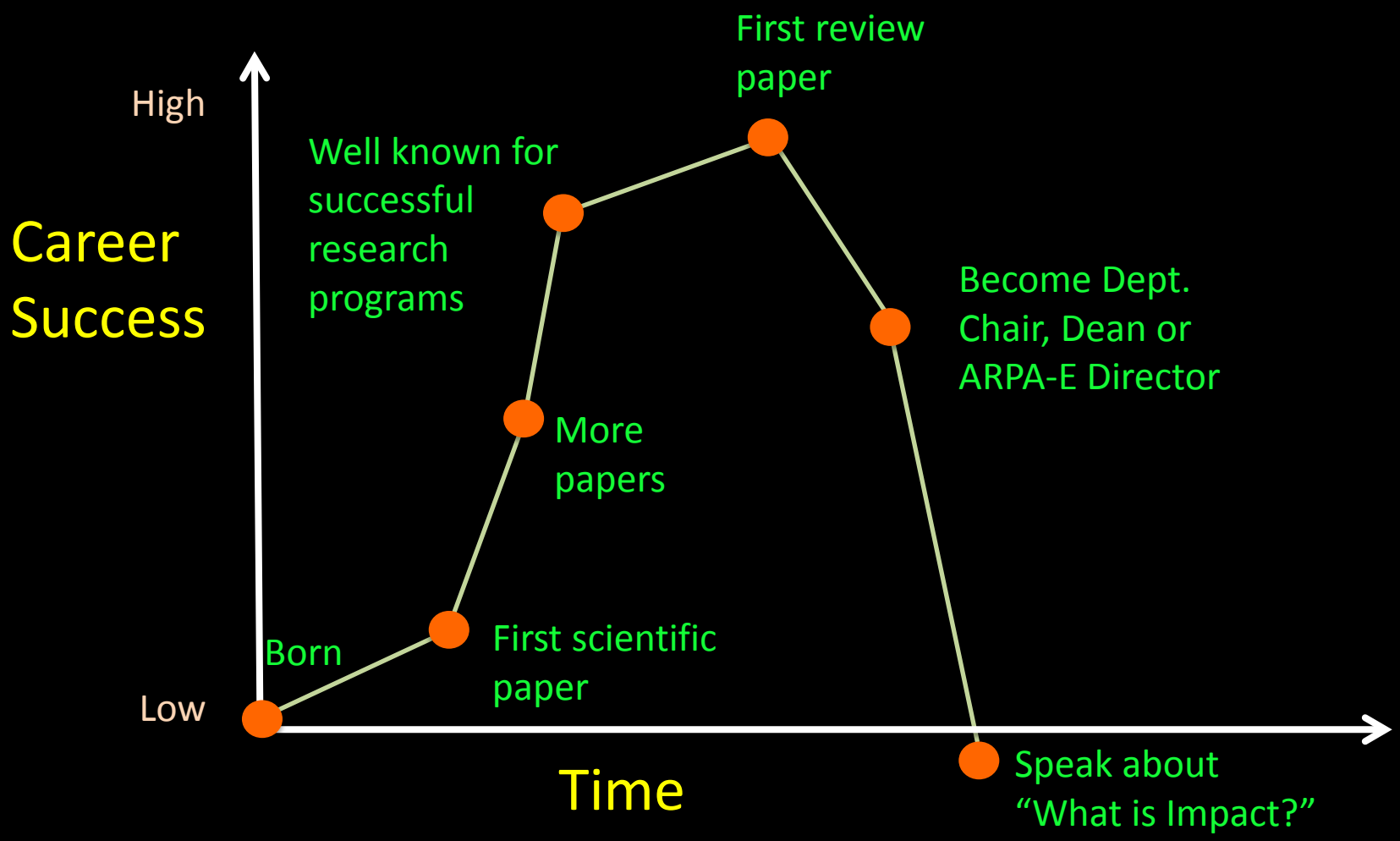
What is Impact?

Lessons Learnt from 20th Century Science & Engineering

Arun Majumdar
Stanford University


First review paper
High
Well known for successful research programs
Career Success
Become Dept. Chair, Dean or ARPA-E Director
More papers
First scientific paper
Born
Low
Time
Speak about "What is Impact?"

Is Impact Measured By

- Papers & Citations: h-index
- Awards & honors
- New fields started
- Patents issued & licensed
- Market value of business(es)
- Students, post-docs & their students/post-docs
- ……..

J. E. Hirsch, "An index to quantify an individual's scientific research output," *PNAS* **102**, 16569 (2005)

Cited: 4,141

For the few scientists who earn a Nobel prize, the impact and relevance of their research is unquestionable. Among the rest of us, how does one quantify the cumulative impact and relevance of an individual's scientific research output? In a world of limited resources, such quantification (even if potentially distasteful) is often needed for evaluation and comparison purposes (e.g., for university faculty recruitment and advancement, award of grants, etc.).

A Majumdar

UCBerkeley/LBL/DOE/Google/Stanford

Google Scholar

Citation indices	All	Since 2009
Citations	30197	19545
h-index	85	68
i10-index	217	179

Title	Cited by	Year
Thermal transport measurements of individual multiwalled nanotubes P Kim, L Shi, A Majumdar, PL McEuen Physical review letters 87 (21), 215502	2085	2001
Enhanced thermoelectric performance of rough silicon nanowires AI Hochbaum, R Chen, RD Delgado, W Liang, EC Garnett, M Najarian, ... Nature 451 (7175), 163-167	2007	2008
Nanoscale thermal transport DG Cahill, WK Ford, KE Goodson, GD Mahan, A Majumdar, HJ Maris, ... Journal of Applied Physics 93 (2), 793-818	1606	2003
Thermal conductivity of individual silicon nanowires D Li, Y Wu, P Kim, L Shi, P Yang, A Majumdar Applied Physics Letters 83 (14), 2934-2936	1000	2003

h = mn

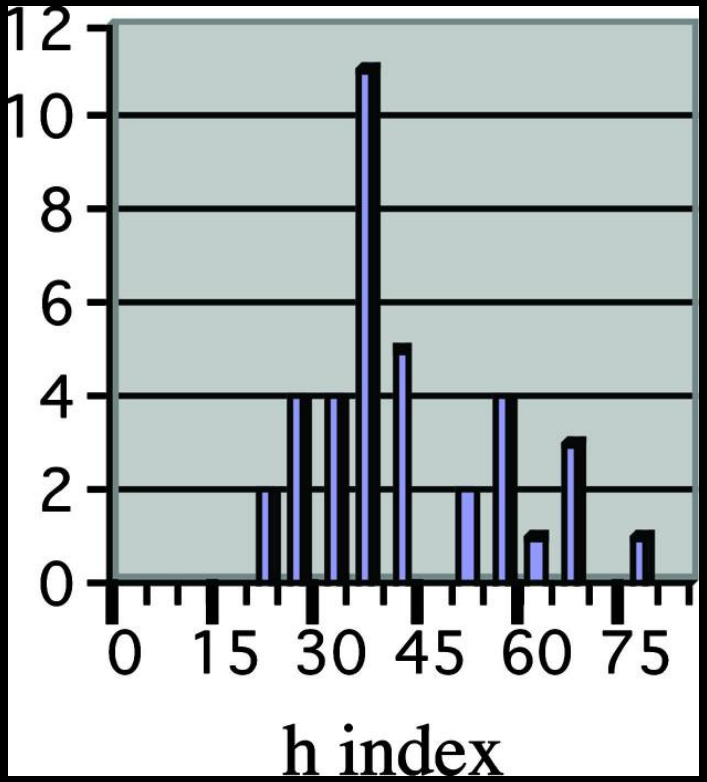
n = # of active years

m ≈ 1 – successful scientist

m ≈ 2 – outstanding scientist

m ≈ 3 or higher – truly unique individuals

Physics Nobels



<h> = 44; σ_h = 15

<m> = 1.14; σ_m = 0.47

2005 NAS Members

Physics & Astronomy: <h>=44, σ_h=14, h_{max}=71, h_{min}=20

Biological Sciences: <h>=57, σ_h=22, h_{max}=135, h_{min}=18

J Bardeen, WH Brattain, "The Transistor, A Semiconductor Triode," *Phys. Rev.* **74**, 230 (1948)
Cited: 762

J Bardeen, L Cooper, JR Schrieffer, "Theory of Superconductivity," *Phys. Rev.* **108**, 1175 (1957)
Cited: 9,703

F. Sanger, "The free amino acid groups of insulin," *Biochemical J.* **39**, 507 (1945)
Cited: 1,813

F. Sanger, S. Nicklen, A. R. Coulson, "DNA sequencing with chain-terminating inhibitors," *PNAS* **74**, 5463 (1977)
Cited: 62,767

S. Brin, L. Page, “The anatomy of a large-scale hypertextual Web search engine,” *Computer Networks and ISDN Systems* **30**, 107 (1998)
Cited: 11,327

(12) **United States Patent**
Page

(10) **Patent No.: US 6,285,999 B1**
(45) **Date of Patent: Sep. 4, 2001**

(54) **METHOD FOR NODE RANKING IN A LINKED DATABASE**

(75) Inventor: **Lawrence Page**, Stanford, CA (US)

(73) Assignee: **The Board of Trustees of the Leland Stanford Junior University**, Stanford, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/004,827**

(22) Filed: **Jan. 9, 1998**

Craig Boyle “To link or not to link: An empirical comparison of Hypertext linking strategies”. ACM 1992, pp. 221–231.*

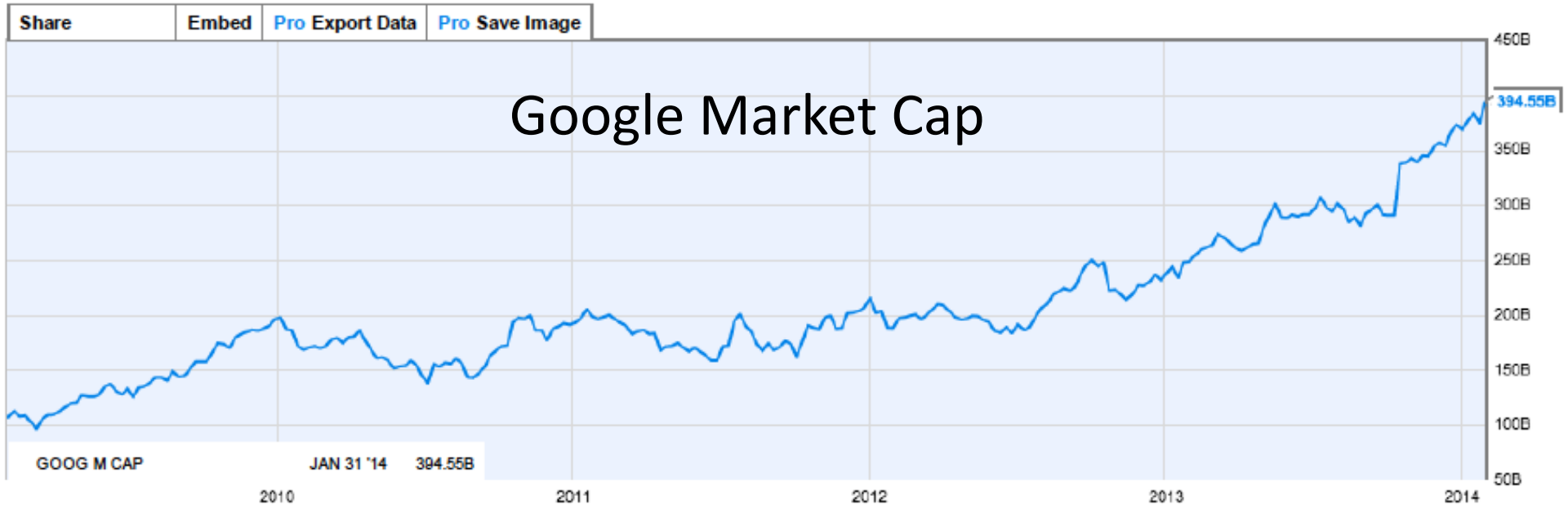
L. Katz, “A new status index derived from sociometric analysis,” 1953, Psychometricka, vol. 18, pp. 39–43.

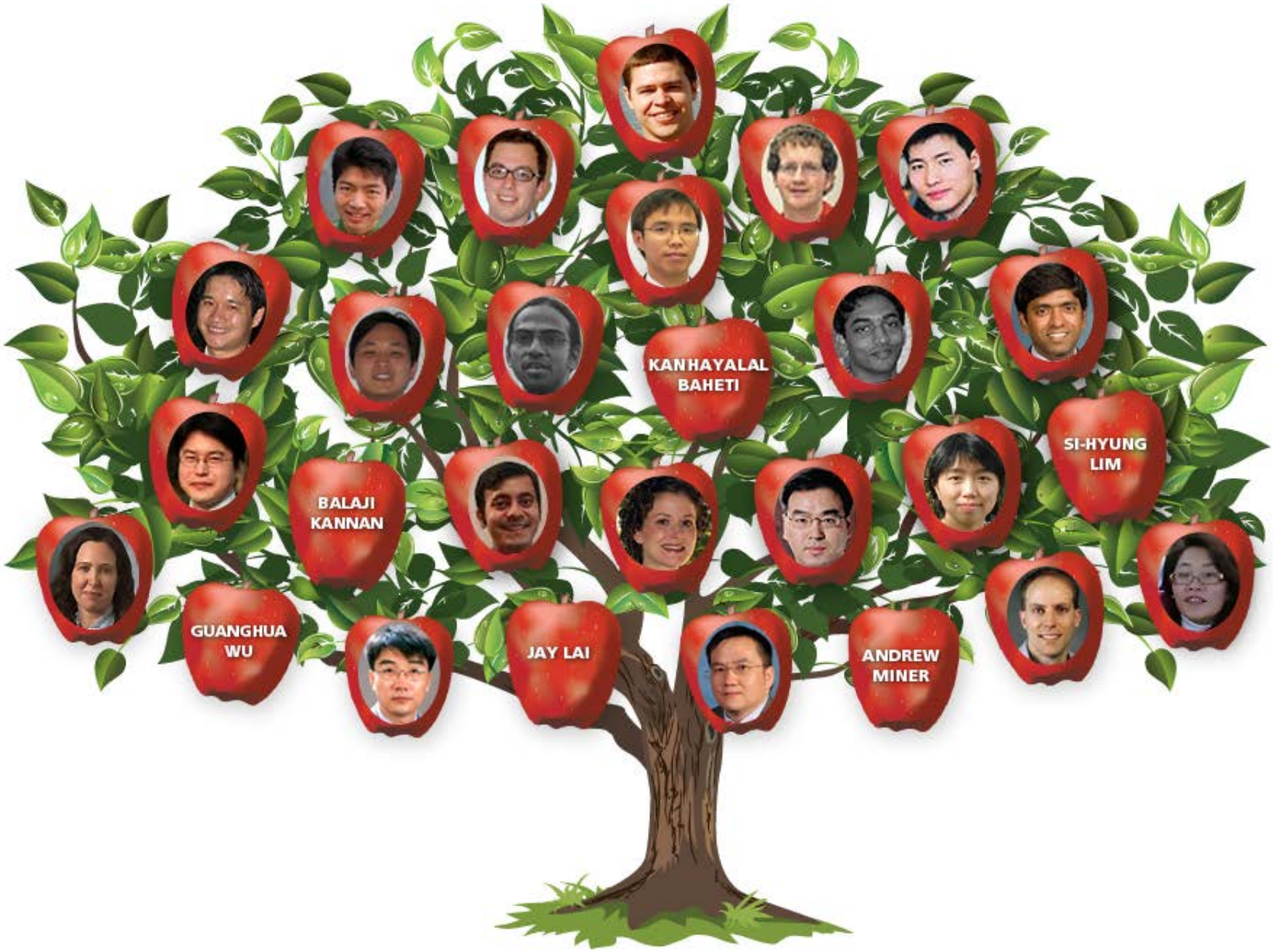
C.H. Hubbell, “An input–output approach to clique identification sociometry,” 1965, pp. 377–399.

Mizruchi et al., “Techniques for disaggregating centrality scores in social networks,” 1996, Sociological Methodology, pp. 26–48.

E. Garfield, “Citation analysis as a tool in journal evaluation,” 1972, Science, vol. 178, pp. 471–479.

Pinski et al., “Citation influence for journal aggregates of scientific publications: Theory, with application to the literature of physics,” 1976, Inf. Proc. And Management, vol. 12, pp. 297–312.




KANHAYALAL
BAHETI
SI-HYUNG
LIM
BALAJI
KANNAN
GUANGHUA
WU
JAY LAI
ANDREW
MINER

Is Impact Measured By

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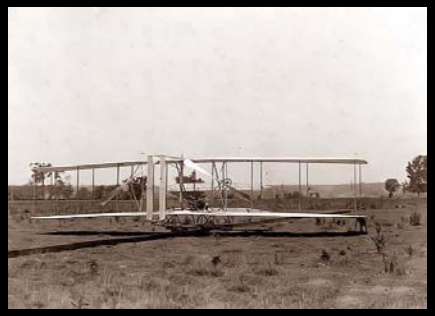
- ……..

What was the most important engineering innovation of the 20th century?

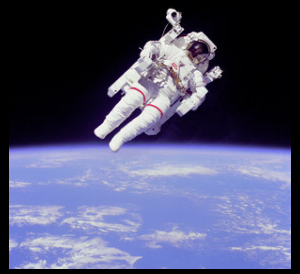


Airplanes

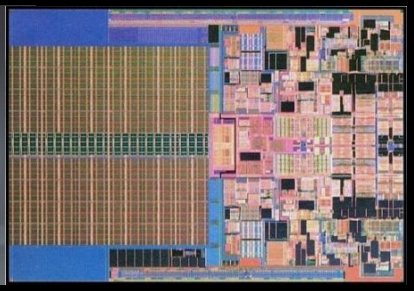
Polio Vaccination

Electrification

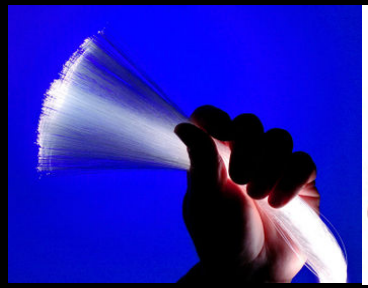
Nuclear Energy



Space



Transistor & Integrated Circuits

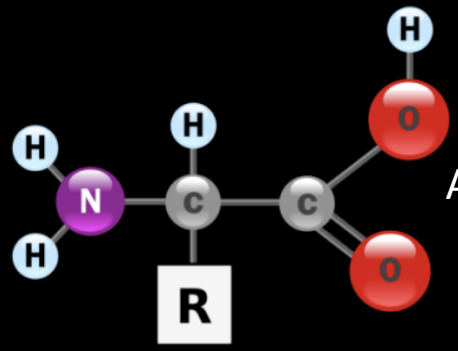


Fiber Optic & Wireless Communication

Internet

Elements of Life

Sir William Crookes
President, British Association for the Advancement of Science



Amino Acid

1898: "Calling upon science to save the world from impending starvation"

C — Atmospheric CO_2 via photosynthesis

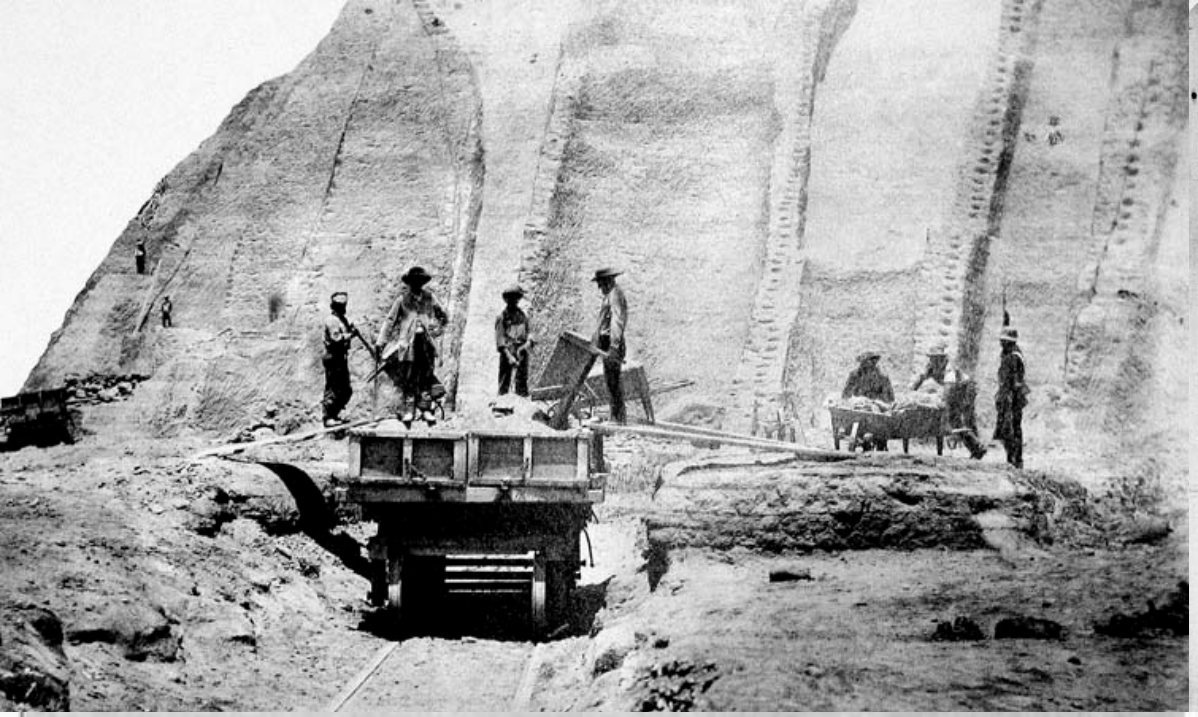
H — Water

O — Atmosphere

N — ?

:N≡N:


COLOMBIA
ECUADOR
BRAZIL
PERU
BOLIVIA
Guano
Islands
PACIFIC OCEAN
CHILE
ARGENTINA
0 km
300
600
900 km



SOLUBLE PACIFIC GUANO

FOR

CORN

POTATOES

TOBACCO

GRASS

ROOT AND GRAIN CROPS
Of all kinds

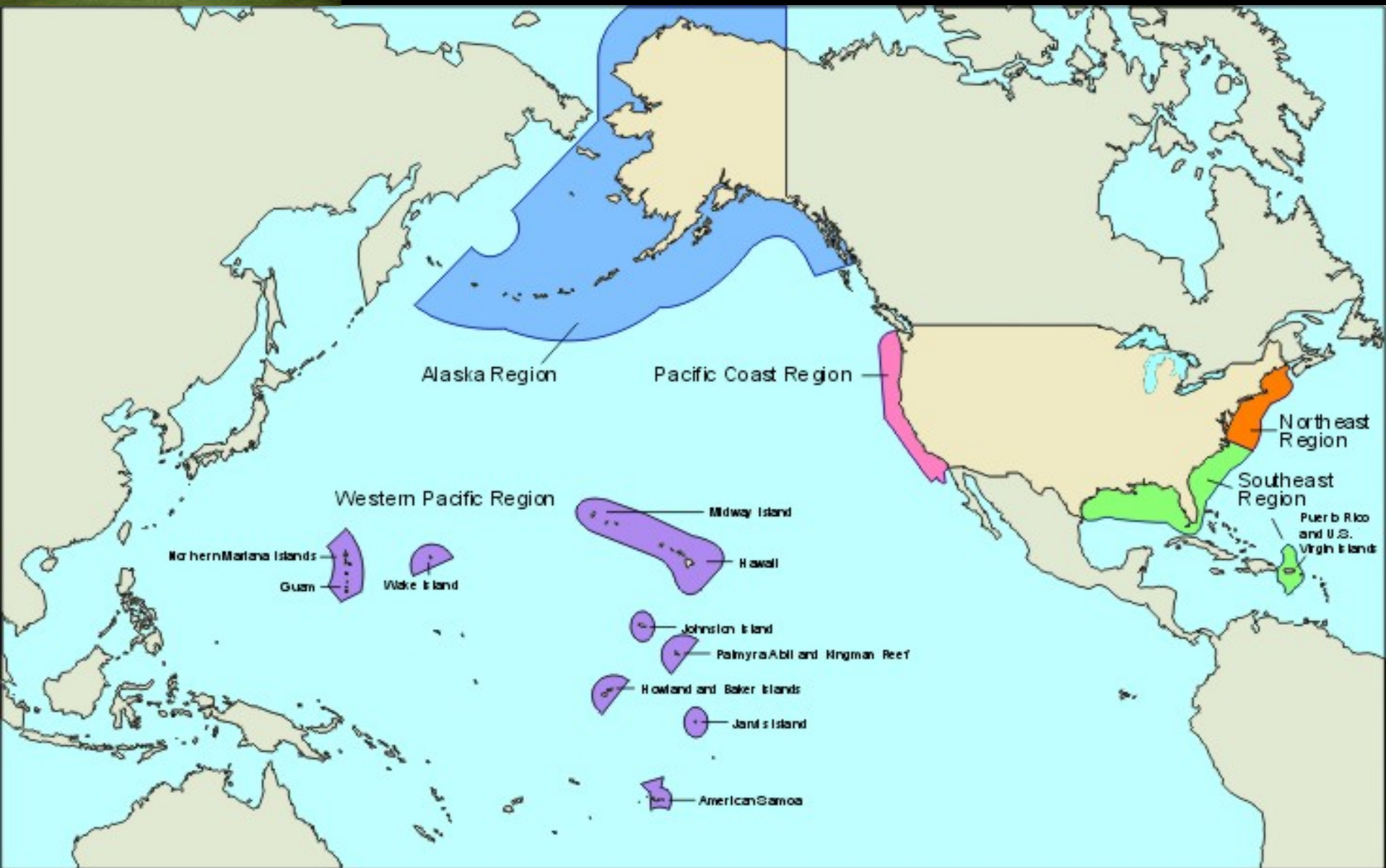
GARDEN VEGETABLES
&c., &c.

ITS USE SECURES TO THE FARMER A
LARGE AND REMUNERATIVE CROP,
And has been found to pay better than any other investment.

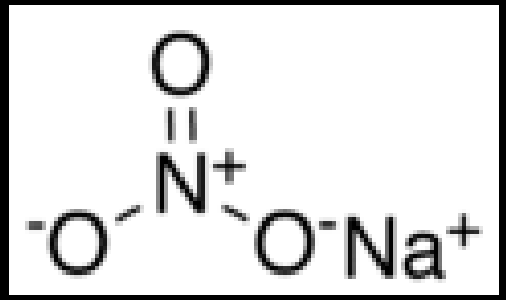
FOR PARTICULARS CALL ON

War of the Pacific (1879-1883)

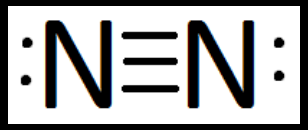
Guano Island Act of 1856



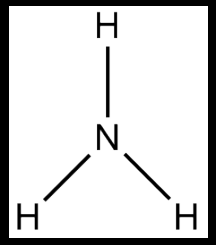
Chilean Saltpeter



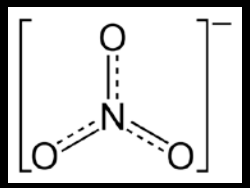
Sir William Crookes
President, British Association for the Advancement of Science



Atmospheric Nitrogen



Ammonia



Nitrate

Fritz Haber

(Chemistry Nobel, 1918)

$N_2 + 3H_2 = 2NH_3$

Discovery
1908

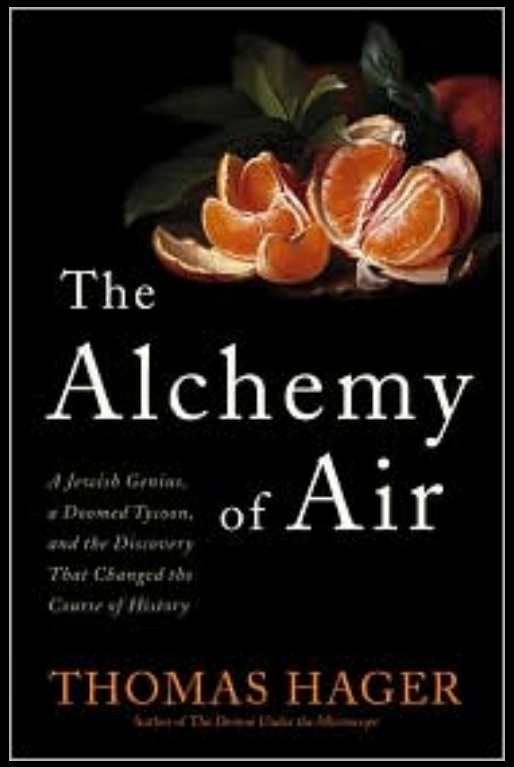
Catalysts: Uranium, Osmium
Pressure: 10 atmospheres

Haber-Bosch Process

Carl Bosch

(Chemistry Nobel, 1931)

Affordable Mass Production @BASF
1913



1.6 billion
(1913)

7 billion
(2013)

Human impact of 100 years of the Haber-Bosch process

Nitrogen fixed by the Haber-Bosch process is within each of us in this room

Is Impact Measured By

- Papers & Citations: h-index
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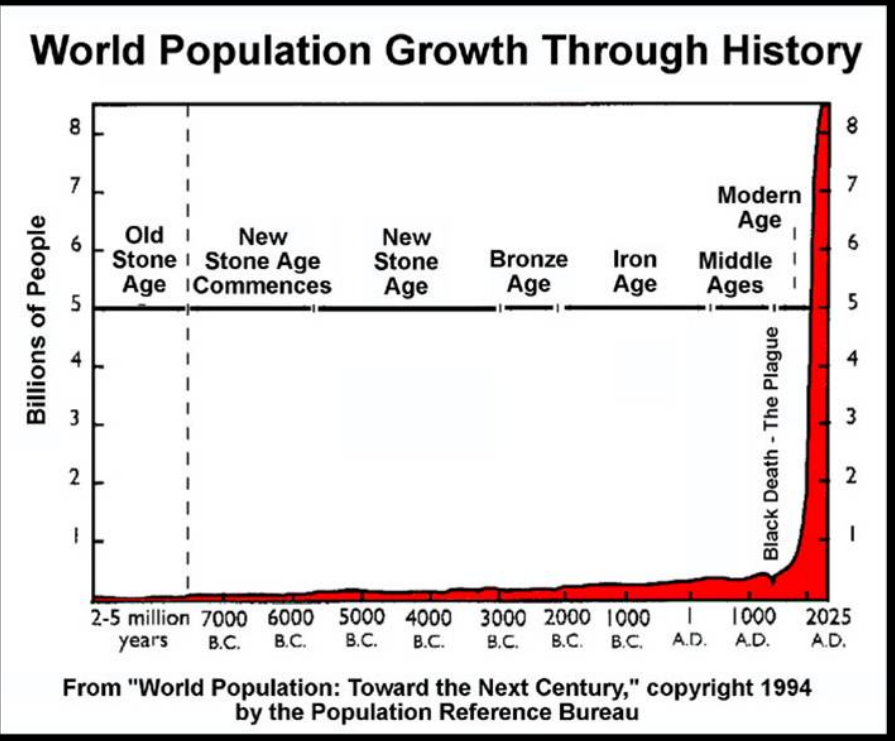
- ……..

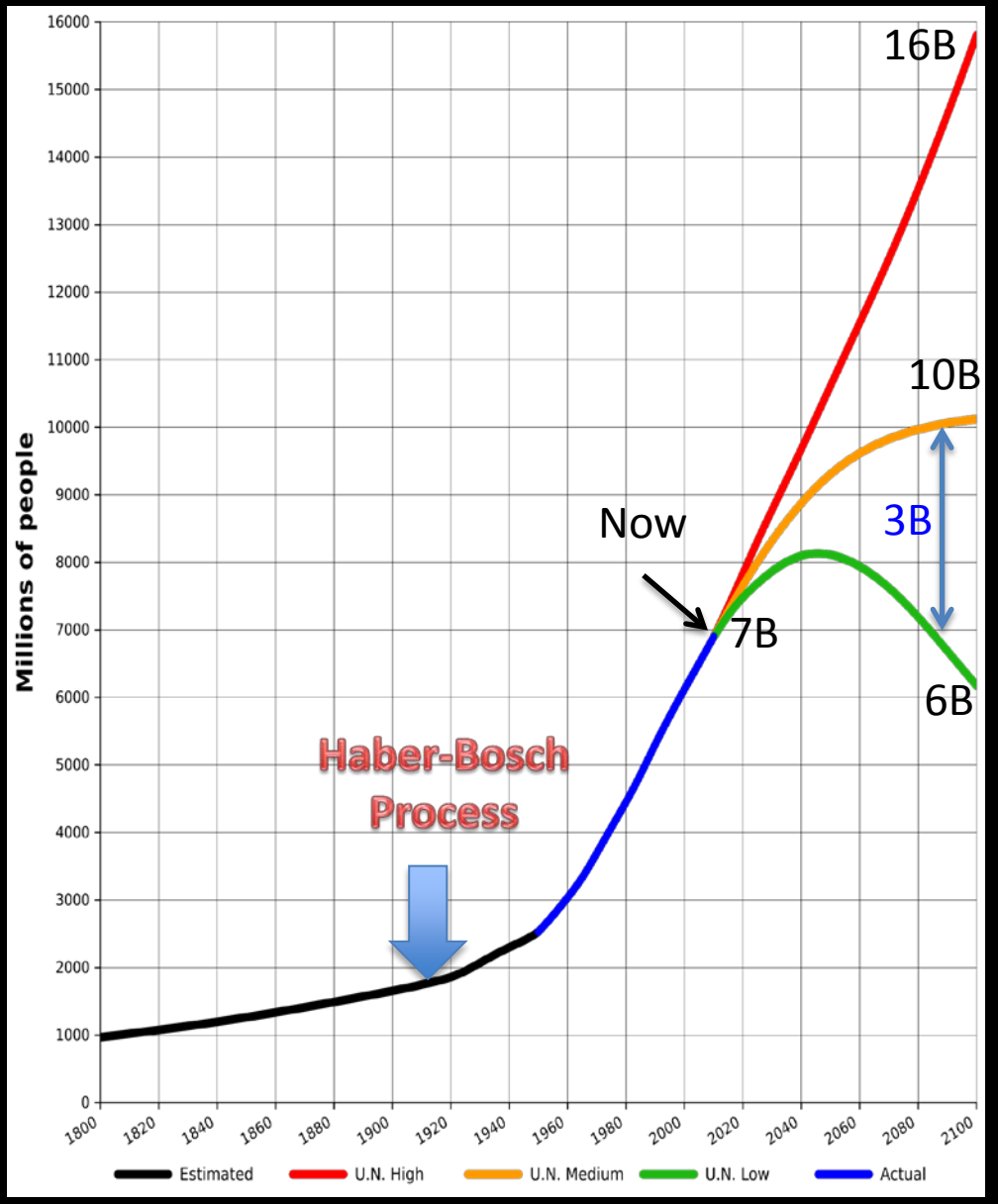
It is all about people, now and in the future

How can we positively impact maximum number of people now and in the future?

World Population



- Increase in the next 50 years will be more than twice the population of China
- Less developed countries will account for 99% of increment in world population



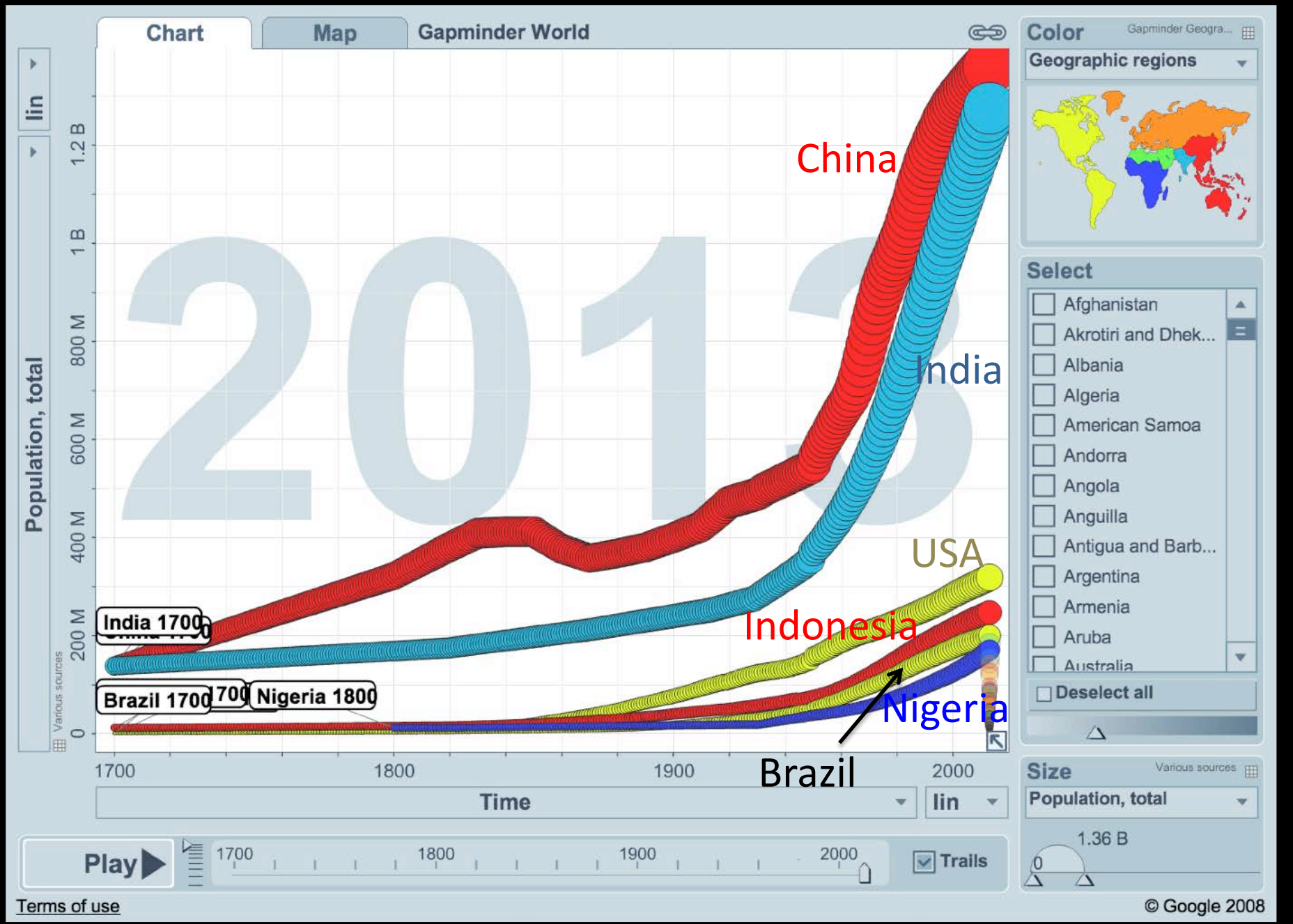
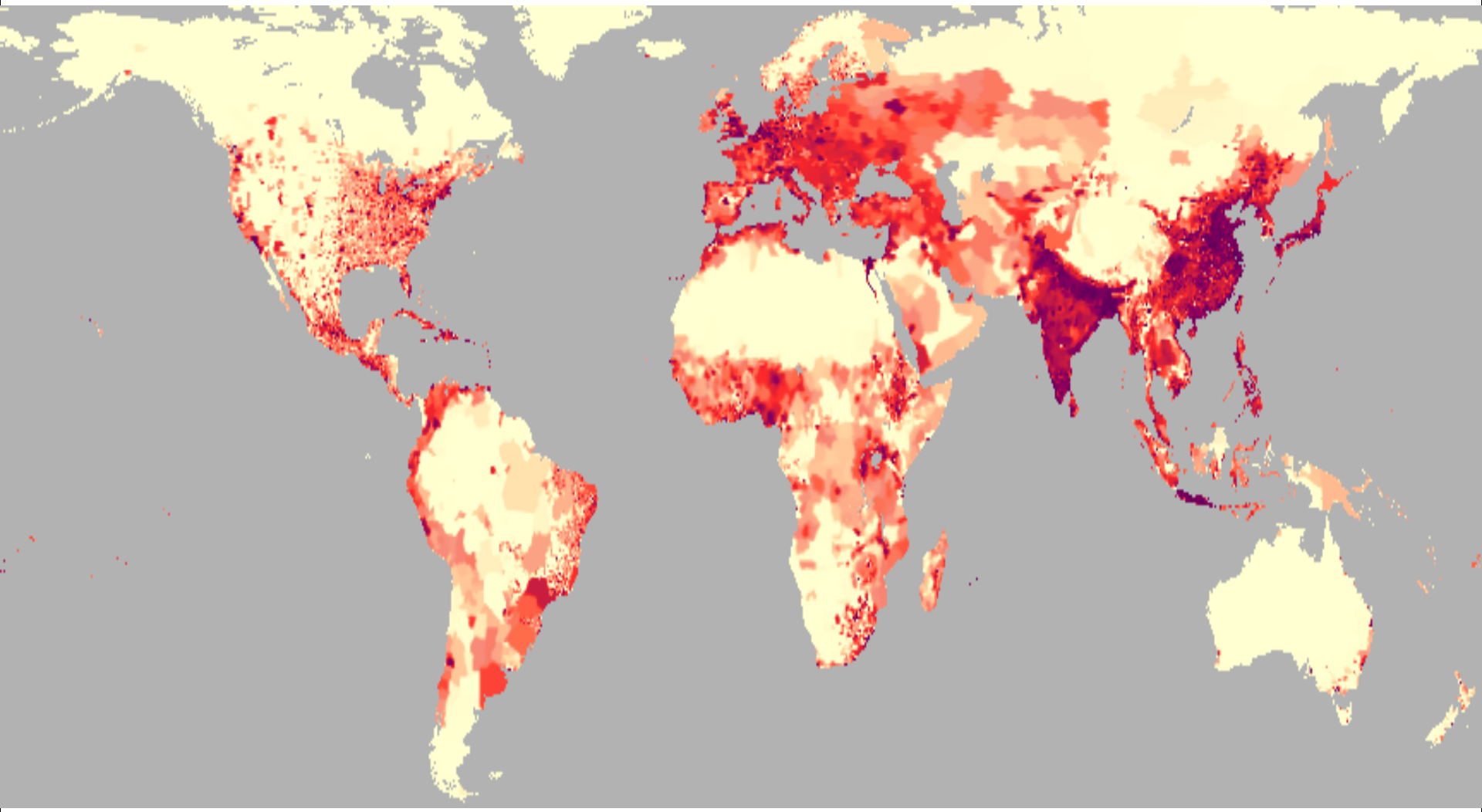


Chart
Map
Gapminder World
Color
Gapminder Geogra...
Geographic regions
Select
Afghanistan
Akrotiri and Dhek...
Albania
Algeria
American Samoa
Andorra
Angola
Anguilla
Antigua and Barb...
Argentina
Armenia
Aruba
Australia
Deselect all
lin
Population, total
Various sources
0
200 M
400 M
600 M
800 M
1 B
1.2 B
2013
China
India
USA
Indonesia
Nigeria
Brazil
India 1700
Brazil 1700
Nigeria 1800
1700
1800
1900
2000
Time
lin
Size
Various sources
Population, total
1.36 B
0
Play
Trails
Terms of use
© Google 2008



3 billion people have either no or very limited access to electricity

By 2100, additional 3 billion people will be added to the same regions

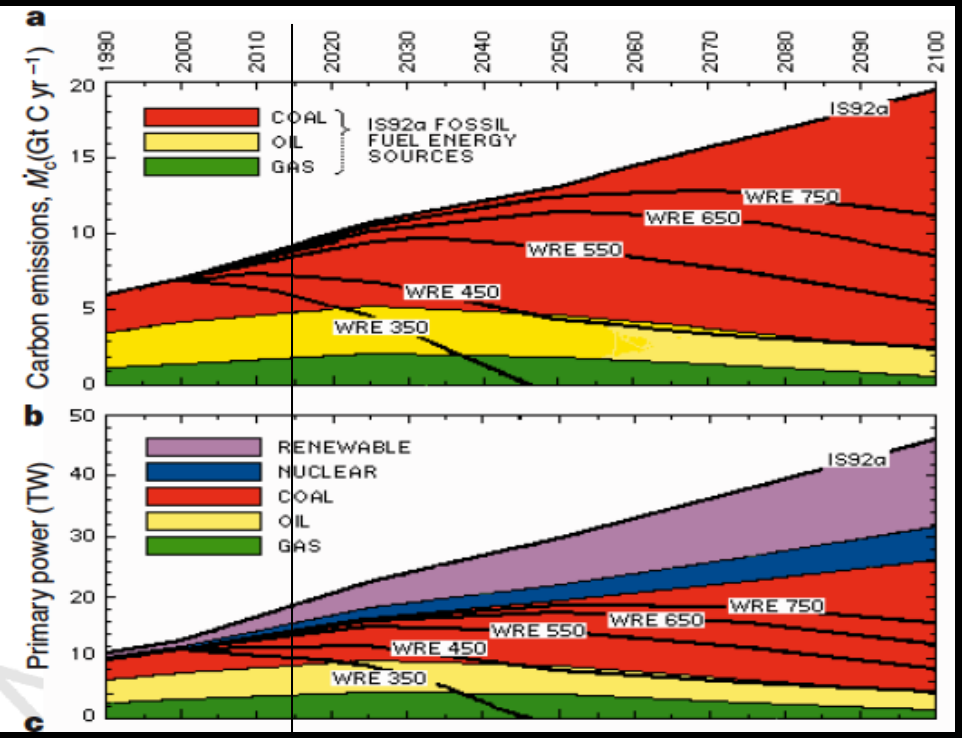
Massive level of urbanization will occur in developing countries

Human Development Index(HDI) versus Annual Per Capita Electricity Use

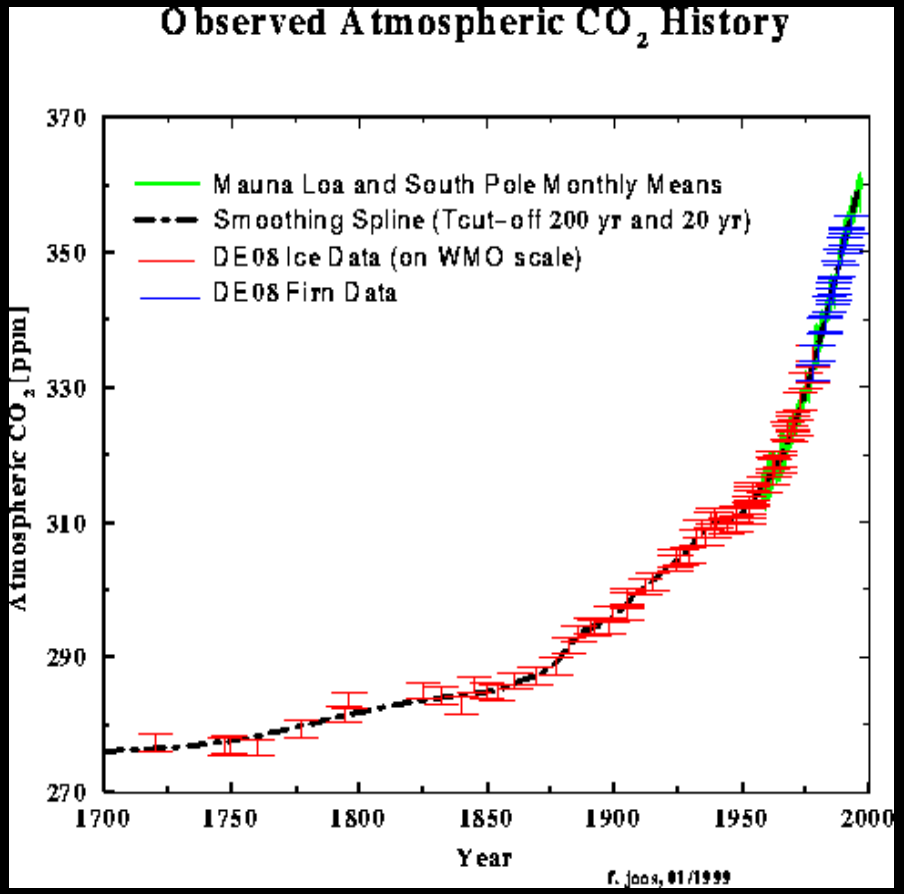
HDI = f(Life Expectancy, Education, Income)

What is our Haber-Bosch like challenge?

Rate of CO_2 Emissions



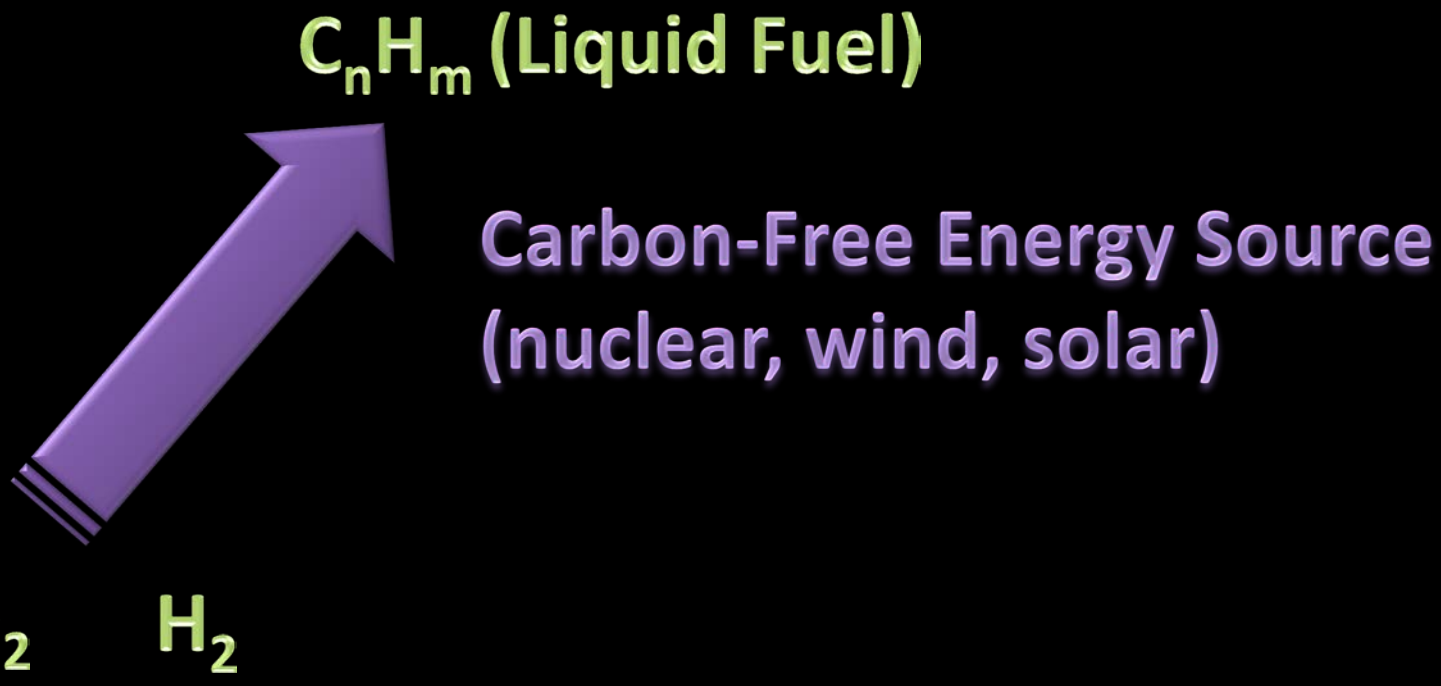
Hoffert et al., Nature (1998)



$$If\ \dot{C}_{em} \propto t$$

$$C_{atm} \propto t^2$$

What is our Haber-Bosch like challenge?



Produce hydrocarbon fuel from CO_2 at scale and at a cost lower than $50 barrel of oil equivalent (<$2/gallon gasoline)

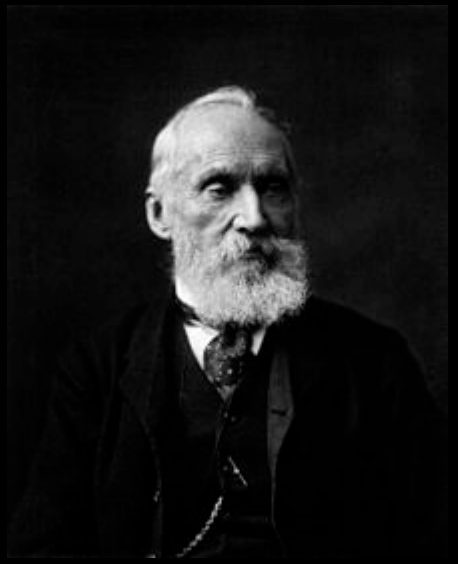
(In)Famous Predictions from the Past

“Radio has no future”

“X-rays will prove to be a hoax.”

“Heavier-than-air flying machines are impossible”

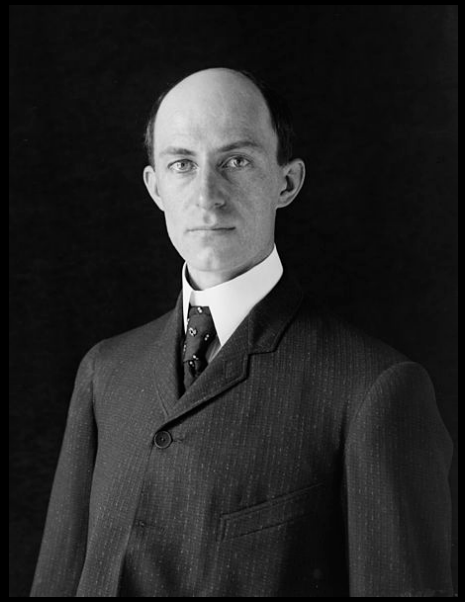
Lord Kelvin in 1890s



(In)Famous Predictions from the Past

"**Man will not fly for 50 years.**"

Wilbur Wright in 1901



Any sufficiently advanced technology is indistinguishable from magic.

Arthur C. Clarke

Thank you!