Key Elements of Teaching Nuclear and Radioactive Aspects of Geology

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Our Neighborhood Fusion Reactor

Sol (aka, the sun)

Hydrogen burning Yellow dwarf

Surface temperature: 6000 K

Core temperature: 1.5 x10^7 K

Principal energy producing reactions:

$^1H + {}^1H \rightarrow {}^2H + \beta^+ + \nu$, Q = 1.44 Mev

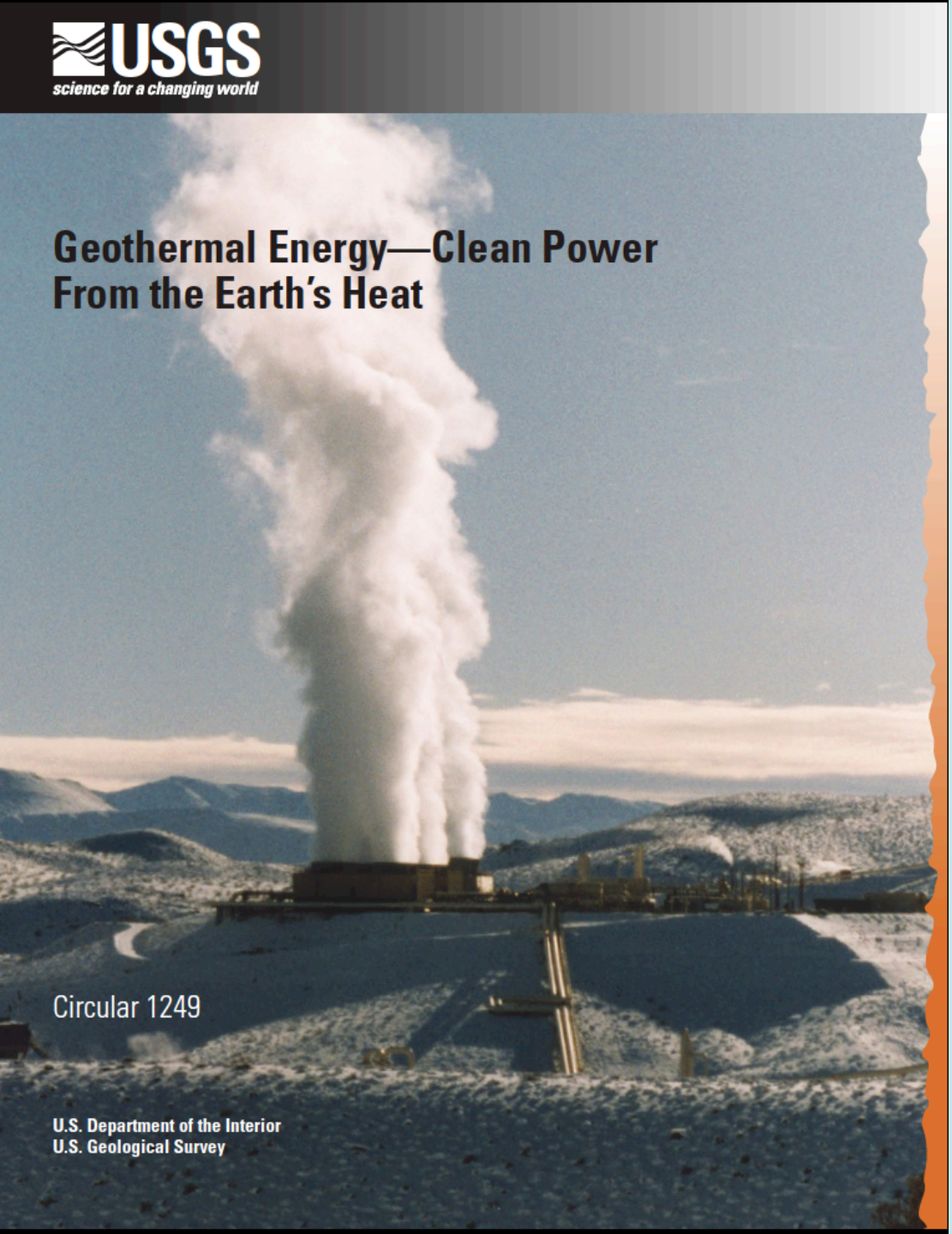
$^1H + {}^2H \rightarrow {}^3He$, Q = 5.49 Mev

$^3He + {}^3He \rightarrow {}^4He + 2\,{}^1H$, Q = 12.86 Mev

Net: $4\,{}^1H \rightarrow {}^4He + 2\,\beta^+ + 2\,\nu$, Q = 26.7 Mev

During the past several billion years, some of this solar energy has been converted into a form that is more easily used for transportation and power production: coal, oil, natural gas.

http://www.cresp.org/NuclearFuelCycleCourseII/Presentations/21_Nash_CRESP_Sustainability_Nash_summary.pdf



The Earth is a bountiful source of thermal energy, continuously producing heat at depth, primarily by the decay of naturally occurring radioactive isotopes—principally of uranium, thorium, and potassium—that occur in small amounts in all rocks.

Radiation-driven Ecosystems

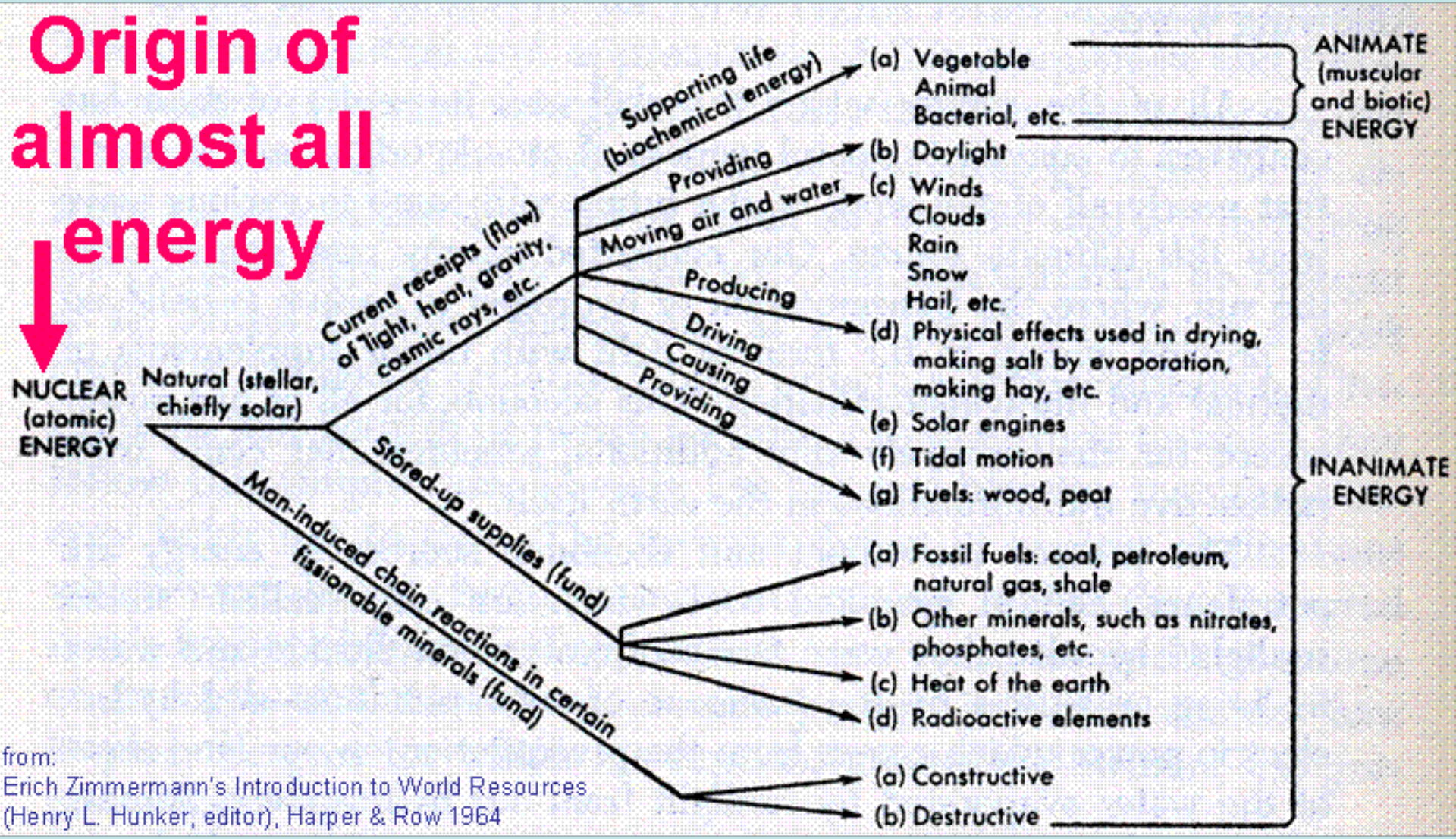
Fusion is the process that takes place in stars like our Sun. Whenever we feel the warmth of the Sun and see by its light, we are observing the products of fusion. We know that all life on Earth exists because the light generated by the Sun produces food and warms our planet. Therefore, we can say that **fusion is the basis for our life**

http://www.lbl.gov/abc/Basic.html

…virtually all of the energy we use originates in the power of the atom. Nuclear reactions energize stars, including our Sun. The energy we capture for use on Earth comes largely from the Sun or from nuclear forces local to our own planet.

http://needtoknow.nas.edu/energy/energy-sources/the-sun.php

Origin of almost all energy



from:
Erich Zimmermann's Introduction to World Resources
(Henry L. Hunker, editor), Harper & Row 1964

UT Austin: Erich W. Zimmermann Regents Chair in Geography (since 1984)

While generations of students and scientists have learned about radioactive decay and the half-lives of various radioactive elements and isotopes, virtually **no one has turned the telescope around** and discussed or documented the reverse view: The same number of half-life years taken back into the past produces a double-life, a doubling of radioactivity for these elements, and an incremental terrestrial background level many times higher than today's levels.

Gerald L. Looney (2003) Radiation hormesis and the radiological imperative (http://www.sepp.org/Archive/NewSEPP/Hormesis-Looney.htm)

Never in Earth history has any part of Earth's surface been void of radioactive isotopes or not exposed to ionizing radiation

Paraphrased from L.A. Pertsov, The natural radioactivity of the biosphere, Israel Program for Scientific Translations, Jerusalem, 1967

Decrease in the activity of the earth's crust due do the decay of long-lived radioactive isotopes

Million years ago	Relative decrease in radioactivity			
	U-238	**U-235**	**Th-232**	**K-40**
5000	2.14	128	1.29	14.3
2000	1.35	7.05	1.08	2.82
present	~1	~1	~1	~1

Simplified from L.A. Pertsov, The Natural Radioactivity of the Biosphere,
Israel Program for Scientific Translations, Jerusalem, 1967

Natural Radioactivity by the Square Mile, 1 Foot Deep

Total volume: 7.894×10^5 m³. Activity levels vary greatly depending on soil type, mineral make-up, and density (~1.58 g/cm³ is the basis of this calculation).

Nuclide	Activity used in calculation	Nuclide mass	Activity found in soil volume
U	0.7 pCi/g (25 Bq/kg)	2,200 kg	0.8 curies (31 GBq)
Th	1.1 pCi/g (40 Bq/kg)	12,000 kg	1.4 curies (52 GBq)
K 40	11 pCi/g (400 Bq/kg)	2000 kg	13 curies (500 GBq)
Ra	1.3 pCi/g (48 Bq/kg)	1.7 g	1.7 curies (63 GBq)
Rn	0.17 pCi/g (10 kBq/m^3) soil	11 µg	0.2 curies (7.4 GBq)
		Total:	>17 curies (>653 GBq)

http://www.physics.isu.edu/radinf/natural.htm

Avner Vengosh, Duke University

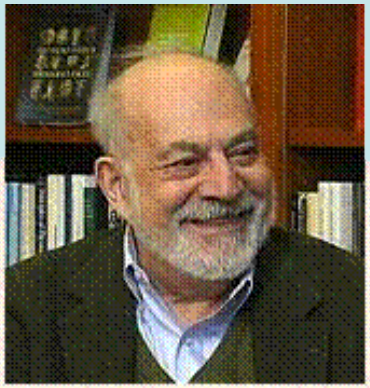
Rooting Out Radioactive Groundwater (Geotimes, May 2006)

When the **Chernobyl** nuclear power plant exploded in 1986… The accident demonstrated the **fragility of any nuclear facility** and raised the level of awareness over the health **threats that radiation poses** to people and the environment.
…the general population is still **at risk from** a different source: **Naturally occurring radioactive particles** exist in many groundwater systems worldwide…
The global **community must aggressively address these challenges, to ensure a safe water supply**.

Laurence A. Coogan & Jay T. Cullen, University of Victoria

Did natural reactors form as a consequence of the emergence of oxygenic photosynthesis during the Archean? (GSA Today, October 2009)

Natural reactors act as point sources of…**toxic byproducts**.
Natural fission reactors would clearly be **environmentally detrimental**.
…whether the formation of these natural reactors had any significant **biocidal impacts…**



ON BULLSHIT

Harry G. Frankfurt

PRINCETON UNIVERSITY PRESS

PRINCETON AND OXFORD

First published 1986


Nigeria
CAMEROON
Gulf of
Guinea
EQUITORIAL
GUINEA
LIBREVILLE
Gabon
Lambaréné
CONGO
Oklo
ATLANTIC
OCEAN
ANGOLA

- Oklo is a worst-case analogue:
  - Rocks were jointed and fractured
  - Permeabilities waxed and waned
  - The ore went critical, enduring fission and high temperatures
  - Confinement remained effective without engineered barriers or carefully designed waste forms
  - Fission products were available for migration for billions of years
- Conclusion: geologic repositories did, do, and will confine radionuclides

  (even without human assistance or Yankee ingenuity)

"Normal" or average v. highest known natural background radiation on Earth

"normal"	Ramsar
Radium in groundwater (Bq/l)	
<10	~500
Radium in soil, rock, food (Bq/g)	
<0.5	~350
Radon inside homes (Bq/l)	
<0.5	>4
Population dose (mSv/yr)	
2-3	20-250

"no consistent detrimental effect has been detected so far"

http://www.ecolo.org/documents/documents_in_english/RamsarHLNRAPaper.doc

Source:
The Very High Background Radiation Areas of Ramsar, Iran: Geology, Radiobiology, and Policy
Andrew Karam, Ph.D., CHP
University of Rochester
Presented to NO CHPS, Radiation Safety Without Borders
November 12, 2002

Background Radiation and EPA and NRC Regulations

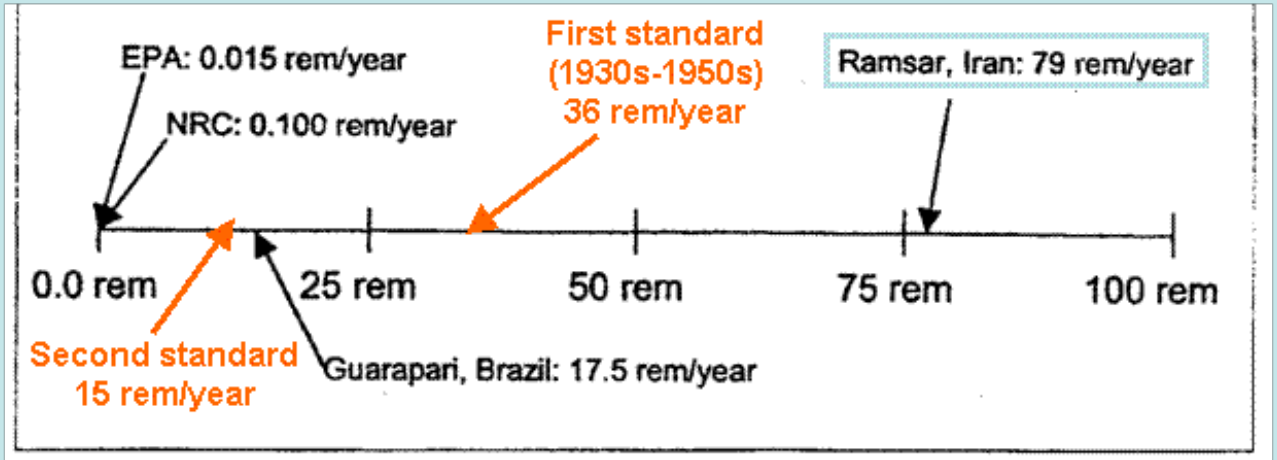


Fig. 2. Scale comparing EPA and NRC regulatory limits to natural background radiation environments (100 rem = 1 sievert; 100 rad = 1 gray)

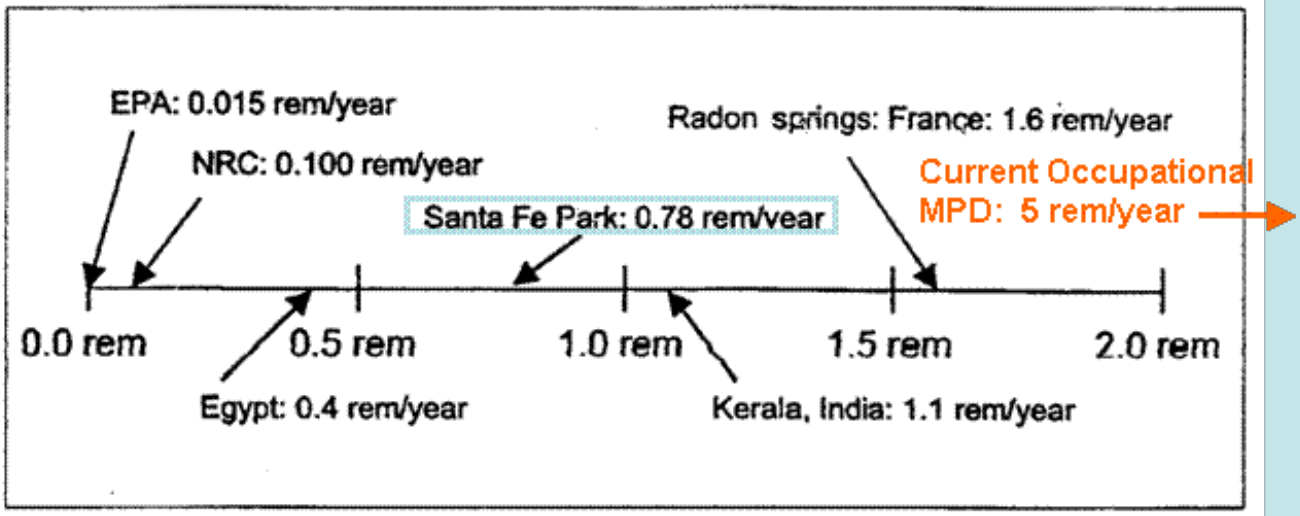
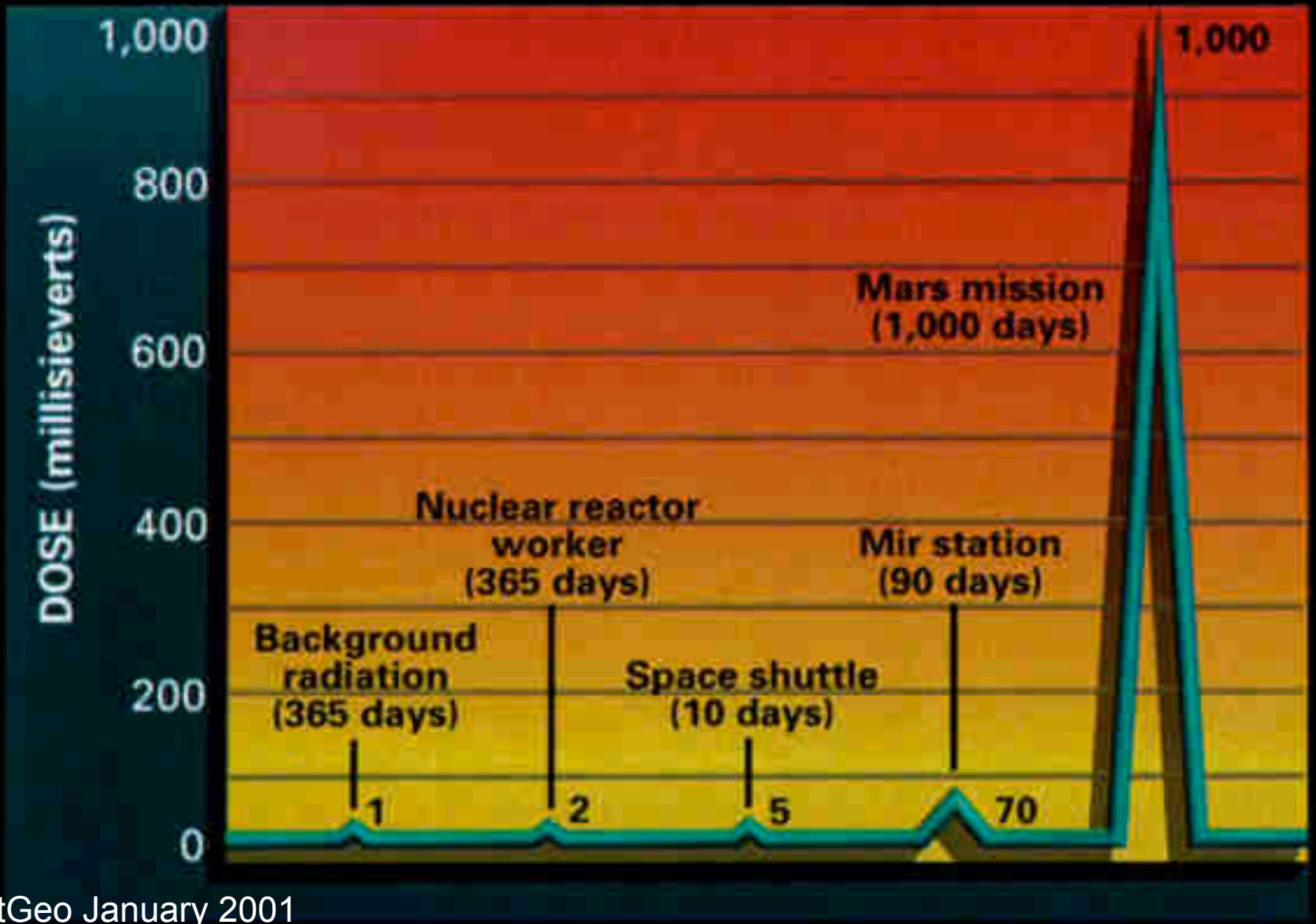


Fig. 3. Expanded scale comparing EPA and NRC regulatory limits to natural background radiation environments (100 rem = 1 sievert; 100 rad = 1 gray)

From Mark M. Hart, "Disabling the terror of radiological dispersal," *Nuclear News* July 2003

RADIATION EXPOSURES



NatGeo January 2001

Precautionary Principle

Anneken Hendriks, Amsterdam, executed 1571

In Action

Death by Regulation: The Need for a Scientific Standard

Society for

Humane

Abolition of

Regulations that

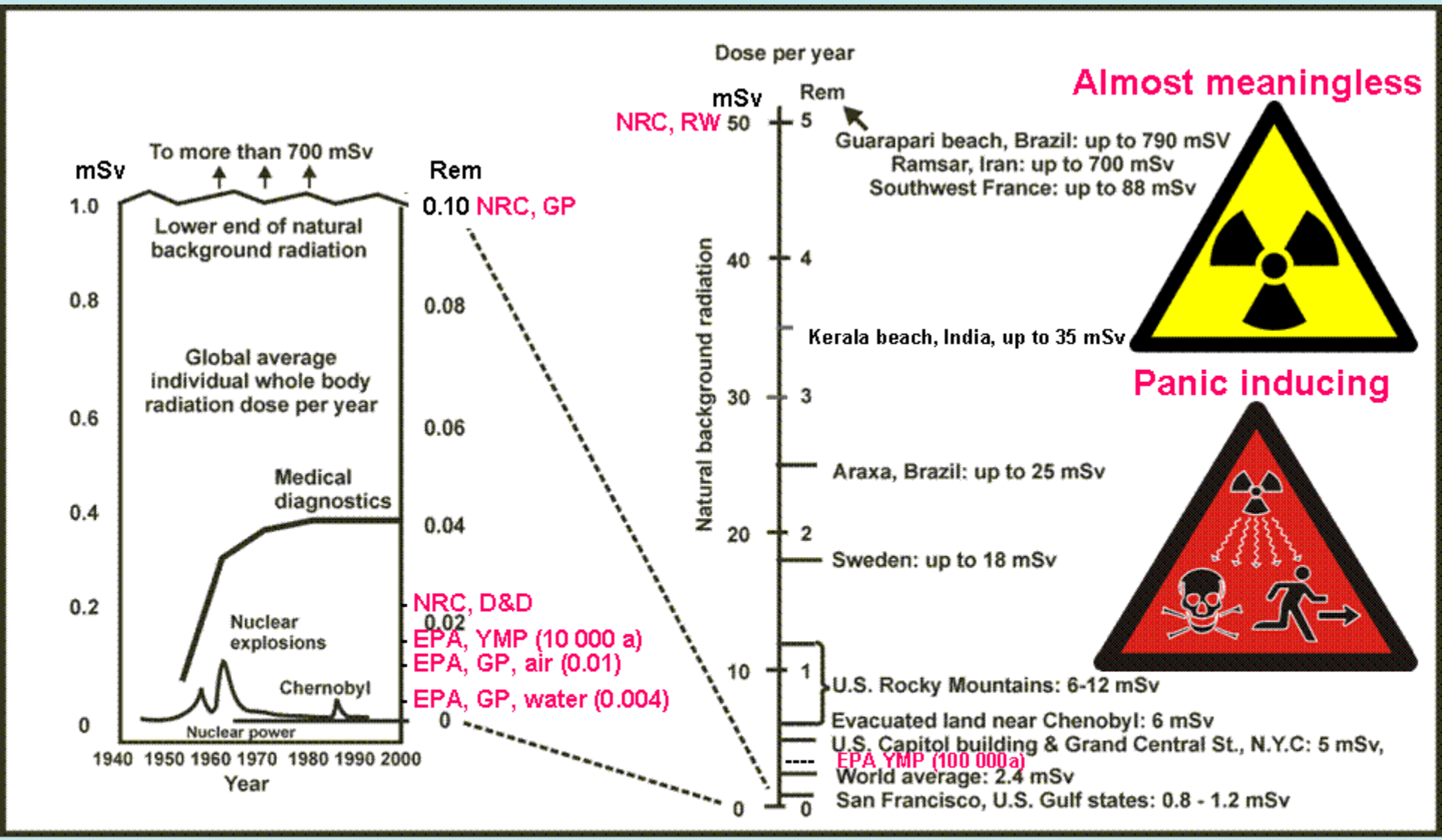
Kill

Jay H. Lehr, Science Director, The Heartland Institute, 2002

20th Annual Meeting of Doctors for Disaster Preparedness, Colorado Springs, CO

Insistence on, and
cadaverous compliance with,
regulations without continuously
questioning and justifying
their factual and rational basis

is the last refuge of
the lazy, incompetent, and
malevolent

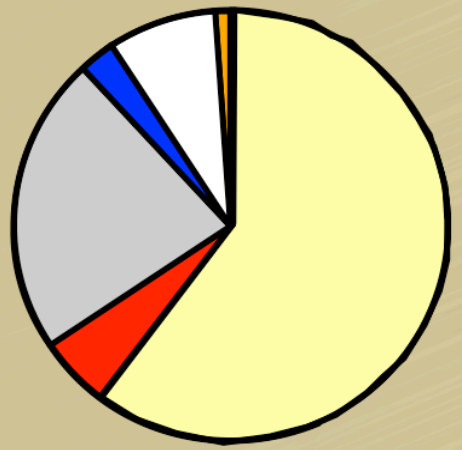


Modified from a
Figure prepared by Ted Rockwell from data found in "Radiation Risk and Ethics", Z. Jaworoski, published in Physics Today, American Institute of Physics, September, 1999 and "Ionizing Radiation and Radioactivity in the 20th Century", Z. Jaworoski, presented at the International Conference on Radiation and its Role in Diagnosis and Treatment", Tehran, Iran October, 2000.

http://www.cns-snc.ca/media/uploads/branch_data/branches/Toronto/radiation/natural_and_human_radiation.html
http://hps.org/publicinformation/ate/faqs/regdoselimits.html
http://dspace.mit.edu/bitstream/handle/1721.1/41588/213482682.pdf?sequence=1

Electricity Options

- Natural Gas
  - Abundant, reliable, price volatility, and cleaner
  - *Challenges: Global deliverability (LNG) and Access*
- Coal
  - Abundant, reliable, cheap and dirty
  - *Challenge: Sequestration (IGCC w/CCS), financing, public perception*
- **Nuclear**
  - **Abundant, reliable, moderate price and cleaner**
  - ***Challenges: Waste disposal, security, public perception***



Nuclear

Le Hague Waste Recycling

Normandy, France

Nuclear Challenges

- Natural and Human Disasters
- Front End Cost
  - ❖Permitting and Regulatory
- Waste Protection
- Proliferation

Cologne City Hall

Friedrich von Spee

http://www.stadt-koeln.de/6/sehenswertes/rathaus/rathausturm/04306/#ziel_0_5

Author of
Cautio Criminalis,
published 1631

http://commons.wikimedia.org/wiki/File:Rathausturm_K%C3%B6ln_-_Friedrich_Spee_von_Langenfeld,_Katharina_Henot_(0840-42).jpg

Katharina Henot

http://www.stadt-koeln.de/6/sehenswertes/rathaus/rathausturm/04306/#ziel_0_5

Burnt at the stake
in Cologne,
May 19, 1627

To accept information about a matter on which totally contradictory evidence exists, and in which investigation of major disputes on the matter is prevented, is not a rational act.

Robert Conquest