Introduction to the Climate-Land-Energy-Water (CLEW) modelling framework

and its use in the Nexus Assessment of the Drin River Basin

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## Agenda

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<th>Time</th>
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<tr>
<td>9:30-9:45</td>
<td>Welcome and introductions</td>
<td>Tassos Krommydas (GWP), Francesco Gardumi (KTH)</td>
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<td>9:45-10:30</td>
<td>Introduction to Nexus assessment methodologies and CLEWS</td>
<td>Francesco Gardumi</td>
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<td>10:30-10:45</td>
<td>Break</td>
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<td>10:45-11:15</td>
<td>Climate-Water-Energy nexus issues in the Drin River Basin: what can be modelled?</td>
<td>Francesco Gardumi</td>
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<td>11:15-12:00</td>
<td>The water-energy model of the Drin River Basin: methodology</td>
<td>Youssef Almulla</td>
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<td>12:00-12:45</td>
<td>Breakout group session: discussion on scenarios with the water-energy model of the Drin River Basin</td>
<td>All, facilitated by KTH</td>
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<td>12:45-13:00</td>
<td>Wrap-up and end of session</td>
<td>Youssef Almulla</td>
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Learning objectives

• Acquire general knowledge about the assessment of the water-energy-food nexus
• Understand the scope and characteristics of the CLEWs nexus methodology
• Understand the methodology underlying the water-energy model of the Drin River Basin
• Relate the scenario results of the water-energy model of the Drin river basin to key numerical assumptions and to the methodology
Introduction to Nexus assessment methodologies and CLEWS

Vignesh Sridharan, Eunice Ramos, Rebecka Engström, Youssef Almulla, Emir Fejzic, Francesco Gardumi

KTH Royal Institute of Technology
The problem

- Sustainable development means untangling a complex web of interwoven concerns and vested interests.
- Decisions can have far-reaching consequences outside the targeted area, sector, or jurisdiction.
- Impacts can be unintended and unforeseen.
- Cross-sectoral and cross-system impacts may be either positive or negative (or both).

A coordinated and integrated process to develop policies and measures with adequate attention given to cross-cutting aspects is needed to best manage synergies and trade-offs.
There is a need for policy coherence

- Systematically identify relevant linkages across the sectors and domains and consider those linkages in design of policies;
- Ensure that policies are consistent across sectors and scales (from local to global);
- Involve relevant stakeholders in design, implementation, monitoring, and evaluation;
- Allocate adequate resources for implementation at all levels and at all scales.
Integrated assessments

- Synergies and trade-offs between systems & sectors need attention
- Resources are finite
- Understanding the consequence of Human actions is paramount
- Integrated assessment is a **blanket term** - takes into consideration more than one system/sector
- Models developed to understand these interactions are called **IAMs (Integrated Assessment Models)**
Interaction and interdependency between selected resource sectors/system/domains [in terms of trade-offs, conflicts, opportunities and synergies].

**nexus approach**

*A systematic process of inquiry* that accounts for water, land, energy, food and climate interactions (and/or other systems), in both quantitative and qualitative terms, with the aim of better understanding their dynamic relationships and inform planning and decision making in these domains.
Nexus approach - Frameworks

CLEWs (IAEA, 2009)

Water-energy-food security nexus (Hoff, 2011)
Nexus approach - frameworks

WELF nexus (Ringler et al, 2013)

WEF nexus approach (FAO, 2014)
Nexus approach - frameworks

Programme of Work 2013-2015 under the UNECE Water Convention, adopted by the Parties

**FIGURE 6**
Phases of development of the TBNA methodology

UNECE, M. Roidt and L. De Strasser, *Methodology for assessing the water-food-energy-ecosystems nexus in transboundary basins and experiences from its application, 2018*
## Nexus approach - frameworks

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<td>1</td>
<td>Identification of basin conditions, the socio-economics</td>
<td>Desk study</td>
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<td>2</td>
<td>Identification of key sectors and stakeholders</td>
<td>Desk study</td>
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<td>3</td>
<td>Analysis of the key sectors</td>
<td>Desk study/ 1st Workshop</td>
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<td>4</td>
<td>Identification of intersectoral issues</td>
<td>1st Workshop</td>
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<td>5</td>
<td>Nexus dialogue and future developments</td>
<td>1st Workshop</td>
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<td>6</td>
<td>Identification of opportunities for improvement</td>
<td>1st &amp; 2nd Workshop/Desk study</td>
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The CLEW's framework
What is the CLEWs framework?

**CLEWs** stands for: **Climate-Land-Energy-Water** systems

Integrated analysis of resource systems’ interactions and quantitative assessment of critical linkages using modelling tools.
Enables evaluation of the general robustness of a particular strategy or policy

- Provide policy support and analysing alternative development pathways/choices
- Investigate implications of technology deployment and sector-specific solutions (irrigation, electricity generation, afforestation)
CLEWs models

- Techno-economic representations of real-world systems
- Designed to assess the role of technology change and technology choice
- Enable scenario-based analysis to evaluate risks and uncertainties
- Intended for long-term analysis of sustainable development issues (e.g., one or more decades)
- Highly customizable/flexible with respect to system boundaries, geographical coverage, level of detail, and economic characteristics
CLEWs models

Caveats to consider when applying the CLEWs methodology

- CLEWs models are not crystal balls
- CLEWs models have idealized representation
- Some policies and measures cannot be represented directly in CLEWs model
Water to Energy

Fuel cycle
- Fossil fuel extraction
- Fuel processing
- Biofuel cultivation and processing

Energy conversion processes
- Transport sector
- Electricity generation

Energy sources
- Hydropower
- Thermal power
- Non-hydro renewables

Source: https://arpa.e.energy.gov/?q=news-item/arpa-e-arid-program-advances-technologies-reduce-water-usage-power-plants
Energy to Water

Operation of water systems
- pumping (extraction and distribution)
- water purification
- wastewater treatment
- non-conventional production of potable water
- pump storage power plants

Use of water
- Water heating
- Energy use and end use (e.g. washing machines)

Energy for agriculture
- Irrigation systems

Energy to Water

Supply
Treatment Plant
Drinking water Distribution System
Stormwater System
Wastewater Collection System

Water to Land

URBAN AREAS & PLANNING

Population distribution and location of water resources

AGRICULTURE

Crop suitability and yields

Natural cover

Livestock

Forests

Wetlands

Inland water
Land to Energy

Fuel Extraction and production / processing
- Mining
- Oil fields, tar sands, shale gas
- Storage

Biomass for energy
- Agroforestry residues
- Biofuel production

Energy infrastructure
- Electricity transmission network
- Power plants

Renewables (large scale PV, Wind, CSP)
- Hydropower (flooded area)
- Thermal power
- Cooling systems, waste deposits
Energy to Land

Fuel Extraction and production/processing
- Environmental degradation
- Soil contamination
- Storage
- Waste production
  - Leakage
  - Tailings deposits, nuclear waste

Biomass for energy
- Deforestation
- Afforestation
- Ecosystem disruption and/or degradation

Energy infrastructure
- Land use change
- Renewables (large scale PV, Wind, CSP)
- Hydropower
- Flooded area
- Thermal power
  - Cooling systems, waste deposits
Mapping systems’ interactions: the whole picture
The CLEWs framework suggests the linkages can be quantified

- developing an integrated accounting model (resources use factors, adding CLEWs elements to sectoral models);
- with the development of sectoral systems models and integration and iteration between these;
- using a single model framework
CLEWs: modelling
Examples of CLEWs Modelling Tools

- OSeMOSYS
- WEAP
- GAEZ
- LEAP
- QGIS
- Water Evaluation And Planning
- Python
Water Management modelling

Critical Questions

• How should water be allocated to various uses in time of shortage?
• How should infrastructure in the system (e.g., dams, diversion works) be operated to achieve maximum benefit?
• What is the demand for irrigated water and what are the associated energy requirements?
Water Management modelling

Required model inputs include:

- Definition of all Catchment areas
- Real Climatic Data: Rainfall, min & max temperature, humidity, ...
- All main rivers & reservoirs plus stream flow data and reservoirs levels
- Modelling of existing canals / distribution systems
- Using GIS: land cover classes to calculate evapotranspiration
- Water Demand data (urban and agricultural) according to national statistics and population density
- Operational rules of hydro power plants
Critical questions

- What investments are needed in generation and network infrastructure to meet electricity demand and when?
- What technologies achieve the least-cost and most reliable energy mix?
- What are the associated impacts on land-use? E.g. from growing biofuels or from large-scale solar PV parks
- What are the associated water requirements for a specific energy mix? E.g. water for cooling, hydropower
- What pollutants are emitted and at what level?
Energy system modelling

• Can be used to assess the impact of predetermined pathways for development; accounting models (LEAP, MAED)
  • Represent decisions of actors within the system; simulation models
  • Potential for replacing existing technologies with low-carbon, more efficient or cost effective alternatives.

• Can be used to optimize a specific system; cost-optimization modelling (OSeMOSYS, MESSAGE, MARKAL, PLEXOS, ARTELYS CRYSTAL...)
  • Technology learning rates, resource availability, technical limitations, environmental criteria, costs etc. directly affect the optimal system design
  • Seeks the least-cost configuration of the energy system (investments and supply)
Critical questions

• What is the potential yield of a range of crops in each region?
• What are the water requirements for each crop?
• How do different climate scenarios affect crop yield?
• What are the energy requirements to ensure a certain yield?
Input:
- Climatic Data
- Detailed soil map and data
- GIS data for landcover
- Irrigated areas

Output:
- Optimal crops, potential water use, and potential yield, ...
How to set up a CLEW case study?

**SYSTEMS PROFILING**
- Current state and historical trends
- Main stress points
- Sectoral policies, plans, strategies

**PRE-NEXUS ASSESSMENT**
- Interlinkages between sectors
- Pressure points between sectors (‘nexus issues’)

**MODEL DEVELOPMENT**
- Development of independent models with integration possibilities
- Scenario development
- Soft-linking of models inputs and/or outputs
How to set up a CLEW case study?

**ANALYSIS**
- Analysis of results
- Revise inputs / assumptions
- Conduct additional model runs

**INFORM POLICY MAKING**
- Report on the quantification of the impacts of sectoral interactions
- Suggestion of strategies and pathways towards sustainability
Selected CLEWS Studies
Mauritius – National CLEWs

- Main revenue has been tourism and sugar exports
  - Expiration of EU agreement and collapse of revenue from the latter.
- Diversification from sugar cane to food crops and vegetables
- Bagasse from refining – cogeneration of heat and electricity
  - Reduction in sugar prod. led to lower electricity generation from bagasse
- Consequent increase in fuel imports – coincided with increase in international fuel prices
- Irrigation requirements higher for food crops-vegetables than for sugar cane
  - Increased water demand
Mauritius – National CLEWs

The impact of transforming two sugar-processing plants to produce second-generation ethanol in Mauritius (projections for 2030).
Sava and Drina River Basins

Aim: to assess water, energy and agriculture at a sub-regional level in a transboundary river basin context.

Main issues:
- Dependency between the basin water resources and the energy sector;
- Hydropower expansion vs climate change and competing irrigation demand;
- Water consumption in agriculture and for cooling systems;
- Relation between CO₂ emissions and water resources use in electricity generation.
Sava and Drina River Basins

Difference in electricity generation due to an increase in irrigation (Sava)

Link: Sava River Basin Nexus Assessment

Link: Drina River Basin Nexus Assessment
Thank you!

Questions?
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<th>Author</th>
<th>Reviewer</th>
<th>Reviser</th>
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<td>2021-07-06</td>
<td>Sridharan, V., Ramos, E.P., Engström, R., Alfstad, T.</td>
<td>Gardumi, F.</td>
<td>Gardumi, F.</td>
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