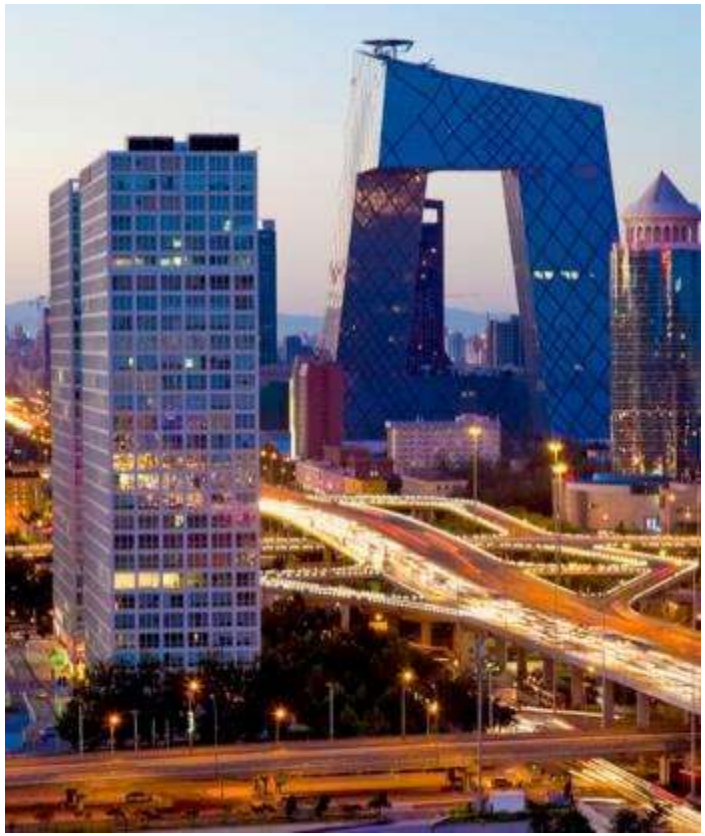
GSA's 125th Anniversary Annual Meeting & Expo

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

National Research FLAGSHIPS Minerals Down Under CSIRO · The University Of Queensland AUSTRALIA · Curtin University of Technology · CQUniversity AUSTRALIA · ANU · UNIVERSITY OF TECHNOLOGY SYDNEY · MONASH University

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

i) Availability

ii) Addiction

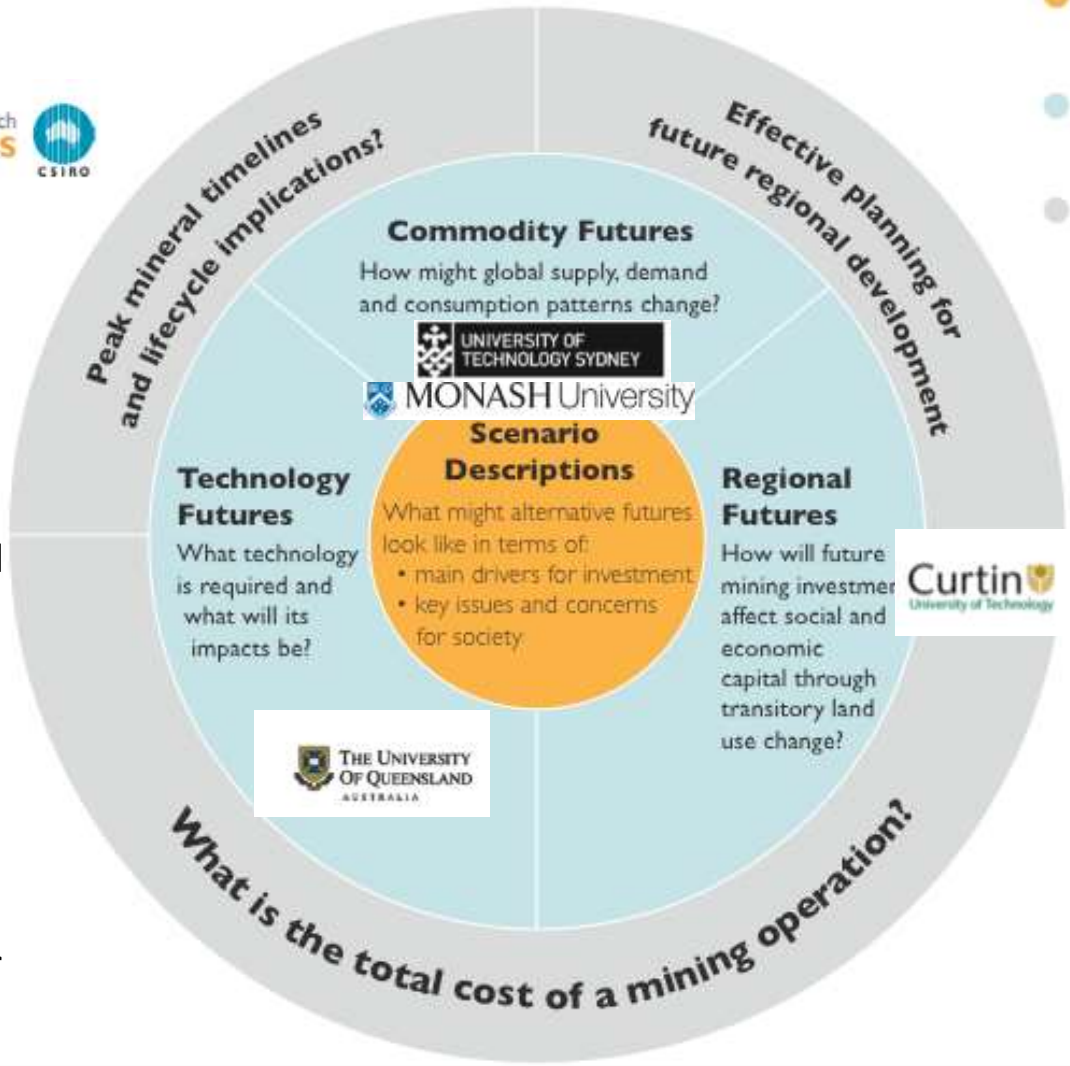
iii) Alternatives

Mason et al. (2011)
Journal of Cleaner Production

Mineral Futures Collaboration Cluster [2009-2013]

Dr Gavin Mudd
Monash

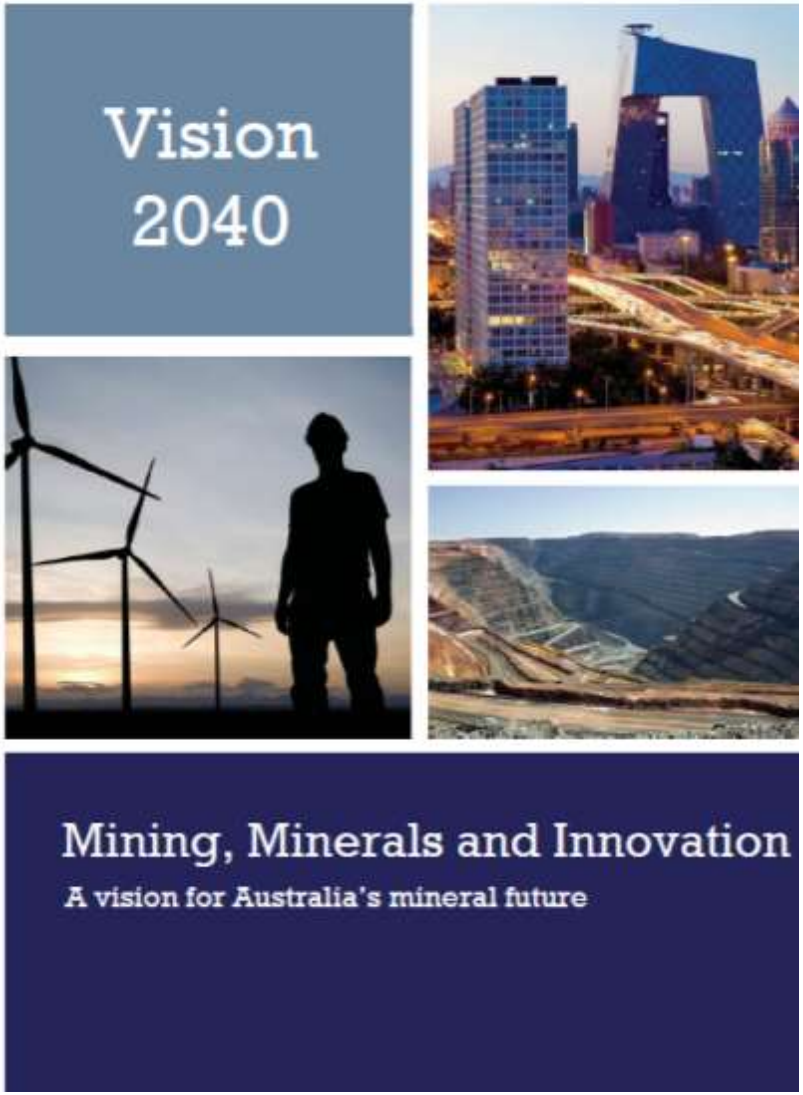
Dr Steve Mohr
ISF, UTS

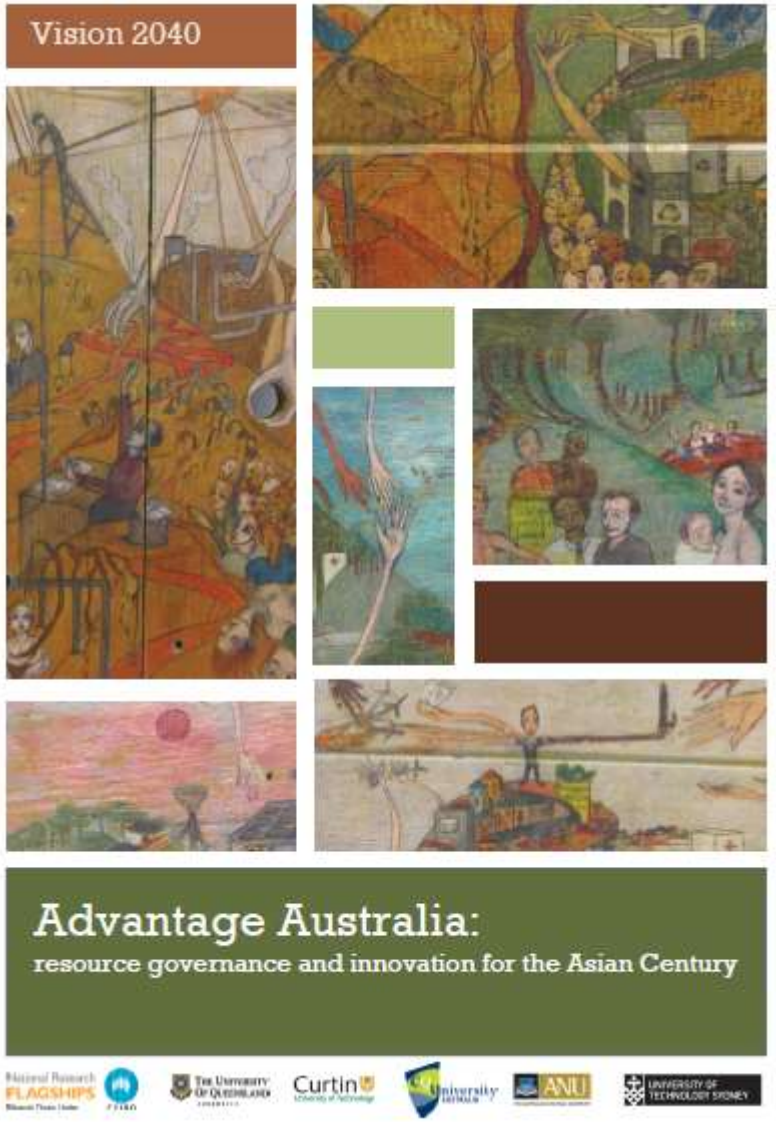


- Role of the mineral futures forum, supported by strategic foresight scoping studies
- Defined lines of inquiry to be developed primarily through the collaboration cluster
- Decision support issues for a sustainable Australian minerals investment strategy

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

Starting a national conversation on mineral futures…







Vision 2040 – 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

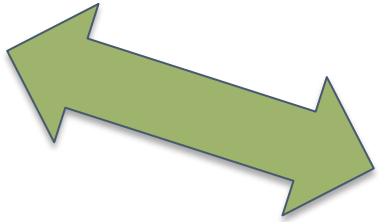
Where
will resources come from,
to enable healthy societies,
in this century?

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

Nauru: economic reserves depleted

Fixed Stock Paradigm

fixed stock of minerals
rising population / demand
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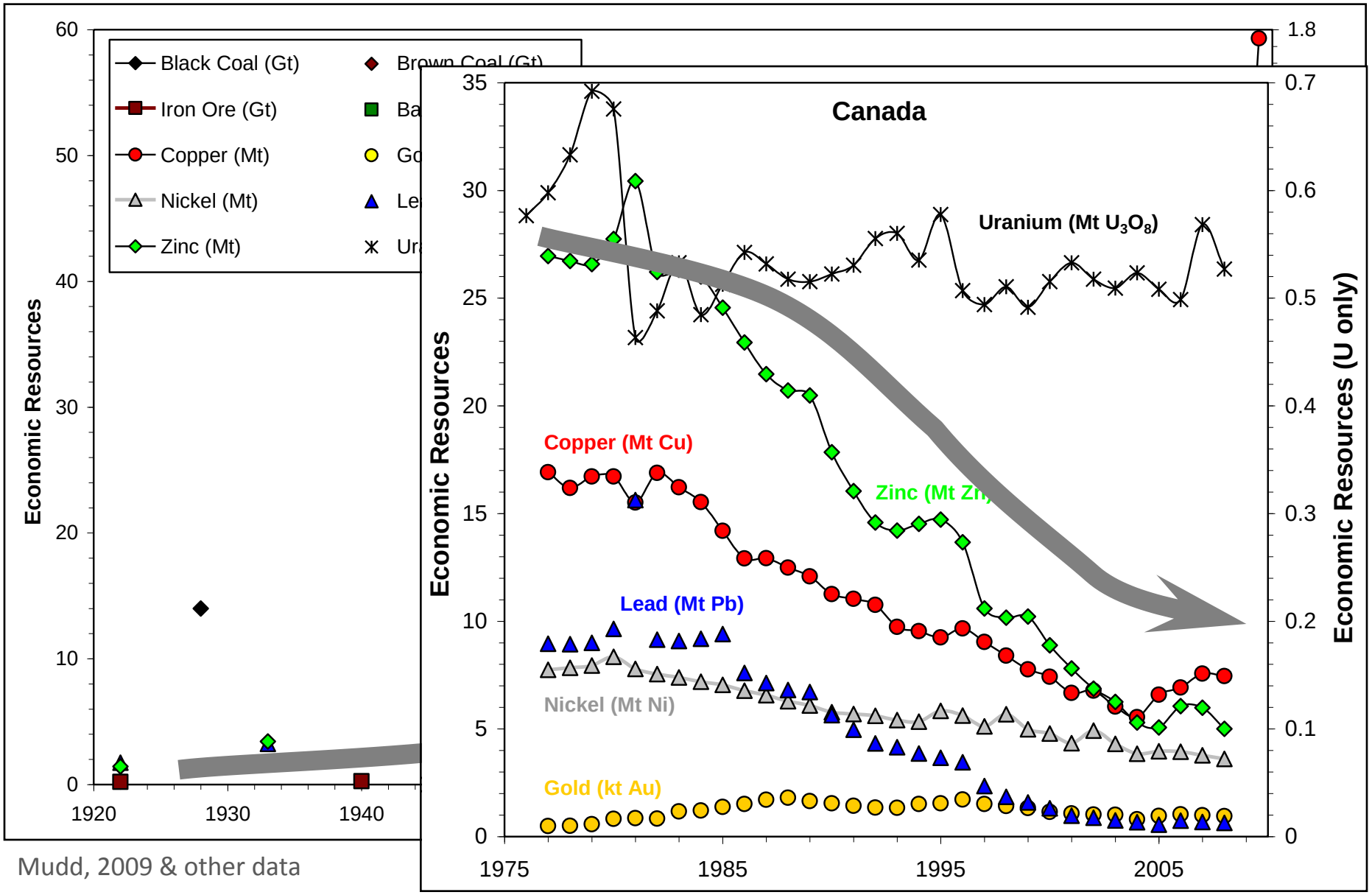
…social costs high and can't access what's there

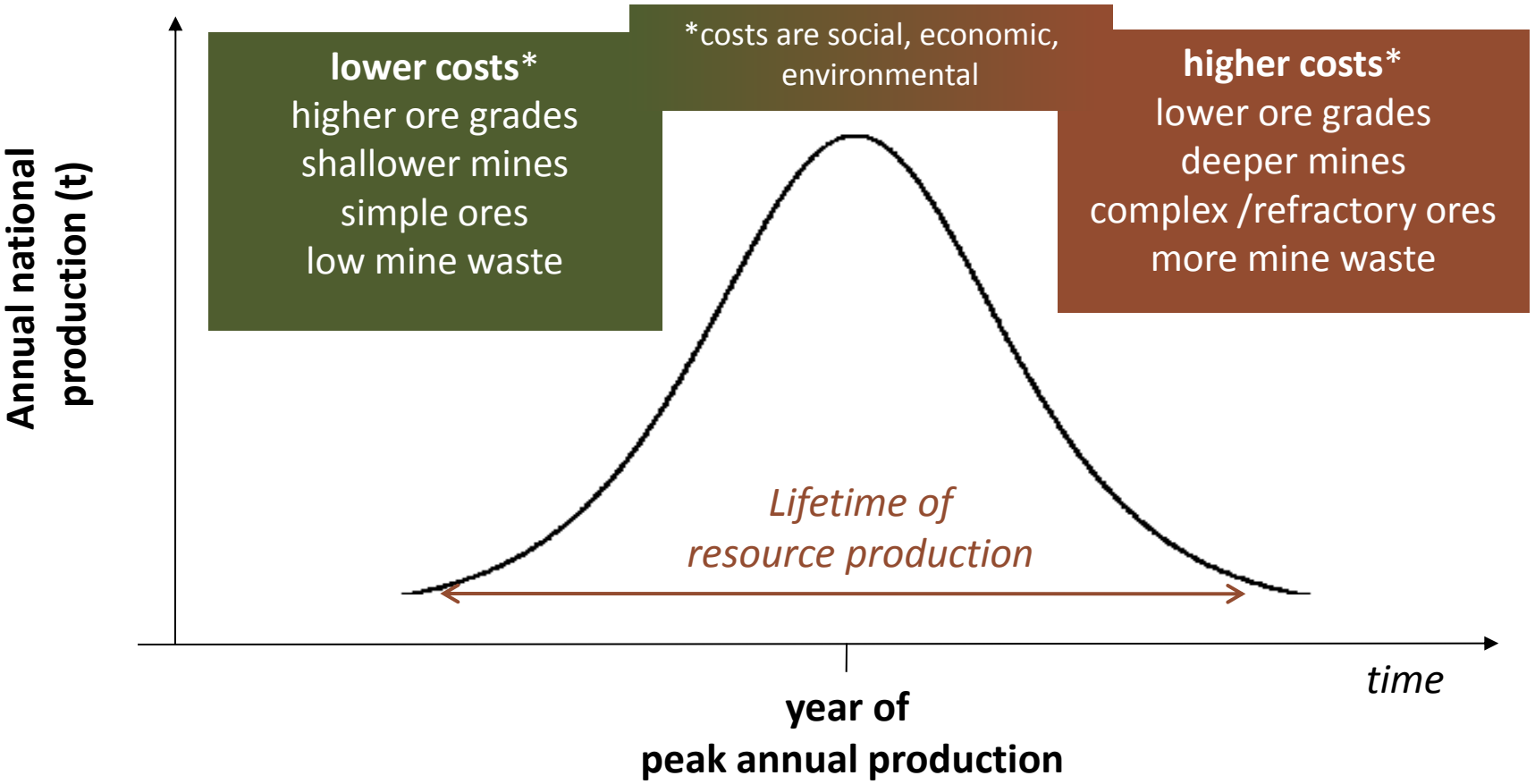
N.B. space, time , metals recyclable, availability requires access

Trends in economic resources (Australia, Canada)



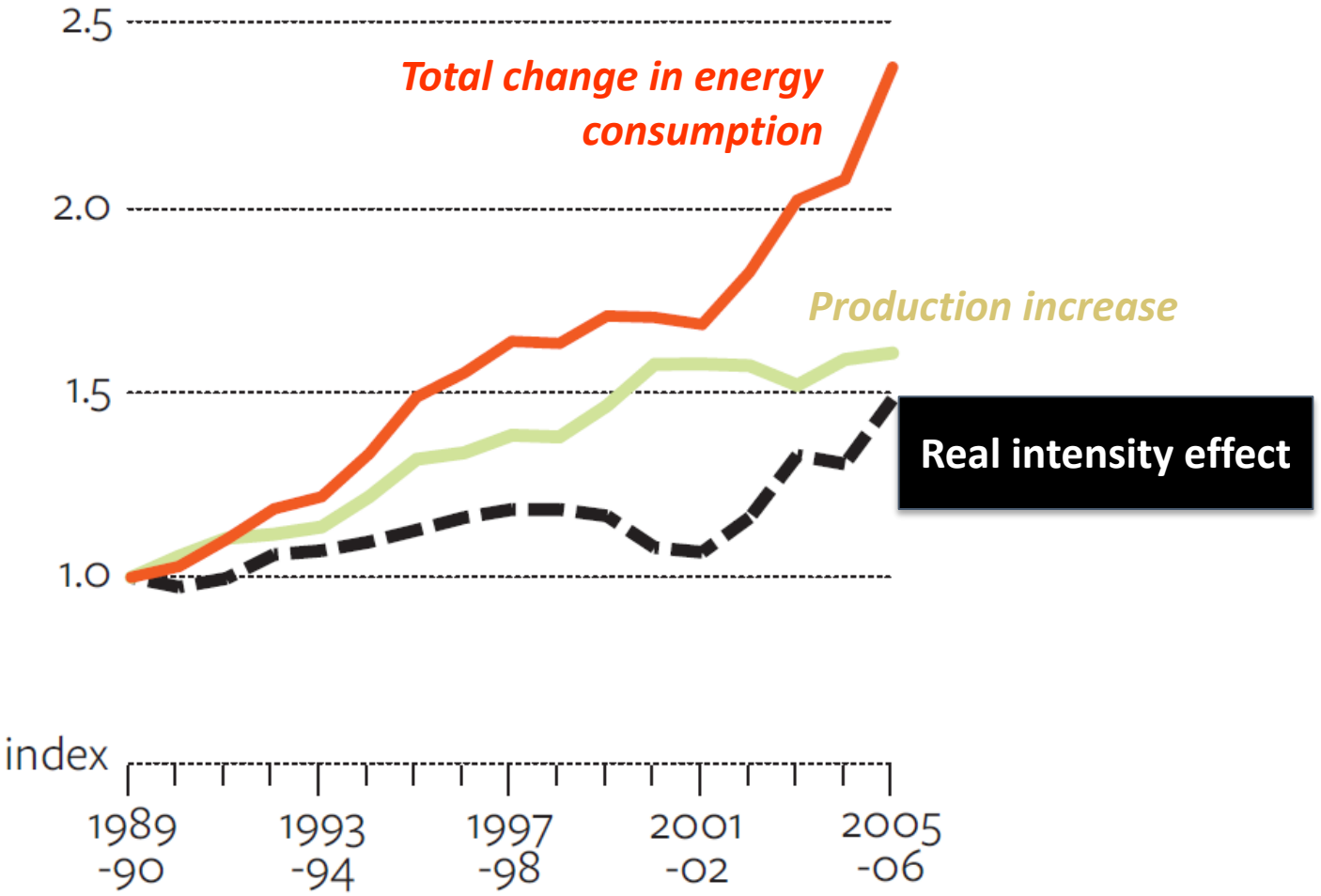
Mudd, 2009 & other data

Peak minerals metaphor: cheaper & easier to complex & costly



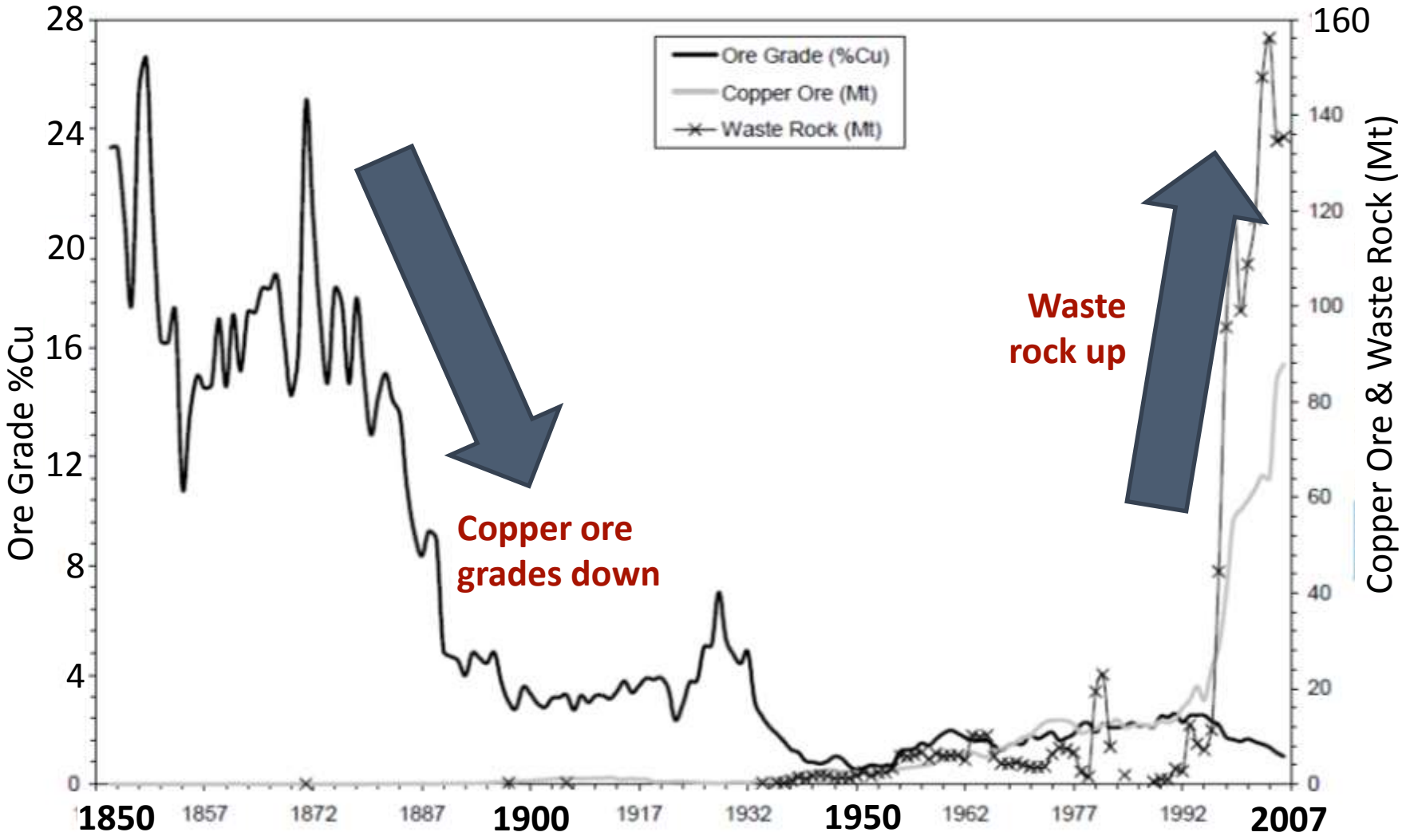
Source: adapted from Giurco et al. (2010) Peak minerals in Australia, Report 1.2

Energy intensity of mining up 50% in Australia



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

Cheaper & easier → more complex & expensive



Data: G. Mudd

Approaches to long term modelling

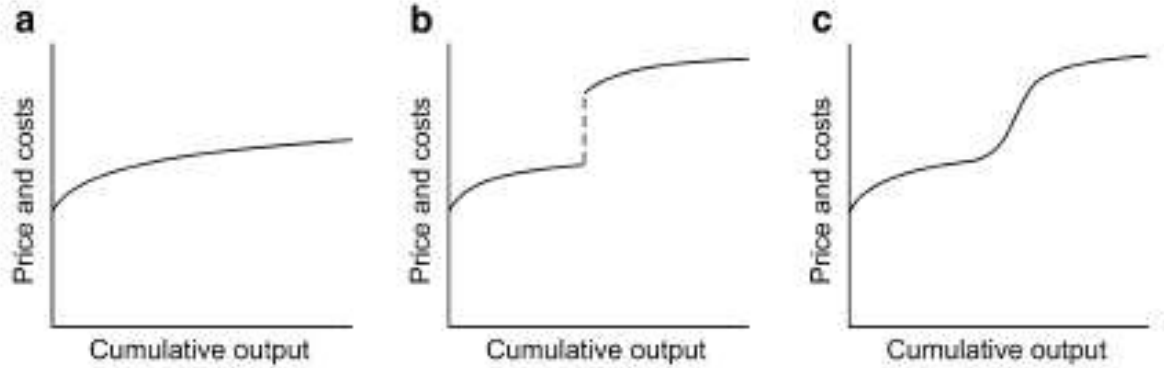
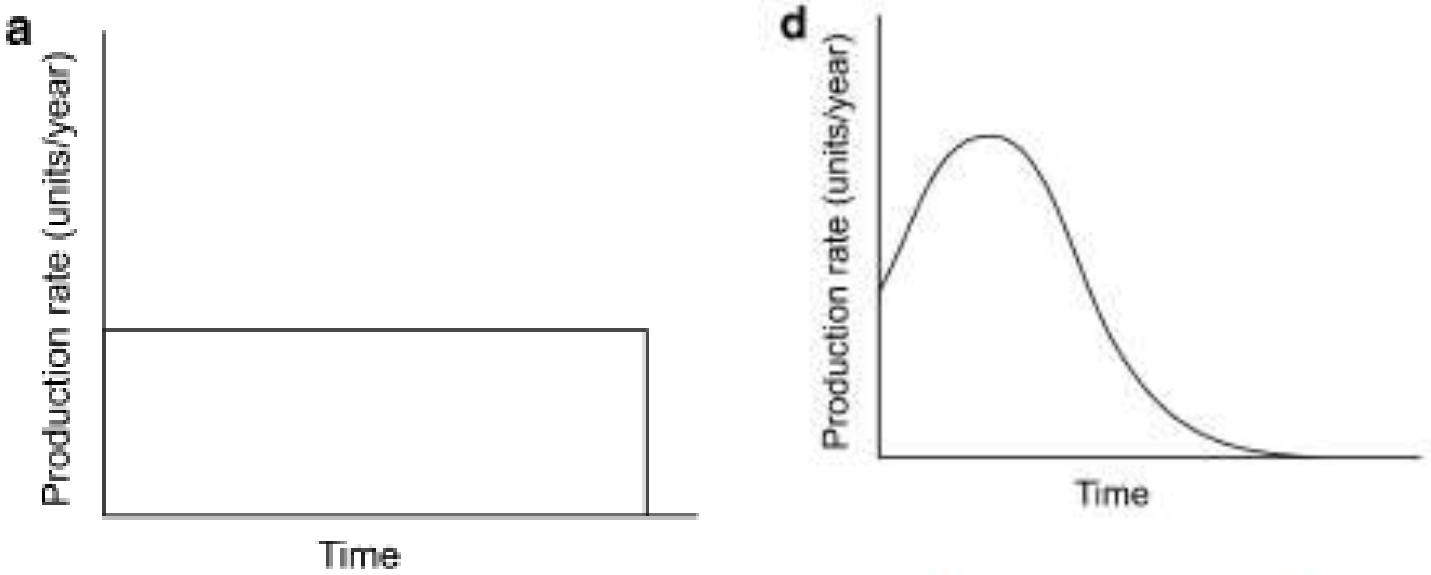


Figure 4 Illustrative cumulative availability curves (Tilton and Skinner 1987). (a) Slowly rising slope due to gradual increase in costs, (b) discontinuity in slope due to jump in costs and (c) sharply rising slope due to rapid increase in costs.

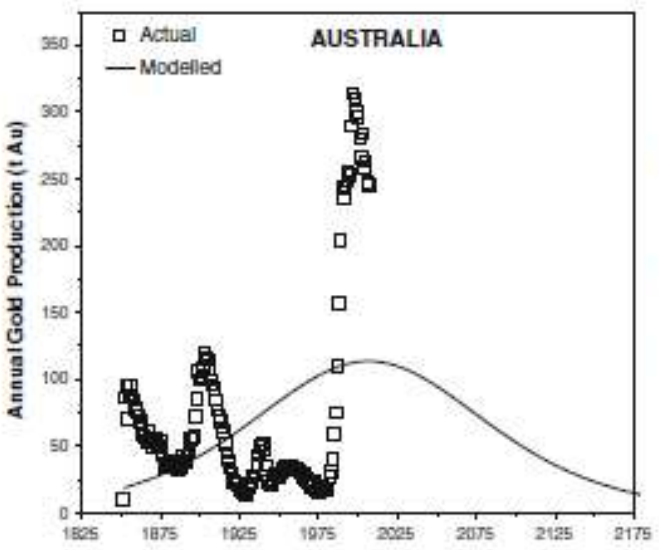


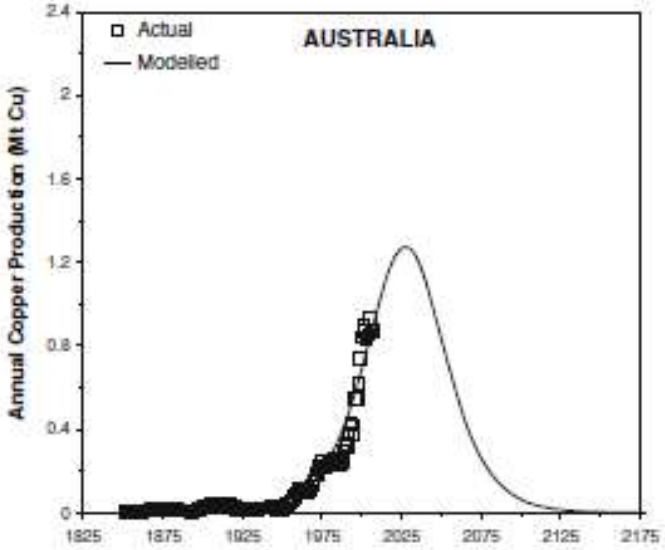
Daniel May,[1] Timothy Prior,[1] Dana Cordell,[1] and Damien Giurco[1,2]

Natural Resources Research, Vol. 21, No. 1, March 2012 (© 2011)

Not all production = smooth curve

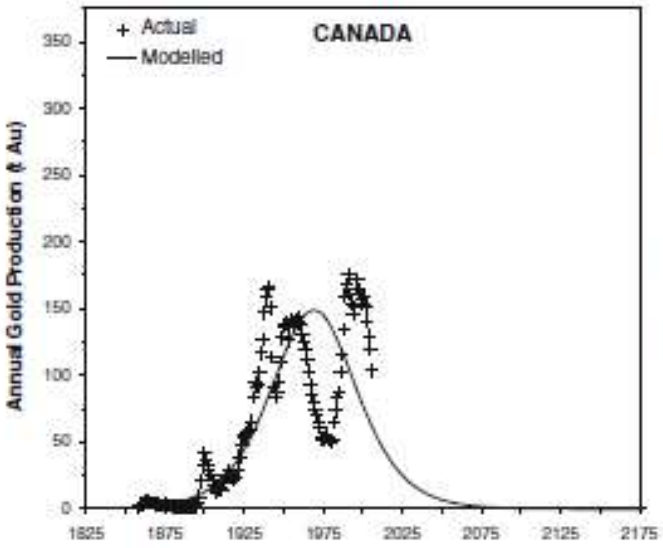
Gold Australia

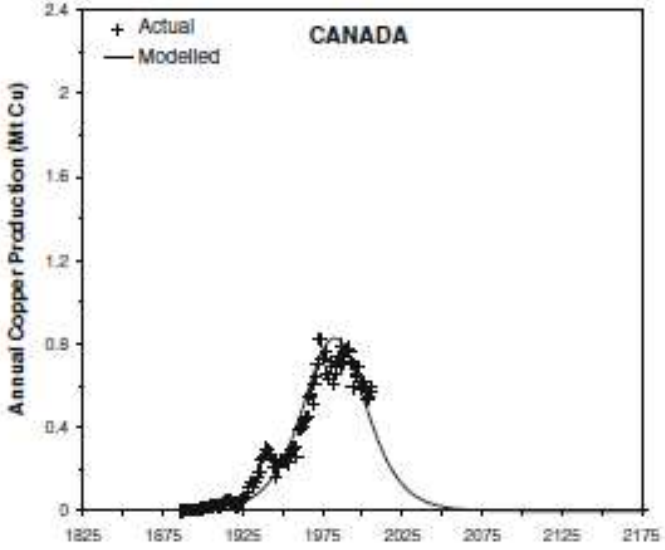




Copper Australia

Gold Canada





Copper Canada

(Mudd and Ward 2008).

Geologic Resources Supply-Demand Model GeRS-DeMo

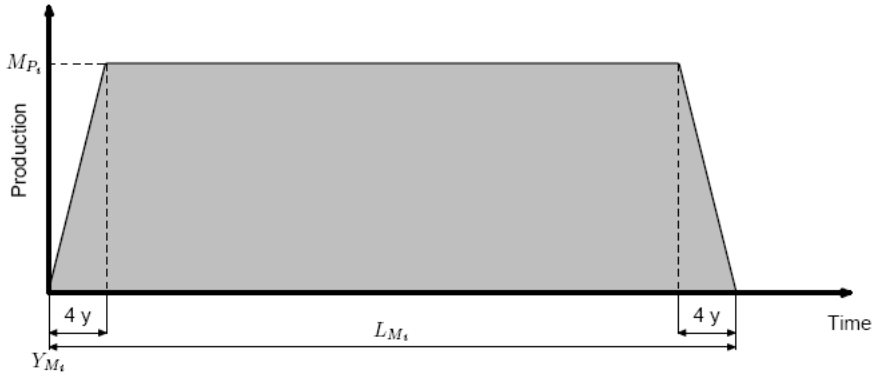
http://datasearch.uts.edu.au/isf/news-events/news-detail.cfm?ItemId=29302
Or Google: GeRS-DeMo

Overall approach

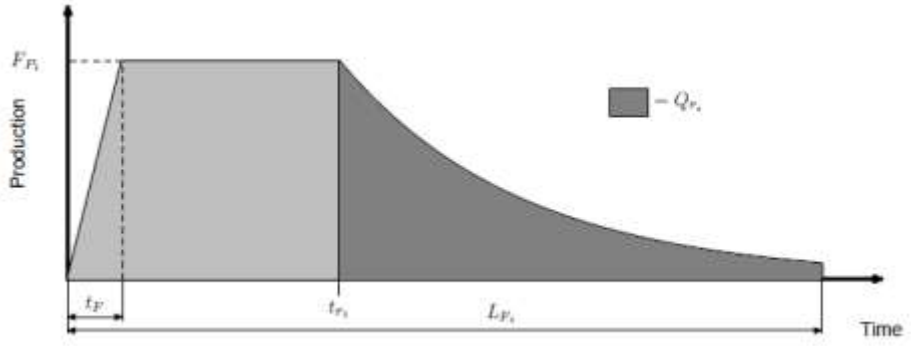
- mine by mine bottom up model
- based on URR for individual countries, typical mine sizes, possible operating patterns
- *number of mines is not fixed*

Modelling resources [GeRS-DeMo]

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



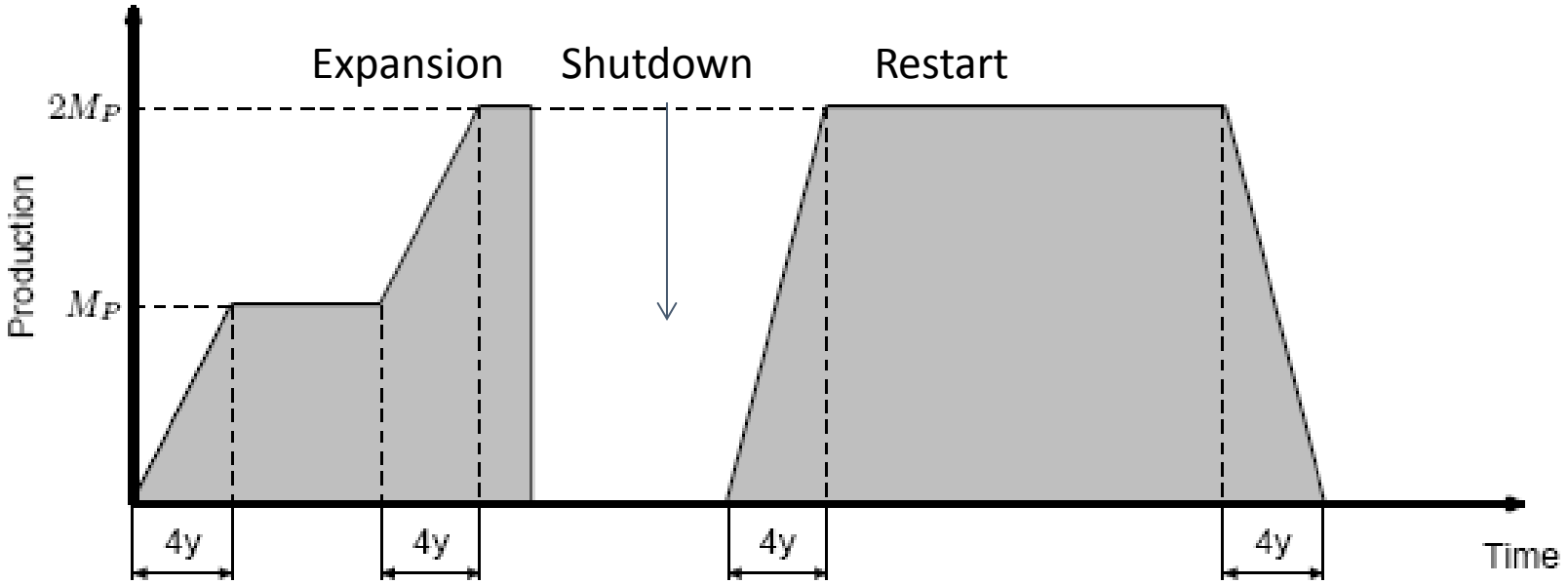
Typical mine



Typical oil/gas field

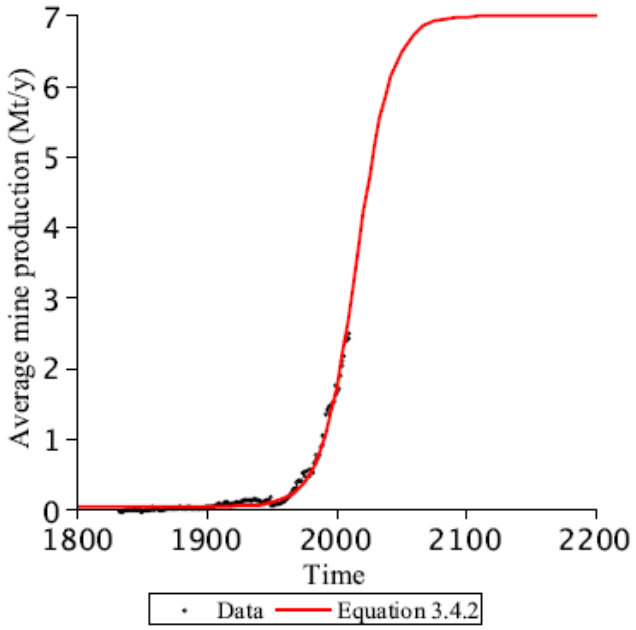
Mining model – additional features

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

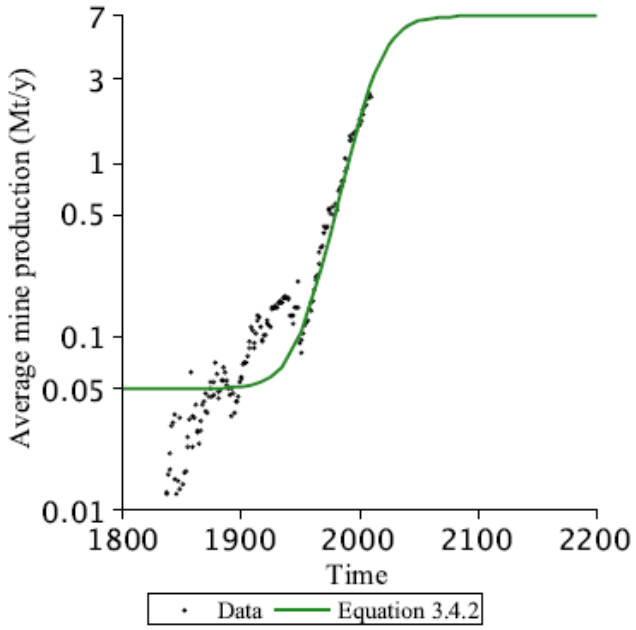


Modelling production

- 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

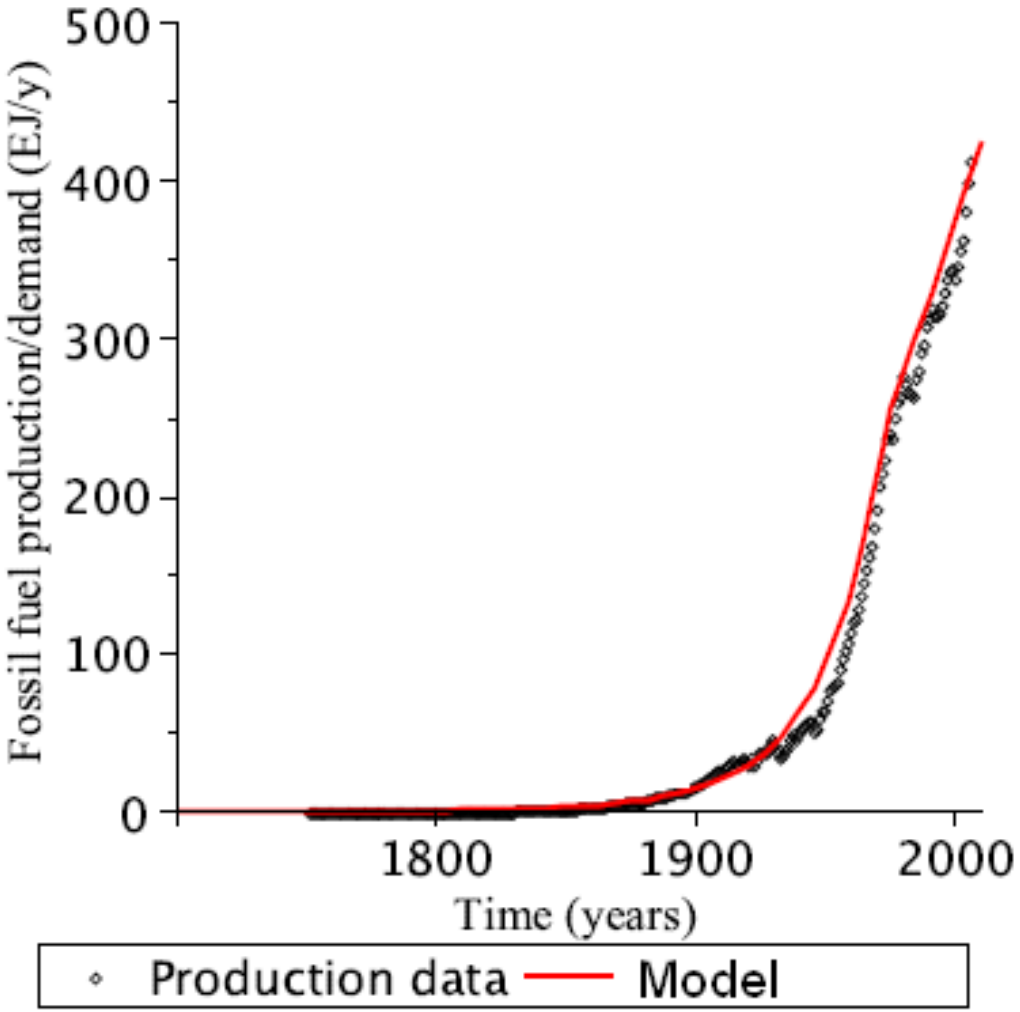


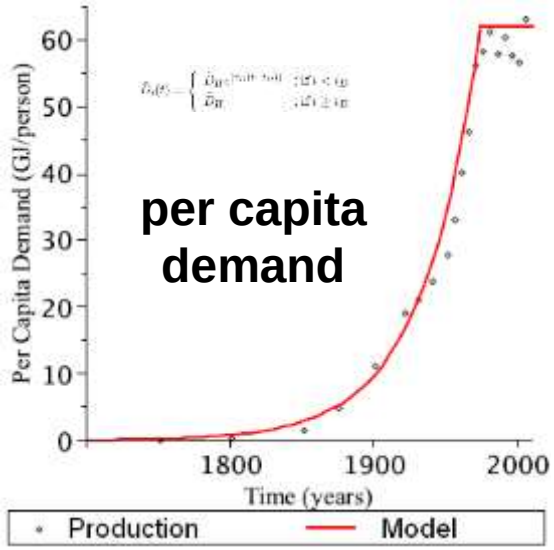
B Logarithmic (base 10) plot

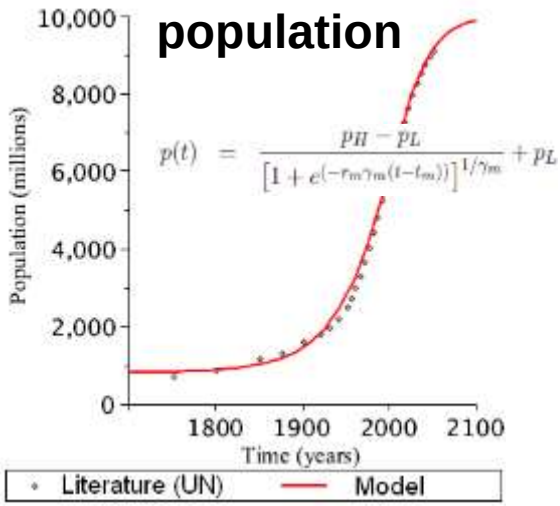
$t_t))$

FIGURE 4.15. Average mine production versus time for NSW coal

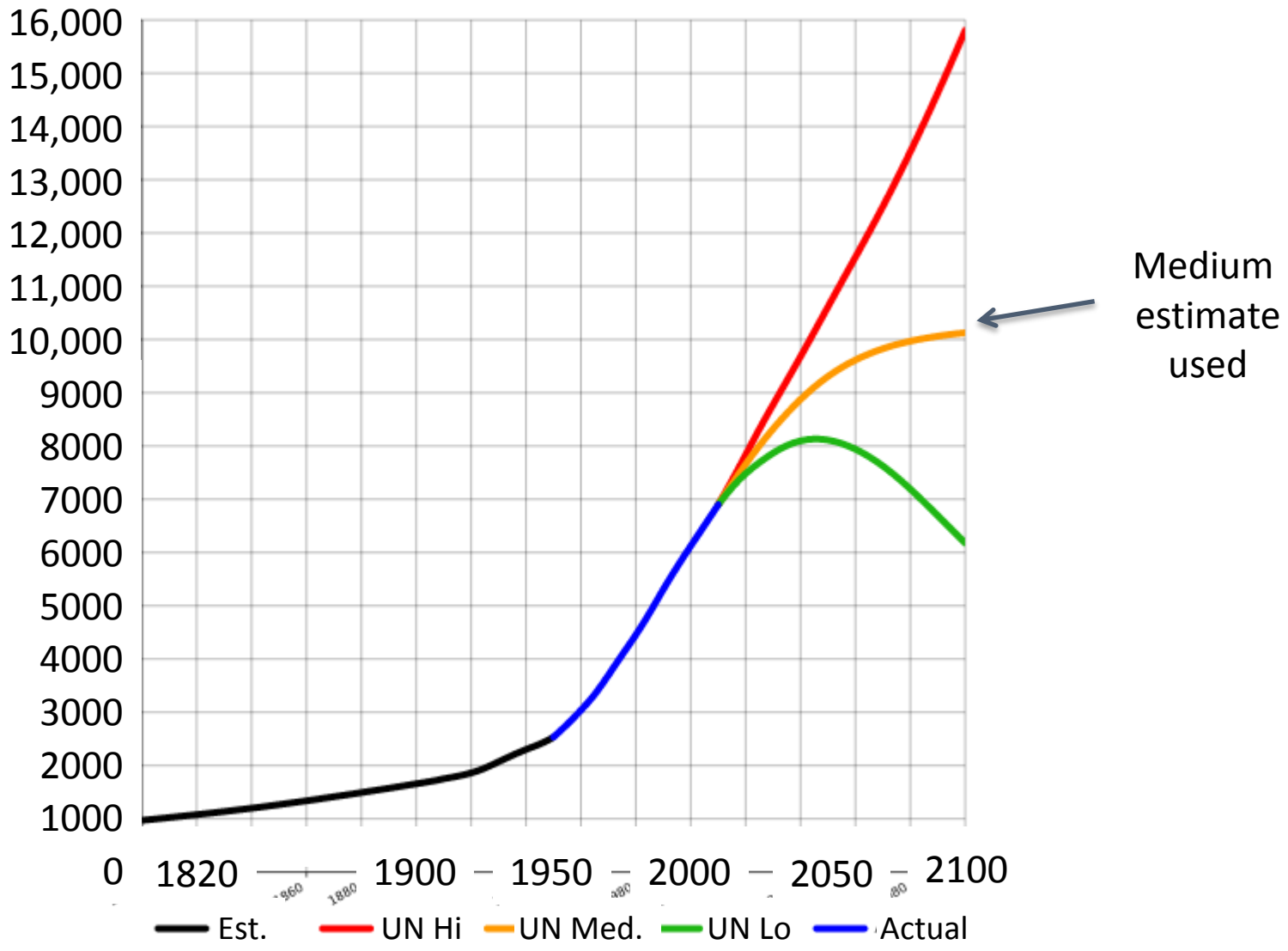
Overall demand = intensity x population



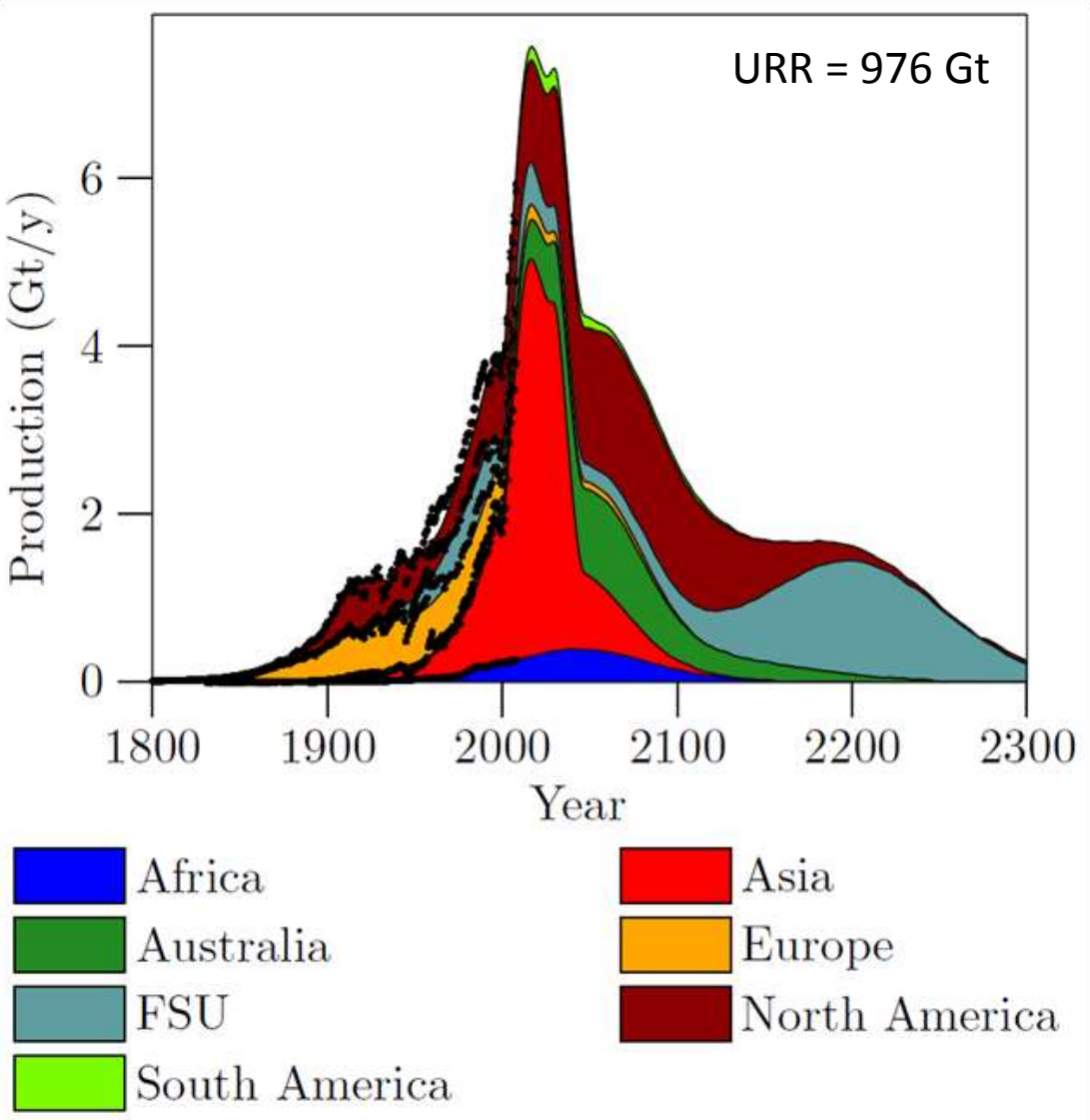




Continued population growth…..or……



Coal: peak global production within a decade

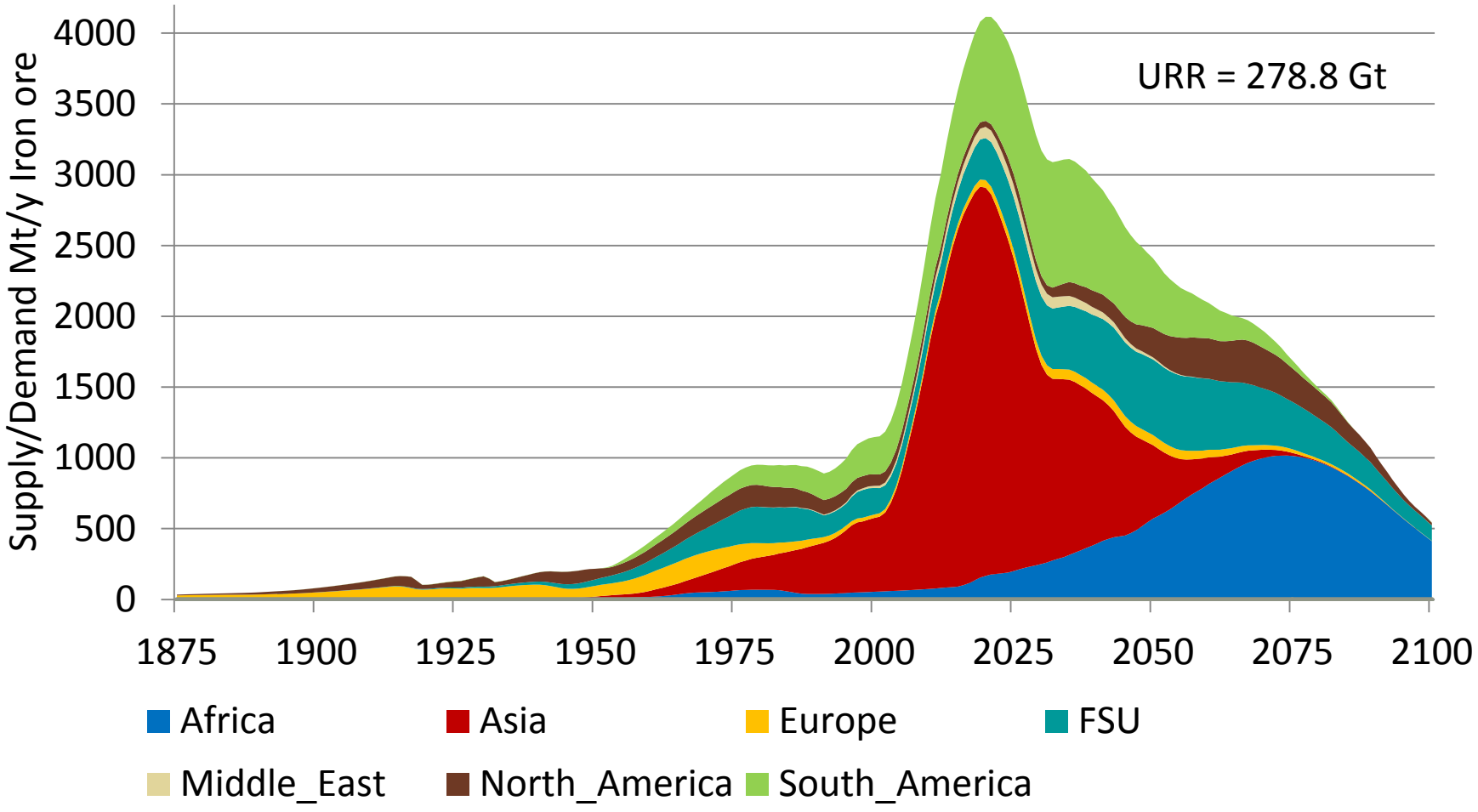


Region	Est. Peak Year	Max Prodn (Gt/y)
Africa	2039	0.4
Asia	2016	4.7
Australia	2060	1.1
Europe	1973	0.6
Fmr Sov Union	2202	1.4
North America	2065	1.7
South America	2029	0.2
Total	**2017**	**7.6**

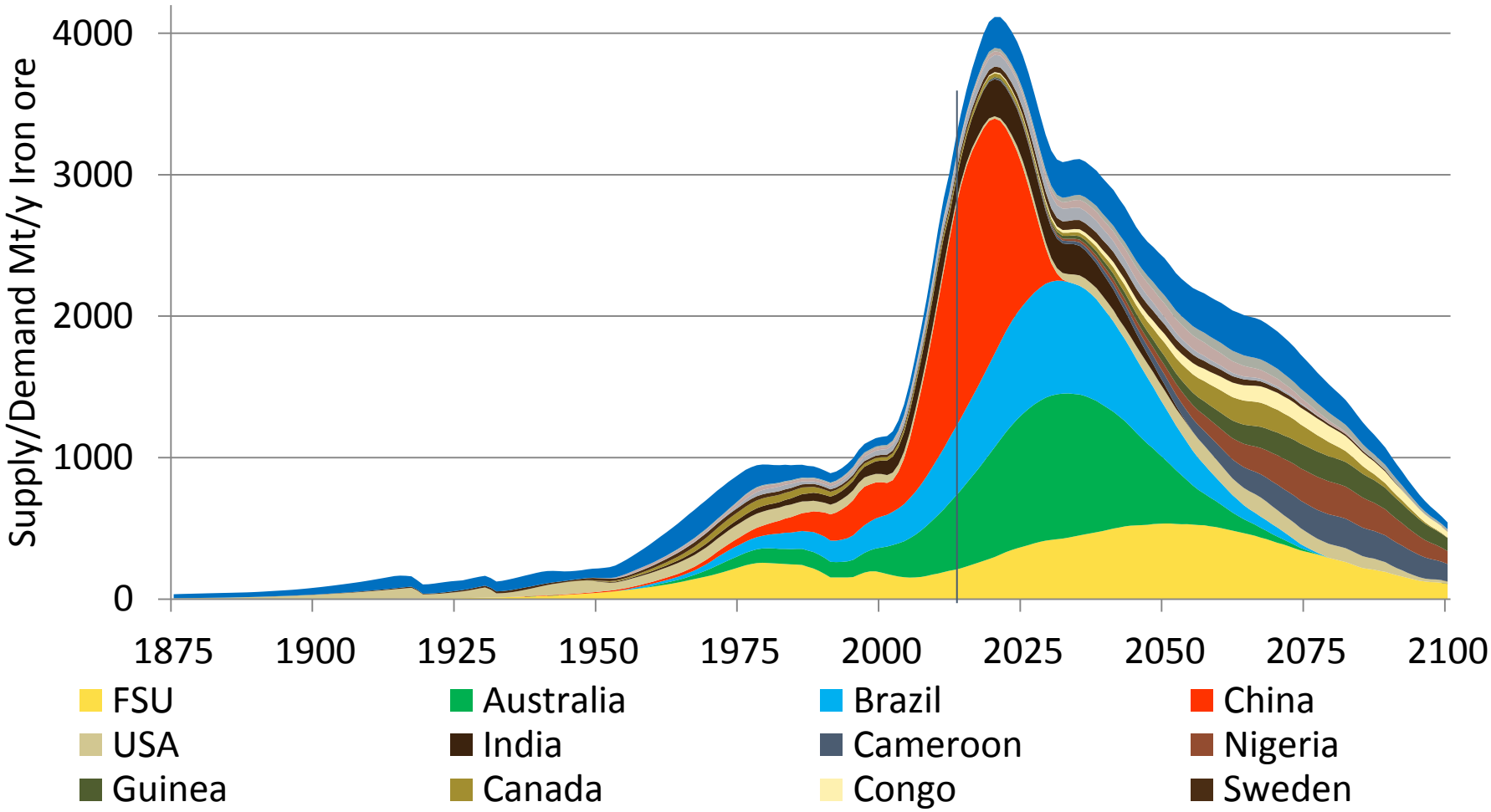
Mohr et al. (2013) Coal, Cluster Report 1.7

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

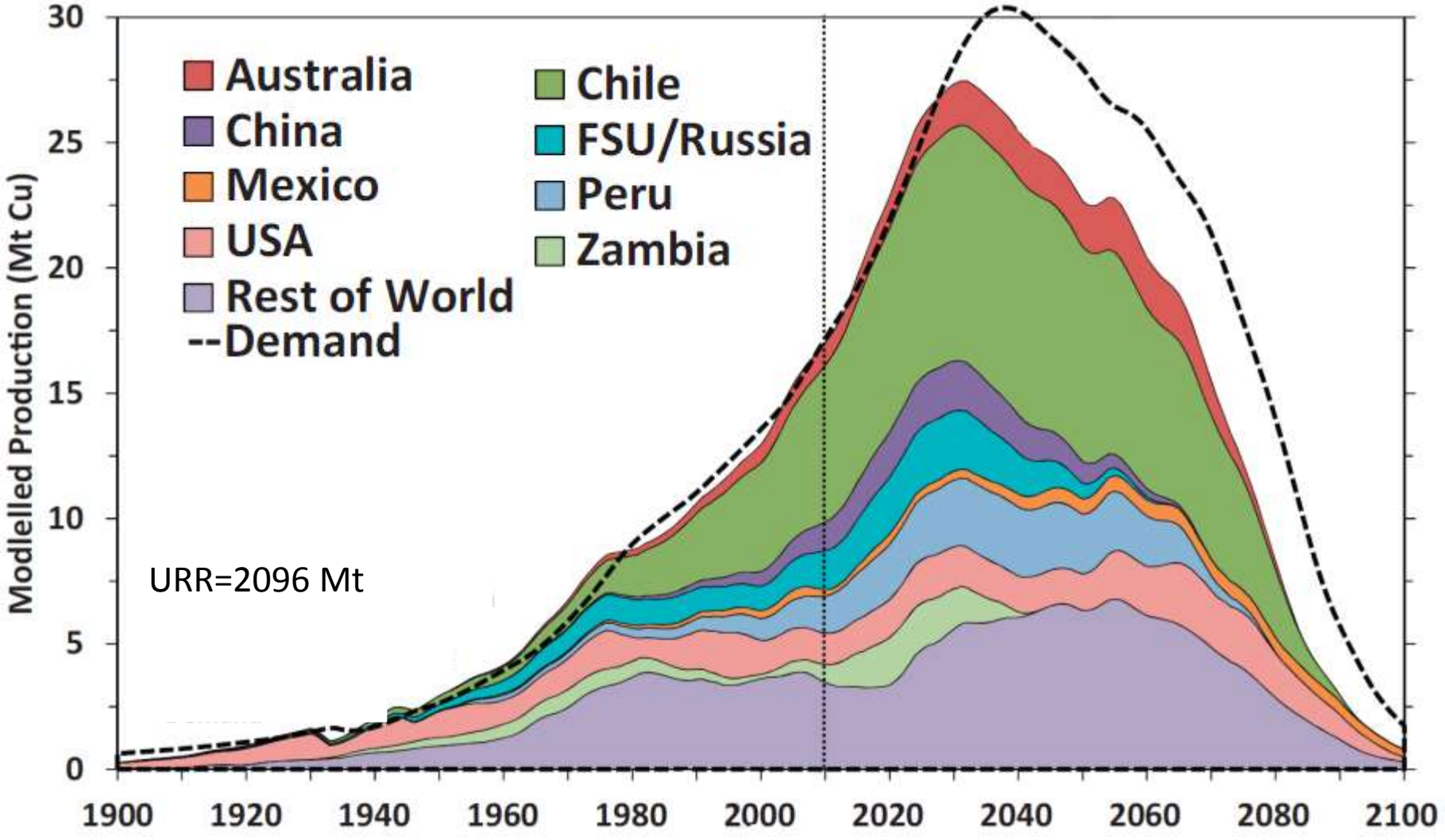
Iron ore – production by country



Iron ore – top fifteen countries

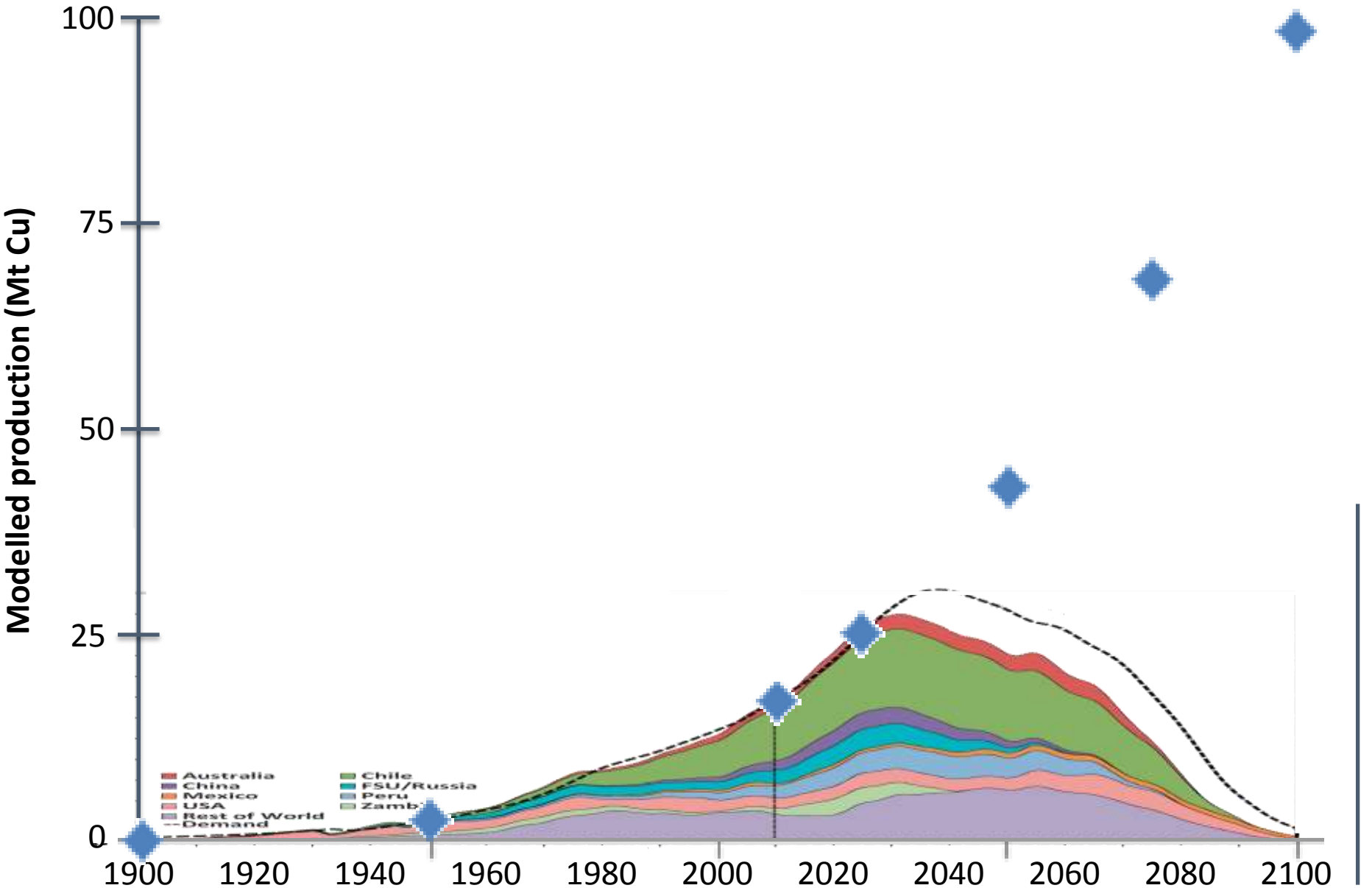


Copper production: historical and projected



Northey et al. (2013) *Resources, Conservation & Recycling*

Historical growth 1.6% p.a. cannot be supported



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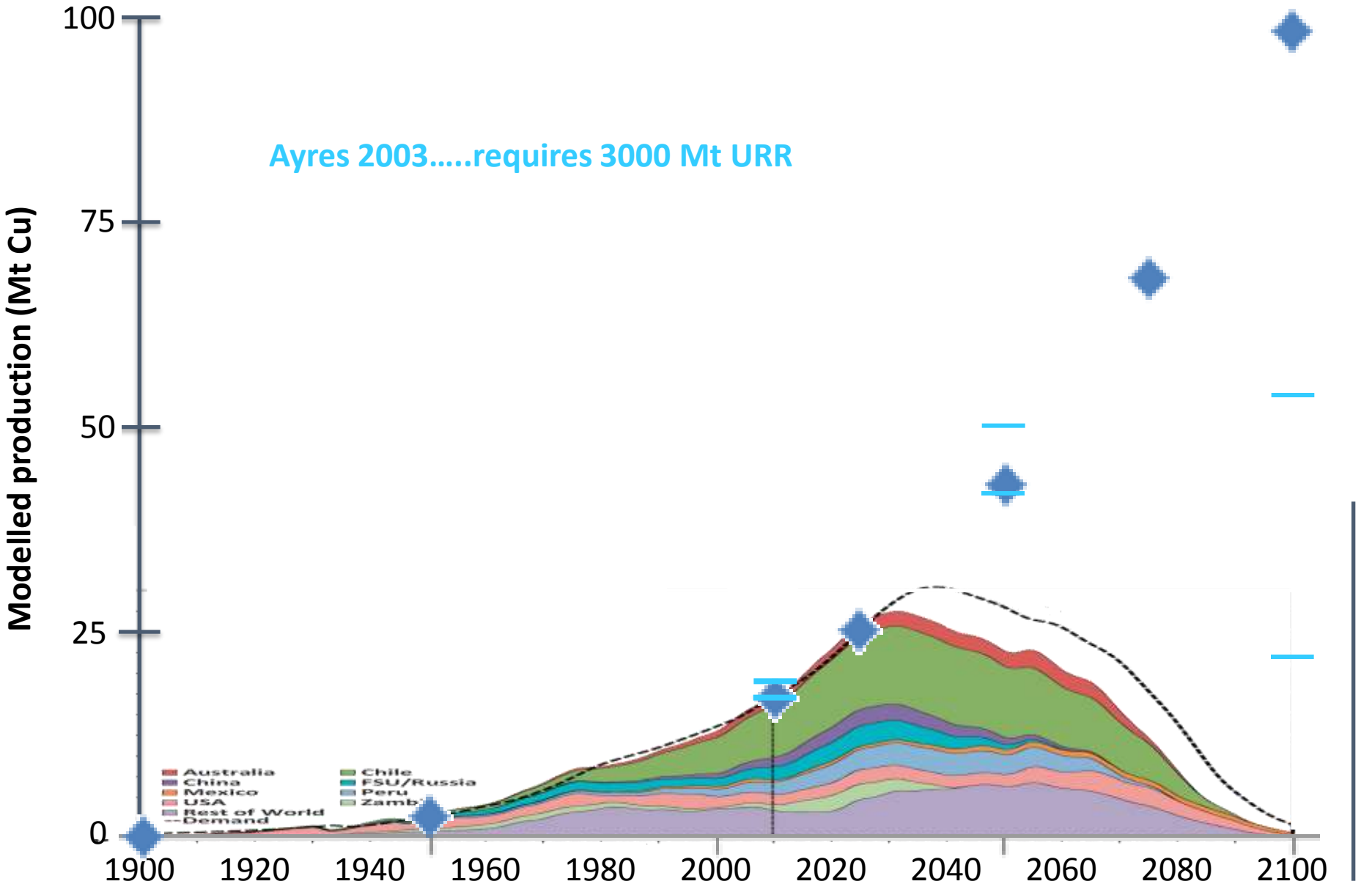
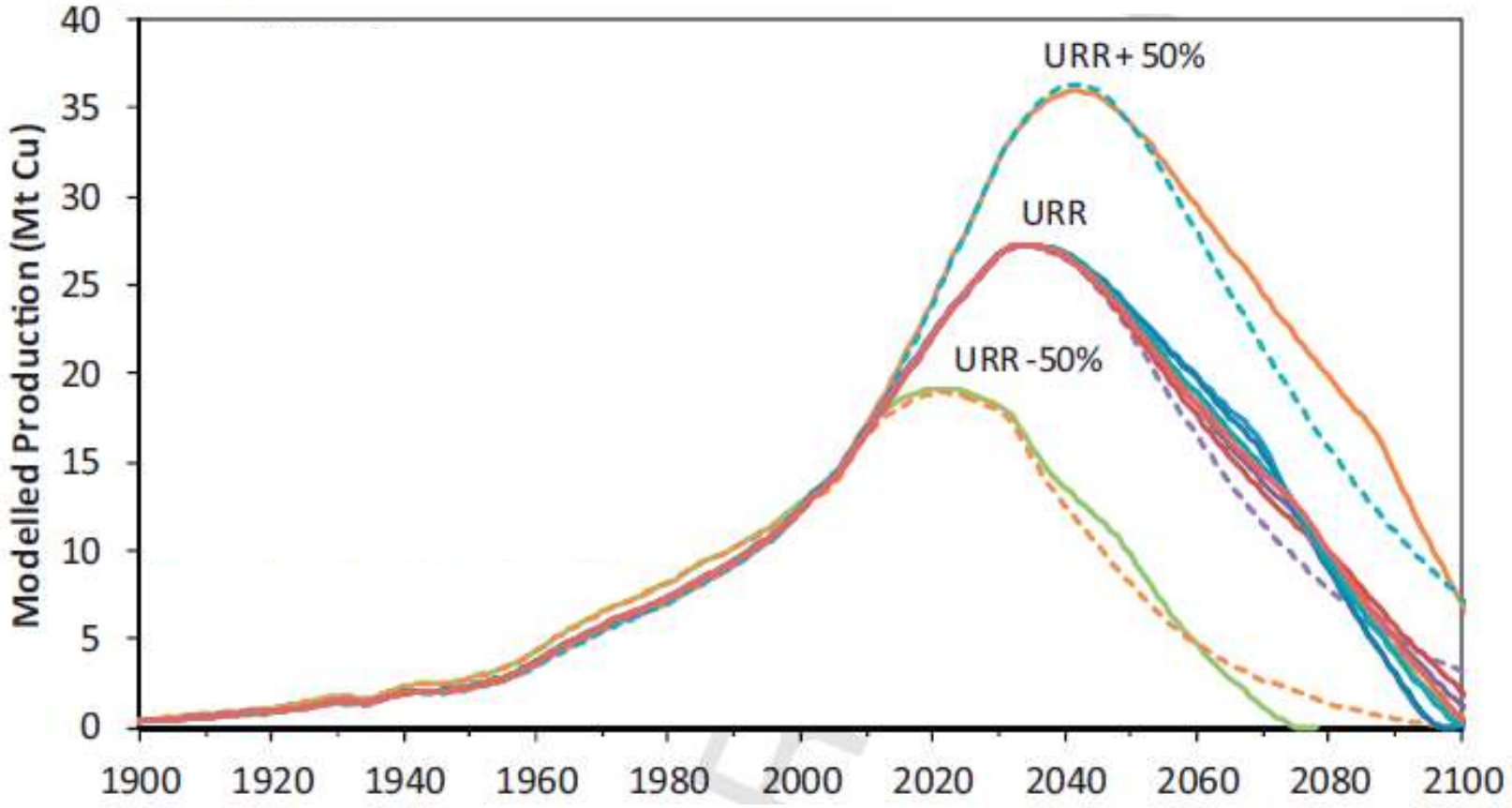
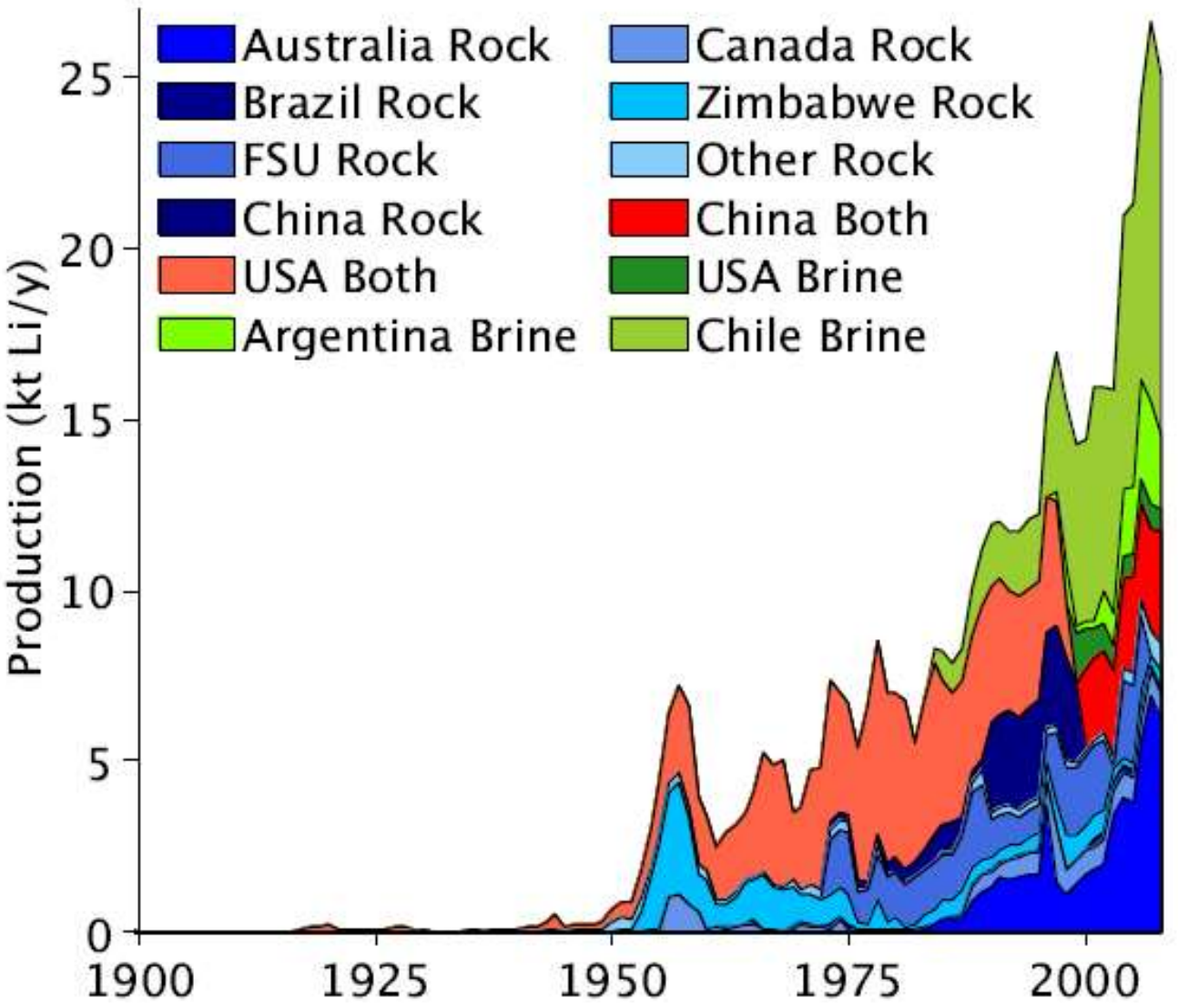


URR sensitivity analysis for global copper



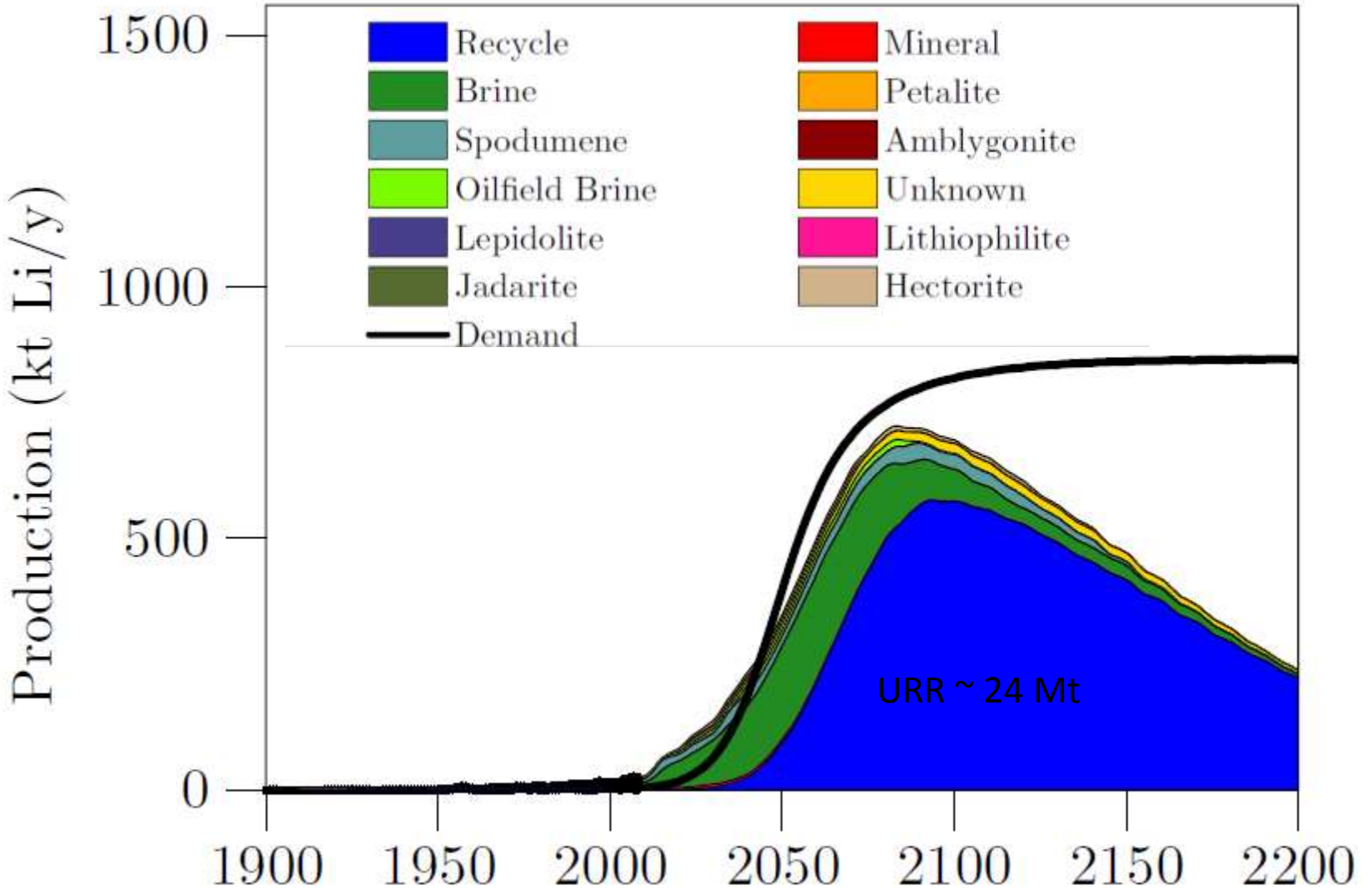
Northey et al. (2013) *Resources, Conservation & Recycling*

Lithium historical production (rock and brines)



Mohr, Mudd, Giurco (2012) *Minerals*

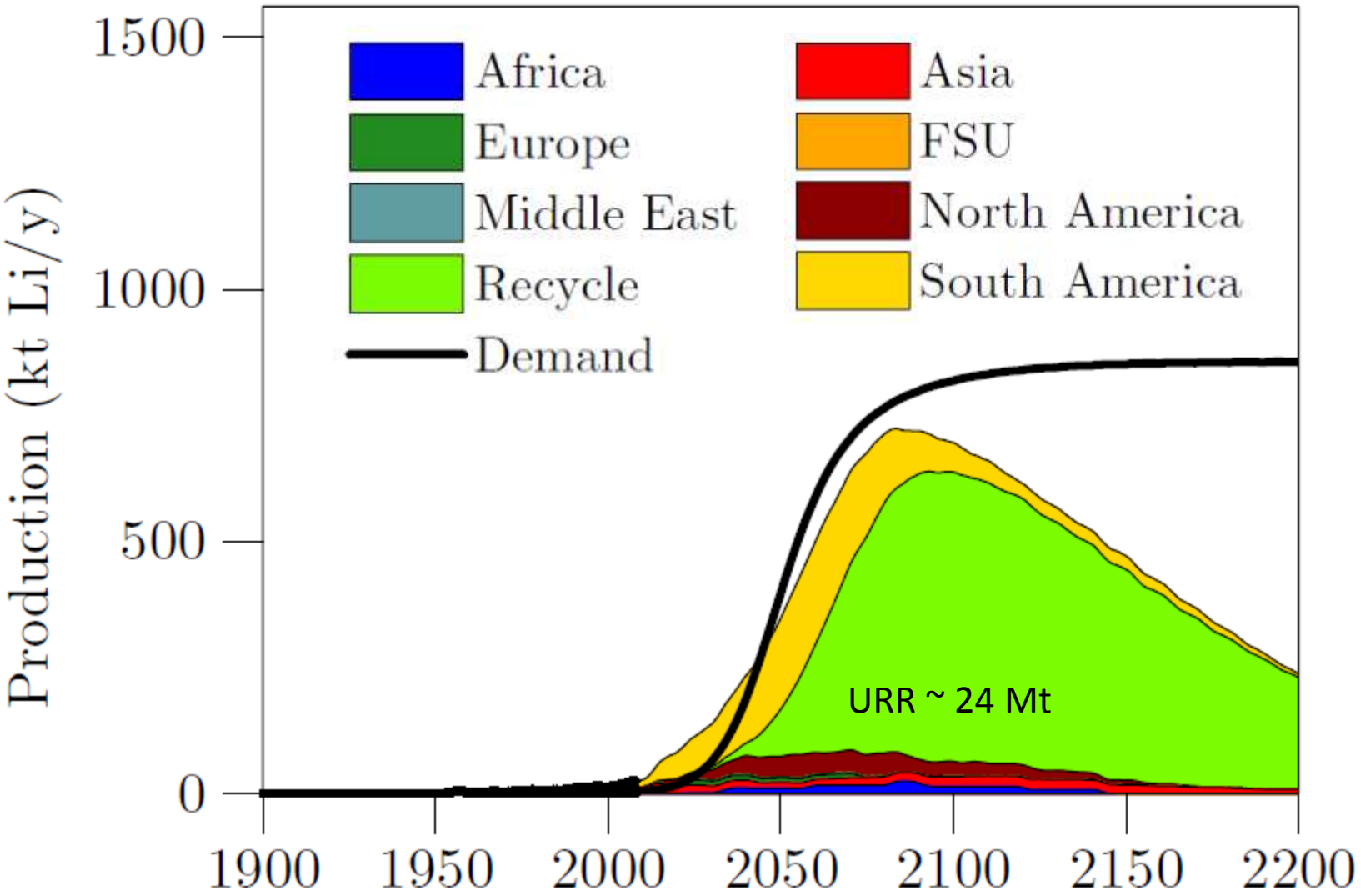
Lithium production projections by mineral



Other URR scenarios 19-55Mt

Mohr, Mudd, Giurco (2012) *Minerals*

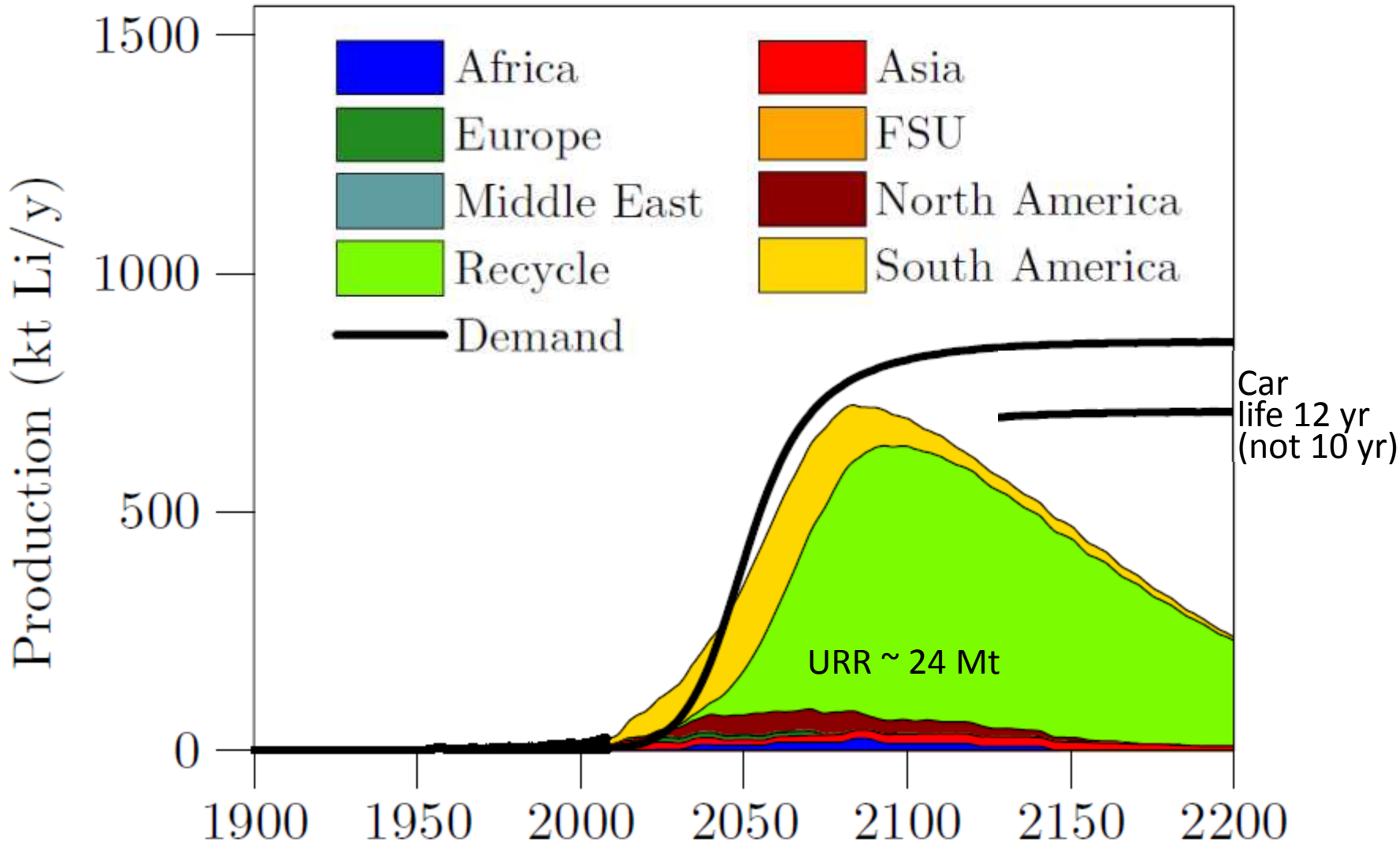
Lithium production projections by region



Other URR scenarios 19-55Mt

Mohr, Mudd, Giurco (2012) *Minerals*

Lithium production projections, lower demand



Mohr, Mudd, Giurco (2012) *Minerals*

Mining below and above ground

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

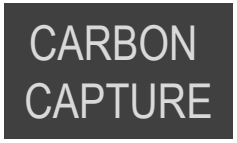
Identifying issues and opportunities

	Availability	Addiction	Alternatives	Uncertainty
Coal				CARBON CAPTURE

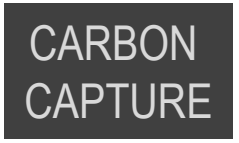
Identifying issues and opportunities

	Availability	Addiction	Alternatives	Uncertainty
Coal				CARBON CAPTURE
Iron				

Identifying issues and opportunities

	Availability	Addiction	Alternatives	Uncertainty
Coal				
Iron				
Copper				

Identifying issues and opportunities

	Availability	Addiction	Alternatives	Uncertainty
Coal				
Iron				
Copper				
Lithium				

- *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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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)

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UTS: Tim Prior, Reza Memary, Aleta Lederwasch, Leah Mason, Daniel May
Monash: Zehan Weng, Mohan Yellishetty , Steve Northey