Energy Connectivity in Central Asia

Scenario modeling approach

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Stockholm Environment Institute

- Bridging science and policy – an independent, non-profit research institute focused on sustainable development
- Over 350 staff worldwide: headquarters in Sweden, centers in the U.S., Kenya, Colombia, Great Britain, Thailand, Estonia
- Principal research areas: climate change mitigation and adaptation, energy, air pollution, water resources, climate finance, environmental economics
- Commitment to stakeholder inclusion, capacity development, and transparency

A sustainable future for all

Project objectives

- Support enhanced energy connectivity in Central Asia with a view to:
  - Improving energy system resiliency
  - Increasing access to reliable, affordable, and sustainable energy
  - Facilitating deep decarbonization
- Key focus areas: electricity and gas
- Complementary workstreams
  - Scenario modeling
  - Roadmap development

Scope of scenario modeling

- Model energy systems of 5 Central Asian countries (KAZ, KGZ, TJK, TKM, UZB)
- Simulate three main scenarios
  - National energy self-sufficiency
  - Regional energy connectivity
  - Regional energy connectivity + connections to other regions
- Analyze key model outputs
  - Energy endowments/reserves
  - Energy supply and demand
  - Deployment of low/zero-carbon technologies: renewable energy, nuclear, H_2, fossil with carbon capture
  - Electricity and gas grid expansion/integration
  - Deployment of energy storage
  - Costs of energy generation, transmission, and storage

Starting point: SEI Central Asia model

- Model of energy systems of Central Asia developed with SEI's Low Emissions Analysis Platform (LEAP) and Next Energy Modeling system for Optimization (NEMO) tools
- All sectors and fuels/energy carriers, mostly top-down structure
- 2010-2050
- Five regions: KAZ, KGZ, TJK, TKM, UZB
- Designed to integrate with a water resources model of Amu Darya and Syr Darya Basins built with SEI's Water Evaluation and Planning (WEAP) system, but can be run independently
- Default time step: annual
- Time step for electricity demand and supply modeling: hourly (one representative 24-hour day/month)
- Electricity supply modeling structure
  - Generation only
  - All major existing, planned, and potential hydropower facilities in Amu Darya and Syr Darya Basins individually modeled
  - Other generation capacity aggregated by technology (33 technologies in total)
  - Power flow and unit commitment not simulated
- GHG emissions from energy demand and supply: CO_2, CH_4, N_2O

Starting point: SEI Central Asia model

- Simulation methods
  - Energy demand: activity analysis and econometric modeling
  - Electricity supply: least-cost optimization
  - Other energy supply: prioritization rules
- Data sources: national governments, international organizations, peer-reviewed literature, publicly available research reports, commercial database of electricity generation capacity (Platts)
- Scenarios: combinations of policy cases and climate change projections
  - Policy cases
    - Baseline: business as usual
    - National focus: Baseline + implementation of national plans for expanding hydropower and agriculture
    - Energy and climate improvements: National focus + implementation of unconditional NDCs, national plans for energy efficiency and renewable energy
  - Climate change projections
    - Historical: no further climate change
    - Hot wet: higher temperatures, increased precipitation (GFDL-CM4 model, SSP 5-8.5)
    - Hot dry: higher temperatures, decreased precipitation (INM-CM5 model, SSP 5-8.5)
    - Hot average: higher temperatures, precipitation at historical levels (MPI-ESM1 model, SSP 2-4.5)

LEAP
Low Emissions Analysis Platform

- A software tool for quantitative modeling of:
  - Energy systems
  - Pollutant emissions from energy and non-energy sources
  - Costs and benefits
  - Health impacts
  - Sustainable development indicators
  - Related externalities
- Created by SEI to support sustainable development
  - Inform decision making
  - Empower stakeholders to perform their own analyses
- Well-suited to medium and long-term planning
- Facilitates data management and documentation, communication with stakeholders

https://leap.sei.org/

Key characteristics of LEAP

Flexibility

- Data inputs and model structure
- Temporal, geographic, and sectoral scope
- Modeling methodologies
- Environmental and social impacts

Usability

- Graphical user interface, powerful visualizations
- Integration with Microsoft Office
- Scenario-based analyses
- Accounting framework

Community

- 64,000 users in over 190 countries
- Free or low-cost licenses for govt./non-profit in non high-income countries
- Active web forums
- Ongoing SEI support

NEMO:
Next Energy Modeling system for Optimization

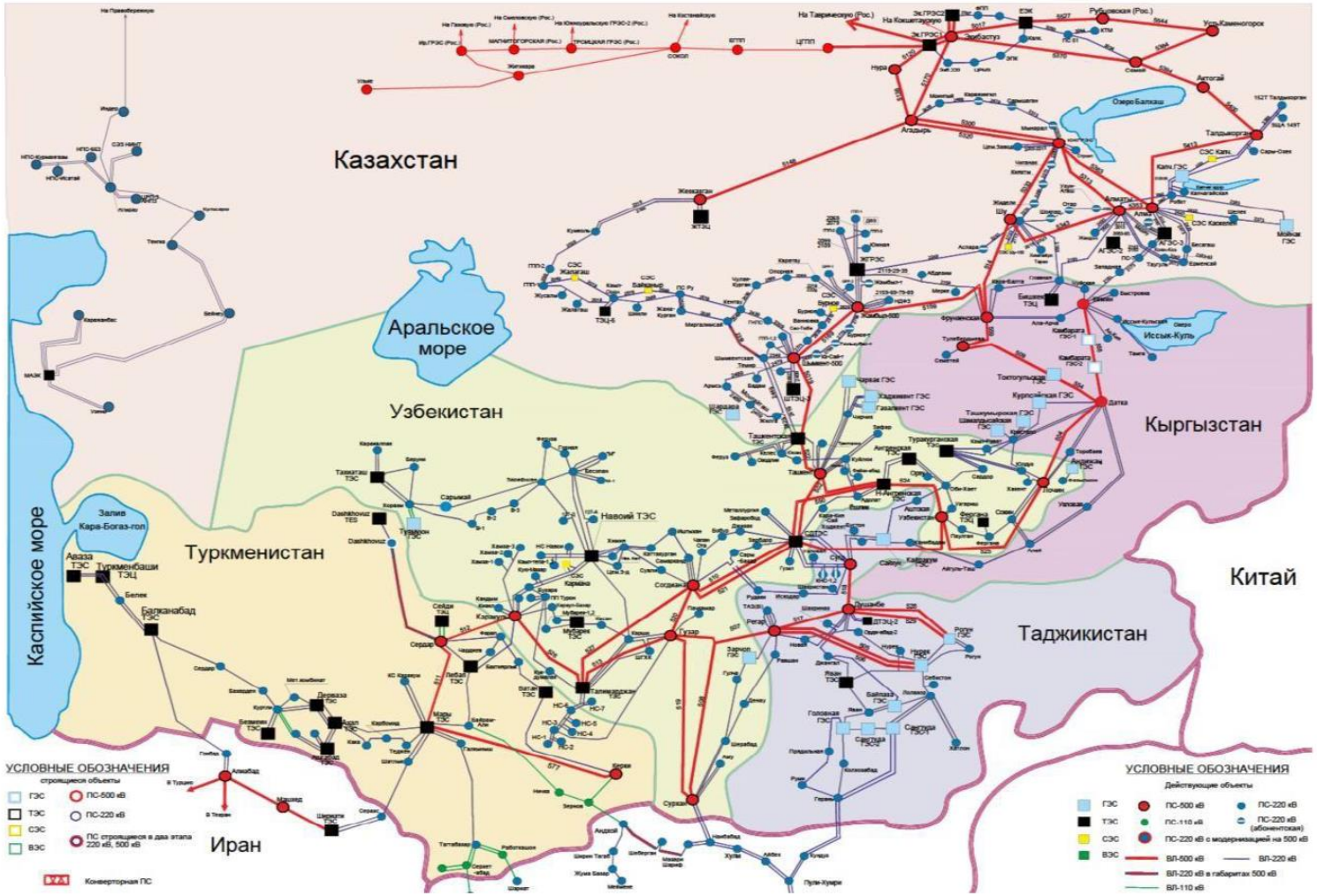
- High performance, open source energy system optimization tool
- Integrates with LEAP as a graphical user interface
- Key features for decarbonization and electricity system analyses
  - Energy storage
  - Nodal networks, power and pipeline flow
  - Emission and renewable energy targets
  - Carbon/pollutant pricing
  - Regional modeling and energy trade
- Parallel processing
- Support for simulating selected years in a modeling period
- Compatible with multiple solvers; numerous performance tuning options

https://leap.sei.org/nemo

Adapting model for Energy Connectivity project

- Modify modeled regions to align with Central Asia's electricity grids
  - Divide KAZ into 3 regions: South, North, West
    - *Key source: Katyshev (2023)*
  - Keep 1 region each for KGZ, TJK, TKM, UZB
  - Maintain pre-existing simulation methods insofar as possible
- Model high-voltage (>= 110 kV) electricity transmission network: lines that connect modeled regions
  - Methods: transshipment (pipeline) power flow, co-optimization with generation and storage
  - *Key sources: Katyshev (2023), World Bank (2023)*

Electricity grids in Central Asia



Source: Katyshev (2023)

Adapting model for Energy Connectivity project

- Disaggregate electricity exports and imports: explicitly model electricity trade within Central Asia and between Central Asia and third countries
  - Methods: power flow model calibrated to historical intra-regional trade, exogenous projections for trade with third countries
  - *Key source: Katyshev (2023)*

Third-country electricity trading partners

Central Asian country	Third country
Kazakhstan	Russia
Kyrgyzstan	Afghanistan/Pakistan (CASA-1000)
Tajikistan	Afghanistan/Pakistan (CASA-1000)
Tajikistan	Afghanistan
Turkmenistan	Afghanistan
Turkmenistan	Iran
Uzbekistan	Afghanistan

Adapting model for Energy Connectivity project

- Update model with recent historical data on electricity generation and generation capacity
  - *Key source: Katyshev (2023)*
- Use model's current capability to simulate production of electricity from renewables – wind, solar, hydro, bioenergy
  - Method: least-cost optimization
  - Include national renewable electricity targets (Energy and climate improvements policy case, *Katyshev [2023]*)
  - Choose a climate change projection (e.g., hot wet), and take availability of water for hydropower from WEAP model
  - Update hydropower costs using data in *Katyshev (2023)*
- Use model's current capability to simulate nuclear electricity production
  - Method: least-cost optimization
  - Implement national nuclear targets (Energy and climate improvements policy case), do not allow endogenous construction of nuclear

Adapting model for Energy Connectivity project

- Add hydrogen demand and supply to model
  - Demand
    - Domestic: H_2 in industry and transport, H_2 storage for electricity production
    - Exports
    - Methods: exogenous projections for industry, transport, and exports if available; least-cost optimization for H_2 storage
    - *Sources TBD*
  - Supply
    - Technologies: electrolysis, steam methane reforming with carbon capture
    - Methods: prioritization rules for capacity expansion and dispatch based on relative costs and resource availability
    - *Key source: UN ECE (2023)*

Adapting model for Energy Connectivity project

- Add power-sector carbon capture to model
  - Technologies: pulverized coal and combined cycle natural gas with carbon capture (retrofits and new builds)
  - Method: least-cost optimization
  - *Key sources: National Renewable Energy Laboratory (2023), UN ECE (2021, 2023)*
- Add grid-connected electricity storage to model
  - Technologies: lithium-ion batteries, H_2, pumped hydro
  - Method: least-cost optimization
  - *Key sources: Danish Energy Agency (2023), National Renewable Energy Laboratory (2023), TBD for pumped hydro potential*

Note: given project's short timeline, it will not be possible to model carbon capture in other (non-power) sectors

Adapting model for Energy Connectivity project

- Model gas transmission network: lines that connect modeled regions
  - Methods: optimized pipeline flow
  - *Sources TBD*
- Distinguish gas trade within Central Asia from trade between Central Asia and third countries
  - *Sources TBD*
- Update model inputs on fossil fuel reserves
  - *Key source: Katyshev (2023)*
- Make other miscellaneous updates to model using data from *Katyshev (2023)*: reserve margin targets and capacity credits for electricity production

Proposed scenario implementation

- National energy self-sufficiency
  - No trading of electricity, hydrogen, or biomass (between Central Asian countries or with rest of world)
  - Trading of fossil fuels allowed (between Central Asian countries and with rest of world)
- Regional energy connectivity
  - Electricity transmission lines between Central Asian countries activated
  - Trading of hydrogen allowed between Central Asian countries
  - Trading of fossil fuels allowed (between Central Asian countries and with rest of world)
  - No trading of biomass (between Central Asian countries or with rest of world)
- Regional energy connectivity + connections to other regions
  - Electricity transmission lines between Central Asian countries activated
  - Electricity trade with third countries activated
  - Trading of hydrogen and fossil fuels allowed (between Central Asian countries and with rest of world)
  - No trading of biomass (between Central Asian countries or with rest of world)

Discussion questions

- Is the proposed scenario framework adequate?
- Can you recommend any sources of data that should be used in the modeling, particularly for the following?
  - H_2 demands
  - Pumped hydropower potential
  - Gas transmission and trade
- Should the model include the short-term forecast of power-sector capacity expansion in the 2022 study *Concept for Development of the Unified Energy System in Kazakhstan and Central Asia*, published by the Energy Coordinating Dispatch Centre and Almaty University of Energy and Communications?

Others welcome!

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