EROI Analysis of Renewables
and
Hubbert Linearization

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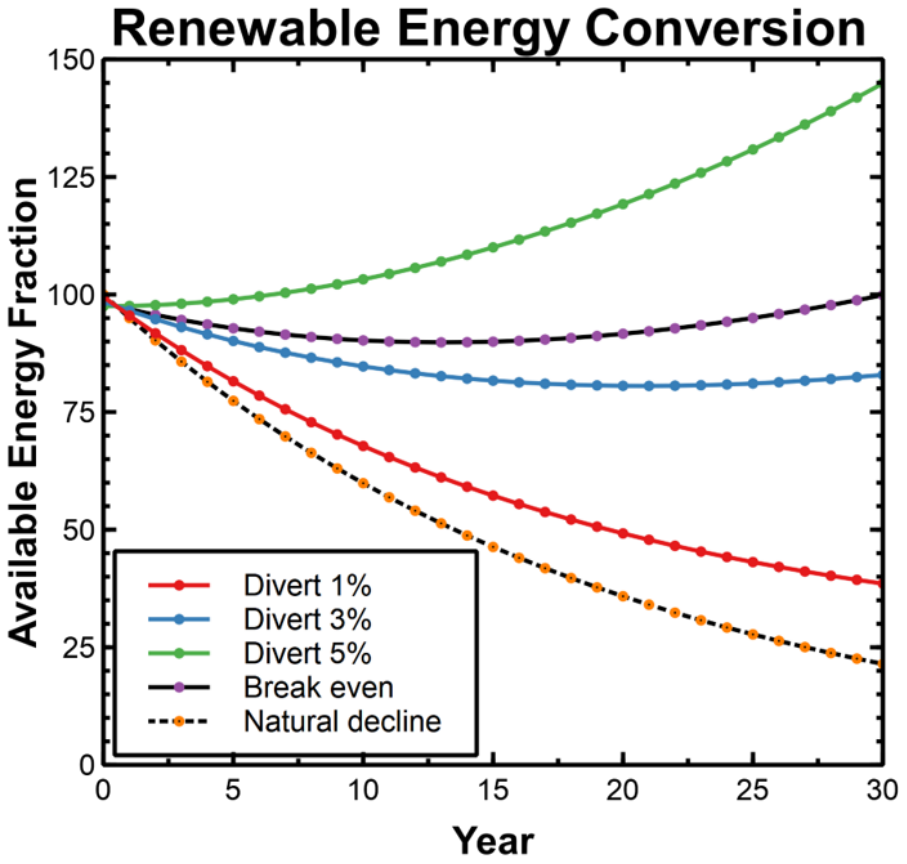
Outline

- **1. Is it possible to divert enough fossil fuel energy into the production of renewables to maintain the same level of energy? (Nils Peterson)**
  - **EROI analysis of energy requirements**
  - **Energy for renewable development in declining oil age**
  - **Challenges beyond a simple EROI analysis**
  - **Evidence based philosophy and conclusions**
- **2. ASPO France published a paper showing a modified Hubbert Linearization. Can you explain their results? (Rolland Sicario)**
  - **ASPO-France Hubbert linearization**
  - **World production and linearization**
  - **Discovery fit to logistic function**
  - **Updated discoveries, production and remaining curves**

EROI of Oil and Renewables

- EROI = Energy Returned over Input
- Renewables have high initial energy input, low maintenance cost
- Annual return for renewables = EROI / Operational lifespan
- Conventional oil requires energy for
  - Initial drilling
  - Well to refinery transport
  - Refinery energy
  - Delivery to endpoint
  - Field pressure maintenance and water cut
- Fracking has higher initial cost from drilling and completion
- Oil EROI is returned over time from well to end use, renewables over lifetime

Peak Oil and Renewables EROI



- Can renewables be built quickly enough to replace declining fossil fuel supplies?
- Assume oil is post-peak, declining 5% per year.
- RE annual production = EROI / lifetime (years)
- Break-even ~ 3.5%
- All scenarios begin with a net energy decline

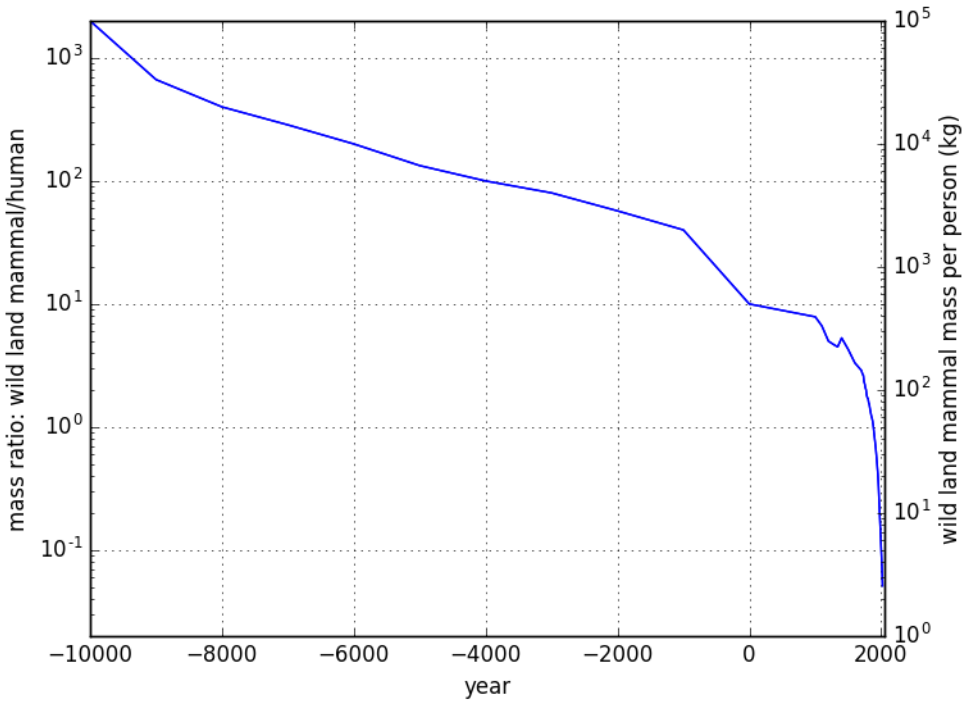
Substituting Renewable Energy for Fossil Fuels is a Doomsday Stratagem – Art Berman

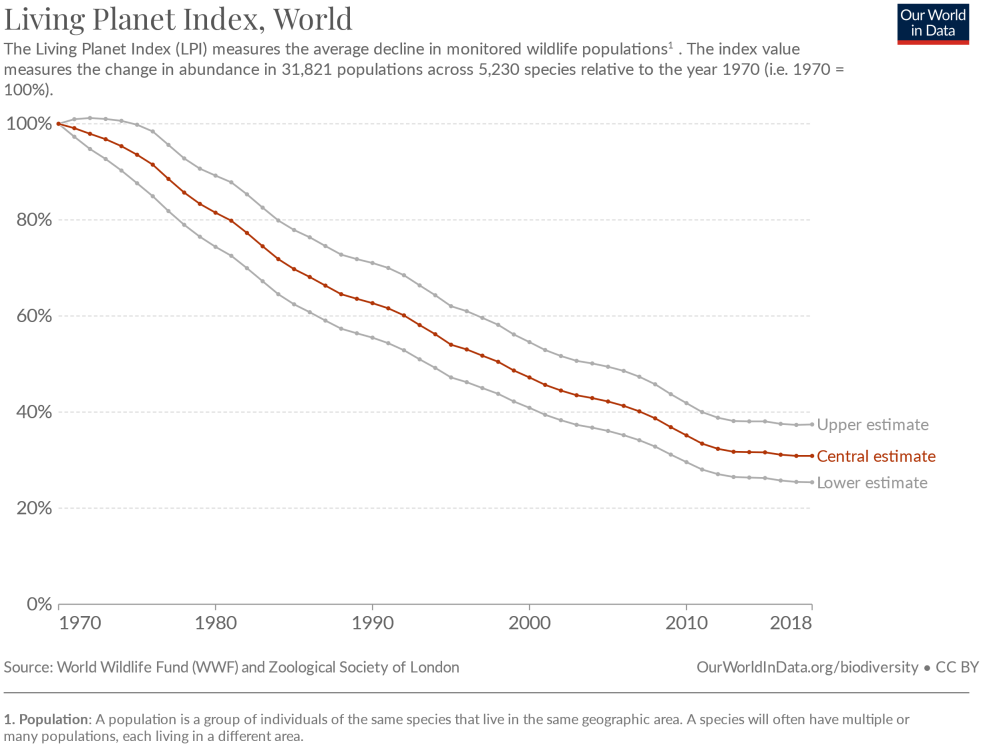
Focusing on only carbon emissions overlooks:

- overconsumption,
- air pollutants,
- resource scarcity,
- biodiversity loss,
- ecotoxicity,
- and eutrophication (algae blooms, dead zones).

Ref: https://energy.utexas.edu/events/substituting-renewable-energy-fossil-fuels-doomsday-stratagem#:~:text=Energy%20substitution%20is%20a%20doomsday,its%20consequence%20of%20no%20growth.

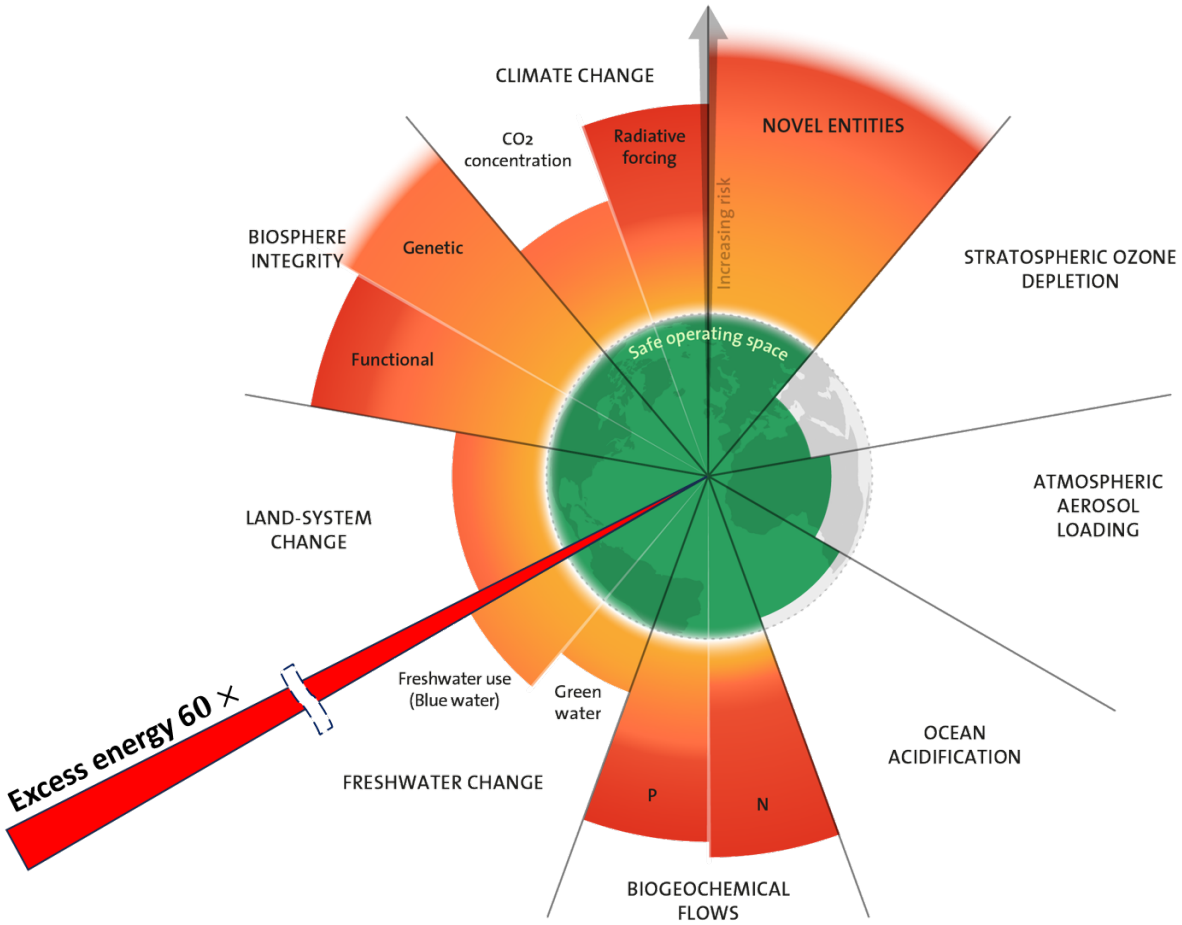
Biodiversity





“We have used it [energy] to expand the human enterprise and population, knock down forests, destroy and fragment habitats, drive extinctions, and generally threaten the vitality of the planet” – Tom Murphy, UCSD Astrophysics.

Earth Boundaries



It needs to be understood that renewable energy is not actually about saving the *planet.*

It's really about preserving *modernity* in the face of CO2. Let's be clear on the goal, here, and how ultimately narrow/misguided it is.

Which is more valuable—modernity or the ecological health of the planet? Which depends on which?

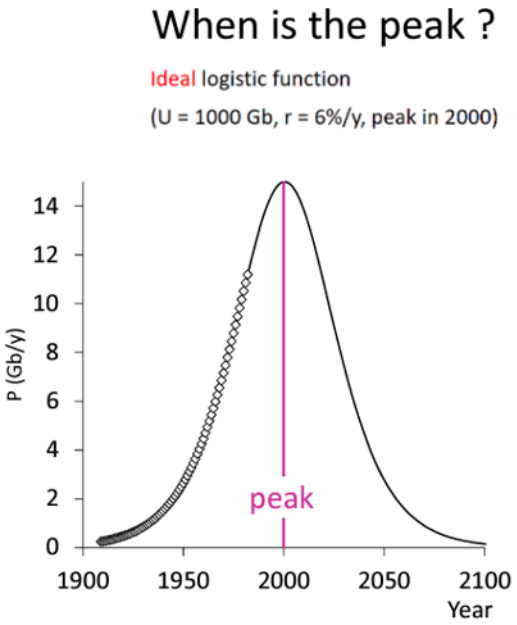
-Tom Murphy

The Sagan Standard

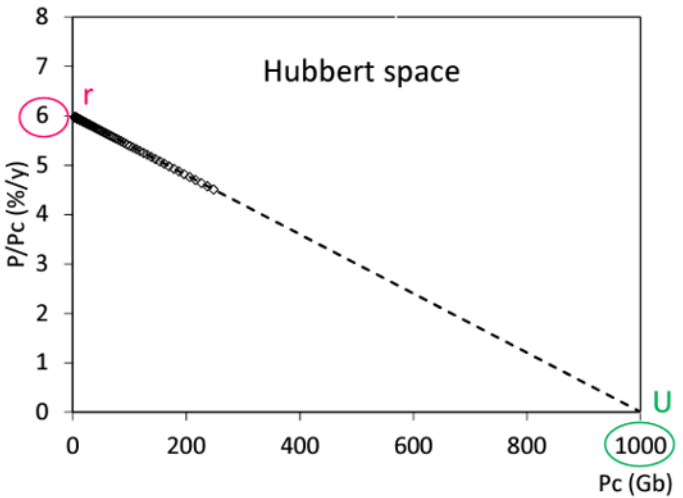
- Extraordinary claims require extraordinary evidence:
- No evidence that renewables are self-sustaining
- No evidence that society will substitute renewables for fossil fuels
- No evidence that new energy sources wouldn’t cause increasing harm to nature

See: Wild Peaches, **The Decline and Fall of the Petroleum Empire**
https://wildpeaches.xyz/blog/the-decline-and-fall-of-the-petroleum-empire/

ASPO Hubbert Linearization



$$P_{c\,(t)} = \frac{U}{1+(\frac{U}{P_{c(t_0)}}-1)e^{-r\Delta t}}$$

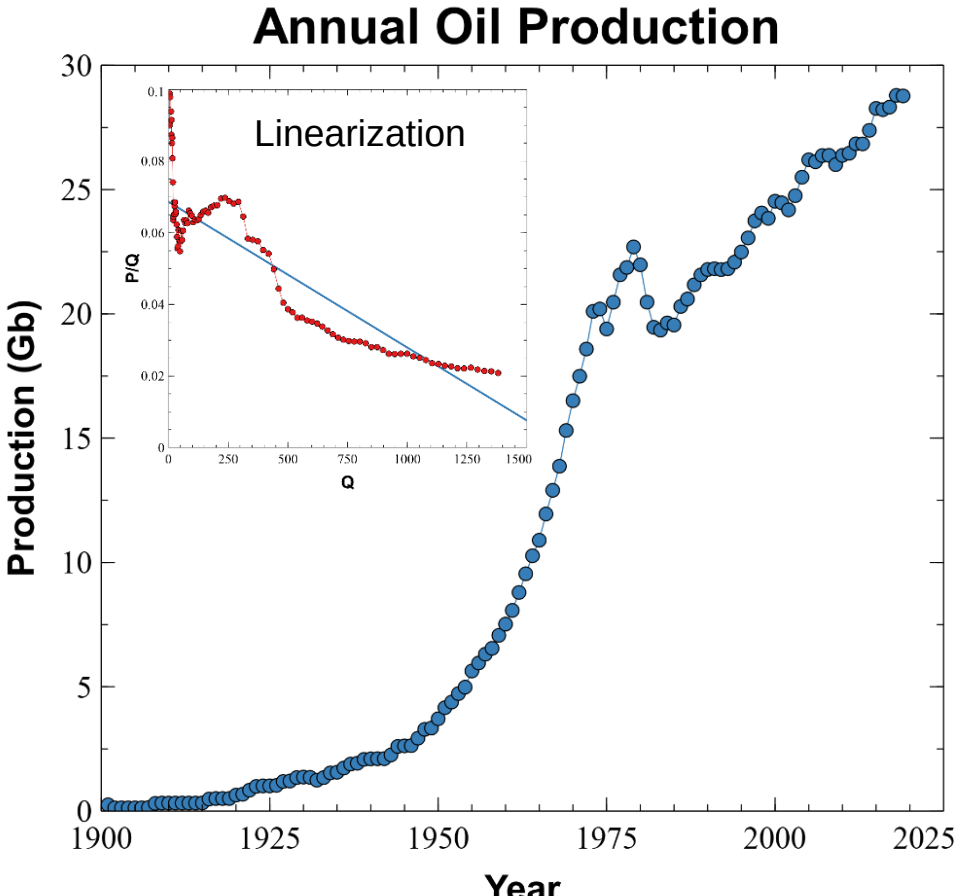


- Hubbert Linearization converts bell shaped production to straight line.
- (total produced) reaches max when
- Growth rate is the highest point on the line.
- Symmetry of production curve means peak is at midpoint.
- Given date of peak can be forecast.

Annual production
Cumulative production
Ultimate recoverable resource
Intrinsic growth rate (%/year)

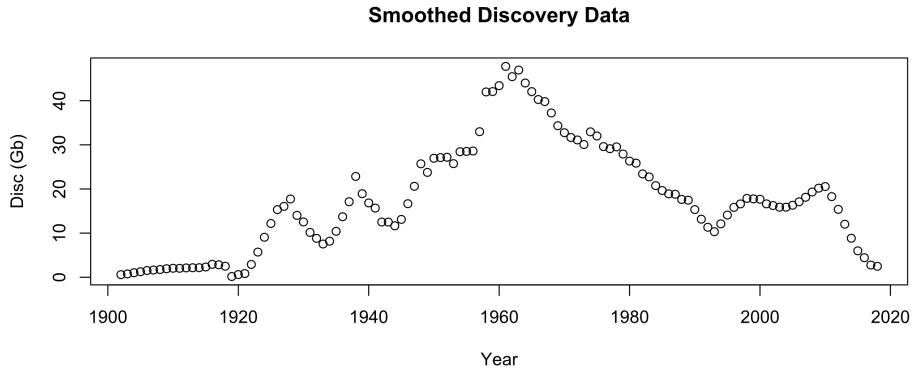
Ref: https://aspofrance.files.wordpress.com/2023/10/peak_oil_aspofrance_17oct2023.pdf

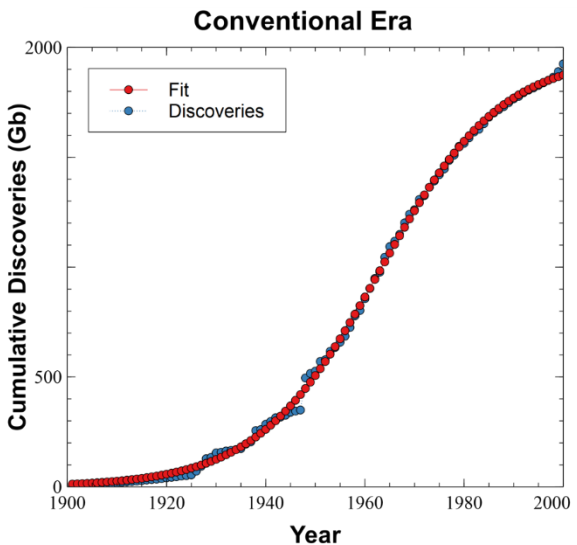
World Oil Production

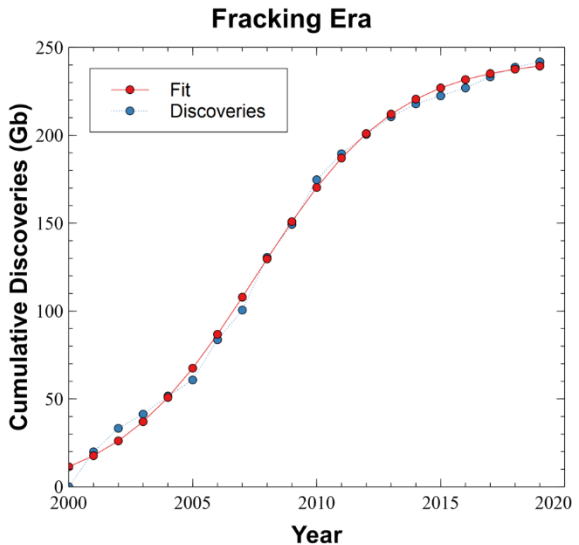


- Hubbert linearization assumes production is Gaussian, or bell-shaped curve
- Hubbert model is invalid if production curve is not Gaussian.
- No assumption can be made about URR
- Peak cannot be assumed at halfway point

Hubbert fit to Discoveries







- Conventional max = 1990 Gb
- Fracking max = 250 Gb
- Total max = 2240 Gb

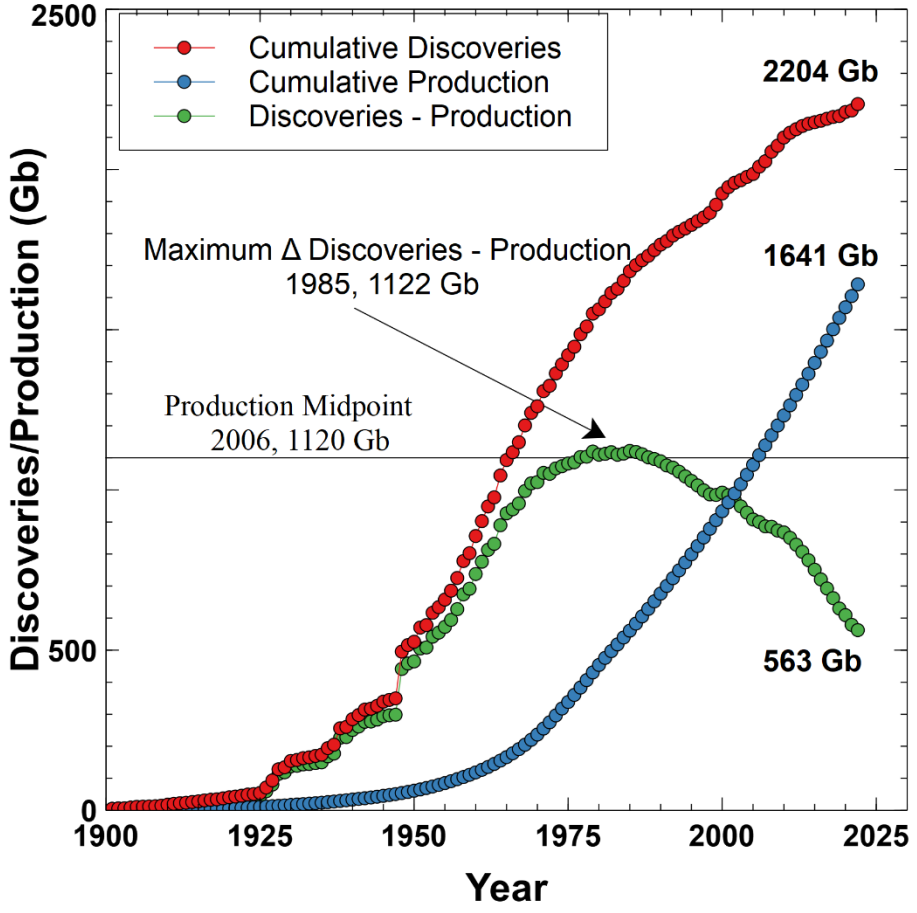
- Discovery data smoothed to show approximate peaks
- Fitted cumulative data has not been smoothed

Logistic function

$$f(t) = \frac{Q}{1 + \exp(-k(t - t_m))} + C$$

- Time (years)
- Time midpoint
- Cumulative discoveries
- Slope at midpoint
- Linear offset (years)

Discoveries, Production and Remaining



- Total expected discoveries = 2240 Gb
- Total discoveries to date = 2204 Gb
- Production to date = 1641 Gb
- Remaining = 563 Gb

- Annual production ~ 36 Gb
- Remaining time ~ 20 years

- Half of all production since 2006
- Peak is well past midpoint