New Perspective on In-situ Recovery (ISR) – the Intelligent Mining Alternative

- ISR – a technology developed in the 1960s, mainly applied to uranium production from sedimentary deposits (meanwhile the predominant U recovery technology worldwide)
- ISR – an attractive recovery technology with significant advantages over conventional mining (underground, open pit) including:
  - Low to moderate costs for mine development – Profitable on lower grade deposits
  - Lower environmental impacts – Reduced solid waste (no waste rock, no tailings)
  - Reduced period of project development and start-up
  - Lower CAPEX/OPEX (energy, labour, equipment, restoration, CAPEX partially distributed over project lifetime)
- ISR – in addition to uranium, industrially applied (at least pilot-tested) to:
  - Some key industrial metals (Cu, Zn, Ni) and others (Au, V, Mo, ...)
  - Several technology metals including Re, Se, Sc, Y, REE

**ISR – just operating wellfields and selectively leaching the metal(s) of interest from the orebody directly**

**ISR – MINING without MINEWORKS**

- Well construction preserving vegetation

**Example: Wellfield installation under desert-like climate conditions**
UIT's Competence – Based on Industrial Practice and Scientific Approaches

- **Feasibility studies** by the generic modelling of potentially ISR amenable deposits and conceptual metal processing
  - Combining advanced ISR-model-based recovery predictions with economic models (schematic below)
- **Advanced exploration technologies** specifically developed and optimized for ISR deposits
  - High-resolution, shallow seismic and other geophysical surveying methods
  - Efficient, highly integrative borehole logging
- **3D structural modelling** combining the hydrogeological framework with ore morphology
- **Performance of dedicated lab tests** and model-based interpretation for upscaling to field conditions
  - Core assays and kinetic leach tests (including radioactive, NORM-bearing samples)
  - Specialized (temperature-controlled, pressurized) column test facilities, precisely controlled and equipped with automated data acquisition and graded sampling
- **3D hydrological modelling** combining
  - Regional hydrology (natural groundwater model)
  - Local wellfield hydrology (based on wellfield design) embedded in regional model
- **1D-3D reactive transport modelling** for simulating and optimizing ISR performance
- **Optimal ISR monitoring** solutions (networks) for environmental compliance
- **Engineering** of wellfields and processing plant
- **Post-mining measures** securing environmental compliance

---

**DEPOSIT CRITERIA**

**Ore Morphology**
- Total resource and deposit extension
- Degree of uniformity in wellfield pattern scale
- 3D ore grade distribution and averages (GT)

**Hydrogeology**
- Host formation (3D)
- Confinement
- Critical connectivities (tectonic faults etc.)
- Depth of ore body
- Free-fluid porosity
- Hydraulic conductivity

**Mineralogy**
- Target metal (ox/red)
- Abundance of reactive (interfering) minerals
- Clay (CEC/AEC)
- Organic matter
- Overall mineral texture/reactive surface

**GW Chemistry**
- Groundwater (GW) composition, pH, Eh
- Salinity
- Saturation conditions
- Temperature

**Microbiology**
- Microbial species and abundances
- (Potential) nutrient resources

---

**ISL PERFORMANCE CRITERIA**

**WF Design**
- Wellfield geometry (pattern) versus ore morphology
- Inj.-extr. spacing
- Well screening (\( \Delta z \))

**ISL Performance**
- Acidic/alkaline – pH/reagents
- Oxidation potential \([A^-]_{reagents}\)
- Complexing ion concentration (if relevant)
- Catalysts (if relevant)
- Injection of microbes/nutrients (if relevant)

**ISL Leaching Kinetics**
- Kinetic rates of metal leaching, interfering rates, thermodynamic constraints

**Production Rate**
- \( Q = \text{flow rate} \times \text{metal concentration in lixiviant as } f(t) \)

**ECONOMIC MODEL**

- **Costs** (CAPEX/OPEX)
- **Revenue** (generated)
- **Cash Flow**
  \[ C_n = \text{Revenue} - \text{CAPEX} - \text{OPEX} \]
  \[ \text{NPV} = \sum_{n=0}^{N} \frac{C_n}{(1 + i)^n} \]
- **NPV** (net present value)

**UIT's partners:**
- HZDR (DE)
- CSIRO (AU)
- BGS (GB)
- IAEA (UN)
- and others