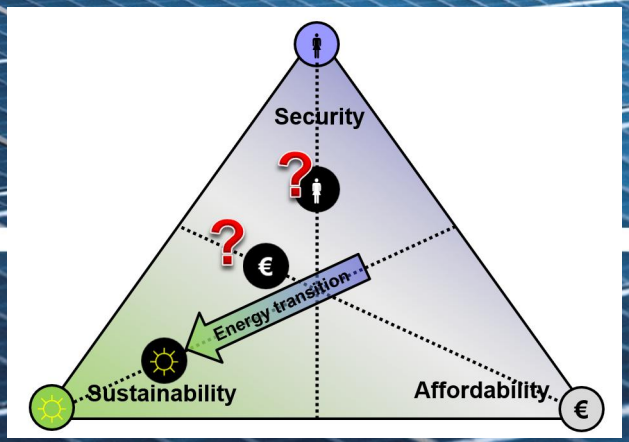
DECISION-MAKING UNDER DEEP UNCERTAINTY

Experiences from oil/gas E&P and energy transition modelling | Ir. C.F.M. Bos



ECN TNO innovation for life

COMPLEX SYSTEM AND UNCERTAINTY MODELLING FOR INVESTMENT DECISION SUPPORT

- Career-long experience in hydrocarbon reserves estimation, oil field production forecasting and development, reservoir simulation modelling, economics, T2B, investment decision & risk analysis, asset performance economic evaluation, portfolio management, lecturing on these topics, CCS + geothermal asset performance modelling, energy system evolutionary modelling (Agent-Based Modelling).

- **Oil / gas E&P and geothermal subsurface system**
  - Highly non-linear (multi-phase flow), spatially heterogeneous (multi-dimensional / -properties), sparsely sampled (only few wells), basic physics not always well understood, interaction of multi-physics poorly understood (FMCT), (poor) statistical correlations → endogenous uncertainties
  - Exacerbated by large market uncertainties (capex, opex, oil price) → exogenous uncertainties) and operational uncertainties (how will asset perform?)
- **Carbon Capture and Storage**
  - Modelling multi-actor CCS chains (T2B), contract modelling, security of supply & security of offtake, “closing chain”.
- **Energy Transition Modelling**
  - Multi-commodity, multi-actor, imperfect foresight, evolutionary dynamic system modelling.

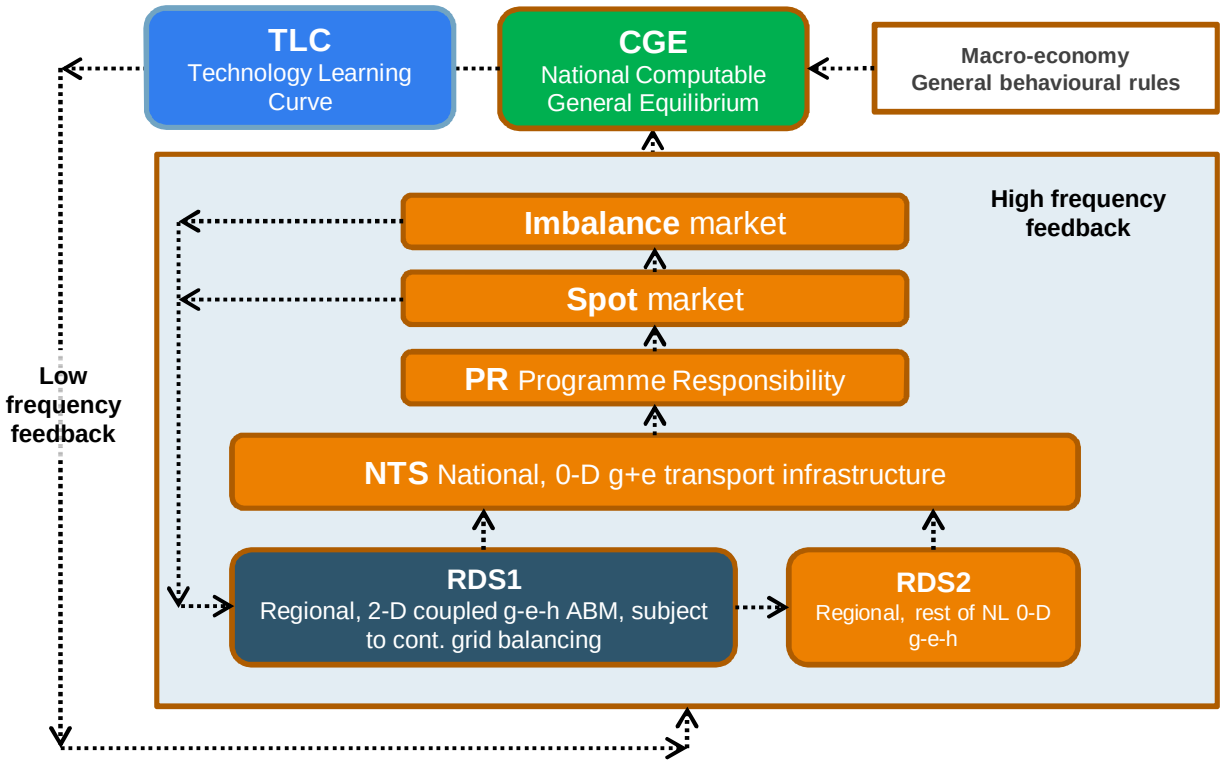
"DEEP" UNCERTAINTY

- "Deep" uncertainty may be characterized by systems that:
  1. have limited performance predictability using models, due to sparse sampling wrt. spatial heterogeneity of properties / state variables for model initialization, high dimensionality of system properties, non-linear relationships, different relevant time-scales, tipping points, multi-components, multiple aggregation levels, ST-MT-LT feedback mechanisms, incompletely known physics / behavioural rules, etc. (system complexity).
  2. have a complex governance: multi-actors with different preferences and constraints; actors influence each other's behaviours; actors are subject to imperfect foresight and strike dynamic options / react on the system's new state variables; actors learn and adapt their behaviours.
  3. are evolving in terms of hardware installed, and are subject to continuous dynamic changes.
- In my experience:
  - Deep uncertainty can be modelled, system performance can be predicted probabilistically (including effect of dynamic options modelling in multi-actor / imperfect foresight setting, including dynamic feedback), PCA / SA / robustness / Bayesian updating etc. can be computed, HOWEVER:
  - Many psychological, intellectual, time-constraint, organizational, communication etc. barriers.

HURDLES

- “There’s too much uncertainty to use probabilistics”
- “The learning curve is too steep”
- “We are not being paid for doing look-back analyses” (“no time” argument)
- “We are rewarded for giving certainty, not for giving uncertainty”
- “Modelling even more underlying processes only complicates the analytics”
- “KISS” / “fit-for-purpose”, without saying explicitly what this means
- “We do not even agree on basic assumptions such as how to include risk in the WACC / discount rate”
- “Modelling probabilistics only relays the problem to a deeper level, such as what stochastic correlation coefficients to use”
- “Decision-makers have no incentive to understand and support transparent decision-analytical techniques, as they thrive on opaque decision-making, which brought them to their current level”
- Macho attitudes, lack of humility and curiosity
- ⇨**Communicating the results of complex-system performance computations is a challenge.**
  - Ref. paper by John Sterman (*All models are wrong: reflections on becoming a systems scientist*)

DYNAMIC ETM USING ABM FOR REGIONS



- It is how private actors invest in energy hardware and systems which drives the energy transition.
  - The ET is in essence addressing the question of how to mobilize private capital.
- Yet this is hardly modelled in current ETMs.
  - No/ltd uncertainty modelling (perfect foresight, no / ltd heterogeneous preferences, no / ltd options modelling
- Most ETMs are not dynamic.

TOWARDS UNDERSTANDING WHICH MODEL FUNCTIONALITY IS REQUIRED FOR WHICH RQ

- Common approach in ETM:
  - Selecting some modelling approach which feels comfortable and brushing aside the limiting assumptions. For example by over-simplifying the research question, e.g. “assuming a single actor with perfect foresight and assuming all processes to be linear, compute the minimum cost option for the stated objective”.
    - Whereas: no single actor, no perfect foresight, processes highly non-linear, minimum cost is never the criterion for investors.

- To better understand which model functionality (functions, resolution etc.) is required for which research question, we should systematically do *benchmarking studies and learn from differences* of using >2 models on the same case.

- Alternative: data-driven black-box models (ANN)? Will that work for a system-in-transition?

SOME TAKE-AWAYS

- Models are for insight, not for predicting the future. The objective are: robustness analysis (downside management) and exploiting uncertainty by creating / striking options (upside management).
  - Obvious, but seems only too often forgotten.
- Research question should be very well articulated: based on this articulation, and given one's understanding of the system's non-linearities and feedback mechanisms, one should be able to select time-resolution, spatial resolution, model functionality, probabilistic modelling options, how to simulate actor behaviour (how do they create options and respond to the model's state variables?), KPIs / decision criteria….. And design SA / Robustness Analysis workflow.
- Communicating about the uncertain future performance of a complex system, and how as a result one can design dynamic options (and assess the VoF), is extremely recalcitrant. Robustness analysis is by and large simplistic / unscientific.
  - "*Make uncertainty your friend*" is a mind-set that has long been advocated, but it is hardly adopted.
  - One seems to prefer ignoring important uncertainties / options, and limit the robustness analysis.
- Existing decision analytical techniques and processes are not exploited to the full.
- We need systematic modelling benchmark studies before going more in-depth with new models.