University of Colorado
Center for Science and Technology Policy Research

Collaboration in energy and materials sustainability

Alan J Hurd
Los Alamos National Lab

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Welcome to the Anthropocene

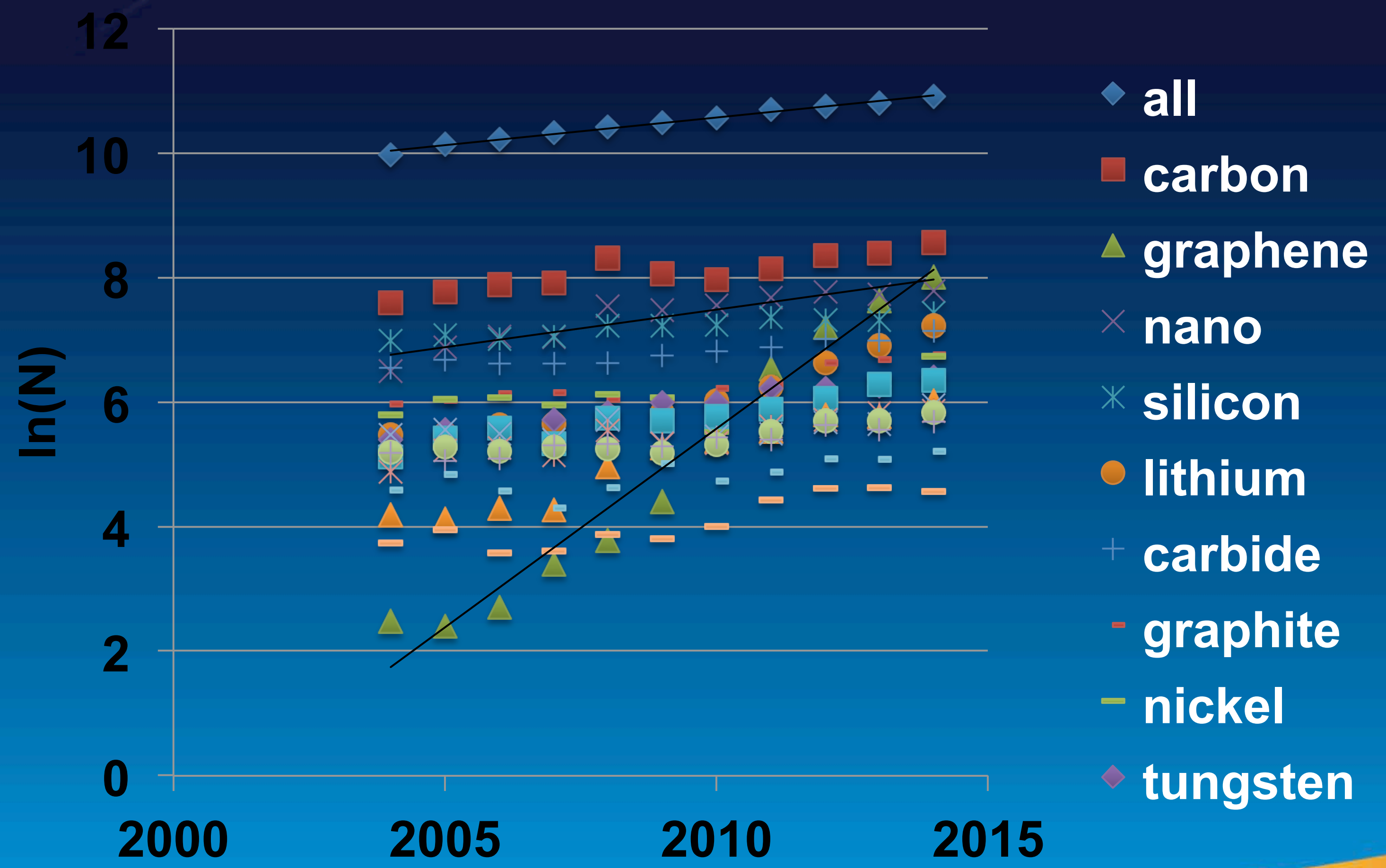
- Human activity is now encoding information into the geologic record

- Boundary Markers:
  - Cretaceous-Paleogene:
    - ***Ir, Pt***
  - Holocene-Antropocene:
    - ***C, Pu?***

1944
Los Alamos

The Human Resource

Research usage of elements in composites



Is this a “CO_2 moment” for materials research?

- Critical materials
- Al Bartlett’s warning
- Elements in composites research
- Helium
- A sustainable solution for research

Roger Revelle
Climate Change (1950s)

GDP Growth Rates

U.S.A. (annual)

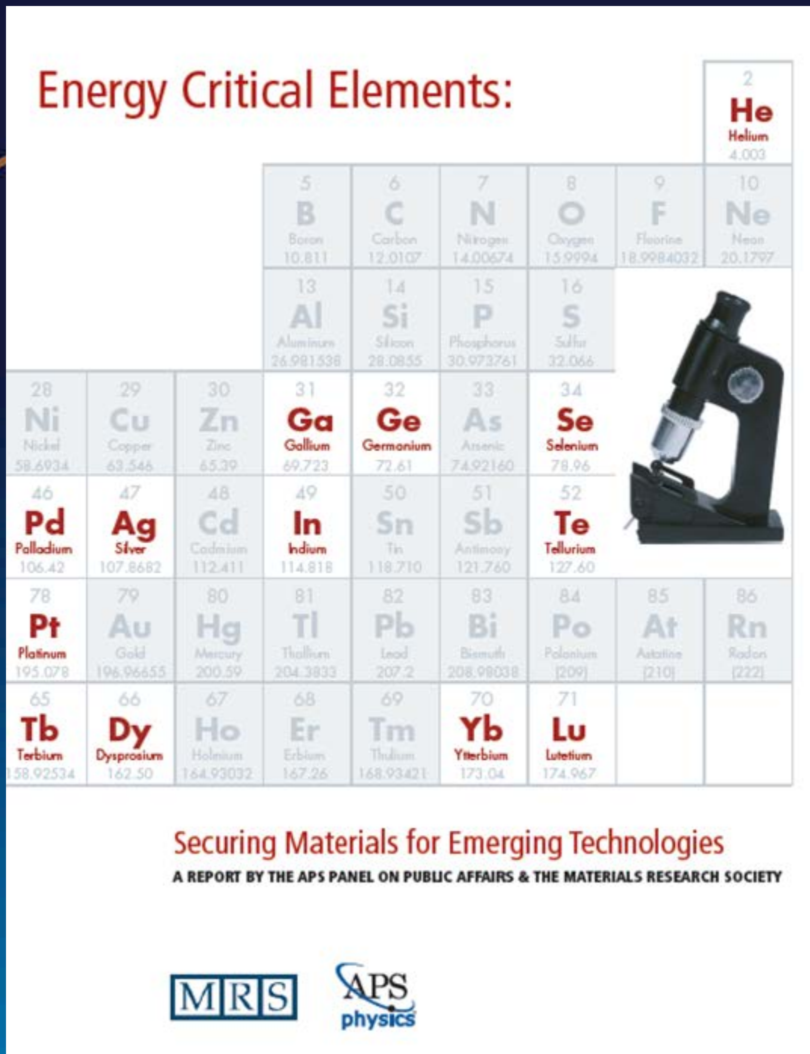
What is a sustainable growth rate for a large economy?

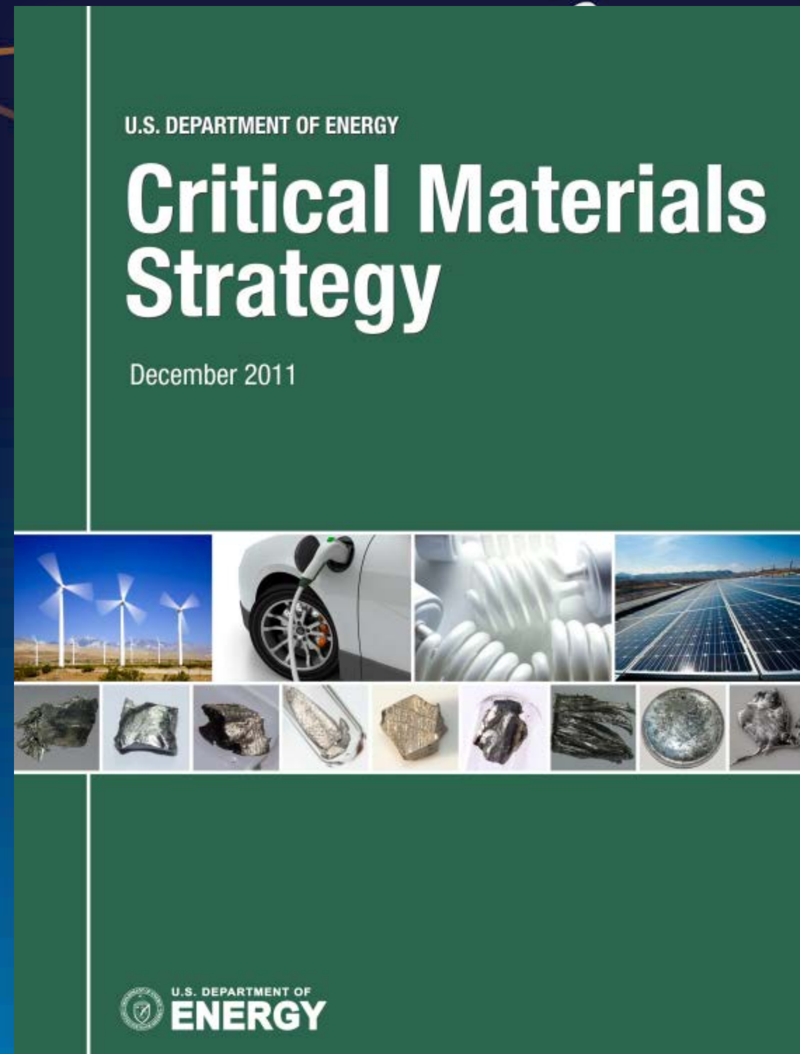
Critical Elements & Materials

Necessary for current and emerging technologies including research and whose supply is at risk

Examples

- In solar cells, energy-efficient displays
- Te solar cells and detectors
- Pt catalysts
- Re superalloys



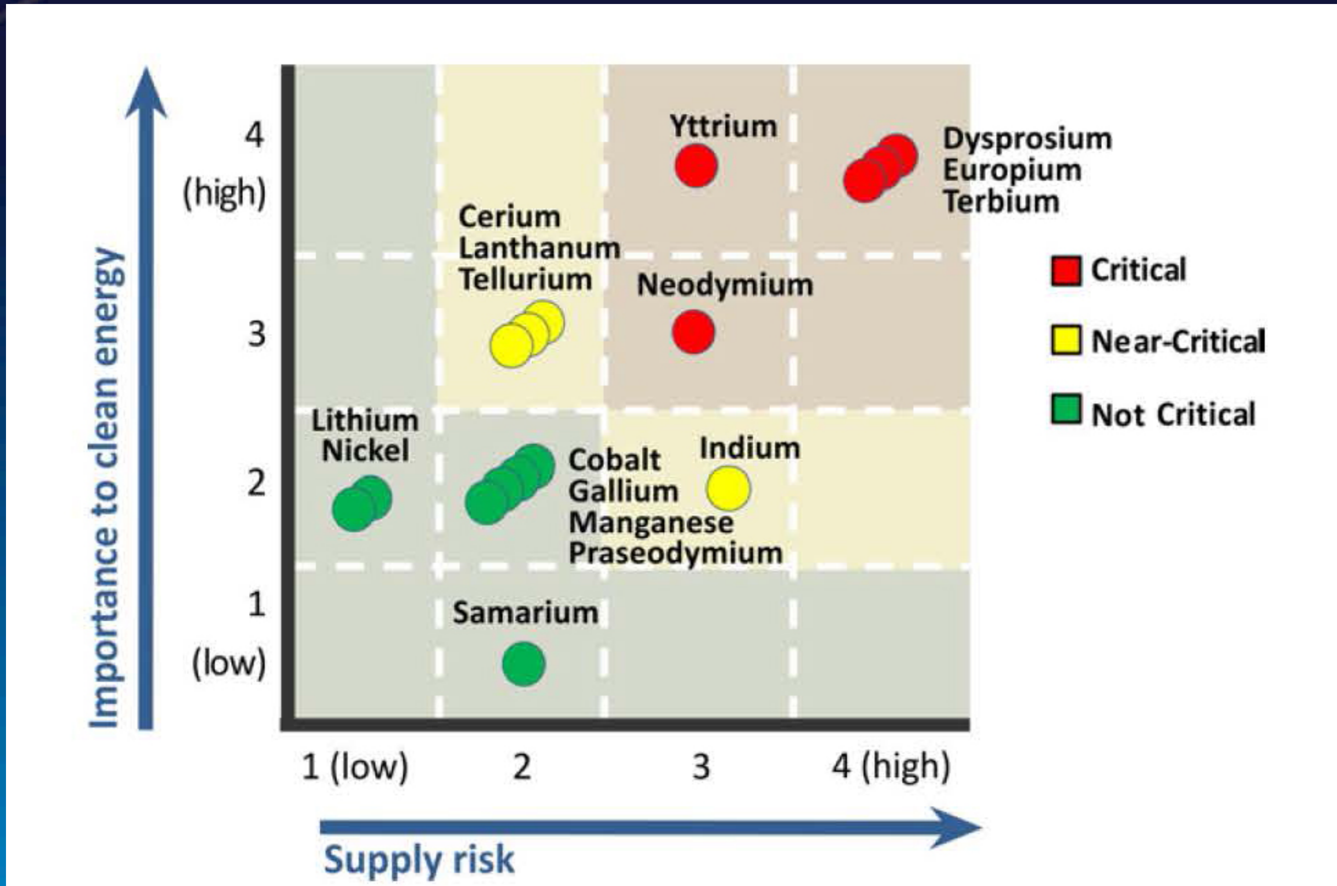


American Physical Society and the Materials Research Society
February 2011

US Department of Energy
December 2011

US Department of Energy Criticality Assessment 2010-2015

"Short term 2010-2015"

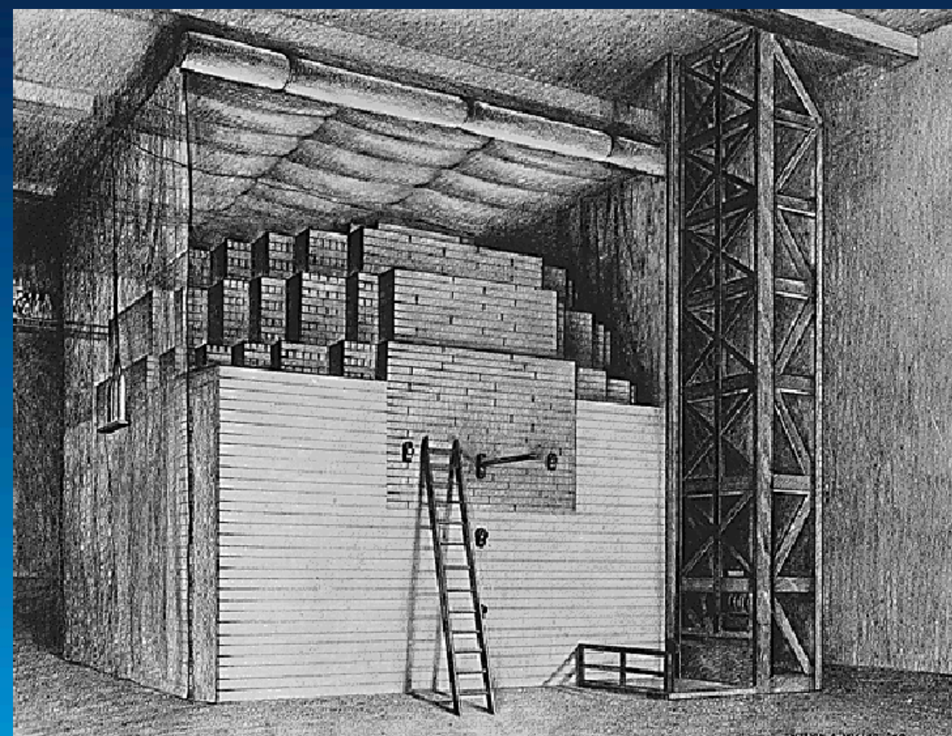


But doesn't research consume too little to worry…?

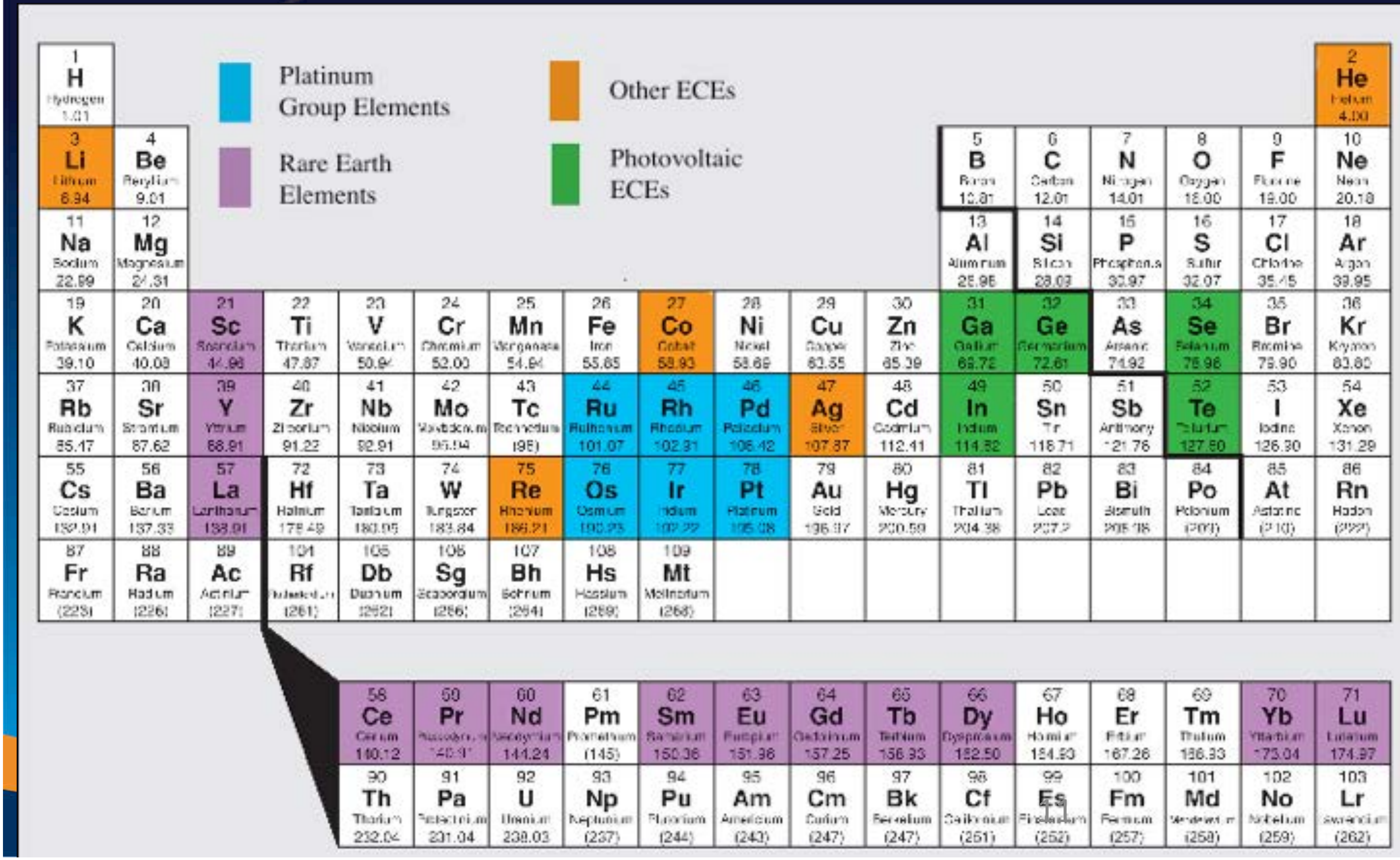
1942: Chicago
Critical Elements would include…

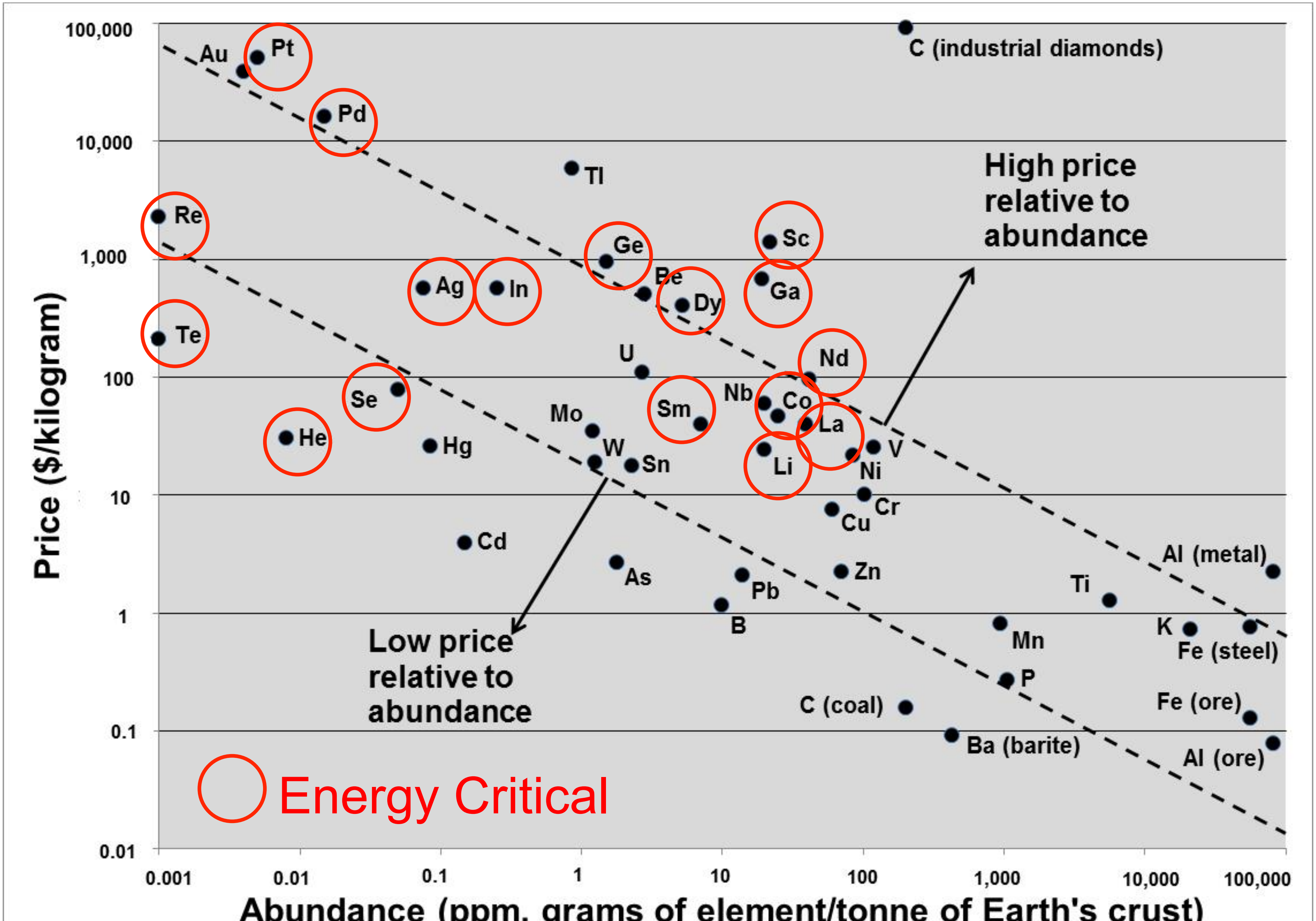
- U (natural)
- ^{2}H (D_2O)
- C (highly pure graphite)

Fermi



The APS-MRS set of Energy Critical Elements



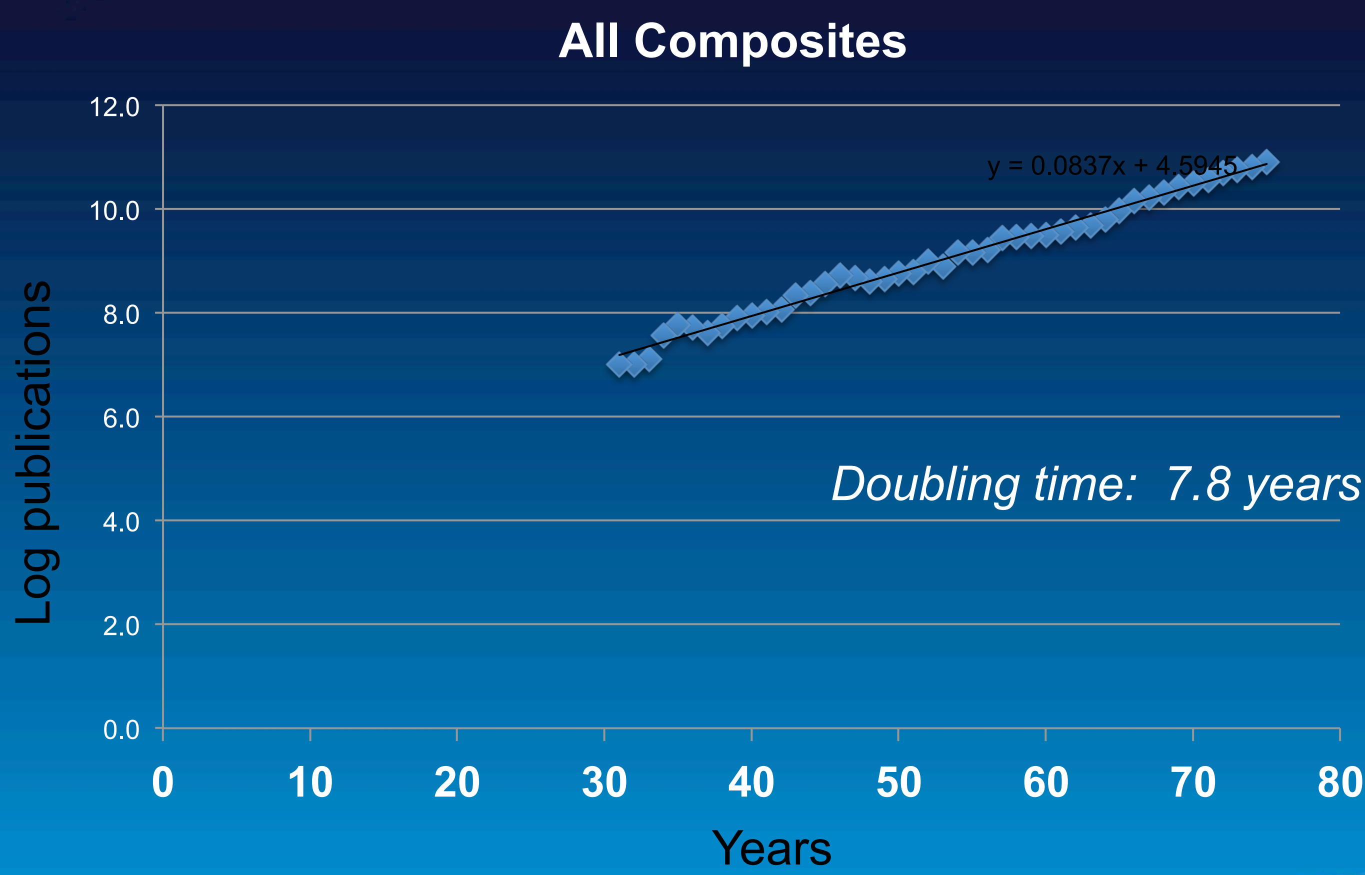


Source of data: USGS, EIA, CRC Handbook of Chemistry and Physics, others

Conflict minerals

- Tin
- Tantalum
- Tungsten
- Gold

Exponential growth in composites research



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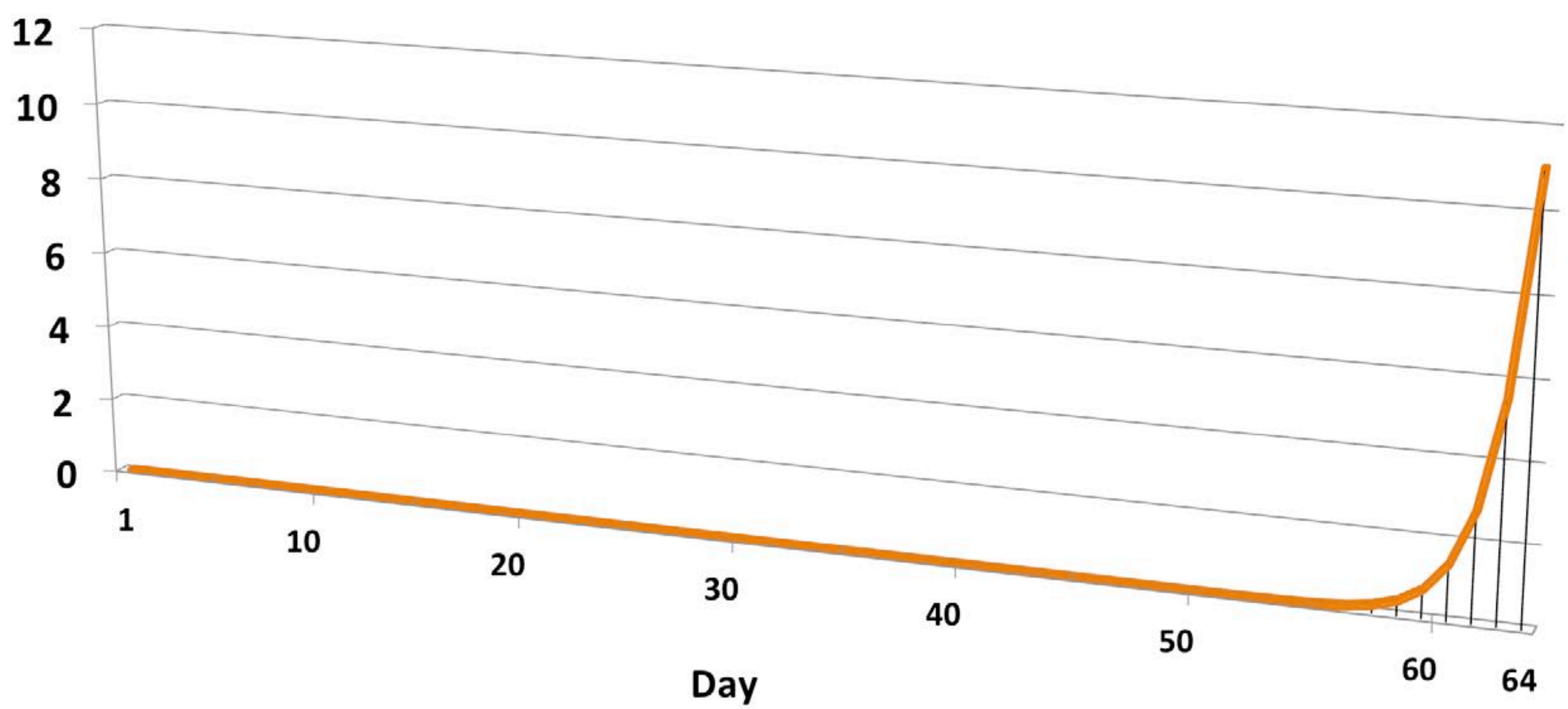
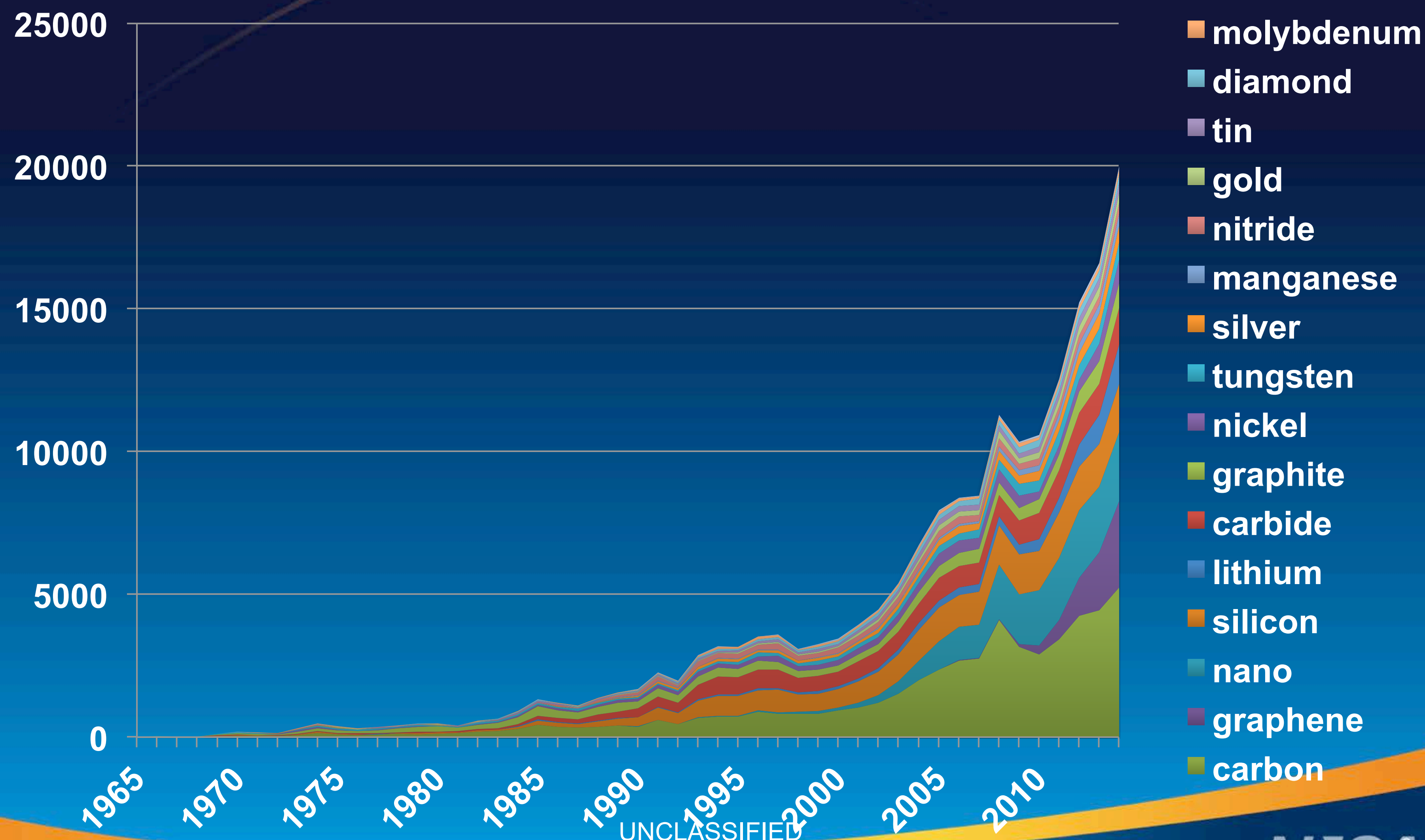
Day 4

Rice as fraction of world production (annual)



$$y(t) = y_0 e^{rt}$$

Number of papers involving composites



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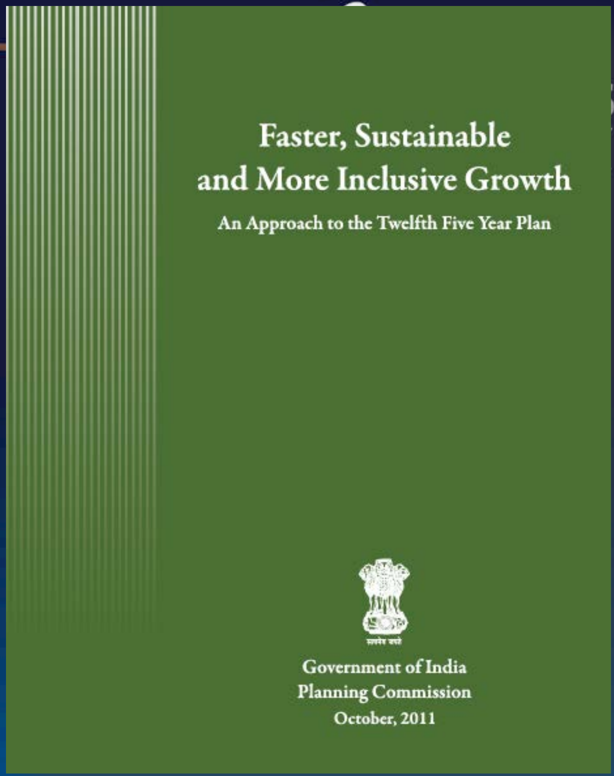
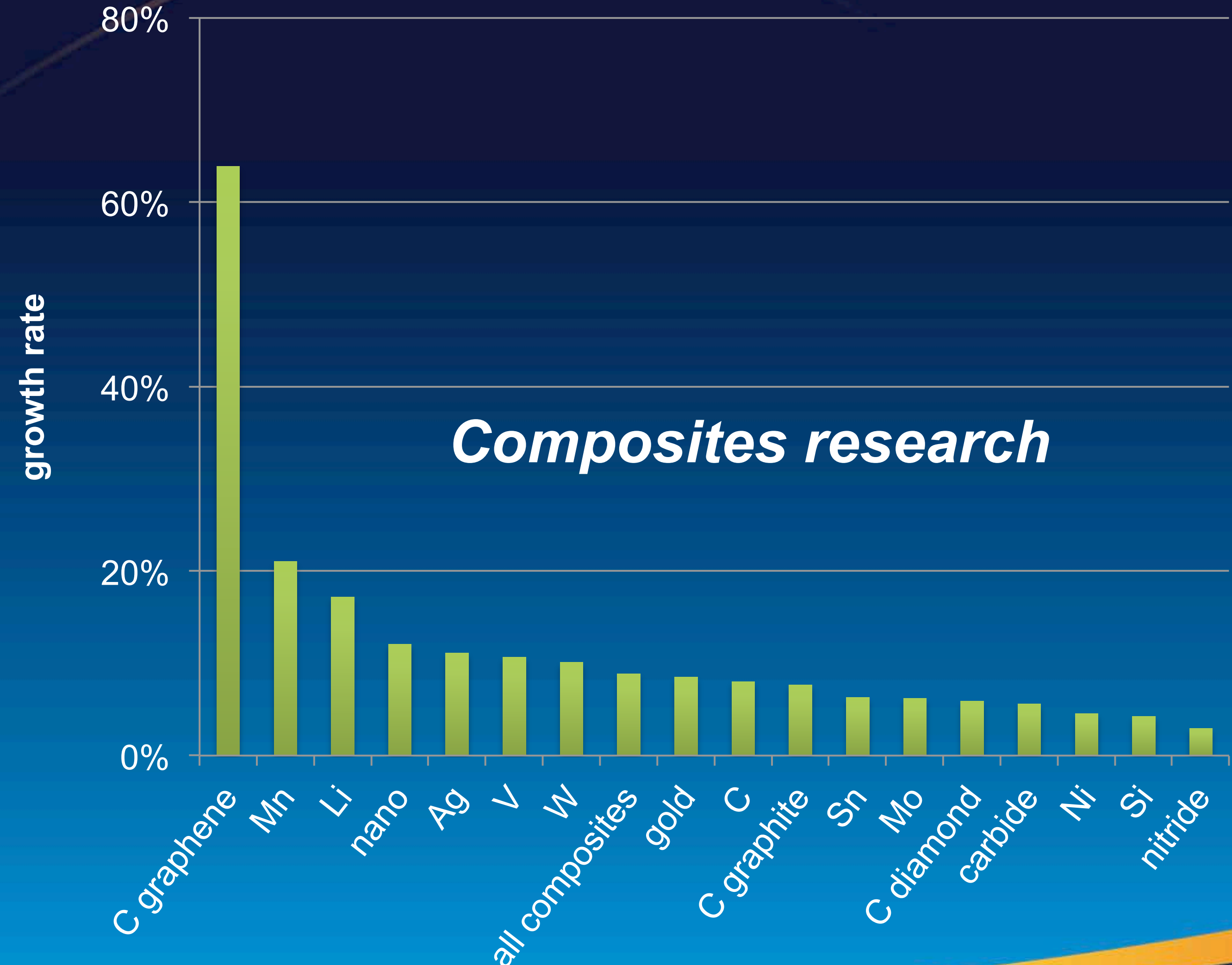
18

Faster, Sustainable and More Inclusive Growth

An Approach to the Twelfth Five Year Plan



publication growth (%/yr)



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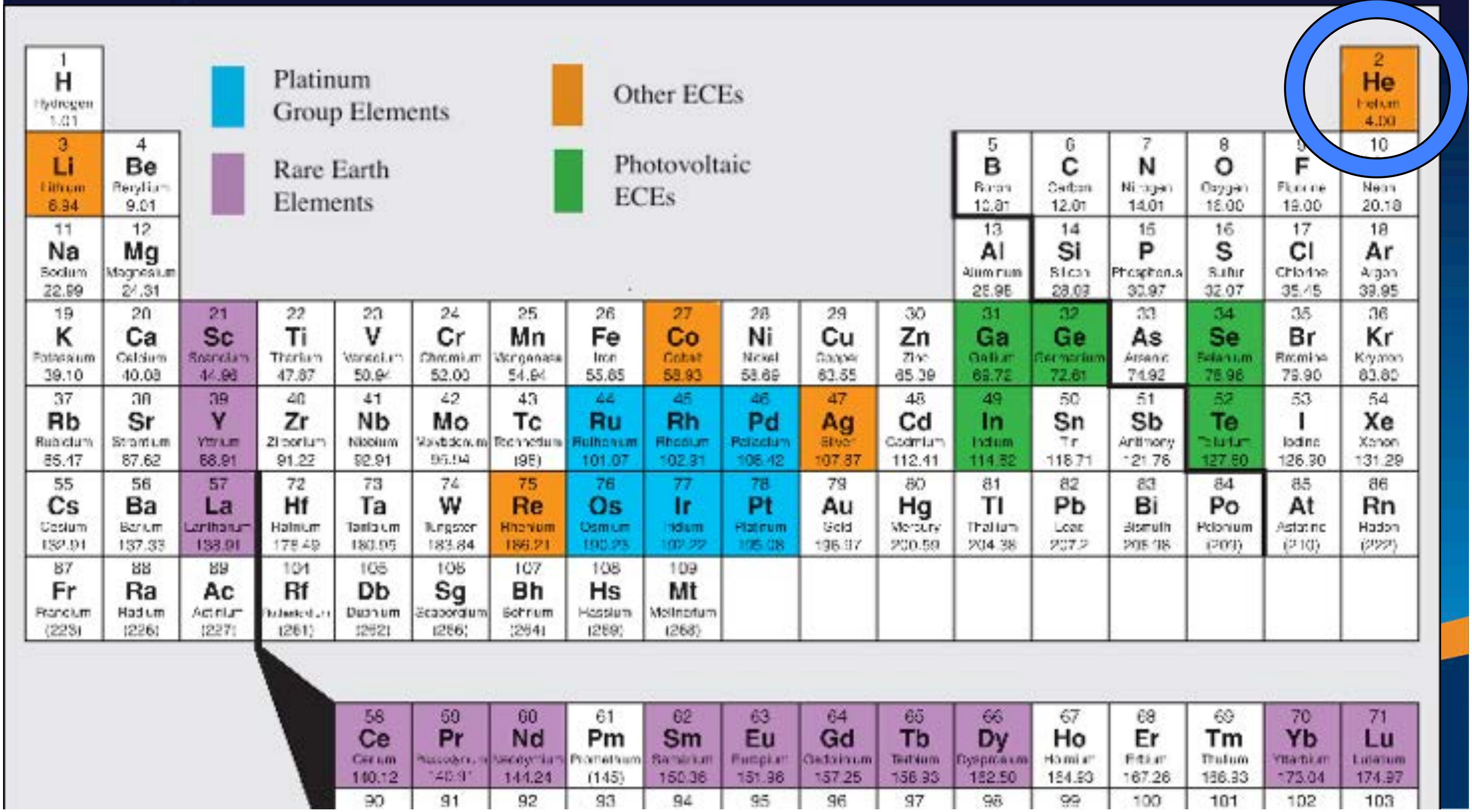
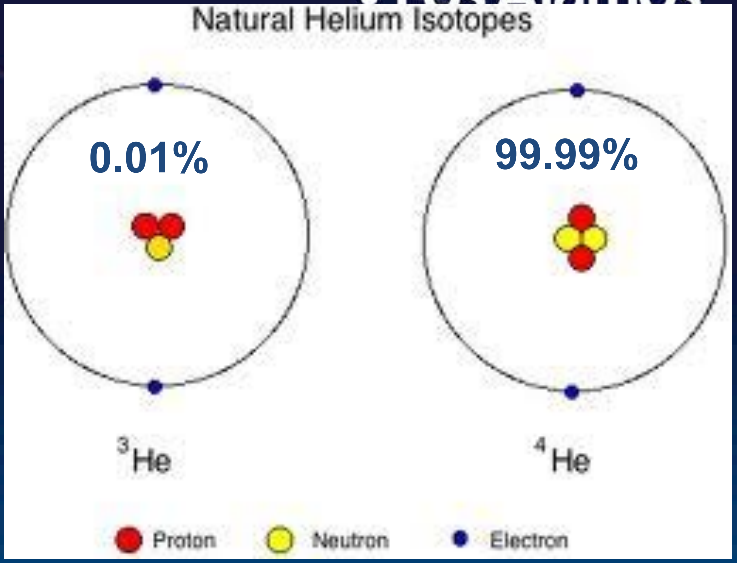
The APS-MRS-ACS set of Energy Critical Elements: Helium Case Study

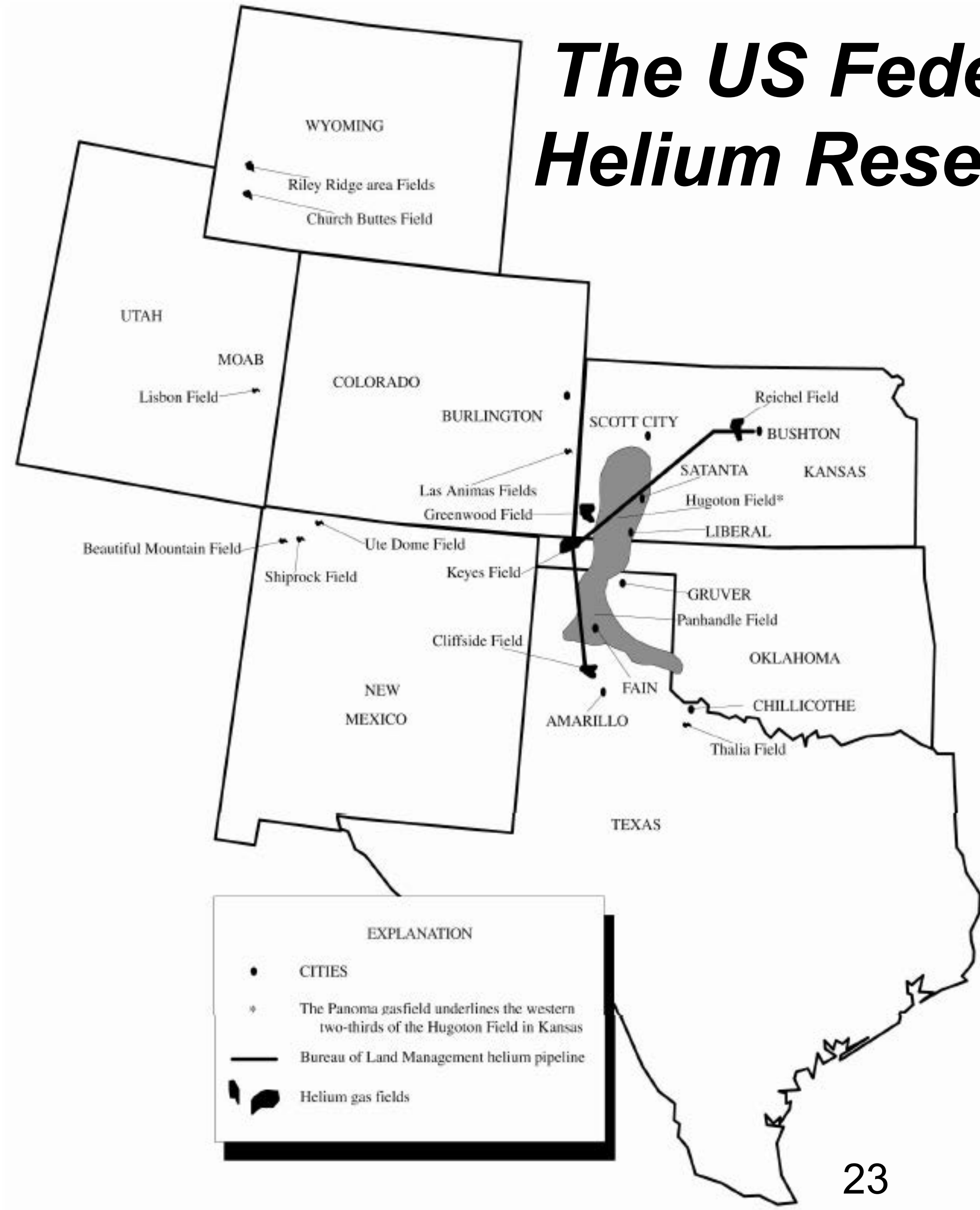


Helium:
A New APS-MRS-ACS Critical Materials Study (2016)



- He-4 second only to H in universe
- Created in Earth by radioactive decay
- Collected from natural gas wells
  - Usually just released
- Stockpiled in Texas mines for:
  - Military dirigibles (1925 et seq)
  - Liquid-fueled rockets flush (1957 et seq)
  - Welding, semiconductor manufacture
  - Cryogenics
  - Particle accelerators
  - Medical MRI
  - Future nuclear reactor coolant
  - Condensed matter research
  - Quantum fluids physics
- ***<u>Not gravitationally bound to Earth</u>***

The US Federal Helium Reserve



lamos LABORATORY .1943

NNSA

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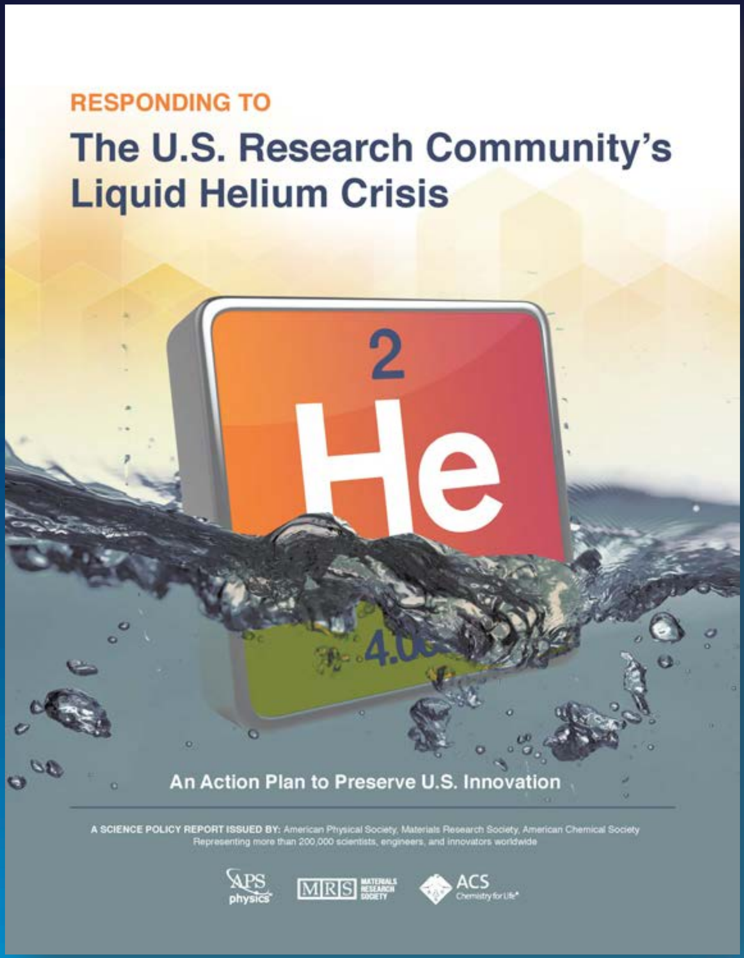
Intermediate Policy Solutions

- In 1996, US Congress had determined to sell off the Federal Helium Reserve by 2020.
- Lawmakers woke up and passed the Helium Stewardship Act in 2013

APS Helium Study October 2016



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APS-MRS-ACS He Panel

- Simon R. Bare, Co-Chair, SLAC National Accelerator Laboratory
- Michael Lilly, Co-Chair, Sandia National Lab
- Janie Chermak, University of New Mexico
- Rod Eggert, Colorado School of Mines
- William Halperin, Northwestern University
- Scott Hannahs, National High Magnetic Field Lab
- Sophia Hayes, Washington University in St. Louis
- Michael Hendrich, Carnegie Mellon University
- Alan Hurd, Los Alamos National Laboratory
- Mike Osofsky, Naval Research Laboratory
- Cathy Tway, The Dow Chemical Company

REPORT ADVISORS

Damon Dozier, Materials Research Society

Ryan Davison, American Chemical Society

APS STAFF

Francis Slakey, Associate Director of Public Affairs

Mark Elsesser, Senior Policy Analyst

Jeanette Russo, OPA Programs Manager

Ronald Lipscomb, Science Policy Intern

He study recommendations

- 1. The ***White House (OSTP) and OMBtogether should develop guidance to federal agencies,*** which use or support the use of helium, on establishing plans to conserve helium without compromising their mission or the vitality of their research and development programs. The ***National Science Foundation's DMR to fund small-scale liquefiers*** for researchers…
- 2. ***Congress should mandate that a portion of the monies raised through the sales of crude helium from the Federal Helium Reserve be used to help finance the capital investment in equipment*** that reduces academic researchers' helium consumption. Executive Summary
- ✓ 3. The Bureau of Land Management ***(BLM) should clarify and then widely publicize its regulations regarding the in-kind helium program*** to explain that federal grantees are eligible for the program…
- ✓ 4. ***BLM should establish a royalty in-kind program for helium***. A portion of the helium extracted from federal lands should be marked as in-kind and sold to vendors based on the current and established pricing methodology. Vendors would be required to refine and resell the helium to federal end-users.
- ✓ 5. The ***professional scientific societies should develop a methodology to help academic researchers*** determine if – given helium costs, scientific requirements and existing infrastructure – it is financially beneficial to make a capital investment in equipment to reduce their helium usage. The societies should facilitate contact between interested researchers worldwide and manufacturers of helium liquefiers and recyclers. ***"Matchmaking website"***

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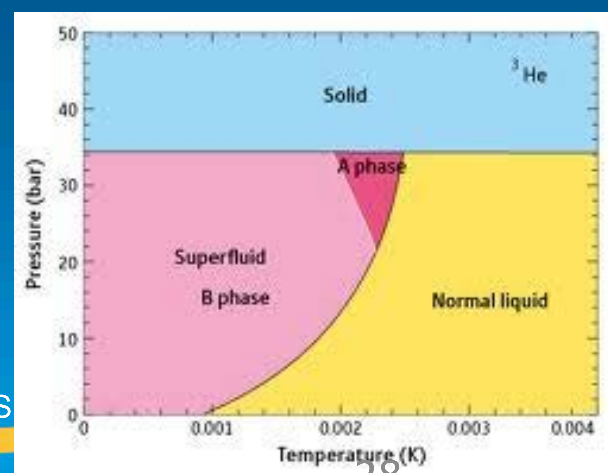
He-3: A case study of colliding priorities

- Formed by decay of tritium
- ***<u>Only one practical global source</u>***: the refurbishment and dismantlement of nuclear weapons (US and Russia)
- Applications
  - Cryogenics!
  - Quantum fluids research
  - Neutron detection
  - Medicine
  - Borehole logging for prospecting

Tritium is used in nuclear stockpiles

Also used in exit signs, gun sights.



Netron Detectors for the US Department of Homeland Security (DHS)…

Los Alamos NATIONAL LABORATORY EST. 1943

- ordered He-3-based neutron detectors for deployment at shipping centers to detect nuclear materials
- over-subscribed the He-3 supply by squeezing out research needs
  - Neutron scattering facilities around the world starved for detectors
  - Crash programs created for alternative detectors based on B-10 and Li-6.

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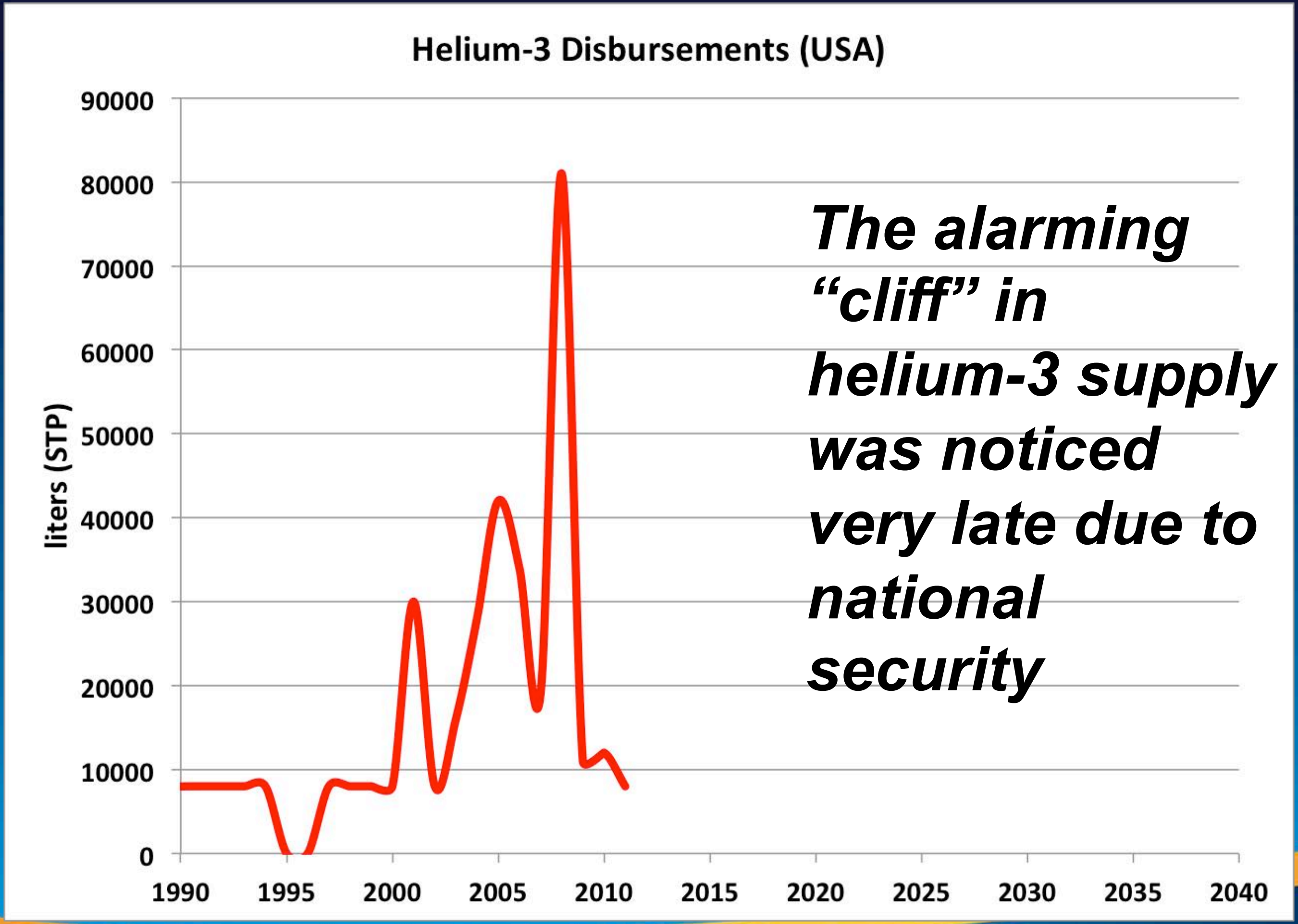
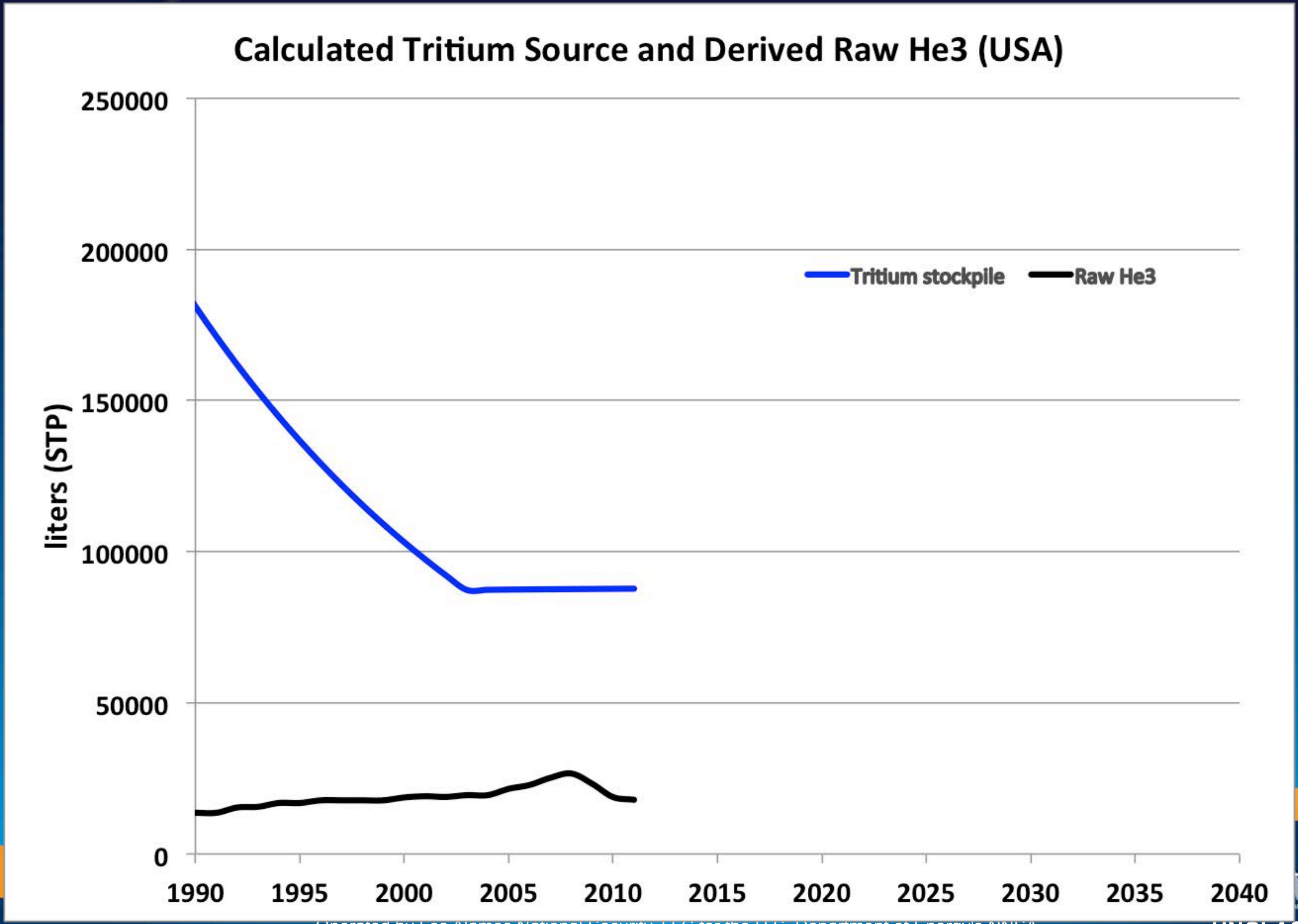
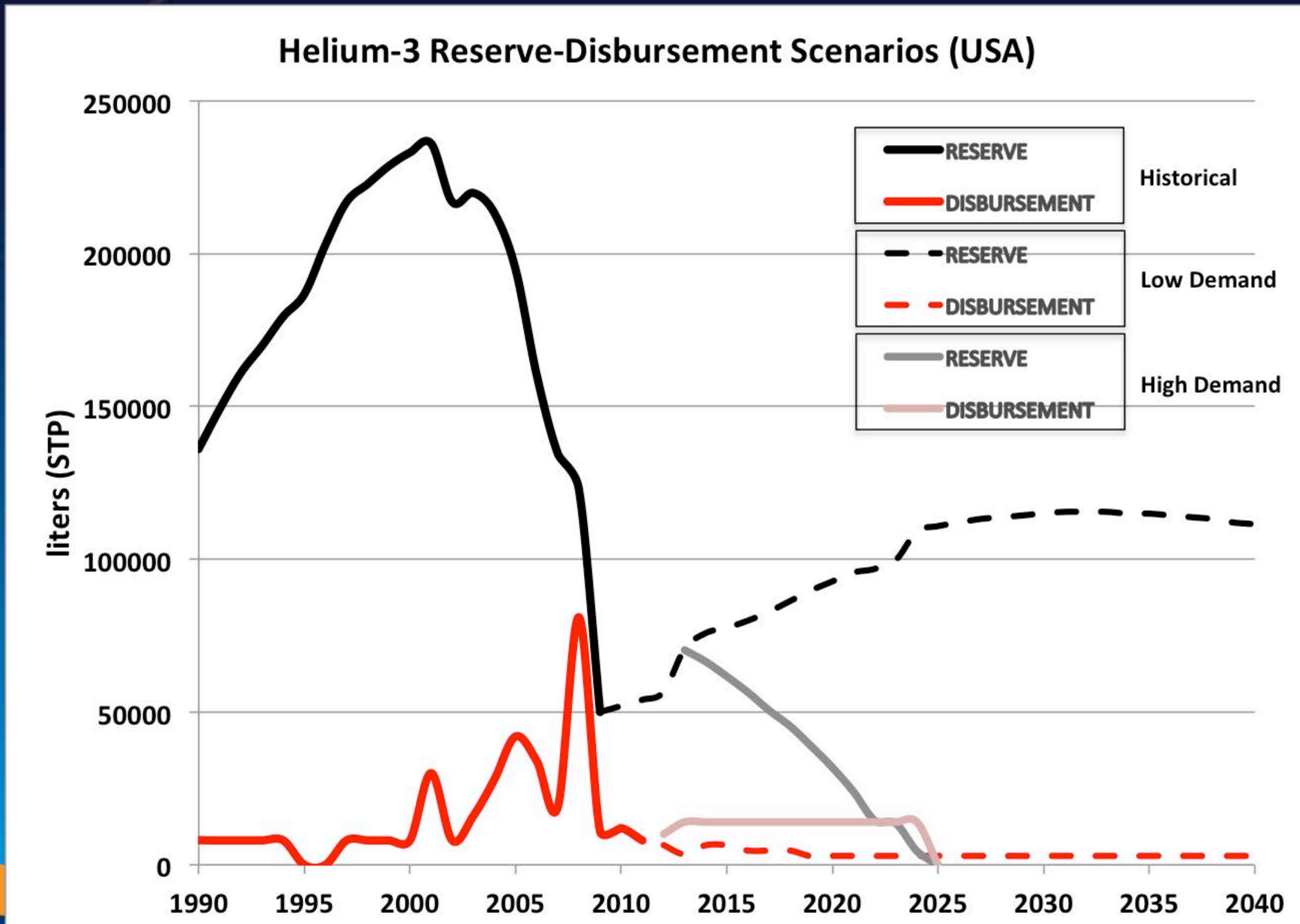
He-3 disbursements in US (from policy statements, usage)



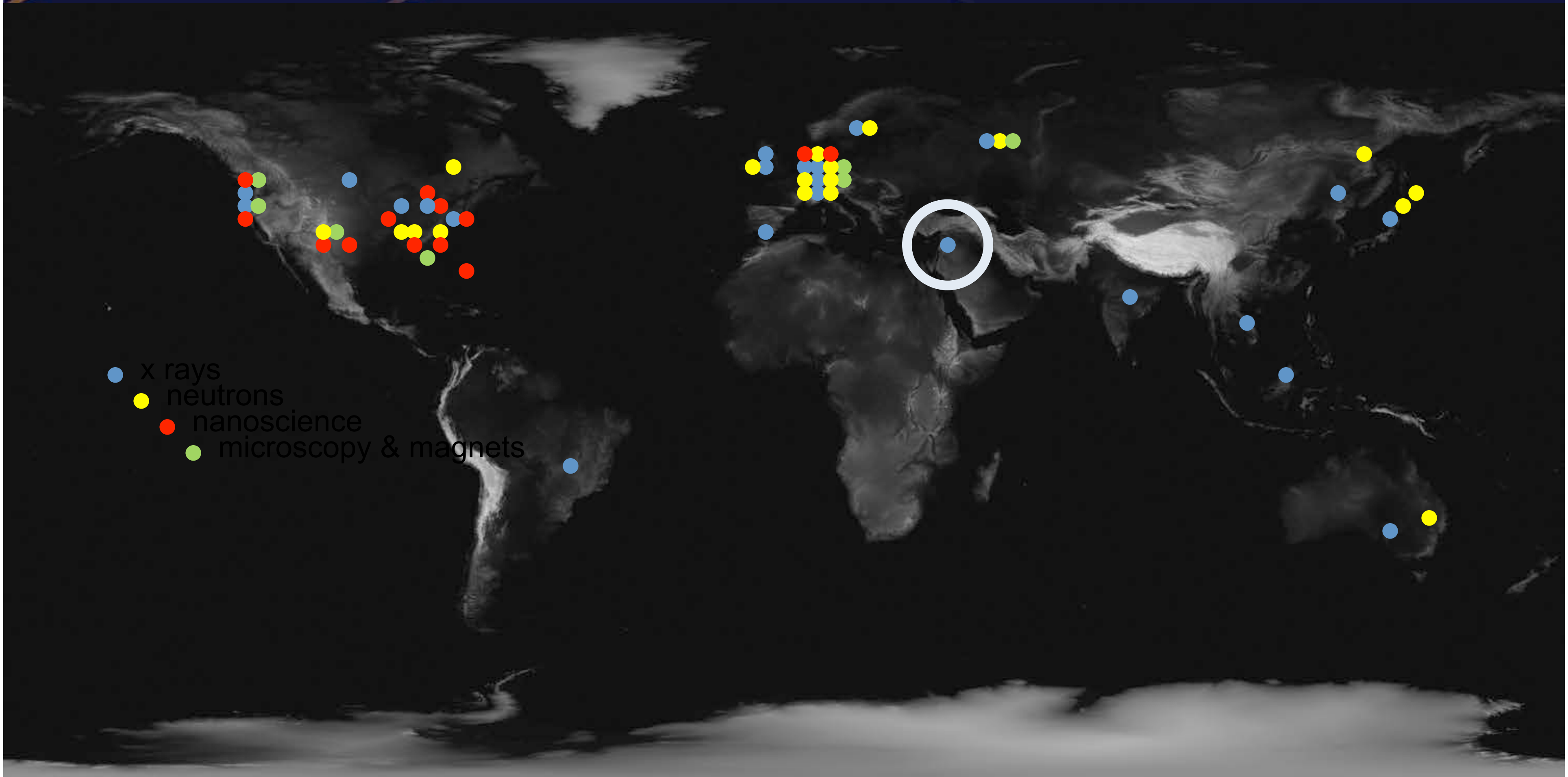
Assumed tritium mother reserve



Low and High Demand He-3 Scenarios [Hurd and Kouzes, Eur Phys J 2014]



Materials Research
A Network of International User Facilities



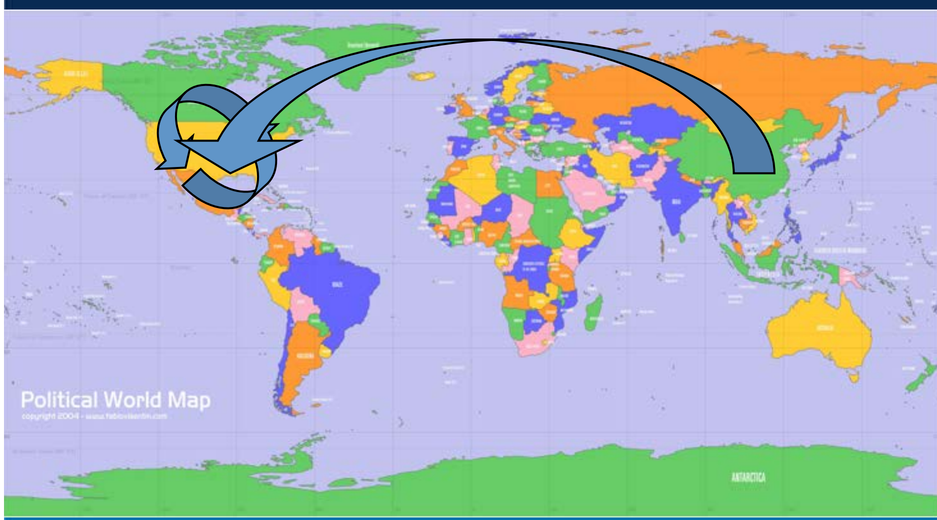
~$35B in capital facilities…
only about half are shown. . .

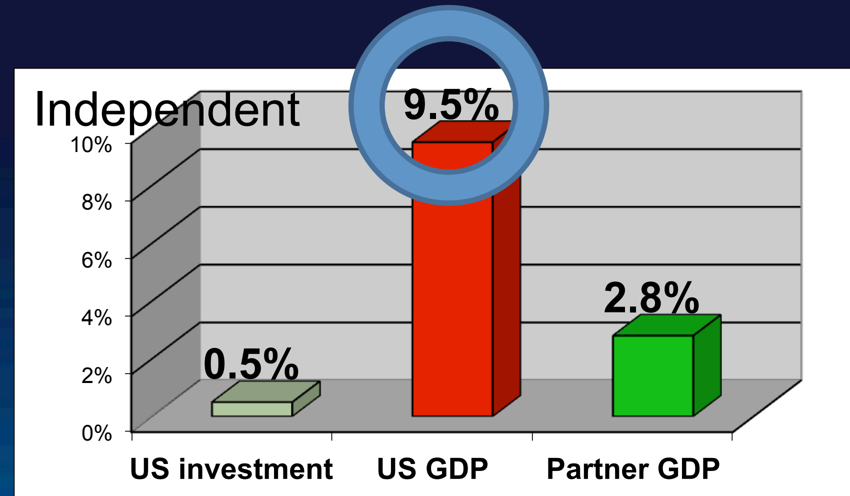
SESAME is a remarkable science diplomacy success

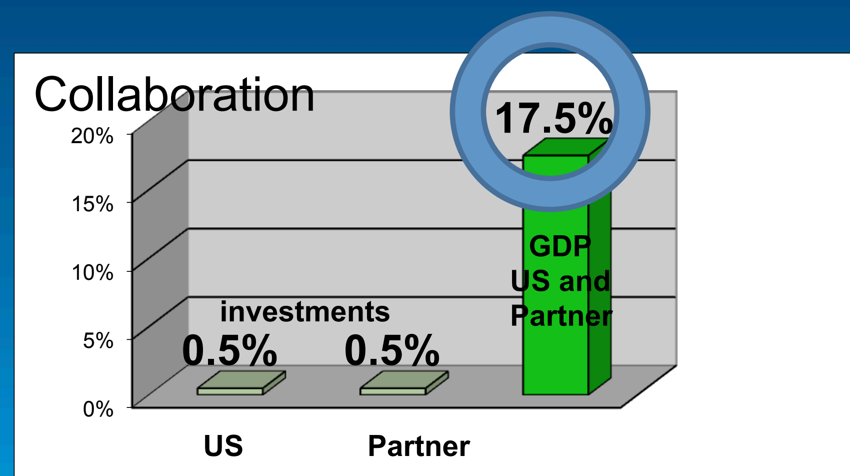
SESAME Members

Collaboration "spillover" benefits

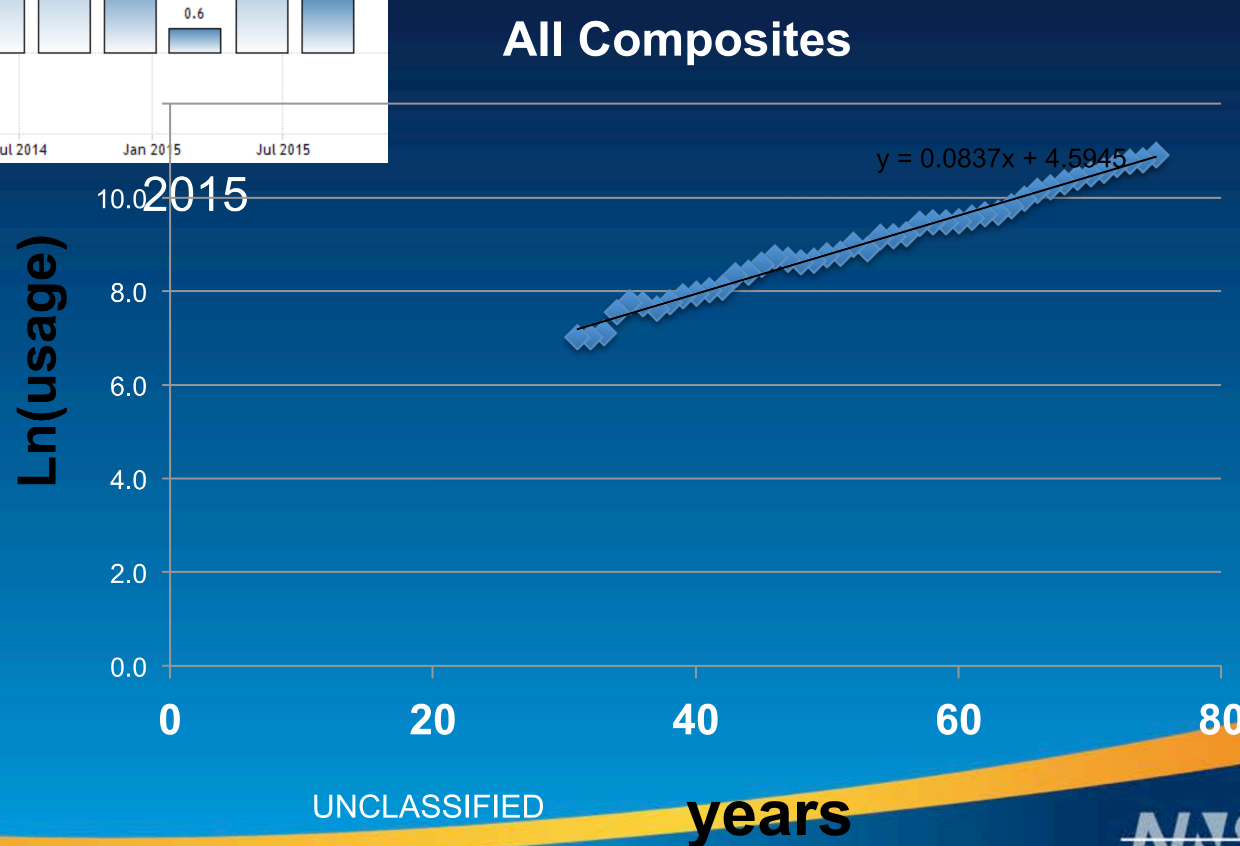
(Coe & Helpman 2007)





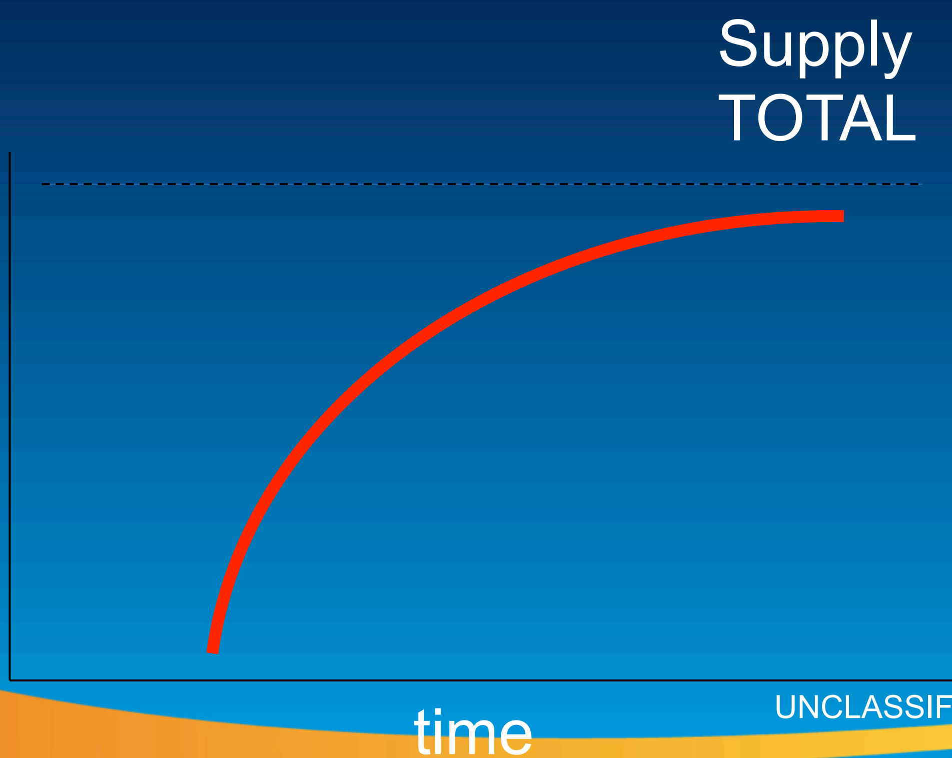


Can we beat the math?



Sustained Availability (A. Bartlett)

$$P = P(0) \exp(-kt)$$



- World petroleum will last 40 years at present rates of consumption, say
- Let $k = 1/40 = 0.025$
- Global use of petroleum declines 2.5% per year
- **The petroleum will last forever!**
- Decay curve has a "half life" of 28 years.
- **At every point on the decaying production curve, the life expectancy of the then remaining resource will be 40 years at the then current rate of production.**

Obligations