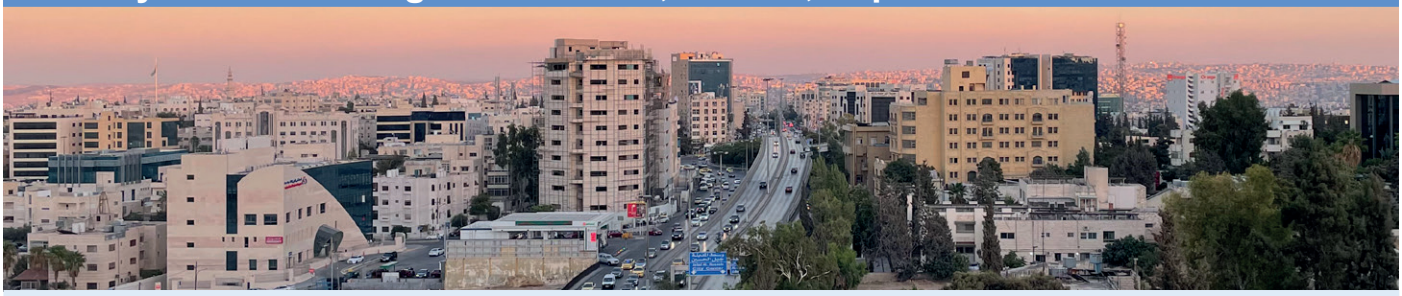
Sustainability Living Lab for Food – Water – Energy in Urban Environments

May, 2022

Documentation of Stakeholder and Expert Workshops, and Strategic Policy Thinker Dialogue in Amman, Jordan, September 2021



The FUSE project held its second set of workshops in Amman in September 2021. The goals of the workshops were to present FUSE modelling results, ask for feedback, and discuss measures needed to implement the proposed policy interventions. With this, the FUSE Sustainable Living Lab (SLL) approach in Jordan has completed its final phase. In this document we present the outcomes of these final workshops. We begin by summarizing the SLL approach by looking back at the initial workshop results and subsequent development of the policy-evaluation model.

FUSE in a nutshell

FUSE (Food-water-energy for Urban Sustainable Environments) is a transdisciplinary research project (2018-2022) involving the Food-Water-Energy resources nexus in Jordan, with a focus on its capital, Amman. The project developed a long-term systems model that was used to identify viable paths to resource sustainability. It brings together scientists, engineers, economists, and stakeholder engagement experts from Stanford University in California, USA, IIASA (International Institute for Applied Systems Analysis) in Laxenburg, Austria, UFZ (Helmholtz Centre for Environmental Research) in Leipzig, Germany, and ÖFSE (Austrian Foundation for Development Research) in Vienna, Austria. The project is a not-for-profit research effort and is part of the Sustainable Urbanisation Global Initiative of JPI Urban Europe and the Belmont Forum. Each of the national teams is supported individually by its own national science-funding agency.

More information: https://fuse.stanford.edu/

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Context:

The provision of food, water, and energy (FWE) resources is crucial to human well-being. Population growth, rising consumption, and growing urban environments increase the demand for these resources. To analyze water security, a long-term integrated approach is needed that considers human decisions under different biophysical and economic constraints. This integrated approach can identify trade-offs and synergies between sustainability paths. The design and implementation of long-term strategies to achieve FWE-sustainability is a challenging task for all actors – including policy makers, civil society, the private sector and academia – who have to consider a broad range of perspectives, ideas, and concerns.

Amman and its greater metropolitan region have been growing rapidly over the past two decades. More than 4 million people currently live in this region, and it is forecast to grow significantly in the future. Such growth presents challenges and opportunities. For example, in the context of increasing water and energy uses for urban areas there is both, dwindling freshwater availability and significant potential for solar energy. Understanding the food-water-energy nexus for Jordan with a focus on Amman is key to evaluating different paths and promoting those that target sustainability while avoiding those that are headed toward crisis.

FUSE is a transdisciplinary research project that aims to contribute to identifying solutions for long-term FWE sustainability in Jordan, with a focus on the Greater Amman region where freshwater provision is the major concern. Building on the knowledge of local stakeholders and experts, FUSE constructed a FWE systems model that captures connections and feedbacks among users, producers, distribution mechanisms, and resources. Our approach integrates narratives of future changes in climate, demographics, land use, and economic development, and considers the behavior of a wide range of actors. The model is used to evaluate policy interventions to identify implementable sustainability options based on a set of metrics of well-being

Sustainability Living Lab Approach

To incorporate the knowledge, expertise and views across Jordan's society, FUSE adopted a Sustainability Living Lab (SLL) approach. The SLL approach includes a stakeholder analysis and two series of workshops, at the beginning and the end of the project period, respectively. In the first set of workshops (held in March 2019), stakeholders affected by future policy interventions and policy experts shared visions, challenges, coping strategies, and potential infrastructural and policy solutions under future conditions in which there are limited FWE resources. Additionally, regional modelling experts contributed insights on nexus dimensions of food, water and energy from an urban perspective.

The information gathered in the initial workshops was then formulated into potential solutions, each requiring policy and infrastructural interventions. We evaluated these interventions under a range of future climate and population change scenarios. The likely benefits of these interventions were explored using a systems model. In a second set of workshops (September 2021), these systems model results were presented to three groups: affected stakeholders, policy experts, and strategic policy thinkers. Feedback was elicited on the feasibility of, or barriers to, implementing the most promising suggested interventions.

FUSE Living Lab Approach

1 First Set of Workshops (March 2019)

The first set of workshops took place in March 2019 and was organized in cooperation with FUSE's local partner organization MIRRA (Methods for Irrigation and Agriculture). In total, the FUSE team and MIRRA organized three workshops involving affected stakeholders (Stakeholder Workshop), policy experts (Expert Workshop), and modelers (Modelling Workshop).

In the **Stakeholder Workshop**, there were 35 participants from different FWE sectors. The goal was to collect FWE challenges, coping strategies, and ideas for solutions. Methodologically, participants first collected current FWE challenges. Subsequently, the FUSE team presented four different perspectives of potential future developments (increasing freshwater vulnerability, urban sprawl, highlands agriculture, and energy needs). Participants jointly developed coping strategies and solutions to these future challenges.

In the **Expert Workshop**, there were 42 participants from the public and private sectors and academia. It aimed at defining policy solutions to reach a common vision for a sustainable Greater Amman Region by 2050. Methodologically, participants first designed the future they want in small groups. Based on the four perspectives presented by FUSE team members, as well as the results of the Stakeholder Workshop, participants discussed how to achieve the future they wish for – despite existing major challenges and the increasing stress on the FWE systems. The solutions proposed in this workshop were used as the **basis for developing interventions** to be explored using the integrated systems model.

In the **Modelling Workshop**, the FUSE team discussed the model structure with 12 modelling experts from academia and public institutions, listened to their feedback, and jointly co-created new ideas for model formulation.

Detailed documentation of the first set of workshops can be found here. It summarizes the key messages of the workshops, gives a more detailed presentation of the four different perspectives of potential future developments, and illustrates the solutions proposed by the participants to address challenges to FWE resource provision. The FUSE team maintained contact with stakeholders after the workshops through regular meetings with its regional partner MIRRA and annual updates provided to stakeholders about project activities and our progress in 2020 and 2021.

2 Model Development & Analysis

2.1 Model Development based on Workshop Input

Challenges and Solutions

The workshops resulted in defining specific **challenges** that affect each of the FWE dimensions. These challenges are the ones that stakeholders felt most strongly needed to be overcome, as they were clearly becoming worse under climate change, population growth, and dwindling freshwater resources. The initial modeling goal was to assess the current impact of these challenges. Later in the process, the same assessment would be done to determine how well potential **solutions** might alleviate the impacts of these challenges. However, during this stage the challenges were distilled to reflect which FWE energy dimensions were most affected and which challenges were most important to the stakeholders.

Based on the workshops, our assessment is that the overwhelming stakeholder concerns (over 90%) were focused on provision and sustainability of freshwater, and on the impacts of water scarcity on households and agriculture. This resulted in our decision to have the modelling effort focus on exploring means to maintain freshwater supply to households, industry, and farms. The integrated model is focused on reflecting these aspects. All of Jordan's surface water and groundwater hydrologic processes as well as the water supply conveyance systems are represented in the model at the subdistrict level for each month through the end of the century. Agriculture is well represented as it is intimately tied to water for irrigation. Challenges to energy provision are substantially divorced from freshwater provision, except for the cost of pumping groundwater for crop irrigation, which is accounted for in the model given our dynamic representation of farmers, their planting decisions based on farm profits net of water, labor, and supply costs, and simulation of pumping impacts on the water table. In addition to this, a separate analysis of model outputs conducted as part of the FUSE project found that substantial increases in the conveyance and pumping energy required to supply water via the public water network will cause additional nexus challenges.

Based on input from stakeholders and experts, a comprehensive **list of 20 FWE challenges** affecting the greater Amman region was distilled (see Figure 1). In the figure, challenges are arranged according to their proximity to one of the three FWE nexus dimensions plus urbanization as a fourth dimension. By studying these challenges, the modeling team was able to select key challenges that could be reasonably represented in the model. This triangle also enabled us to visualize interdependencies between potential solutions and specific challenges.

Given the inherent complexity of the FWE system, the model did not address certain challenges, such as water quality degradation or issues of livestock carrying capacity. Our model therefore focused on analysis of the challenges of freshwater supply and exploration of what Jordan can do to improve its water security now and in the future. We target **10 key challenges** that are focused on freshwater (circled in red on Figure 1).

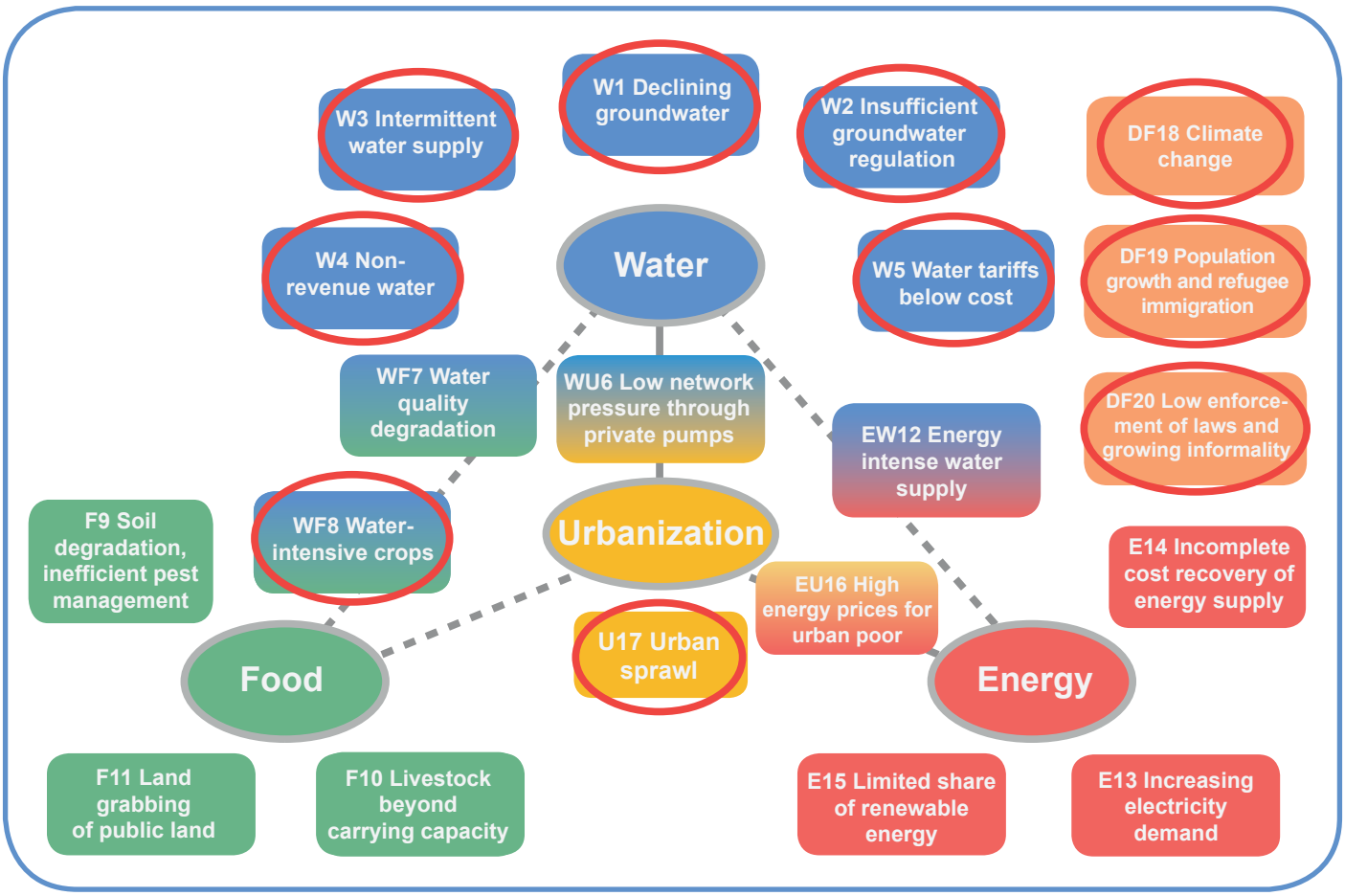

Figure 1: FWE challenges identified during the first set of workshops

Given these challenges, the integrated systems model is a tool to provide policy evaluation analysis that is relevant to the process of policy maker and practitioner informed decision-making.

Before discussing the candidate solutions, we first address the question: What constitutes relative success of one solution versus another? To explore how well the challenges are addressed through candidate potential solutions, the team adopted **four metrics**, all focused on freshwater security: **vulnerability**, **stress duration**, **equity**, and **economic benefit**. These metrics are defined as:

Vulnerability	Percent of population receiving less than 40 liters/person/day
Stress Duration	Number of continuous months receiving less than 40 liters/capita/day
Inequity	Gini coefficient of water use (1 = supply disparity, 0 = equity)
Economic Benefit	Consumer surplus (benefit to consumers)

These metrics were used to quantify the effectiveness of proposed solutions to address the major challenges to freshwater security on Jordan society. **Potential solutions** proposed by participants in the Expert Workshop were compiled into categories based on which FWE resource they addressed.

From Solutions to Policy Interventions

Many candidate solutions were generated: some were focused, some general, some feasible, some infeasible. The FUSE team **selected and grouped the solutions into interventions** so that a wide range of reasonable solutions could be analyzed under one set. This process was guided by the following principles:

- **Feasibility:** The interventions should be technically and administratively feasible.
- **Suitability**: The interventions should be suitable for mitigating or solving nexus challenges.
- **Comprehensiveness**: The selection of interventions reflects the range of nexus challenges and the diversity of possible policy measures.

- **Policy-relevance**: The selection of interventions takes into consideration governmental plans.
- **Capability:** The model is capable of estimating the main and side effects of the interventions.

Using this approach, the FUSE team formulated **five main interventions** that cover specific nexus dimensions and their linkages, as well as an additional **Comprehensive Intervention** that provides an analysis of how different interventions interact (see Figure 2). These interventions were then refined, concretized, and finally tested and analyzed using the **integrated FWE model** with a **focus on freshwater security. Baseline Conditions** were used as a reference, in which the existing water supply system with no additional interventions was assumed. This work draws on Yoon et al. (2021), who based their analysis on **Intervention I, II, III and VI**.

Intervention I:	**Agriculture to Urban Transfer (Food-Water)**
Solution:	Shift to climate-adapted crops to free up water for cities
Action:	Basline conditions + **25% transfer of groundwater** production capacity from the agricultural to the municipal sector
Intervention II:	**Water Supply Enhancement (Water)**
Solutions:	Large supply projects & leakage reduction
Action:	**Red Sea Desalinization**: 80 MCM/year – Phase I & 150 MCM/year – Phase II **All Planned Water Supply Projects:** 150 MCM/year **Fix the Leaks:** physical non-revenue water reduction
Intervention IIa:	**Water Supply Purchases Israel (Water)**
Recent Development:	Purchase of 50 MCM for 2021 from Israel
Action:	**Annual purchases**, increasing by 50 MCM/year until 200 MCM/year in 2065
Intervention III:	**Demand Management Intervention (Urban-Water)**
Solutions:	Encourage water saving, reduce administrative non-revenue water
Action:	**Cost recovery**: Doubling of piped water tariffs for higher cost tiers **Equity**: Equalization of piped supply access for all household users on a per capita basis **Theft reduction**: Cut in half of current losses of non-revenue water
Intervention IV:	**Solar Farming for Water (Energy-Food-Water)**
Solution:	Using solar energy to desalinate water
Action:	Solar farming in Aqaba & Red-Sea desalination investment
Potential Action:	Trade with Israel: 35 TWh/year for 281 MCM/year
Intervention V:	**Decentralized Urbanization (Urban-Water)**
Solution:	Redirect urban growth to smaller cities
Issue:	High urban growth stresses water supply systems
Intervention VI:	**Comprehensive Action (Food-Water-Urban)**
Action:	Intervention I - III

Figure 2: Interventions tested and analyzed in the integrated FWE model

2.2 Analysis and Results

Narratives: Testing Interventions under Scenario Sets

To make meaningful statements, the FUSE team tested the six interventions and the Baseline Conditions under **four different future scenario sets**: Optimistic, Drier Climate, Population Growth, and Crisis. The scenario sets, described in detail below, involve several factors that Jordan cannot control.

Scenario sets

Optimistic: Moderate climate change (RCP 4.5), higher transboundary flows (agriculture in the Syrian Yarmouk basin remains low), moderate socioeconomic growth (SSP 2), crop prices steady

Drier Climate: Adverse climate change (RCP 8.5), lower transboundary flows (agriculture in the Syrian Yarmouk basin recovers), SSP 2, crop prices steady

Population Growth: RCP 4.5, higher transboundary flows, aggressive population growth (SSP 3)

Crisis: RCP 8.5, lower transboundary flows, SSP 3, crop prices increase, plus refugee wave beginning in 2030

- The **first factor** is the **varying yet unknown severity of future climate change impacts** on temperature and precipitation: RCP 4.5 with temperatures in Jordan stabilizing at about 2C° above recent conditions, and RCP 8.5 with temperatures climbing 6C° above recent conditions by 2100 (Figure 3a), and greatly diminished precipitation over time (twice as many droughts of longer duration) (Figure 3b).

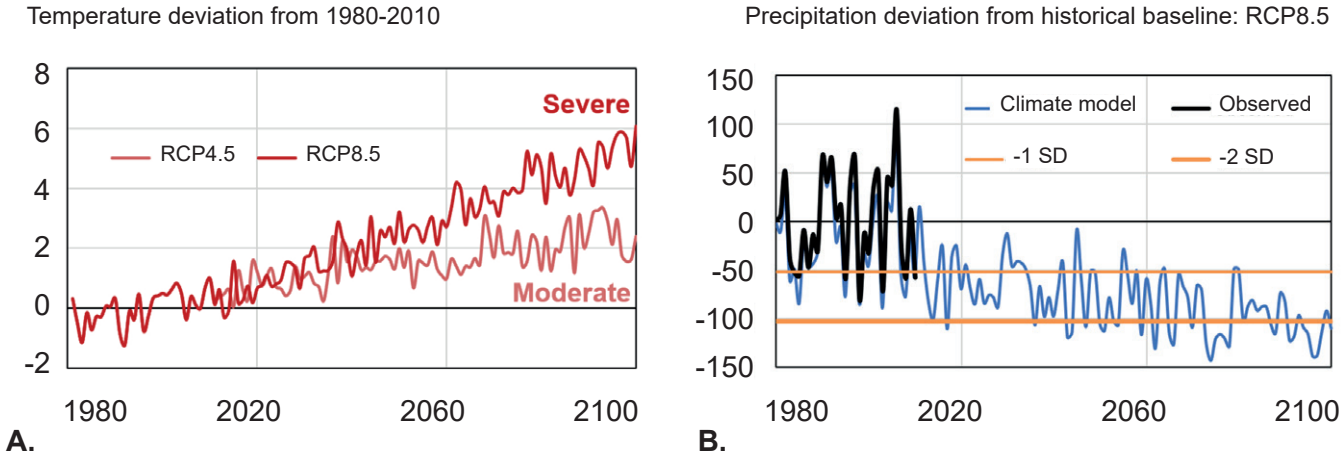

*Figure 3: **A.** Temperature change (°C – y-axis) under moderate and severe climate change relative to 1980-2010 average conditions. **B.** Annual precipitation change (mm – y-axis) relative to 1980-2010 baseline average under RCP8.5. Orange lines are -1 and -2 standard deviations of ~50 mm and ~100 mm, respectively.*

- The **second factor** is **changing socio-economic conditions**. These are represented by the **SSPs** (Shared Socio-economic Pathways) which are part of the IPCC report and specific to Jordan. **SSP 2** represents modest population growth coupled with rapid economic growth and **SSP 3** represents greater population growth and modest economic growth. The **Crisis scenario** additionally assumes a new wave of refugees beginning in 2030 (see Figure 4a/b).

- The **third factor** is the future degree of transboundary river flows from Syria to Jordan. Flow from Syria was historically the greatest single surface water source to Jordan, but since 2005 flows have been reduced by 50% to 75% due to flow interception and use by Syria.

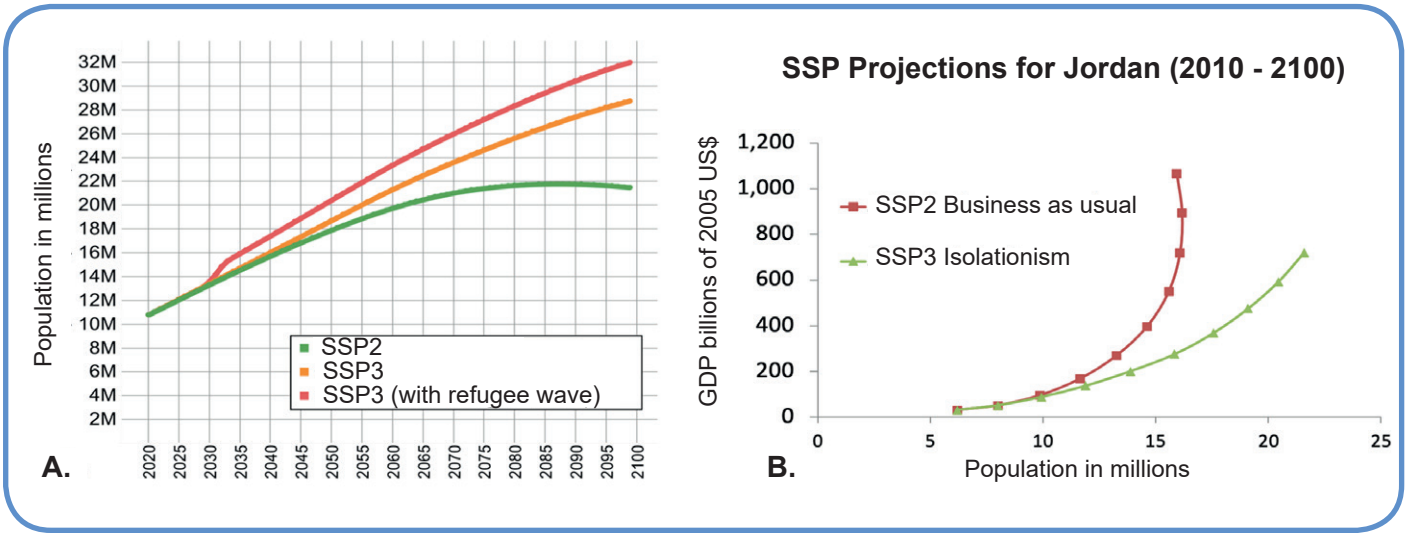

*Figure 4: **A.** Population change under Shared Socio-economic Pathways SSPs 2 and 3, plus SSP3 with a new influx of refugees beginning in 2030. **B.** GDP with population growth under SSP2 and SSP3.*

Finally, interventions and scenarios were then combined and analyzed to see how the metrics (e.g., vulnerability, stress duration, inequity, economic well-being) evolve under a prescribed scenarios set. **The combination of a single scenario set and a particular intervention is defined as a narrative**. For example, one narrative is the Baseline Conditions under the Optimistic Scenario. Another narrative is the Enhanced Supply Intervention under the Population Growth Scenario. Analyzing the **Five Interventions** (**Baseline, I, II, III** and **VI**) under the **Four Scenario Conditions (involving Climate, Demographic, and Socio-economic Changes)** provided us with 20 narratives. Although these 20 narratives were presented at the workshops, we actually simulated many more detailed conditions to show such effects as the impacts on groundwater depletion, surface water availability, and sectoral water availability.

Results: The need to do it all

At the workshops, we presented the model as described here, and we provided our projections of each narrative and the evolution of the metrics through 2100. To streamline our presentation, we focused on the **vulnerability metric** – the percent of the population receiving less than 40 liters per capita per day. Figure 5 shows our results for that metric for the **Baseline Conditions, Intervention III (Demand Management), Intervention I (Agriculture to Urban), Intervention II (Supply Enhancement)**, and the case that **Interventions I-III** are all taken together in **Intervention VI – Comprehensive Action**.

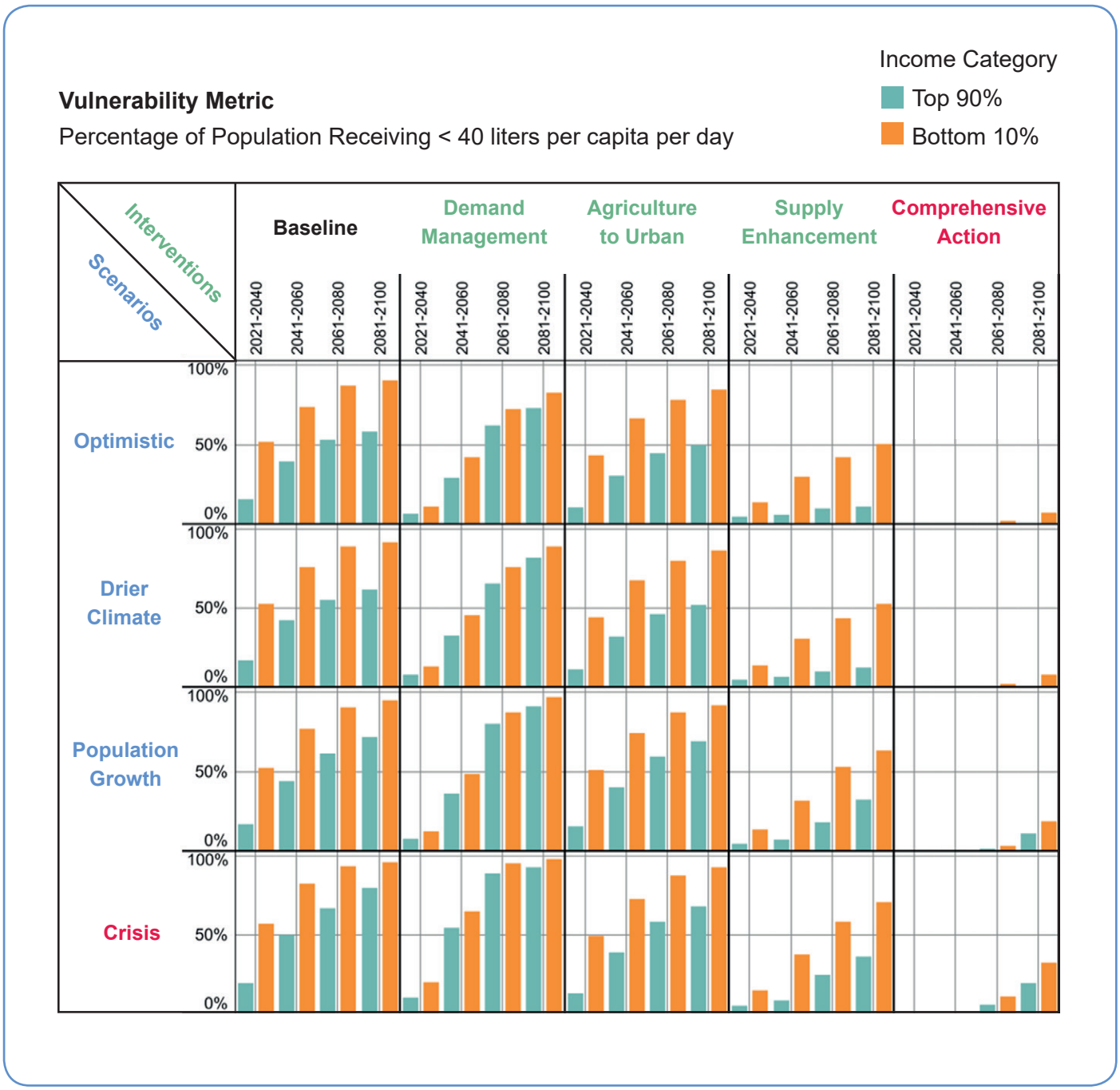

Figure 5: Narrative projections for vulnerability metric

Under **Baseline Conditions**, even under the **Optimistic Scenario**, 50% of those in the bottom 10% of income will receive less than 40 liters per capita per day during the next 20 years, and by mid-century 90% of the population will also experience that level of vulnerability. **Demand Management** shows modest improvement compared to **Agricultural to Urban** transfers, but the lower 10% income group remains highly under-supplied. **Supply Enhancement**, with desalinated water from the Red Sea, produces significant relief to the general population but still leaves lower income individuals vulnerable, particularly after mid-century. **Comprehensive Action** is capable of drastically reducing vulnerability under all but the **Crisis Scenario** at the end of the century. However, **Comprehensive Action** requires a myriad of interventions that no other country is likely able to do – including a large-scale infrastructural project, significant water reallocation from agriculture, theft reduction, fixing the pipes, and doubling water tariffs on the largest consumers.

3

Second Set of Workshops

SLL2: 2nd Set of Workshops in Amman – September 2021

In September 2021, the FUSE team returned to Amman to present and discuss the analyses of its modelling results. Due to the COVID-19 pandemic, the workshops had to be delayed for several months.

Again made possible by the close collaboration with FUSE's local partner MIRRA, three workshops and a networking event were organized: A one-day **Expert Workshop** on September 6 was followed by a one-day **Stakeholder Workshop** on September 8. The second set of workshops in Amman and hence the third step of FUSE's SLL approach was concluded by a novel **Strategic Policy Thinkers Dialogue** and a **Networking Event** on September 9.

The Expert and Stakeholder Workshop both began with a review of the SLLs in 2019, followed by a presentation of modelling results. The key message was that Jordan needs to take comprehensive action to address the country's existing and worsening water crisis. However, all nexus dimensions and their interconnections must be considered to avoid disruptions to food and energy systems and to assess their contributions to a sustainable Jordan.

Besides evaluating the modelling results, the workshops focused on identifying barriers that prevent the implementation of the interventions and on measures to overcome those barriers. While participants of the Expert Workshop identified barriers, attendees of the Stakeholder Workshop and of the Policy Thinkers Workshop discussed how to overcome these barriers.

Finally, the Strategic Policy Thinkers Dialogue provided an opportunity to reflect once again in a focused way on the analyses of the modeling results, as well as on the outcomes of the workshops and next steps.

Expert Workshop (September 6, 2021)

What: Discuss the model results, give feedback on their feasibility, and elaborate on those interventions that need to be implemented as soon as possible.

Who: There were 35 participants from academia, public institutions, NGOs, the private sector as well as former government officials.

How: After a presentation of the common vision and the challenges resulting from the first set of workshops in 2019, the most attractive vision element and the most pressing challenges were chosen and discussed and then followed by a presentation of the modeled interventions and the results. The participating experts provided feedback on the credibility of those results. Subsequently, they discussed concrete policy interventions and barriers to their implementation in five groups, followed by a final fishbowl discussion on how to overcome the implementation barriers.

Step 1: Review of the SLLs in 2019: Visions and Challenges

FUSE team members Ines Omann and Bernd Klauer presented the common vision, developed by the experts, and the challenges (see Figure 1 above). In small groups, participants looked at the posters and came up with one statement, what they like most about visions and up to three statements, what worries them most about the challenges.

The participants picked diverse elements of the vision as those most important to them:

- Better management of water supply
- Master plan for national development
- Amman reaches water self-sufficiency
- Trust in government
- Enforcement of regulations

When it comes to the challenges, there was strong agreement that declining groundwater levels result in higher pumping costs and can result in poor water quality of deeper groundwater. In addition, climate change and increasing population are pressing challenges.

Step 2: Model Results and Feedback

Project leader Steven Gorelick and Christian Klassert presented the concept of the integrated model, the interventions (see Figure 2), and their impacts. Modelling results clearly show that the FWE situation will be traumatic in the future and that all interventions need to be implemented as soon as possible to have a viable and sustainable future in Jordan. After the presentation, participants provided feedback on the different interventions and their modelling results, related to four categories (agreement on the proposed interventions and measures, concerns, additional ideas, and general remarks).

Generally speaking, participants were **supportive** of most interventions and their related measures. Among these are: *repair of leaking pipes, reduction of water theft, cost recovery, and the Red Sea - Dead Sea desalination and conveyance system.* However, **concerns** were raised related to *the costs of pipe leak repair or the environmental impact of desalination* of water from the Red Sea. The increased use of *solar energy for electricity and solar farming* was supported. The measure of transferring *25% of groundwater production capacity from agricultural to municipal sector* is supported but seen with skepticism regarding its feasibility.

Other concerns included the feasibility of the supply measures, related to grid strengths or storage of energy and low trust in a water-for-energy contract with Israel. Low awareness for the urgency of these interventions and lacking behavioral changes were a concern related to most interventions.

Highlighted additional measures brought forward by participants were: a water contract with Syria, solar energy for desalination, water harvested from floods, restoration of forests and grazing land, public-private partnerships, desalination not only from the sea but also from wells, stronger penalties for water theft, more grey and waste water use, improved irrigation efficiency and cultivation of water-efficient crops, awareness campaigns for demand management measures and increasing engagement of local communities.

Step 3: Group Work on Interventions

This step was the core part of the Expert Workshop. Participants chose one of the presented policy interventions according to their interest and expertise. They discussed their respective chosen intervention, including barriers and means to overcome them. Primary results of the discussion:

Agriculture to Urban and Climate-adapted Crops:

Key messages:

- Increase wastewater reuse in the Highlands
- Introduce water saving technologies and climate-adapted crops
- Enforce control and law enforcement against illegal groundwater pumping
- Improve cooperation between ministries

The discussion distinguished between measures for the Highlands, and for the Jordan Valley. In the Jordan Valley, treated wastewater from Amman and Irbid is transported, used, and has high acceptance. In contrast, in the Highlands, a lot of groundwater pumping takes place, partly because there is an insufficient number of local wastewater treatment plants. One part of the group stated that acceptance for wastewater use is low in this region. The group argued for more control and law enforcement against illegal pumping and water theft. However, they also brought up the stability aspect: Protests against tighter measures in rural areas could lead to political instability. Participants argued that agricultural yields have to increase in a sustainable way without higher freshwater use and proposed to increase wastewater use in the Highlands by using decentralized wastewater treatment plants. They further argued for better coordination between the Ministry of Water and Irrigation and the Ministry of Agriculture. Participants suggested introducing new technologies to enhance irrigation efficiency such as smart agriculture. They also recommended a shift to seasonal crops and locally adapted seed varieties that are adapted to new conditions due to climate change – e.g., wheat or barley.

Water Supply Enhancement

Key messages:

- Measures to enhance water supply should be taken
- Water supply in Jordan always bears an international (transboundary) dimension
- To be effective, measures and new technologies need to be supported by all levels

Participants agreed that Jordan must make every effort to improve its water supply. The participants of the discussion called for the implementation of new technologies related to new water sources. In particular, measures should focus on infrastructure for water networks, desalination of water, use of unconventional water sources and the consideration of further sources. Participants also highlighted that the availability of water in Jordan always bears an international dimension. Jordan shares most of its water sources with neighboring countries and relies on water treaties with e.g., Israel, Syria and Saudi Arabia. International financing for the implementation of water projects was also deemed important. Participants further stressed that measures and new technologies must be supported by all levels, meaning that top-down implementation is not enough. Rather, citizens must also support these processes by raising their awareness of water issues and related social issues, such as the economic impact of water tariffs. This, in turn, will not be possible without supportive action from the government.

Water Demand Management

Key messages:

- Demand-side management is complementary to supply enhancement measures
- Work on behavioral changes at multiple levels is needed, e.g., awareness raising, information campaigns, community-based cooperation, etc.

From the perspective of water demand management, the discussion was principally about potential measures to re-evaluate the tariff structure, efficient re-allocation and redistribution of water resources to improve equity, water theft reduction, and use of unconventional water sources such as rainwater harvesting and reuse of grey water. Notable obstacles to implement these measures are awareness issues: people often do not realize how severe water scarcity is, and are used to getting water at low cost; financing issues: the reallocation of water across the city to achieve greater equity as supply costs can be very expensive due to missing infrastructure and technical difficulties in certain areas.

Solar Energy

Key messages:

- The challenge is not the availability of energy, but the stability of the grid
- Isolated network system prevents deals with neighboring countries
- Renewable energy needs incentives

The discussion on the intervention to increase the availability of energy through decentralized solar farming revealed that the availability of energy is not the main challenge in Jordan. However, an increased use of renewable energy was advocated. In this context, concerns with regard to feasibility were raised, in particular concerning the stability and absorption capacity of the grid. It was highlighted that Jordan relies on a largely isolated network system that does not allow for energy transfers – and possible energy-water deals – with neighboring countries. Therefore, participants highly recommended initiatives to change the current situation and to stabilize the grid. Further, investments in storage technologies as well as in enhanced production capacities were proposed. On a political and administrative level, the current regulation of the Jordanian energy sector was scrutinized in terms of steering effects toward efficiency and incentives for innovation. Incentives for farmers and households to invest in renewable energy sources were considered too low and long-term (gas) contracts identified as a barrier to switching the energy base.

Decentralized Urbanization

Key messages:

- Decentralization strategies suffer from lack of political will, land ownership issues, and complex administrative structures.
- Strong incentives for Amman residents would be needed to give up the good access to jobs, education, and recreation in Amman, if the plan is to allocate resources outside of the greater Amman region.

Jordan is a highly centralized state with most economic and institutional weight concentrated in Amman. Decentralized urbanization strategies have been tried for Amman in the past (satellite towns), but largely failed due to complex administrative structures and lack of incentives. Amman municipality does not have an interest in losing its central position in Jordan by shifting public institutions to other cities. Land ownership is a big issue in Jordan: often belonging to tribes, it is often seen as status and not developed further or sold. Another barrier for decentralization is the concentration of capital (money, infrastructure, but also access to facilities, jobs, or services) in Amman. Strong investments would be needed.

Implementation of the proposed intervention is only possible with better cooperation between land owners and investors to create new development, if public institutions are shifted to accessible places outside greater Amman region and if there are incentives for investors.

Harvest of Working Groups

The group discussions were accompanied by an intensive harvesting by group hosts and note takers. It resulted in harvest sheets that depicted a) *a common understanding of the intervention*, b) *the identification of barriers, winners and losers in the context of the intervention*, and c) *next steps needed to implement the intervention*. While a) was important to lead a meaningful discussion within the group, b) served the FUSE team to identify and cluster barriers, which were systematized after the Expert Workshop and represented an important input to the Stakeholder Workshop; c) eventually steered and stimulated the discussion in the final fishbowl session.

Step 4: Fishbowl Discussion of Implementation Strategies

In a fishbowl discussion, the active discussants in an inner circle are silently observed by an audience in an outer circle. However, people from the outer circle can join the active discussants at any time, and discussants from the inner circle can move into the audience. As a starting point of the fishbowl session, representatives of each working group presented their results. The aim of this discussion was to integrate the results of the working groups and to come up with initial ideas for implementation. After a first round, in which one representative per working group presented key results, other participants joined the discussion and added their thoughts and ideas.

Key messages from the discussion:

- Coordination and collaboration among different FWE sectors are needed after identifying the gaps between different governmental (national and local) bodies and ministries. Participants suggested that the Ministry of Water and Irrigation should initiate this process.
- Besides the governmental collaboration, the private sector needs to be involved, for instance through public-private partnerships including new business plans (creating demand for new technology/ interventions, make them available and affordable).
- Regulations such as solar energy regulation need to be updated.
- Increased awareness-raising and education about FWE and climate issues is necessary.
- One proposal was to install a high committee, directly linked to the Prime Minister, allocated with sufficient resources, which could lead the development of the above mentioned implementation plan.
- Such a plan should be accompanied by a dialogue with citizens to understand their real needs and to raise awareness of climate change, pollution and other environmental problems.
- Another important item is related to urban sprawl. Vacant land accounts for 40% of the greater Amman region. A master plan for the urban intensification strategy, including better infrastructure and highrise building, is needed instead of paving and developing more and more land outside the region's boundaries.

Stakeholder Workshop (September 8, 2021)

What: The purpose of the stakeholder workshop was: 1) to inform participants about model results and receive feedback, and 2) to develop ideas on how to overcome implementation barriers.

Who: There were 30 participants from Non-Governmental Organizations (NGOs) in the areas of water, food, energy, urban matters, environmental protection, social issues, as well as youth group representatives and small companies.

How: After briefly summarizing results of the first workshops in 2019, the FUSE team presented the model concept and model results for different policy interventions. As a next step, participants discussed how to overcome different barriers to FWE sustainability that had been identified during the expert workshop two days earlier.

Step 1: Review of the SLLs in 2019: Challenges

After an introductory round, the FUSE team presented the main FWE challenges that had been brought up in the first stakeholder workshop in 2019. Each participant selected one challenge that they considered the most worrisome. Subsequently, those challenges were discussed in small groups, which agreed upon the most important challenges. The groups selected declining groundwater, water loss due to non-revenue water, lacking enforcement of transboundary water treaties, and water quality as the main challenges.

Step 2: Model Results and Feedback

After this group exercise, Steven Gorelick and Christian Klassert presented the modelling results in a similar manner as in the Expert Workshop described above. After the presentation, participants asked questions and provided comments and feedback.

Step 3: Group Work on Overcoming Barriers

For the next part of the workshop, the FUSE team summarized and classified barriers for implementation that had been identified in the Expert Workshop. **Four types of barriers** were identified: **technical and financial** barriers, **governance and enforcement** barriers, barriers related to **sovereignty and cooperation**, and barriers related to **awareness** (see Figure 6). After the FUSE team presented the barriers, participants formed groups, discussed those barriers and developed ideas on how to overcome them

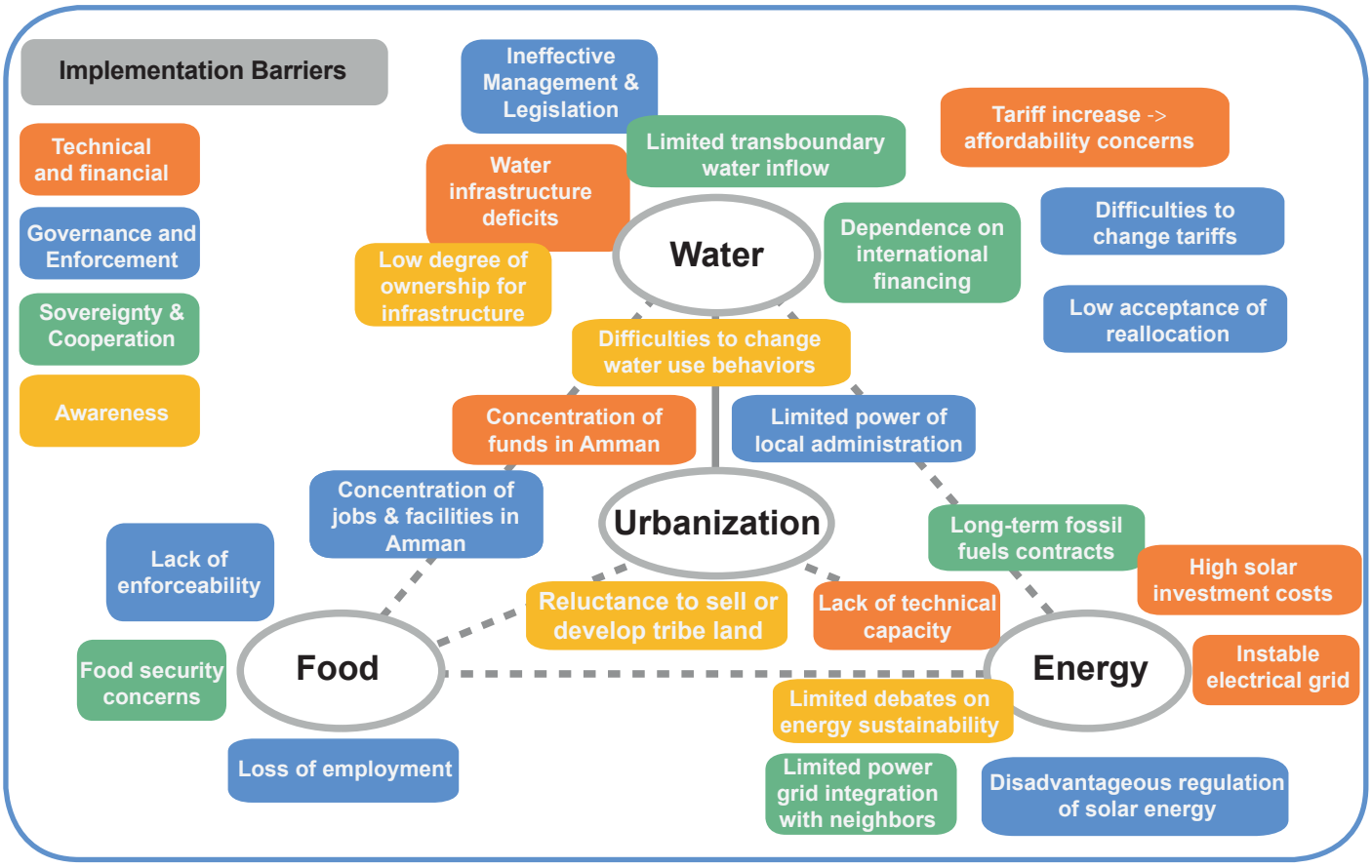

Figure 6: Barriers to the implementation of interventions

Technical and Financial Barriers

Key messages:

- Water supply system needs major improvements
- Lacking funds and technical capacity are bottlenecks
- Higher water and energy tariffs could lead to large consumers leaving the public system and end-product prices to rise

Financial and technical barriers regarding the implementation of nexus interventions were identified and ranked. They relate to water and energy infrastructure deficits (leakages and instability, respectively), unequal distribution of funds, largely being concentrated in Amman, affordability concerns in case of price increases for large consumers, limited technical capacity of public staff and high investment cost for switching to solar energy.

Barriers related to Governance

Key messages:

- Need for more effective management and regulation
- Degree of enforceability must be increased
- Strengthen the powers and quality of local administration

In its assessment of the barriers related to governance, the group concluded that ineffective management and the lack of enforceability applies to all nexus dimensions.

Additionally, the limited powers of the local administration were highlighted as a major barrier. Whereby it was discussed, whether the limitations lie in the lack of regulations, the low willingness and political feasibility to enforce existing laws or the overall quality of local

administration. Another discussion revolved around the topic of water tariffs. Opinions differed widely on what effective taxation of water might look like and who should pay more and who should pay less. However, participants agreed that long-term plans and people with expertise in the respective positions are needed.

Barriers related to Sovereignty and Cooperation

Key messages:

- Enhance diplomatic and economic relations with neighboring countries and China
- Enhance dialogue with Syria about transboundary water agreements
- Promote renewable energy production in Jordan

The working group argued for more exchange and cooperation in different fields. On the one hand, participants stated that diplomatic and economic relations with China and the Arab Union should be enhanced, in addition to existing relations with the US. Also related to food security and agricultural technology, cooperation with neighboring countries from the Arab region should be intensified. The working group also proposed to intensify the dialogue with Syria to honor their transboundary water agreements, and to bring the issue of transboundary water agreements to the United Nations to promote their fulfilment. They argued for phasing out the gas agreement and to heavily promote renewable energy from Jordan, and discussion underlined the important role of civil society to put pressure on decision makers for advancing these measures.

Barriers related to Awareness

Key messages:

- Education in schools about FWE issues should be enhanced
- More cooperation between government and NGOs, and local communities is needed
- Awareness-raising measures via influencers and social media are important

The working group discussed that school education should contribute more to awareness raising on ecological issues and that in turn children would also influence their parents' behavior. Participants argued for a more active role of the government in developing guides and instructions e.g., for sustainable water use, to be distributed in cooperation with NGOs and schools. They also suggested closer cooperation between the government and local communities, and for making greater use of influencers and social media to reach out to important target groups, e.g., such as housewives, who influence water use in households, or to migrants.

Step 4: Key Take-aways

After a short presentation of the results of each working group, the workshop closed with a **final round**, where participants pointed out their key take-away. Participants stressed the importance of science-policy dialogue for taking informed decisions. They underlined the value of bringing together experts from different sectors to develop solutions for overcoming barriers. Long-term planning based on scientific inputs, collaboration between different ministries, enforcement of laws, and the importance of education were reiterated as key for advancing FWE sustainability.

Final Events (September 9, 2021)

Strategic Policy Thinkers Dialogue

The purpose of this dialogue was to present the FUSE modelling results as well as results of the expert and stakeholder workshops to a small group of policy thinkers, to get their feedback, and to develop further ideas on how to overcome barriers to FWE sustainability.

Becoming familiar with FUSE modelling results were welcomed by the participants as they can contribute to increase awareness among policy makers for the urgency of the water situation in Jordan.

The following policy measures were discussed during the workshop: In order to **reduce agricultural water-use** in the highlands, participants suggested developing water saving plans together with farmers, including crop changes, and enforcing existing regulations. Participants also stated that better service of water authorities, such as fixing pipe leaks and improving water quality could contribute to changing behavior of water consumers and to increase their willingness to pay higher tariffs. This would require substantial investment in the water infrastructure. To combat water theft, fines have to be increased and enforced; agricultural water use can be monitored via analysis of satellite images.

Furthermore, **reform of water authorities** was deemed necessary: coordination between water authorities needs to improve continuity, and therefore expertise of employees has to substantially increase. The need for more **continuity and coordination** was also stated related to donor projects. Participants proposed to strengthen public-private partnerships as a good alternative for how public authorities and business can work together to improve the FWE situation. In addition, participants proposed to install a high level council on climate change and the FWE nexus, maybe located at the Royal Court, with involvement of the Prime Minister as well as other politicians and experts.

Networking Event

At the end of the three intense workshop days, MIRRA and the FUSE team organized a networking event at a farm outside Amman. All participants were invited to take part in this event, to deepen discussions, to exchange their impressions and to get to know each other in a different setting. Around 50 participants accepted the invitation. Workshop participants and the FUSE team had a wonderful time together in an open and kind atmosphere. The evening concluded with singing and dancing, and FUSE team members enjoyed learning new dance steps. We would like to thank all participants for this unforgettable evening.

Outlook / Next Steps

The FUSE team was delighted to be able to return to Jordan after a delay of more than one year due to the COVID-19 pandemic, and we were glad that our results were received with a lot of interest and support. Throughout the discussions in the different workshops, stakeholders and experts deepened their awareness of the importance of the Nexus dimensions for water security. There was a general agreement that without decisive measures, the already dire water situation will significantly worsen in the next years in Jordan. To be effective, strategies will have to consider interdependencies of the Food-Water-Energy Nexus, such as

- improving coordination in the **water-food** nexus to better adapt agriculture to water scarcity and save water for increasing urban demands;
- using **energy-for-water** (for desalination) to increase the supply of freshwater;
- enhancing cooperation related to **water-energy** with neighboring countries, in particular Israel, e.g., trading water for solar energy;
- achieving a **more efficient and equitable distribution** of water to ensure sufficient water access for all.

The FUSE project has made important contributions to understanding what lies ahead for Jordan in terms of Food-Water-Energy (FWE) resource provision and sustainability. Given climate change, population growth, and the trajectory of socio-economic development in Jordan, the provision and access to freshwater is a growing concern. Jordan is an intricately coupled human-natural-engineered system, and only through a systems perspective can the impact of policy interventions be quantitatively assessed. As such, our work provides Jordan with a window into its future and an ability to identify which solutions will work and which will not work. As the FUSE project ends, we hope that our results and systems model can continue to help guide policies aimed at achieving FWE resource sustainability. Insights from our many Jordanian stakeholders and our interactions with Jordan's Ministry of Water and Irrigation, have been essential to our success, and for which we are most grateful.

More information about FUSE in Jordan can be found here. A short impression of the atmosphere in the workshops can be found here.

Participants in Stakeholder Workshop

Participants in Expert Workshop

The FUSE team thanks all participants for their valuable contributions and MIRRA (in particular, Dr. Samer Talozi and Alham Walid Al-Shurafat) for their support.

We are grateful to Jordan's Ministry of Water and Irrigation for their expertise, information, data, and feedback over the many years we have been working in cooperation with their fine leaders and staff.

Participating Institutions

Agricultural Engineers Association
Al-Bait University
Alcazar Energy Partners
Arabic Protection of Nature (APN)
Association for Climate Change and Environmental Protection of Jordan (JOCCEPS)
Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)
EDAMA
Energy & Minerals Regulatory Commission (EMRC)
German Jordanian University (GJU)
Greater Amman Municipality (GAM)
Green Generation Foundation (GGF)
Hashemite University (HU)
Housing & Urban Development Corporation (HUDC)
International Union for Conservation of Nature (IUCN)
International Youth Ambassadors Foundation (IYAF)
Jordan Aqua Conservation Association (JACA)
Jordan Climate Change and Environmental Protection Association (JACCEPA)
Jordan Environmental Union (JEU)
Jordan Food and Drug Administration (JFDA)
Jordan Green Building Council (JGBC)
Jordan Renewable Energy Society (JRES)
Jordan Research and Training Reactor (JRTR)
Jordan Uranium Mining Company (JUMCO)
Jordan Valley Authority (JVA)
Jordanian Engineers Association
Jordanian Hashemite Fund for Human Development (JOHUD)
Ministry of Water and Irrigation (MWI)
Ministry of Agriculture (MOA)
Ministry of Energy and Mineral Resources (MEMR)
Ministry of Transport (MOT)
Ministry of Water And Irrigation (MWI)
National Alliance Against Hunger and Malnutrition (NAJMAH)
National Center for Agricultural Research (NARC)
National Electric Power Company (NEPCO)
Royal Scientific Society (RSS)
Royal Society for Nature Conservation (RSCN)
SOLVillion – Infinite Engineering Solutions
Stockholm International Water Institute (SIWI)
University of Jordan (JU)

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