per MWh of energy produced. Energy technologies such as wind power and PV consume little to no water during energy production.

3.4. Financial sustainability and regulation of the sector

Energy costs amounted to 19% in the year 2011 when energy costs reached its pick. The Jordanian government debt makes around 60% of GDP and it continues to grow steadily. The increase in government debt is mainly because of the energy bill and subsidies to cover the costs of energy imports. The energy subsidies in Jordan account at around 10% of all governmental expenditures. However, the change of the subsidy regime should be a gradual process as the removal of subsidies in 2012 resulted in a 23% increase in heating costs and a 15% increase in transportation costs. Social protests in Jordan in 2018 were also connected to the changes in energy tariffs.

The electricity sector is regulated by the Ministry of Energy and Mineral Resources as well as by the Energy Regulatory Commission. The generation sector includes the privately-owned generation company Central Electricity Generating Company, the state-owned Samra Electric Power Generating Company, independent power producers, large industries and international grids. The distribution sector includes the Jordanian Electric Power Company (JEPCO), the Irbid District Electricity Company (IDECO), and the Electricity Distribution Company (EDCO). The National Electric Company (NEPCO), responsible for the transmission grid, is owned by the state and regulated by the Ministry of Energy and Mineral Resources.

The tariffs for electricity are established in accordance with the General Electricity Law, which is the main law for the electricity sector. The Electricity Regulatory Commission, which is responsible for the liberalisation of the Jordanian electricity market and for guaranteeing its efficiency, reliability, and development, establishes electricity tariffs in accordance with the law. The tariffs for generation are established by NEPCO in accordance with the bulk supply license. The generated electricity is sold to NEPCO, which is the single buyer on the Jordanian electricity market and operates the entire electricity transmission grid. Large electricity consumers such as industries are supplied by NEPCO directly.

Electricity tariffs are established in accordance with the following principles: recovery of full costs of business activities, a reasonable return on capital investment, incentives for improvement of technical and economic efficiency and quality of services, non-discriminatory principle for consumers of the same category and among categories, and reduction of cross-subsidies.

All power stations with capacities above 1MW are subject to licenses from the regulatory authority. Local supply networks with a capacity below 100kW or power stations can operate without licenses, however, only for the goals of self-consumption. The licensing procedures are equally applied to conventional and RES power stations.

There are a number of laws in Jordan which stimulate the deployment of RES projects. The Renewable Energy and Energy Efficiency Law aims to stimulate private investment into RES projects. The law allows private companies to enter into direct negotiation with the Ministry of Energy and Mineral Resources for RES projects and obliges NEPCO and regional distribution companies to purchase electricity generated by RES and to pay for their grid connection. The Environment Protection Law supports the deployment of RES and speaks about the complete removal of subsidies for oil and the establishment of fiscal incentive packages on RES and energy efficiency equipment. The National Green Growth Strategy covers energy and water sectors and speaks about the need to attract investment into RES and energy efficiency in both sectors. The money from international donors (EU, Gulf Cooperation Council, and others) for the development of RES projects are channelled through the Renewable Energy and Energy Efficiency Fund, whose main aim is to stimulate RES development and deployment of energy efficiency measures in the country. The fund is managed by the Ministry of Energy and Mineral Resources and is exempt from taxes.

3.5. Targets of energy policy

One of the targets of energy policy in Jordan is to reduce the dependence of the country on imported oil from 82% to 40% by 2020. The share of natural gas should increase to 29%, of shale oil should make 14%, RES should make 10% and nuclear should contribute to 6%. Energy policy in the country is shaped by three major documents: National Energy Strategy, National Master Plan of Energy Sector and National Renewable Energy Strategy.

The ***National Energy Strategy*** was developed for the period 2011-2020 with the main goal to diversify energy supply through the development of solar and wind capacities, nuclear power, and shale oil. The strategy aims to transfer Jordan to a net energy exporter by 2030.

The ***National Master Plan for the Energy Sector*** was developed for the period 2007-2020. Its main objective is to reduce energy consumption and to increase the quality of life at the same time. Other targets include balancing of energy imports and exports, the reduction of production costs, enhancement of competitiveness of local industries, and reduction of required investments in energy generation and distribution. Further targets are the improvement of the level of available investments and opening up of energy markets.

The ***National Strategy for the Development of Renewable Resources*** is part of the National Energy Strategy and foresees large-scale deployment of renewable energy sources as a key priority. The strategy established the target of 10% RES by 2020. It also provides recommendations on energy efficiency in different sectors such as industrial, commercial, housing, transport, services, and water pumping.

4. Water security in Jordan

4.1. Background in the water sector: supply and demand

4.1.1. Water supply

Jordan is facing a deepening multipronged freshwater crisis, exacerbated by a long-term decline in precipitation, declining groundwater levels, and regional conflict and immigration. The Jordan's per capita water availability has decreased from 3600 m^3/year in 1946 to 135 m^3/year in the present, putting the nation far below the 500 m^3/year level of "absolute water scarcity". The water supply in Jordan comes mainly from three major sources: groundwater (59%), surface water (27%), and treated water (14%)[12].

Groundwater contributes to around 59% of the total water supply, which makes around 618.8 MCM per year. The groundwater mainly comes from 12 major groundwater basins. Six of these basins, which means 50% of all existing groundwater supply, are already over-extracted. Four basins function at their full capacity and two basins are underexploited. The number of working wells in Jordan exceeds 3211 wells. The groundwater level in the main aquifers drops at a rate of 2 meters per year but the decline in some depleted areas reaches 5 to 20 meters. The safe yield abstraction quantity from renewable groundwater is 275 MCM, while the safe yield abstraction quantity from non-renewable groundwater for 50 years is about 143 MCM. Quantity of over pumping from groundwater is about 200 MCM[13].

Jordan is now accessing non-renewable water resources from fossilized deep-water aquifers. As the groundwater basins map from 2017 shows, fossil aquifers are non-renewable and are situated mostly in the South Eastern parts of Jordan (Figure 1). The map shows the safe yield and actual abstraction for each basin. The most important non-renewable groundwater resources are the Disi and the Jafr fossil aquifers[14].

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[12] Ministry of Water and Irrigation of Jordan, 2017

[13] Water Strategy, 2016

[14] Ministry of Water and Irrigation of Jordan, 2017

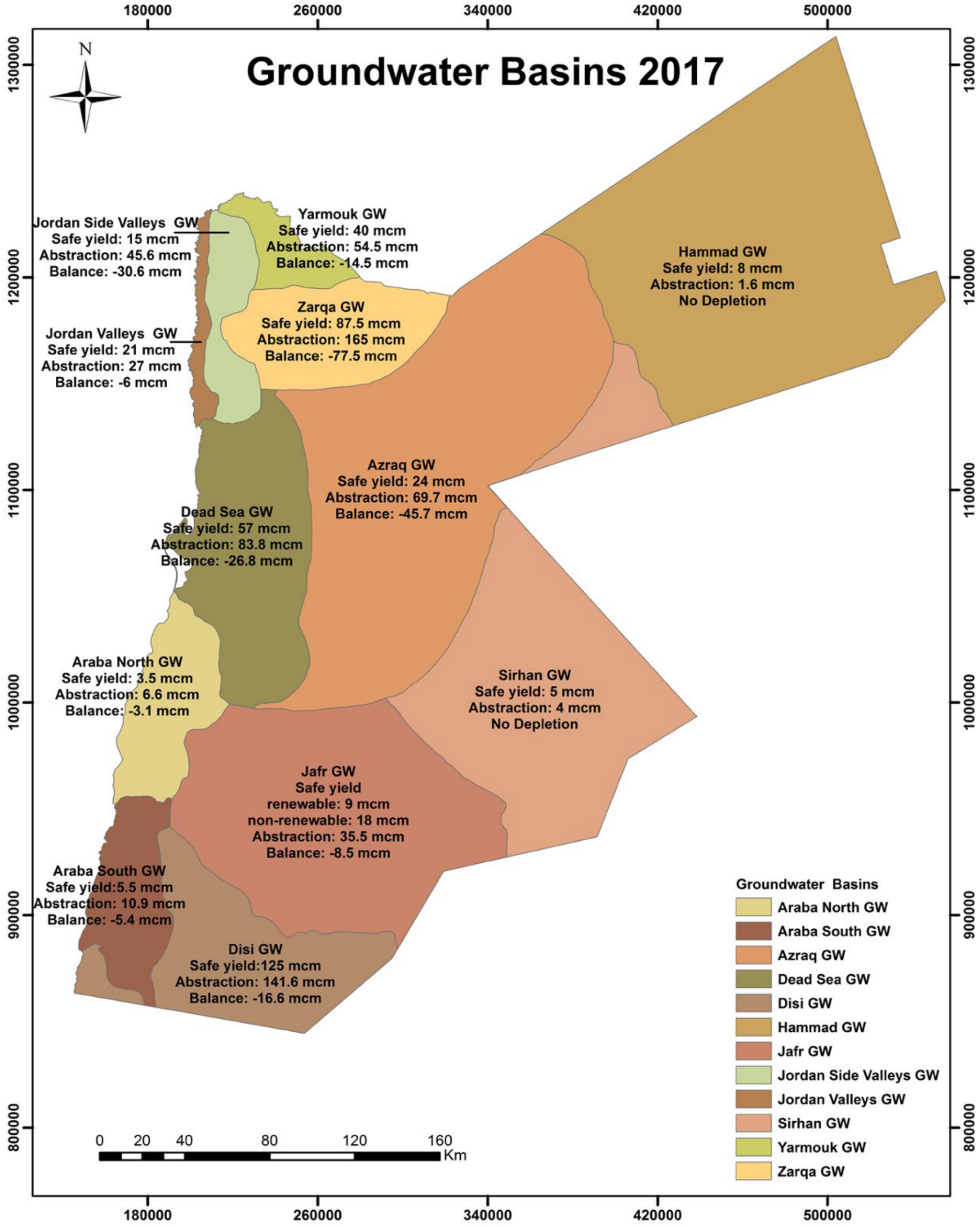

Figure 1: Groundwater basins Map for 2017
Source: Ministry of Water and Irrigation of Jordan, 2017

The ***surface water*** contributes to 27% of water supply which makes around 288.1 MCM per year. The surface water comes from 15 surface water basins. The country depends on most of its surface waters from Syria and Israel via the transboundary Yarmouk Jordan River. Jordan receives water from the Yarmouk River, the largest and most important tributary of the Jordan River, with an annual average flow of around 400 to 500 MCM. Flow into Jordan is controlled by Al-Wehda dam which is the largest dam in Jordan with a capacity of 110 MCM. The dam is located at the Jordan-Syria border and serves as the centerpiece of the 1987 transboundary water-sharing agreement between the two nations. However, since the construction of Al-Wehda dam in 2005, the annual flow into the reservoir steadily declined from 150 to 15 MCM by 2011. This is largely due to the increase in upstream water use and diversions via a number of Syrian dams and reservoirs, the development of which ran counter to the intent of various water treaties with Jordan. The transition period from 2006 to 2011 is important because it represents the time after which the Al-Wehda dam officially started functioning in accordance with the Jordan-Syria water agreement of 1987 and right before the decline in agricultural land use following the onset of the Syrian crisis. The reservoir inflows started rising in 2013[15].

The ***treated water*** makes 146.7 MCM annually. In the year 2017, the treated water in Jordan made around 8 851 m^3/hr. Jordan is a world leader in wastewater treatment for irrigation and urban water supply largely due to the current subsidies for wastewater treatment. The wastewater treatment is the only available option, as the country's limited coastline permits hardly any water desalination activities. In 2013, more than 30 wastewater treatment plants were in operation with a total production of 121 million m^3 of treated wastewater[16].

4.1.2. Factors influencing water supply

The following factors are influencing water supply in Jordan: geographic and climatic conditions, impacts of climate change, political issues.

Geographic and climatic conditions are shaping the availability of water in Jordan. The Jordanian climate is arid to semi-arid with low precipitation and high evaporation rates. About 94% of Jordan's territory receives less than 200 mm of precipitation per year. In 2013 Jordan experienced 8,120 million m^3 of precipitation per year, of which 7,689 million m^3, or 94.7% were lost due to evaporation. In 2013, Jordan experienced 8,120 million m^3 of precipitation per year of which 7,689 million m^3, or 94.7%, were lost due to evaporation[17].

Predictions about ***climate change impacts*** on water availability in Jordan vary depending on the applied models for their generation and input parameters. These results show a broad range of impacts from severe impacts to only minor impacts. The climate change impacts include an increase in temperature and dry spells, a drop in the frequency of precipitation and an increase in the intensity of extreme weather events, which are influencing the situation in the water sector. Climate change impacts will affect both, water quality and quantity. According to the Global Freshwater Initiative, the precipitation in Jordan will decline by 30% and the occurrence of drought will triple by 2100 as a result of climate change. Figure 2 shows the current and projected droughts in Jordan's major river basins.

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[15] Ministry of Water and Irrigation of Jordan, 2017; Rajsekhar and Gorelick, 2017

[16] Ministry of Water and Irrigation of Jordan, 2017 and 2018; National Water Strategy, 2016

[17] Ministry of Water and Irrigation of Jordan, 2017 and National Water Strategy, 2016

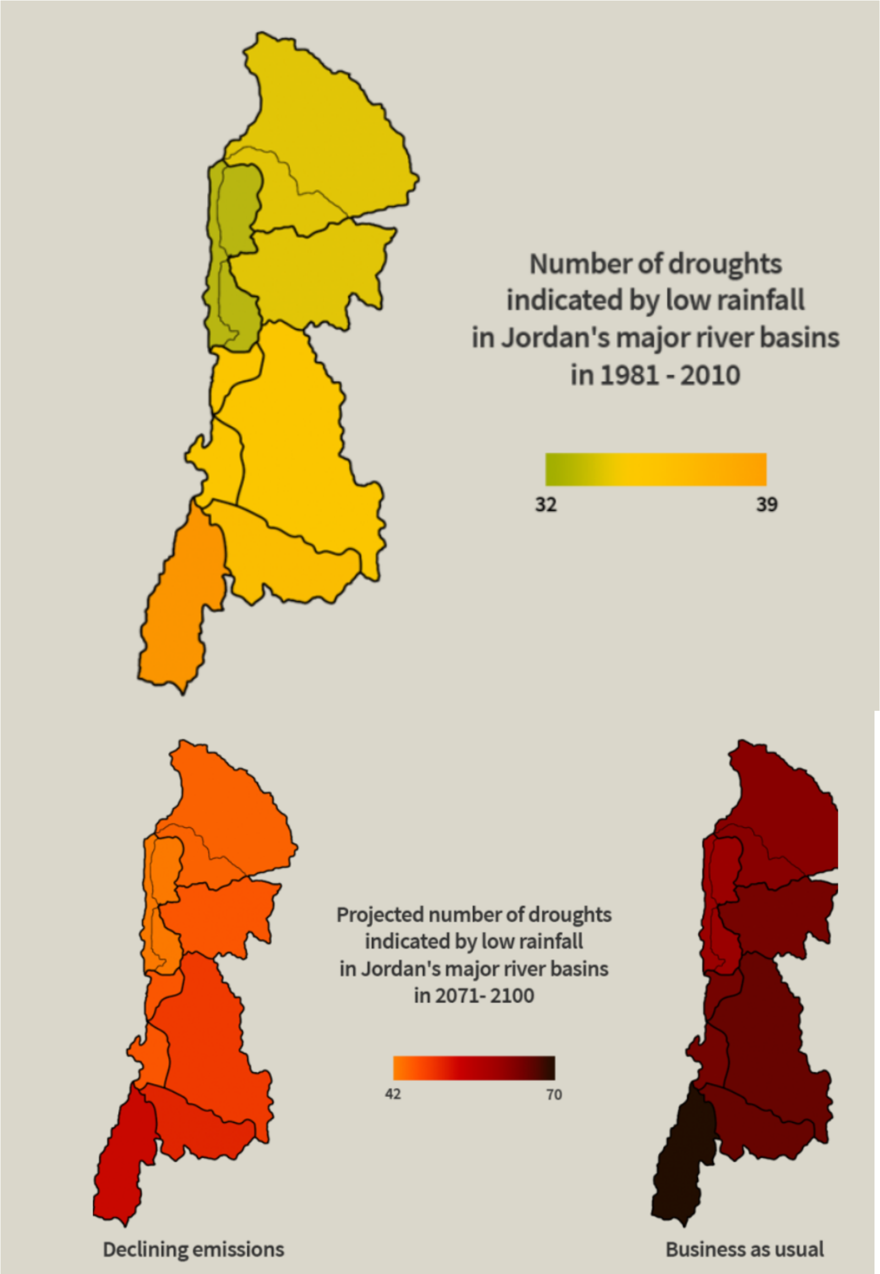

Figure 2: Current and projected droughts in the major Jordan's river basins.
Source: Müller et al. 2016

Climate change impacts on the water will intensify over time and will result in a significant decrease in water availability. It is projected that the decrease in water availability will be particularly severe after the year 2040, according to simulations of the Regional Initiative for the Assessment of Climate Change Impacts on Water Resources and Socio-Economic Vulnerability in the Arab Region (RICCAR). Figure 3 shows a comparison of unmet water demand (in MCM) in the Jordan basin due to climate change impacts versus socio-economic development until the year 2050. The red curve shows the unmet demand as a result of decreasing water availability due to climate change. The grey curves show the unmet demand as a result of increasing water demand due to different socio-economic development pathways[18].

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[18] Climate Change Policy for a Resilient Water Sector, 2016

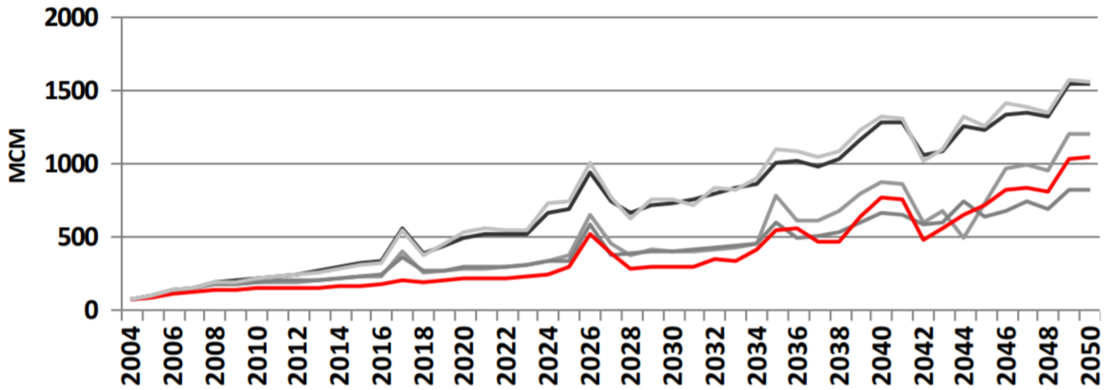

Figure 3: Comparison of unmet water demand (in MCM) in the Jordan basin due to climate change impacts versus impacts from socio-economic development until the year 2050
Source: Hoff et al. (2011)

The key conclusion is that climate change impacts and the decreasing water availability equally contribute to the growing water demand gap as the increase in water demand due to socio-economic development.

4.1.3. Water demand and influencing factors

The water demand in Jordan is shaped by three major water-consuming sectors: agriculture, which is the largest water consumer and consumes around 544.7 MCM annually, domestic consumption, which also includes private households, is the second-largest consumer and consumes around 469.7 MCM of water annually. The industry is the third consumer, however, the volumes of consumption from this sector are much lower in comparison to all other ones and make 32.1 MCM. The estimated water demand quantity for all sectors is 1412 MCM in 2017[19]. Agriculture is by far the largest user of water. Currently, the agricultural sector accounts for 64% of Jordan's water usage. At the same time, this sector contributes only to 3% of GDP[20]. The following factors are influencing water demand in Jordan: the geopolitical situation and migration, urbanisation and changing lifestyles, growth in population, as well as rising needs for irrigation and industrial use.

Geopolitical situation and migration are influencing existing water resources and availability of water in the future. The rapid growth of the population, which also includes migration of refugees to the country, increases demand in water and energy supply as well as in wastewater.

Urbanisation and changing lifestyle. The rate of urbanisation of around 4% per year during the last decade resulting in currently 84% of the Jordanian population live in urban centres. The increasing rate of urbanisation and changing lifestyles put additional stress on water resources.

4.2. Energy demand by the water sector in Jordan

Electricity pick demand is growing steadily in Jordan and is projected to grow by 7.4% on average per year between 2014 and 2020, from 3,000 MW in 2012 to 15,000 MW in 2040. According to NEPCO, electricity demand will reach 4,300 MW by 2020 and 8,130 MW by

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[19] Ministry of Water and Irrigation of Jordan, 2017

[20] National Water Strategy, 2016

2030. The highest share of electricity is consumed by private households and public buildings (43%), followed by industry (25%), services (15%), water pumping systems (14%), and street lighting (2%).

Currently, the average electricity consumption per cubic meter of billed water is 4.31 KWh/CM. Water pumping is the largest energy consumer in the water sector because water supply in Jordan relies mainly on resources that are located at a considerable distance from the cities. Consequently, the water sector uses energy extensively to pump water. In 2017, it consumed around 14% of the total electricity generated in Jordan, which resulted in the total amount of 1,685 GWh.

Energy consumption in 2017 for municipal water supply made 7.51 kWh/m^3 (billed) according to the data of the Water Authority of Jordan (WAJ), which is mainly responsible for municipal water supply. Energy consumption for irrigation and industrial use made 0.274 kWh/m^3 (billed), according to the Jordan Valley Authority (JVA) which is responsible for water supply for irrigation and industry in the Jordan Valley.

Electricity consumption by the water sector continues to grow due to the groundwater depletion that requires pumping water from lower levels, the increased water desalination projects and the increased water demand. For instance, in the year 2017 electricity consumption of the water sector increased by 34% in comparison to the year 2010. It is expected that electricity demand will increase by 2.5-3% per year for the next twenty years, resulting in a 60% increase in electricity demand by the water sector in twenty years in comparison to the electricity demand nowadays.

For example, about 90% of the drinking water supplied to Amman comes from water sources which are situated 125 to 325 km away from Amman. The sources are elevated up to about 1200 m. The water supply system has 5 pumping stages. Another example is the drinking water supply of the northern governorates of Jordan. Around 42 % of the drinking water comes from the water sources situated 20 to 76 km away. They are elevated up to about 1200 m. The system has 4 pumping stages in elevation which translated into higher cost for water supply.

A significant share of electricity is wasted because of inefficiencies and physical losses. For example, in the year 2017, the estimated non-revenue water made 48%, which means that 50% of used energy was lost. The administrative inefficiencies account for more than 50% of these losses, the remaining losses are due to physical losses from the networks[21].

4.3. Financial sustainability of the water sector

The financial sustainability of the water sector is threatened by growing expenses that cannot be covered by growing revenues. During the last decade, the revenues of the water sector exceeded 100% but they could cover only around 70% of total operation and maintenance costs, which also include capital costs, depreciation, and recovery[22].

The weighted average consumption for the public sector water facilities is 4.31 kWh/m^3. Given that the water sector is highly subsidized, the total energy bill paid by MWI (including JVA and WAJ) in 2014 was JOD 138 million, which is equivalent to an average specific power cost of 0.087 JOD/kWh. However, this figure does not reflect the actual power costs paid by the

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[21] Ministry of Water and Irrigation of Jordan, 2017

[22] National Water Strategy, 2016

Government. Costs of electricity make the largest part of the Jordanian water sector expenses. In the year 2017 electricity costs constituted 43% of the total operation and maintenance costs of the water sector. The electricity bill amounted to 161 million JD in the year 2017 alone[23].

Current production and distribution costs exceed the revenues for the water sector. The growing tariffs pose a significant threat to the financial sustainability of the water sector considering the large share which electricity bills make in operation and maintenance costs. In the year 2017, the water sector purchased electricity with a tariff of 0.094 JD per kWh. In the year 2018, the electricity tariffs jumped to 0.140 JD per kWh. It is expected that the electricity tariffs for water will be stabilized and a compromise can be set with the ministry of Energy and Mineral resources.

According to the MWI strategy, the financial sustainability of the water sector could be improved with a reduction in the costs and with an increase in the revenues.

The reduction of costs can be achieved with the implementation of three measures:

- Improvements in energy efficiency by modernizing key infrastructure, including setting up renewable energy generation near pumping stations
- Reduction of physical water losses
- System optimization

The revenues of the water sector can increase through the application of a gradual approach of the following measures:

- Reduction of administrative water losses (for instance, unauthorized connections and billing inefficiencies)
- Increase of revenue collection through administrative improvements and the outsourcing of billing to third parties
- Increase of water and wastewater service costs for households, industry, and farmers

4.4. Targets of water policy in Jordan

Jordan faces a complex set of development challenges stemmed from the chronic water scarcity. To address these challenges all targets of the water sector can be categorized under four main themes, as follows:

- Financial sustainability of the water sector
- Enhanced services of water and wastewater
- Supply of water to meet the demand for all uses
- Water resources sustainability and protection

The National Water Strategy for the period 2016-2023 is the major document regulating the water sector. It addresses challenges of the water sector in provisions on climate change and water-energy-food nexus.

It also speaks about possible strategies to deal with the challenges in the water sector such as:

- Sustainability of overexploited groundwater resources,
- Adaptation of new technologies,
- Decentralised wastewater management,
- Utilization of surface water in municipal supply,

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[23] Ministry of Water and Irrigation of Jordan, 2017

- Reuse of treated wastewater.

The water-energy nexus is mainly regulated by the “Energy Efficiency and Renewable Energy Policy for the Jordanian Water Sector” which was published in 2015. This policy established two priority actions:

a. The energy consumption of billed water should be reduced by 15%. This will correspond to 0.46 kg reduction of CO_2 emissions for the production per each billed M^3 of water.
b. The share of RES in power generation for the water sector should be increased by 10%. This will correspond to a total saving of 0.26 kg of CO_2 emissions per each billed M^3 of water.

Many new policies and efficiency improvements have been undertaken to augment, conserve, reuse and recycle all available freshwater. MWI has developed many policies in 2016 that are dealing with different aspects in the water sector, such:

Water Demand Management Policy. This policy addresses the management of water demands in all sectors, including municipal, industry, tourism, agriculture and other activities of national importance. According to the priorities stated in the National Water Strategy, water for municipal purposes is a top priority among all sectors, followed by industry, tourism, and agriculture.

Energy Efficiency and Renewable Energy in the Water Sector Policy. The purpose of this policy is to improve energy efficiency in the Jordanian water sector, to reduce water supply costs and to contribute to the growth of the Jordanian economy. Furthermore, this policy directs the utilization of renewable energy technologies for power supply at the water facilities, and consequently, reduces the volatility of the energy prices that are typically linked to fossil fuel prices.

Water Substitution and Re-Use Policy. The objectives of this policy are efficient management of scarce water resources, maximization of the benefits and economic returns for managing water efficiently, recommendations of further actions for implementation, enhancing economic efficiency, ensuring sustainability and preserve freshwater, and protecting the environment and nature.

Water Reallocation Policy. This policy plans to serve as a vehicle to set action plans for redistributing the water flexibly between sectors and governorates. It intends to employ a conveyance system for water connecting the southern and northern regions and another conveyance system for treated wastewater in the Jordan Valley to maximize the use of treated wastewater for irrigation and free the expensive freshwater to be used for domestic purposes.

Surface Water Utilization Policy. The objective of this policy is to present in more detail what is envisioned towards the maximum utilization and optimum use of surface water, its protection, its management, and propose measures needed towards successfully integrating all its components.

Groundwater Sustainability Policy. The objective of this policy is to manage and monitor groundwater resources. The policy deals with many aspects to manage groundwater resources optimally and sustained for future generations. It includes a set of actions to manage groundwater abstraction, raise the awareness of public and farmers about its usage, encourage participatory governance, implement a monitoring system and collect a database, modify the legislation to conserve groundwater and increase the dependency on treated water for the agriculture instead of groundwater.

Climate Change Policy for a Resilient Water Sector Policy. This responds to the challenges posed by climate change. The Policy provides the background, concept and solutions and implementation of a mechanism for building resilience to absorb disturbances while maintaining structure and function.

Decentralized Wastewater Management Policy. This plan sets out Government Policy for the provision of decentralized wastewater management, i.e. the collection, treatment, disposal and reuse of wastewater, with the aim to fulfil the national target for wastewater services. In 2018, MWI developed a policy for Drought Management, to clearly outline specific rules for efficient and sustainable management of scarce water resources, taking into account the drought hazards in the water sector. This policy has outlined the measures and actions necessary to achieve the long-term national water security goals, which are guided by results based on the previously adopted comprehensive policies, and plans that are being updated and built on an ongoing basis[24].

Performance indicators and targets from these policies for the period between 2014 and 2025 are summarized in Table 1.

Table 1: Water sector indicators and targets for the period 2014-2025

Goal	Indicator	2014	2025
Financial Sustainability	Percentage of operation and maintenance coverage	70%	127%
	Government support (Million JOD)	170	180
	Net debt (Million JOD)	1170	1200
	Energy used per M^3 billed (KWh/M^3/billed)	4.31	3.66
Enhance the services of Water and Wastewater	Percentage of water service coverage	94%	95%
	Percentage of wastewater service coverage	63%	80%
Supply of Water to meet the Demand for all uses	Water share per capita (L/C/D)	61	105
	Available water resources (M^3/year)	832	1341
	Water share for all uses (m^3/year)	90	114

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[24] Water Sector Policy for Drought Management, 2018

	Dams storage capacity	325	400
Water Resources sustainability and protection	Non-revenue water	52%	30%
	Percentage of over-abstraction	160%	140%
	Percentage of protected resources	35%	60%

Source: National Water Strategy, 2016

4.5. The institutional structure of the water sector in Jordan

The institutional structure of the water sector in Jordan is formed by three major stakeholders: Ministry of Water and Irrigation, Water Authority of Jordan and Jordan Valley Authority.

Ministry of Water and Irrigation (MWI) is the official body responsible for the overall monitoring of the water sector, water supply, and wastewater system and the related projects, planning and management, the formulation of national water strategies and policies, research and development, information systems and procurement of financial resources. Its role also includes the provision of centralized water-related data, standardization, and consolidation of data.

The MWI was established in 1988 by the law issued by the executive branch of the Government under the Jordanian Constitution. The establishment of the Ministry of Water and Irrigation was in response to Jordan’s recognition of the need for a more integrated approach to national water management. Since its establishment, MWI has been supported by several donor organization projects that have assisted in the development of water policy and water master planning as well as restructuring the water sector.

The Ministry of Water and Irrigation embraces the two most important entities dealing with water in Jordan: the Water Authority of Jordan (WAJ), which is in charge of water and sewage systems, and the Jordan Valley Authority (JVA), which is responsible for the socio-economic development of the Jordan Rift Valley, including water development and distribution of irrigation. This relative position with respect to WAJ and JVA reinforces the MWI's leading role as Jordan's lead entity on water issues.

5. Options to address water scarcity in Jordan

5.1. Desalination

Another option is desalinated water. It is considered one of the priorities by the government of Jordan, which commissioned several studies on the feasibility of various options of desalination of the saline well water. Since 1997 the government was constructing several desalination projects in various regions of Jordan, using reverse osmosis in order to reduce the salinity of water mainly from wells. According to the data from 2017, Jordan had 21 desalination plants which were distributed among various directorates of the kingdom (5 in Mafraq, 4 in Balqaa', 4 in Karak, 3 in Aqaba, 2 in Zarka, 1 in Irbid, 1 in Jerash, and 1 in Ma'an). In addition to the 21 treatment plants, there are three mobile desalination plants. The government of Jordan considers desalination plants for seawater was a long-term solution to address water scarcity, however, the major problem with this option is the too high consumption of energy as desalination of brackish/seawater alone would require additional 800 GWh/Year of energy.

5.2. International cooperation

There is a number of international projects to increase the water supply of Jordan. It is projected that by 2025 the water demand in Jordan will exceed the available water resources by more than 26%. It is expected that the Red Sea-Dead Sea project (RSDSP) will significantly improve this situation by reducing the water supply deficit. However, even with the successful implementation of the project, the water deficit will still amount to 6%. The Read Dead Sea Project (RSDSP) should become one of the main sources of the increased water supply in Jordan. It will start with the construction of a desalination plant in the north of Aqaba city. The plant will have a capacity of 80-100 mcm/year of desalinated water and will convey the resulting brine to the Dead Sea in order to reduce the degradation of its water level. The main components of the project are a seawater intake structure, an intake pump station, a seawater pipeline, a desalination plant, a desalination brine conveyance pipeline, two lifting pump stations, hydropower plants, and discharge facilities at the Dead Sea.

This is an international project which includes three beneficiary parties: Jordan, Israel, and Palestine. The major aim of this project is to save the Dead Sea from environmental degradation and to provide desalinated water to reduce water shortage in Jordan. The feasibility study conducted by the World Bank showed that RSDSP is a feasible project, even despite high investment costs of around 11 billion US dollars, and that the financing for this part of the project which relates to the goal of saving the Dead Sea from environmental degradation should be covered by grants since the Dead Sea is an international heritage and its protection lies in responsibility of international community. The World Bank expressed its readiness to start with the project implementation already in the year 2013 however the implementation of the project is currently delayed because of political tensions between the participating countries.

5.3. Implementation of renewable energy sources

The Ministry of Water and Irrigation (MWI) of Jordan has developed Energy Efficiency and Renewable Energy Policy in the Water Sector in 2016 to manage the use of energy in the Jordanian water sector efficiently and sustainably. There are three scenarios of savings dependently on the share of renewable energy sources, from a 10% scenario to a 50% scenario (Table 2).

Table 2: Scenarios of various renewable energy sources (RES) shares

	10% RES scenario	**25% RES scenario**	**50% RES scenario**
Produced Energy (GWh)	174.0	435.0	870.0
Annual Savings in the direct investment Scheme (MJOD)	20.9	52.2	104.4
Annual Savings in the private sector participation Scheme (MJOD)	17.40	43.5	87.0

Source: Ministry of Water and Irrigation of Jordan

There is a number of projects currently to deploy RES for the water sector.

*The **Dhluiel PV Solar Project*** is a 50 MW wheeling build-operate-transfer (BOT) project with an annual production of 82 GWh. The estimated project costs are 50 million JD. The implementation of the project will allow saving 8.2 million JD of electricity costs per year.

*The **PV Solar Project in AlQwairah*** is a 103 MW wheeling project with an annual production of 68 GWh. The estimated project costs are 75 million JD. The implementation of the project will allow saving 8.16 million JD of electricity costs per year.

*The **Ma'an Wind Farm project*** is an 80 MW wheeling project with an annual production of 81 GWh. The estimated project costs are 81 million JD. The implementation of the project will allow saving 9.72 million JD of electricity costs per year.

There are also a number of PV projects being applied in selected pumping stations. These are 30 MW net metering projects with an annual production of 51 GWh. Their investment costs are 25 million JD and the implementation of the projects will allow saving 6.12 million JD of electricity costs per year.

5.4. Energy and water efficiency measures

Various energy efficiency measures are currently being implemented for pumping stations and wells with the overall annual capacity of 51 GWs, investment costs of 25 million JD and possible energy costs savings of 7 million JD per year.

5.5. Pump storage and load shifting options

Hydro Pumped Storage is one of the most competitive systems to store large quantities of energy. Flexible management of water pumping can greatly contribute to shaping energy demand profiles by shifting loads from energy peak consumption hours to energy peak production hours. Water can be used to store energy in the dams along the Jordan Valley and in Aqaba (using seawater and a new reservoir). King Talal, Wadi al Arab, and Mujib HPS could provide 500 MW power and store 3,000 MWh/day of energy. Table 3 shows the potential projects for the water-energy nexus.

Table 3: Hydro pump storage projects

Demand-side management		**Hydro pumped storage**		**Additional water & energy**	
Project	Power shifted (MW)	Project	Power/Storage (MW/MWh day)	Project	Add. Water-Energy. (MCM/GWh Year)
Load shifting Zay	40	Mujib	225/1350	Water desalination	150/1200
Load shifting WAA	30	King Talal	95/570	Closing KAC	60/300
Load shifting Zara	10	Wadi al Arab	215/1290	Samra expansion	35/25
Total	80	Total	535/3210	Total	245/1525

Source: Ministry of Water and Irrigation of Jordan

However, the pump storage and the load shifting infrastructure will require a large investment. To make it work efficiently, a differentiated energy tariff scheme is also necessary.

6. Methodology

6.1. Participatory governance of water-energy nexus

While speaking about participatory governance of water-energy nexus there are multiple ways to design and run a participatory process. Also, the need for local stakeholders' participation is being increasingly recognized, as expert knowledge can also be limited, particularly in relation to local knowledge on the ground. Participatory governance also includes socio-political acceptance of new institutional frameworks, for example about how to re-structure decision-making processes towards necessary involvement and participation, as well as institutional shifts in the energy and water sector away from top-down centralized large scale, fossil fuel-based energy generation, towards inclusive decision making. There is growing evidence that trust is a key issue in the successful deployment of any kind of infrastructure and that participatory governance and co-production methods increase the level of trust. Also, significantly greater trust is given nowadays to stakeholders and to their knowledge during the decision-making process. There is growing evidence from various countries that it is possible to base energy policies on co-creation processes as policies are understood as explicit and implicit norms, regulations, and expectations that regulate the behaviour of individuals and interactions between them.

Co-creation methodology is a central element of participatory governance. It was developed originally in the works of Arnstein (1969) which followed public protests in Europe and the requirements from various groups of stakeholders to be actively involved in decision-making processes on infrastructure which affects their lives. It was further developed by Rao in 2012 and Manzini in 2015 by bringing in interactional quality and the strength of social ties resulting from participatory activities. Originally, co-creation was developed as a process of active involvement of end-users in various stages of production. There is also understanding that co-creation and co-production, which are synonyms, can improve the efficiency of processes, yield faster response times, make them more secure by reducing human errors and increase inclusion, democracy, and participation as it provides the same opportunities to different actors. Co-creation processes also provide legitimacy to decision-making on energy policy formulation and implementation. They help to increase transparency and to contribute to good governance. They also increase the acceptability of the decision-making outcomes and their implementation at various levels of governance.

Water-energy nexus is a complex policy problem that requires upgrading of existing infrastructure, changes in legal and institutional frameworks, new technological solutions and new forms of cooperation between various stakeholders involved in the energy and water sectors policy development and implementation. Without the development of cooperation schemes and compromise solutions on contested issues that are more or less acceptable to all stakeholders, such complex policy process can lead to conflicts or decision-making processes in which some parties are trying to exclude others, thus creating winners and losers. It can also lead to inefficiencies when benefits from synergies in water and energy policy and efforts are lost. Therefore, a participatory governance methodology is needed which will integrate views, visions, and opinions of different stakeholders' groups. Such methodology tends to be more sustainable, less prone to conflict and better balanced, even though sometimes they require more time for stakeholders to engage.

The entire background framework of participatory governance is a decision analytical approach for co-creation in a multi-stakeholder and multi-criteria environment, supported by elaborated decision analytical tools and processes. It can include various scientific tools and methodologies such as a framework for elicitation of stakeholder preferences, a decision engine for strategy evaluation, a machinery for risk analysis, a set of processes for negotiation, a set of decision rule mechanisms and processes for combining these items. Such a framework can include various components that apply to decision-making processes such as agenda settings and overall processes, goals, strategies, policies, sub-strategies, part-policies, understanding of consequences and effects, qualifications and sometimes quantifications of the components, negotiation protocols, and decision rules and processes.

6.2. Water-energy nexus criteria

We identified a number of criteria during interviews and a background literature review. We conducted interviews in the period from August to October 2019. The interview protocol was developed based on existing evidence from previous projects and realised by the topics of the energy and water sectors' development in Jordan. These were qualitative in-depth interviews with open and semi-open questions which lasted for one or two hours. Interviews were conducted in Arabic or English languages. The majority of interviews were conducted in person. Some interviews were conducted via Skype.

Altogether, we interviewed 7 participants from the German International Cooperation (GIZ), Water Authority of Jordan, Ministry of Water and Irrigation as well as Dorsch International Consultants.

Altogether, we identified 25 criteria which we clustered into 12 criteria based on their similarities. Following further discussions on scenarios and necessary inputs for their development, we reduced the number of criteria to 7. Then we classified all criteria into four major groups: economic, environmental, technical, and institutional/regulatory (Table 4).

Table 4: Criteria of water-energy nexus for discussion during the first participatory workshop

Group	**Criteria**
Economic	Annual system costs per kWh
Institutional and regulatory	Transboundary political feasibility Internal institutional feasibility
Technical	Security of water supply Security of energy supply
Environmental	Local environmental impacts Global environmental impacts

Economic criteria:

Annual system costs per kWh. This criterion includes three sub-criteria which are investment, operation and maintenance costs as well as tariffs. Investment criterion includes all costs which are connected with planning, preparation and construction of energy or water infrastructure. It also includes all other related investment costs. Operation and maintenance criterion includes all costs connected with operation and maintenance of water and energy infrastructure. Tariffs criterion includes tariffs for water and energy paid by private and industrial/institutional consumers. The annual system costs per kWh should be the basis for tariffs for different consumers.

Institutional and regulatory criteria:

Transboundary political feasibility: this criterion includes all issues with transboundary cooperation over resource availability such as transboundary water management issues or the functioning of interconnected critical infrastructures. This criterion also includes political dialogue with neighbouring countries.

Internal institutional feasibility: this criterion includes all efforts necessary for dialogue and cooperation in a horizontal perspective between various ministries or on the coordination of donor efforts or in vertical perspective between local, regional and national levels of governance. It also includes the need to change, adapt, streamline existing legal and institutional frameworks for water-energy nexus issues, as well as the necessary capacity-building efforts.

Technical criteria:

Security of energy supply: this criterion includes all issues connected with the safety of the social functioning of critical energy supply infrastructures as well as reliable energy generation, transmission, and distribution, including covering supply and demand gap, intermittency risks and protecting energy critical infrastructure from various natural and man-made hazards.

Security of water supply: this criterion includes all issues connected with the safety of societal functioning of critical water supply infrastructures as well as reliable water generation, transmission, and distribution, including covering supply and demand gap, intermittency risks and protecting water critical infrastructure from various natural and man-made hazards.

Environmental criteria:

Local environmental impacts: this criterion includes pressure on local land, air, water, soil and other kinds of environmental resources resulting from extraction, generation, transmission, and distribution of energy and water services.

Global environmental impacts: this criterion includes emissions and pollution resulting from energy and water extraction, generation, transmission and distribution, which have impacts from a global perspective.

The six different scenarios dealing with challenges in the energy and water dimensions (described in the next section), including desalination, international cooperation in water-energy issues, implementation of renewable energy sources, efficiency measures as well as pump storage and load shifting will be evaluated against of the set of 7 energy-water criteria. Further on, criteria will be ranked according to their importance for two groups of stakeholders – stakeholders from water and stakeholders from energy communities.

6.3. Water-energy scenarios

Based on literature review and expert interviews prior to the workshop, different scenario options, driven by two main dimensions – water and energy – are introduced on the first workshop day and ranked using a MCDA, as described in the previous chapter. Following the discussions of the first day, the EUF team will alter and adjust initially set characteristics for each dimension to accommodate for opinions and requests of the workshop participants.

On the second day, the preliminary strategy options under the water and energy dimension, are introduced and discussed in three groups. This discussion should lead to a qualitative and partially quantitative description of the different strategies within a dimension. The discussion will be supported by a simplified model to assess the effect of the discussed parameter on the system.

The two dimensions, energy and water, can be described by future developments and (political and economic) strategies acting on these developments. For a Baseline Scenario this may entail expected trends and developments as stated within the NEPCO's or WAJ's annual reports. This could mean large scale PV and wind installations, as well as small scale nuclear and oil shale developments for the energy sector for increased energy independence. For the water sector decentralized wastewater management and the introduction and adaption for new technologies can be strategies to deal with increased water demand and/or changing weather patterns (less precipitation).

The following futures of interest for the energy and water dimension and resulting six scenarios were identified and will be the initial basis for the discussion on scenarios. Alterations and additions will be based on the discussions on the first workshop day.

Table 5: Energy and water dimensions of scenarios

		Energy dimension		
		Baseline Energy (BE)	*No Imports (NI)*	*Interconnected Gulf system (IGS)*
Water dimension	*Baseline Water (BW)*	BW_BE	BW_NI	BW_IGS
	Smart Operation (SO)	SO_BE	SO_NI	SO_IGS

Energy dimension

Baseline Energy (BE). Expected trends and developments as stated in NEPCO annual reports. Large scale PV and Wind installations, as well as small scale nuclear. A higher priority is given to oil shale developments. Mainly energy sector driven, with a focus on achieving a higher share of renewable energies in the electricity sector. Difficulties: grid stability, power cut offs and after effects

No Imports (NI). No import assumption is based on findings of the MENA Select project, aiming at energy independence, with up to 78 GW of installed capacity needed, including substantial wind and solar installations as well as geothermal plants. Large-scale CSP projects are needed as well as Biomass. Difficulties: Sourcing of biomass, grid stability increasingly difficult with large share of volatile energy sources introduced, large scale RE developments needed (high costs)

Interconnected Gulf System (IGS). Interconnected Gulf System based on mentioning in NEPCO annual report 2018. Interconnections possible with Egypt, Palestine, Iraq and Saudi Arabia to use strengths of an interconnected electricity system. Difficulties: political issues

Water dimension

Baseline Water (BW). In the baseline future, driven by water supply, deeper and additional wells, as well as dams to cover the increasing water demand are considered. A high priority is given to desalination and reduction in water losses. This scenario follows expected trends and planning processes already in the works in the water sector, while analyzing the expected change in energy inputs. Difficulties: disposal of brine (desalination), effect of power cut offs on water supply

Smart Operation (SO). Use synergies of water and energy sector, e.g. using excess energy of electricity system for water pumping (smart operation of pumps) etc.

Possible scenarios

A scenario consists of a combination of a future in the energy and the water dimension.
For example:

SO_NI: Smart Operation (water dimension) and No Imports (energy dimension)
Using a smart operation of water plants with decentralized storage options could mitigate the difficulties of a volatile energy system.

BW_IGS: Baseline Water (water dimension) and Integrated Gulf System (energy dimension)
Interconnected Electric Gulf System with the expected trends within the water system.

The following six scenarios were identified to reflect the goals of a water-energy nexus policy.

BW_BE: Baseline Water and Baseline Energy
BW_IGS: Baseline Water and Interconnected Gulf System
SO_BE: Smart Operation and Baseline Energy
SO_NI: Smart Operation and No Imports
SO_IGS: Smart Operation and Interconnected Gulf System

6.4. Multi-criteria decision making analysis

A multitude of methods for analysing and solving decision problems with multiple criteria have been devised during the last decades. A common approach is to make preference assessments by specifying a set of attributes that represents the relevant aspects of the possible outcomes of a decision. Value functions are then defined over the alternatives for each attribute and a weight function is defined over the attribute set. One option is to simply define a weight function by fixed numbers on a normalised scale and then define value functions over the alternatives, where these are mapped onto fixed values as well, after which these values are aggregated and the overall score of each alternative is calculated, an additive model.

One of the problems with the additive model as well as other standard multiple criteria decision models is that numerically precise information is seldom available, and most decision-makers experience difficulties with entering realistic information when analysing decision problems, and with the elicitation of exact weights that demands an unreasonable exactness which does very seldom exist. There are other problems, such as that ratio weight procedures are difficult to accurately employ due to response errors. The common lack of reasonably complete information increases this problem significantly. Several attempts have been made to resolve this issue. Methods allowing for less demanding ways of ordering the criteria, such as ordinal rankings or interval approaches for determining criteria weights and values of alternatives, have been suggested, but the evaluation of these models is sometimes quite complicated and opaque, and thus difficult for decision-makers to accept.

Some main categories of approaches to remedy the precision problem are based on capacities, sets of probability measures, upper and lower probabilities, interval probabilities (and sometimes utilities), evidence and possibility theories, as well as fuzzy measures. The latter category seems to be used only to a limited extent in real-life decision analyses since it usually requires a significant mathematical background on the part of the decision-maker. Another reason is that computational complexity can be problematic if the fuzzy aggregation mechanisms are not significantly simplified.

For the evaluations in this workshop, we will, therefore, utilise a method and software for integrated multi-attribute evaluation under risk, subject to incomplete or imperfect information. The software originates from our earlier work on evaluating decision situations using imprecise utilities, probabilities, and weights, as well as qualitative estimates between these components derived from convex sets of weight, utility and probability measures. To avoid some aggregation problems when handling set membership functions and similar, we employ higher-order distributions for better discrimination between the possible outcomes. For the decision structure, we use the common tree formalism but refrain from using precise numbers. To alleviate the problem of overlapping results, we use a new evaluation method based on the resulting belief mass over the output intervals, but without trying to introduce further complicating aspects or concepts into the decision situation. During the process, we consider the entire range of feasible values of the alternatives presented across all criteria as well how plausible it is that an alternative outranks the remaining ones, and thus provide a robustness measure.

Typically, a multi-criteria decision situation is modelled like a tree, such in Figure 4 below, where the w:s are criteria weights and the v:s are values of alternatives under the different criteria.

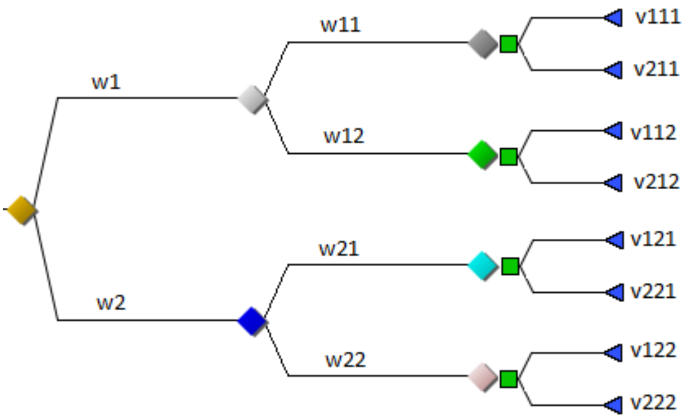
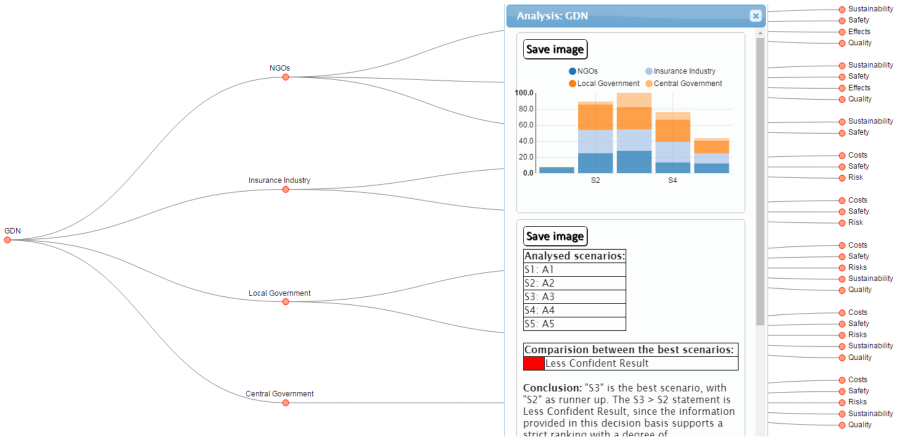


Figure 4. A multi-criteria decision tree.
Source: Danielson and Ekenberg

As noted above, one of the problems with most models for criteria ranking is that numerically precise information is seldom available. We have addressed this by introducing surrogate weights. This, however, is only a part of the solution since the elicitation can still be uncertain and the surrogate weights might not be a fully adequate representation of the preferences involved which, of course, is a risk with all kinds of aggregations. To allow for analyses of how robust the problem is to changes in the input data, we will also introduce intervals around the surrogate weights as well as around the values of the options. Thus, in this elicitation process, the possibly incomplete information is handled by allowing the use of intervals, where ranges of possible values are represented by intervals (in combination with pure orderings without the use of surrogate weights at all if the latter turns out to be inadequate).

Because of the complexity in these calculations, we use the state-of-the-art multi-criteria software DecideIT or Decision Wizard for the analysis, which allows for imprecision of the kinds that exist in this decision situation. Versions of DecideIT have been successfully used in a variety of decision situations, such as large-scale energy planning, allocation planning, demining, financial risks, gold mining, and many others. Figure 5 shows the multi-criteria multi-stakeholder tool Decision Wizard, developed for group decisions regarding infrastructure policymaking in Swedish municipalities.



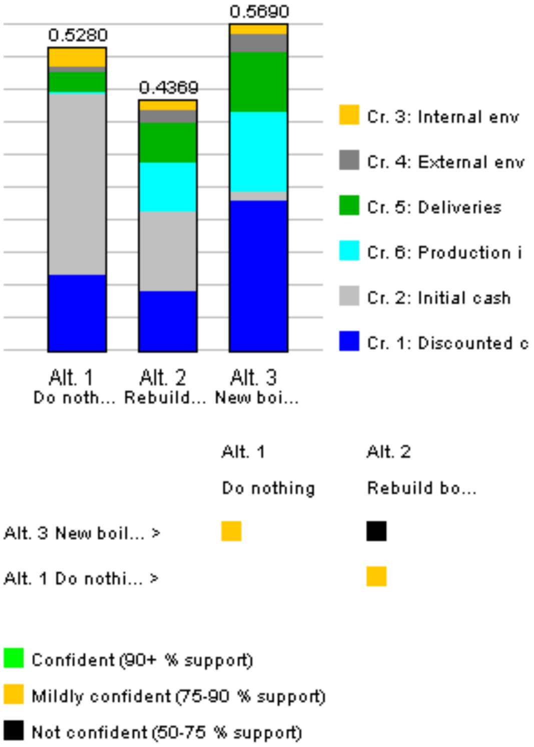
Analysed scenarios:
S1: A1
S2: A2
S3: A3
S4: A4
S5: A5

Comparision between the best scenarios:
🟥 Less Confident Result

Conclusion: "S3" is the best scenario, with "S2" as runner up. The S3 > S2 statement is Less Confident Result, since the information provided in this decision basis supports a strict ranking with a degree of

Figure 5. The Group Decision tool Decision Wizard – a simplification of DecideIT

Figure 6 shows an example of one of the result windows from the DecideIT tool.



	Alt. 1 Do nothing	Alt. 2 Rebuild bo...
Alt. 3 New boil... >	🟨	⬛
Alt. 1 Do nothi... >		🟨

🟩 Confident (90+ % support)
🟨 Mildly confident (75-90 % support)
⬛ Not confident (50-75 % support)

Figure 6. Main decision evaluation result.

6.5. Renpass model

Renpass is an open-source model that is freely available and uses open data. It is based on the Open Energy Modelling Framework (oemof). During the first workshop, a simplified model will be applied that incorporates main features and the structure of the Renpass model which are illustrated in the figure below.

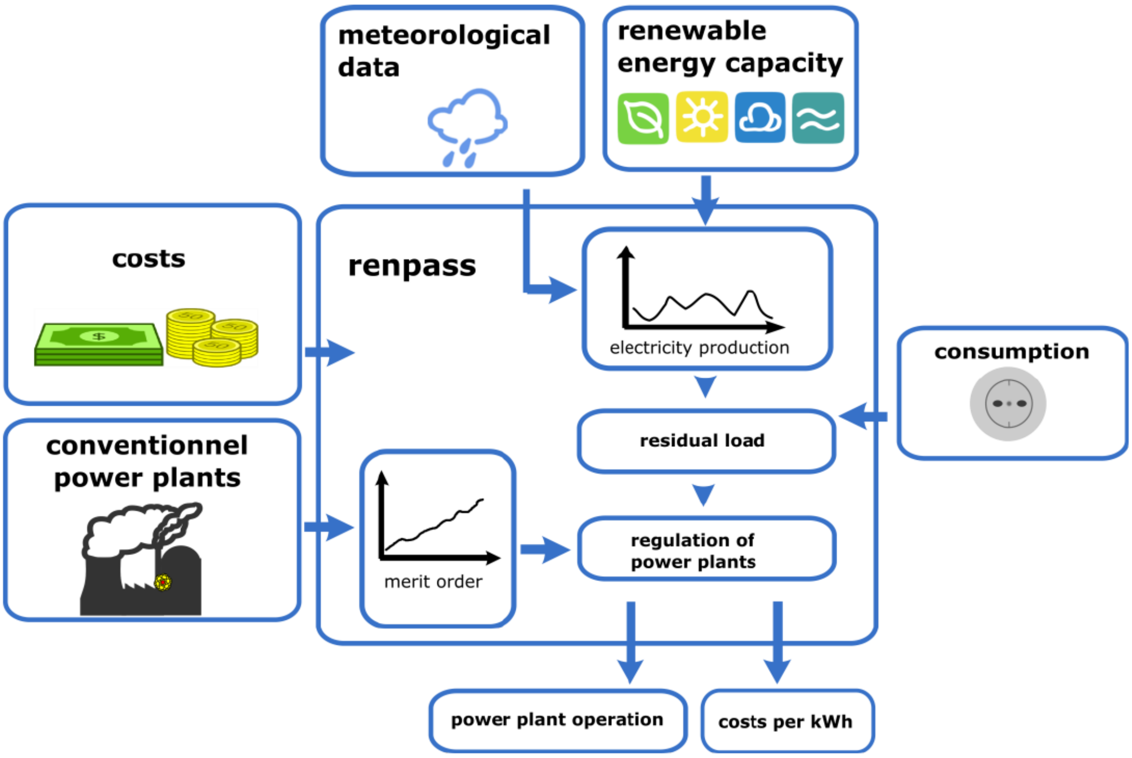


Figure 7: the Renpass model
Source: University of Flensburg

By using a simplified model during the workshop, all input parameters can easily be adjusted and potential effects on the system can be assessed instantly.

Central input data to the model include meteorological data such as solar radiation, precipitation and wind speeds in a high temporal and spatial resolution, technical parameters of different types of power plants and the transmission grid, financial parameters such as operational expenditures. The main driver of the model is the electricity demand, represented by the hourly load curve.

The fluctuating electricity production of wind and photovoltaics (PV) is based on the meteorological input data. Subtracting this energy production from the hourly load results in the so-called residual load. A positive residual load requires additional power generation from other sources, a negative residual load reflects surplus energy in the system that needs to be handled, for example, stored. In the model approach, a positive residual load causes dispatchable technologies in the system to operate. Their order of utilization is based on the merit order, which means the technology with the lowest marginal costs produces first.

7. Agenda of the workshop

7.1. Day 1: MCDA analysis

The MCDA analysis will include three sessions and the following elements: discussion of criteria, preference, and weight elicitation.

First, the identified criteria will be presented to participants, including their definition. The presentation will be followed by a roundtable discussion about the identified criteria where participants can suggest further criteria, to remove or to modify the identified criteria. Further on, they can provide suggestions about a modification of the definitions of criteria. Later on, during this session, we will present different strategies dealing with challenges in the energy and water dimensions. The participants can then suggest further options or provide their comments to the identified options.

During the second session, we will collect preference elicitations when each of the identified water-energy scenarios will be ranked under each criterion, meaning that we will have a number of ranking exercises with various scenarios being ranked in each of these exercises.

During the third session, we will collect weight elicitation where criteria will be ranked according to their importance for participants.

During the second and the third sessions we will have rankings first made separately by water and energy community stakeholders and then obtain final joint rankings for the entire group together. We will document conflicting options and rankings.

The criteria ranking procedure is as follows. The group of stakeholders is provided with a set of coloured cards with the criteria names written on them. They are also given a set of blank cards. Then, they are asked to rank the coloured cards from the least important (valuable) to the most important (valuable), where criteria of equal importance (value) are grouped together. The moderator then introduces blank cards and explains that they show the relative difference in importance (value) of different criteria. The greater the difference in importance (value) between two criteria, the more blank cards should be positioned in-between these criteria. The semantics for the criteria importance could be as suggested in Table 6. It is important to keep in mind that the ranking is made of the value range (or value span), i.e. the difference between the best and the worst alternative, within each criterion.

Table 6: Suggested semantics for the criteria ranking

Blank cards	
Equal level of cards	Equally important
No blank card	Slightly more important
One blank card	More important (clearly more important)
Two blank cards	Much more important
Three blank cards	Extremely much more important

Following this, a discussion to identify lines of conflicting opinions should follow and be documented. An example of a final result can be seen in Figure 8. The meaning is that the value span in criterion 1 is much more important than that in criterion 3 that, in turn, is equal to criterion 4. Both of these are more important than criterion 2, which is slightly more important than criterion 5.

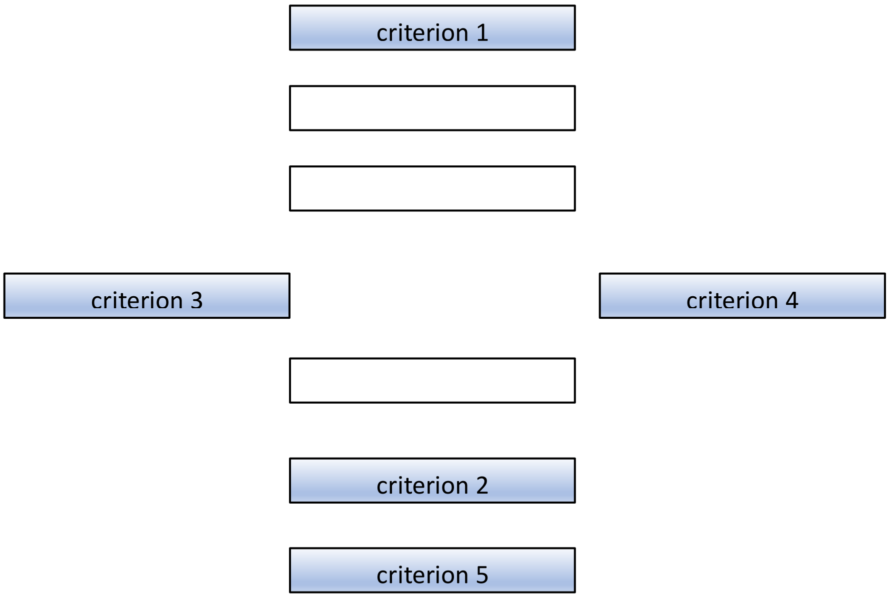


Figure 8. Example of a final criteria ranking

Rankings of the alternatives under each criterion are handled analogously. Figure 9 shows alternatives' ranking under the three first criteria. The meaning is that under criterion 1, alternative 3 is slightly better than alternative 2, which, in turn, is slightly better than alternative 1, and that alternative 1 is better than alternative 4.

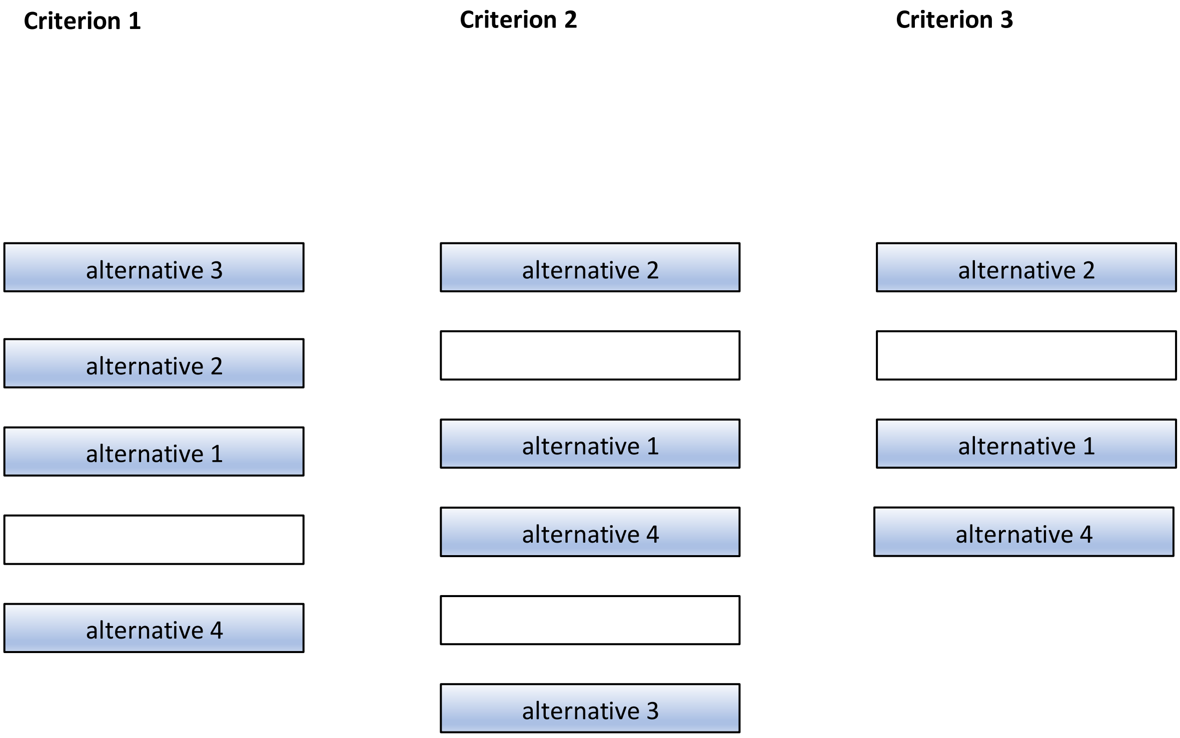


Figure 9. Part of an alternative ranking under some criteria

Thereafter, the entire decision structure can be analysed and tentatively discussed.

7.2. Day 2: Scenario Development

Based on a literature review and expert interviews prior to the workshop, different scenario options, driven by two main dimensions – water and energy – are introduced on the first workshop day and ranked using an MCDA method as described in the previous section. Following the discussions of the first day, the EUF team will alter and adjust initially set characteristics for each dimension to accommodate for opinions and requests of the workshop participants.

On the second day, the preliminary strategy options under the water and energy dimensions are introduced and discussed in three groups. This discussion should lead to a qualitative and partially quantitative description of the different strategies within a dimension. The discussion will be supported by a simplified model to assess the effect of the discussed parameter on the system.

The two dimensions, energy and water, can be described by future developments and (political and economic) strategies acting on these developments. For a Baseline Scenario this may entail expected trends and developments as stated within the NEPCO's or WAJ's annual reports. This could mean large scale PV and wind installations, as well as small scale nuclear and oil shale developments for the energy sector for increased energy independence. For the water sector, decentralized wastewater management and the introduction and adaption of new technologies can be strategies to deal with increased water demand and/or changing weather patterns (less precipitation).

The result should be a joint elaboration of such a matrix, with both dimensions and different strategies, which then can be linked to form water-energy nexus scenarios.

	Energy dimension		
Water dimension	*Baseline energy (BE)*	*Energy strategy 2*	*Energy strategy 3*
Baseline water (BW)	Scenario 1	Scenario 2	….
Water Strategy 2			
Water Strategy 3			

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