Understanding the opportunities and challenges of the WEFE Nexus

Session 1 of the PRIMA Online training: „Addressing the Water-Energy-Food-Ecosystems (WEFE) Nexus in the context of Climate change in the Mediterranean region”

Annika Kramer, Dr Sabine Blumstein
We want to get to know you and your background!

1. From which country are you joining this online training today?
2. In which of the Nexus sectors lies your main professional expertise?
3. Have you previously participated in a WEF Nexus training?
4. What are your expectation on the training? What would you like to learn about?
Outline

Chapter 1: Background to the Water-Energy-Food (WEF) Nexus
  ▪ Introduction to the WEF Nexus

Chapter 2: Water-Energy-Food Interactions
  ▪ Concepts of water, energy and food security and trade-offs
  ▪ WEF Nexus Solutions

Chapter 3: Assessment
  ▪ Assessment tools for Decision Support
Water, Energy and Food Security: pillars of development!

- Water, Energy and Food Security are at the heart of human survival/wellbeing and economic development.
- Therefore, communities strive to achieve water, energy, and food security.
- Actions to achieve this may take place at local, national and global level.
- Achieving each of these securities requires resources and has external effects.
Achieving WEF development goals in a dynamic world

Present
Unmet demands!
- 2.0 billion people have no access to safely managed drinking water (2020)
- 0.8 billion people have no access to electricity (2021)
- 2.4 billion people are food insecure (2020)

Future
Increasing demands!
- Due to population growth, economic development and changing consumption patterns
- The uncertainties of global change exacerbate the difficulty in achieving these goals

Figure: Food-insecure people by region, 2020 and 2050 projections
Source: IEP, 2021
Single-mindedly pursuing individual goals may interfere with other goals

Example: Increasing electricity production
- More abstraction of water for cooling
- Less water for other sectors and the environment
- Less water security

Example: Intensifying agricultural production
- More land used for growing food
- Competition over land resources (e.g. biofuels vs. crops as food)
- More use of fertilisers
- Contamination of water resources
- Less water security downstream

→ Need for a systematic WEF Nexus approach!

U.S. Department of Energy, 2006
LaB, 2010
Time for a quick quiz game!
How closely are the WEF sectors interrelated globally?

1. How much water does agriculture withdraw (as a % of total global freshwater withdrawals)?
2. How much water does the energy sector withdraw (as a % of total global freshwater withdrawals)?
3. How much energy do agriculture & food chain account for (as a % of global energy demand)?
The WEF sectors are closely related

Examples of interconnections:

- Agriculture accounts for 70% of total global freshwater withdrawals
- The energy sector accounts for about 10% to 15% of the global freshwater withdrawal
- Agriculture & food chain account for 33% of global energy demand

GWP, 2019
WEF Nexus from the ecosystem perspective

- Ecosystems take a central role in this WEF Nexus concept
- But there are numerous other frameworks (check out resources at: https://www.water-energy-food.org/)
What is the WEF Nexus approach?

"The WEF Nexus provides a holistic and integrated approach in order to secure access to water, energy and food in the long term."

– Global Nexus Secretariat, 2020
What is the WEF Nexus approach?

Key components

A framework to determine trade-offs and synergies

Promotion of policy coherence and multi-sectoral cooperation

A tool to achieve sustainable development
<table>
<thead>
<tr>
<th>Benefits of Nexus approach</th>
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<tbody>
<tr>
<td><strong>Reducing sectoral trade-offs</strong></td>
</tr>
<tr>
<td>Avoid or limit negative externalities</td>
</tr>
<tr>
<td><strong>Enhancing resource efficiency</strong></td>
</tr>
<tr>
<td>Solutions designed to address multiple challenges simultaneously</td>
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<tr>
<td><strong>Political benefits</strong></td>
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<tr>
<td>Increased political legitimacy, political stability</td>
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<tr>
<td><strong>Leverage synergies towards overarching development goals</strong></td>
</tr>
</tbody>
</table>
Synergies

Wastewater for energy and food production in Jordan

As-Samra wastewater treatment plant

- Treats 365,000 m³ of wastewater/day
- Effluent is used for agricultural irrigation
- 80% of energy used is produced by plant itself (biogas and hydraulic energy)

Source: Consolidated Contractors Company
Synergies

Agrivoltaics in Mali and Gambia: sustainable electricity by integrated WEF systems

Integrated triple land-use system
- Includes food production, energy generation and water harvesting
- Using the synergies to:
  - increase the land use efficiency
  - enhance agricultural conditions
  - decrease water requirements

Figure: Schematic diagram of a triple land use through agrivoltaics

© Fraunhofer ISE
Synergies

Manantali multi-purpose dam – Mali, Senegal, Mauretania

- Manantali is jointly owned and operated by three countries
- 200 MW power plant generates electricity for Senegal, Mali and Mauretania
- Reservoir provides water for irrigation of 130,000 ha of agricultural land
- Water regulation component for navigation (not realized)

Source: Benoît Rivard/Flickr CC BY-NC-ND 2.0
The Sustainable Development Goals

1. No Poverty
2. Zero Hunger
3. Good Health and Well-being
4. Quality Education
5. Gender Equality
6. Clean Water and Sanitation
7. Affordable and Clean Energy
8. Decent Work and Economic Growth
9. Industry, Innovation and Infrastructure
10. Reduced Inequalities
11. Sustainable Cities and Communities
12. Responsible Consumption and Production
13. Climate Action
14. Life Below Water
15. Life on Land
16. Peace, Justice and Strong Institutions
17. Partnerships for the Goals

UN, 2015
Understanding the links between SDGs

SEI, 2017
Nexus interlinkages with other concepts and resulting global policy processes

- Disaster risk reduction: Sendai Framework
- Climate Change: Paris Agreement and resulting Nationally Determined Contributions (NDCs)
- Circular Economy

Figure: Application of the integrated circular economy-nexus approach to food-energy-water resources

Source: Parsa et al., 2021
Governance Challenges of Nexus Implementation

- Government structures organized in silos, lack of coordination (horizontally and vertically)
- Lack of up-to-date data on status of WEF sectors that can be used for decision-making
- Deficiencies in knowledge about complex Nexus interlinkages
- Lack of transdisciplinary science
- Lack of (knowledge of) applicable assessment tools such as modelling tools, scenario-development, participatory processes etc.
Possible measures for Nexus implementation

- Introduce legislation and norms that stipulate a Nexus approach
- Coordinated institutions (ministries, agencies, etc.)
- Build joint committees and informal working groups
- Engage other institutions with cross-sectoral competence
- Cross-sectoral knowledge base for policy-making
- Strengthen interfaces within a given institution
The Water-Energy-Food security Nexus is a concept and approach which looks at interconnections which are usually overlooked, yet are very important.

The WEF Nexus concept is about harnessing synergies and addressing trade-offs.

The next section will focus in more detail on the interactions between water, energy and food sectors.
Q & A on Introduction to the WEF Nexus

Any questions on Chapter 1?
Thank you for your time!

Break: see you again in 10 Minutes!

17 December
2021
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# Outline

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</table>
Concepts of water, energy and food security and trade-offs

Chapter 2: Water-Energy-Food Interactions
Overview: Water, Energy and Food Security

Water security:
- 2.0 billion people lack safely managed drinking water services (2020)
- Global water demand could exceed total water supply by 40% in 2030 (based on 2015 levels)

Energy security:
- 0.8 billion people are without access to electricity (2021)
- Total primary energy demand is projected to increase by 9% in 2030 (based on 2020 levels)

Food security:
- 2.4 billion people are food insecure from which 930 million face a severe form (2020)
- Food demand is expected to increase by 50% in 2050 (based on 2020 levels)
Water for Food

Global water demand by sector between 2014 and 2040

Agricultural water withdrawals by region, 2010

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<thead>
<tr>
<th>Region</th>
<th>Agricultural water withdrawal as % of total water withdrawal</th>
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<td>World</td>
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Source: IEA, 2016

Agricultural water withdrawals by region, 2010

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Source: own illustration based on UN, 2021
Local water uses versus global trade of agricultural products

Source: Hoekstra & Mekonnen, 2012
Increasing food production: Main trade-offs

- Increasing food production
- Growing land use
  - Less land for energy (biomass, solar, wind,)
- Removal of woods
- Increase in water abstraction
  - Decrease of water available for WASH, energy production, environment
Time for a quick quiz game!
How much water is needed in the energy sector?

1. We have seen previously that 90% of energy produced today is water-intensive, meaning that nearly all forms of energy rely on water.
   ▪ Which part of the energy sector accounts for the largest amount of water withdrawals?
Water for Energy

Water withdrawals and consumption in the energy sector, 2014

Total water withdrawals: 398 bcm

- Power: renewables 2%
- Power: nuclear 28%
- Power: fossil fuels 58%
- Primary energy production 12%
- Coal 3%
- Oil 2%
- Biofuels 7%

Natural gas <1%

Primary energy production: biofuels 25%
Primary energy production: oil 13%
Primary energy production: coal 22%
Primary energy production: natural gas 3%

Total water consumption: 48 bcm

Power: fossil fuels 28%
Power: nuclear 8%
Power: renewables 1%

Source: IEA, 2016
Source: own illustration based on IEA, 2016
## Water for Energy

### Energy-related water consumption

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<th>Region</th>
<th>Consumption (bcm)</th>
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<tr>
<td>World</td>
<td><strong>48</strong></td>
<td><strong>59</strong></td>
<td><strong>76</strong></td>
</tr>
</tbody>
</table>

Source: own illustration based on IEA, 2016
Potential trade-offs with climate policies

Political aim to decrease CO2 emissions

More Hydropower

Evaporation

Water is not released at times when it is needed

Changes in ecosystem functioning

Less Water for agriculture

Climate change/global warming

Impacts on livelihoods (fisheries, tourism)
Time for a quick quiz game!
How much energy is used in the water sector?

1. What share of the global electricity is consumed in the water sector (in %)?
2. Which part of the water sector uses most electricity?
3. Which part of the water sector is projected to use most electricity 20 years from now?
Energy for Water

Electricity consumption in the water sector by process and region, 2014

Source: IEA, 2016
Energy for Water

Electricity consumption in the water sector by process, 2014 - 2040

Source: IEA, 2016
Time for a quick quiz game!
How is energy used in agri-food systems?

1. We have previously seen that agri-food systems account for 33% of global energy demand. Which segment of the agri-food chain needs the most energy (globally)?
Energy for Food

Share of total energy consumption globally and in high- and low-income countries, by segment of agri-food chain

Source: FAO, 2011
Energy for Food
Energy consumption in agri-food systems by region, 2000-2018

Source: FAOSTAT, 2021
Agriculture for Energy

Sources of biomass supply of primary energy worldwide in 2018, by region (in exajoules)

Land demand projected for future transport biofuel production, 2010 - 2050

Source: IEA, 2011

Source: Statista, 2021 based on WBA, 2020
Discussion on WEF Interconnections

1. Any questions so far? (use chat function)
2. Which further trade-offs within the WEF Nexus or beyond are you aware of, from your own professional context or from your country/region? (mentimeter)
WEF Nexus Solution Categories

Technical and Engineering
- Multi-purpose infrastructure
- Integrated waste(water) management

Nature-based Solutions
- Constructed wetlands
- Catchment management

Governance

Policy & financial frameworks
- Regulatory instruments (impact assessments, wastewater standards)
- Financial instruments (taxes, subsidies)

Planning Procedures
- Integrated infrastructure planning
- Policy coordination
- Strategic policy planning
Nature-based Solutions

Nature-based Solutions (NbS) are actions to:

- Protect, sustainably manage and restore ecosystems
- Address societal challenges
- Provide human well-being and biodiversity benefits

The umbrella term of NbS encompasses different approaches, e.g. Ecosystem-based Adaptation (EbA).

Source: IUCN 2016
NbS Example – constructed wetlands

- Wastewater treatment by passage of water through man-made wetlands
- Nutrients remain in the effluent – beneficial use of reclaimed water in agriculture for food production
- Biomass grown in wetlands can be harvested as biofuel, e.g. biogas for cooking – reducing GHG emissions

The potential for constructed wetlands to influence WEF interactions at village and municipal scale

Source: Avellan et al., 2017
NbS Example – catchment management

Tana River Basin in Kenya
- provides 95% of the drinking water for Nairobi
- generates 70% of the country’s hydropower
- irrigates about 645 km² of farmland

Siltation issues caused by erosion impacts hydropower and drinking water supply

Upper Tana-Nairobi Water Fund: funding for sustainable land management in the catchment (terracing, reforestation, farm management) with benefits for agricultural production, energy and water supply

Increased carbon storage and climate resilience

Source: Nick Hall in Abell et al., 2017
# Governance Solutions

## Policy and financial frameworks

<table>
<thead>
<tr>
<th>Type/ Example</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regulatory instruments</td>
<td><strong>Impact assessments</strong>&lt;br&gt;Systematize environmental and social impact assessment across WEF-sectors for all new infrastructure</td>
</tr>
<tr>
<td></td>
<td><strong>Wastewater treatment and reuse standards</strong>&lt;br&gt;Specify regulations for wastewater treatment and reuse (e.g. in agriculture or urban use)</td>
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<tr>
<td>Financial instruments</td>
<td><strong>Water user charges</strong>&lt;br&gt;Levied by public authorities for services provided for water supply and treatment to incentivize efficient water use for food and energy production</td>
</tr>
<tr>
<td></td>
<td><strong>Subsidies</strong>&lt;br&gt;Linking subsidies to the efficient use of resources (e.g. link agricultural subsidies to efficient use of water and energy resources, environmental impacts)</td>
</tr>
</tbody>
</table>
Governance Solutions

Brazil – Agricultural subsidies

- Since 2008 all subsidies provided to farmers are linked to fulfilling environmental criteria
- Agricultural subsistence tool: mainly rural credits that aim to improve productivity and manage risks
- To receive subsidized credits farmers have to fulfill requirements of the rural environmental registry (CAR)

Figure: Areas of permanent protection and legal reserve under the Rural Environmental registry

Source: WWF 2016
# Governance Solutions

## Planning Approaches

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<tr>
<td>Policy coordination</td>
<td><strong>Cross-departmental working groups</strong>&lt;br&gt;Permanent or issue-specific groups working across horizontal and vertical (in federal states) lines to discuss different WEF perspectives</td>
</tr>
<tr>
<td>Expert and public consultations</td>
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</tr>
<tr>
<td>Strategic policy planning</td>
<td><strong>Cross-sectoral strategies</strong>&lt;br&gt;Coordination of policies at a strategic, higher authority level (e.g. sustainability strategy)</td>
</tr>
</tbody>
</table>
Governance Solutions

South African National Waste Management Strategy 2020

- Developed under lead of Department of Forestry and Fisheries and the Environment (DFFE) with broad cooperation of other sectors including energy and land/food
- Addresses key interlinkages with other WEF sectors:
  - promotion of energy recovery from sewage and organic waste
  - Prevention of food waste is key pillar for strategy minimize waste minimization
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Value of nexus assessments

- Facilitating inter-sectoral dialogue: shared knowledge base for prioritizing issues, identifying synergies and trade-offs
- Joint identification of cross-sectoral nexus solutions e.g. synergetic RE projects, sustainable catchment management, etc. and discussing necessary nexus investments
- Initiating, broadening, revisiting coordination/cooperation frameworks (baskets of benefits)
- Insights on impacts of policies and strategic decisions from modeling and scenarios on key questions
Interconnectedness and Scale

Daher et al., 2017
## Various scopes of assessment

<table>
<thead>
<tr>
<th>Scope</th>
<th>Details</th>
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</thead>
<tbody>
<tr>
<td>Context analysis</td>
<td>what is the current situation in the Nexus sectors and how are they interlinked</td>
</tr>
<tr>
<td>Assessing impacts of changes</td>
<td>develop development/policy scenarios and analyse/quantify impacts on sectors and sustainability</td>
</tr>
<tr>
<td>Assessment of specific interventions</td>
<td>in terms of their efficiency in resource use, social, economic and envi. impacts</td>
</tr>
<tr>
<td>Comparison of interventions</td>
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</tr>
</tbody>
</table>
Examples of assessment approaches

- Collaborative/participatory tools (workshops, questionnaires, focus groups, etc.)
- Indicator frameworks (sectoral/cross sectoral)
- Conceptual visualisation tools/mapping
- Modelling tools
- Governance assessment
- Policy coherence assessment
Context Analysis – what is the current situation?

The current state of WEF security and pressures on natural resources systems

Socio-economic situation and expected developments, trends and drivers on resources systems

Interconnections between water, energy and food systems

Governance framework: sectoral goals, policies and strategies; coherence of policies, extent of regulation of uses

Planned investments, acquisitions, reforms and large-scale infrastructure

Key stakeholders, decision-makers and user groups, existing coordination mechanisms
<table>
<thead>
<tr>
<th>Water Pillar</th>
<th>Energy Pillar</th>
<th>Food Pillar</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water-access Sub-pillar</strong></td>
<td><strong>Energy-access Sub-pillar</strong></td>
<td><strong>Food-access Sub-pillar</strong></td>
</tr>
<tr>
<td>The percentage of people using at least basic drinking water services.</td>
<td>Access to electricity (% of population).</td>
<td>Prevalence of undernourishment (%)</td>
</tr>
<tr>
<td>The percentage of people using at least basic sanitation services</td>
<td>Renewable energy consumption (% of total final energy consumption).</td>
<td>Percentage of children under 5 years of age affected by wasting (%)</td>
</tr>
<tr>
<td>Degree of WRM implementation (1-100).</td>
<td>Renewable electricity output (% of total electricity output).</td>
<td>Percentage of children under 5 years of age who are stunted (%)</td>
</tr>
<tr>
<td>Annual freshwater withdrawals, total (% of internal resources).</td>
<td>Electric power consumption (kWh per capita).</td>
<td>Average Dietary Energy Supply Adequacy (ADES/EA) (%)</td>
</tr>
<tr>
<td>Renewable internal freshwater resources per capita (cubic meters).</td>
<td>Energy imports, net (% of energy use).</td>
<td>Average value of food production ($ per capita).</td>
</tr>
<tr>
<td>Environmental flow requirements (10^3 m^3/annum).</td>
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<td>Average precipitation in depth (mm per year).</td>
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<td>CO₂ emissions (metric tons per capita).</td>
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Source: wefnexusindex.org
Examples of cross-sectoral indicators

Need to be adapted to context and scope of analysis

- Total fossil energy consumption in agriculture/ agriculture gross production value
- Area under agricultural water management as a % of irrigation potential
- Share of monitoring sites in agriculture areas that exceed recommended drinking water limits for nitrates, phosphorous and pesticides in surface water and groundwater
- Agricultural water productivity
- Water use efficiency in different sectors
Visualisation Tool Nexus Interconnections Diagram

Meza et al., 2015
Assessing policy coherence

Scoring system for assessing the interaction of policy objectives (Nilsson et al. 2012)

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<thead>
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Screening matrix of coherence among policy objectives in the water-land-food-energy-climate (WLEFC)-nexus domains (SIM4NEXUS)

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</table>

What happens to objective x \( \rightarrow \) (affected)
If we make progress on objective y \( \downarrow \) (affecting)

Munaretto et al 2017
The Transboundary River Basin Nexus Approach (TRBNA)
Various scopes of assessment

Context analysis – what is the current situation in the Nexus sectors and how are they interlinked

Assessing impacts of changes: develop development/policy scenarios and analyse/quantify impacts on sectors and sustainability

Assessment of specific interventions in terms of their efficiency in resource use, social, economic and envi. impacts

Comparison of interventions
Modelling Tools to Assess the WEF Nexus

- Models are used to simulate complex socio-ecological systems
- They help us understand interconnections between drivers (e.g. climate, socioeconomic development) and the individual elements of the WEF Nexus
- Models can simulate future scenarios as decision support for planning
- Uncertainties need to be considered!
Approaches of Modelling Tools to assess the WEF Nexus

- fully integrated, multi-resource modelling tools in which interlinkages can be investigated with the use of only a single software
- extended (single system) models
- single models that are combined through soft-linking
  - different models are available for different sectors (e.g., WEAP, LEAP, GAEZ, OSeMOSYS, CropWat, Agent-based models, etc.)
Integrated system approach to assess Nexus interconnections with the aim to:

- Understand the systems within their natural or organizational boundaries
- Assess interconnections between different resource sectors to attain insights into trade-offs and potential synergic solutions
- Provide policy relevant information
- Highlights the need for a collaborative approach incl stakeholders

Considerable number of applications, spanning different spatial and temporal scales and political contexts, discussing two or more resource interactions with different purposes
CLEWs: Nexus Challenges in Burkina Faso

Priority A: Food Security and Agricultural Production
- Increase yields of food crops to maintain food security for a growing population
- Increase yields of cash crops for export
- Production of local biofuels

Priority B: Increasing Access to Water
- Increased water access for rural and urban population
- Expand irrigated areas for agriculture

Priority C: Increasing Access to Modern Forms of Energy
- Decrease the use of wood as fuel source
- Increase electrification rates
- Ensure an increase in per capita energy availability in a growing population
- Increase the use of local renewable energy sources

Quantifiable Interlinkages
- Fertilizer input
- Mechanization
- Biofuels production
- Irrigation water
- Water pumping & diversion
- Water for hydropower
- Use of local biofuels

Hermann et al., 2012
Various scopes of assessment

Context analysis – what is the current situation in the Nexus sectors and how are they interlinked

Assessing impacts of changes: develop development/policy scenarios and analyse/quantify impacts on sectors and sustainability

Assessment of specific interventions in terms of their efficiency in resource use, social, economic and envi. impacts

Comparison of interventions
FAO Nexus Rapid Appraisal Tool: Example

Intervention: On-grid wind energy for water desalination for agriculture

<table>
<thead>
<tr>
<th>NEXUS ASPECT</th>
<th>OVERALL PERFORMANCE SCORE</th>
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<td>Water (W)</td>
<td>2.76</td>
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<tr>
<td>Energy (E)</td>
<td>1.68</td>
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<td>Food/land (F)</td>
<td>4.5</td>
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<td>Labour (L)</td>
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<tr>
<td>Capital (C)</td>
<td>3.56</td>
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</tbody>
</table>

Flammini et al., 2014
Nexus Rapid Appraisal Tool: Comparison

A. SOLAR IRRIGATION IN REGION a

B. HYBRID DIESEL-SOLAR IRRIGATION IN REGION a

C. MINI-HYDRO IN REGION a

Flammini et al., 2014
Thank you for your time!

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