DRIN NEXUS ASSESSMENT

WATER–ENERGY MODELING

6th July 2021

Polytechnic University of Tirana:
Klodian Zaimi

KTH, Royal Institute of Technology:
Dr. Francesco Gardumi
Dr. Vignesh Sridharan
Youssef Almulla
Emir Fejzic
In this presentation ...

• Part 1:
  • Overview of energy systems modeling and various modeling tools
  • Introduction to OSeMOSYS, its key characteristics, inputs and outputs.

• Part 2:
  • Overview of the Drin Integrated Water-Energy model
  • The main scenarios and their key assumptions.
  • Introduction to the Hands-on exercise
Part 1:
Energy systems modeling and OSeMOSYS
Energy system and planning

The energy trilemma in policy

**Sustainability**
- What needs to be done to supply modern energy sources to remote areas?
- What needs to be done to increase the share of renewable technologies?

**Security**
- Should electricity import be allowed?
- Should existing nuclear facilities be closed down?

**Affordability**
- Can an energy conservation program help in reducing cost of energy supply?

Modeling tools are needed to help decision makers and investors understand the potential impacts of decisions aimed to address such questions.
Energy modelling tools

Bottom-up and top-down tools

MODELLING TOOLS

TOP-DOWN

ECONOMETRIC
INPUT/OUTPUT
CGE
ACCOUNTING
SIMULATION
OPTIMIZATION

BOTTOM-UP
Energy modelling tools

Why use optimization tools?

- To identify least-cost energy systems
- To identify cost-effective responses to restrictions on emissions
- To evaluate new technologies and priorities for R&D
- To evaluate the effects of regulations, taxes, and subsidies
- To project future greenhouse gas emissions
- To estimate the value of regional cooperation
- Investigate scenarios (possible futures);
- Explore alternatives to business as usual practices;
- Inform decisions (policy and strategic planning)
Energy modelling tools

Scope

Picture source: M. Welsch, 2013, J, Author permission
OSeMOSYS

What is it?

www.osemosys.org

Model generator converting the energy system structure represented by equations into a matrix to be solved by specific solvers

- Linear optimization
- Paradigm comparable to MESSAGE and TIMES
- Freely available and open source
- Dynamic
- (Usually) Perfect foresight
- (Usually) Deterministic

OSeMOSYS

What does it do?

• It determines the energy system configuration with the minimum total discounted cost for a time domain of decades, **constrained by:**

• Demand for commodity (e.g., electricity, heating, cooling, km-passengers, etc.) that needs to be met
• Available technologies and their techno-economic characteristics
• Emission taxations and generation targets (e.g., renewables)
• Other constraints (e.g., ramping capability, availability of resources, investment decisions, etc.)
Basics of OSeMOSYS

Structure

Sets (Components)
- REGION
- YEAR
- COMMODITY
- TECHNOLOGY
- ...

Input data (Parameters)
- Historical capacity
- Annual Demand
- Load
- Efficiency
- Capital, fixed, variable costs
- Emission Activity Ratio
- Availability Factors
- ...

Output variables (Results)
- New Capacity
- Total Annual Production by Technology
- Annual Emissions
- Discounted Costs
- Model Period Cost
- ...

[Diagram showing the structure with sets, input data, and output variables]
Basics of OSeMOSYS

Set: Technology

- A technology can be used to:
- Supply or produce a resource
- (e.g., biomass production, natural gas imports)
- Convert one commodity into another
- (e.g., conversion of natural gas to electricity, electricity to light)
- A technology can represent:
- A single process/plant or
- A group of processes/plants with similar characteristics
Basics of OSeMOSYS

Set: Commodity

- Commodities can be used to represent:
  - Flows between technologies
    - (e.g., electricity, natural gas, coal)
  - Final demands
    - (e.g., demand for lighting, cooling, heat, or clean water)
The results provide insights on questions such as:

- Which technologies are phasing out? By when?
- What are the optimal investments in new technologies to meet the demand in the future? When is it best to invest?
- What are the key generation technologies in the total energy mix?
- What costs will the energy system incur?
OSeMOSYS
Interpreting its results

Electricity Supply (Pi)

Picture source: Open Energy system Models, image, license under CC-BY-SA 4.0
OSeMOSYS

Use in CLEWs models

• Minimize:

• Total system cost

• Over a given time period (e.g., 2020 – 2050)

• Subject to a set of constraints (e.g., demand requirements, resource limits)
OSeMOSYS applications

Where and who?

- Research and teaching
- Capacity development

*Only some key uses!*

Picture source: search.creativecommons.org/, image, license under CC0 1.0
OSeMOSYS applications

What

• TEMBA – The Energy Model Base for Africa. Link
• IEA WEO 2014 – Africa Energy Outlook.
• World Bank – Enhancing the Climate Resilience of African Infrastructure. Link
• Among the UN Modelling Tools for Sustainable Development. Link
• Used by UNECE for assessment of water-energy cooperation benefits in transboundary river basins. Link
• Used by UNDP, UNDESA in CLEWs technical capacity development programmes for update of Nationally Determined Contributions
Part2: Drin Integrated Water-Energy model
WHAT WE ARE TRYING TO DO?

**Aim:**
To quantify the costs and benefits of shifting to a **“flood-smart”, cooperative hydropower operation** regime along and between the two hydropower cascades in the Drin basin.
How? (Methodology)

Integrated Water-Energy model

Soft Linking

Panta Rhei

OSeMOSYS

* Panta Rhei: a Hydrological Model for the Drin Basin.

* OSeMOSYS: Open Source energy MOdeling SYStem.
Panta Rhei: Hydrological model

- Application of the hydrological model in around 20 000 km².
- The model outputs are: rainfall (mm) distribution, ETP (mm), Volume (m³), Average discharge (m³/s)

The number of hydrometeorological stations with available data in the tables below:

<table>
<thead>
<tr>
<th>Sub-basin</th>
<th>Discharge</th>
<th>Water level</th>
<th>Storage elevation curve</th>
<th>Cross-sections</th>
<th>Rating curve</th>
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<tr>
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<td>15</td>
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<td>1</td>
<td>n.a.</td>
<td>n.a.</td>
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<tr>
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<td>5</td>
<td>9</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
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<tr>
<td>Macedonia</td>
<td>6</td>
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<td>2</td>
<td>5</td>
<td>n.a.</td>
</tr>
<tr>
<td>Kosovo</td>
<td>15</td>
<td>17</td>
<td>n.a.</td>
<td>11</td>
<td>n.a.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sub-basin</th>
<th>Precipitation</th>
<th>Air temperature</th>
<th>Snow</th>
<th>Sunshine duration</th>
<th>Global radiation</th>
<th>Relative humidity</th>
<th>Wind</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albania</td>
<td>31</td>
<td>28</td>
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<td>n.a.</td>
<td>n.a.</td>
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<tr>
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<tr>
<td>Kosovo</td>
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<td>3</td>
<td>n.a.</td>
<td>n.a.</td>
<td>n.a.</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

n.a. time series data are not available.
* In addition to the above, all power plants are classified into (inside Drin and Outside Drin).
SCHEMATIC REPRESENTATION OF THE DRIN RIVER CASCADES

Change in water availability (Panta Rhei)  →  Change in Electricity generation (OSeMOSYS)
Scenarios:

- Integrated Water-Energy model
  - Soft Linking
    - Panta Rhei (Hydrological Model)
    - OSeMOSYS* (Energy model)
    - Reference (RF)
    - Climate Change (CC)
    - New Dam (Skavica) (ND)
    - Flood Protection (FP)
    - Energy Optimization (EO)
    - Cooperation
      - COOP5%
      - COOP10%
      - COOP15%
      - COOP20%
    - NO Cooperation
Reference Scenario (RF): Key assumptions

- Represents the current situation in the **four countries:** Albania, North Macedonia, Montenegro and Kosovo.
- Flow: the **average discharge** in the river segments based on historical data from 2001-2010.
- Temporal resolution: **weekly representation** (52 weeks), for the period (2020-2050).
- Renewable Capacity factors: are based on hourly data* and separated for inside and outside Drin basin.
- Future investments (**hydro, solar, wind**): are considered as follows:
  - **Confirmed** projects: are forced into the model
  - Projects with **no commissioning dates**: are allowed as **optional** capacity investments.
  - Additionally: the **max cap** on solar and wind are **gradually relaxed** after 2030.

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* Source: https://www.renewables.ninja/
Reference Scenario (RF): Key assumptions

- Electricity trade: is modelled in a simplified manner due to lack of data (volumes and prices). One export and one import technology for each country.

- An upper limit on imports for each country was set based on historical records (2011-2018).

- Similar approach was used for all other scenarios.

Source: https://www.eqmagpro.com/
Scenarios:

- Integrated Water-Energy model
- Reference (RF)
- Climate Change (CC)
- New Dam (Skavica) (ND)
- Flood Protection (FP)
- Energy Optimization (EO)
- Panta Rhei
  (Hydrological Model)
- OSeMOSYS*
  (Energy model)

Soft Linking

- Cooperation
  - COOP5%
  - COOP10%
  - COOP15%
  - COOP20%
- NO Cooperation
Climate Change scenario (CC):

- **Flow**: based on two sets of projections:
  - 2025: with avg (-3%) change in precipitation.
  - 2050: with avg (-6%) change in precipitation.
  - linear decline in water flow assumed between (2021-2025) and (2026-2050).

- Changes implemented to all ‘catchments’ and upstream river segments.

- Not included: annual variability in water flow due to climate change.

### Climate Change projections - change in Precipitation

<table>
<thead>
<tr>
<th></th>
<th>2025 % Change in Precipitation</th>
<th>2050 % Change in Precipitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Min</td>
<td>-2.6</td>
<td>-5.3</td>
</tr>
<tr>
<td>Avg</td>
<td>-3</td>
<td>-6.1</td>
</tr>
<tr>
<td>Max</td>
<td>-3.4</td>
<td>-6.9</td>
</tr>
</tbody>
</table>
Scenarios:

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- Reference (RF)
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- Energy Optimization (EO)

Cooperation:
- COOP5%
- COOP10%
- COOP15%
- COOP20%

NO Cooperation
## New Dam - Skavica:

<table>
<thead>
<tr>
<th>Skavica</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity (in MW)</td>
<td>196</td>
</tr>
<tr>
<td>Investment cost</td>
<td>EUR 500 mln</td>
</tr>
<tr>
<td>Reservoir size (in Mm3)</td>
<td>2300</td>
</tr>
<tr>
<td>Installation year</td>
<td>2025</td>
</tr>
<tr>
<td>Buffer zone area (masl)</td>
<td>441</td>
</tr>
<tr>
<td>Spillway capacity</td>
<td>2800</td>
</tr>
<tr>
<td>Number of turbines</td>
<td>2</td>
</tr>
<tr>
<td>Flow in each pentock in (m3/sec)</td>
<td>87</td>
</tr>
<tr>
<td>Project Net Head</td>
<td>140 (around)</td>
</tr>
</tbody>
</table>
Flood Protection (FP) scenario:

• In this scenario we explore the impact of increasing the buffer volume in certain reservoirs on
  • Electricity generation from HPPs
  • Flood area downstream and flood damage.

• Two reservoirs were chosen (one in each country) to study this scenario:
  • Spilje (N.M): 506 MCM
  • Fierza (AL): 2350 MCM

• Sensitivity analysis: increasing the buffer volume by
  • 5%
  • 10%
  • 15%
  • 20%

• Changes were applied in the wet season (Oct-May)
## Flood Protection (FP) scenario:

### Additional buffer volume (MCM) in Spilje

![Bar chart showing additional buffer volume in Spilje](image)

### Changes in the water level (masl) under different rules

<table>
<thead>
<tr>
<th>month</th>
<th>hist_level (m)</th>
<th>level (m) +5% buffer</th>
<th>level (m) +20% buffer</th>
<th>Diff in m (+5%)</th>
<th>Diff in m (+20%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>569</td>
<td>566.3</td>
<td>564.7</td>
<td>2.7</td>
<td>4.3</td>
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<td>566</td>
<td>564</td>
<td>562.2</td>
<td>2</td>
<td>3.8</td>
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<td>567</td>
<td>564.7</td>
<td>563</td>
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<tr>
<td>4</td>
<td>570</td>
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<td>2.9</td>
<td>4.3</td>
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<td>567.1</td>
<td>565.7</td>
<td>2.9</td>
<td>4.3</td>
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<tr>
<td>11</td>
<td>568</td>
<td>565.5</td>
<td>563.9</td>
<td>2.5</td>
<td>4.1</td>
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<tr>
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<td>569</td>
<td>566.3</td>
<td>564.7</td>
<td>2.7</td>
<td>4.3</td>
</tr>
</tbody>
</table>
Flood Protection (FP) scenario: Fierza

Additional buffer volume (MCM) in Fierza

<table>
<thead>
<tr>
<th>Month</th>
<th>Hist Level (m)</th>
<th>5% Level (m)</th>
<th>20% Level (m)</th>
<th>5% Diff in m</th>
<th>20% Diff in m</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>279</td>
<td>278.5</td>
<td>275</td>
<td>0.5</td>
<td>4.2</td>
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<td>2</td>
<td>276</td>
<td>274.9</td>
<td>270</td>
<td>1.1</td>
<td>5.8</td>
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<td>3</td>
<td>280</td>
<td>279.7</td>
<td>276</td>
<td>0.3</td>
<td>3.8</td>
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<tr>
<td>4</td>
<td>285</td>
<td>285.3</td>
<td>283</td>
<td>-0.3</td>
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<td>278.5</td>
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<td>0.5</td>
<td>4.2</td>
</tr>
</tbody>
</table>
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- Cooperation
  - COOP5%
  - COOP10%
  - COOP15%
  - COOP20%

- NO Cooperation
Energy Optimization (EO) scenario: Fierza

- Increasing the storage level in Fierza dam to the maximum allowed level in the regulations.

<table>
<thead>
<tr>
<th>Month</th>
<th>hist_level(m)</th>
<th>New_level(m)</th>
<th>diff(m)</th>
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<tbody>
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</tr>
<tr>
<td>12</td>
<td>279</td>
<td>290</td>
<td>11</td>
</tr>
</tbody>
</table>
Insights can be driven at:

• The Basin Level

• The National Level

Change in Electricity Generation (GWh) in Albanian HPPs - Ref and CC scenarios
Hands-on exercise:

• In the breakout groups,
• Based on the insights shared in today’s presentations, your valuable knowledge in the region and the insights shared in the (Drin_CB.html) file; we would like you to work with your team and answer (1-3) of the questions shared in the (Drin_CB.html) file.
• Group discussion: 20-25 min.
• Report back in plenary: 10-15 min.
• Three groups:
  • Groups1 and 2: Albania
  • Plenary: North Macedonia
Hands-on exercise:

<table>
<thead>
<tr>
<th>#</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Plenary</th>
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<tbody>
<tr>
<td>1</td>
<td>Albi Islami</td>
<td>Eblerta Ajeti</td>
<td>Toni Markoski</td>
</tr>
<tr>
<td>2</td>
<td>Euglert Beshello</td>
<td>Aleksandra Dorri</td>
<td>Slavko Milevski</td>
</tr>
<tr>
<td>3</td>
<td>Fatjon Zekaj</td>
<td>Djana Bejko</td>
<td>Marjan Glavinceski</td>
</tr>
<tr>
<td>4</td>
<td>Elgi Haxhiraj</td>
<td>Elio Voshtina</td>
<td>Vignesh Sridharan</td>
</tr>
<tr>
<td>5</td>
<td>Elton Radheshi</td>
<td>Arbesa Kamberi</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Enerida Markokaj</td>
<td>Orland Muca</td>
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<tr>
<td>7</td>
<td>Artur Mustafaraj</td>
<td>Eriona Gega</td>
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<tr>
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<td>Jonida Rika</td>
<td>Alban Doko</td>
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<tr>
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<td>Fationa Sinojmeri</td>
<td>Francesco Gardumi</td>
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<td>10</td>
<td>Youssef Almulla</td>
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