Fuel cycle modelling as a disarmament verification tool

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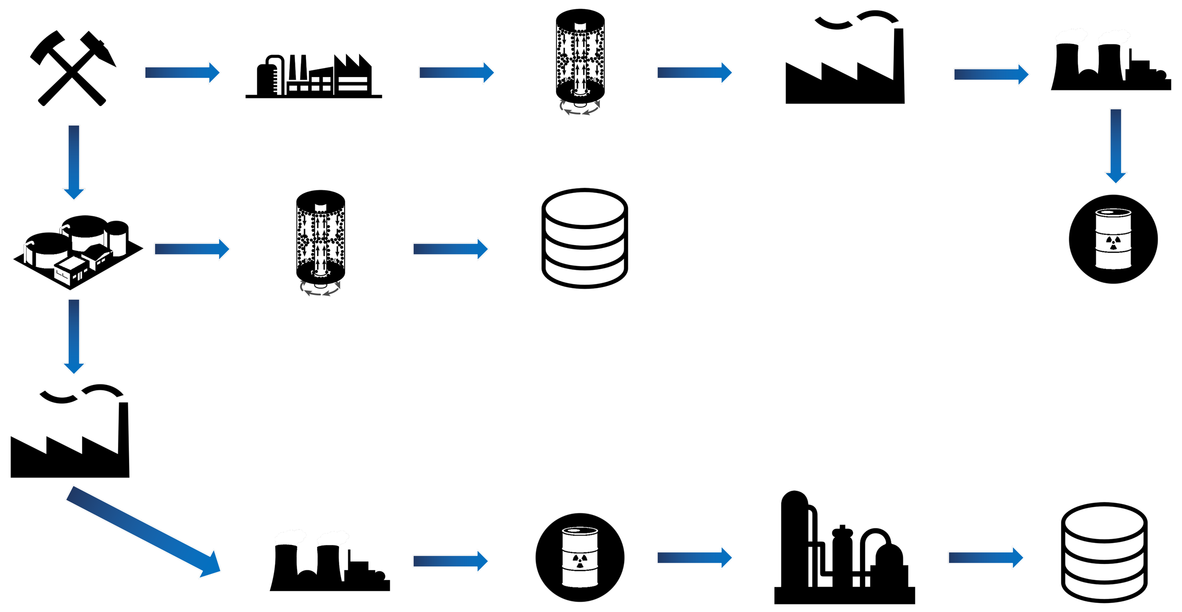
BACKGROUND:

Understanding a state's fuel cycle is a prerequisite step to plan for disarmament verification. Fuel cycle modelling can provide an enriched understanding of how a state's fuel cycle operates. Existing approaches to estimate fissile material inventories use direct estimates of enrichment capacity and reactor production of plutonium. **These approaches are limited when knowledge of the fuel cycle is uncertain.** Modelling the fuel cycle as a system can assess the validity of the chosen scenario and consider the possibility of clandestine facilities.

WE PROPOSE TO EVALUATE THE FUEL CYCLE AS A SYSTEM

A **baseline scenario, compiled from open source information,** can be built using a **nuclear fuel cycle modelling software**. The software treats **each facility** within the fuel cycle **as a node within a system.** Based on a parameter set for each facility, the software performs the mass balance calculations and tracks the flows of fissile isotopes across the fuel cycle.



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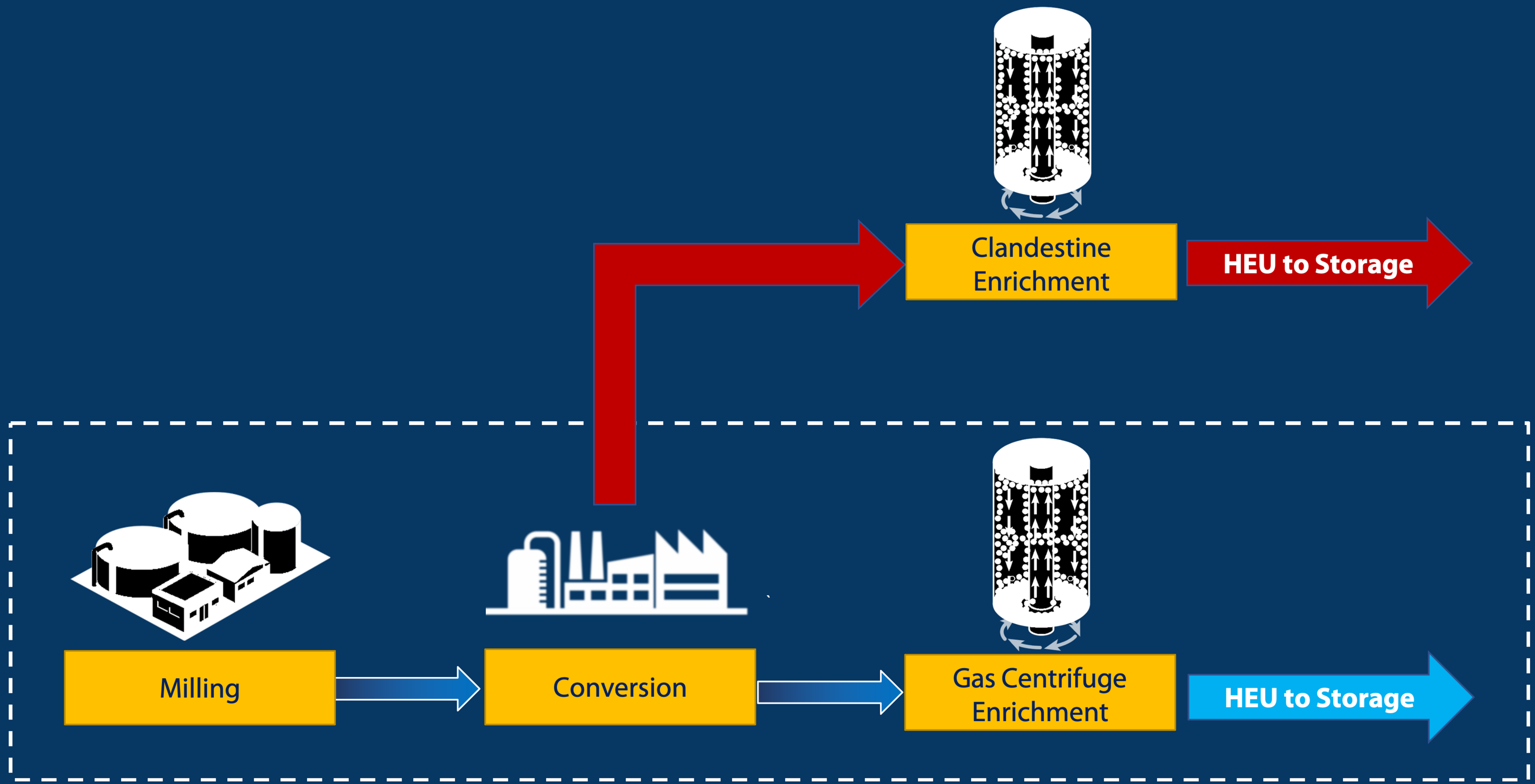
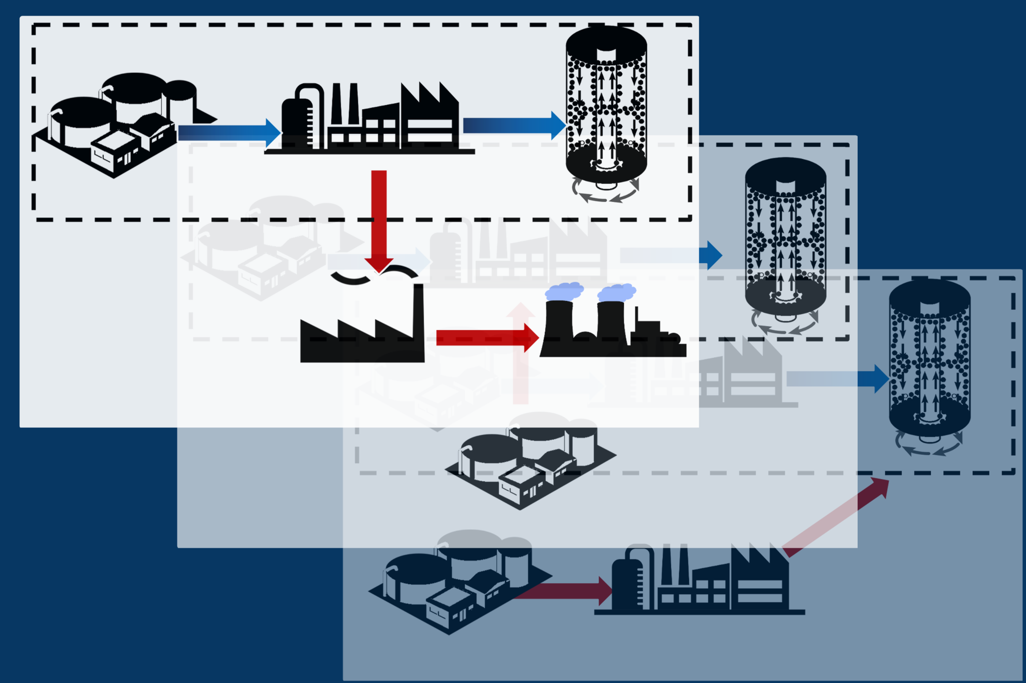
Modelling the fuel cycle as a system allows for the assessment of **inconsistencies** and identification of **key facilities**



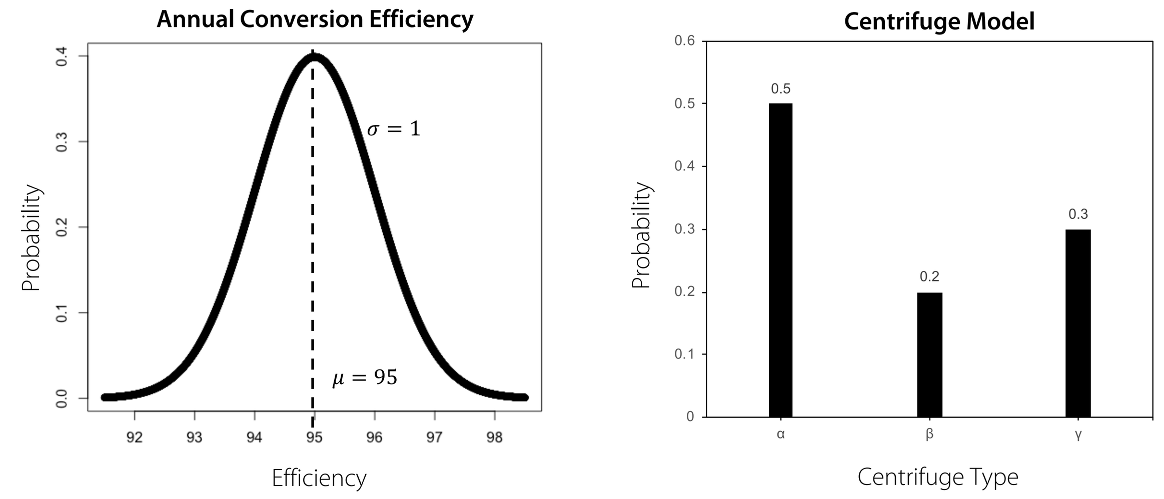
Models explore **the range of possible fuel cycle scenarios**



This can be used to support and guide verification efforts

Take a picture to download the full paper, see future work and see what other scenarios could be consistent with the baseline assumptions.

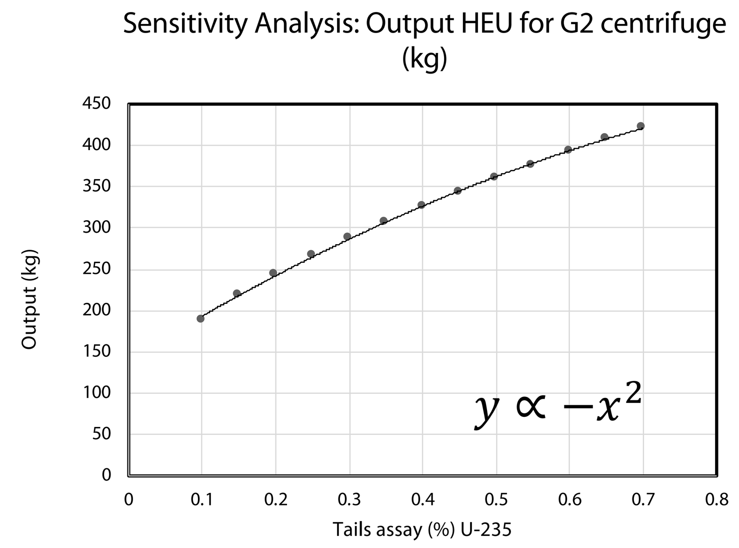
UNCERTAINTIES :



Whilst many input variables can be modelled as normally distributed, this is **not** always the case in complex systems such as nuclear fuel cycles.

The operating parameters for each facility may not be known. To model this, input parameters from the fuel cycle can be estimated from open sources and assigned a credible uncertainty and suitable distribution. Uncertainties are often normally distributed. However, **many of the model parameters nuclear fuel cycle are not.**

SENSITIVITY ANALYSIS:

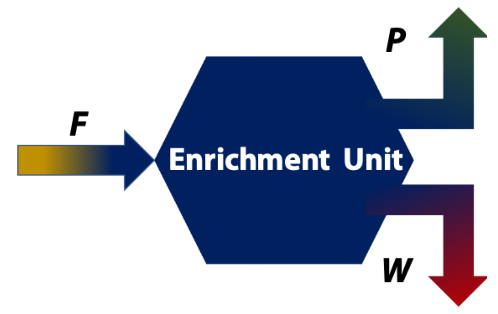


As input parameters are varied, the facility throughput changes. Sensitivity is the study of how an output variable, or an outcome, is impacted by changing the input variables. For example, **models for centrifuge enrichment will exhibit non-linear relationships between inputs and output**. The graph above shows a quadratic relationship between the tails assay and output of an ideal centrifuge cascade.

$$F = P + W$$

$$V((N) = (2N-1)\ln\frac{N}{1-N}$$

$$\delta U = PV(N_P) + WV(N_W) - FV(N_F)$$



A few of the key equations that characterise the centrifuge are found below. Here, F is feed, P is product, W is waste, N_x is the respective fraction of U-235 in each stream, V is the value function and δU is the separative power of an enrichment unit.

SYSTEMS LEVEL EFFECTS:

A baseline scenario can be built based **from open source information**. Some sets of input parameters may be distributed such that **multiple scenarios with differing fuel cycle configurations become equally likely.** For example, an addition of a clandestine enrichment facility to the baseline scenario is consistent with available material flows.

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