Nuclear Energy Division (DEN)
Nuclear Activities Direction of Saclay (DANS)
Institute for Techno-Economics of Energy Systems (I-tésé)

# Long-term availability of uranium resources: a bivariate statistical approach

Antoine MONNET*, Jacques PERCEBOIS**, Sophie GABRIEL*

*CEA/DEN, F-91191 Gif-sur-Yvette, France
** Université Montpellier 1 – UFR d'Economie – CREDEN (Art Dev UMR CNRS 5281), Avenue Raymond Dugrand, CS 79606, 34960 Montpellier

Corresponding author: A. MONNET
antoine.monnet@cea.fr

## Background and objectives – Uranium resources

The expansion of the world nuclear fleet depends on the uranium resource availability

↓

Necessity to analyze the supply/demand equilibrium in the long term

**Supply model**

**Price formation mechanism**

**Exogenous demand**

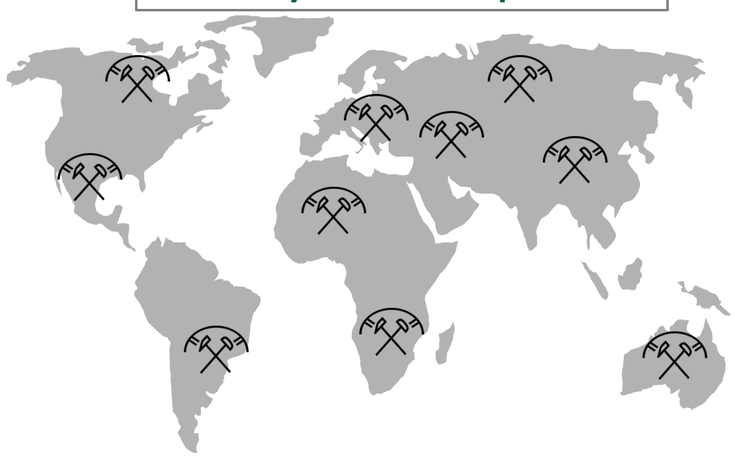
What quantities? At what cost? (Cumulative supply curve)

**Long-term U price**

World nuclear power scenarios

## Methodology – Supply model

**Today's known deposits**



**IAEA uranium data: UDEPO**

1 deposit ↔ 1 grade, 1 tonnage

**Regional statistical approach**

**Specific regional economics and geology**



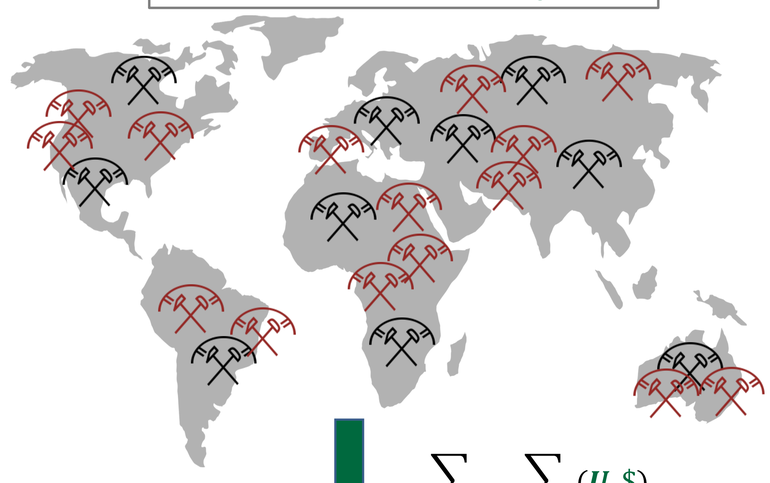
**Bivariate supply model**

**Deposit cost and U content**
**Functions of grade and tonnage**

**WISE data** (Recent mining projects)

1 mining project ↔ 1 U quantity ***U***, 1 unit cost ***$***

**Known & unknown deposits**



$\sum_{regions} \sum (U, \$)$

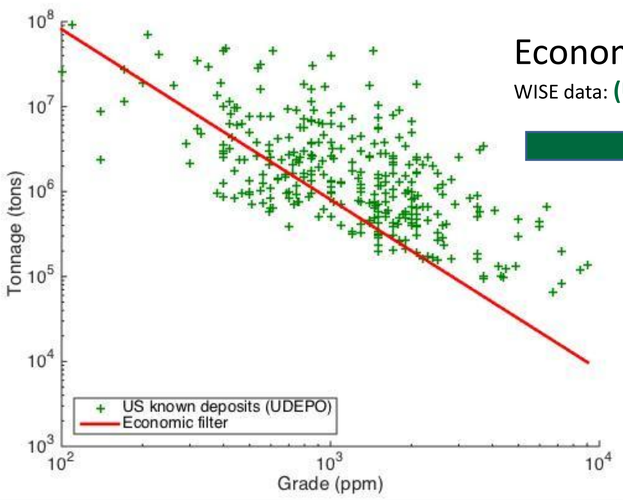
**Long-term cumulative supply curve**

The other recent supply models are either very simplified (cost and cumulated quantities are functions of grade only, cf. Schneider, MIT) with world aggregated data and no regional specificity, or very detailed (multi-parametric, cf. USGS), allowing for precise regional appraisals but no systematic approach for the world due to unavailable data in many countries.

## Early results – Supply model: the case of the United States

**Known US deposits (teneur, tonnage)**
(IAEA uranium data: UDEPO)

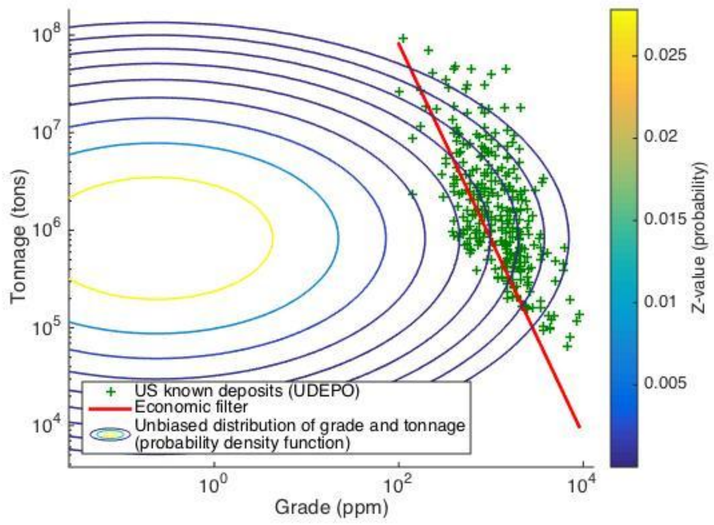
Bias due to the discovery of bigger and richer deposits first




Economic filter
WISE data: (U,$)

**Unbiased grade & tonnage distribution: known & unknown US deposits**

Bivariate lognormal model



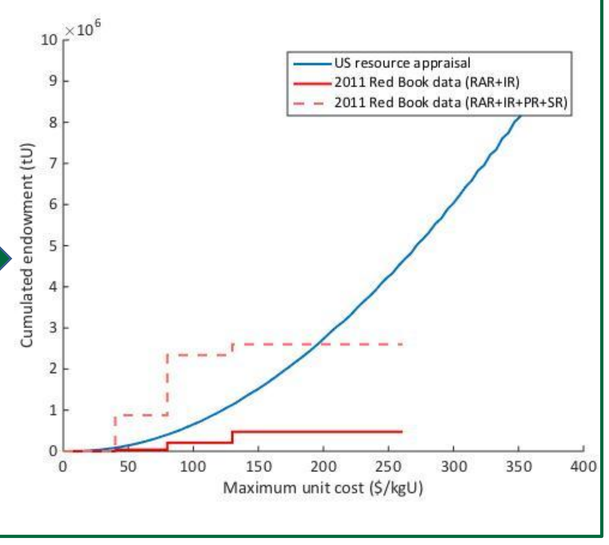

**US cumulative supply curve**

Economic appraisal
WISE data: (U,$)

Cost of all deposits (U,$)

Resource aggregation following a merit order

$\sum (U, \$)$




## Further developments – Price formation mechanism

From **supply model** to **price formation mechanism**:

- The application of the supply model to the US will be conducted for the world allowing the long-term resource depletion to be included in the mid-term dynamics of the price mechanism.
- Existing price formation mechanisms: generally limited to short/mid-term applications with limited production rates but with no resource depletion.

The **price formation mechanism** will take account of:

- Limited regional production rates, based on profitability
- Resource depletion through the supply model
- Discoveries as a function of exploration activities
- Mining development, potentially dependent on allocated profits, and individual strategies

**References**

A. Monnet, et al., *Assessing the potential production of uranium from coal-ash milling in the long term*, Resources Policy, vol. 45, pp. 173-182, 2015.
A. Monnet, et al., *Statistical model of global uranium resources and long-term availability*, Global 2015, September 20th-24th, Paris, France (Accepted).
A. Monnet, S. Gabriel, *Uranium from coal ash: resource assessment and outlook on production capacities*, Proceedings of the International Symposium on Uranium Raw Material for the Nuclear Fuel Cycle (URAM 2014 conference, IAEA, Vienna).
A. Monnet, et. al., *Unconventional uranium & feeding the future nuclear fleet*, Presentation at the Technical Meeting on Uranium from Unconventional Resources (IAEA, Vienna, 2014).