Energy Resources
Are we running out of fossil fuels?

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Resources in a nutshell

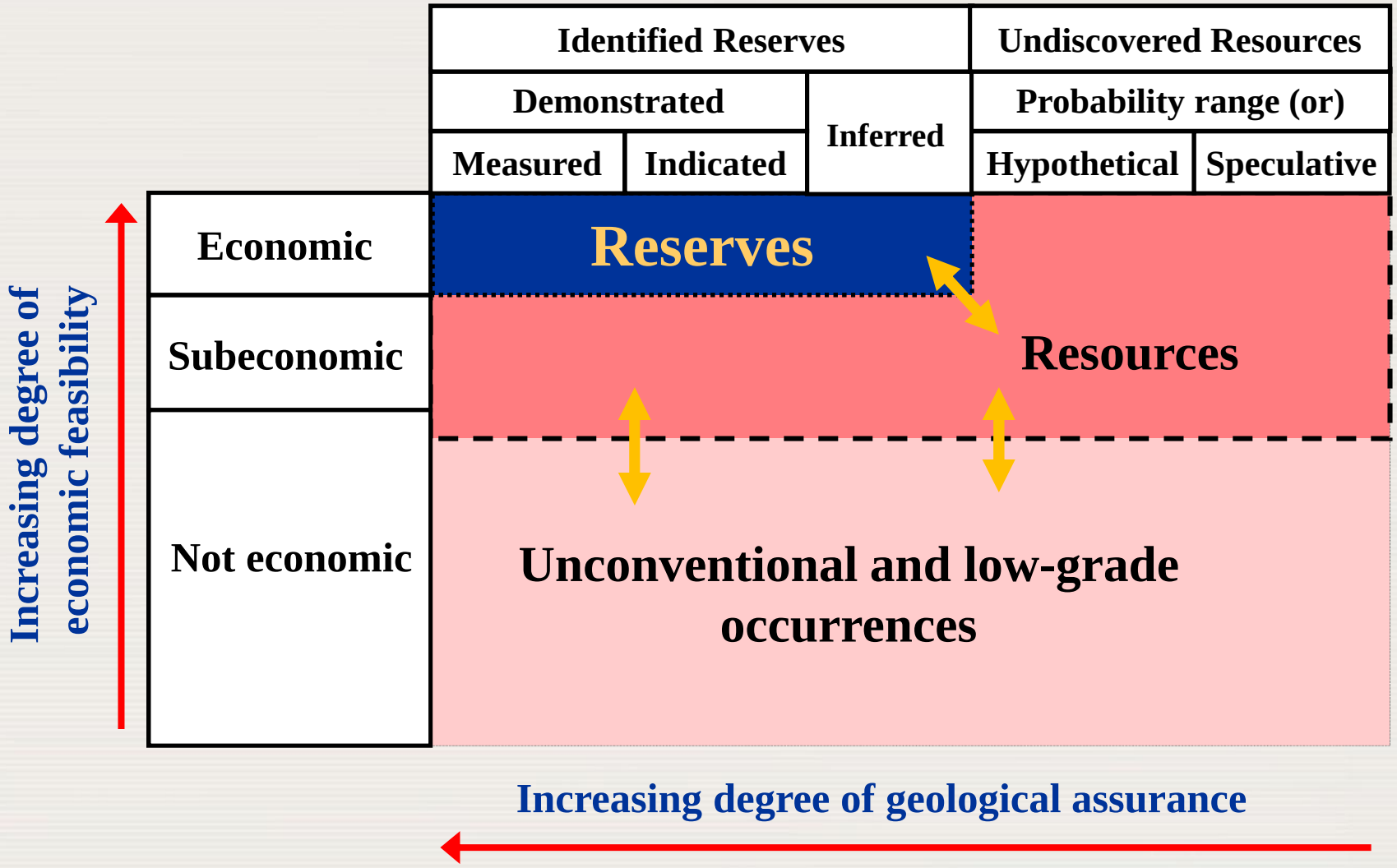
- **Occurrence of hydrocarbons and fissile materials in the earth's crust are plentiful**
  - **There is enough carbon in the ground to fuel global warming**
  - **Above ground investments unlock below ground resources**
    - **Exploration**
    - **Production capacity (incl. upgrading)**
    - **RD&D in innovative technology**
- **Renewable energy flows are gigantic**
  - **RD&D and investment required for the commercialization of technologies tapping renewable energy flows**
- **Resources per se pose no inherent limitation to meeting even rapidly growing future global energy need as long as timely upstream and/or technology investment is forthcoming**

Resources are not – they become[1)]

- The quantity of carbon occurrences in the Earth's crust is but one consideration = neutral stuff
- Reserve assessments are the futile effort of estimating the economic portion of an unknown total (M. Adelman)
- Reserves are "created" by a mutual interdependence of
  - Demand and markets
  - Investment and technology (determine production capacity)
  - RD&D and innovation (pushing frontier)
  - Environmental and social constraints (policy)
- In many cases the "low-hanging" fruit has already been harvested

[1)] E. Zimmermann

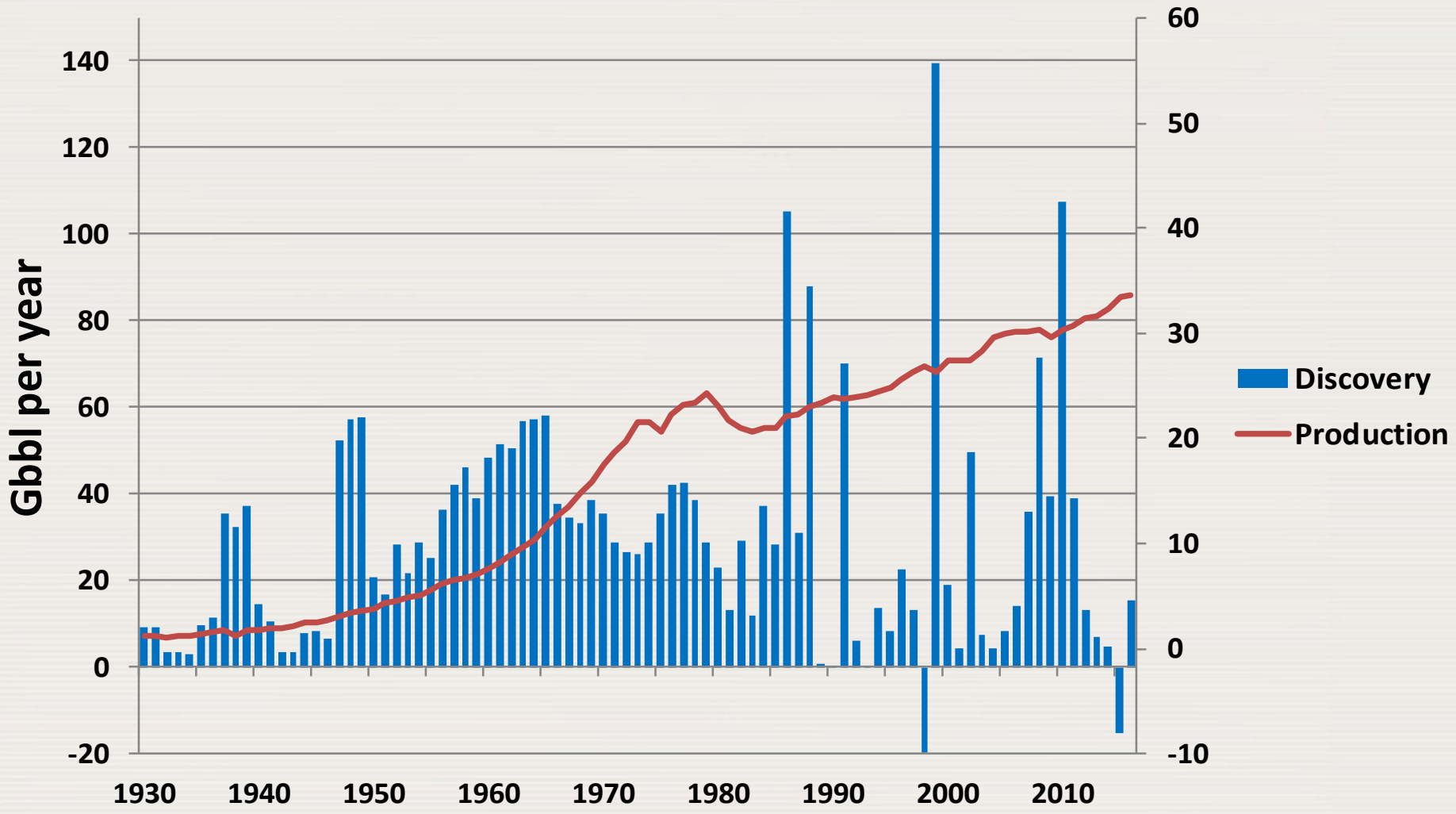
Resource classification: The McKelvey Box



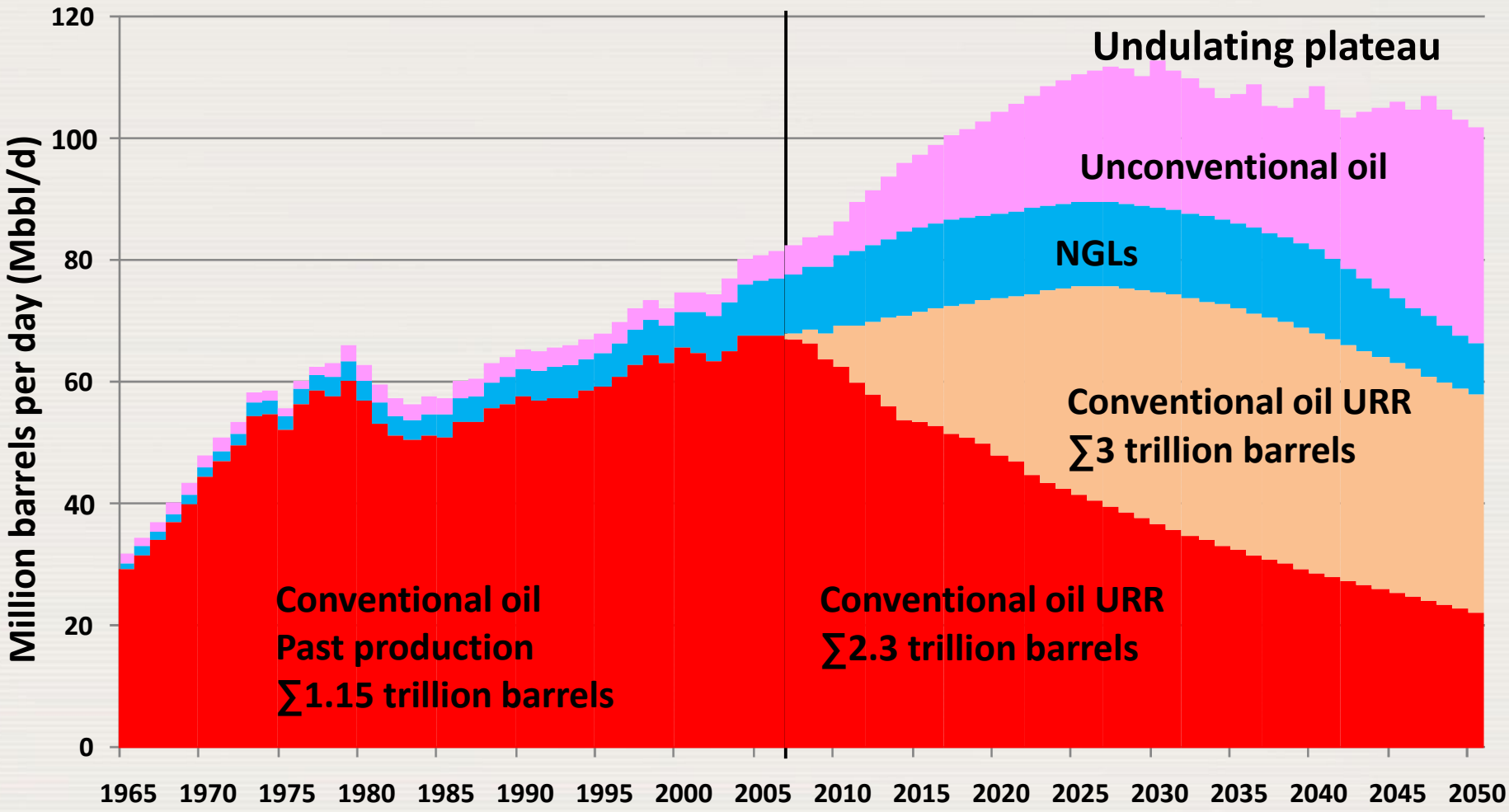
Comments on the “peak” debates

- **The “peak oil (gas, coal, uranium) debate” is a matter of definitions (boundaries):**
  - **Conventional versus unconventional occurrences**
  - **Minimum concentration**
  - **Technology and innovation**
  - **Economics (full costs including externalities versus alternatives) and prices**
  - **Energy security**
  - **Environment policy, esp. w.r.t. climate change**
  - **Social preferences (demand)**

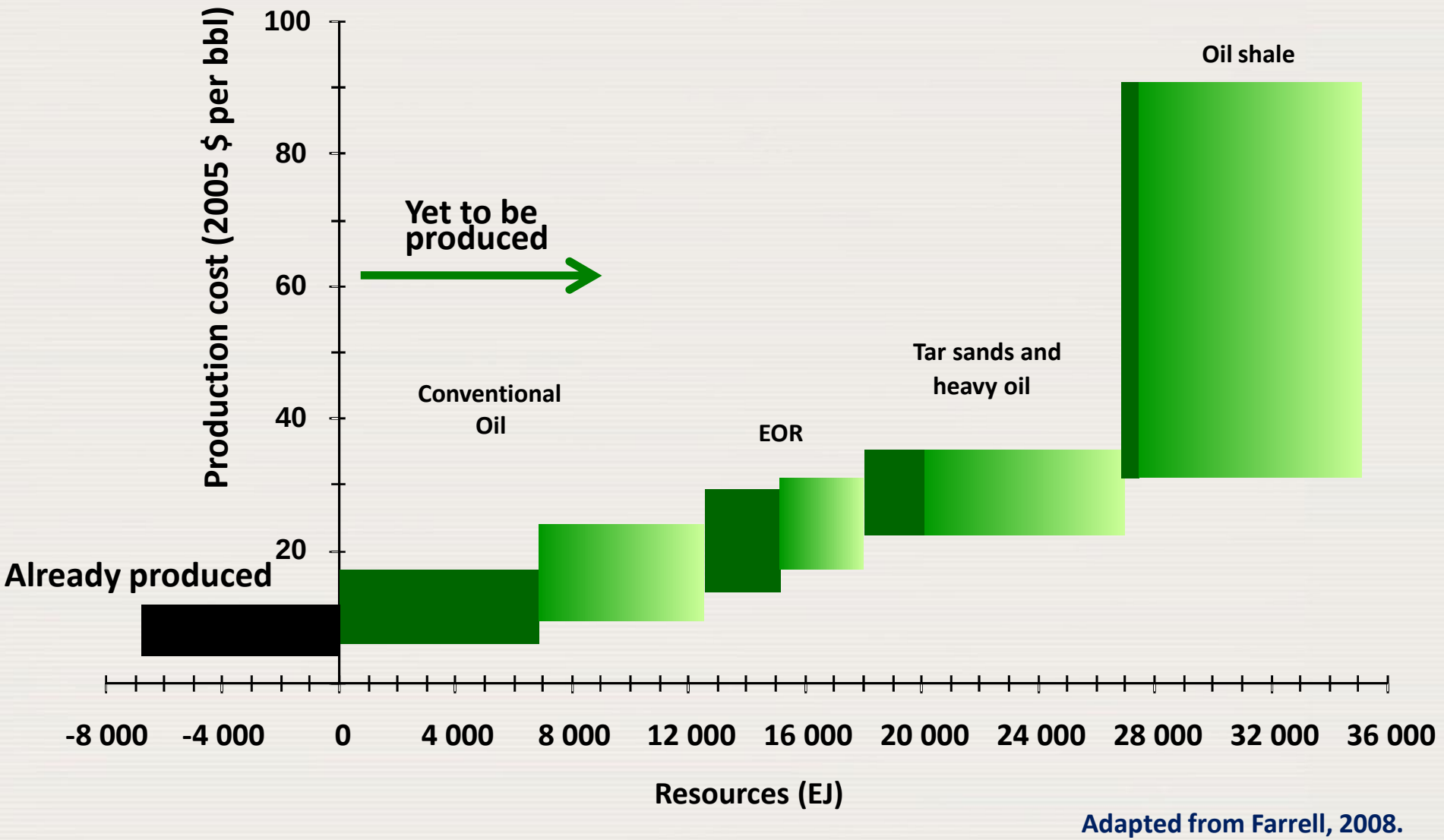
Oil reserve discoveries & production



Peak oil or undulating plateau?

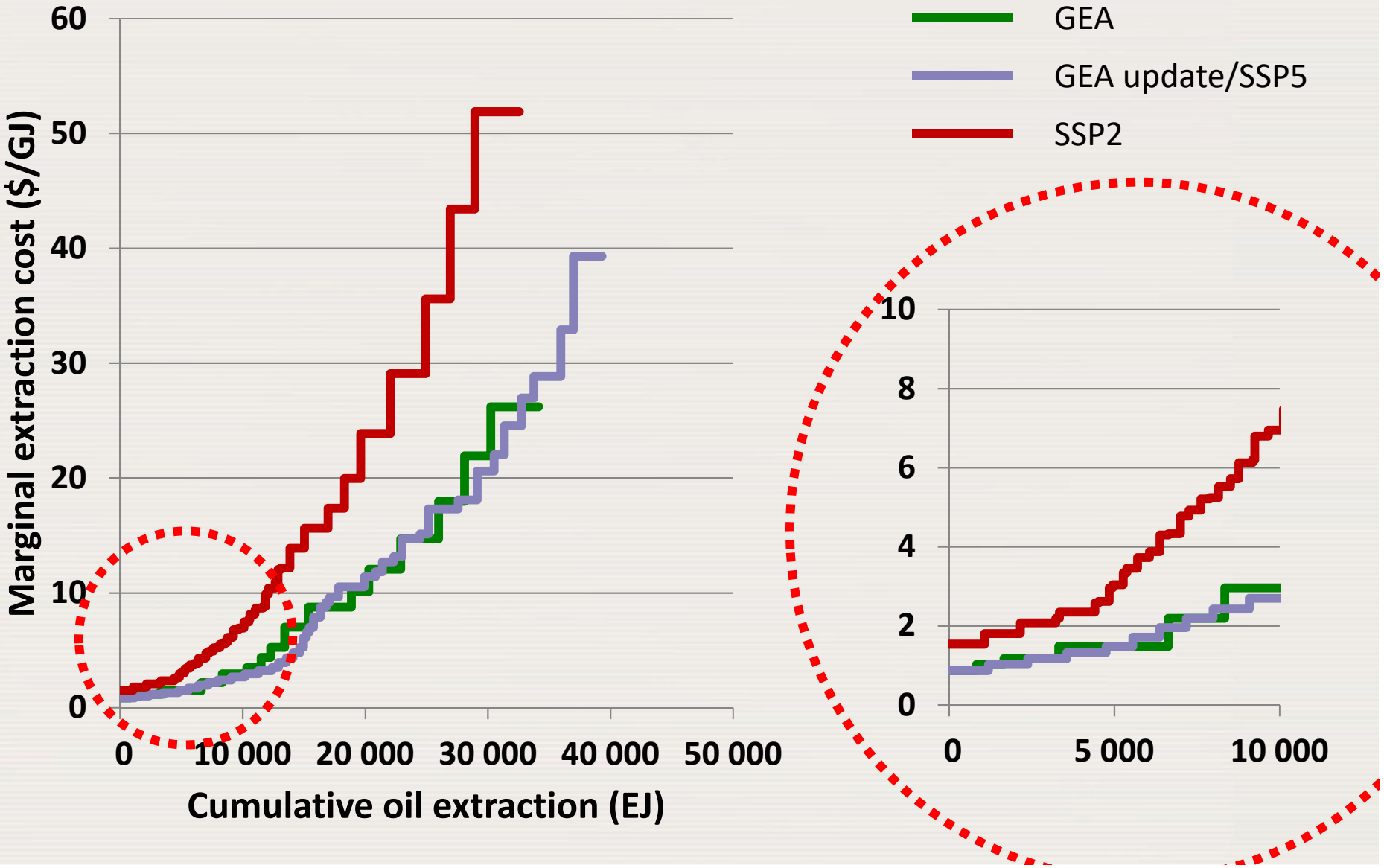


Oil based liquid fuel supply potentials and production costs



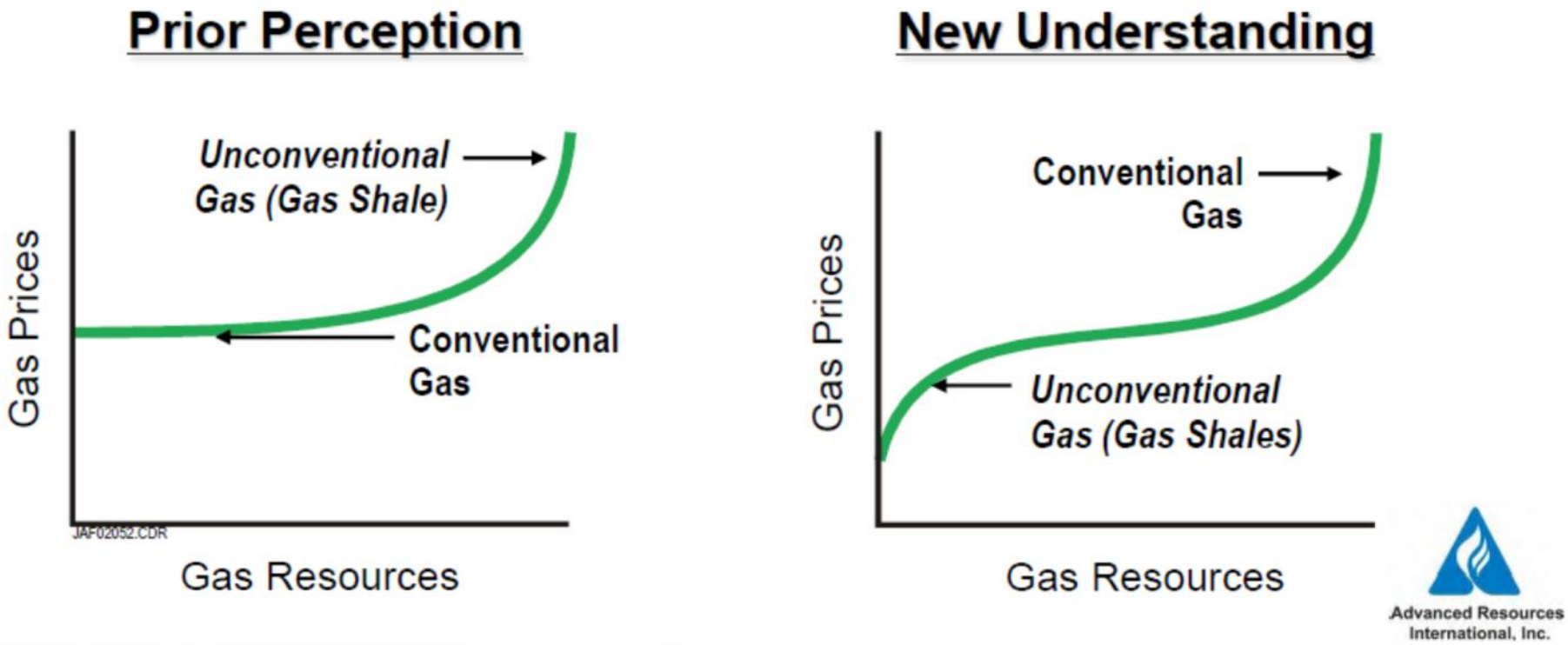
Adapted from Farrell, 2008.

Oil supply cost curves



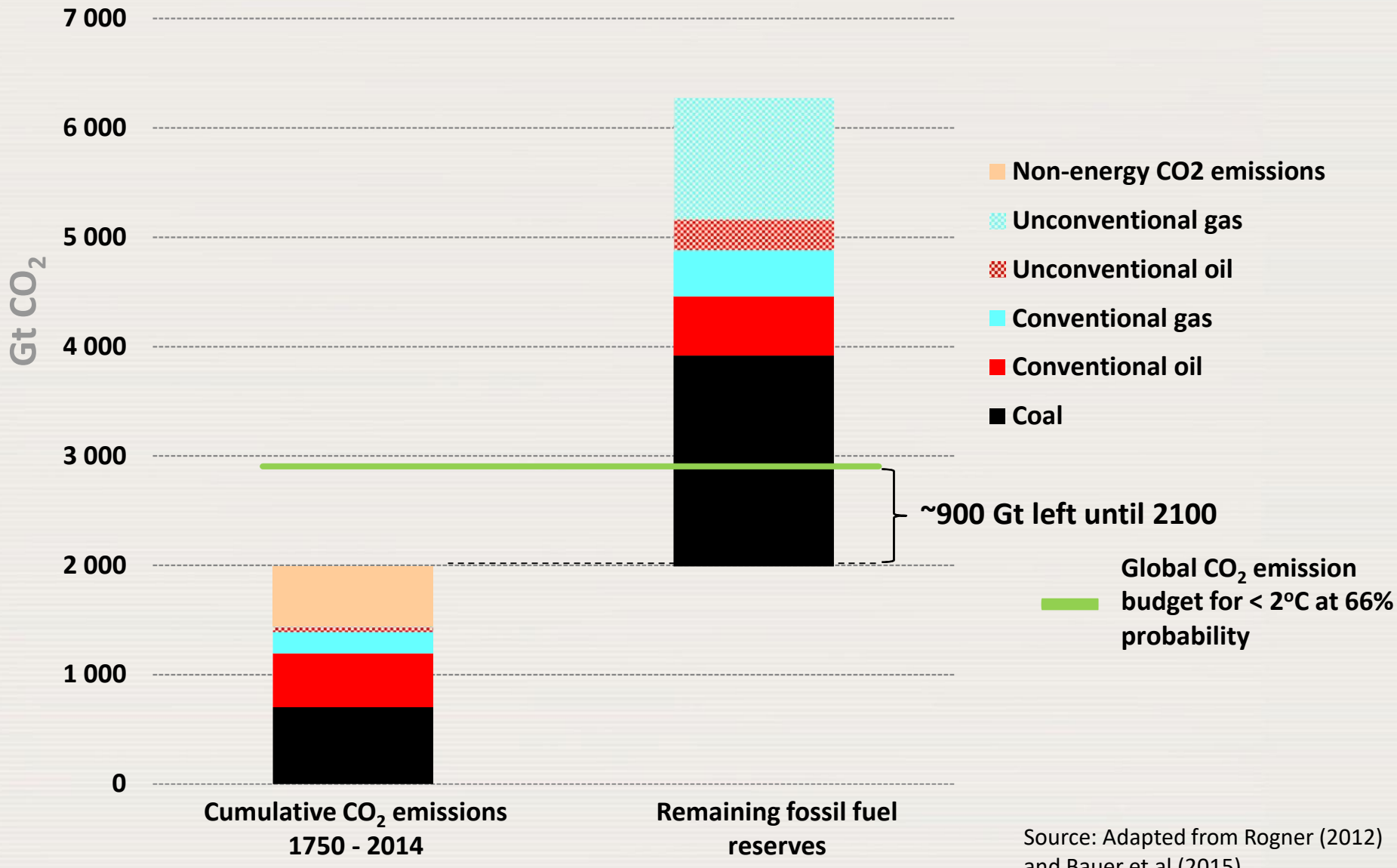
Shale gas impact on natural gas prices

Unconventional gas (particularly the higher quality gas shales) is today the low cost portion of the natural gas price/supply curve.



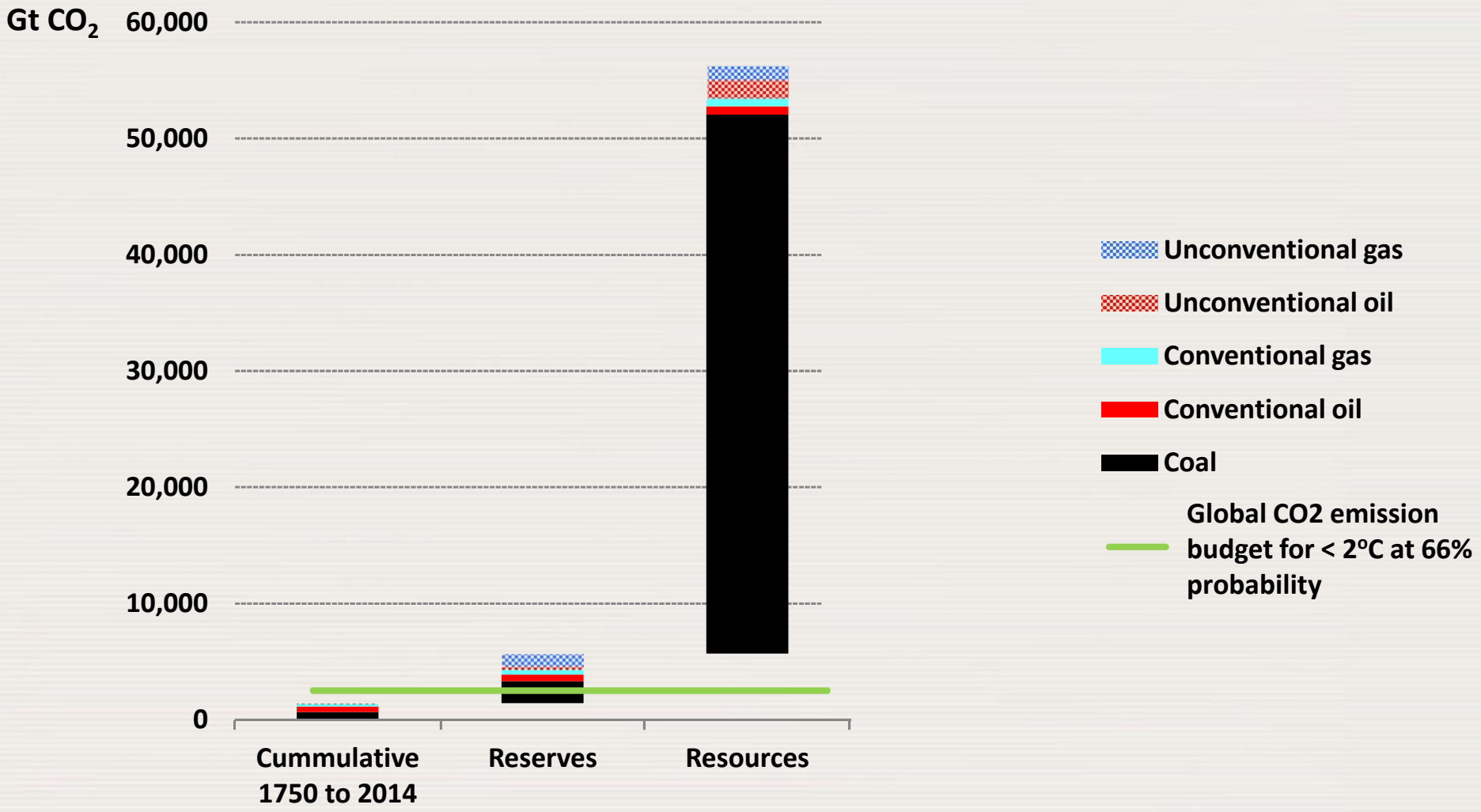
	Historical production through 2016		Production 2016		Reserves	Resources	Additional occurrences
	[Gtoe]	[Gt C]	[Gtoe]	[Gt C]	[Gtoe]	[Gtoe]	[Gtoe]
Conventional oil	176	152.28	4.4	3.80	241	147	
Unconventional oil	16	13.87	0.45	0.39	134	502	> 1 000
Conventional gas	93	59.0	2.6	1.66	168	254	
Unconventional gas	5	3.2	0.52	0.33	1 603	2 912	>24 000
Coal	188	202.8	3.7	3.95	413	10 390	
Total FOSSIL	477	431	11.6	10.1	2 558	14 204	

Fossil reserves, carbon contents & emission budget



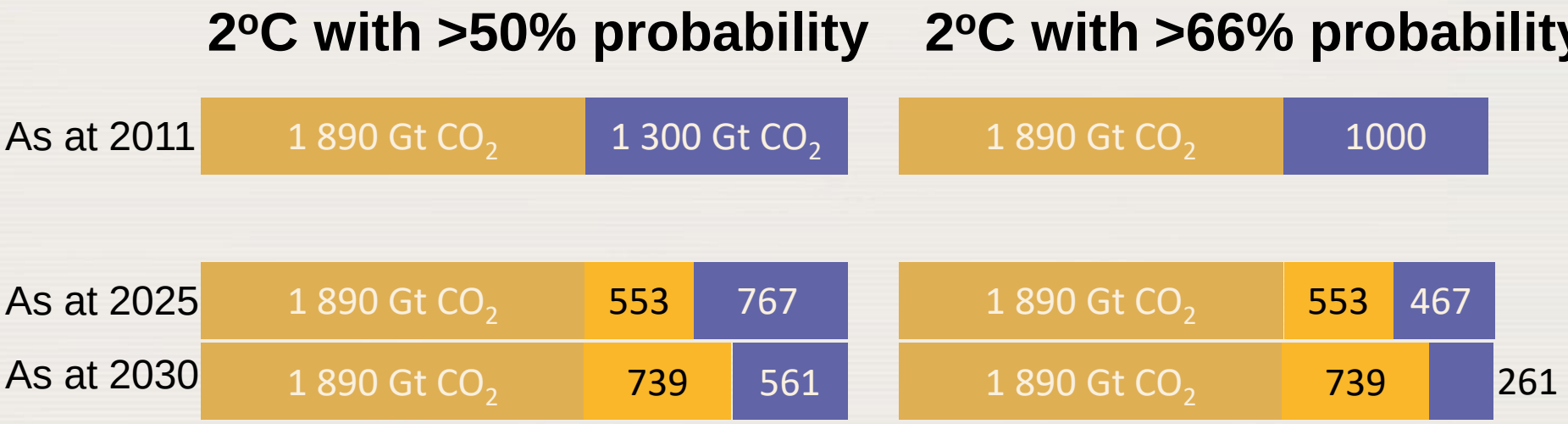
Source: Adapted from Rogner (2012) and Bauer et.al (2015)

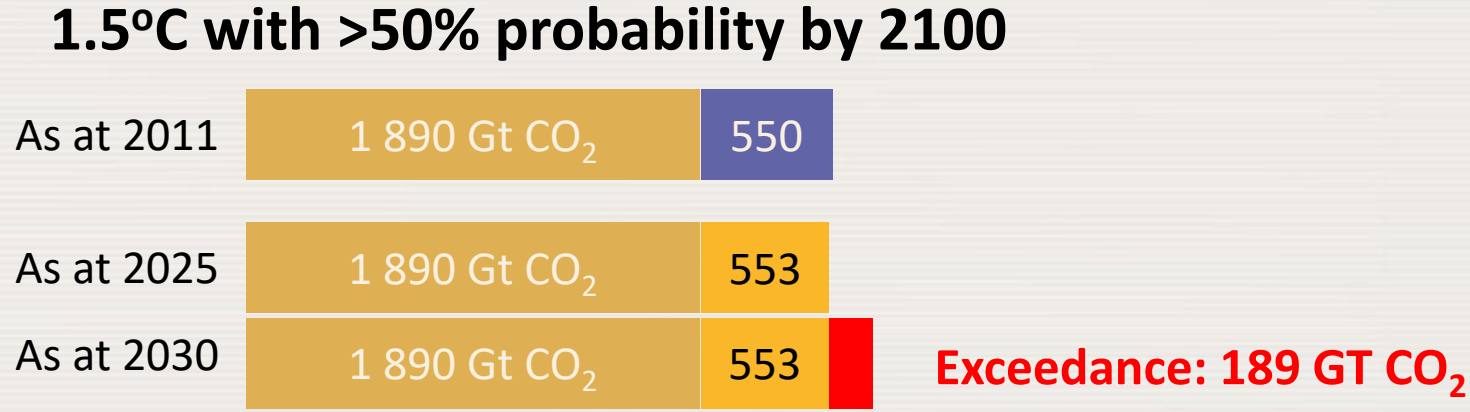
Fossil resources, carbon contents & emission budget



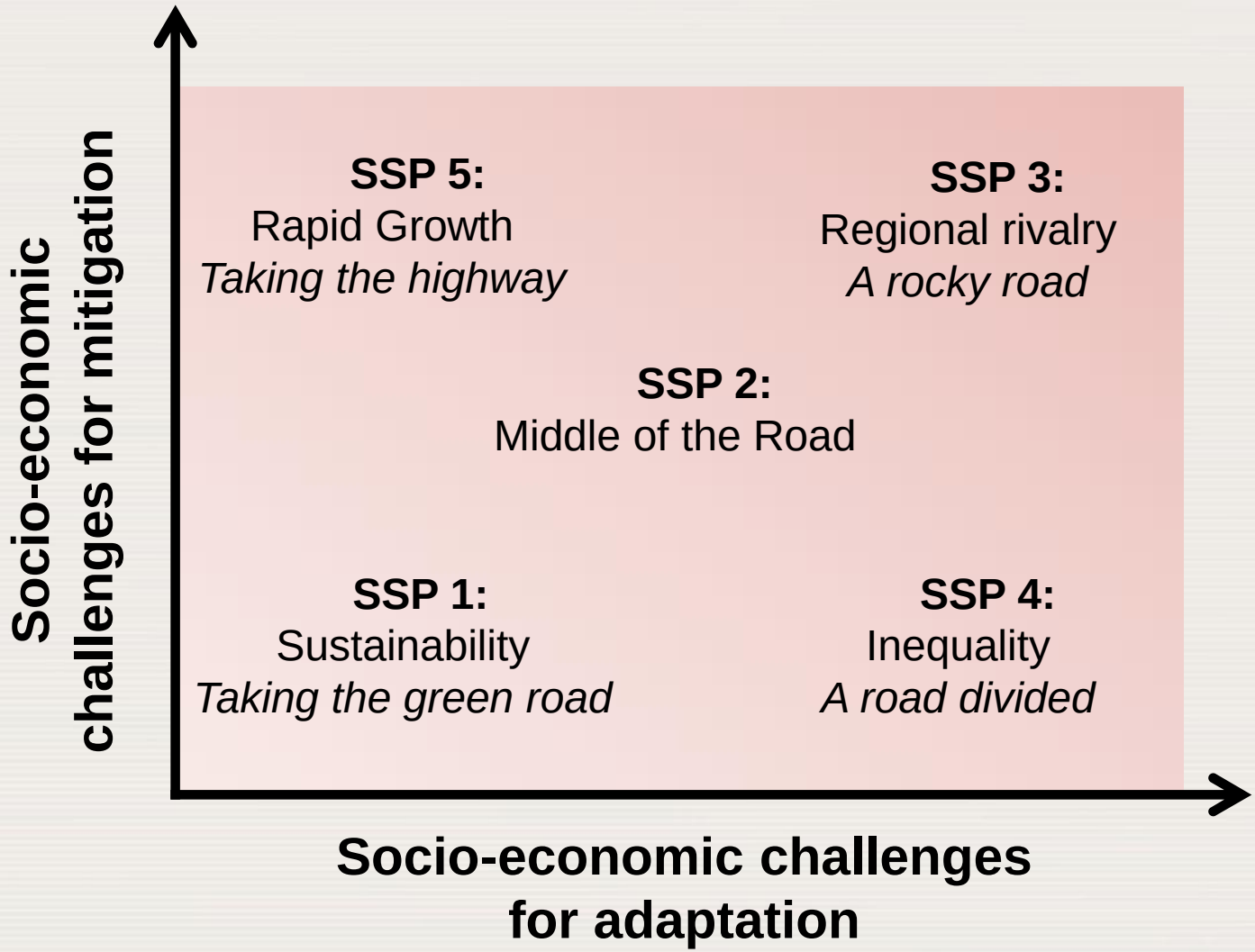
Source: Adapted from Rogner (2012) and Bauer et.al (2015)

Cumulative CO2 emissions with the goal of keeping global average temperature rise below

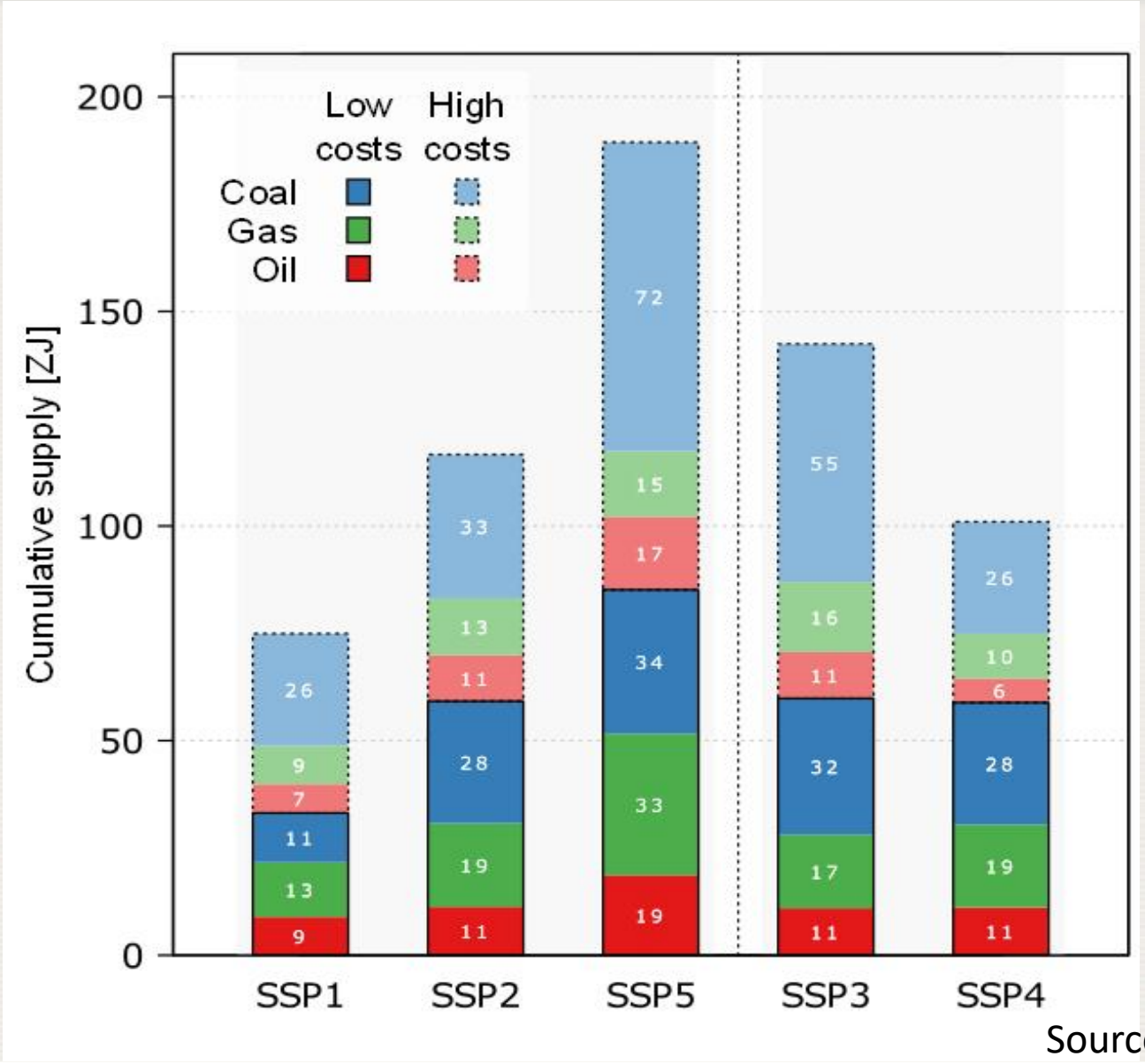




Shared Socio-economic Pathways (SSPs)

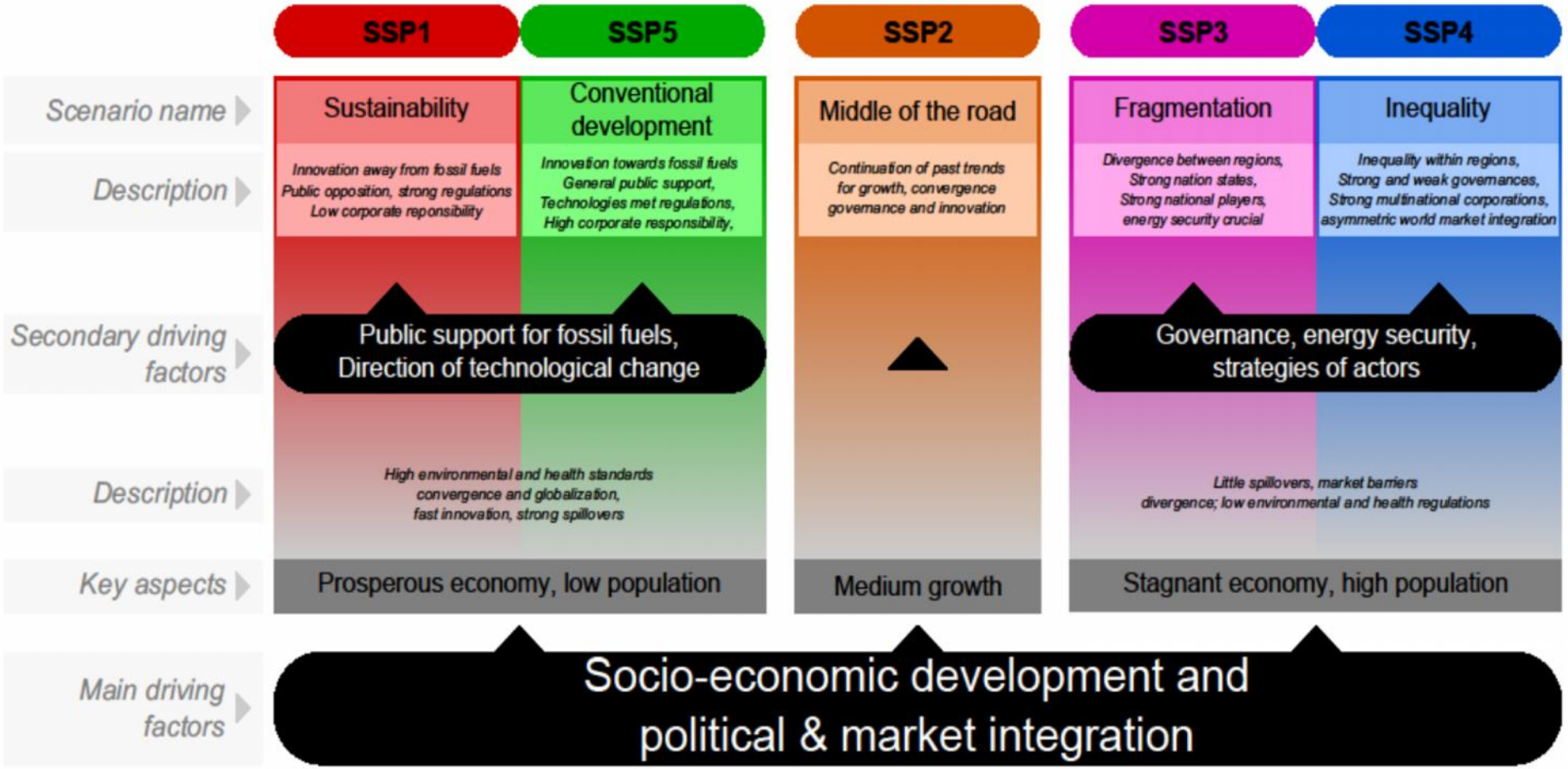


SSPs and Fossil Resources



Source: Bauer et.al, 2015

SSPs and Fossil Resources



Source: Bauer et.al, 2015

Supply cost curves