PRIMA WEF Nexus Workshop

Nexus Modeling: Idea to Policy Making

Rabi H. Mohtar, Bassel Daher, Jauad Elkharraz

December 6, 2021

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Description

This workshop describes nexus principles starting with a resource hotspot, problem conceptualization, identification of the system, interlinkages and data. It helps identify scenarios, define an evaluation measure and sets tradeoffs analysis protocol.

The workshop will provide a detailed training on the use of WEF Nexus 2.0 and how to set scenarios, compile data and run various simulations.

The workshop will take the tradeoff analysis and outline steps to engage stakeholders for improved decision and policy making.

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Workshop Outline

8:00 Introduction
8:05 Theory and concepts (Mohtar)
8:45: Q/A
8:55: Break
9:00: WEF Nexus 2.0 (Daher)
9:45: Q/A
9:55: Break
10:00 Science to Policy (Kherraz)
10:45: Q/A
11:00 Adjourn

First Module:
Examining the Water-Energy Food Nexus
A Focus on ESCWA Region

Rabi H. Mohtar

Texas A&M University

American University of Beirut

Program Overview

I. Research

1. **Water-Energy-Food-Health Nexus Platform**

2. **Green Water accounting:** scalable thermodynamic modeling tools for improved water resources accounting

3. **Feasibility of non-traditional water to help bridge the water gap**

II. Engaging Texas and the World

NEW COURSE
CVEN 689
BAEN 689

Water-Energy-Food Nexus
Toward Sustainable Resource Management

SPRING 2015

- Understand the interrelationships between water, energy, and food.
- Explore implications of water-energy-food nexus at local, national, and international level through case studies and real-world projects.
- Use a quantitative framework for assessing sustainable tradeoff of resources.

III. Preparing Students

Global Service Learning - at home and abroad

Outline

1. Introducing the Water-Energy-Food Nexus
2. Obstacles and solutions to Nexus Integration
3. Regional Perspective of the Water-Energy-Food Nexus
4. Decision Support systems: Nexus Analytical tools
5. Water for Energy Production as a Policy Guide

Grouping of Arab countries depending on how energy intensive water extraction and delivery is

1. High-energy demand: countries that depend on groundwater and desalination
   - GCC countries
2. Medium-energy demand: countries that depend on a mix of sources
   - Jordan, Lebanon, Tunisia, and Yemen
3. Low-energy demand: countries that largely depend on surface water
   - Egypt and Syria

Water-Energy-Food Nexus

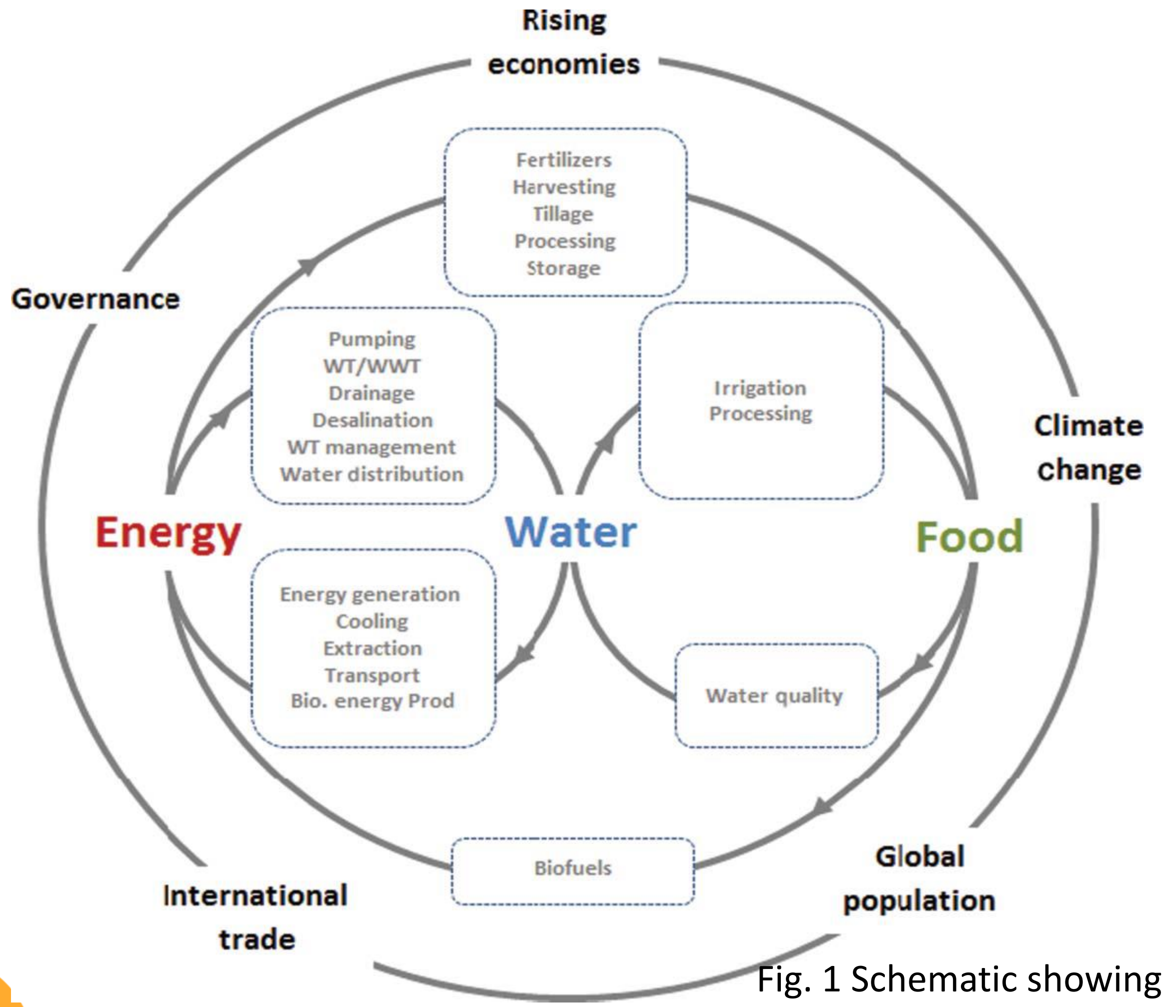

Fig. 1 Schematic showing the water–energy–food nexus with effecting parameters (Source: Daher and Mohtar, 2015)

Water-energy food nexus approach requirements

1. Be inclusive of all stakeholders and create dialogue
2. Be quantitative and provide clear indicators for decision makers in the policy making process
3. Be evidence based and create synergies for data generation and sharing
4. Build on current structures and scenarios rather than have a substitution approach

Obstacles and Solutions: Lack of coherence: ‘Silo’ thinking

- ‘Silo’ or fragmented approaches arise from competition between urban and rural local governments and inadequate management coordination.
- How to best allocate water to meet the needs calls for finding synergies and trade-offs across all sectors.

Obstacles and Solutions: Data Gaps

- Lack of coordination is due to poor or non-existing data regarding the availability, demand and regulations of primary resources.
- The absence of this information can make the the nexus implementation very inefficient.
- These inefficiencies can carry across sectors and make it hard for governments to respond adequately to demands and stresses.

Obstacles and Solutions: Technological barriers

- Technologies and existing infrastructure in most of the developing countries are inefficient.
- Promoting innovations in technology and governance systems will help countries move forward towards sustainable development goals and sustainable growth.
- Example: production of solar energy in the desert areas of many of the MENA region and the affect of dust storms.

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Obstacles and Solutions: Lack of negotiation and communication tools and skills

- Reaching water and energy security requires that all sectors find a common platform to agree on what their national security goals are.
- Lack of communication tools and skills:
  - Different institutions governing resources do not communicate with each other
  - Unclear interface between science and policy making
  - Decision makers to do not have appropriate tools to analyze trade-offs
- A W-E-F nexus approach is an important tool to create platforms for dialogues and facilitate a better integration of scientific data and policy considerations

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Obstacles and Solutions: War and conflict

- Impacts of water scarcity and energy insecurity are exacerbated by regional conflicts
- Energy and water insecurity combined with other global issues risk fueling conflict
- Thinking systematically about the oil and water conflicts in the region will allow nations to
  - Craft intelligent foreign policy
  - Create cooperation and implement technologies that support efficient production and consumption of resources

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Obstacles and Solutions: Production and consumption behaviors

- Per capita consumption of domestic water in the Arab world ranks among the highest in the world
- The Gulf region is one of the major energy demand regions in the world.
- Energy consumption is growing at an annual rate of 3-4%, twice the world average.
- Electricity generation is growing at an annual rate of 6-8%, three times the world average
- In Syria, up to 9% of annual electrical energy consumption is attributable to groundwater pumping and desalination (data prior to recent conflict)

Governance models, implementation and financing of the Nexus

- Governance solutions must be country-specific and only be identified through collaborative partnerships
- Models for regulating nexus:
  1. Distributed (decentralized) model
  2. Centralized model

Operationalizing these models in the Arab region

1. Private Public Partnerships (PPP):
    - Private enterprise provides a public service and assumes financial, technical and operational risks
    - Need for seed funding
    - Great importance in states where resources have been privatized
    - Community partnership (PPCP) and social partnership (PPSP)
        - Governments, private enterprises, and social organizations for social welfare work together in a private model

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Operation of these models in the Arab region cont.

2. Cooperative (community) model
    - Useful in remote or rural communities in West Asia and North Africa
    - These communities' associations or coops own small scale projects for off-grid production of renewable energy and/or water distribution
    - For example: Tunisia
        - Water users' associations developed pricing system of their own that encouraged more efficient use of water

Water-Energy Security Nexus in the Arab region

- 3 main different zones
  1. **The Gulf**: Oman, Saudi Arabia, United Arab Emirates, Yemen, Kuwait, Qatar
  2. **Eastern Mediterranean zone**: Iraq, Jordan, Lebanon, Syria, Palestine
  3. **North Africa**: Algeria, Egypt, Libya, Morocco, Tunisia, Sudan, Djibouti, Eritrea

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Energy Governance Models

1. In the ESCWA region: regional cooperation and grid integration can help stabilize and secure electricity
   - Example: DESERTEC
2. In rural areas: decentralizing energy sources due to off the grid technologies being more economically feasible

Capacity Building and knowledge and institutional gaps

1. Assemble multi-stake holder working group from the WEF sectors to help guide management
2. Develop specific institutional and individual capacity building programs across sectors
3. Determine right tools and data sets for scale specific conditions and goals
4. Apply outcomes from holistic nexus tools and comprehensive data sets to guide the management of WEF resources
5. Create training programs across sectors to build capacity on the analytics and the negotiation aspects of the implementation of nexus solutions

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Review of existing tools uses and data requirements

- Adopting a nexus approach to sector management encompasses the use of different quantitative and qualitative decision support tools.
- Helpful to choose the tools that meet three important criteria
  1. Address at least 2 of the 3 elements of the nexus
  2. Allow policy analysis at national and local levels
  3. Have an open access for end-users

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Resource Nexus Tools

- Identify interlinkages of energy, water, food systems
- Identify sustainable resource management strategies governed by the WEF nexus
- Identify resources needed for given scenario (water, energy, land, financial requirements, & environmental impacts

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The WEF Nexus tool 2.0

- Allows the user to create different scenarios with varying food self-sufficiencies, water sources, energy sources, and countries of import.
- The user can discover and visualize the amount of resources consumed by different proposed scenarios.
- The tool calculates the "sustainability index" of each scenario
  - Two major components of the sustainability index: Resource requirements and Importance factors for each of the systems
- *www.**wefnexustool**.org/*

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Global Calculator tool

- Mainly focuses on climate change and the effects of human activity
- Model of world's energy, land and food systems
- Explores options for reducing global emissions to 2050 and see the the climate consequences to 2100.
- Best suited for long-term, global strategic questions
- http://uncached-site.globalcalculator.org/

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FAO tool

- Management of nexus to help determine national and local nexus-related goals and ways to achieve them
- Includes stakeholder dialogue and defines dialogue with explicit goals, interests and uses
- Proposes interlinkage matrices as a tool to identify clear nexus synergies and tradeoffs
- ***http://www.fao.org/3/a-i3959e.pdf***

LEAP/WEAP tool

- Long range Energy Alternative Planning (LEAP)
  - Creates a platform for integrated energy planning and GHG mitigation assessment.
  - Capable of assessing cost-benefit of energy and emissions
- Water Evaluation and Planning (WEAP)
  - incorporates supply, demand, water quality and ecological considerations to better allocate limited water resources.
- Integration of WEAP and LEAP
  - Interphase allows both models to exchange parameters and results
  - Help planners understand tradeoffs and evaluate outcomes against their policy goals and priorities
- ***WEAP: http://www.weap21.org***
- ***LEAP: http://www.energycommunity.org***

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Markal/Times tool

- TIMES
  - Economic model generator for local, national or multi-regional energy systems
  - Aims to supply energy services at minimum global cost while making equipment investment and operating, primary energy supply and energy trade decisions
  - *http://www.iea-etsap.org/web/Times.asp*
- MARKAL
  - A proven process of multinational cooperation
  - An international network of analysts
  - A methodology for energy and environmental policy analysis
  - A basic standard model that finds least-cost solutions for directly comparable national results
  - A set of national energy technology databases that are current and consistent
  - A track record of transferring its soft technology to new users.
  - *http://www.iea-etsap.org/web/Markal.asp*

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Climate, Land-use, Energy and Water strategies (CLEWs)

- Investigates interconnections between these different resource sectors
- Provide insights regarding trade-offs and help highlight potential synergic solutions to overcome them
- The provision of policy relevant information is of key importance
- Research is being done to develop a global CLEWs model that accounts for trade and other constraining resources
- However, it is data and resource intensive, time consuming and not compatible with short-turnaround projects
- *http://clews.info/tools.html*

MuSiasem

- Multi-Scale Integrated Analysis of Societal and Ecosystem Metabolism
- Allows for use of technical, economic, social, demographic and ecological variables in the analysis of patters of modern societies
- Analyzes nexus considering many factors at the national or sub-national level
- Calculates flows in relation to funds instead of a traditional input-output analysis
- http://www.nexus-assessment.info/methodology/musiasem

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Water, Energy and Food Nexus: The Q-Nexus Model

A technology-oriented framework for water–energy–food nexus that offers an opportunity to overcome intersectoral WEF data availability and allows improved quantitative WEF nexus analysis. The model offers a science-based technology-oriented approach for quantitative assessment of water–energy–food nexus. It also offers opportunities and practical considerations (Karnib, 2020)

https://www.q-nexus.net/login

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Data Gaps and Capacity building

- Extensive data inputs are needed for most of the tools, and in many cases, the data is not available.
    - Energy production, consumption and transformation data is available
    - Data availability for water is limited and gaps remain due to its physical characteristics
    - Even more complex to obtain data of water consumption in electricity generation.
- "Water for Energy Framework" initiative
- Creating a common database platform among sectors is another tool in creating synergy and productive negotiations

Examples of Water-Energy-Food Nexus and Sustainable Development Goals in Morocco

Alternative Pathways & Interventions

Green Morocco Plan

% olive production: ***Increase 76%***
% citrus prodcution: ***Increase 54%***
% fruits and vegetables: ***Increase 40%***
% cereals: ***Decrease 20%***

Morocco Water Strategy 2030

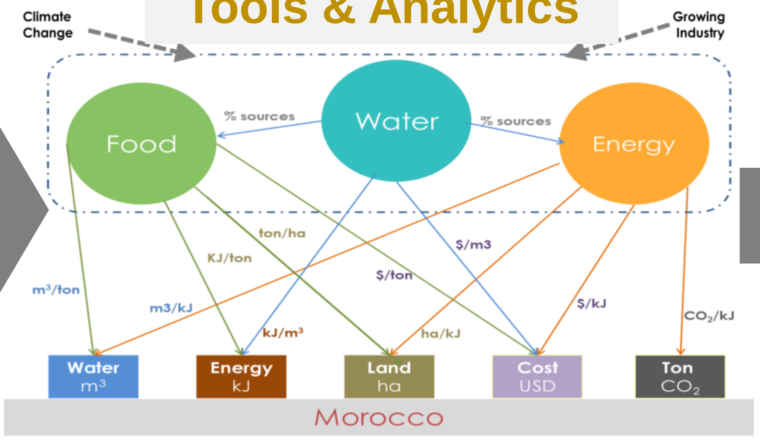
Kingdom of Morocco
Ministry of Energy, Mines, Water and Environment
Department of Energy and Mines

Desalination: ***400,000,000 m3***
TWW: ***300,000,000 m3***

Morocco Energy Strategy 2030

Solar: ***2 GW***
Wind: ***2 GW***
Hydro: ***2 GW***
% renewable: ***Increase up to 42%***

Tools & Analytics



Trade-off Analysis

Food:

(-) security (cereal)

(+) water, land, energy

Energy (renewable):

(+) security, emissions

(-) financial, land, water

Water & TWW:

(+) security

(-) energy, financial

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(Mohtar and Daher, 2016)

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Water-Energy-Transportation Nexus
Scenarios & Results

Scenario Inputs:
- Oil Price
- Natural Gas Price
- Lateral Length
- Water-reuse

Scenario 1
Oil - $110, Gas - $2,
Lateral Length - 5000
Water-reuse- 10%

Scenario 2
Oil - $80, Gas - $4,
Lateral Length – 5000
Water-reuse- 10%

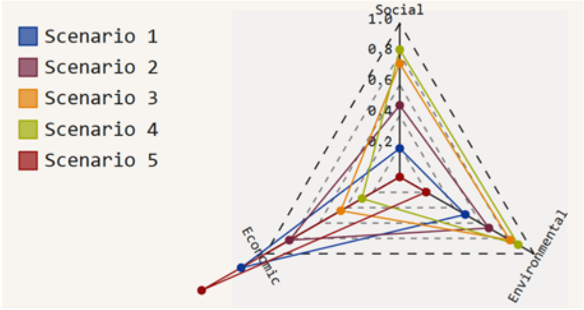
Scenario 3
Oil - $60, Gas - $4,
Lateral Length – 6000
Water-reuse- 15%

Scenario 4
Oil - $40, Gas - $4,
Lateral Length – 6000
Water-reuse- 15%

Scenario 5
Oil - $120, Gas - $2,
Lateral Length – 7000
Water-reuse- 20%

Trade-off Analysis

Sustainability Index



Dialogue for Setting Priorities

Implications
- Policy, regulations, tax, subsidy, etc.
- Innovations in technology
- Consumer behavior

Key messages

1. There is no one-size-fits-all approach to an integrate and sustainable management of resources.
2. Human rights and access to water, energy and food resources should be the foundation of these primary resources production and management
3. People centered approach grounded in the SDGs will allow to map the needs and create cooperation
4. Build capacity of local structures and institutions
5. The WEF nexus governance can be implement in the existing institutional programs that are country and region specific
6. Public sector should be looked at as a major stakeholder.

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Key messages

7. Develop strategies that allow Arab countries to implement the national and international commitments already signed for economic and sustainable development
8. Important to look at different type of governance of the primary resources management such as decentralization of governance
9. DSS for nexus management and interlinkages allow decision makers to look at various scenarios
10. Decisions affecting the energy sector need to include water resources consideration to avoid strains in the water sector
11. The energy requirement and carbon footprint for water technologies such as desalination and water treatment should be considered as a policy guide in the water sector

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Concluding Remarks

Pending Questions

1. Implementations
2. Who owns the Nexus and Nexus solutions?
3. What is the best Governance structure?
4. What are needed incentives for participation?
5. Who funds nexus solutions?
6. How to facilitate converging dialogues?
7. Science
8. Model integration (do not invent the wheel)
9. Scaling issues
10. Integrating physical and human scales
11. Data needs

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Thank You

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Second Module: Daher

Tools & Analytics: A catalyst for inclusive trade-off dialogue

WEF Nexus 2.0

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Research Fellow | Institute for Science, Technology, and Public Policy

Adjunct Assistant Professor | Department of Biological and Agricultural Engineering

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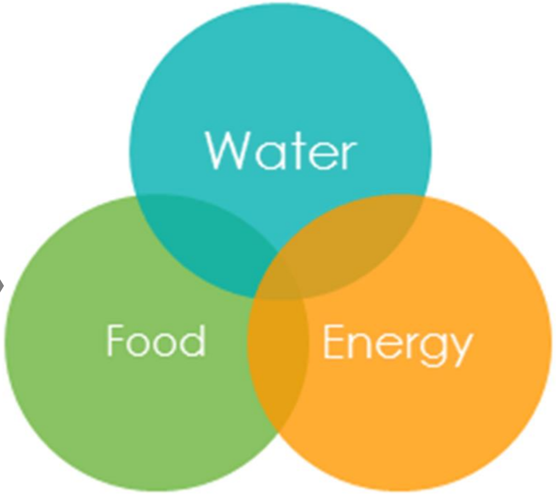
Trade-off Tools & Analytics: a catalyst for inclusive dialogue

Alternative pathways & interventions

- Policies/laws
- Technologies
- Social



Tools & Analytics

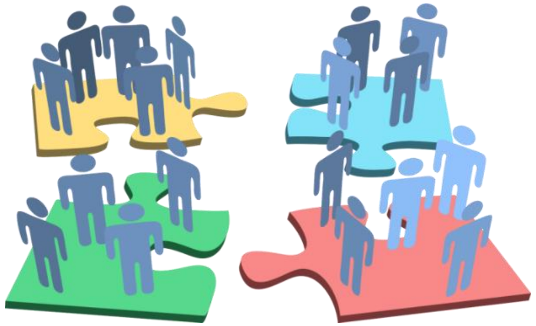
Trade-off Analysis

Scenario Assessment

1- Water Requirements (m3)
2- Energy Requirements (kwh)
3- Financial Investment/Cost ($)
4- Carbon Footprint (ton CO_2)
5- Land Requirement (ha)

Sustainability Index
(Social, Economic, Environmental Indicators)

Stakeholder Preferences



Dialogue

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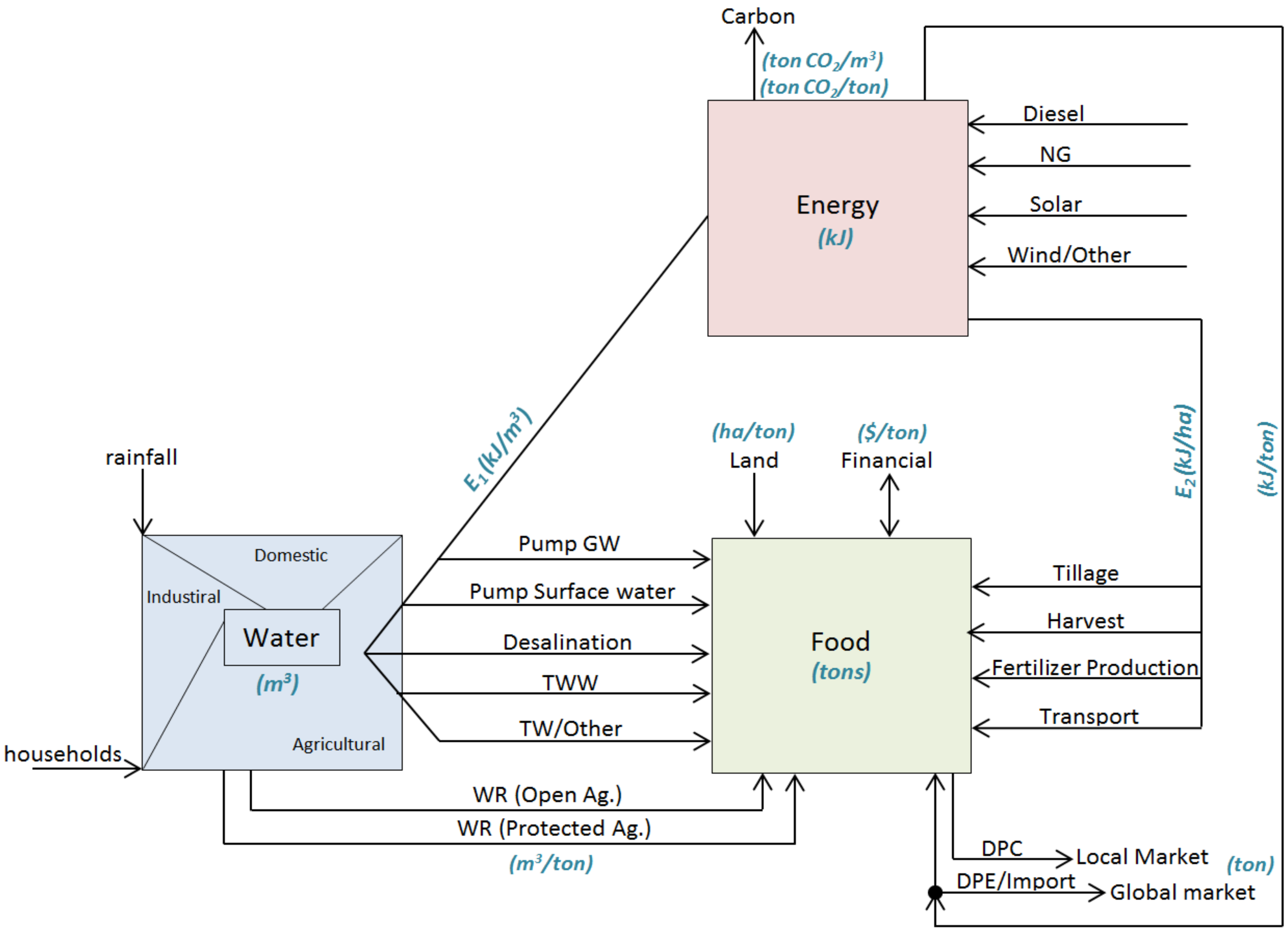
(Daher et al., 2019; Mohtar and Daher, 2016; Daher and Mohtar, 2015)

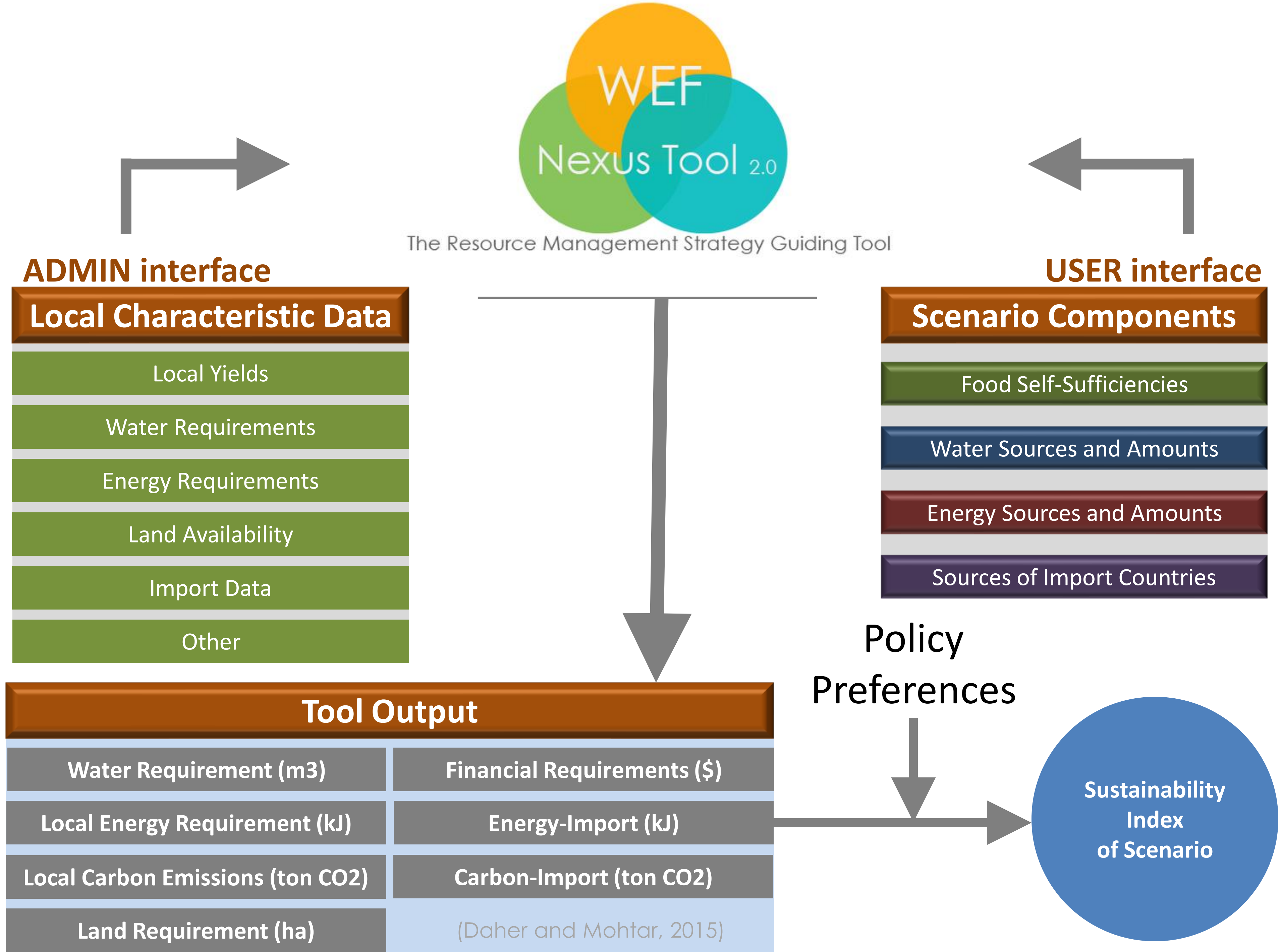
- Ranks 3rd in NG reserves; Ranks 12th in Oil reserves
- Arid Climate
- **Water**: 99% Desalination
- **Agriculture**: limited by low water quantity and quality, unsuitable soil, climatic conditions→ low crop yields
- Food imports exceed **<u>90%</u>**
- Qatar National Vision 2030
- Qatar National Food Security Program (QNFSP)

(Source: Athaia, 2011)

Water–Energy–Food Interconnections



(Daher and Mohtar, 2015)



WEF
Nexus Tool 2.0
The Resource Management Strategy Guiding Tool
ADMIN interface
Local Characteristic Data
Local Yields
Water Requirements
Energy Requirements
Land Availability
Import Data
Other
USER interface
Scenario Components
Food Self-Sufficiencies
Water Sources and Amounts
Energy Sources and Amounts
Sources of Import Countries
Tool Output
Water Requirement (m3)
Financial Requirements ($)
Local Energy Requirement (kJ)
Energy-Import (kJ)
Local Carbon Emissions (ton CO2)
Carbon-Import (ton CO2)
Land Requirement (ha)
(Daher and Mohtar, 2015)
Policy
Preferences
Sustainability
Index
of Scenario

Scenarios using WEF Nexus Tool 2.0

Combined self-sufficiency = 15% (2010)

Tomato & **Cucumber** are partially grown using protected ag.

Groundwater is main source for agriculture

Natural Gas is main source of energy

Imports secured from **15 different countries**

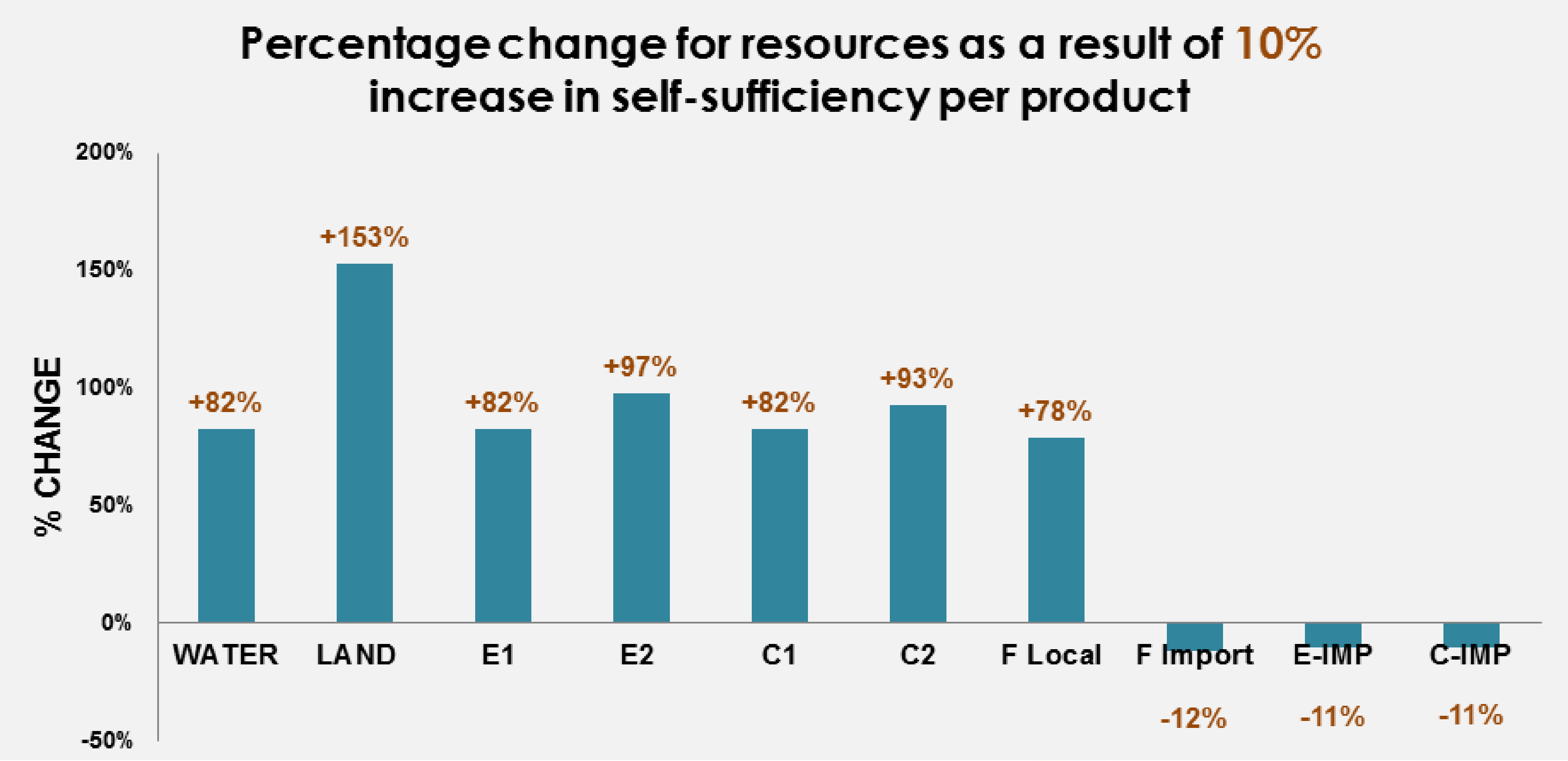
WATER (m3)	5,783,797
LAND (ha)	792
E1 (kJ)	24,699,706,932
E2 (kJ)	15,000,733,177
C1 (ton CO2)	3,039,436
C2 (ton CO2)	1,089
F Local (QAR)	48,940,200
F Import (QAR)	3.68E+08
E IMP (kJ)	1.2117E+12
C IMP (kJ)	92,987








Hypothetical Scenario



Key messages

- Shift in narrative from full self-sufficiency to trade-offs
- Develop robust trade strategies for primary food needs; identify countries of low risk; diversify import sources
- High water, energy, land, $ costs = higher security
- Improve yields of locally produced food products and invest in research to crops best suited to dryland agriculture

Morocco: Overview

Water
- highly water-stressed
- decreasing GW and SW supply
- **15%** of **agriculture is irrigated**; **85%** is rainfed

Climate Change
- more frequent, more intense, and longer heat waves
- **Precipitation** projected to **decrease by up to 27**%

Energy
- Imports **>95 %** of energy

Economy
- Major Sectors: industry, services, & agriculture
- **Ag.: 13.8% GDP**; employs **40%** of population

Food
- Global Ranking: 19th in Wheat production,
  7th in olive production

Phosphate Production
- Top global phosphate producer
- x2 mining & x3 chemical processing 2015-2020

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Goals and Local Strategies

Goal 2: FOOD	Goal 6: WATER	Goal 7: ENERGY
2 ZERO HUNGER — End hunger, achieve food security and improved nutrition and promote sustainable agriculture	6 CLEAN WATER AND SANITATION — Ensure availability and sustainable management of water and sanitation for all	7 AFFORDABLE AND CLEAN ENERGY — Ensure access to affordable, reliable, sustainable, and modern energy for all

Local Strategies

Green Morocco Plan

المغرب الأخضر
LE MAROC VERT

% olive production: ***Increase 76%***
% citrus prodcution: ***Increase 54%***
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Morocco Energy Strategy 2030

iea

Solar: ***2 GW***
Wind: ***2 GW***
Hydro: ***2 GW***
% renewable: ***Increase up to 42%***

(Daher and Mohtar, 2021)

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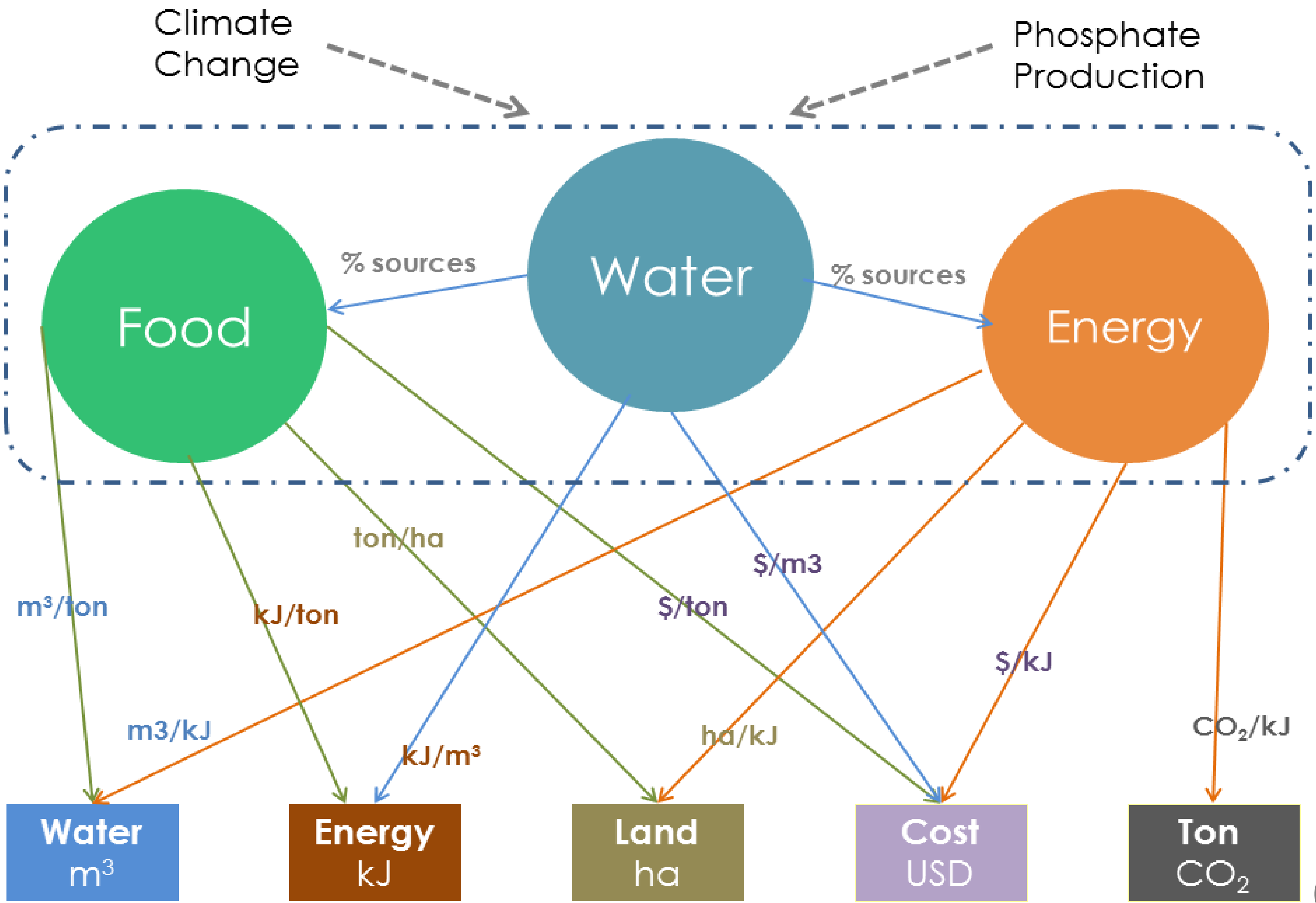
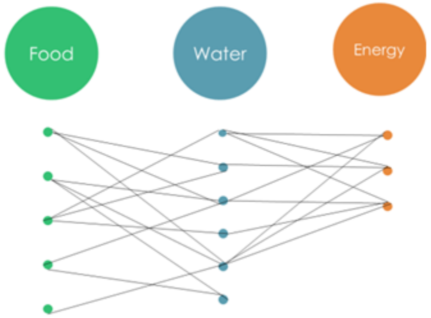
Interconnections Framework



(Daher and Mohtar, 2021)

Tool Structure

Background



Input

MAIN

1- FOOD (% increase of)
- Olives
- Citrus
- F&V
- Cereals

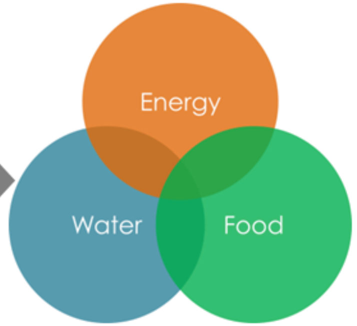
2- WATER (%)
- Desalination target
- TWW target

3- ENERGY (% increase of)
- Wind
- Solar
- Hydro

STRESS COMPONENTS

1- **Climate Change** (low, moderate, high)

2- **Phosphate Production** (low, moderate, high)



SDGs Nexus Tool in Morocco

Output

Scenario Assessment

1- Water Requirements (m3)
2- Energy Requirements (kwh)
3- Financial Investment/Cost ($)
4- Carbon Footprint (ton CO_2)
5- Land Requirement (ha)

Trade-off Analysis

Stakeholder Input

Sustainability Index

(Daher and Mohtar, 2021)

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Trade-offs

Food:

(-) security (+) water, land, energy

Energy:

(+) security, emissions (-) financial, land, water

Water:

(+) reduced water stress (-) land, energy, financial

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Key messages

- **Clear competition** exists among achieving different national strategies over water, energy, land, and financial resources.
- Morocco's strategy to **reduce cereal production** reduces potential stresses on **land** and **water** resources (choice to accept **less self sufficiency in cereals**, in order to allocate resources to other areas, mainly **renewable energy**).
- Investing in **renewable energy** comes at a **high cost**, yet provides Morocco with a higher level of **energy security**, and **carbon dioxide reduction.**
- **Spatial and temporal attribute of resources** components of the resources.

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Overall concluding reflections

- Need for developing and improving **assessment tools for trade-offs analysis** in support of stakeholder dialogue
- **There is NO** 'one-size-fits-all' tool: different tools
    - answer **different questions** at **different scales**,
    - require **different data resolution**
    - involve **different stakeholders**
- **Holistic** yet **localized** assessments and solutions are necessary
- Potential in bridging **physical and social sciences**
- Potential in aligning **WEF research with SDGs**

wefnexustool.org

WEF NEXUS Tool 2.0 light

WEF Nexus Tool 2.0

The Resource Management Strategy Guiding Tool

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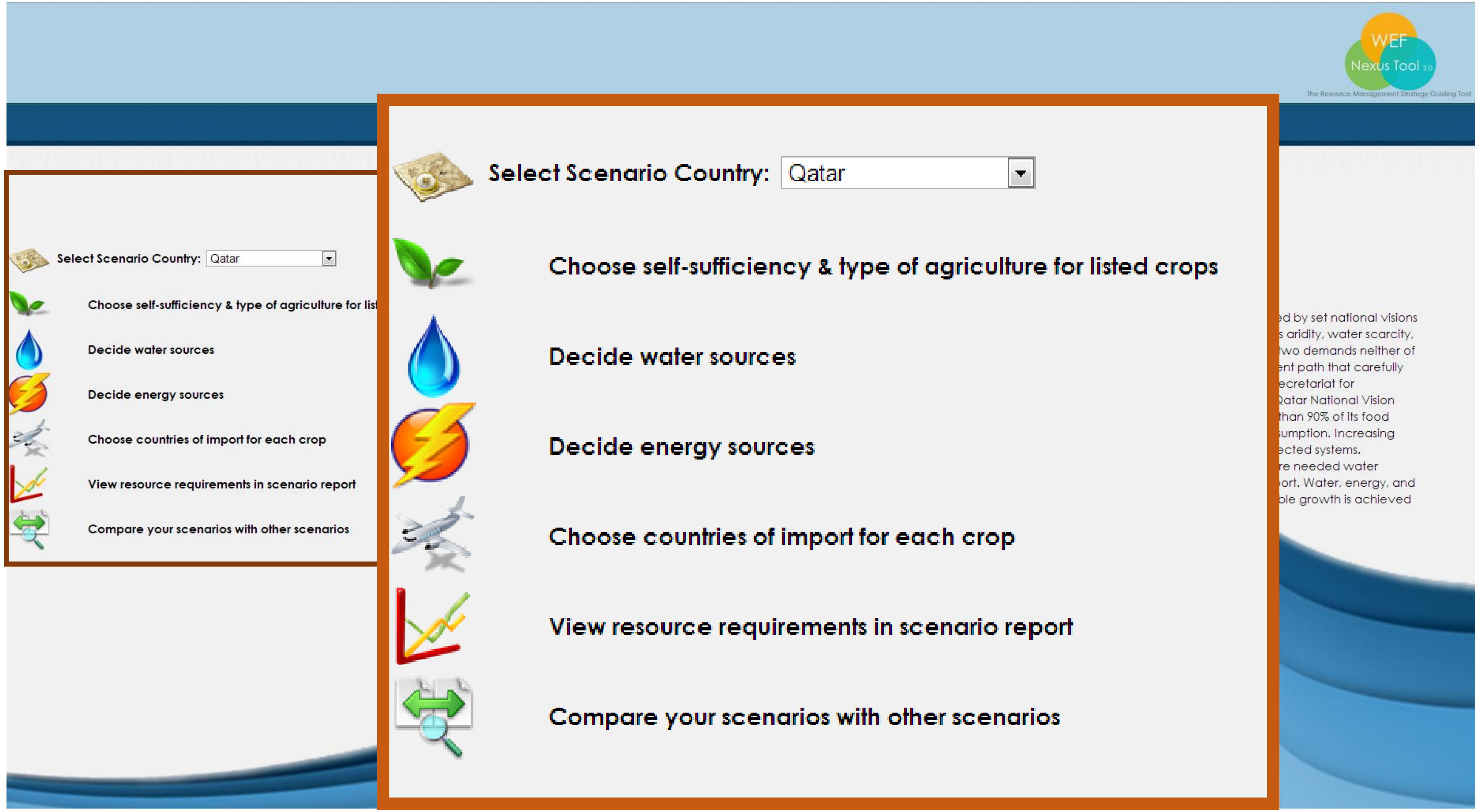
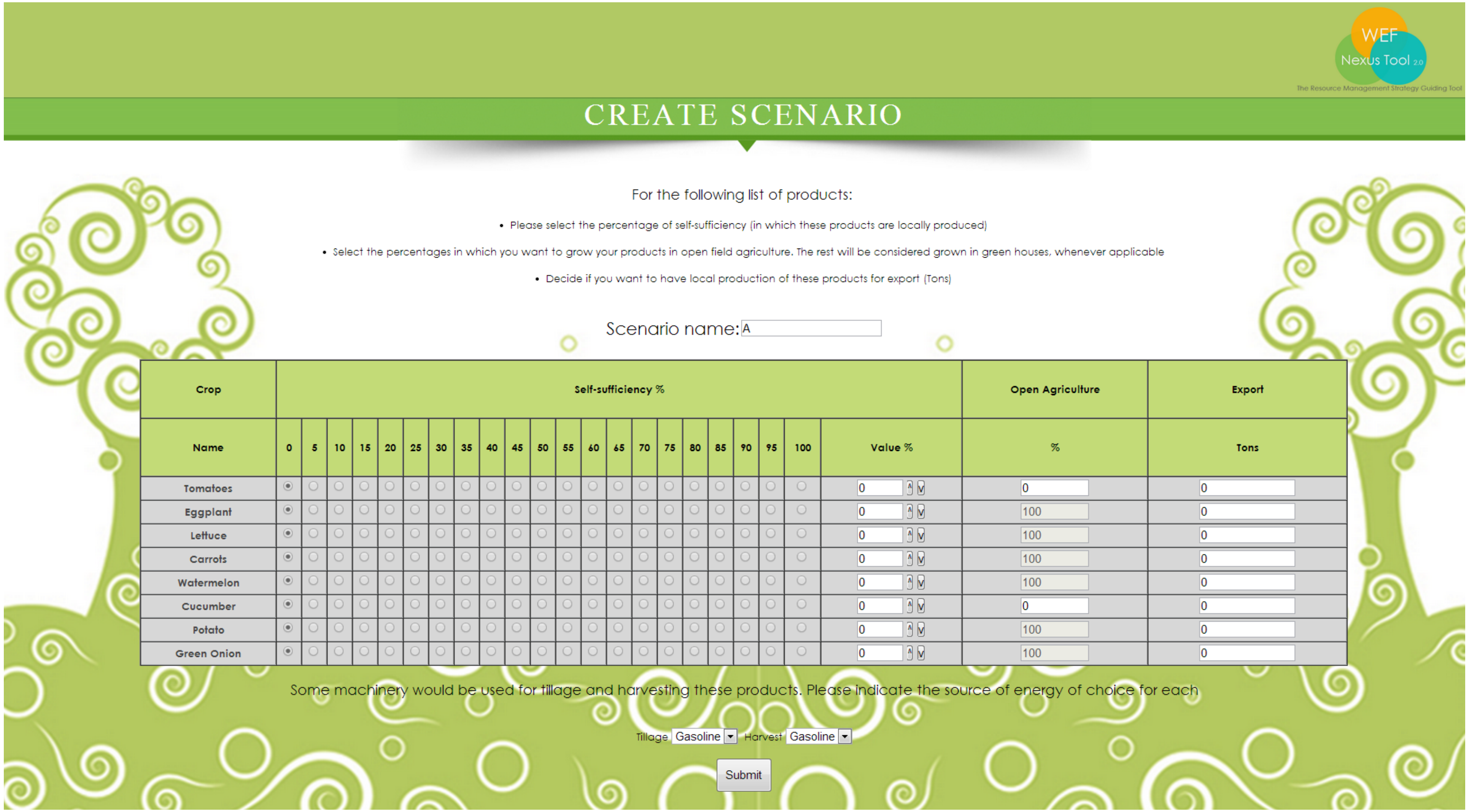
background key concepts about us contact us what's new WET

User Interface



Choose self-sufficiency & type of agriculture for listed crops



CREATE SCENARIO

For the following list of products:

- Please select the percentage of self-sufficiency (in which these products are locally produced)
- Select the percentages in which you want to grow your products in open field agriculture. The rest will be considered grown in green houses, whenever applicable
- Decide if you want to have local production of these products for export (Tons)

Scenario name: A

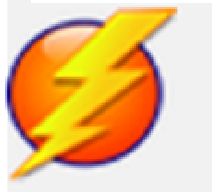
Crop	Self-sufficiency %																					Open Agriculture	Export
Name	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100	Value %	%	Tons
Tomatoes	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	0	0	0
Eggplant	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	0	100	0
Lettuce	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	0	100	0
Carrots	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	0	100	0
Watermelon	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	0	100	0
Cucumber	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	0	0	0
Potato	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	0	100	0
Green Onion	●	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	0	100	0

Some machinery would be used for tillage and harvesting these products. Please indicate the source of energy of choice for each

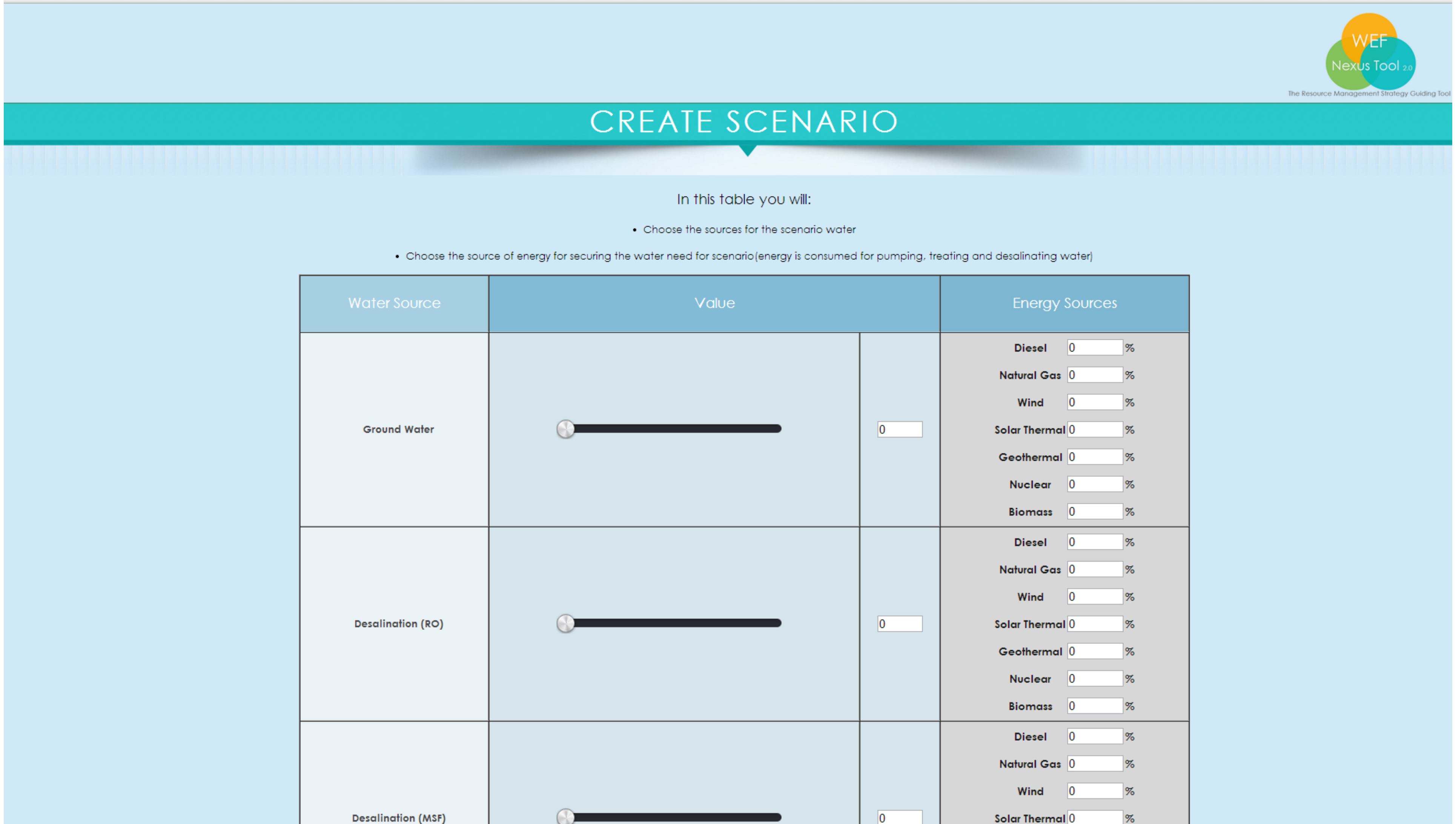
Tillage Gasoline Harvest Gasoline

Submit

Decide water sources



Decide energy sources



Choose countries of import and method of transport for each crop

In this step you will choose the countries in which you want to get your imports from. You will also choose your preferred method of transporting these food products

Please make sure that the sum of the Import Percentages add up to 100%

TOMATOES LIST				
Country	Transport Method	Imports %	Edit	Delete
JORDAN	ROAD	50	EDIT	X
LEBANON	AIR	50	EDIT	X

Add Import Country

Total Imports Percentage for this table: 100%

EGGPLANT LIST				
Country	Transport Method	Imports %	Edit	Delete
NO IMPORT COUNTRY FOUND!				

Add Import Country

Total Imports Percentage for this table: 0%

LETTUCE LIST				
Country	Transport Method	Imports %	Edit	Delete

View resource requirements in scenario report

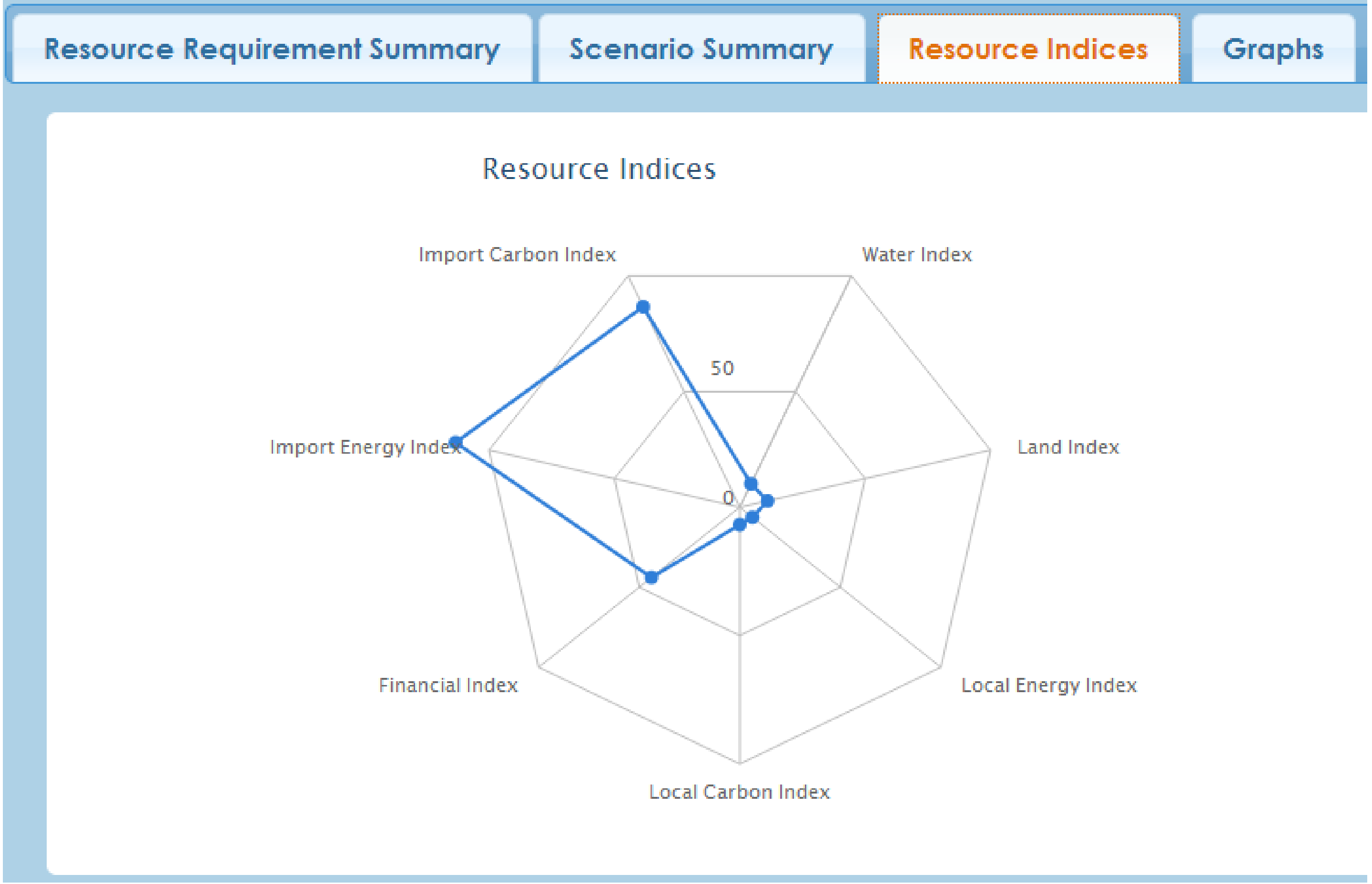
SCENARIO RESULTS

Resource Requirement Summary | Scenario Summary | Resource Indices | Graphs

RESOURCE REQUIREMENT SUMMARY	
Total Water Requirement (m^3)	4,036,638
Total Land Requirement (ha)	1,105.85
Total Local Energy Requirement (kJ)	58,080,139,488
Total Local Carbon Footprint (ton CO_2)	6,334,184
Financial Requirement (QAR)	439,650,135
Total Import Energy (kJ)	1,047,650,248,306
Total Import Carbon Footprint (ton CO_2)	80,104

Print

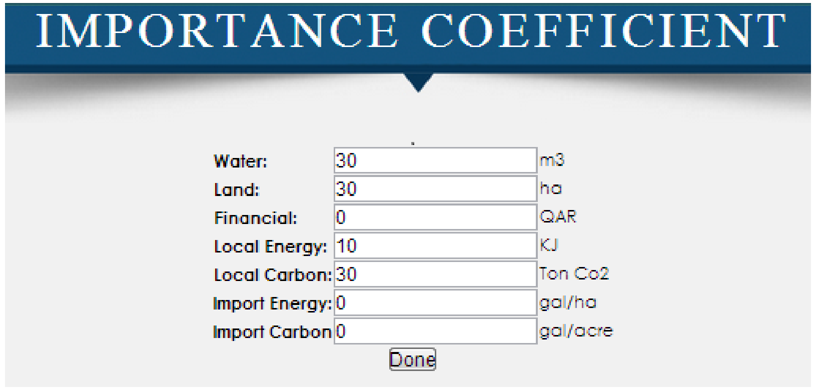
View resource requirements in scenario report



View resource requirements in scenario report

Resource Requirement Graphs

Edit Importance Coefficients



Sustainability Index

3 Scenarios

Scenario 1

- Food Self Sufficiency = 10%
- 100% Open Agriculture
- 50% Groundwater (100% Diesel)
- 50% RO (100% Natural Gas)
- Gasoline for tillage and harvest
- Countries of Import

Scenario 2

- Food Self Sufficiency = 50%
- 100% Open Agriculture
- 50% Groundwater (100% Diesel)
- 50% RO (100% Natural Gas)
- Gasoline for tillage and harvest
- Countries of Import

Scenario 3

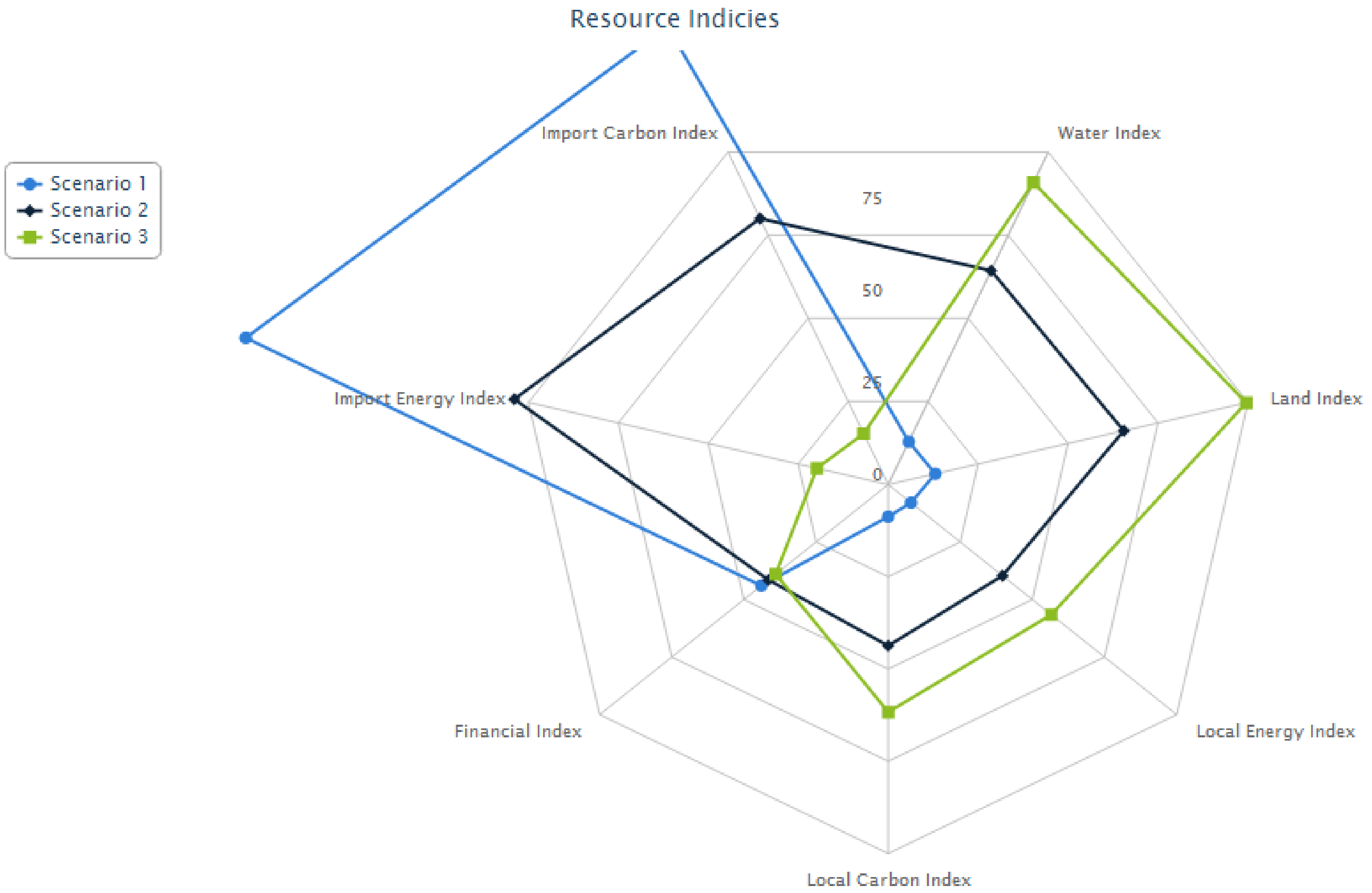
- Food Self Sufficiency = 90%
- 100% Open Agriculture
- 50% Groundwater (100% Diesel)
- 50% RO (100% Natural Gas)
- Gasoline for tillage and harvest
- Countries of Import

- What are the resource requirements for each scenario?
- What are the trade-offs associated with each?

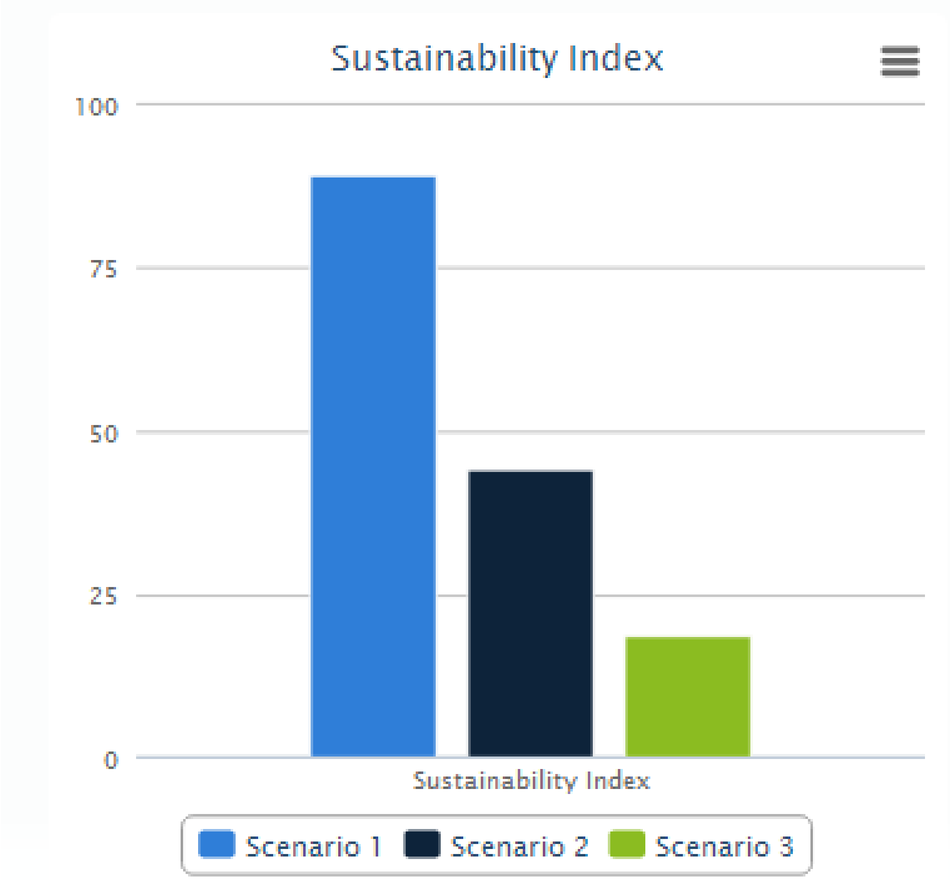
Scenario Comparison: Resource Requirements

WEF Nexus Tool 2.0
The Resource Management Strategy Guiding Tool

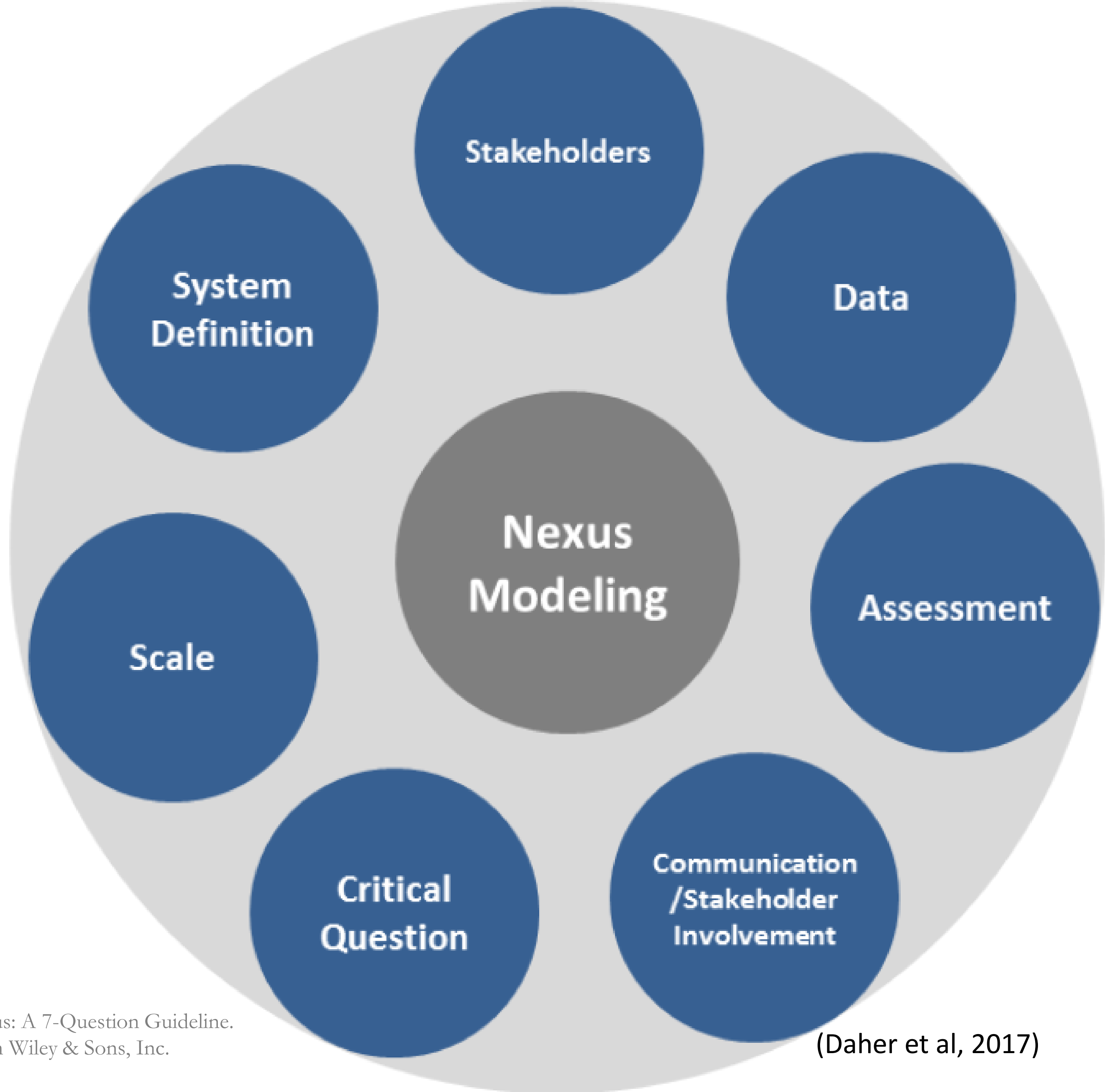
Scenario Comparison: Resource Indices



Scenario Comparison: Sustainability Indices



7-Question Guideline for modeling nexus hotspots



(Daher et al, 2017)

Daher, B., Mohtar, R. H., Lee, S., & Assi, A. A. (2017). Modeling the Water-Energy-Food Nexus: A 7-Question Guideline. In *Water-Energy-Food Nexus: Principles and Practices* (Salam et al., Editors) Vol. 229, pp. 57-66. John Wiley & Sons, Inc. https://doi.org/10.1002/9781119243175.ch6

***Case Study Title:* ……**

Briefly answer the following questions. An explanation for each of the questions is provided on page 2.

1- ***What is the critical question?***

2- ***Who are the players/stakeholders?***

3- ***At what scale?***

4- ***How is the system of systems defined? (complementary figure recommended)***

5- ***What do we want to assess?***

6- ***What data is needed?***

7- ***How do we communicate it? Where do we involve the decision-maker in the process?***

For more details on the 7-Q guideline:

- Daher, B., Mohtar R.H, Lee, S.H., Assi, A. 2017. **Modeling the Water-Energy-Food Nexus: A 7-Question Guideline**. Water-Energy-Food Nexus: Principles and Practices 229, 57. download

For detailed example:

- Daher, B., and Mohtar, R.H (2015). **Water-energy-food (WEF) Nexus Tool 2.0: guiding integrative resource planning and decision-making**, Water International, DOI:/02508060.2015.1074148. download

The 7-Question Framework

- ***What is the critical question?*** It is important to identify what is driving the study; whether it is water scarcity, food insecurity, economic development or other. The central question, around which the interconnections and system of systems will be framed, is a starting point and a building block.

- ***Who are the players/stakeholders?*** Defining the critical question comes hand in hand with identifying the stakeholders, the beneficiaries of addressing those questions as well as other players connected to the systems being considered. Stakeholders need to be involved and accounted for in the process and be part of any prescribed solution. It is important that we understand the role of policy, private sector, public sector, as well as the role of civil society. These players do interact, and understanding that interaction is critical in evaluating the feasibility and effectiveness of any proposed solutions.

- ***At what scale?*** Is the critical question to be addressed at farm, city, state, national, regional, global or some other level? Identifying the scale has a major impact on how the model is created; who are the stakeholders; and what data is needed. The question also helps identify how scenarios might be assessed.

- ***How is the system of systems defined?*** It is important to define the systems based on the critical question/s identified. The more components the model includes, the more complex it will be to create and manage. Simplify the system as much as possible, without losing the key interactions of interest. Our understanding of how resource systems are interconnected may be the result of a specific methodology or approach that helps capture our understanding of more generic processes and interactions. Having said that, the level of urgency to looking at these interlinkages may vary from one country to another depending on local characteristics.

- ***What do we want to assess?*** How a scenario is assessed is an important step that allows the modeler to identify outputs that need to be quantified; and this is highly dependent on the stakeholders and the availability of data.

- ***What data is needed?*** Depending on the end use of the analysis, data resolution and complexity can be determined. If we are looking at quick assessment to better understand certain trends, a coarser level of data may be sufficient. This is particularly useful in the absence of capacity, resources, and time. If more specific interlinkages are of particular importance, more granular data may be needed.

- ***How do we communicate it? Where do we involve the decision-maker in the process?*** The point at which a decision-maker becomes involved is critical. The model should be presented so that unnecessary complexities are eliminated: such complexities should be addressed within the model, but appear 'transparent' to the stakeholder. The model should not take over the decision-maker's authority or make decisions on their behalf, rather, it should be able to assess possible scenarios and highlight the trade-offs associated with each. These trade-offs would then be presented to the decision-maker who would prioritize them and make choices based on simplified results.

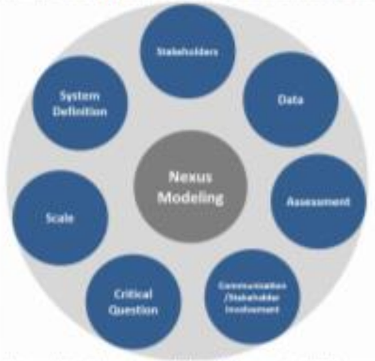


Figure 1: 7-Question guideline (Daher et al., 2017)

Third Module: Kherraz

WEFE Nexus: From Research to Practice

Session 2 - Nexus Modeling: from ideas to policy makers

Science to Policy

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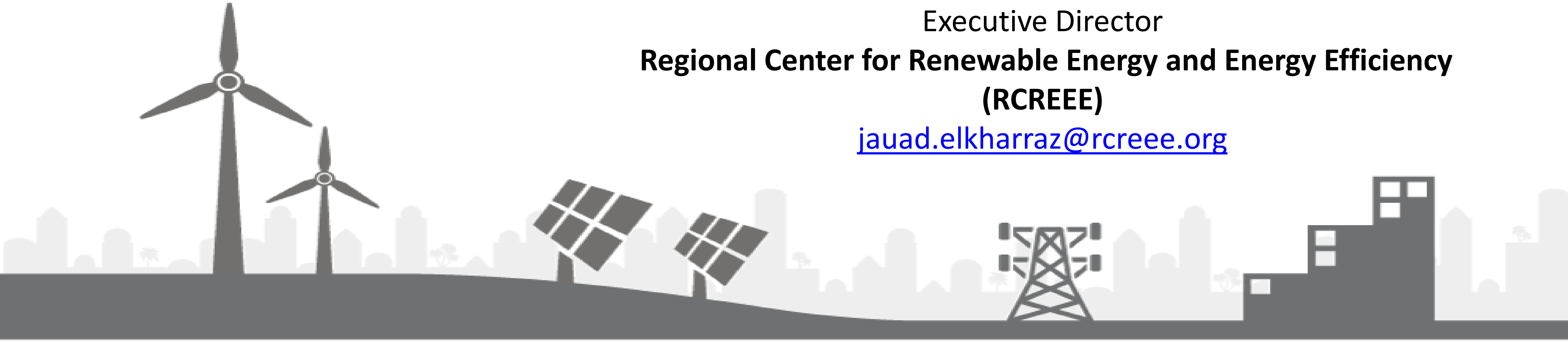


RCREEE
Regional Center for Renewable Energy and Energy Efficiency
المركز الإقليمي للطاقة المتجددة وكفاءة الطاقة

Global challenges needs Scientific and Political solutions

Increasing Water Scarcity

Threat of Waterborne Illness

Growth of Developing Nations

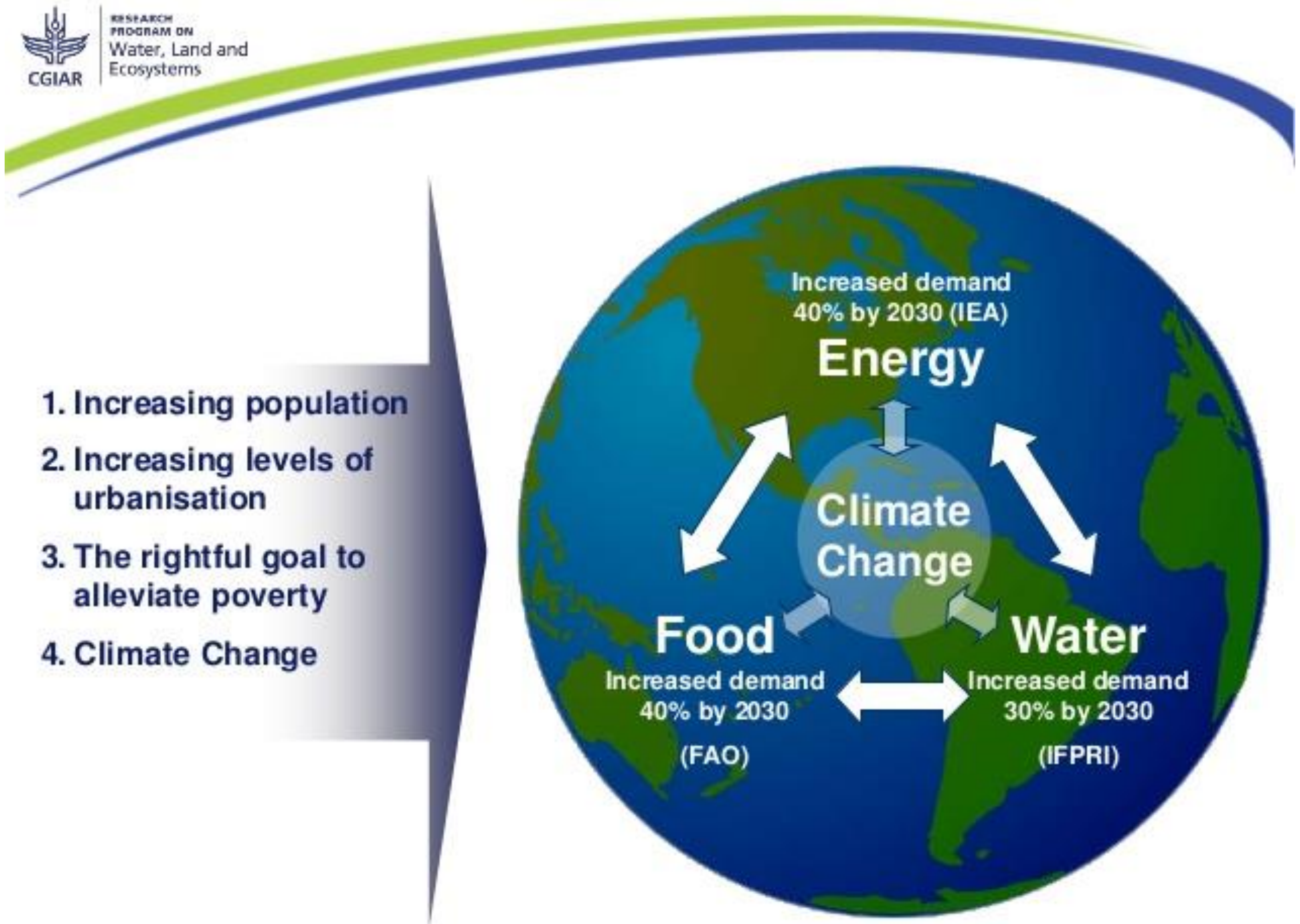
Rising Cost of Energy

New Stringent Regulations

Massive Infrastructure Needs

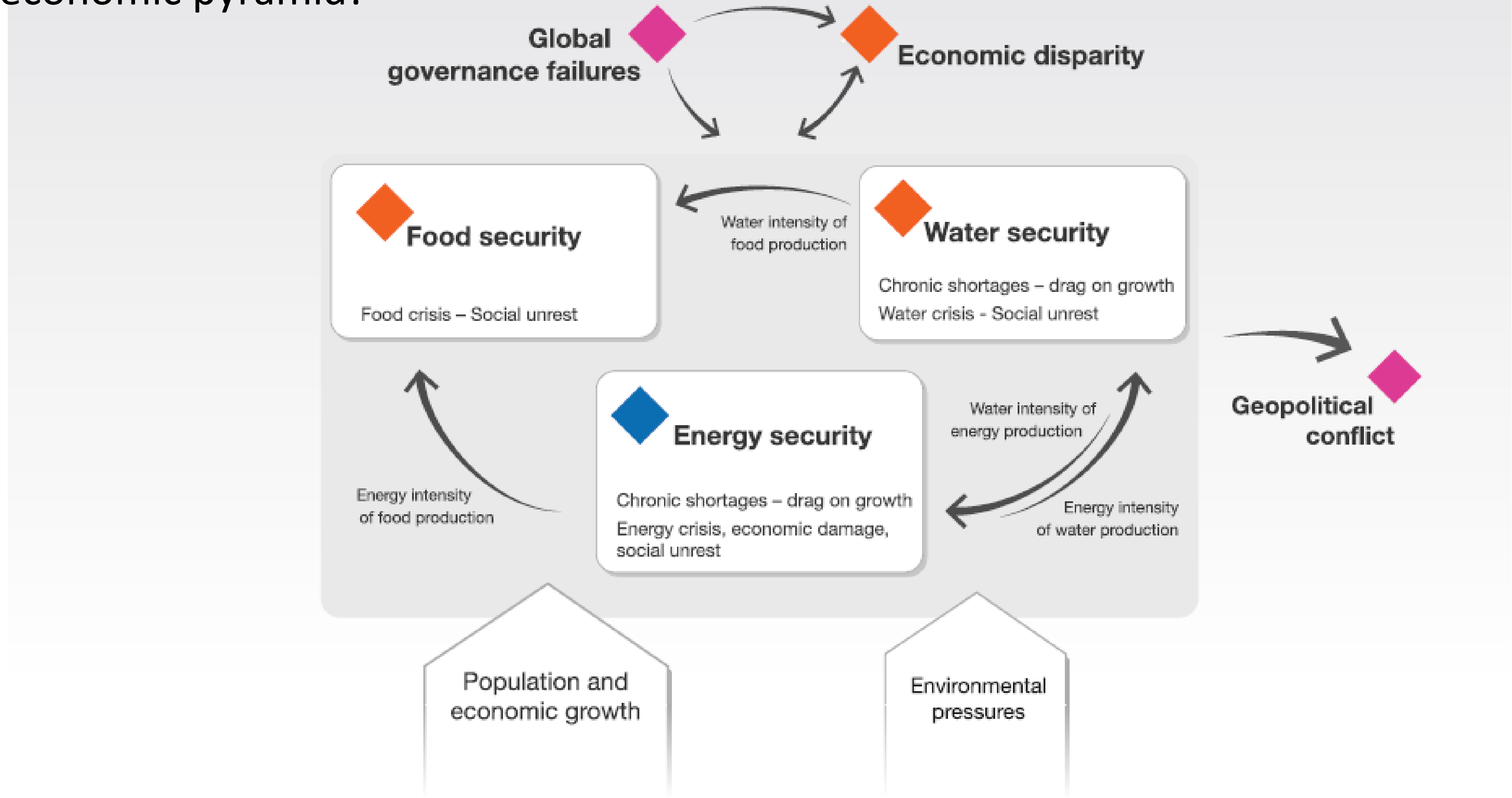
Water – Energy – Food Nexus

- Society: population, urbanisation, culture
- Technology: new developments, breakthrough potential
- Economics: growth, development, financing
- Politics: privatization, political shifts
- Environment: impacts on ecosystems, global climate change



The WEFE Nexus

- …innovative concepts and tough trade offs will increasingly be needed between energy, climate, food and water in terms of **resource allocation, planning and long term sustainable growth** that accommodates those at the bottom of the economic pyramid!



Source: World Economic Forum

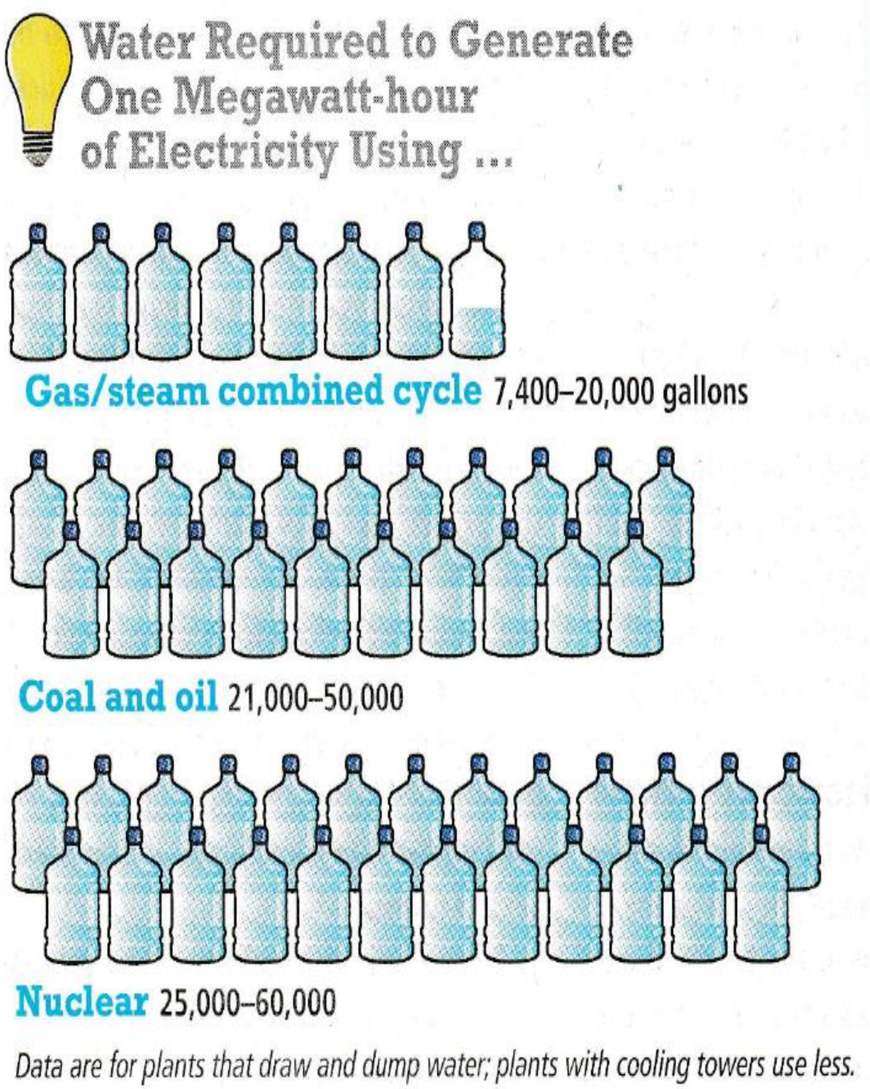
RCREEE

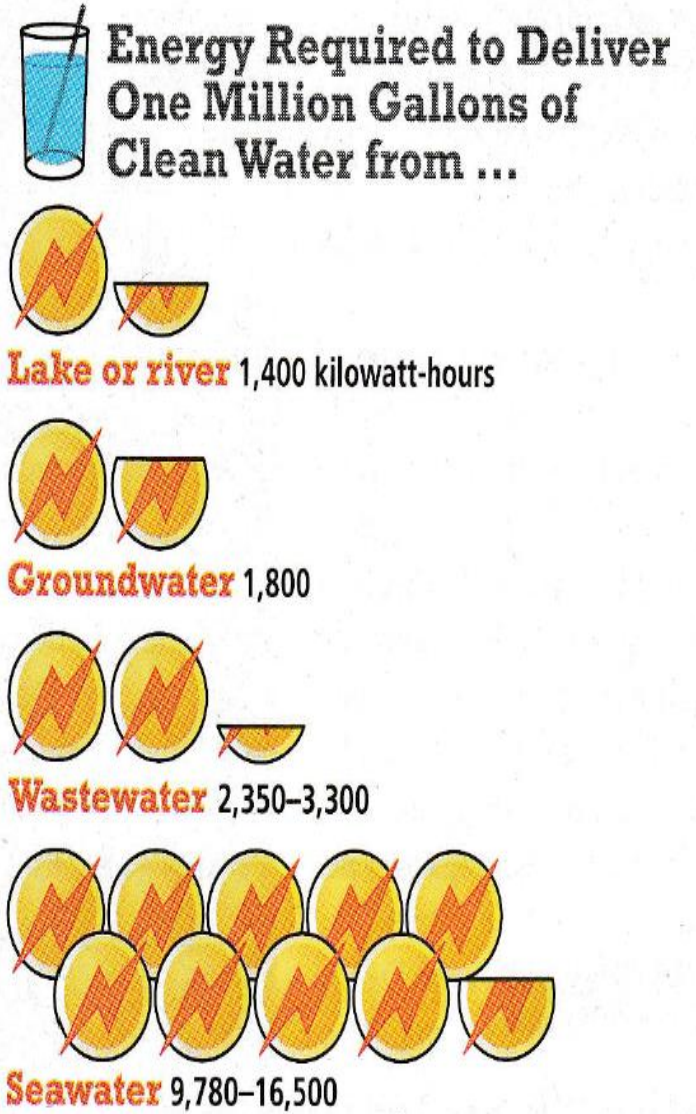
WEF Nexus

The Nexus approach aims at enhancing the efficiency of the entire system rather than increasing the productivity of specific sectors often at the expense of other sectors!

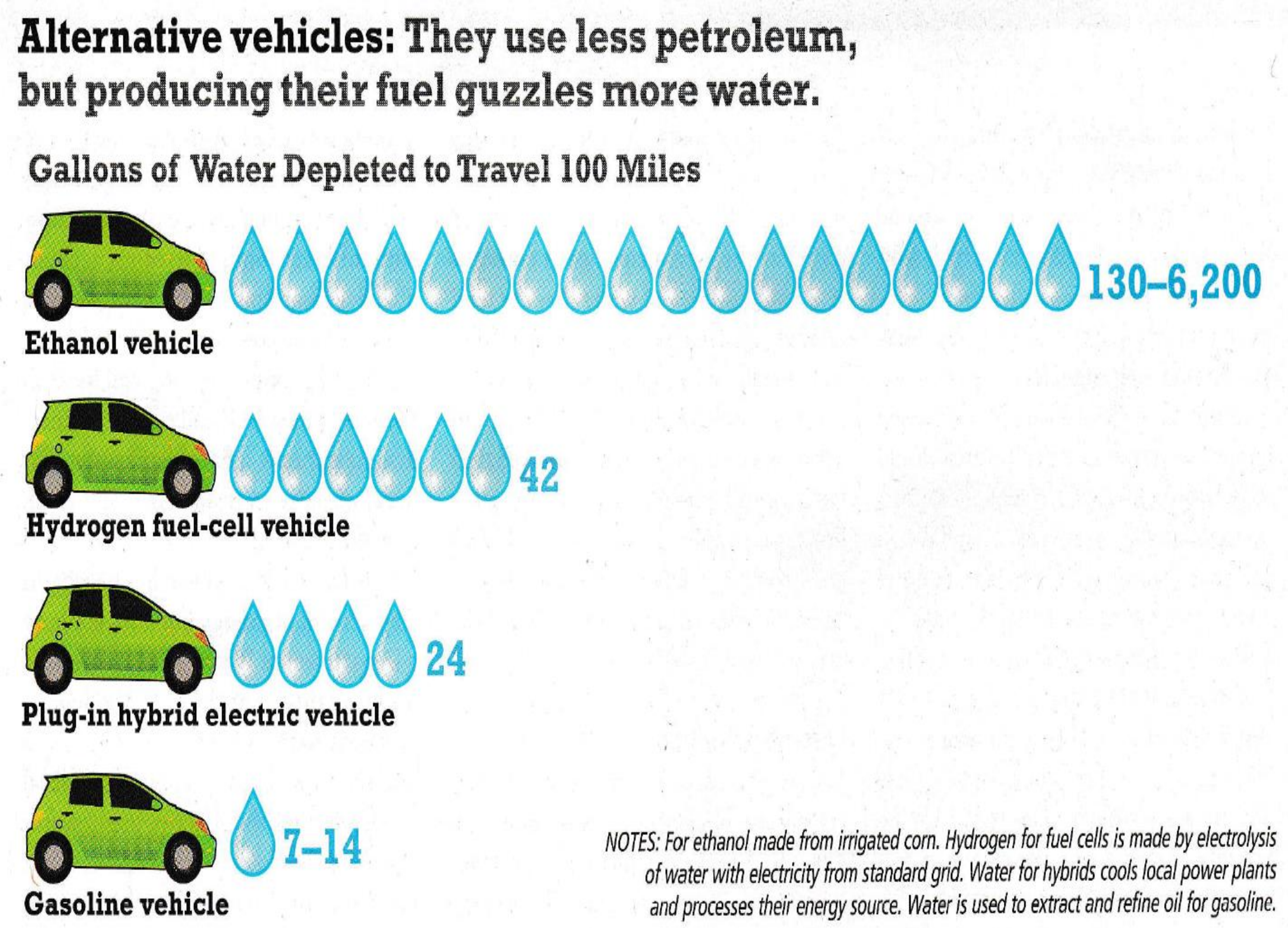
Water-Energy	Energy-Food	Food-Water	Water-Food-Energy
• 80% of renewable energy comes from hydropower.	• Energy is used during every stage of agriculture: cultivation, harvest, storage and transport.	• Agriculture is the largest consumer of water in the MENA region. • Water constraints on agriculture may worsen with climate change.	• Energy is needed to pump irrigation water to cultivated land. • Water that is diverted for energy may no longer be available for use in agriculture.

Challenges of the WEF Nexus: Dilemmas





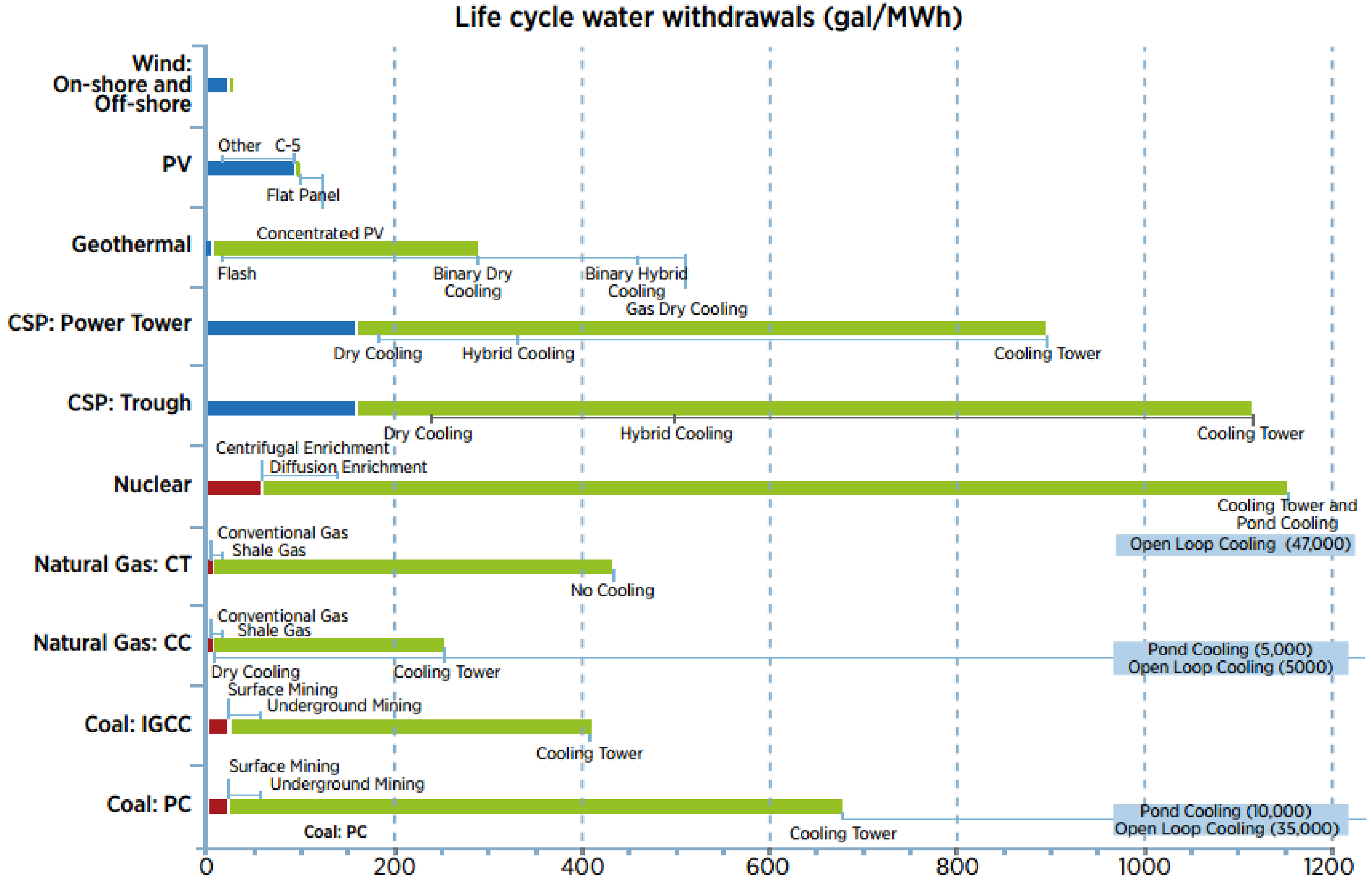
Challenges of the WEF Nexus: Dilemmas



RCREEE

Renewable energy in the water–energy nexus

Some renewable energy technologies (e.g. solar PV, wind) are significantly less water intensive than conventional



Source: IRENA, 2015
based on NREL data

What does the future hold.....?

WATER:

- Water deficit is projected to increase from 50 BCM per year today to 150- to 235 BCM per year by 2050, based on the level of water use efficiency and wastewater reuse adopted, 2/3 times the physical volume of the Nile River flow…***scary!***

ENERGY:

- Correspondingly, about 31 billion barrels of fuel is needed to desalinate about 150 BCM of water per year by 2050 (e.g., KSA today uses > 1.5 million bbls/day for desal)…***not sustainable***

Environmental impacts/GHG Emissions:

- Which corresponds to 9.6 GtC (gigatonnes of carbon) of CO_2 emissions per year by 2050….***not sustainable (global good)***

And food security…?

- 60 % of food from irrigated agr. (21 Mha, consuming 251BCM+)
- In some areas, fossil groundwater is being exploited for irrigation…***not sustainable***…rainfed plays a good role but threatened by Climate Change.

Rationale for action

- Water is scarce in the region, and getting scarcer with time…water will become a challenge to growth…***the trend is not sustainable***

- Desalination on a larger scale has environmental and energy implications (brine, GHG emissions, energy security)…***should be sustainable***.

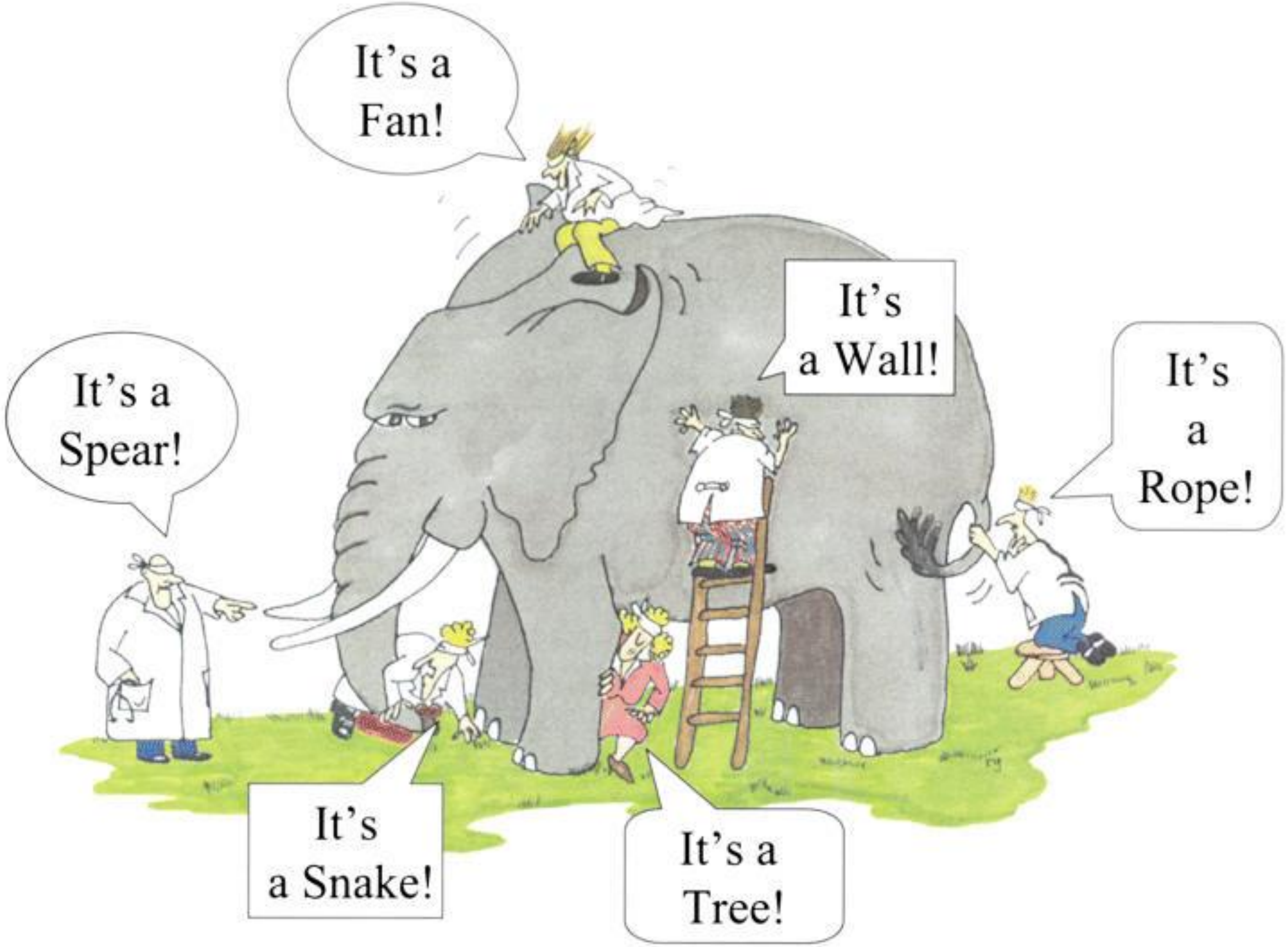
- Renewable energy (e.g., CSP) is possible, making it a feasible energy alternative…***MED is also suitable for CSP.***

- Countries in MENA are already leading the innovation and market demand for desal:
  - Some countries use desal water for 100% of their water need
  - MENA countries are on the cutting edge of innovation in the combined use of desal and RE

- The region would benefit from cultivating the desert for a growing population and economy, using the natural resources that are barely tapped: desert land, salty water and solar energy, in order to ensure **sustainable development**…***but action has to start soon and on large scale to benefit from economy of scale.***

Challenges of the nexus implementation (1/3)

Silo thinking: Silo (fragmented approaches) arise from inadequate management coordination among departments and ministries, and competition between urban and rural municipal governments.



RCREEE

Challenges of the nexus implementation (2/3)

Lack of Communication:

- The nexus requires that all sectors find a common platform to agree on what their national security goals are.

  - ✓ No National information systems or different institutions managing resources do not communicate with each other
  - ✓ Unclear or inexistent interface between science and policy making
  - ✓ Decision makers do not have appropriate tools to analyze trade-offs

Lack of data or harmonized data:

- ❖ Lack of coordination caused by poor or non-existing data regarding the availability, demand and regulations of primary resources.
- ❖ The absence of this information challenges the nexus implementation
- ❖ These cross-sectoral inefficiencies makes it hard for governments to respond appropriately to demands and stresses.

Challenges of the nexus implementation (3/3)

Technological challenges:

- Inefficient technologies and infrastructure in some cases.

Nowadays, the Mediterranean countries are on the top of innovation when it comes to desalination, wastewater treatment, solar and wind technologies. This will help promoting the nexus approach!

Science inputs into the nexus

Desalination plant

SCADA system

Solar desalination

Fibre glass pipes

Remote Sensing

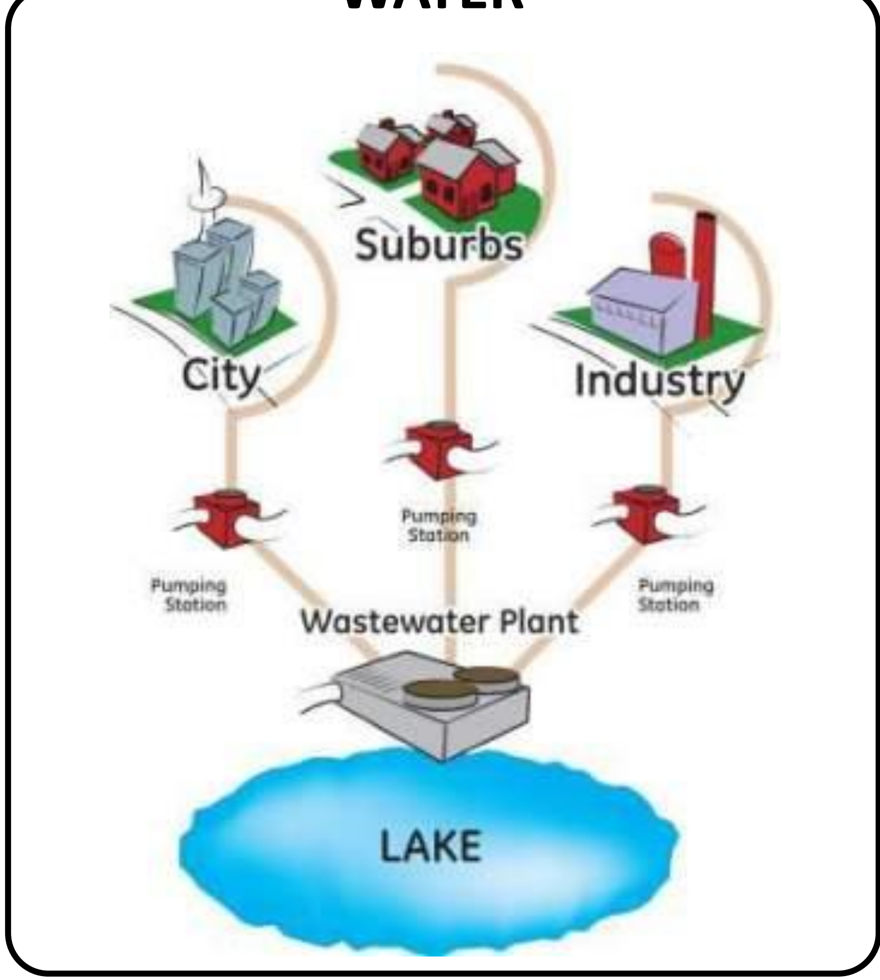
Wetlands

RCREEE

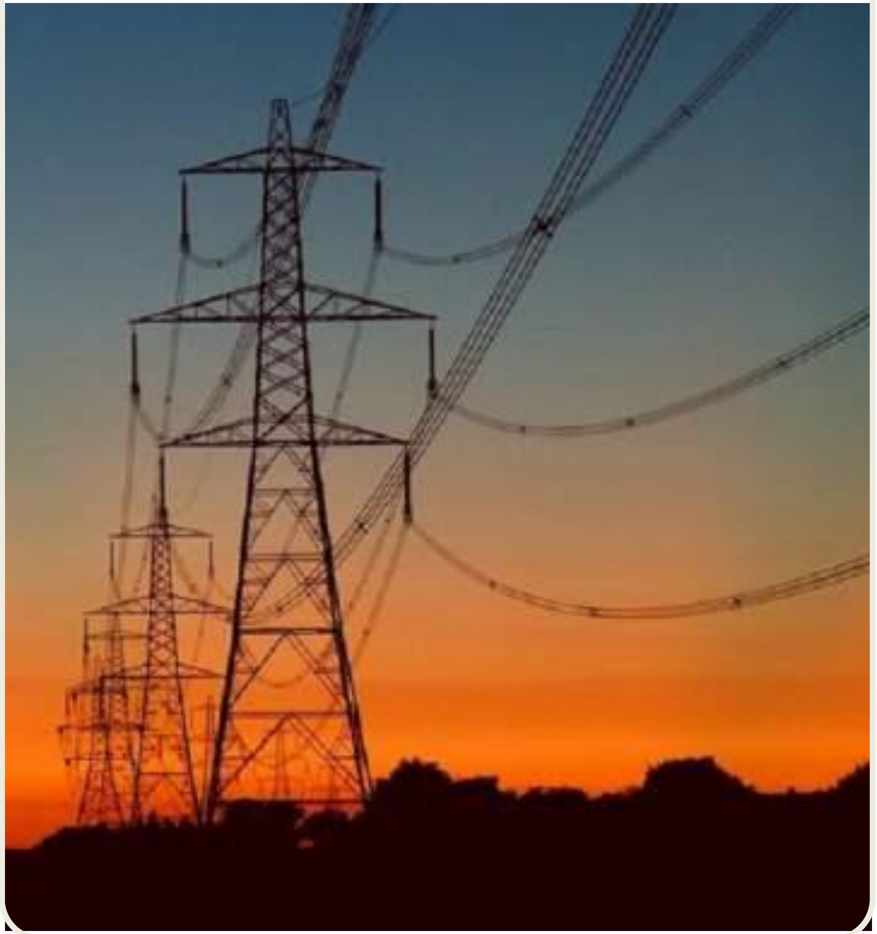
14

Nexus #1: 6-18% of a city's energy demand is used to produce, treat & transport water

WATER

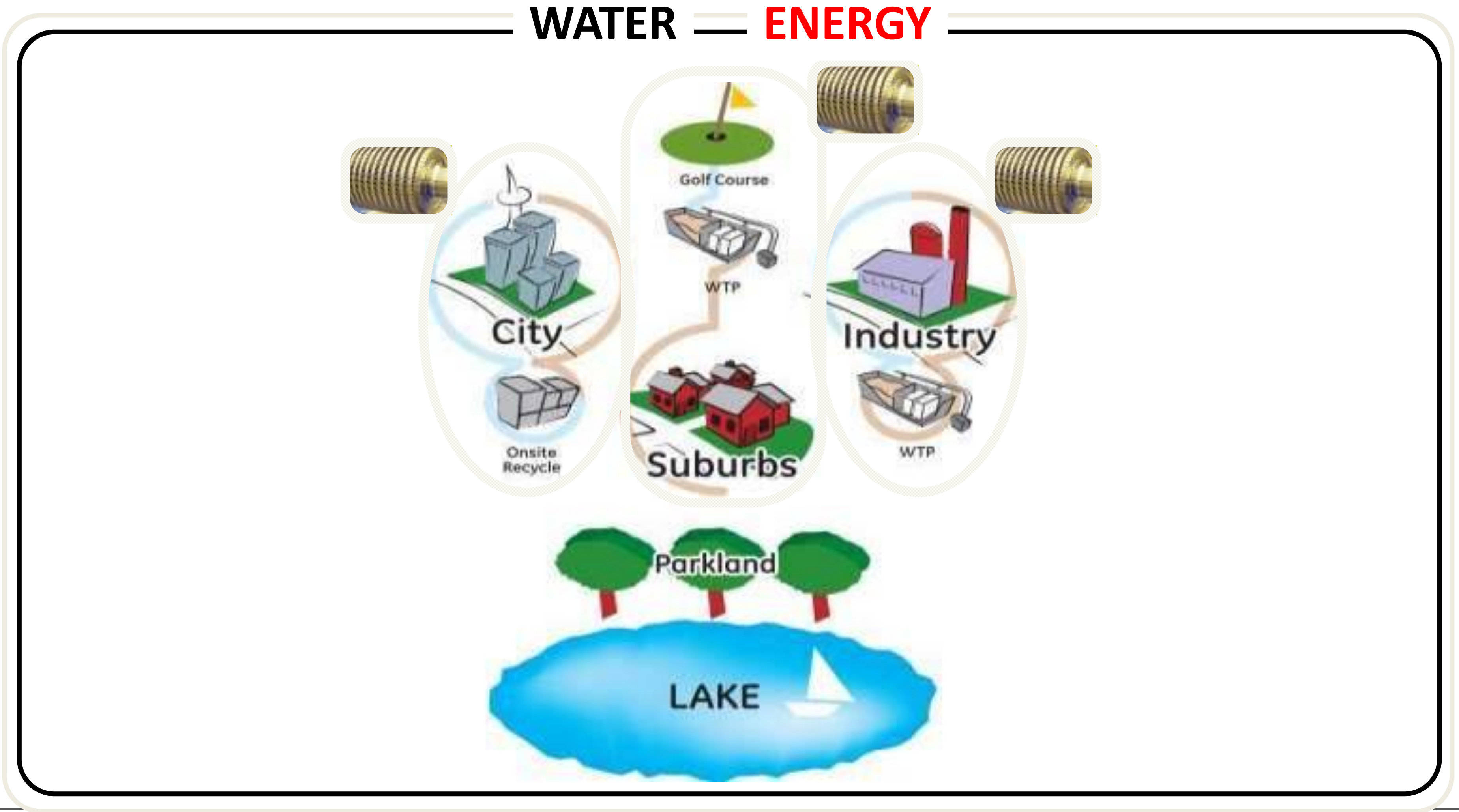


ENERGY



RCREEE

Solution #1: Distributed water & power… right mix, right place, right price

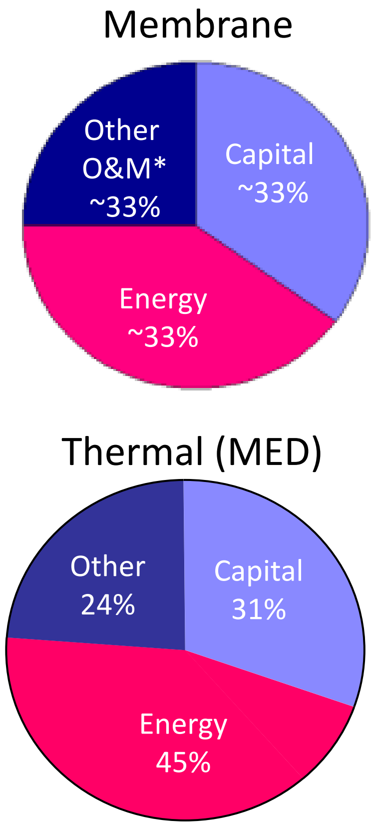


RCREEE

Nexus #2: Higher technology to treat impaired water requires higher energy demand

WATER

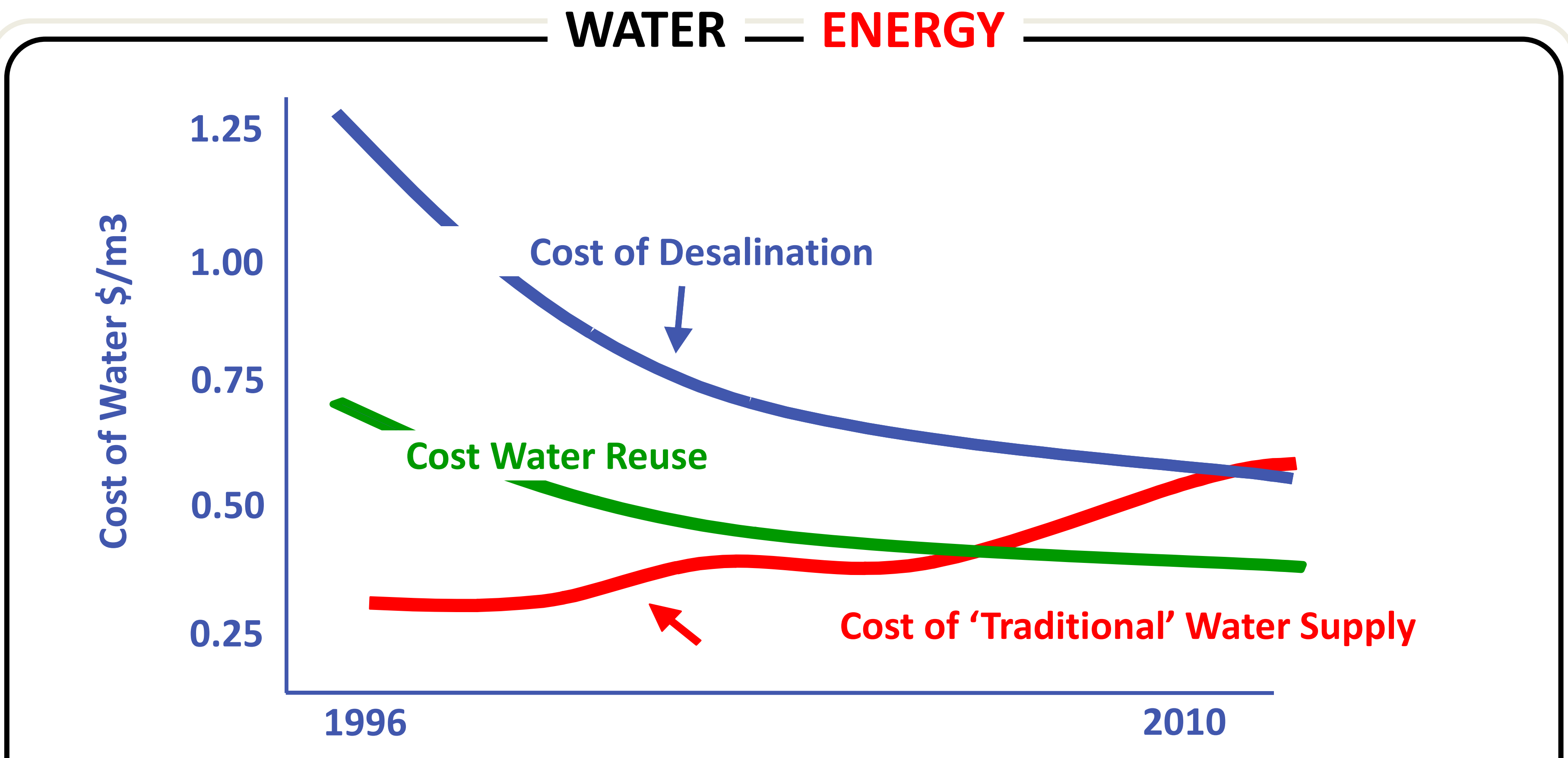
ENERGY



* Membrane replacement, Chemicals, Labor, Maintenance

RCREEE

Solution #2: Joint technology development driving energy and cost out



The cost of desalination with membranes has fallen by more than 80% in the last two decades

Source: GE

Nexus #3: Declining reservoir levels reduce hydro generating capacity

WATER

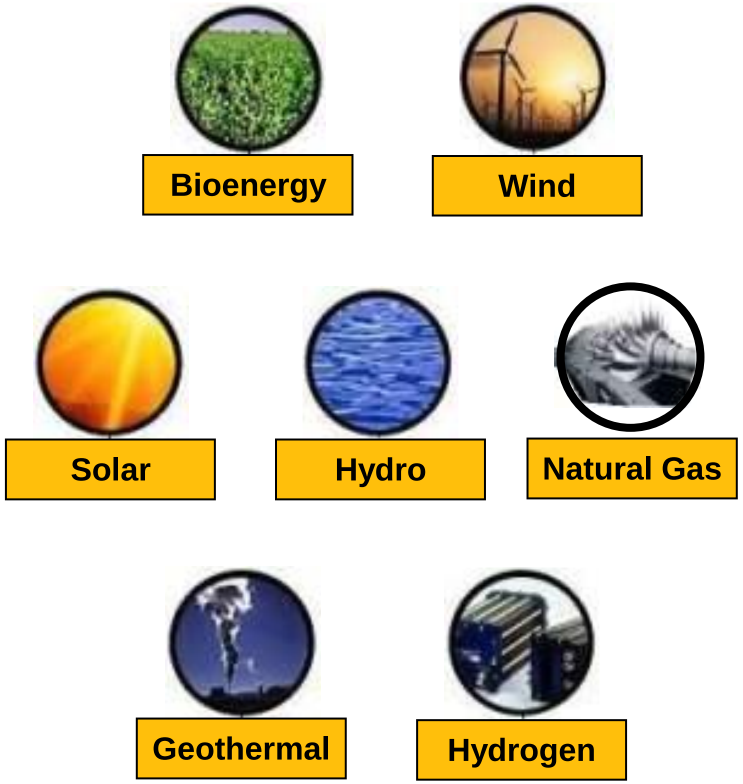
ENERGY

RCREEE

Solution #3: Reduce water consumption, replenish reservoirs, alternative energy sources

WATER — ENERGY

Cauley Creek water reuse facility (Georgia, US)…restoring lake levels by treating municipal wastewater



Nexus #4: Power generation requires large quantities of water

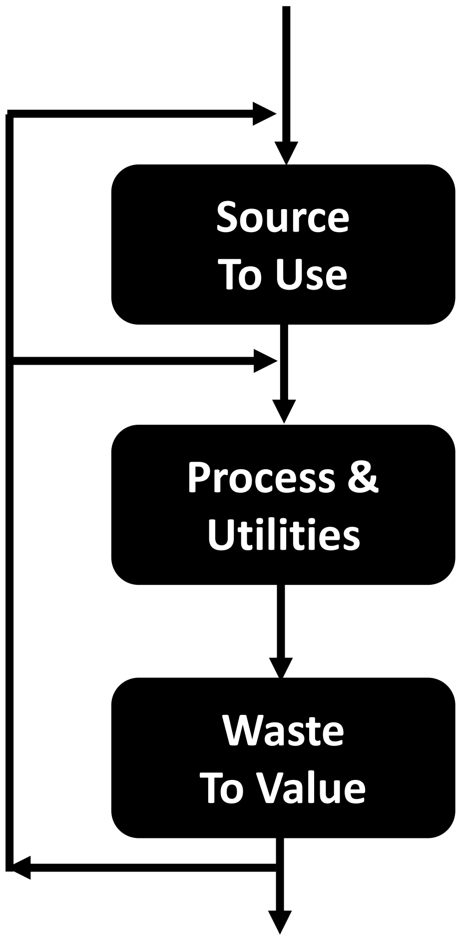
WATER

> 50% of global industrial water consumption is used to generate power

ENERGY

RCREEE

Solution #4: Reduce water consumption per MW produced



Align optimum water source with consumption need

Optimize water & energy consumption in boiler, cooling and fuel systems

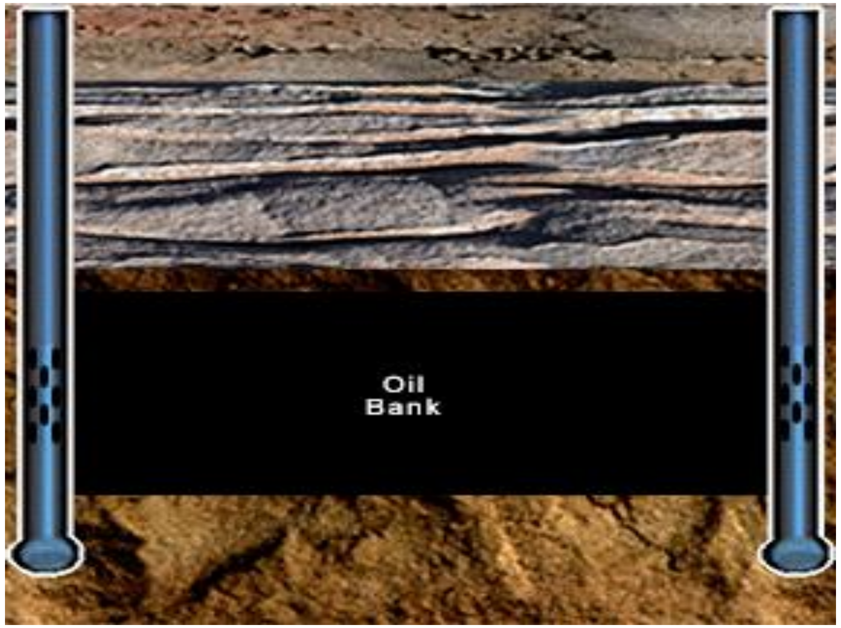
Convert waste streams into value & minimize risk

1) Baseline water & energy footprint
2) Identify efficiency opportunities
3) Prepare optimization plan & engage stakeholders
4) Execute & calibrate

RCREEE

Nexus #5: Energy exploration & production generates large quantities of wastewater

WATER



ENERGY

Solution #5: Advanced wastewater solutions reduce water losses and enable water reuse

WATER — ENERGY

RCREEE

Nexus: Evaluating and Assessing Trade-offs

1. Energy production

- Water use in all steps of the thermal energy value chain
- Water storage for hydropower
- Water for bio fuels

3. Industry & urbanization

- Domestic use
- Industrial use
- Waste water treatment
- Desalination
- Tourism

Tradeoffs

2. Primary production

- Agriculture
  (irrigation & rainfed)
- Forestry
- Fisheries

4. Environmental services

- Water quality management
- Biodiversity & conservation
- Flood & drought protection
- Navigation

SIWI, 2015

Nexus: Responses

Responding justly to WEFE challenges will require:

- Increased recognition of socially defined goals for water, energy, food and ecosystems outcomes
- An increased recognition of ecological rights
- Reduced use of markets as an allocation mechanism (**Market values** are not more important than **ecological values**) --- SDGs
- Increased use of reciprocity and redistributive policy to reach national and global ecological goals.

WEFE Nexus: What model to use?
From data to resources use efficiency

Understanding the Nexus

- Calculating basic data to demonstrate linkages and identify key problem, risks or opportunity areas

Governing the Nexus

- Guiding an institutional/governance or policy response

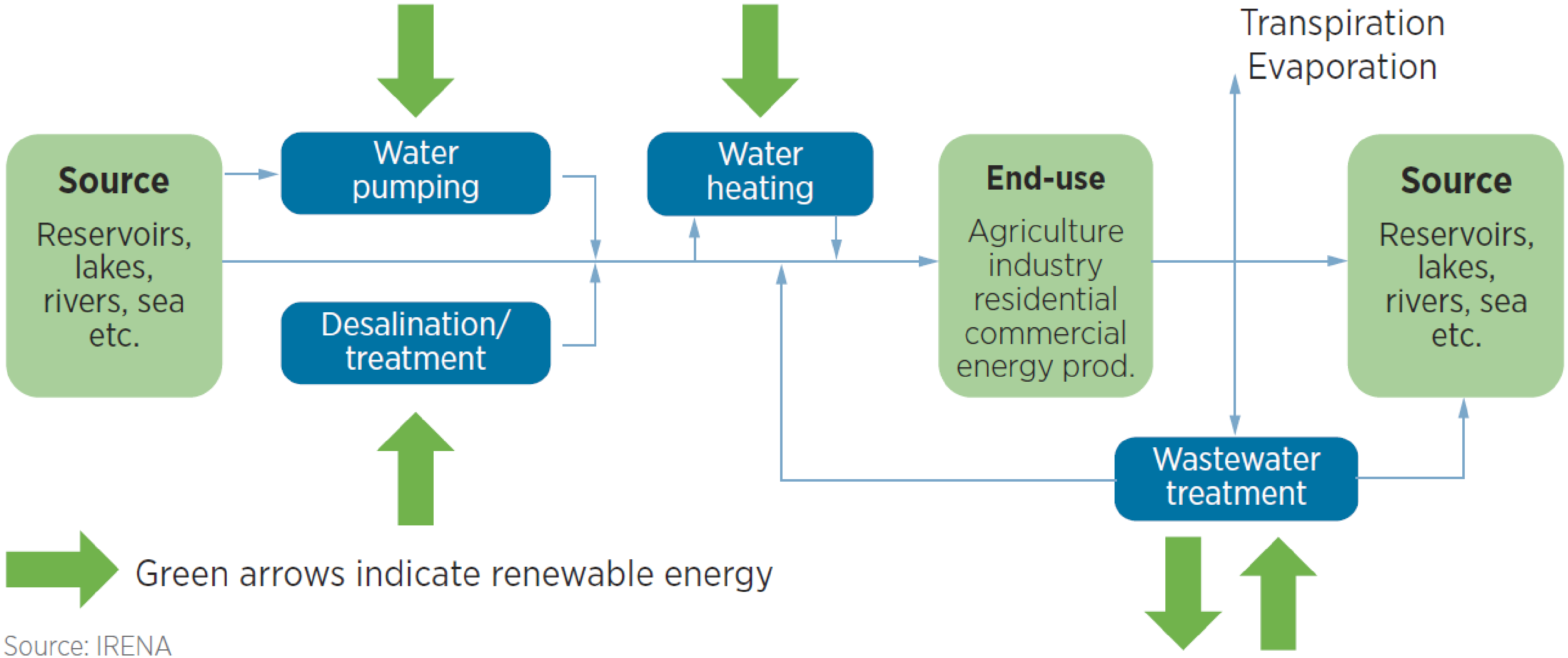
Implementing the Nexus

- Guiding a technical intervention to improve efficiency/ effectiveness of resource use

Innovation in Renewable energy technologies: Impact in the nexus

Renewable energy technologies can boost water security by improving accessibility, affordability and safety

- Renewable energy in the water supply chain



Source: IRENA

Source: IRENA (2015), *Renewable Energy in the Water, Energy & Food Nexus*

Primary production: Renewables-based water pumping

- Renewables represent a technically-proven and cost-effective option for water pumping, with benefits for both farmers as well as governments.

Farmers

- Reliable energy supply
- Improved crop yields and food security
- Increased incomes
- Climate resilience
- Additional benefits for health, education and poverty alleviation

Local and national

- Reduction in electricity and fuel use
- Subsidy savings
- Reduced fuel imports
- Improved reliability of power system
- Increased agriculture economic output
- Emissions reduction

- Distributed solar solutions can reach different types of farmers (small-holder, commercial, subsistence) through diverse business and financing models. **BUT in some cases it led to overexploitation of aquifers!!**

Renewable energy in the energy-food nexus

Renewable energy opportunities in the food supply chain

Energy inputs (traction, electricity, mechanical, heat/cooling)

Primary Production	Post-Harvest and Storage	Transport and Distribution	Processing	Retail, Preparation and Cooking
• Solar, wind-based water pumping • Biofuels for tractors and on-farm machinery • Solar-based desalination, heating and cooling for protected cropping • Biomass residues use for on-site energy generation • Indirect renewable energy inputs for fertilisers	• Solar, geothermal food drying • Solar cooling and refrigeration	• Biofuel use for transportation and distribution • Solar cooling and refrigeration	• Solar, wind, hydro-based milling, threshing • Renewable energy-based electricity and heat applications	• Renewable energy-based water purification • Modern biomass use for cooking applications

Source: Based on FAO, 2011b; Practical Action, 2012

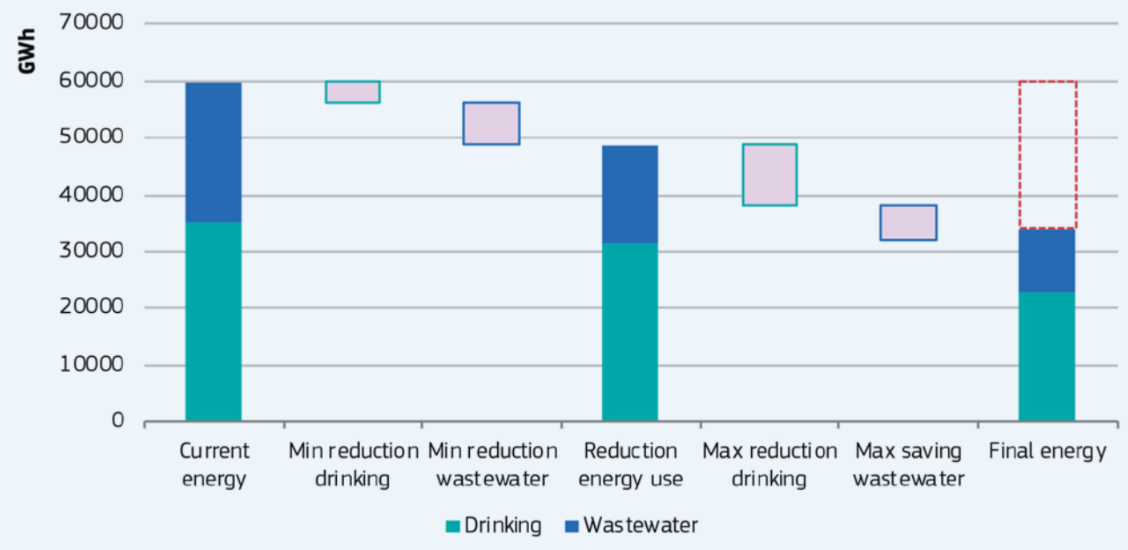
Source: IRENA (2015) based on FAO (2011) and Practical Action (2012)

Energy-saving potential for drinking water supply

Domain	Volume (billion m³)	Energy (GWh)	Energy (share)	Share of EU electricity
Drinking water supply	49.5	35 000	43.5 %	1.13 %
Desalination for municipal use	2.1	20 695	25.7 %	0.67 %
Wastewater treatment	47.9	24 747	30.8 %	0.80 %
Total	99.5	80 442	100 %	2.60 %

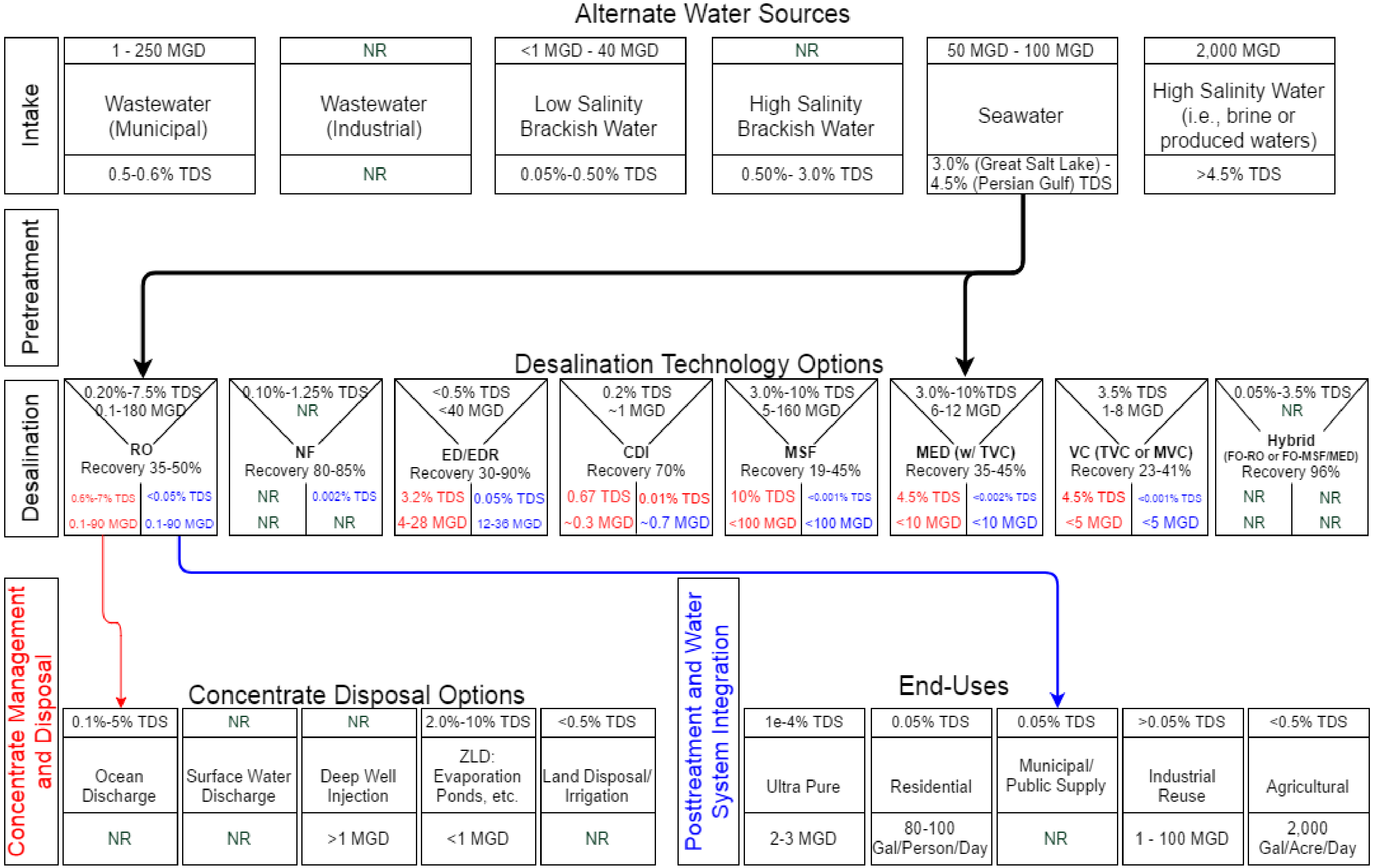
Breakdown of volume treated and energy requirements for each stage of the water sector in 2017. (Source: water volumes: [Eurostat 2018], [GWI 2018], analysis: JRC)

Potential energy saving in water supply and wastewater treatment achievable through energy efficiency and operational measures (JRC)



New Tool - Energy Bandwidth Study

2017 DOE/LBNL/Energetics



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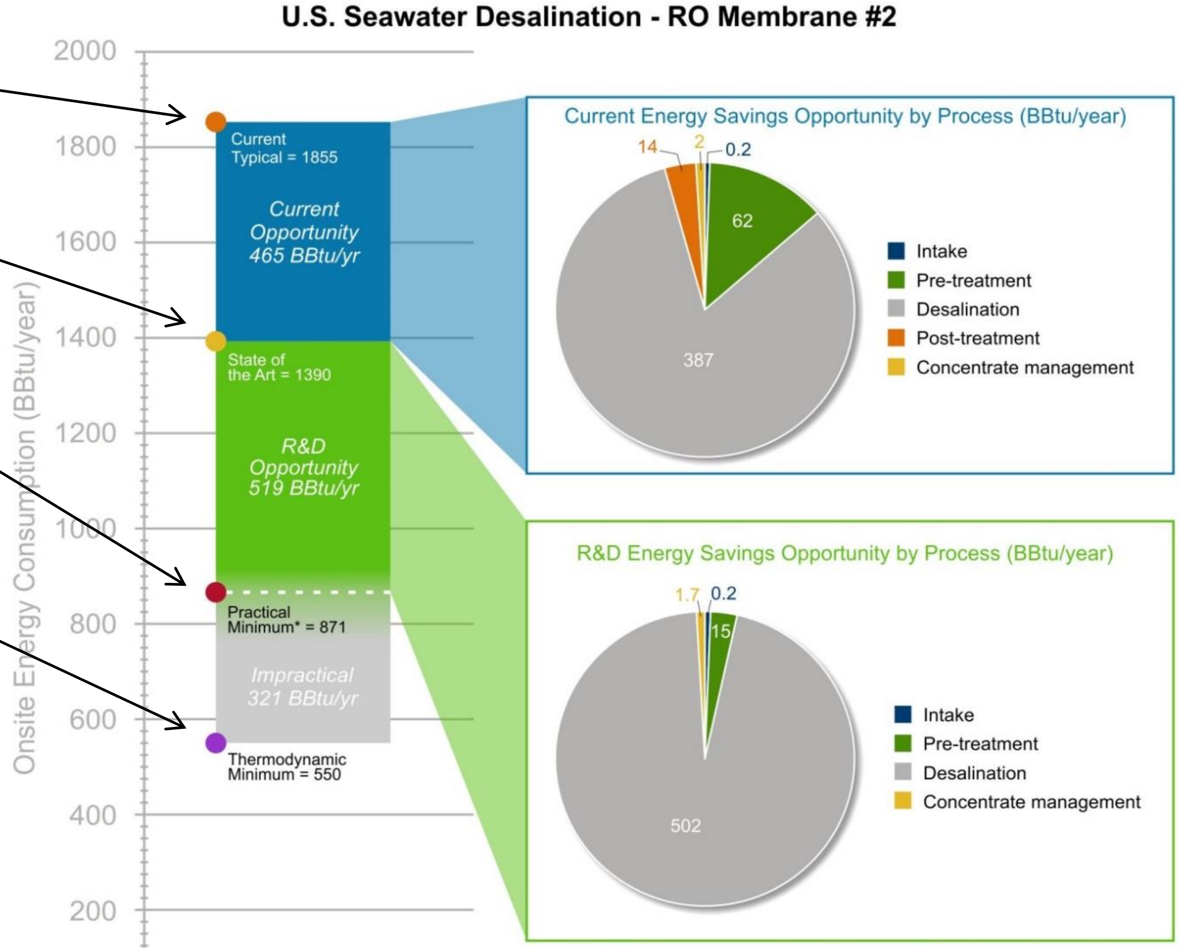
New Tool - Energy Bandwidth Study

CT - 3.3 kWh/m^3

SOA – 2.7 kWh/m^3

PM – 1.5 kWh/m^3

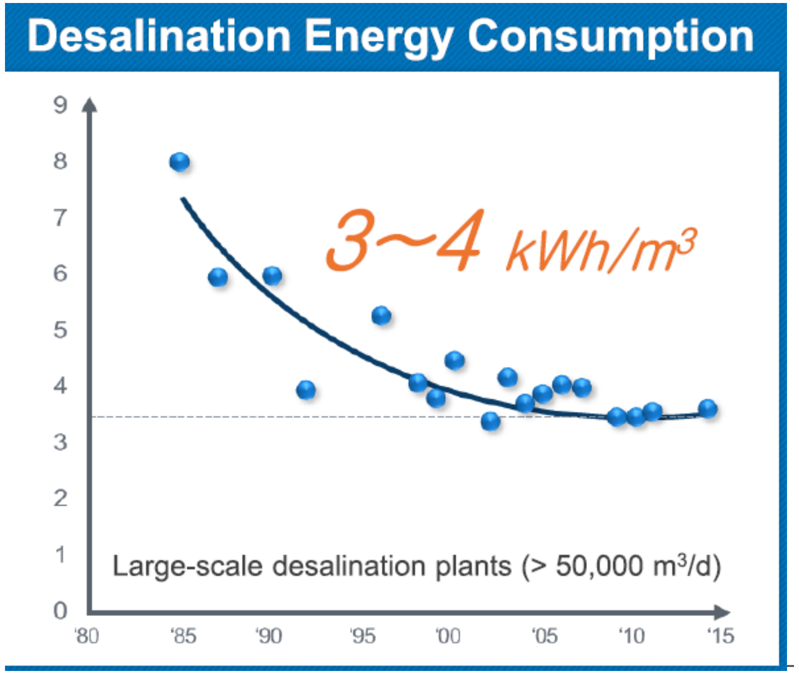
TM – 1.05 kWh/m^3

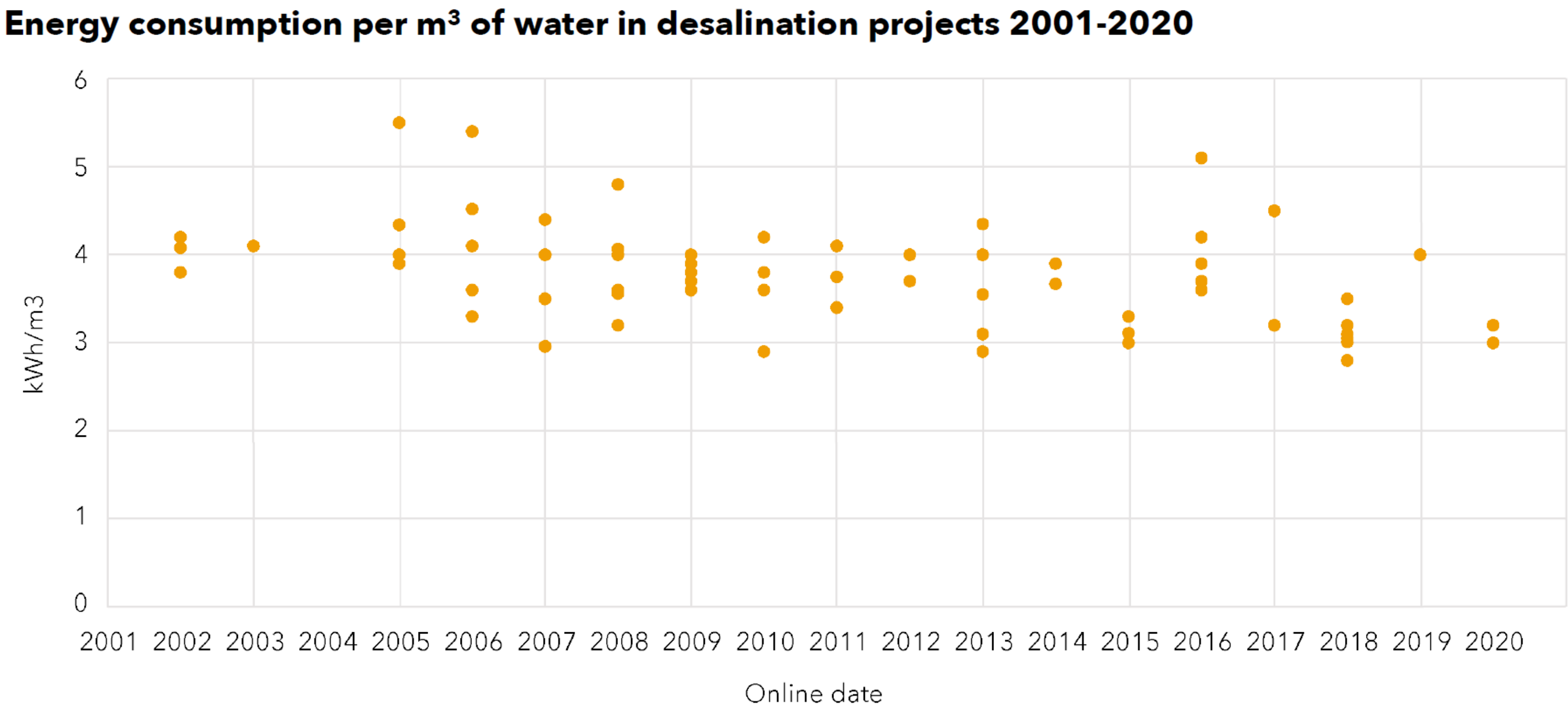


CT, SOA, TM operating conditions: RO-based system at 50% recovery of 500 ppm (0 ppm for TM) product water from 35,000 ppm feedwater. PM operating conditions: semi-batch RO-based system at 42% recovery of 379 ppm product water from 36,357 ppm feedwater.

Energy demand for desalination RO technology

- Current state-of-the-art RO plants for desalinating seawater may consume approximately **3.5 kWhe/m3** when all unit operations of the overall system are considered.
- Currently the most efficient seawater desalination plants consume around 2.9 kWh/m3. In addition to the reverse osmosis process, energy is used elsewhere in desalination plants in intakes, pretreatment and dispatch.





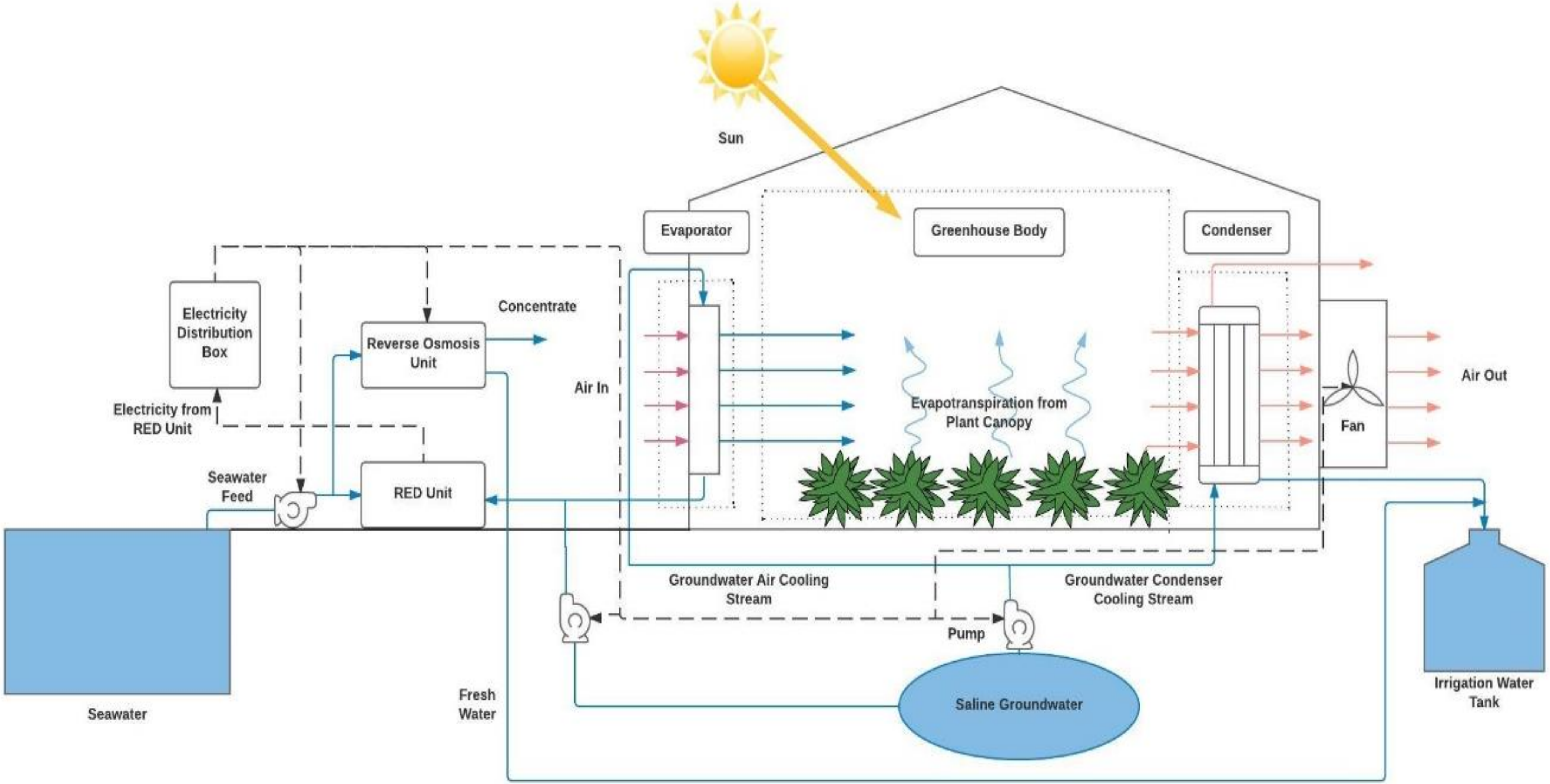
Source: GWI, 2020

Innovation/Scientific Deficit?

- Without water stress/food shortage/energy shortage, institutions and technologies evolve slowly
- In the absence of regulatory pressure and public funding, change is slow
- Disruption by new technologies is slow due to large sunk costs in existing systems

(The Innovation Deficit in Urban Water. Michael Kiparsky, et. al., 2013)

WEFE nexus project pilot: PV-RO to produce food



Source: MASDAR

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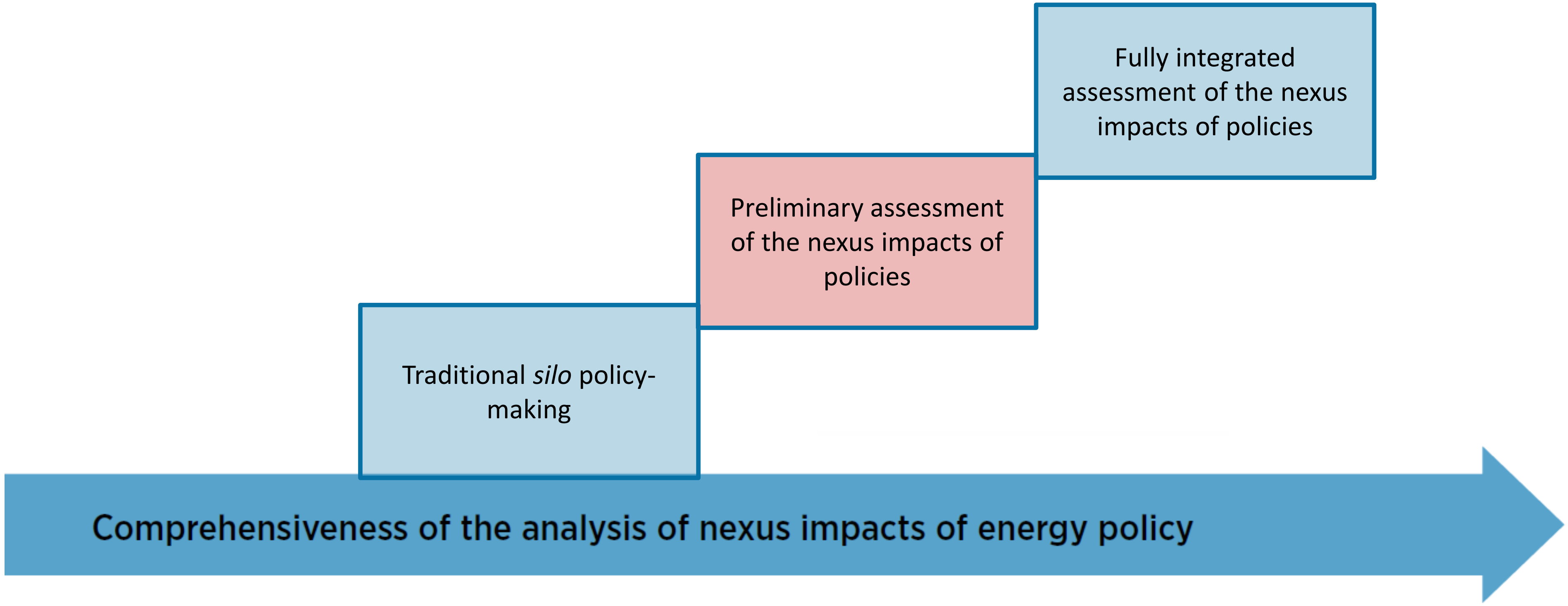
Decision-making tools with a nexus perspective

- No doubt that tools can help in achieving a more integrated decision-making
- Available tools vary in terms in comprehensiveness, inputs and outputs
- Need to adequately consider decision making timeframes
- Preliminary assessment tools can be useful as a first step



Nexus implementation: Key considerations

- What is the starting point for nexus?
  - Energy-system level analysis on water and food is necessary, but with practical outputs that can inform decision making
  - Integrate water/land constraints into existing energy models
  - Breaking down ministerial barriers to truly tap into the “win-win” opportunities

- Data, data and data.
  - Clarity on technologies and costs (e.g. renewable-based desalination)
  - Limitations for analysis and tools: data (availability, accessibility, comparability, scale, time series) and resources (human, time, financial)

- Impacts may be more local than energy sector decision-making (e.g. water for agriculture)

Nexus implementation: From Science to Policy

1. Scientists and academicians need **to communicate with the decision makers**, and the **decision makers need to include scientists** and create dialogue
2. Decision makers like numbers $$$, therefore scientists need **to be quantitative and provide clear indicators in the policy making process**
3. Both stakeholders need to be evidence based and create synergies for **data generation and sharing**
4. **Build on current structures and scenarios** rather than have a substitution approach
5. Governance solutions must be country-specific and only be identified through collaborative partnerships
6. **PPP financial mechanism** demonstrated to be successful in the region in financing nexus projects (e.g. Khirbet As Samra WWTP, Agadir desal plant, etc)
7. **Capacity building** is important: in developing dialogue platforms, promoting technological innovation, data production and sharing, finding financial sources for nexus implementation

Nexus implementation: Multi-pronged approach is a must

1. Demand side management:

a) Strengthen institutions to support a move towards more efficient resource use
b) Support policies that rationalize demand for water and energy services
c) Support investments in efficiency improvement

2. Supply side management:

a) Introduce/scale-up technologies (e.g. desalination and reuse)
b) Support innovations in renewable energy (e.g. Green H2)
c) Support innovations in concentrate management
d) Support water quality protection and storage capacity, including aquifer recharge…

Nexus implementation: Remarks

- A nexus approach integrates management and governance across sectors and scales
- A nexus approach can support the transition to Green Economy, which aims, among other things, at resource use efficiency and greater policy coherence
- Innovative and affordable local actions contribute to improved social, economic and environmental benefits
- Integrating desalination with renewable power is a unique opportunity to advance the implementation and uses of renewable energies,
- There are some good examples on the adoption of innovative solutions within the nexus in many MEDITERRANEAN countries. These include: Sahara Wind Power Project in Morocco; renewable energy for wastewater treatment and reclaimed water use in agriculture in Jordan; Solar desalination in Morocco and Tunisia; landfill-gas-to-energy project and aquaponics-energy production in Lebanon.
- These case studies demonstrate the potential and benefits to be unlocked if technology and innovation are fully harnessed within the WEF nexus.

Science to Policy process

- The current nexus projects in the region (REGEND, MINARET, Hydrousa, PRIMA funded projects, etc.) provide evidence for the viability for scaling and replicating pilot projects on the WEFE nexus in the MEDITERRANEAN region.
- These projects should contribute to inform and reform public policy in terms of economic incentives, scale of investment in the nexus, and new knowledge for sustainability. Besides, these projects provide evidence for the significance of science-policy interface.
- The Nexus will facilitate a better integration of scientific data and policy considerations!
- Political commitment and scientific backing are key!

Recommendations

- **Encourage collaborative and focused applied R&D on the nexus by forming regional research teams and alliances to promote innovation and technology transfer;**
- **Scale up, replicate and fund on-going projects related to the nexus including integrated seawater energy and agricultural system, renewable energy for wastewater treatment and reuse, and solar desalination;**
- **Support and provide incentives for strategic partnerships and cooperation between research centres and the private sector; and**
- **Build capacity for policy makers and institutionalize regional knowledge management systems to share best practices on the WEF nexus.**
- **The Nexus is not a mystery and not a solution**: Improved coordination across sectors is part of the equation, but action lies in **detailed intelligence to support decision-making**

Thank You

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