An overview of IAEA tools and methodologies for integrated energy system planning

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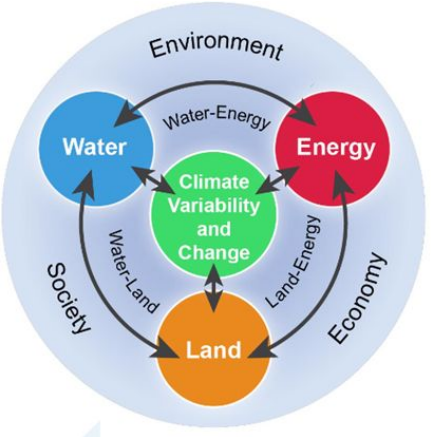
Transitions towards sustainable and low-carbon secure energy systems

Energy transitions that countries need to go through will be very complex, and will require **comprehensive energy planning to support evidence-based decision-making**,

All low-carbon technologies will be needed, including renewables, abated fossil fuels, storage, grids, and, for some countries, nuclear.

- careful assessment of the benefits of each technology, how they complement each other, integrate within future energy systems, grid development and interconnections, etc
- Also, climate – land – water – and energy challenges are becoming increasingly linked – so this nexus needs to be accounted for, including to build climate-resilient systems



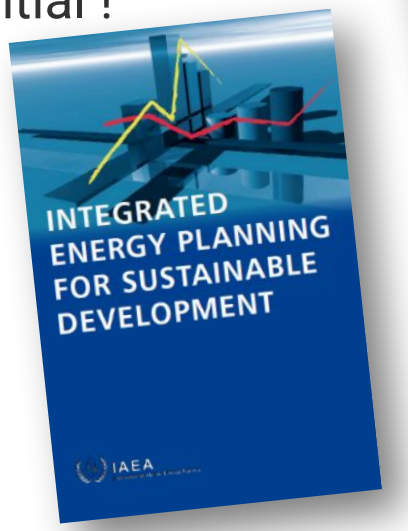
IAEA's Capacity Building for Energy Planning

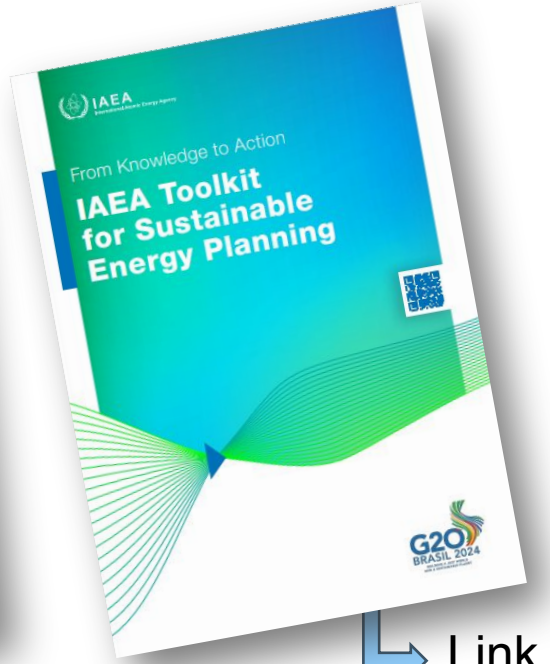
Energy planning is integral part of policy and investment decision-making in the energy sector

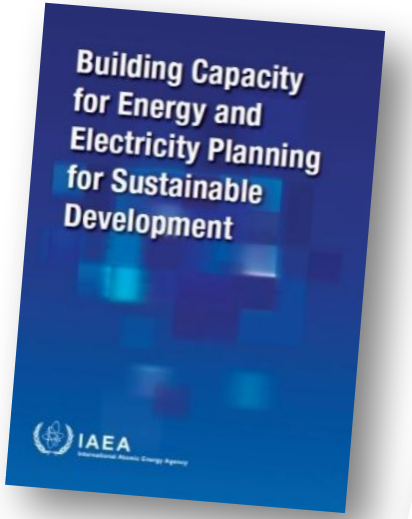
IAEA has pioneered capacity building activities and has decades of experience in supporting Member States in energy planning.

IAEA supports decision and policy making by assisting Member States to strengthen national capabilities in energy system analysis, so that countries can develop their own sustainable energy strategies

National expertise is essential !



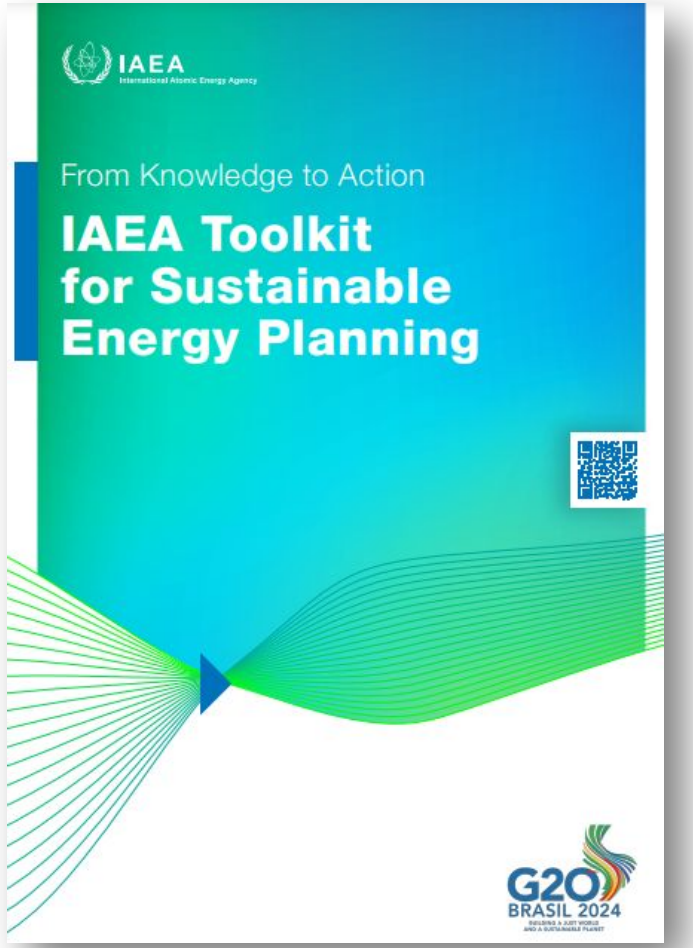




Link to 2024 Outlook

IAEA has a unique support programme

- ***To assist*** Member States in reinforcing national capabilities to conduct energy system analysis, so that countries can assess options and ***develop their own sustainable energy strategies***, i.e. support informed national decision and policy making



IAEA's Capacity Building Program for Energy Planning

Capacity Building for Energy System Assessment

Analytical Tools, Training and Support

Information Dissemination

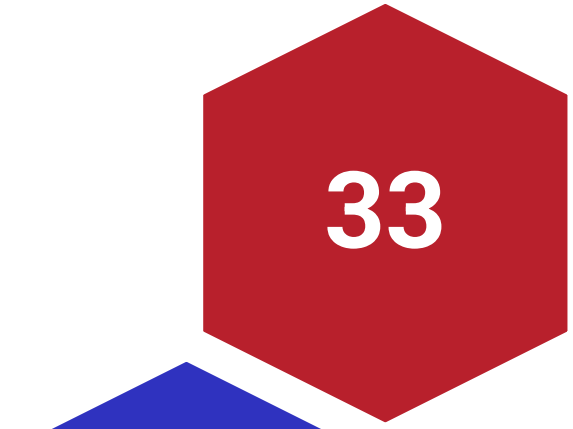
Technical Assistance for Energy Studies

COLLABORATION

Comprehensive Capacity Building in Energy Planning

- Distance learning
- Field trainings
- Expert missions
- Advanced trainings
- Teachers' trainings
- Fellowships (on-the-job training)
- Continuous Support
- External experts

KPIs for IAEA CB Programme in energy planning 2024



Number of training events conducted

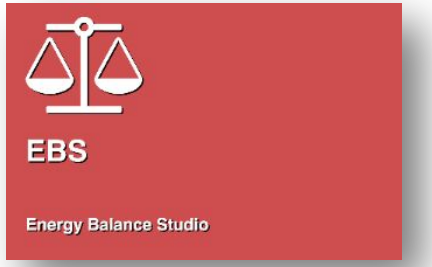
23 In-Person + 10 Virtual

Number of unique professionals trained

357 In-Person + 44 Virtual

Number of countries received support and training

IAEA's Energy System Assessment Tools



Energy Statistics and Energy Balances compilation

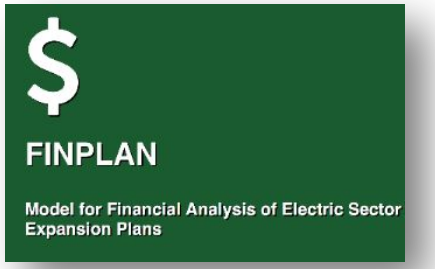
Energy Demand Analysis and Projections

Energy Supply Optimization and Simulation

Energy Scenario Simulation Tool for fast estimates

Power Generation Investments and Expansion Planning

Analysis of Power Plants Environmental Impacts



Analysis of financial viability of power generation projects

Quantification of macroeconomic effects of strategies

Energy Demand Analysis and Projections

- Input
  - Energy sector data (Energy balance), socio-economic data (GDP, economy structure, population…), lifestyle (housing, types of energy services…)
  - Scenario assumptions, socio-economic and technological data/changes; substitutable energy uses; process efficiencies; hourly load characteristics
- Output
  - Useful energy demand; Final energy demand by sector/fuel; electricity demand; rate of electrification; hourly electric load; load duration curves

- MAED provides a systematic framework for evaluating the effect of a change in socio-economic and technical development on energy demand

Power Generation Investments and Expansion Planning

- Inputs
  - Load projections
  - Existing power plants
  - Candidates for new build / expansion
  - Constraints: reliability, fuel, generation and emissions
- Outputs
  - Build schedule of new generating capacity
  - Generation, fuels consumption
  - Costs (investment, operational, fuel)
  - Emissions

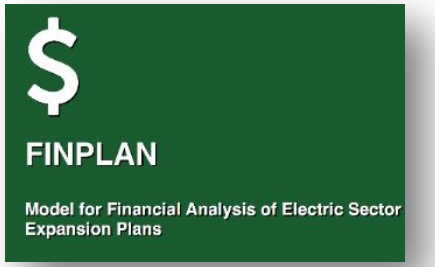
- WASP helps to determine least-cost expansion plans for power generation within user provided constraints

Energy Supply Optimization and Simulation

- Inputs
  - Energy system structure (including vintage of plants and equipment)
  - Base year energy flows and prices; energy demand projections (results of energy demand analysis
  - Technology and resource options and their technoeconomic performance profiles; technical and policy constraints
- Outputs
  - Primary and final energy supply structure
  - Emissions and waste streams;
  - Resources use; land use
  - Import dependence; investment requirements …

- MESSAGE is designed to formulate and evaluate alternative energy supply strategies consonant with user defined constraints on new investment, market penetration rates for new technologies, fuel availability and trade, and environmental emissions

Analysis of financial viability of power generation projects



- Inputs
  - Investment programme for power generation capacity additions and operating expenses
  - Economic and fiscal parameters (inflation, escalation, exchange rates, taxes);
  - Financial parameters and options(credits, bonds…)
- Outputs
  - Cash flows; Balance sheet, Statement of sources, Applications of funds
  - Financial ratios: working capital ratio, leverage ratio, debt repayment ratio, global ratio

- FINPLAN evaluates financial implications of an expansion plan for a power generation system. Since financial constraints are often the biggest obstacle to implementing an optimal energy strategy, the model is particularly helpful for exploring the long term financial viability of projects

Quantification of macroeconomic effects of energy strategies

EMPOWER

Macroeconomic Analysis

- Inputs
  - Input-output tables at regional, local or national level
  - Data on industrial development, households, employment and government budget
  - Structure of generation/capacities
  - NPP construction schedule, investment and operational aspects, localisation rate
- Outputs
  - GDP
  - Disposable income
  - Total and sectoral production
  - Total and sectoral employment
  - Private consumption
  - Exports & imports

- EMPOWER (**E**xtended Input Output **M**odel for Sustainable **Power** Generation) is being used to study macroeconomic effects of investments into nuclear energy and nuclear applications (for example radiopharmaceuticals and irradiation technologies)
  - Can consider construction and operation phase of an NPP
  - Offers considerations of various effects (direct, indirect, induced, labour market response, feedback effects from (partial) public financing of investments through tax increases or mark-up on electricity prices)

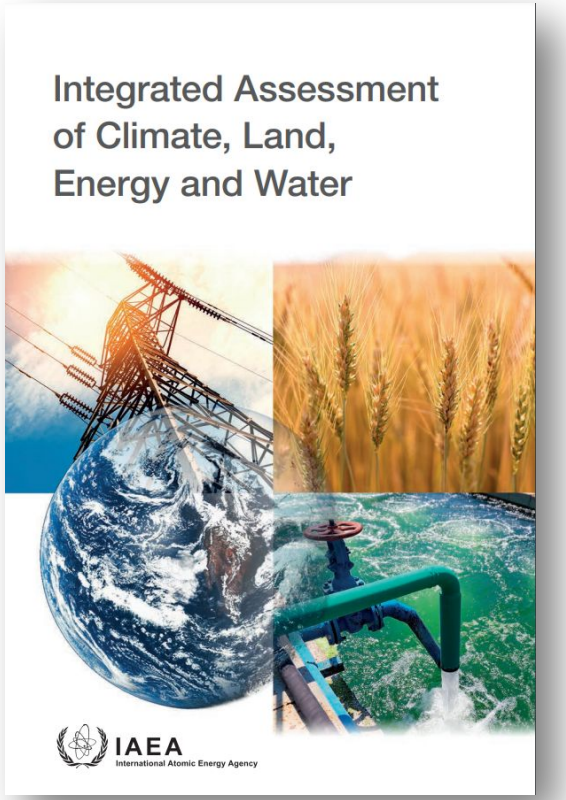
Climate, Land and Water use and Energy Interactions

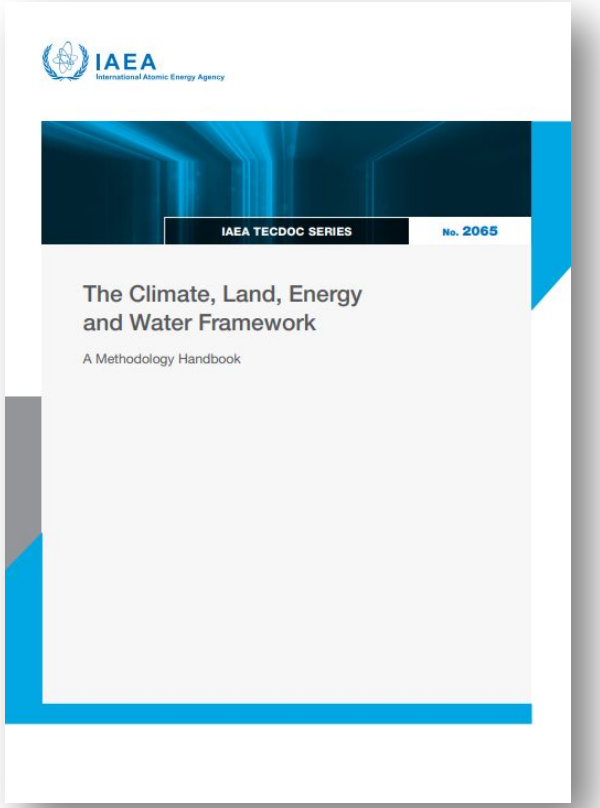
CLEW

Climate, Land, Energy and Water Nexus

- The CLEW framework integrates assessment approaches and methodologies and facilitates collaboration among policy analysts and planners dealing with complex interactions and linkages between climate, land, energy and water
- Potential applications
  - Identifying policy synergies and avoiding conflicting policies
  - Assessing the impact of technologies on multiple resources
  - Exploring scenarios to identify robust development pathways

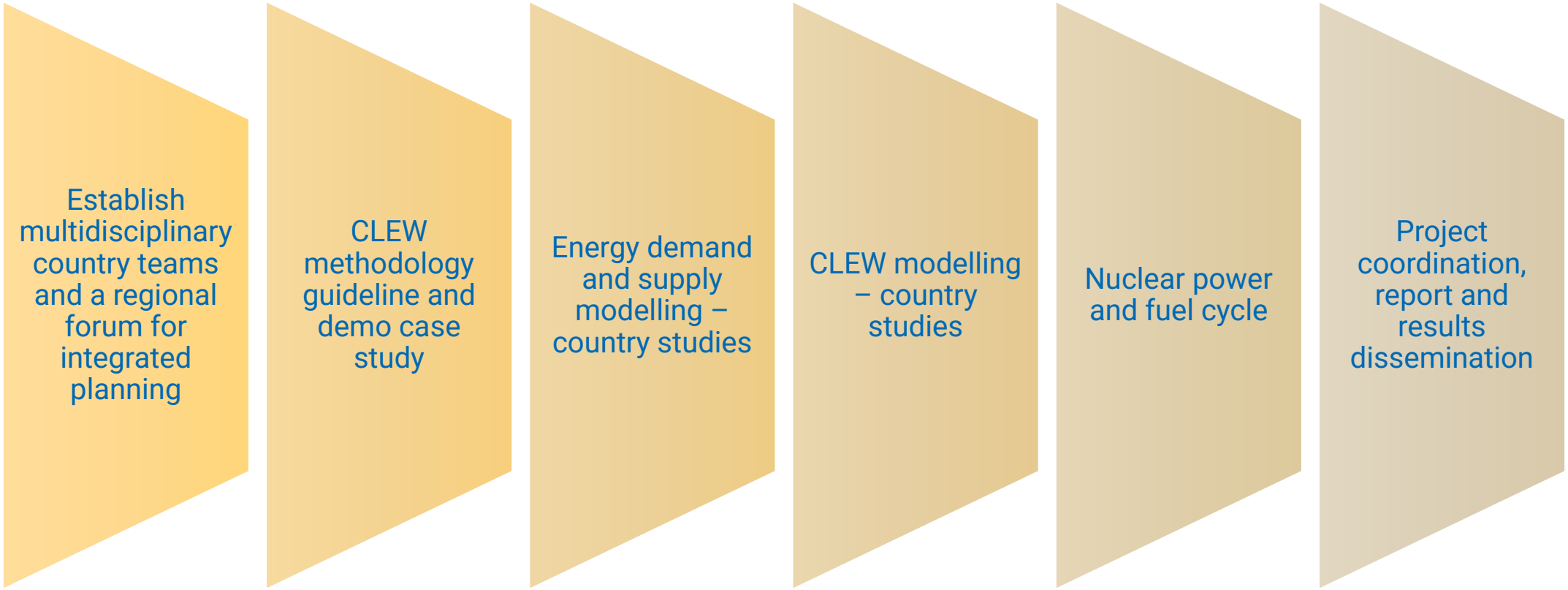
Long term planning within CLEW framework





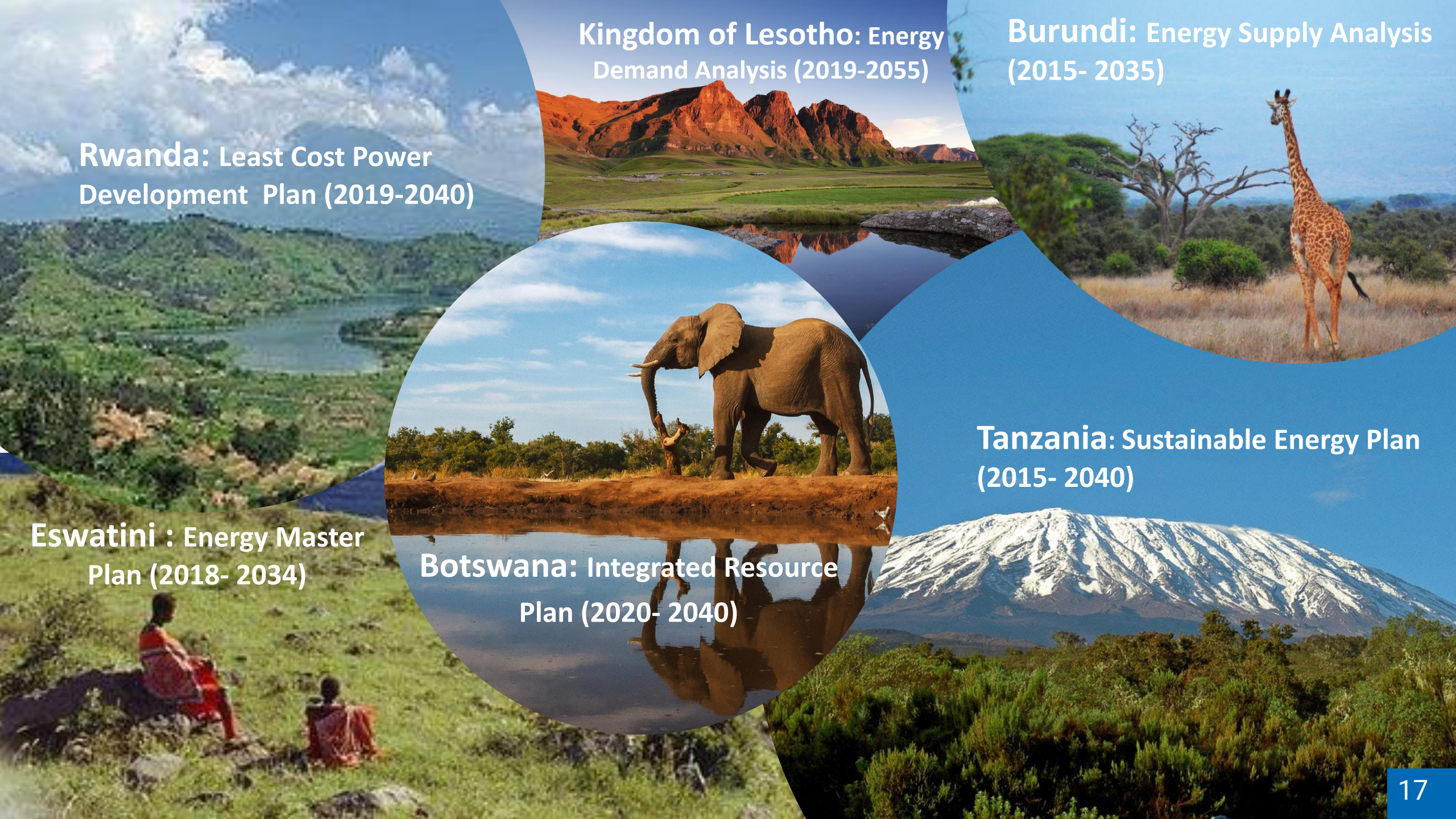
[Link: Methodology Handbook]

Example: Planning Sustainable Energy in LAC within CLEW framework

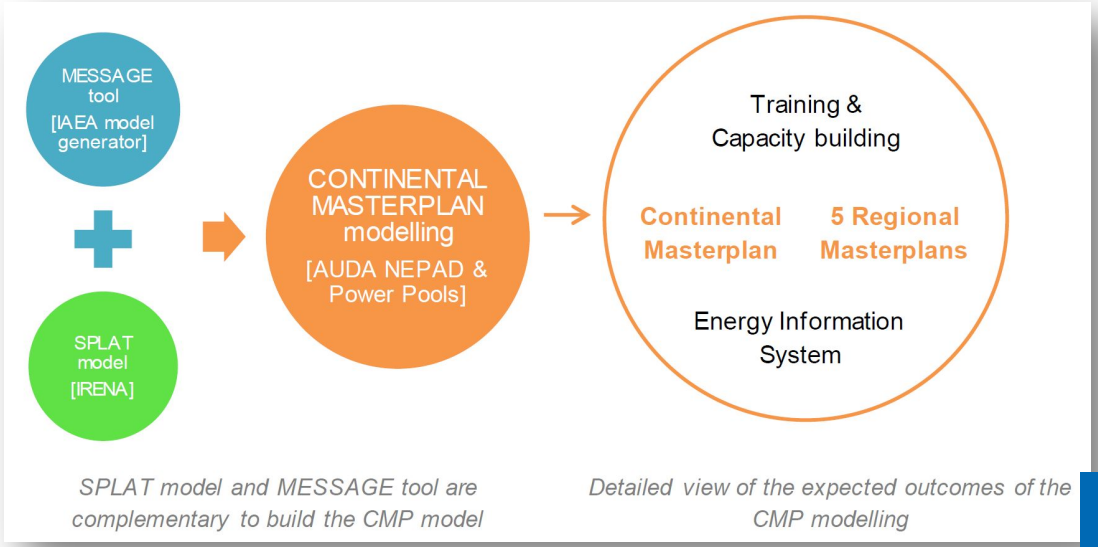


17 countries

Argentina, Bolivia, Brazil, Chile, Colombia, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Paraguay, Uruguay and Venezuela


Rwanda: Least Cost Power Development Plan (2019-2040)
Kingdom of Lesotho: Energy Demand Analysis (2019-2055)
Burundi: Energy Supply Analysis (2015- 2035)
Botswana: Integrated Resource Plan (2020- 2040)
Tanzania: Sustainable Energy Plan (2015- 2040)
Eswatini : Energy Master Plan (2018- 2034)

Powering up Africa: A Continent-Wide Power System Development Plan



SPLAT model and MESSAGE tool are complementary to build the CMP model

Detailed view of the expected outcomes of the CMP modelling

Cooperation – Collaborations – Partnerships

Provision of tools

Exchange of information

Join trainings

Complement in country support

Events participation

Example of cooperation with ADB – Trainings on energy supply model MESSAGE:

- In 2023, trainings were conducted for Southeast Asia and Central and West Asia countries
- In May 2024, training was conducted for South Asia countries in Dhaka, Bangladesh
- In Sep/Oct 2024, training was conducted for South Pacific countries in Nadi, Fiji
- In Sept 2025: IAEA, ADB, CCG and ESCAP to support the 1st Energy Modelling Platform Training for Asia and the Pacific (EMP-APAC), in Bangkok.

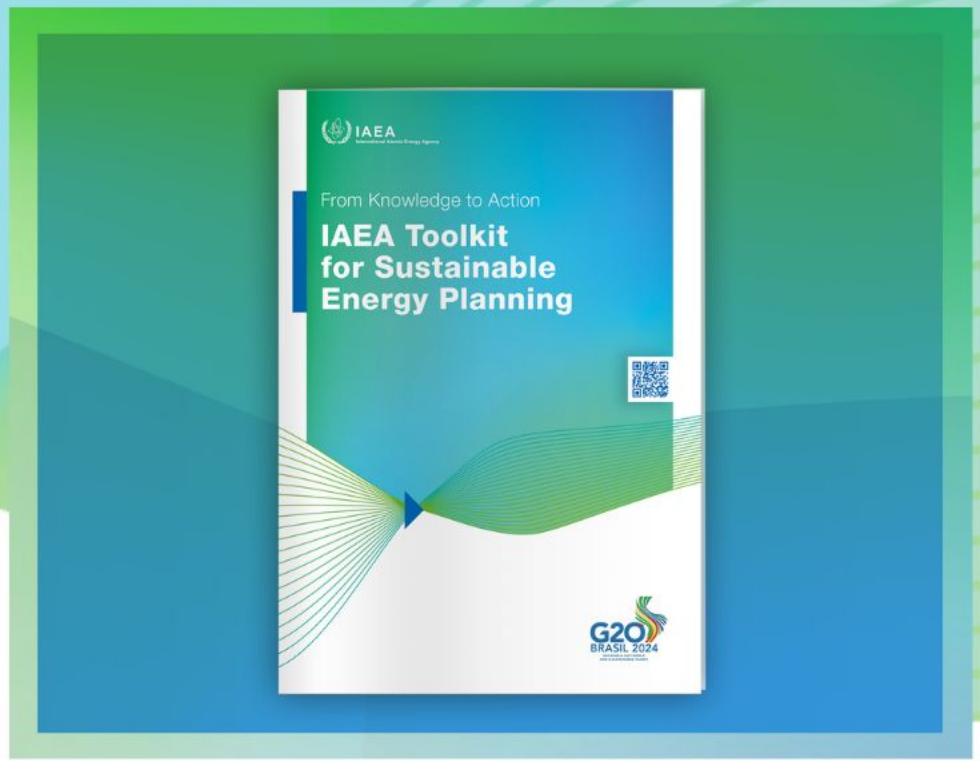
GLOBAL COALITION FOR ENERGY PLANNING

Principles:

1. Promoting Transparent and Effective Energy Planning
2. Facilitating Knowledge Exchange and Capacity Building
3. Catalyzing Investments through Enabling Environments
4. Encouraging National Ownership and Inclusive Participation
5. Leveraging Existing Initiatives and Partnerships

IAEA
International Atomic Energy Agency

From Knowledge to Action:
IAEA's Toolkit for Sustainable Energy Planning



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Thank you!

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Additional slides (not for presentation)

Energy Statistics and Energy Balances compilation

- **Inputs**
  - Energy products / commodities balances in natural units (energy statistics)
  - Specific conversion factors
- **Outputs**
  - Energy balance in energy units
  - Electricity tables

- EBS allows construction of Energy Balances from statistical data on production, import, export, transformation and use of different energy products
- EBS follows International Recommendations on Energy Statistics (IRES) and utilizes UNSD* annual energy questionnaire

*UNSD: United Nations Statistics Division

Energy Scenario Simulation Tool

- Inputs
  - Historical energy balance
  - Changes in the structure of final energy consumption
  - Existing generating capacities by fuel type, economic parameters (investment, fuel cost…)
  - Structure of desired future generation (user assumptions)
  - Hourly patterns (demand and production curves)
  - Generation capacity availability (FOR and MOR)
- Outputs
  - Future energy balances
  - New generating capacity / investments
  - Emissions
  - LCOE (input parameter based and estimate based on hourly simulation)
  - Simple hourly simulation results; energy not served; energy mix, other costs components

- ESST could be used as the first step in analysis and for identification of scenarios to be later analysed with more details with other, more sophisticated tools

FOR – Forced Outage Rate; MOR – Maintenance Outage Rat

Simplified Analysis of Power Plants Environmental Impacts

SIMPACTS

Simplified Approach for Estimating Impacts of Electricity Generation

- Inputs
  - Pollutant emission rates
  - Regional population density; local population; response functions adjustments
  - Source location; Stack characteristics;
- Outputs
  - Total exposure
  - Quantification of health impacts
  - Monetisation of impacts

- SIMPACTS estimates and quantifies health and environmental damage costs (externalities), of different electricity generation technologies. It consists of separate modules for estimating the impacts on human health, agricultural crops and buildings resulting from routine atmospheric emissions of pollutants from energy facilities

SEA of National Nuclear Power Program

- SEA is a decision support tool that aims to assist the preparation of policies, plans and programmes that are environmentally sustainable, which is essential for the development of nuclear power
- SEA should not be confused with EIA (Environmental Impact Assessment). EIA is done at the project level, while SEA is done at program level.
- Application
  - Support understanding of potentially significant negative and positive environmental implications when implementing nuclear power programme
  - Identification of development options and mitigation measures and assessing their environmental impacts from the outset of the formulation of policies, plans and programmes.
  - Can help to significantly reduce the costs that would otherwise be incurred with further pursuing certain plans/programmes
  - Provides a platform for effective communication with the public and other stakeholders, thereby offering opportunities for addressing the concerns they may have