

*GSA's 125th Anniversary
Annual Meeting & Expo*

*Pardee Keynote Symposium
P12: Resourcing Future
Generations
27-30 Oct 2013, Denver USA*



Resources and supply-demand over the very long term

Damien Giurco, Steve Mohr – Institute for Sustainable Futures, University of Technology, Sydney

Gavin Mudd – Department of Civil Engineering, Monash University, Melbourne

*Where
will resources come from,
to enable healthy societies,
in this century?*

- i) Availability*
- ii) Addiction*
- iii) Alternatives*



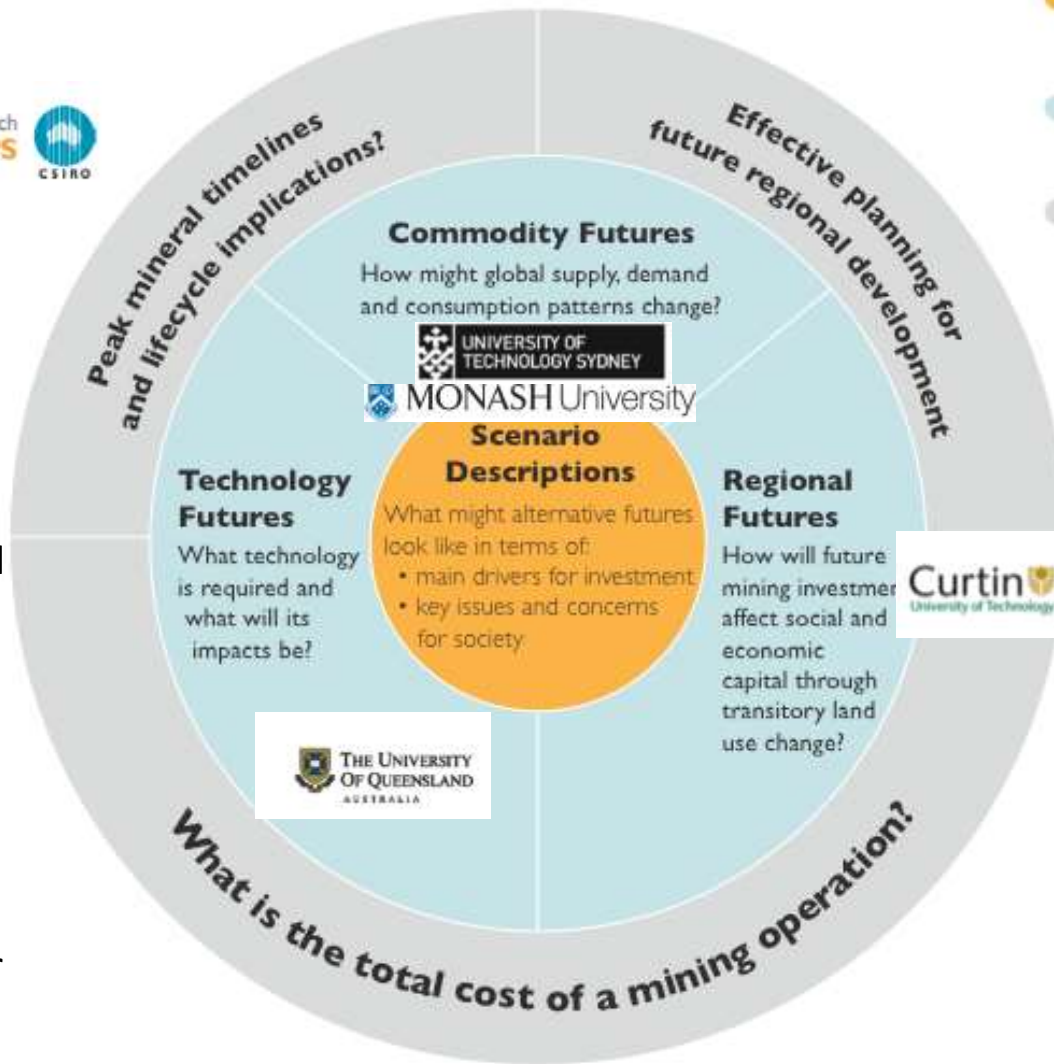
Mineral Futures Collaboration Cluster [2009-2013]



Dr Gavin Mudd
Monash



Dr Steve Mohr
ISF, UTS



- Role of the mineral futures forum, supported by strategic foresight scoping studies
- Defined lines of inquiry to be developed primarily through the collaboration cluster
- Decision support issues for a sustainable Australian minerals investment strategy

How should Australia utilize its mineral resources to underpin long term benefit?



Starting a national conversation on mineral futures...

Vision 2040

Mining, Minerals and Innovation
A vision for Australia's mineral future

Vision 2040

Advantage Australia:
resource governance and innovation for the Asian Century

National Research **FLAGSHIPS** Research Theme Leader

The University of Queensland

Curtin University

University of Western Australia

ANU

UNIVERSITY OF TECHNOLOGY SYDNEY



Vision 2040 – Key Themes

1. A National Minerals Strategy & National Mineral (Sustainability) Account
2. Transformational innovation & remediation
3. Brand Australia: responsible minerals
4. Building long-term benefit for Australia: Sovereign Wealth Funds

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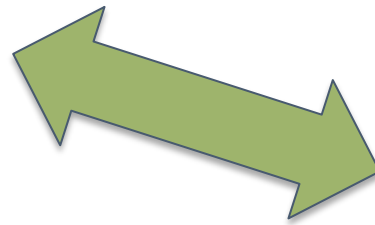


Spectrum of approaches to mineral availability

after Tilton (2002)

Opportunity Cost Paradigm

resource scarcity..
...higher prices/ lower demand
...new technologies - lower grades
...more resources



Fixed Stock Paradigm

fixed stock of minerals
rising population / demand
eventually we'll run out...or
...social costs high and can't
access what's there

*N.B. space, time ,
metals recyclable,
availability requires access*



Spectrum of approaches to mineral availability

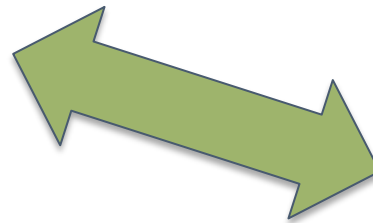
after Tilton (2002)

Opportunity Cost Paradigm

resource scarcity..
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Nauru:
economic
reserves
depleted



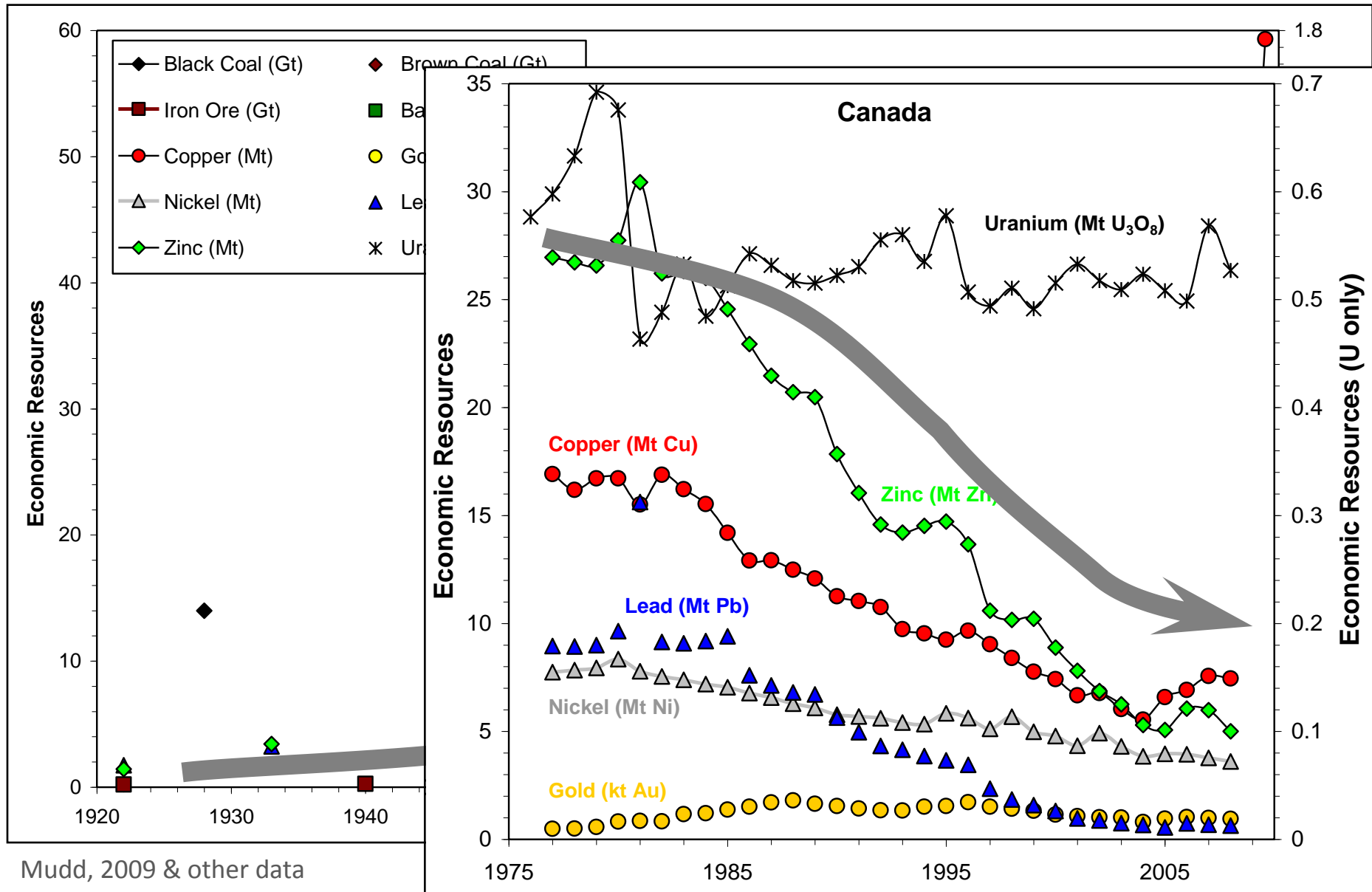
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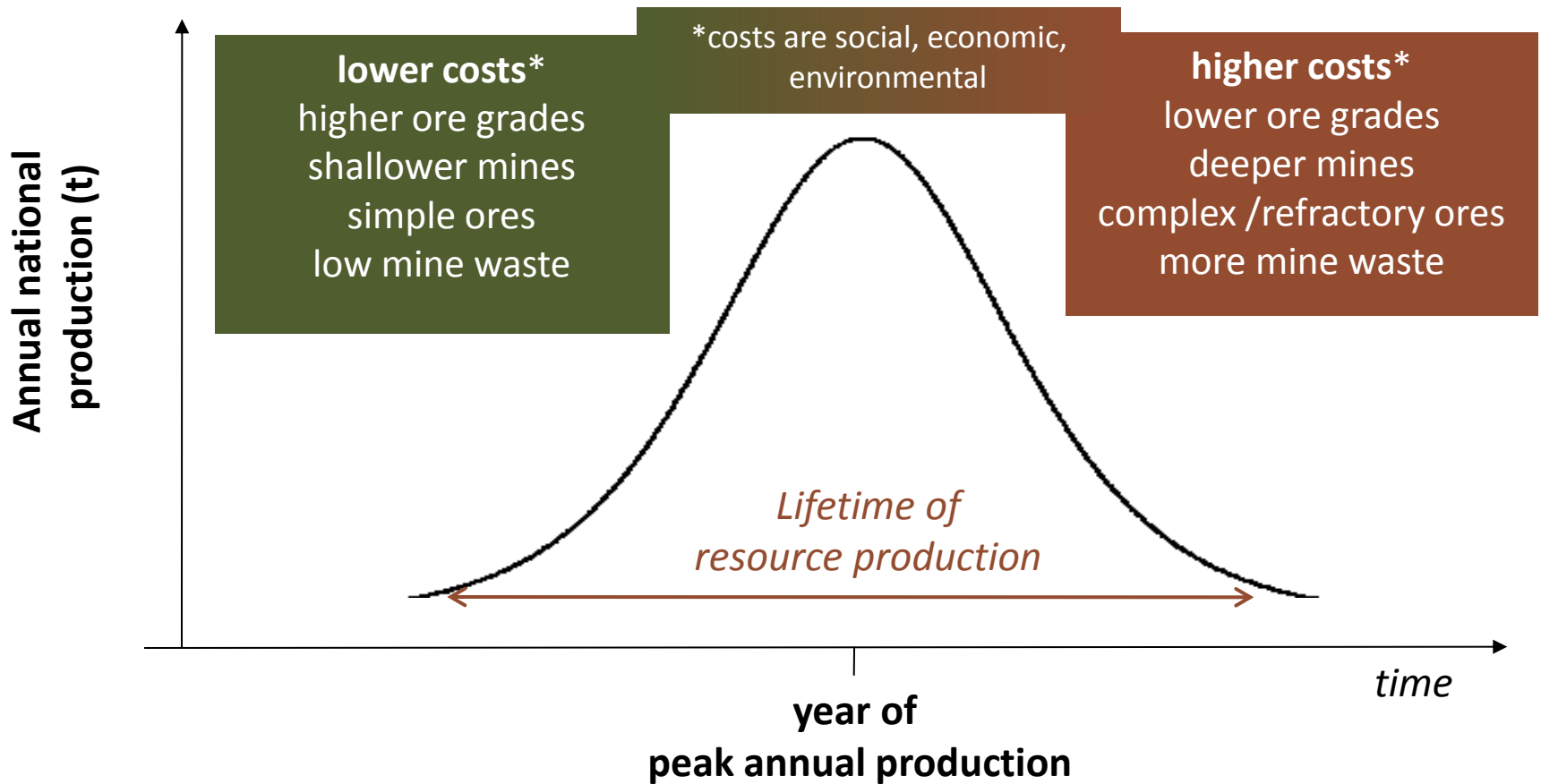


Trends in economic resources (Australia, Canada)



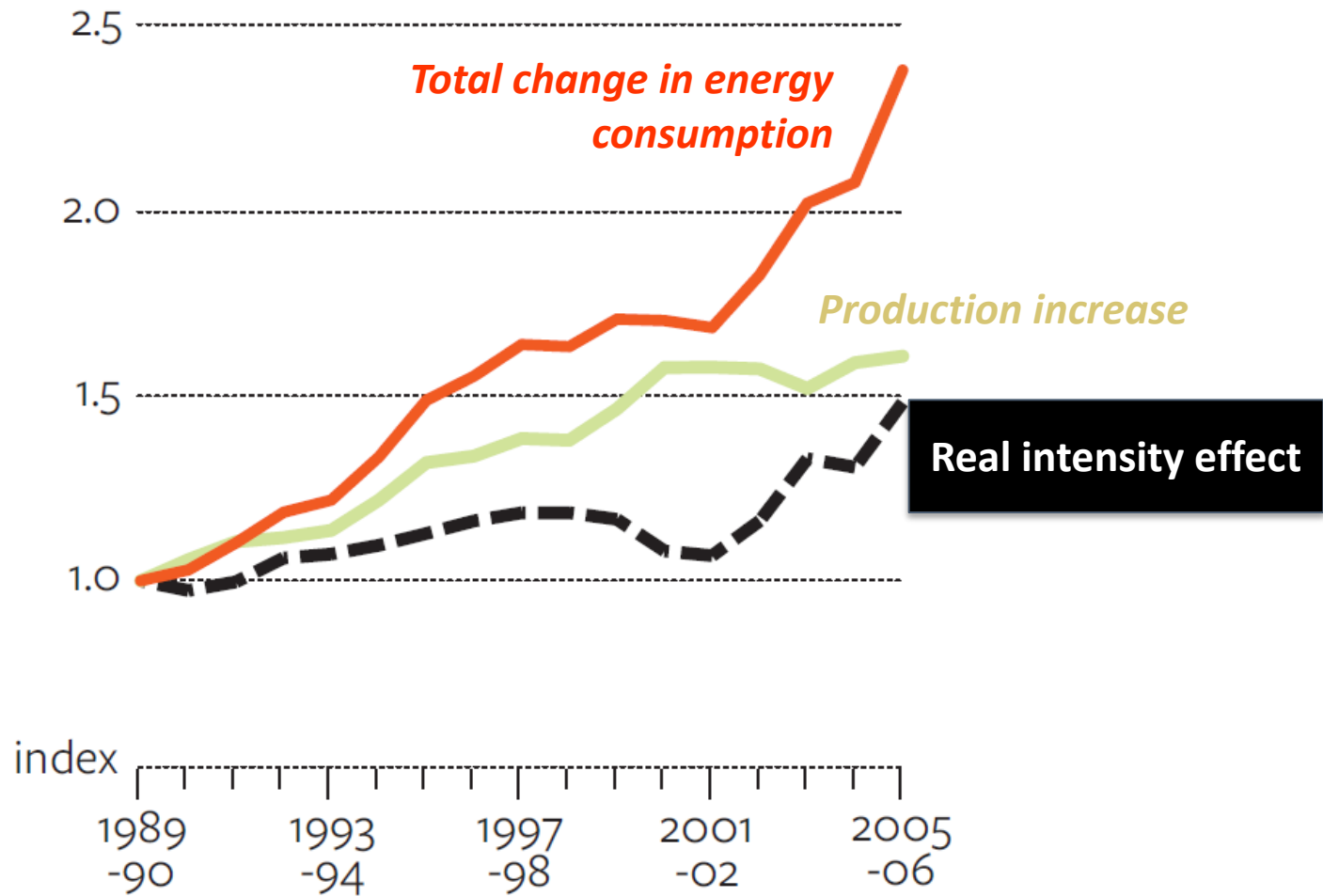


Peak minerals metaphor: cheaper & easier to complex & costly





Energy intensity of mining up 50% in Australia



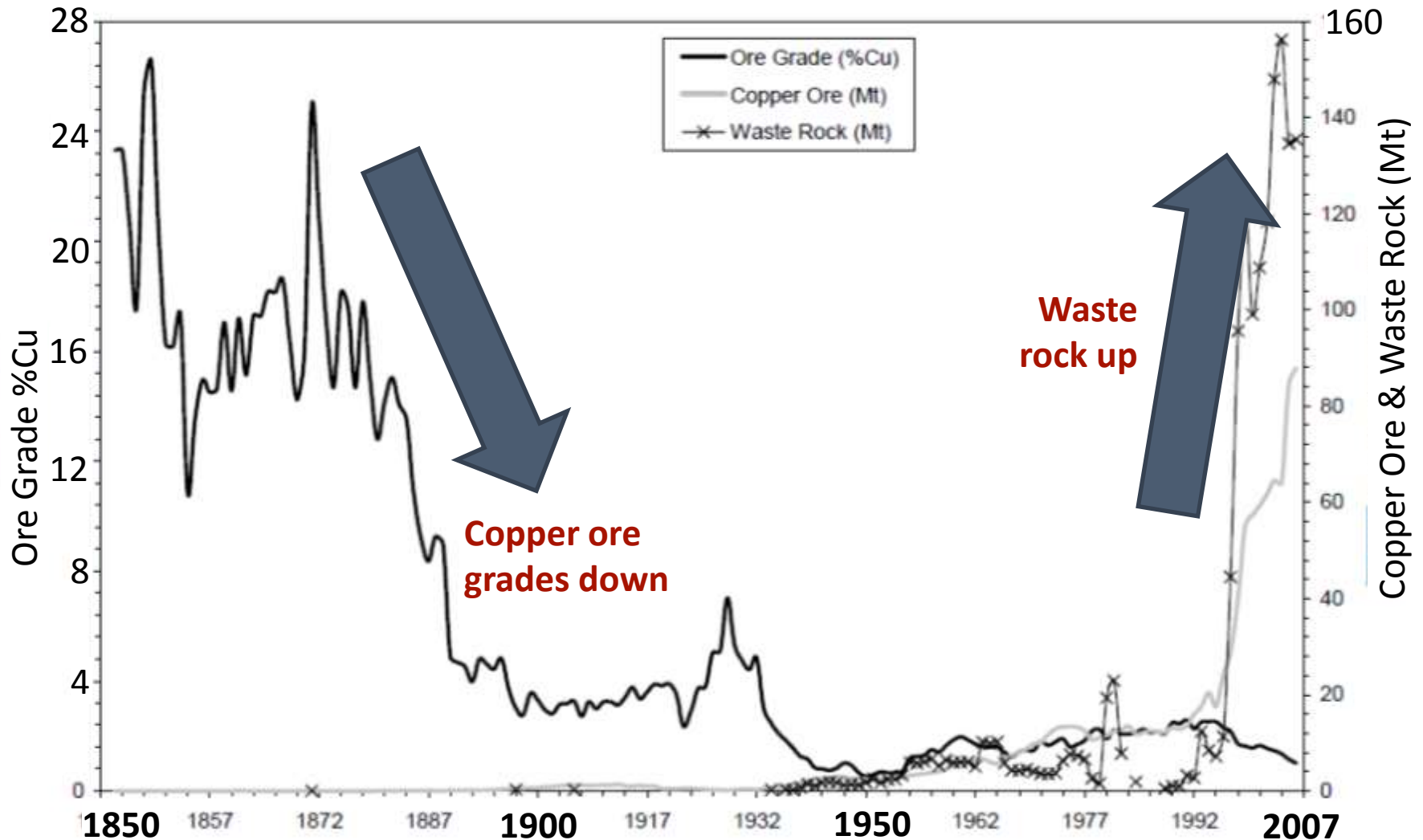
Source: Sandu & Syed, (2008) Trends in Energy Intensity in Australian Industry



Cheaper & easier



more complex & expensive





Approaches to long term modelling

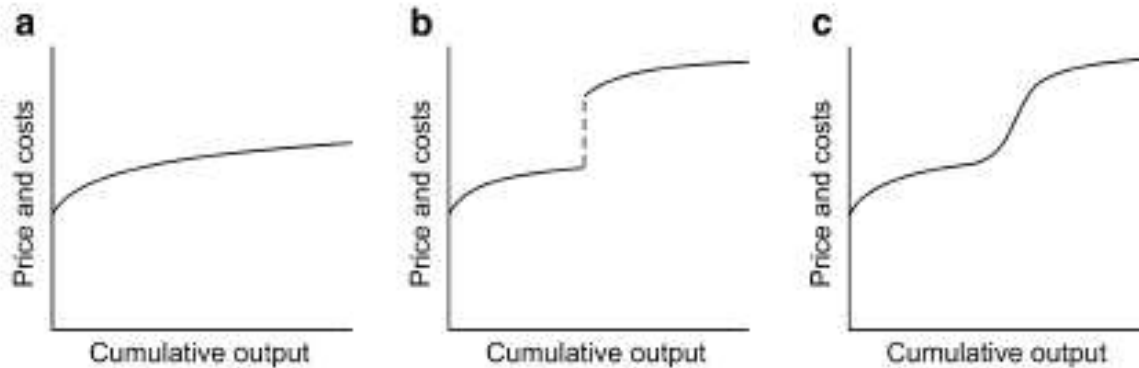
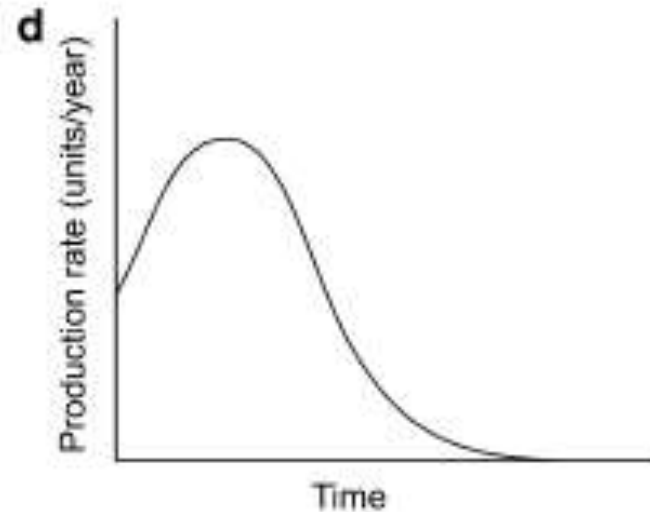
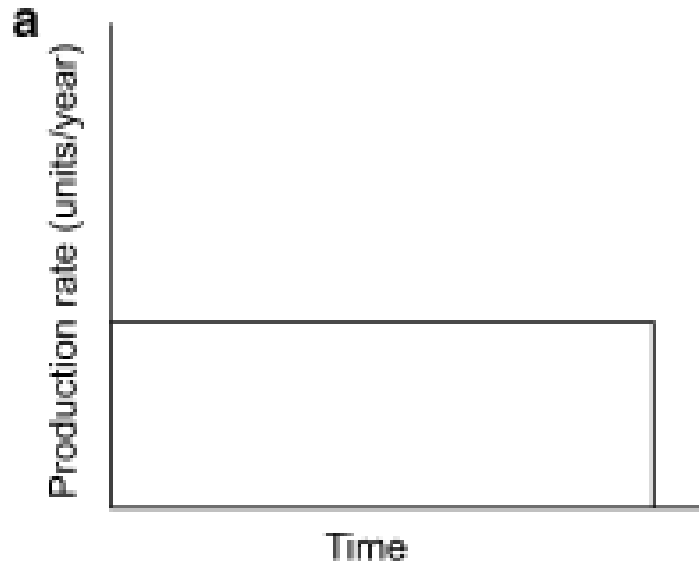


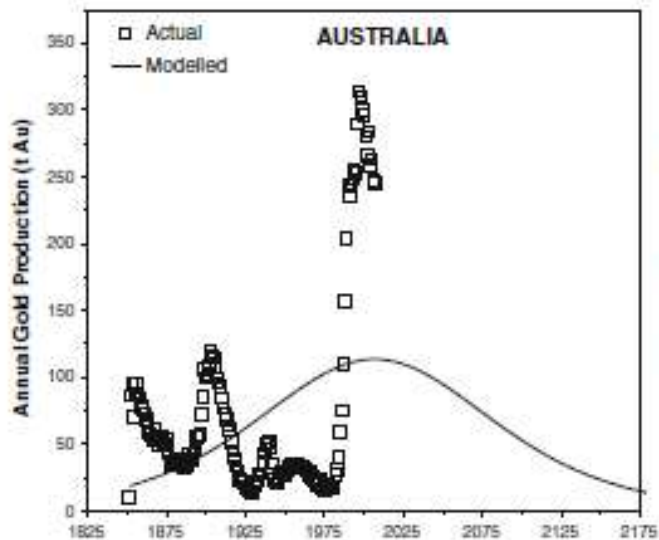
Figure 4 Illustrative cumulative availability curves (Tilton and Skinner 1987). (a) Slowly rising slope due to gradual increase in costs, (b) discontinuity in slope due to jump in costs and (c) sharply rising slope due to rapid increase in costs.



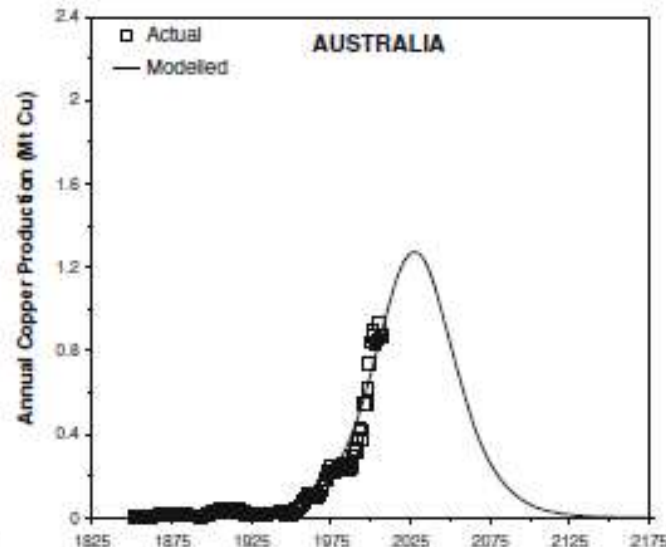


Not all production = smooth curve

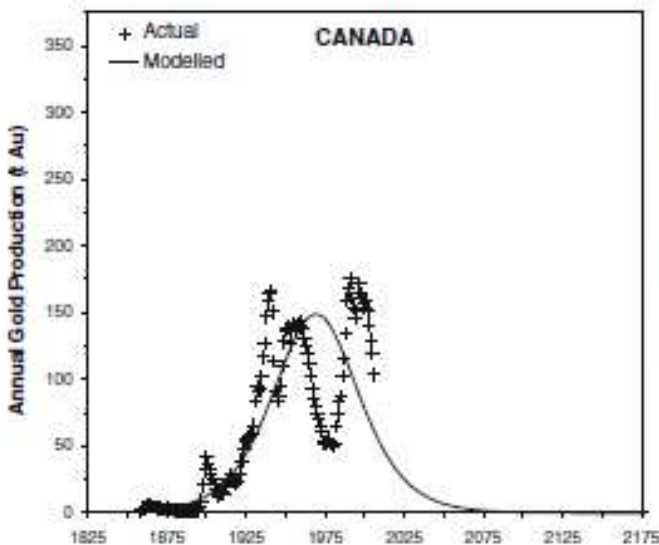
Gold
Australia



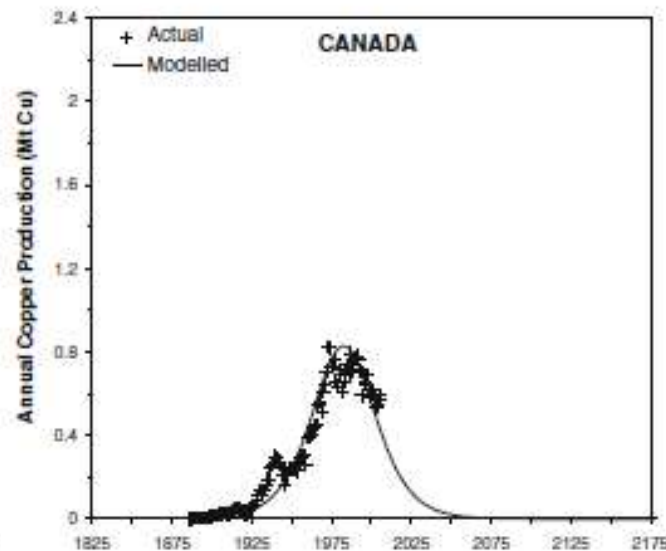
Copper
Australia



Gold
Canada



Copper
Canada





Geologic Resources Supply-Demand Model GeRS-DeMo

<http://datasearch.uts.edu.au/isf/news-events/news-detail.cfm?ItemId=29302>

Or Google: GeRS-DeMo

The screenshot shows a news article on the website of the Institute for Sustainable Futures. The article is titled "Geologic Resource Supply-Demand Model" and is dated 14 December 2011. It features a line graph with the title "Australia's black coal supply and demand". The graph shows two lines: a black line representing "Production" and a brown line representing "Demand". The x-axis is labeled "Year" and ranges from 2000 to 2020. The y-axis is labeled "Mtpa" and ranges from 0 to 100. The production line starts at approximately 60 Mtpa in 2000 and rises to about 80 Mtpa by 2010. The demand line starts at approximately 60 Mtpa in 2000 and rises to about 100 Mtpa by 2010. The article text explains that the model, known as GeRS-DeMo, was developed by ISF research consultant Dr Steve Mehr during his PhD research. It estimates the demand, production (from mines or fields) and recycling of any geologic resource. Specifically, it can be used to predict the historic and future production, amount of recycling and demand of a metal, fossil fuel, or mineral. The article also mentions that the model has been used successfully to model coal (black and brown), oil (conventional, shale, natural bitumen/tar sand and extra heavy oil), gas (conventional, tight, coalbed methane, shale) phosphorous, lithium, gold, nickel, copper resources. The model has been successfully used on world, country and regional levels. The model was used to inform ISF's research into peak minerals in Australia that examined the changing benefits and impacts of mineral resource extraction and processing in Australia. The model currently only works on Windows 32 bit, and excel 2007/2010. It does not work on excel 2002 or other operating systems. If there is sufficient demand for the model to work in different platforms or older versions of excel, then resources will be spent fixing the macros accordingly. Steve has made an illustrative step-by-step guide on how to install GeRS-DeMo. Input.xlsx contains information on the model, and the inputs required as well as a blank ready to use input file. Also included are five examples of input files that are ready to run at the click of a button. GeRS-DeMo is available from the ISF web site.

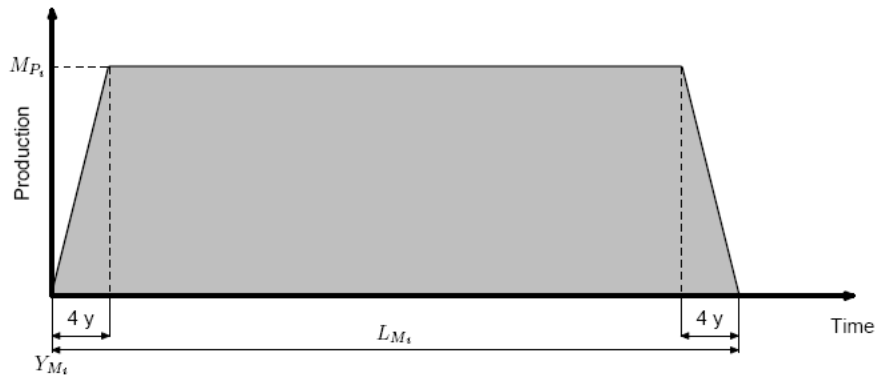
Overall approach

- mine by mine
- bottom up model
- based on URR for individual countries, typical mine sizes, possible operating patterns
- *number of mines is not fixed*

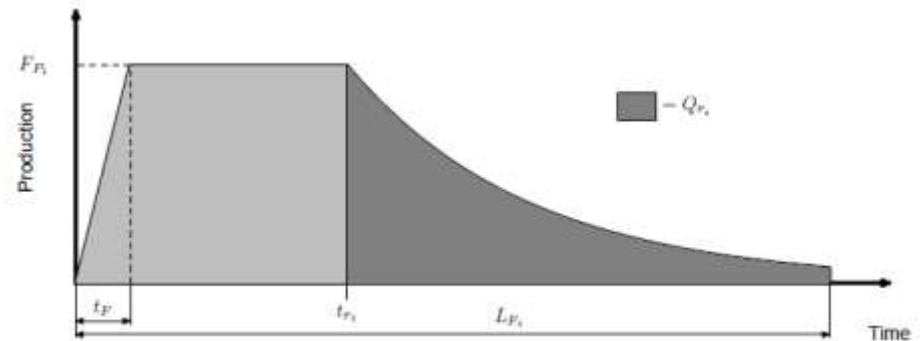


Modelling resources [GeRS-DeMo]

- > Production for minerals is fundamentally different to oil and gas
 - modelled differently.



Typical mine

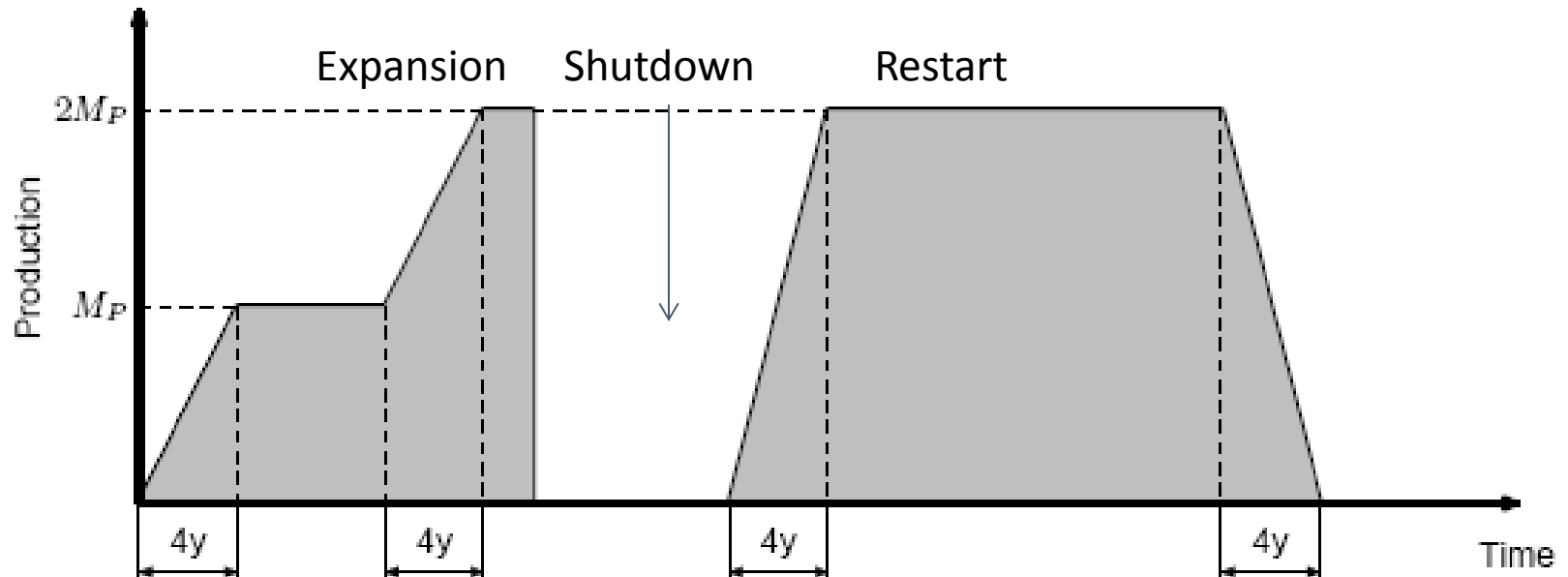


Typical oil/gas field



Mining model – additional features

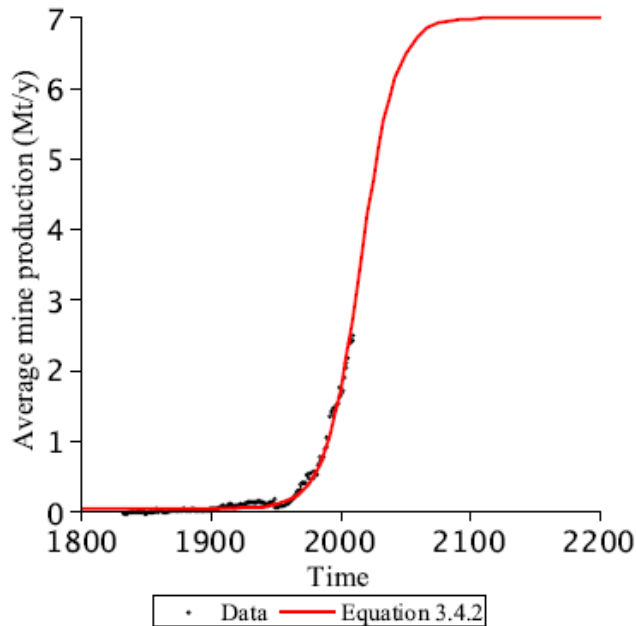
- > A more realistic mine does the following:
 - It can **upgrade** its production capacity
 - It can **shut down** and **restart** later (due to economic conditions)



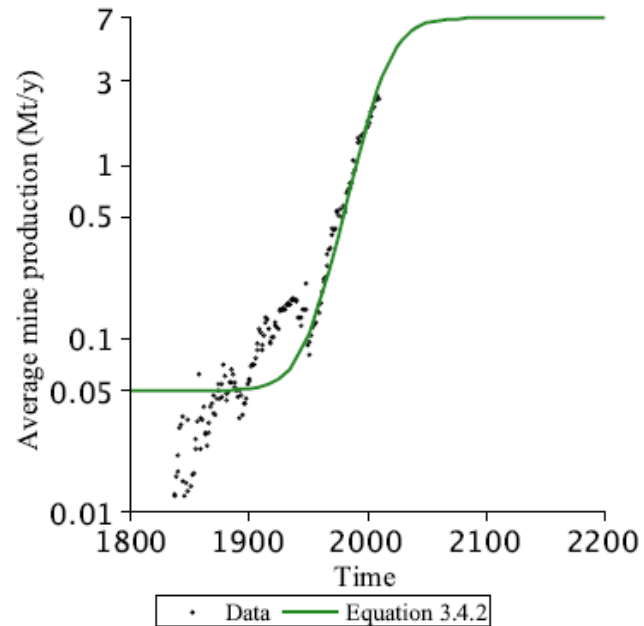


Modelling production

- > Model allows for mines to increase in size over time (commodity & region specific calibration)
 - Number of mines that will operate is not set



A regular plot



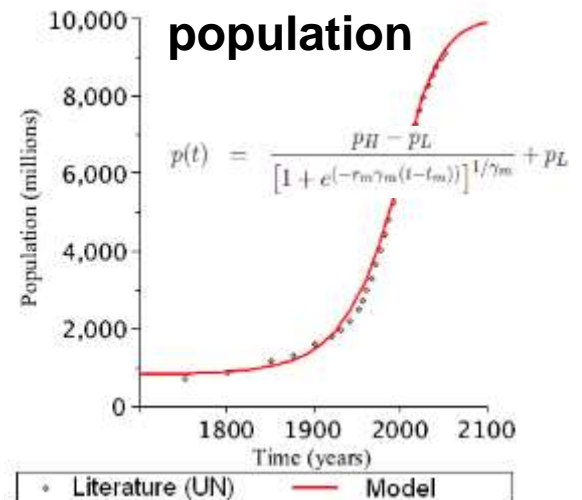
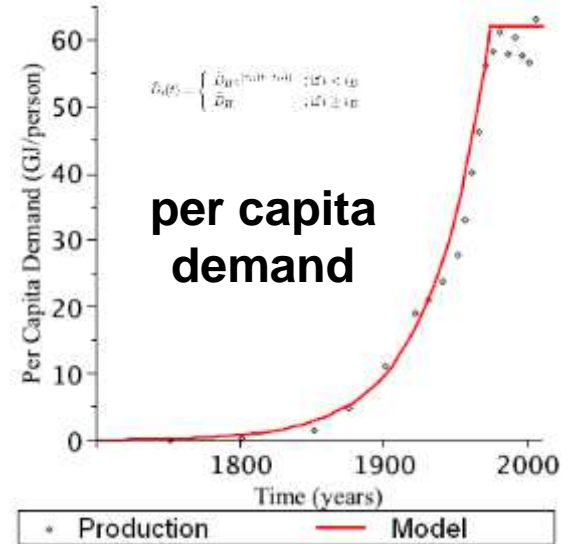
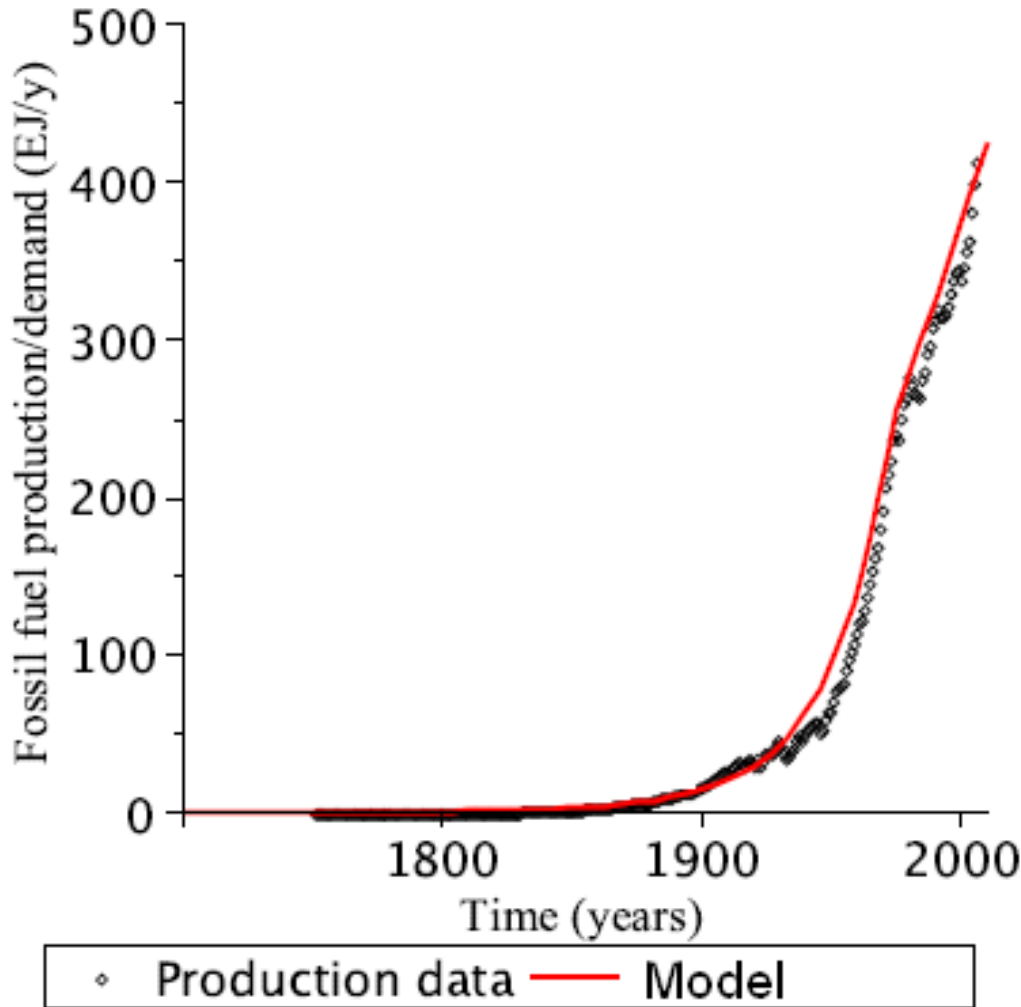
B Logarithmic (base 10) plot

t_t)

FIGURE 4.15. Average mine production versus time for NSW coal

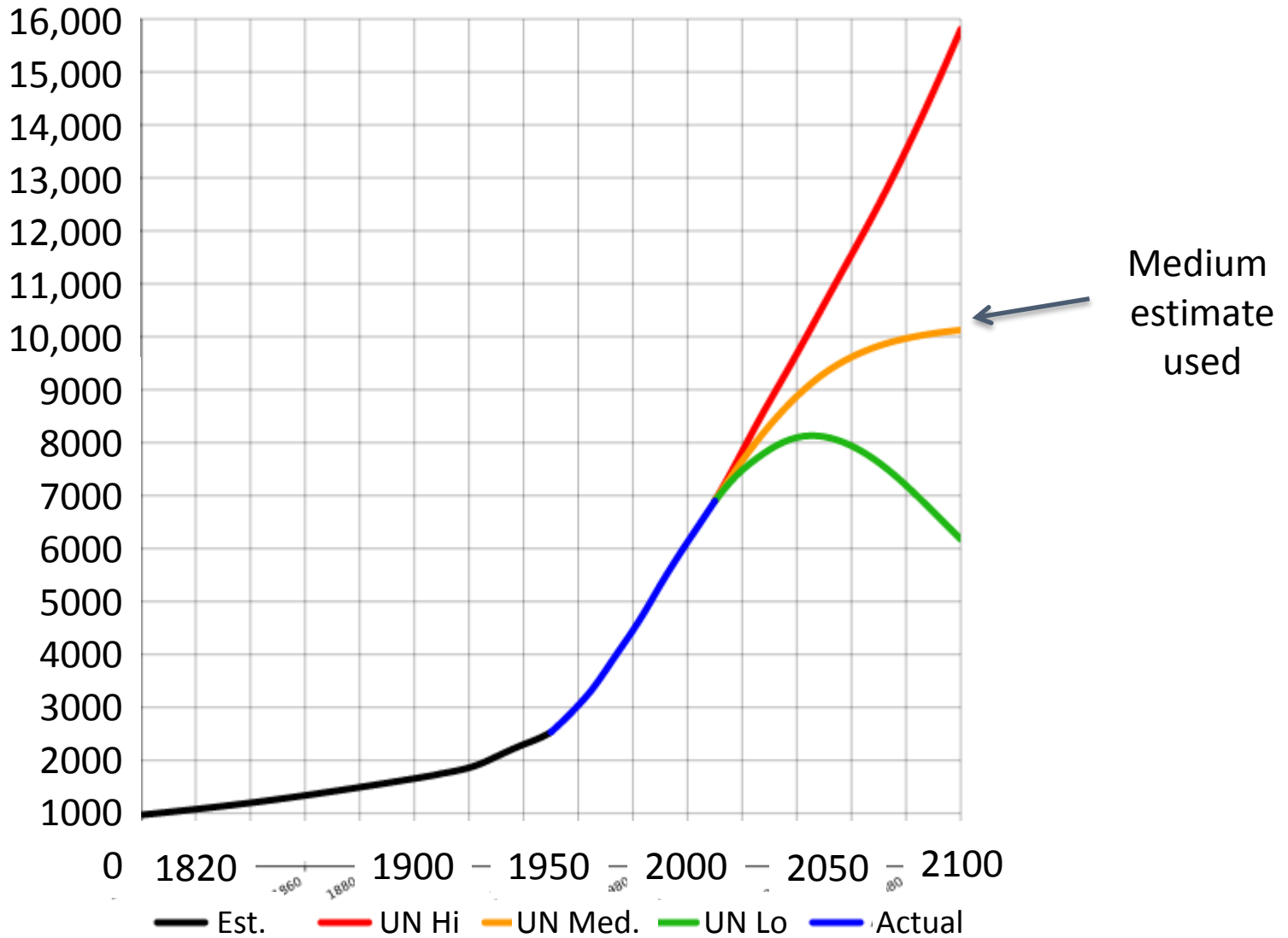


Overall demand = intensity x population

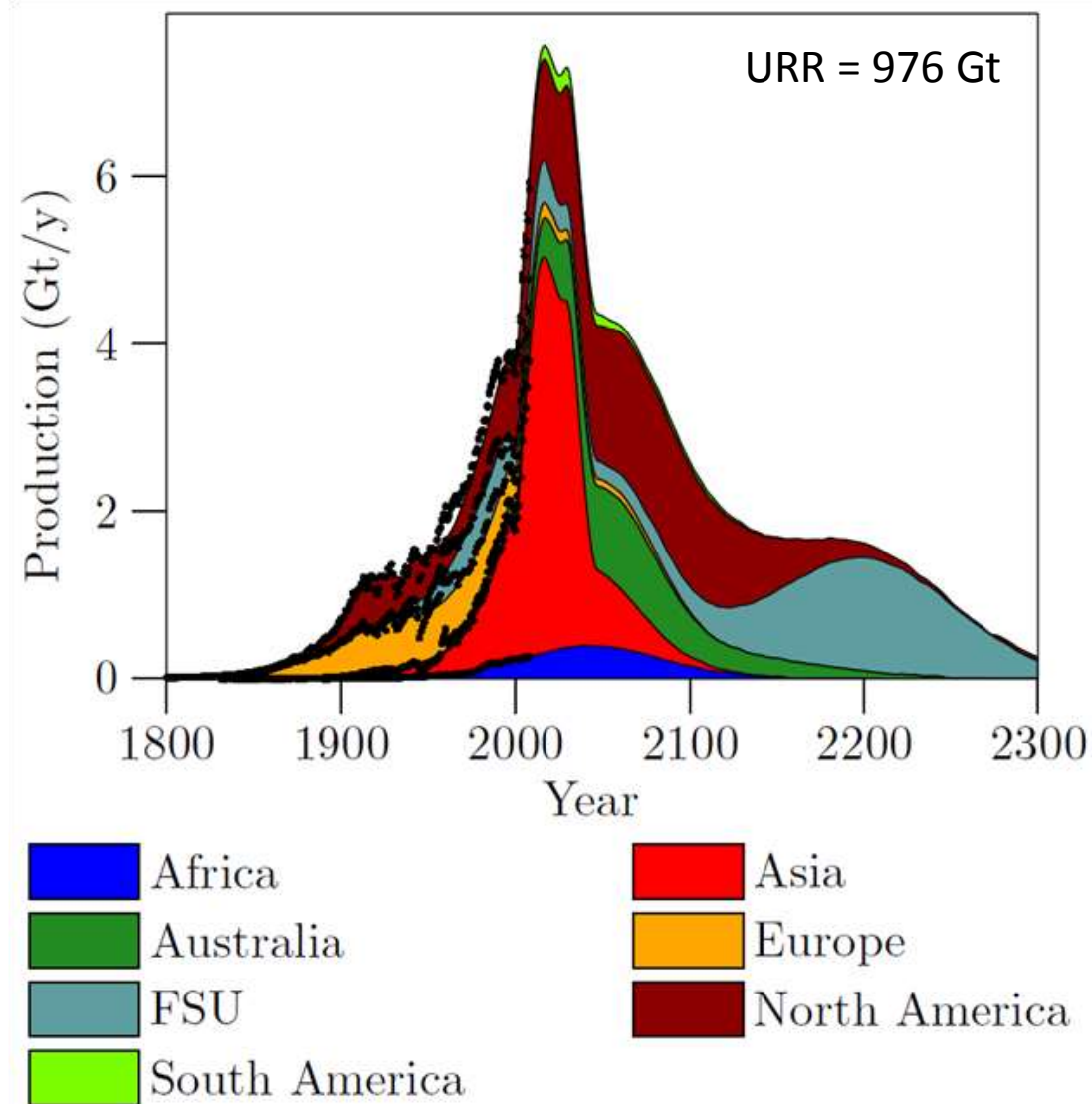




Continued population growth....or.....



Coal: peak global production within a decade



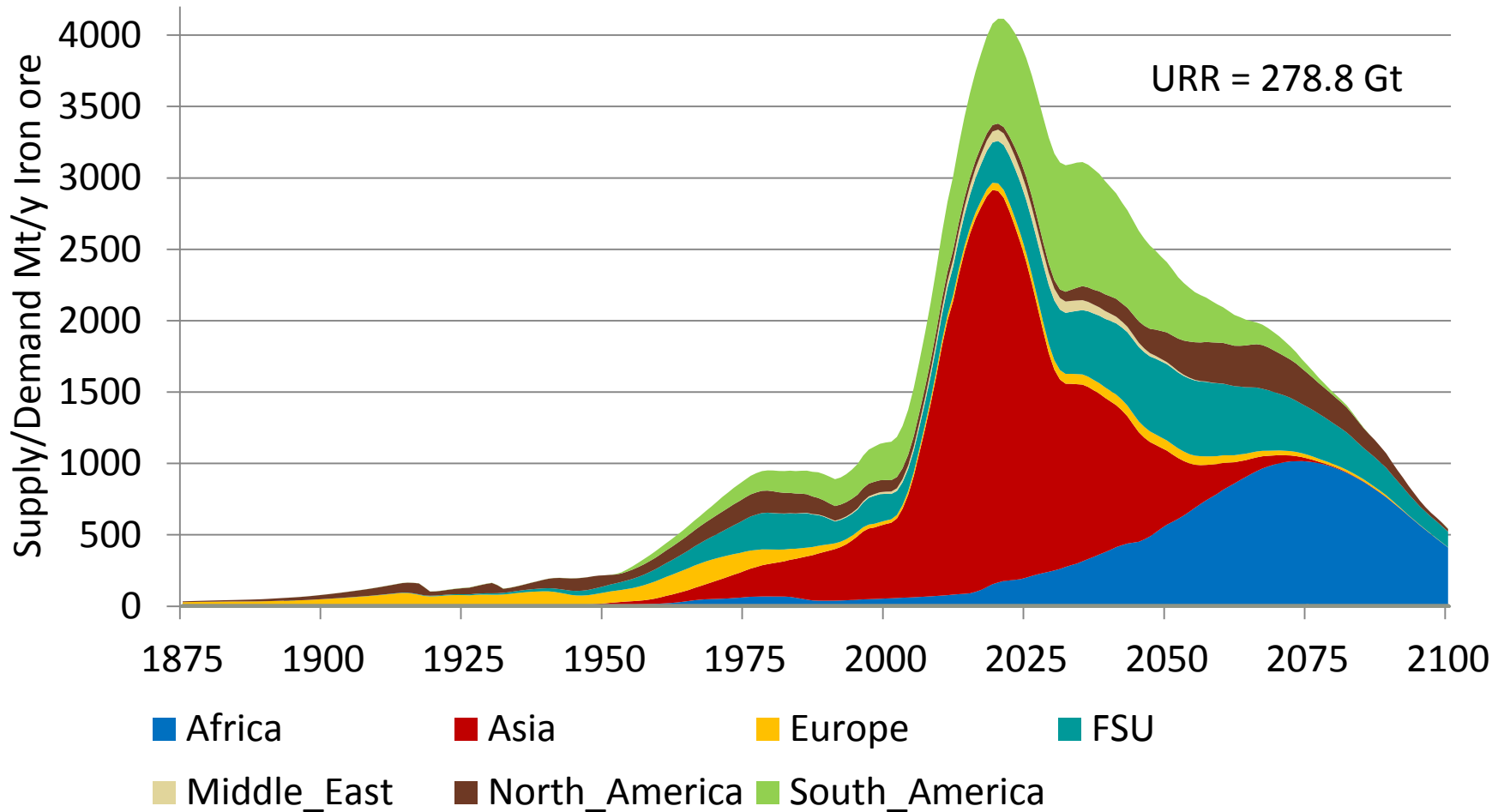
Region	Est. Peak Year	Max Prod'n (Gt/y)
Africa	2039	0.4
Asia	2016	4.7
Australia	2060	1.1
Europe	1973	0.6
Fmr Sov Union	2202	1.4
North America	2065	1.7
South America	2029	0.2
Total	2017	7.6

Mohr et al. (2013) Coal, Cluster Report 1.7

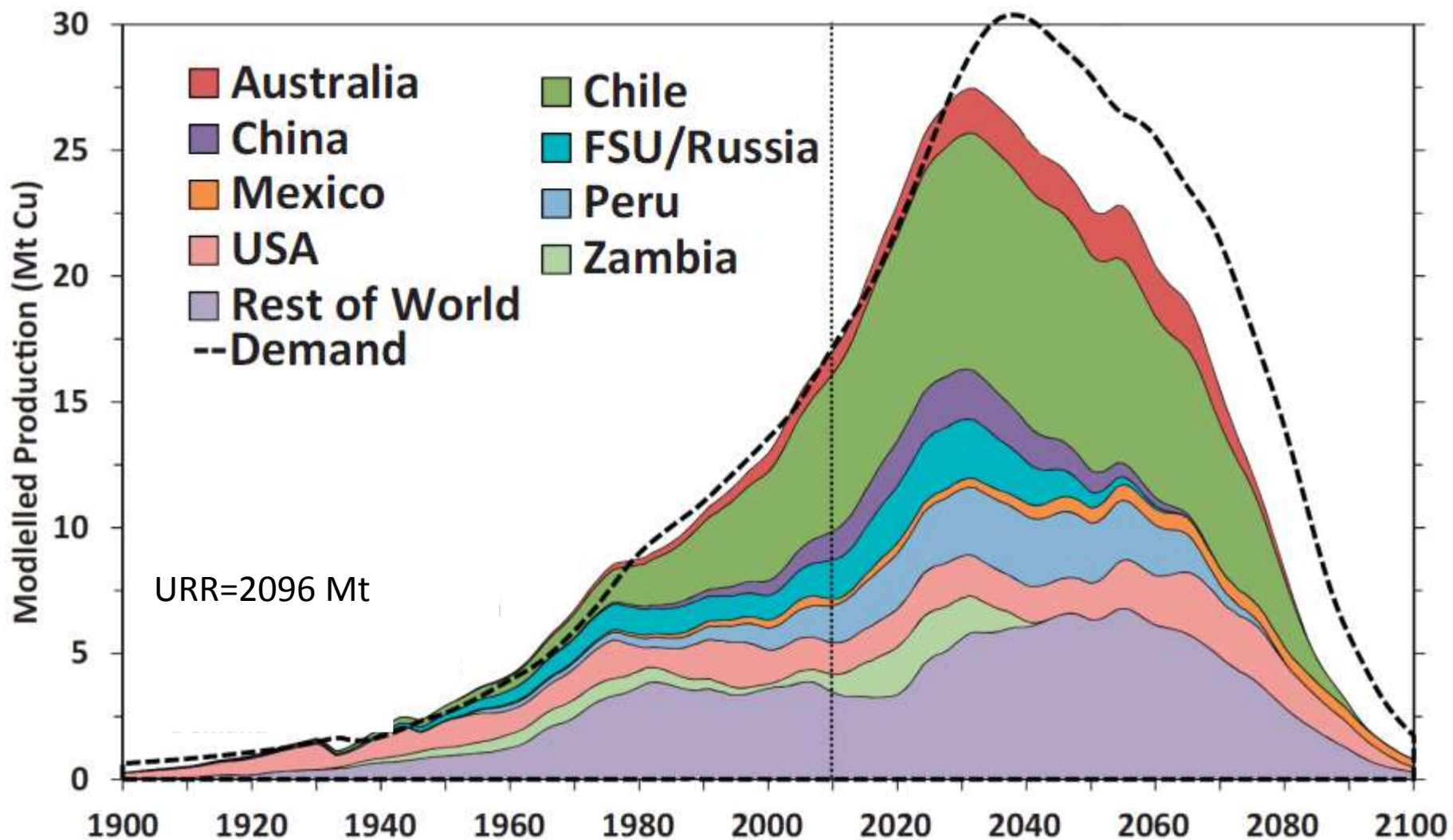
See also Mohr & Evans. (2009) *Fuel* for other scenarios with URR 700-1243Gt



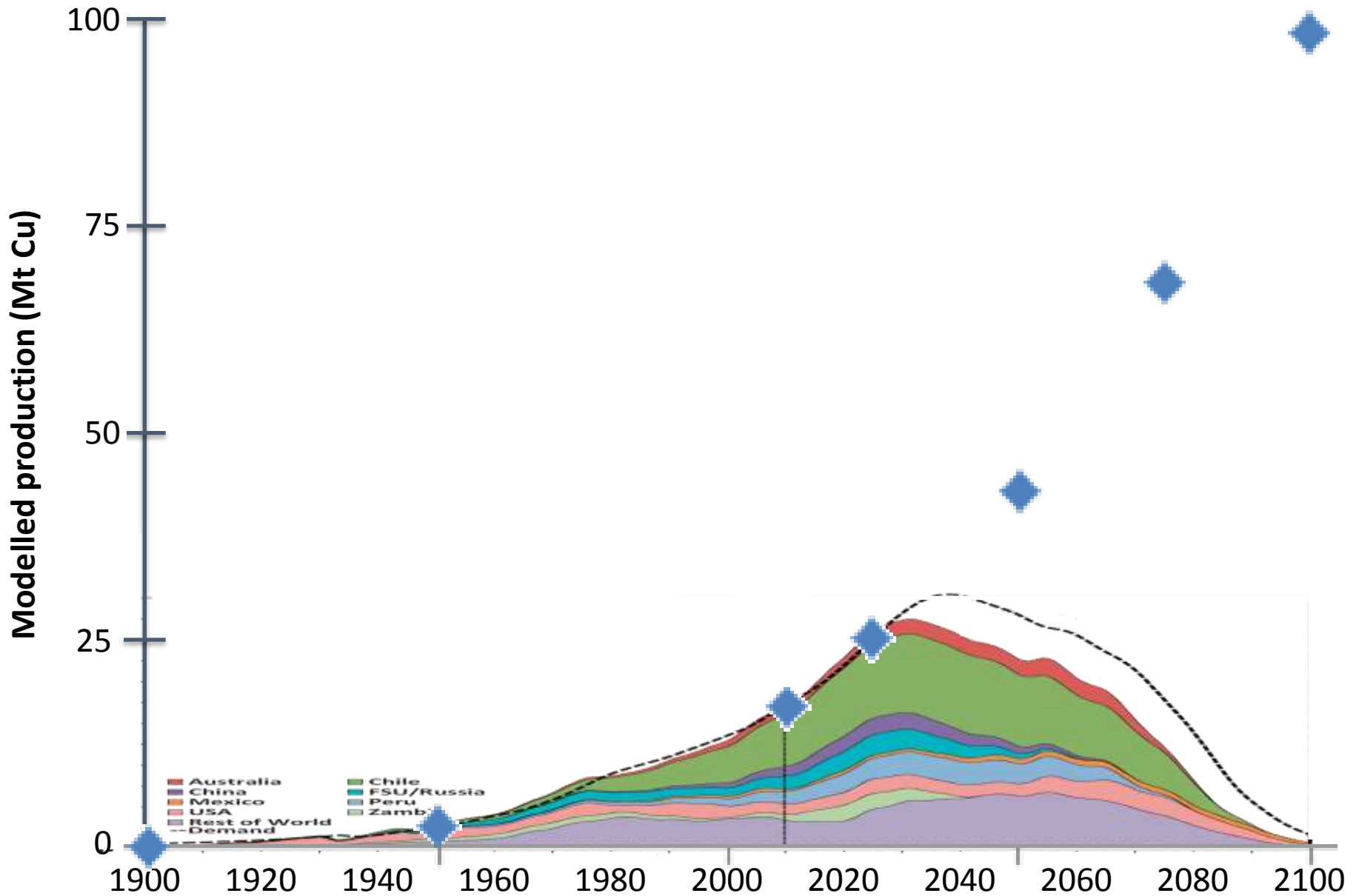
Iron ore – production by country



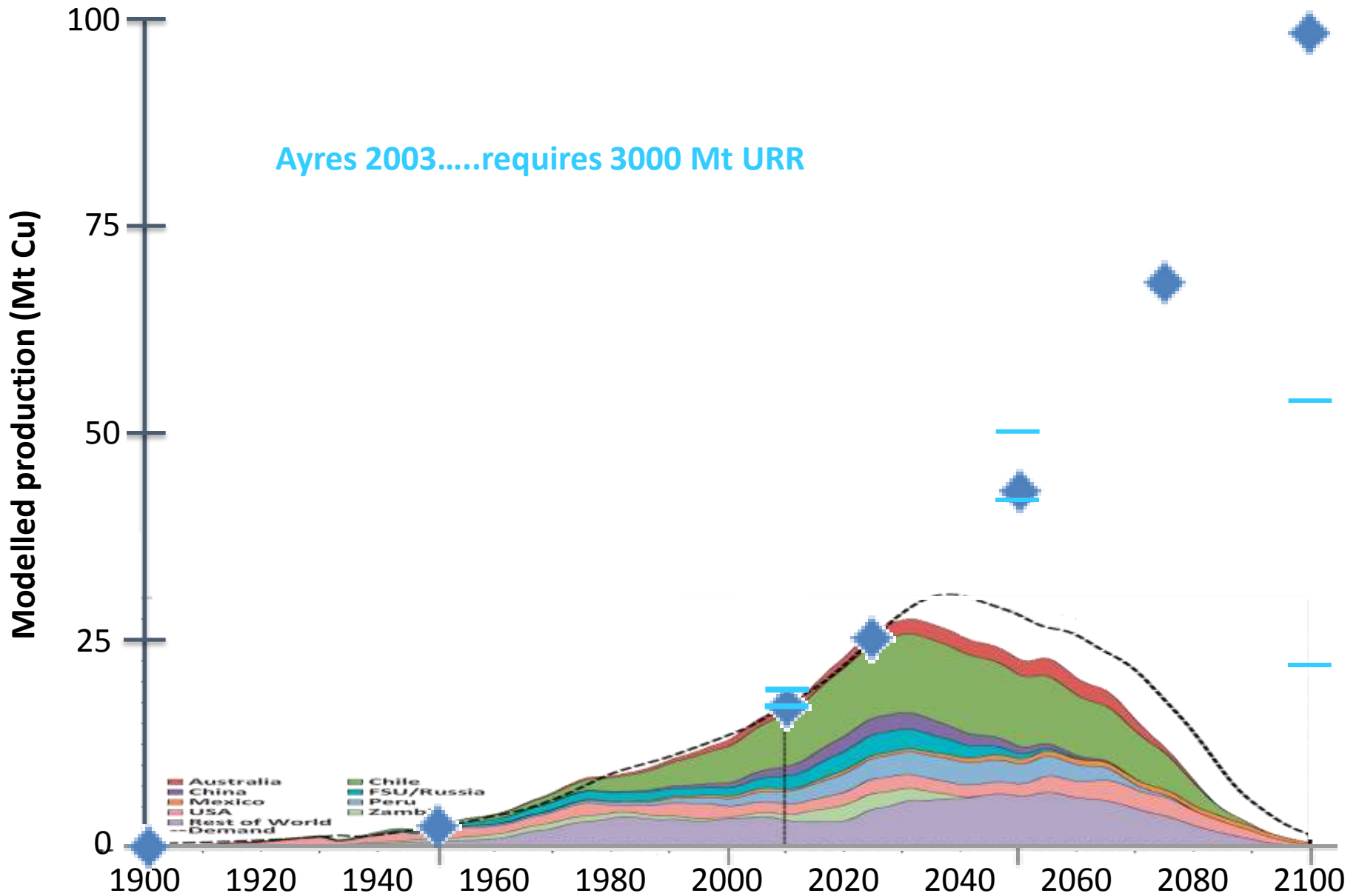
Copper production: historical and projected



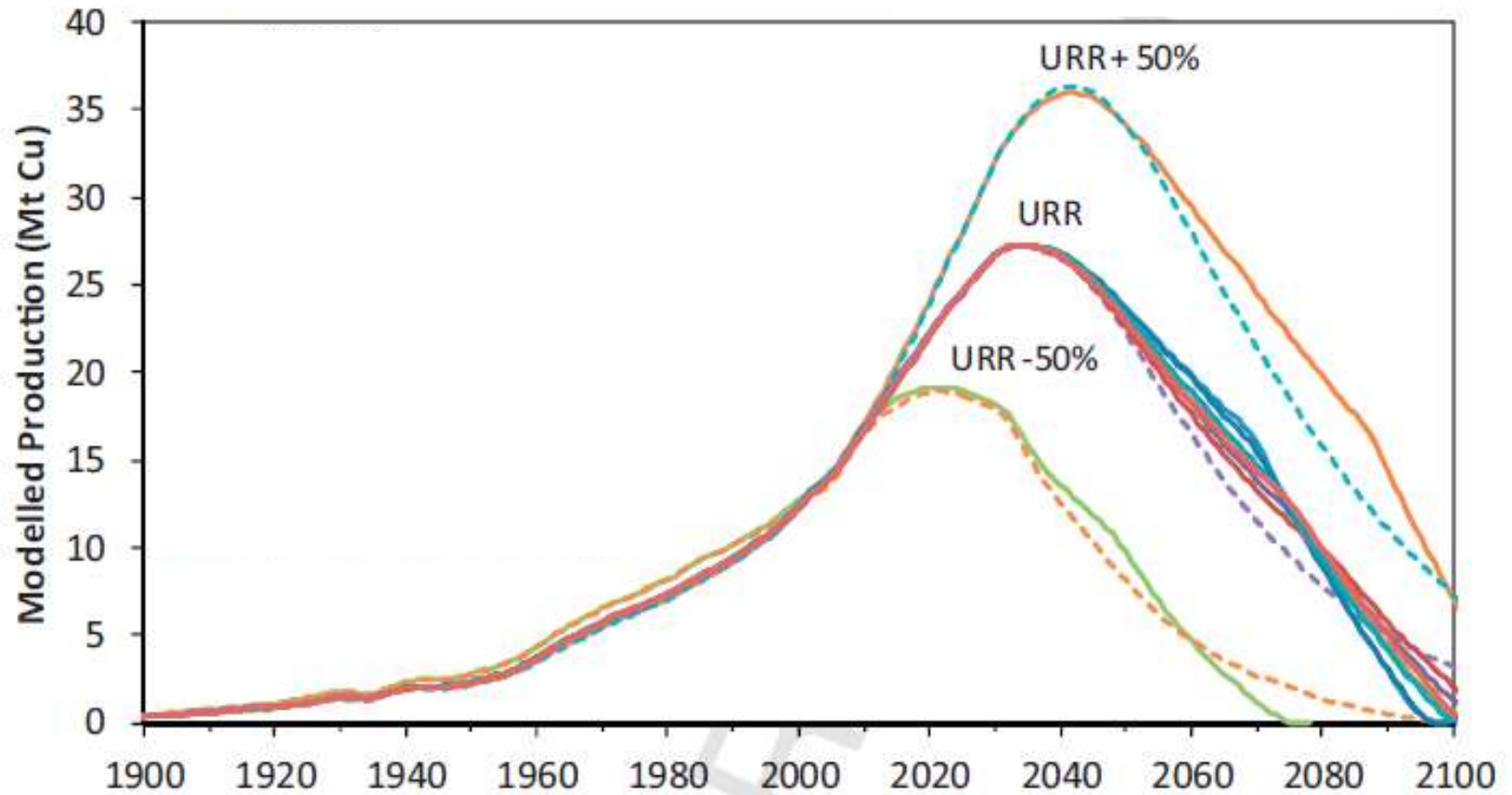
Historical growth 1.6% p.a. cannot be supported



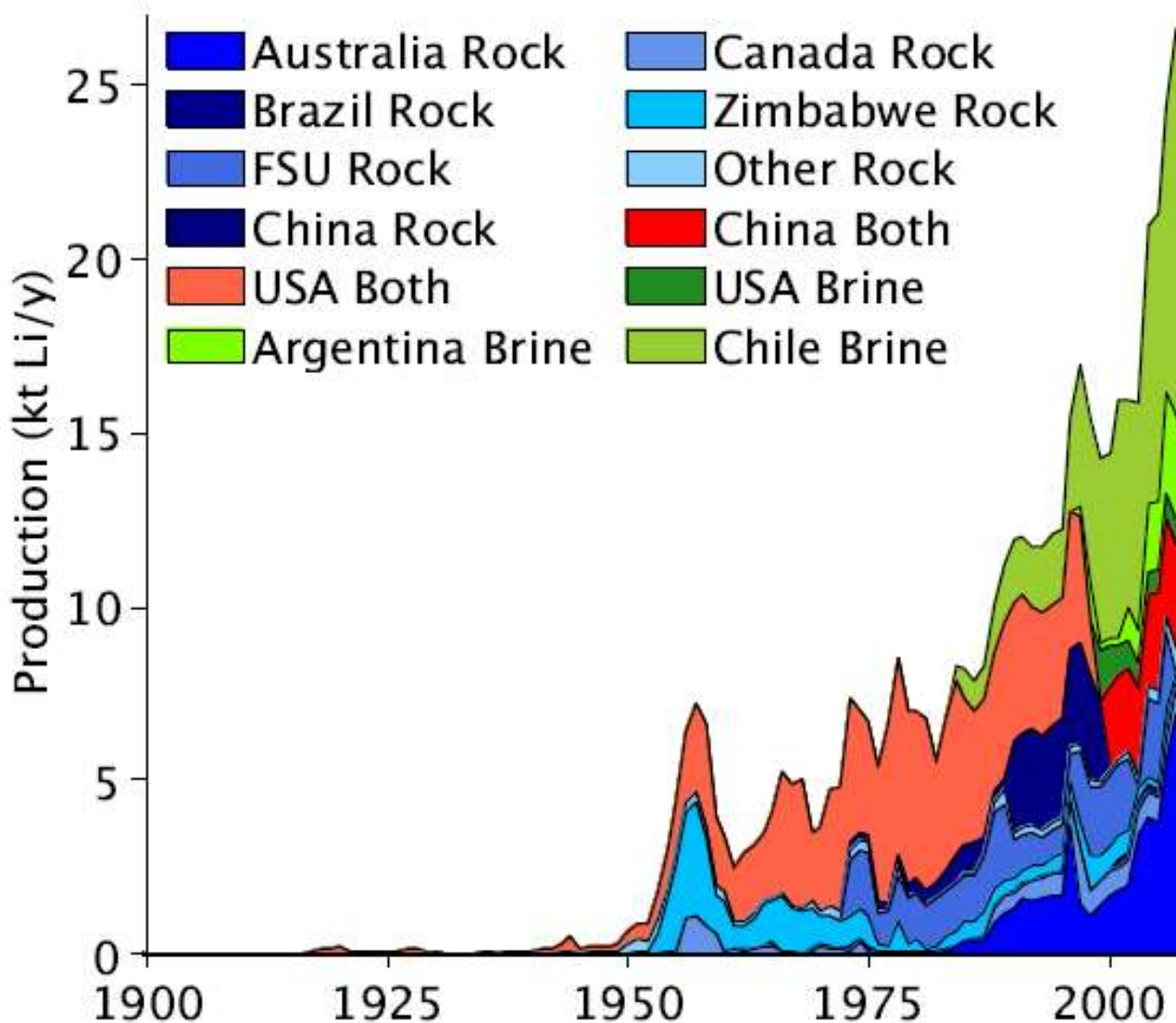
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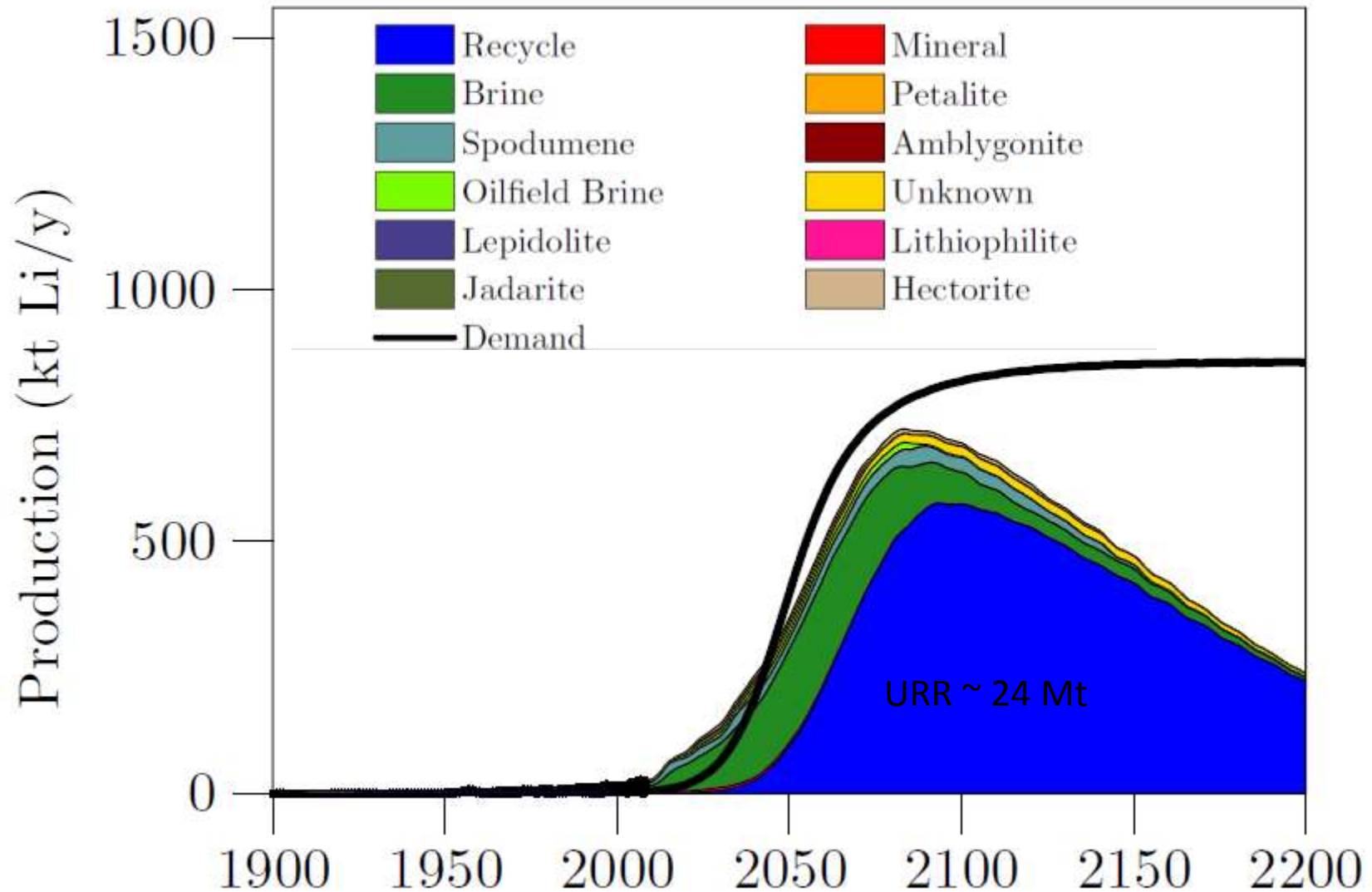
URR sensitivity analysis for global copper



Lithium historical production (rock and brines)



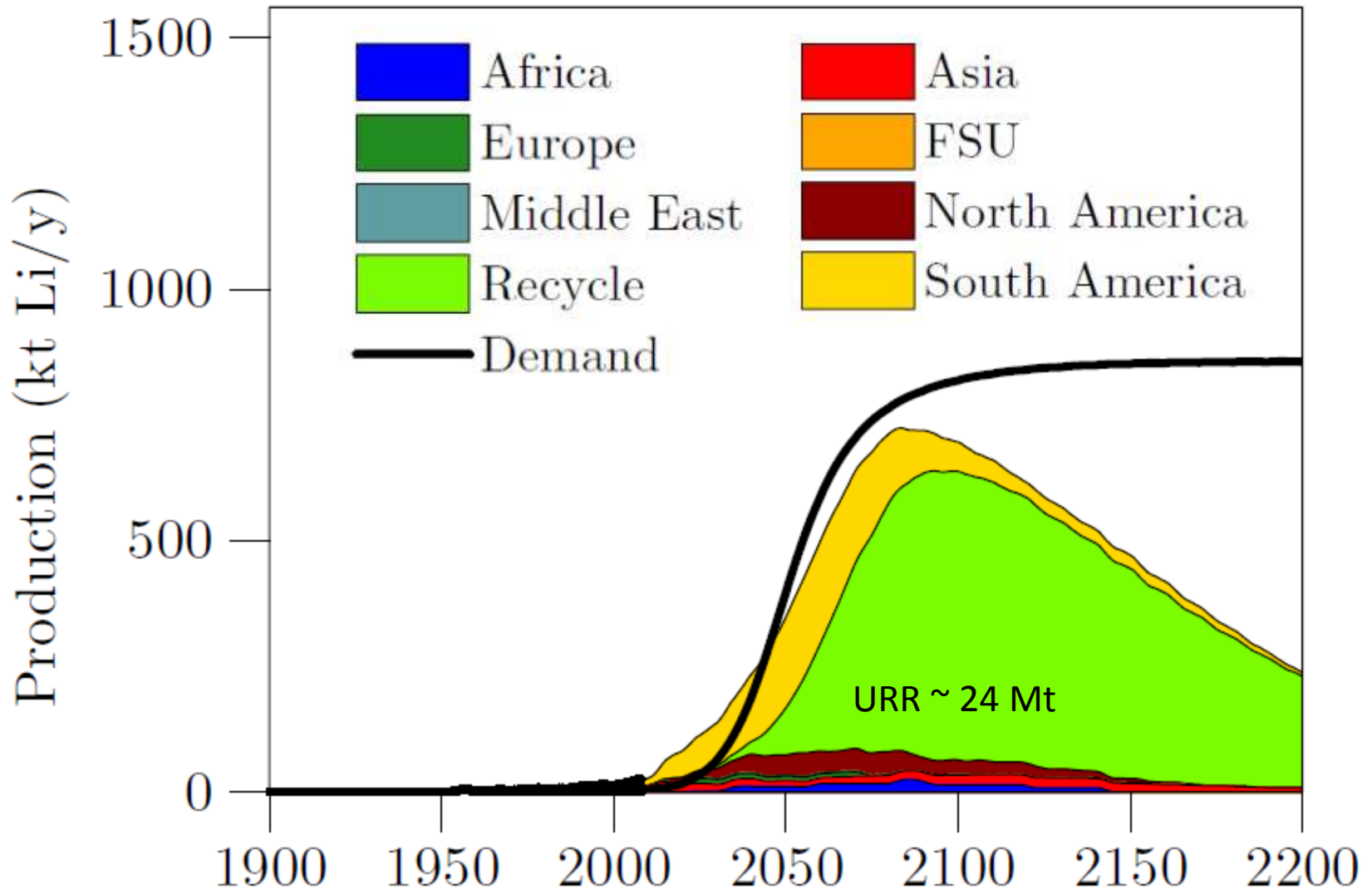
Lithium production projections by mineral



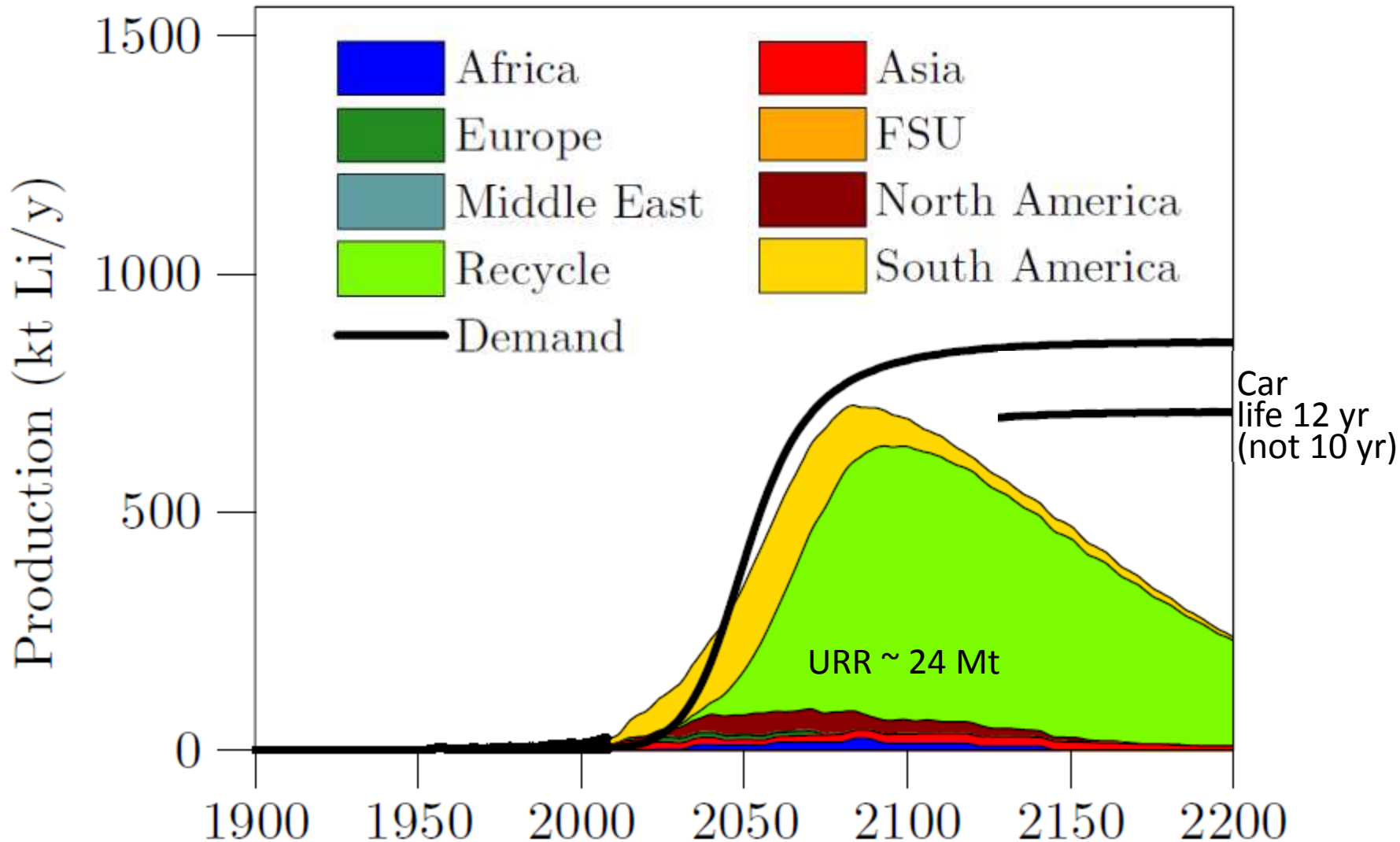
Other URR scenarios 19-55Mt

Mohr, Mudd, Giurco (2012) Minerals

Lithium production projections by region



Lithium production projections, lower demand





Mining below and above ground



10 KILOGRAMS of mobile scrap

ONE GOLD RING

10 TONNES of gold ore

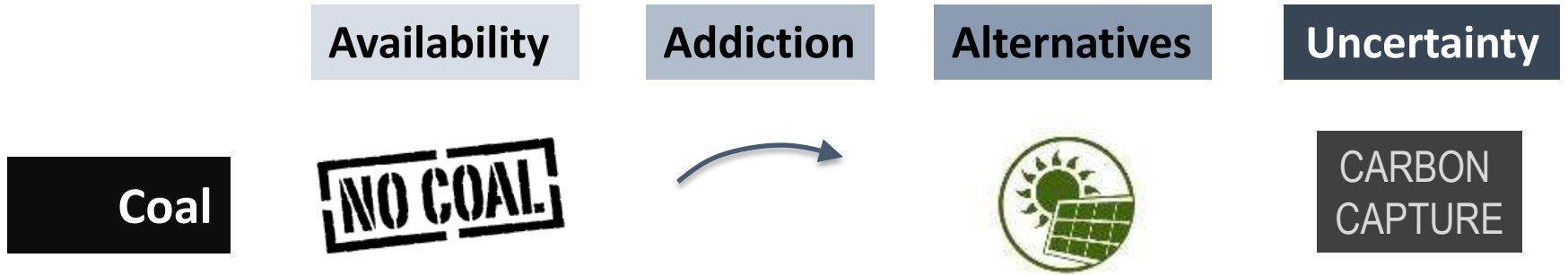


www.futureexploration.net

source: Boliden Sustainability Report

Resourcing future generations will require the study of *urban ores*

Identifying issues and opportunities



Identifying issues and opportunities

Availability

Addition

Alternatives

Uncertainty

Coal

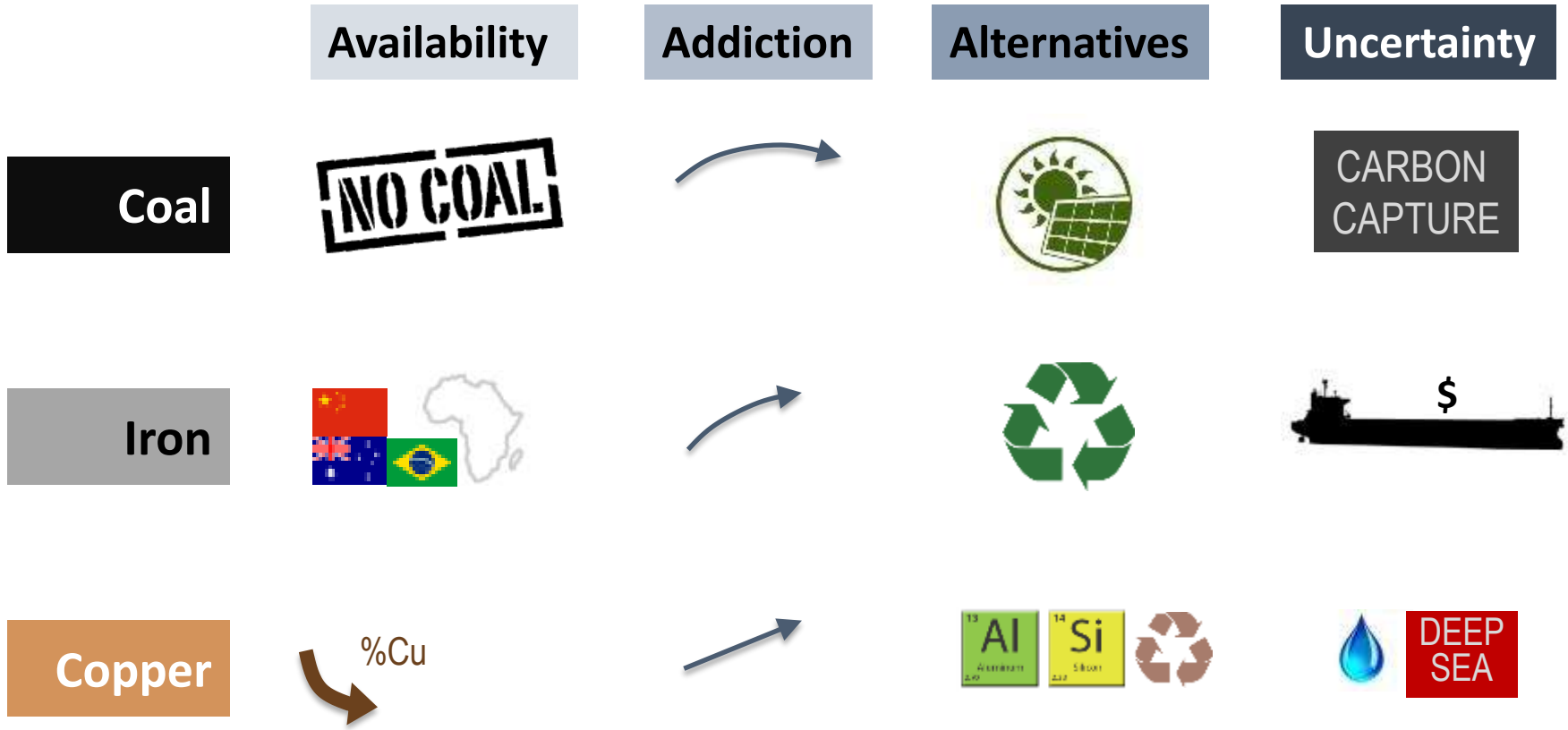


CARBON CAPTURE

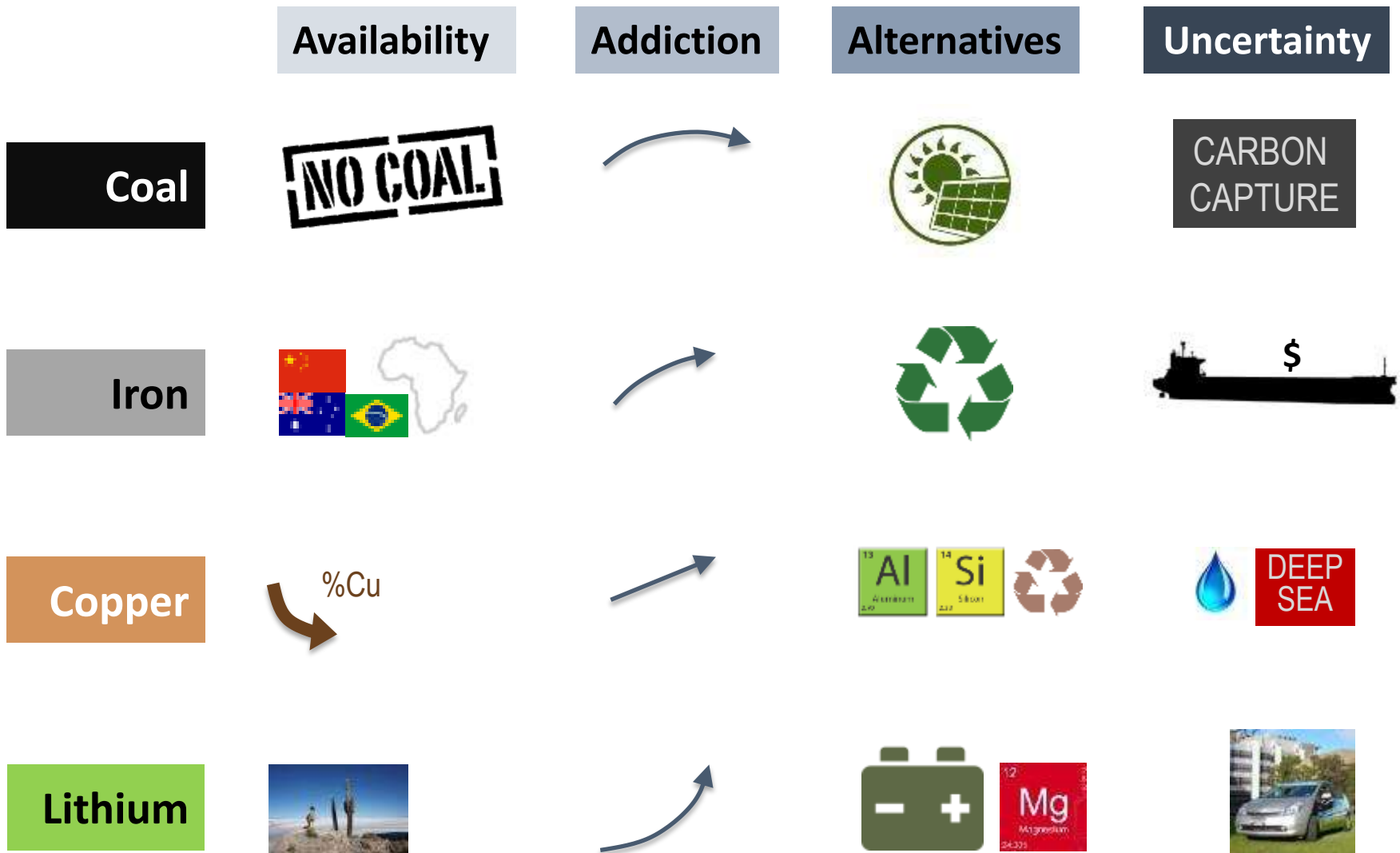
Iron



Identifying issues and opportunities



Identifying issues and opportunities





- > *Build a vision for resources in future generations*
 - *Efficiency; behaviour; sustainability accounts*

- > *Production projections [GeRS-DeMo]*
 - *Robust country / mine model*
 - *time series & geographical insights*
 - *engages policymakers, public, industry*
 - *Future development*
 - *data for all commodities; demand; recycling*
 - *add environmental impact profile*

The next generation is critical.....

Contact details

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Institute for
Sustainable
Futures



www.isf.uts.edu.au

Publications

Mineral Futures Collaboration Cluster (Reports)

www.csiro.au/partnerships/mineral-futures-collaboration-cluster.html

Journal articles from web bios (Steve Mohr, Gavin Mudd, Damien Giurco)

Acknowledgements

CSIRO Minerals Down Under Flagship

UTS: Tim Prior, Reza Memary, Aleta Lederwasch, Leah Mason, Daniel May

Monash: Zehan Weng, Mohan Yellishetty, Steve Northey