
**Ben McLellan**
Kyoto University
Graduate School of Energy Science

# Critical minerals and energy

## impacts and limitations of moving to unconventional resources

**Benjamin C. McLellan, Eiji Yamasue, Tetsuo Tezuka – Kyoto University**
**Glen Corder, Artem Golev – University of Queensland**
**Damien Giurco – University of Technology, Sydney**

# Critical minerals

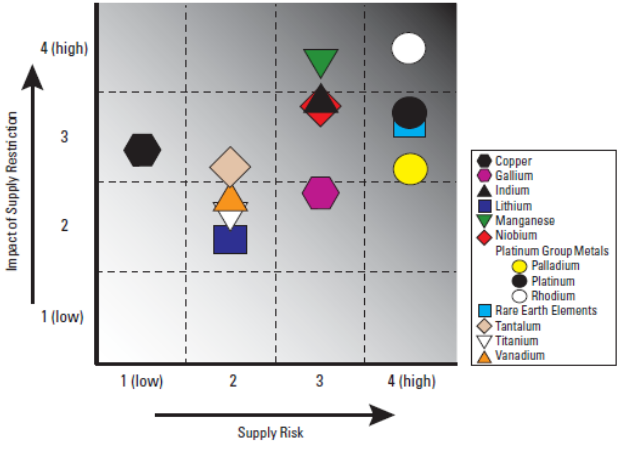
…a mineral can be regarded as critical only if :

- it performs an essential function for which few or no satisfactory substitutes exist

AND

- there is a high probability that
  - supply may become restricted, leading either to:
  - physical unavailability or
  - significantly higher prices

**Criticality Matrix for the USA**

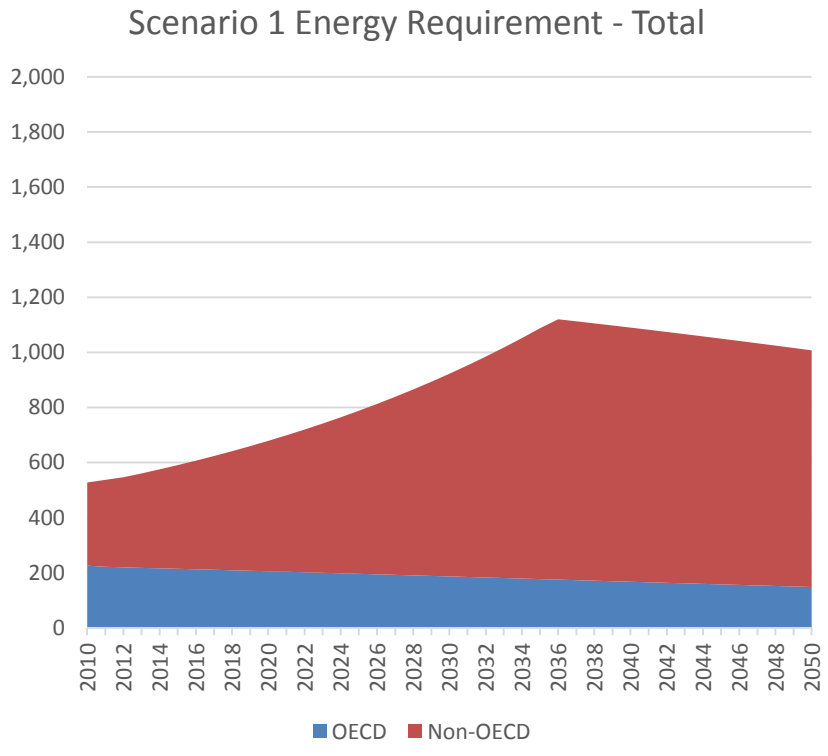


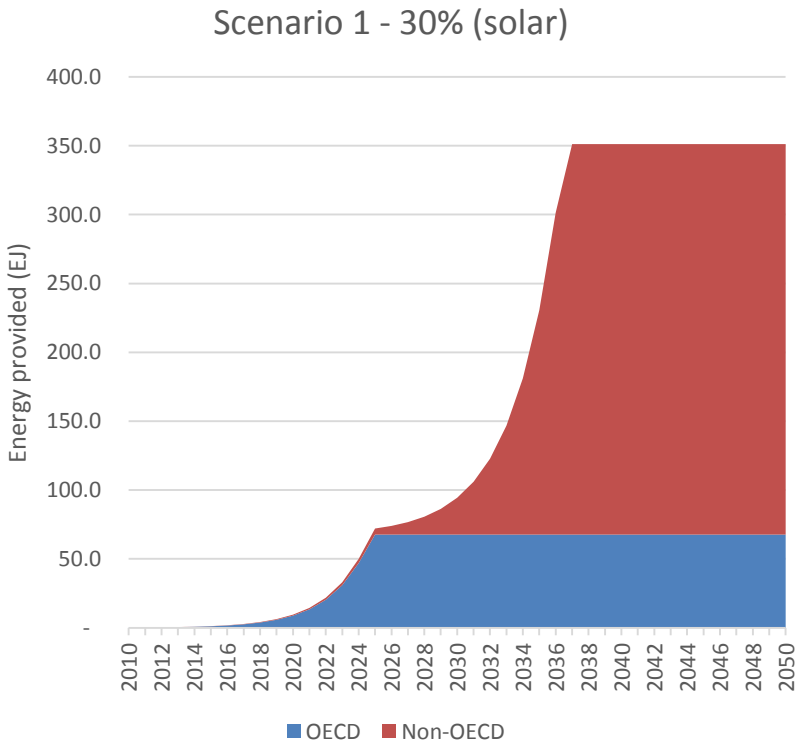

*USGS, 2010*

# Critical minerals in clean energy technologies

| | Minerals | Function |
|---|---|---|
| **Wind turbines** | Dy, Nd | Permanent magnets |
| | Cu | Generator windings and wiring |
| **Photovoltaics** | In, Ga, Se, Te | Photo-active materials |
| | Cu | Electrical connections and power electronics |
| **Fuel cells** | Pt | Electrodes / catalysts (PEM FC) |
| | Y, La | Electrolyte and electrode materials (SOFC) |

# Energy and minerals demand

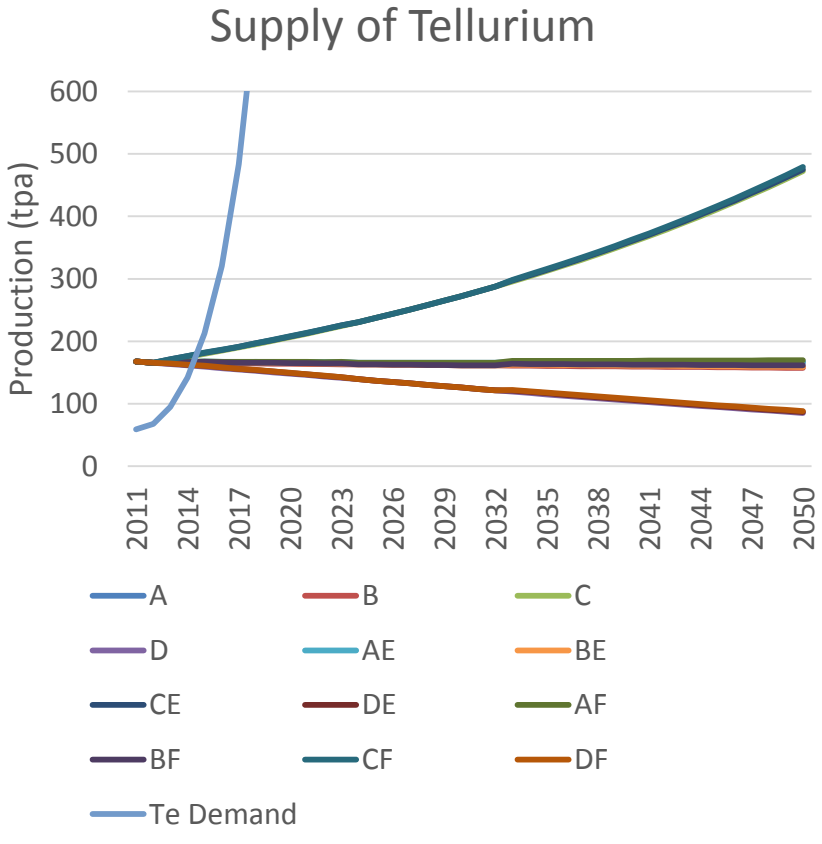


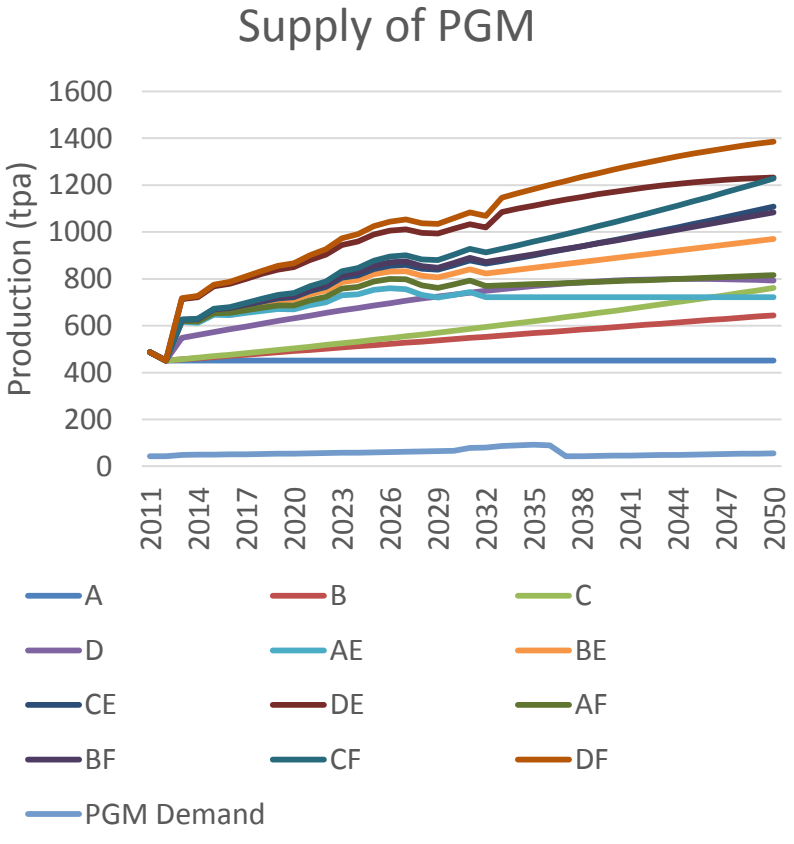



# Scenarios for mineral supply

| Scenario | Characteristics |
|---|---|
| A | Constant 2012 production |
| B | Linear trend growth extrapolated from 2002-2012 onwards |
| C | Year-on-year trend growth extrapolated from 2002-2012 onwards |
| D | Hubbert peak curve estimate |
| **Two recycling scenarios applied to A-D** | |
| E | Current recycling rate (20 year lifetime / lag for materials to be recycled) |
| F | Improvement in recycling rate growing to 90% by 2050 (20 year lifetime / lag) |

# Supply scenarios and one demand scenario



# Supply restrictions

- Tellurium, Selenium, Indium, Nd/Dy – by 2020
- Copper, Yttrium – by 2030
- PGM – no restrictions under the scenarios modelled

# Comparison of Grade of "Energy Urban Ores" and Deep Ocean Deposits

| Critical materials | Grade (wt%) | | | |
|---|---|---|---|---|
| | Energy system urban ore | | Deep ocean | Terrestrial Deposits |
| | Component | System | | |
| Dy, Nd | 30% (magnet)<br>(28% Nd /2% Dy) | 0.03% | >0.0023% Nd / >0.0004% Dy (Pacific muds) | 0.05% Nd /0.02% Dy<br>~<br>0.8% Nd /0.5% Dy |
| Cu | ~100% (wire windings) | / 0.8% (Wind)<br>0.1% (PV) | 6.8% (Solwara I)<br>0.5% (Izena Cauldron) | >0.5% (typical cut-off grade) |
| In, Ga, Se, Te | 0.5% (panel)<br>14.5% (panel without glass) | 0.3% | | In (<0.01%) in Zn ores<br>Se (~8%) in Cu slimes<br>Se (<0.00001%) in Cu ores<br>Te (~1%) in Cu slimes |

# Other criteria for thought…

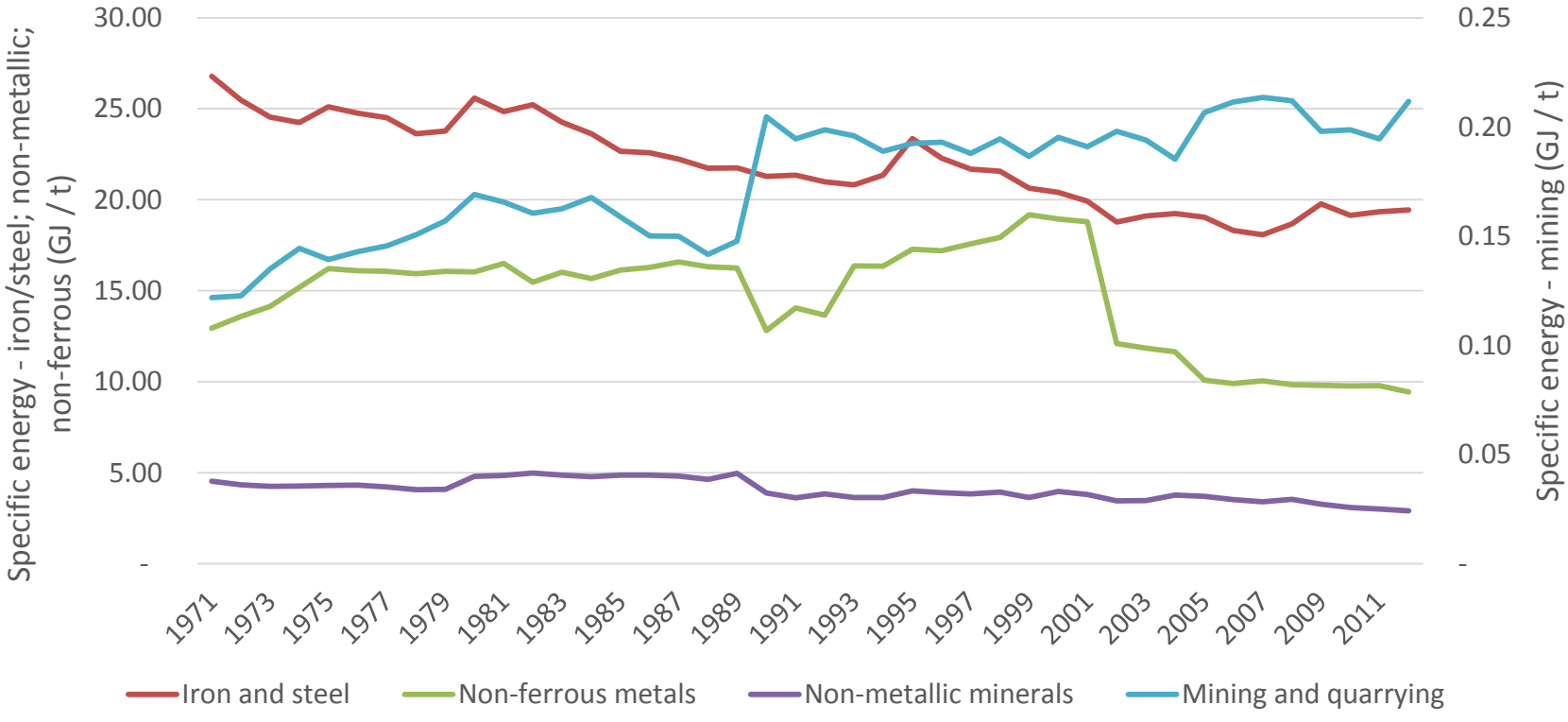
| Technology | Critical materials | Mass density of contained metals ($t / km^2$) | | Size of Deposit (t) |
|---|---|---|---|---|
| | | Residential scale | Power plant scale | Power plant scale |
| Wind turbines | Dy, Nd | 0.24 | 6 | 170 |
| | Cu | 1.8 | 117 (onshore) | 3500 |
| | | | 300 (offshore) | 9000 |
| Photovoltaics | In, Ga, Se, Te | 2.3 | 83 | 930 |
| | Cu | 0.34 | 12 | 140 |
| Fuel cells | Pt | 0.001 | 2 | 0.2 |
| | Y | 0.15 | 309 | 40 |

# Mass is tonnes of contained metal

# Considerations for Urban Energy and Deep Ocean Ores

- Low deposit size (orders of magnitude)
- Low deposit geographical density (material spread out across a wide area, particularly if residential usage is anticipated)
- Variable deposit grades (not always higher than conventional resources).

# Estimated energy per tonne




Based on USGS and IEA data; Iron and steel includes blast furnace and coke production;

Dr Ben McLellan
Associate Professor
Graduate School of Energy Science
Kyoto University

Telephone +81 (0)75 753 9173
Email b-mclellan@energy.kyoto-u.ac.jp

# QUESTIONS?



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