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OASES

MODELLING TOOLS

How models are made? Scientific programming

Standard basic level skills in starting scientific programming include git & Python

Model landscape

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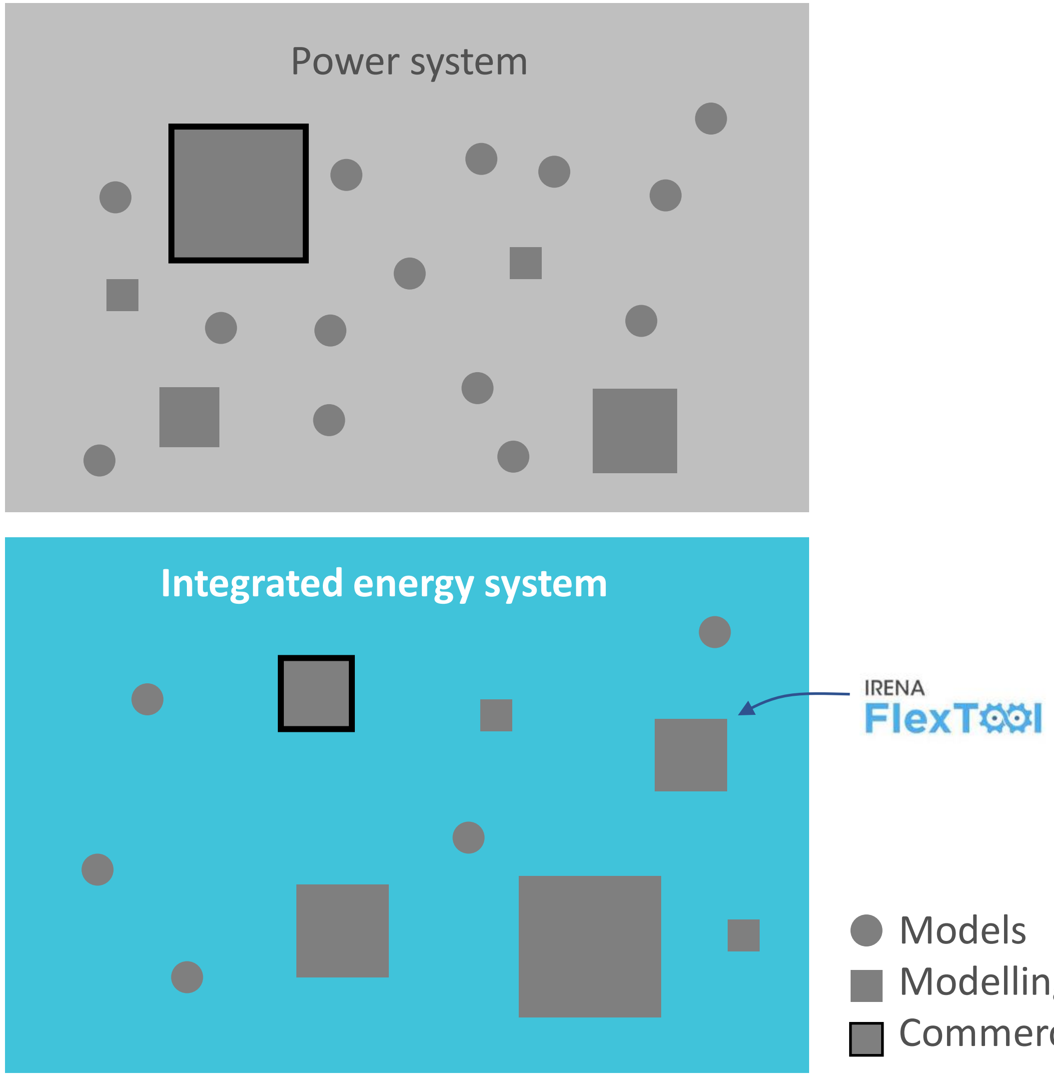

1. Under any model category, there is a multitude of ad-hoc models built for single purpose.
2. The more complex the model category, the less models exist.
3. Some models are built for repeated use as ”modelling tools” or ”frameworks”. Some are in-house, some commercial, some open-source.

Challenge: Models are developed individually and in parallel. Often the smarter choice to creating an own model is using open-source framework as is or as basis.

Why open source?

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1. Transparency and accessibility
2. Cost-efficiency
3. Customization and adaptability
4. Community collaboration and continuos improvement
5. Long-term availability

However, open-source models can be more complex to operate and require more expertise in use, development and integrations than proprietary software. Lack of customer support, and possible intellectual property concerns.

FIVE FREEDOMS

Freedom 0: To run the program for any purpose.

Freedom 1: To study how the program works, and change it to make it do what you wish.

Freedom 2: To redistribute and make copies so you can help your neighbour.

Freedom 3: To improve the program, and release your improvements/ modifications to the public.

Freedom 4: Redistribute the modified program as proprietary licenced software.

IRENA FlexTool is published under GNU Lesser General Public License (LGPL), allowing for Freedoms 0-3, but not Freedom 4.

Some well-known modelling tools

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Optimization models

- MARKAL/TIMES: Traditional large-scale long-term optimization
- OSeMOSYS: Open-source similar to MARKAL/TIMES
- MESSAGE: Traditional energy supply and demand optimization

Originally power system models, but expanded to integrated

- PLEXOS: Commercial electricity market and power system analysis
- PyPSA: Open-source detailed power system simulation

Scenario and policy analysis models (built for specific purpose)

- LEAP: National large scale long-term modelling
- NEMS: US energy policy
- PRIMES: EU energy policy
- SAM: NREL model to study financial viability of renewable energy projects

These are the tools IRENA FlexTool shares similarities with, however it is for planning integrated energy systems, with high time resolution (typically 8760 h/y) and medium time-scale (typically 5-30 years)

MODELLING PROCESS

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Modelling process

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1. Clear scope: geographical / temporal / system detail
2. Data gathering
3. Base case development
4. Testing and validation against base year
5. Scenario analysis
6. Reporting

Spine Toolbox approach to supporting the process

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Spine Toolbox was created to support the technical implementation of the modelling process:

Several data sources and their updates

Non-coder modellers

1. Clear scope: geographical / temporal / system detail
2. Data gathering
3. Base case development
4. Testing and validation against base year
5. Scenario analysis
6. Reporting

Several data transformations between data, model and results

Sharing, documenting and explaining work to others

Up to hundreds of scerarios

→ Workflow, data and scenario management

UNDERSTANDING THE IRENA FLEXTOOL APPROACH

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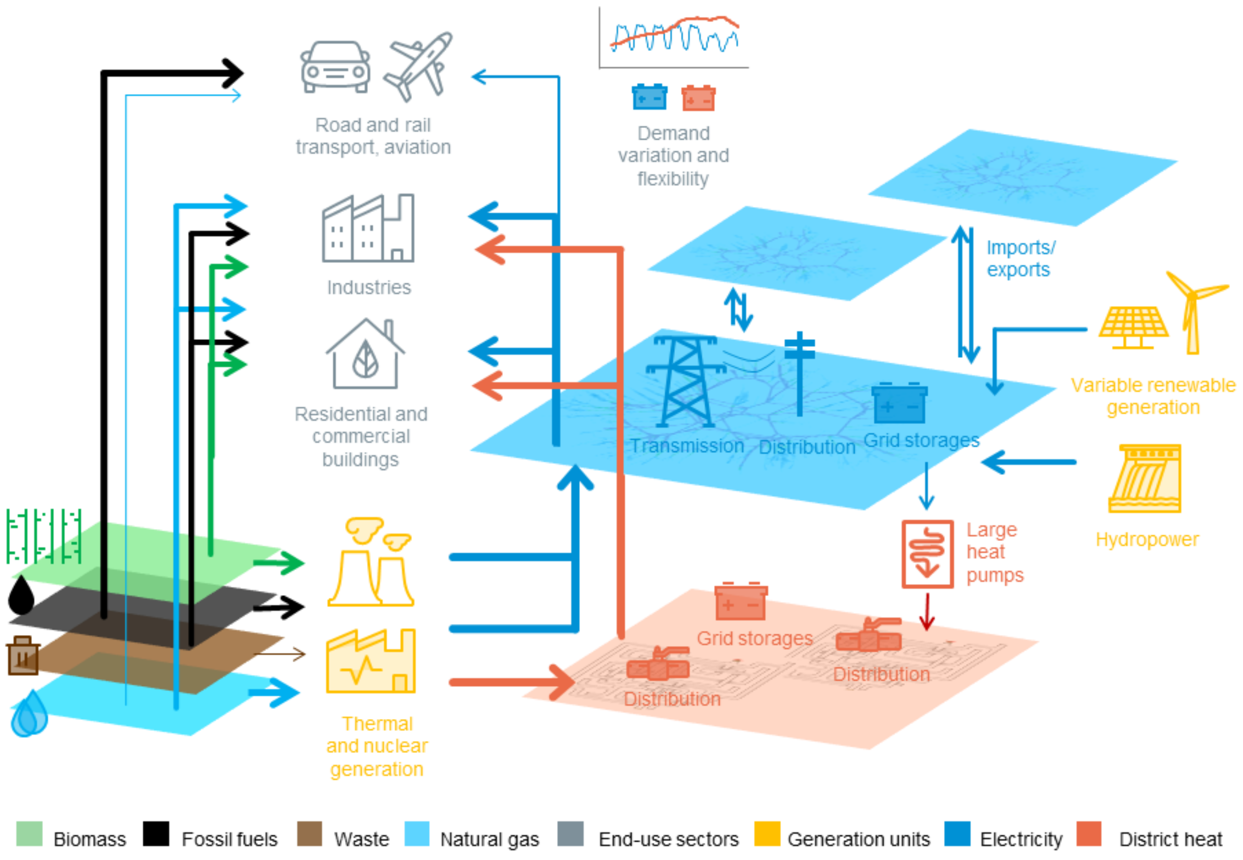
IRENA FlexTool modelling approach



Single-objective linear and mixed-integer linear optimization (annual system cost minimization)

For multiple energy sectors

In local, national and regional scales

INVEST PLANNING / CAPACITY EXPANSION

What would be the most cost-optimal investments for a certain system in a certain future setting?

OPERATIONAL PLANNING / SCHEDULING

How a certain future system would operate with given investments according to least-cost unit commitment?

Clarification: Linear optimization

FlexTool is a linear and mixed-integer linear optimization model

- Optimization means, in this context, that the model minimizes total system costs
- Model makes all choices between different options by minimizing total costs from the whole model horizon
- However, model has to satisfy the energy balance and obey constraints (e.g. generation from a unit plus reserve provision is less than the capacity of the unit)
- The model finds the least cost solution given the assumptions

Linear means, in this context, that everything can change between 0% and 100%

- Linear models are very fast to solve
- This allows us to include a large range of features into the model
- Linear models don't allow binary decisions (e.g. on/off)
- Users can give constraints to a large range of properties (e.g. share of solar power required)

Mixed-integer linear can be used for e.g.

- Minimum load constraints
- Bulk investments

However, it is significantly slower to solve, therefore use only when needed

Clarification: Energy balance and flexibility indicators

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The most important assumption of the FlexToolis energy balance → demand and supply must always match

This leads to many different kind of ‘what if’ situations

- What if there is too little production?
  → Model produces ‘loss of load energy’ to balance the demand and supply.
- What if there is more wind and solar than demand?
  → Model curtails part of the VRE production or uses storages to store extra energy.
- What if there is some flexibility issue, e.g. consumption at west, production in east, and too little transmission capacity?
  → Model has to find a way to solve the situation, e.g. to invest new transmission lines (if investments are allowed) or produce ‘loss of load’ in west and ‘curtailments’ in east.

Clarification: FlexTool solution

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CHALLENGE

How to compare these alternatives?

How to combine these criteria?

	Nuclear	Coal steam	Gas CCGT	Wind onshore & solar PV
Investment cost	Very high	Moderate	Low	Moderate-high
Construction time	4-10 years	4-5 years	2-3 years	0.5-2 years
Operational & maintenance cost	Low-moderate	Moderate-high	Low	Very low
Fuel costs	V[illegible]	[illegible]	[illegible]	Nil
Operational characteristics	Baseload, limited flexibility	Baseload, moderate flexibility	Mid-load, high flexibility	Intermittency, low load factor
$CO_{2\text{-eq}}$ emissions	Negligible	High-very high	Moderate- high	Negligible
Key risks	Completion, regulatory (policy changes), public acceptance, market	Regulatory (CO_2 and pollution), public acceptance, market	Regulatory (CO_2 and pollution), market	Regulatory (policy changes)

How to interpret the results?

FLEXTOOL SOLUTION

Technology neutral bottom-up approach

1. Monetize all possible parameters
2. Annualize
3. Use high temporal resolution
4. Use constraints where you can't monetize

Minimize annualized system costs (operational and investments)

FlexTool doesn't dictate result analysis, but is optimally used for comparison of different scenarios and assessing flexibility needs in system

Image source: Rogner (2017)

Clarification: Inputs and outputs

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INPUTS

Generation capacity (as aggregated units with parameters, per node)

Demand (as hourly time series)

Storage (per unit-node)

Energy transfers (per node)

Commodities and capacity factors (timeseries, prices)

Spatial data (as nodes)

Temporal settings

Technology invest costs

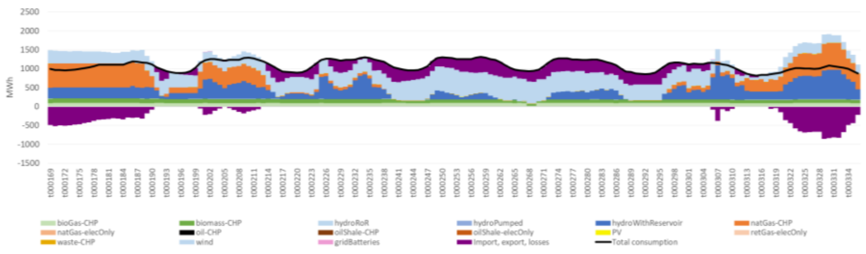
OUTPUTS

INVEST PLANNING

Invested amount of each type of generation, other technology and transmission

SCHEDULING

Unit commitment and dispatch



Emissions
Costs
Prices
Flexibility indicators