What is happening to the world?

Key challenges as we approach the third decade of the 21st Century

Professor Sir John Beddington
Oxford Martin School, Oxford University

Contributed presentation at the 61st AARES Annual Conference,
Brisbane, Australia, 7-10 February 2017

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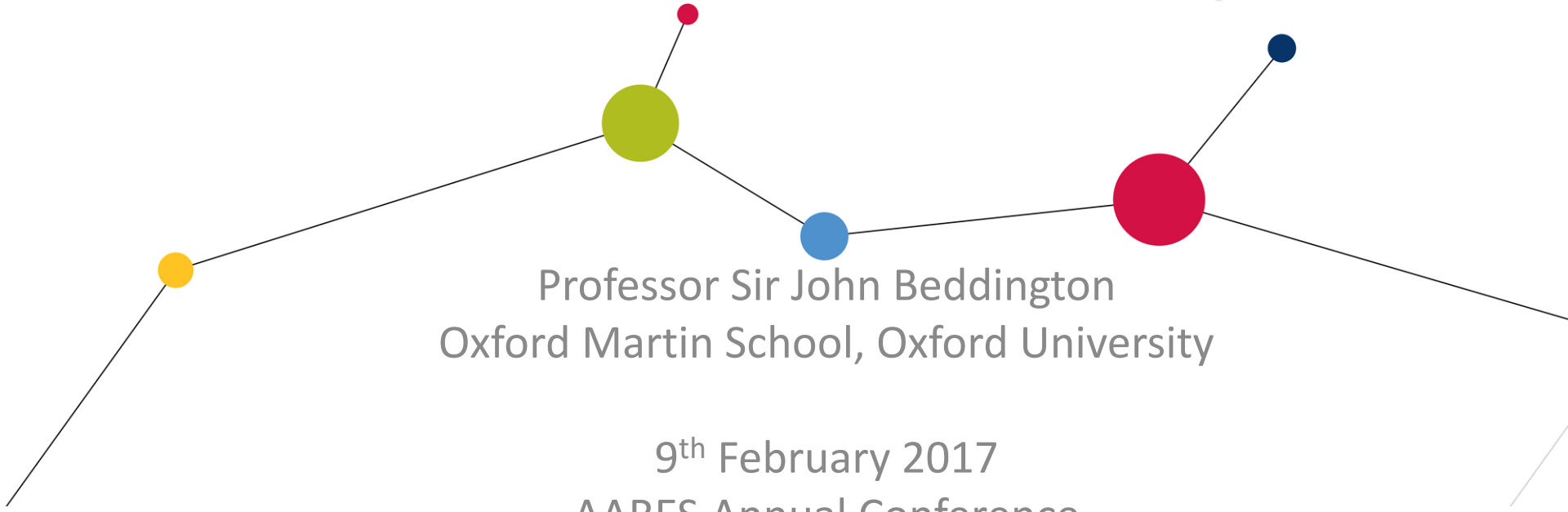

Professor Sir John Beddington
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9th February 2017
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The Legacies of the 20th Century

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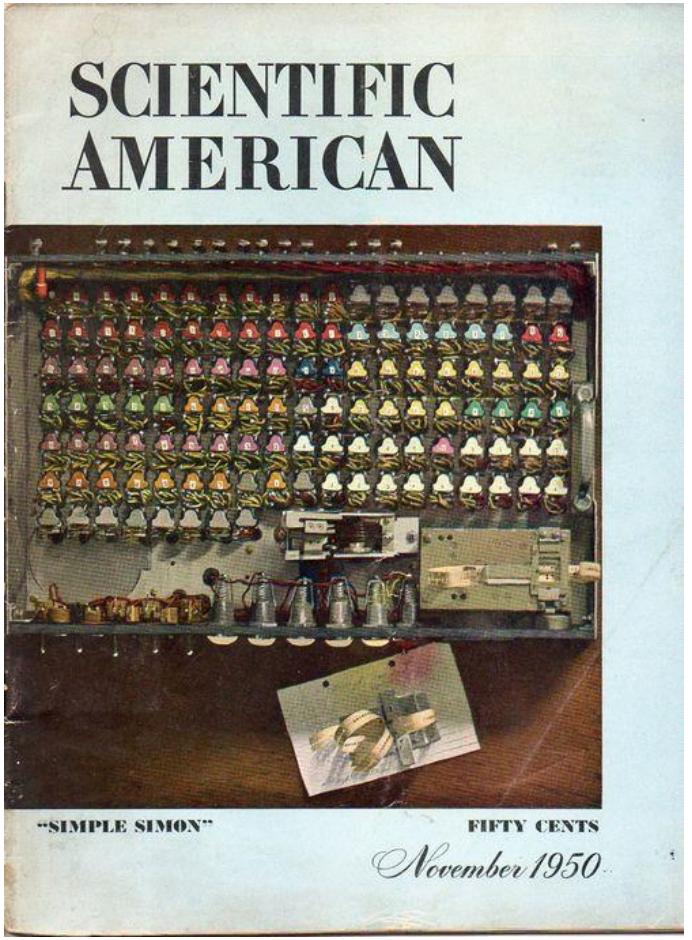
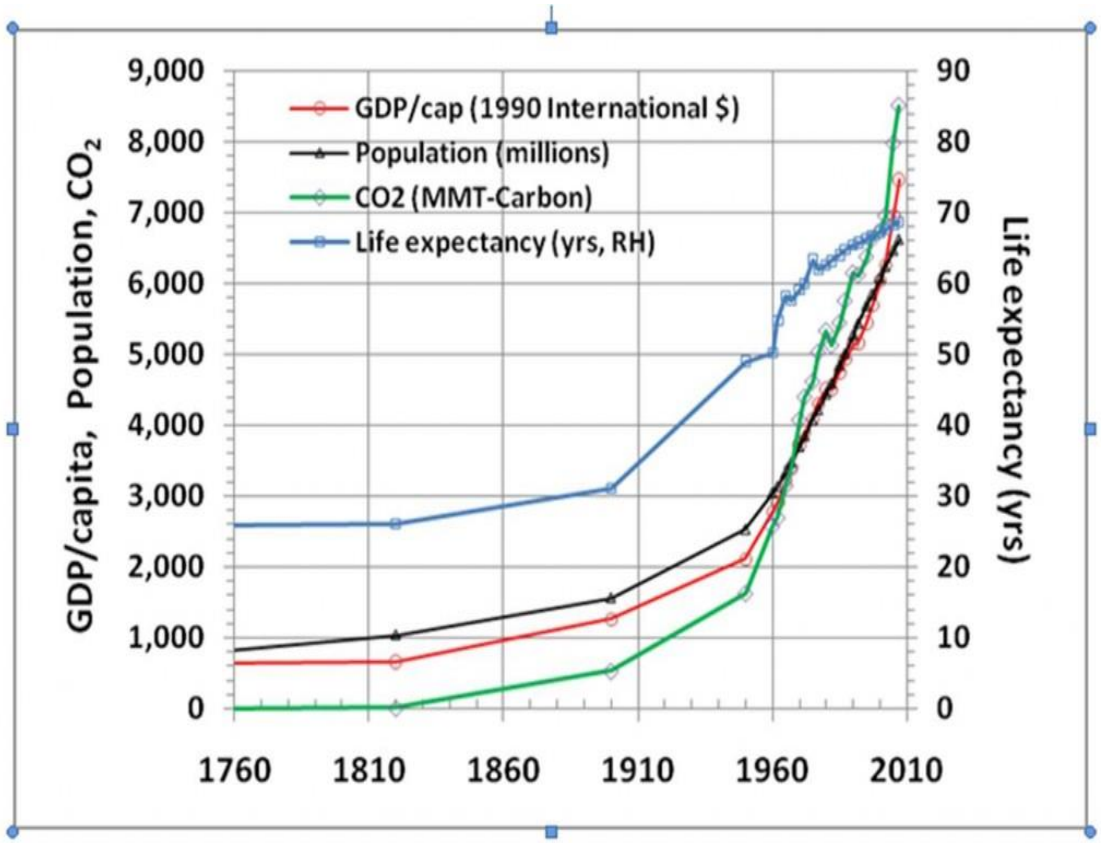
The state of the world in 1950

- No knowledge of DNA
- No widespread use of antibiotics
- Few co-ordinated vaccination programs
- Serious threats from smallpox, polio, whooping cough, diphtheria, and syphilis
- Little international co-ordination for scientific research
- Only the most primitive of computers
- Cost of oil (inflation-adjusted): $26/barrel
- No space travel, no satellites
- No contraceptive pill



The last half of the 20th Century: five decades of exponential growth and achievement



Innovation & scientific progress

Disease & poverty alleviation

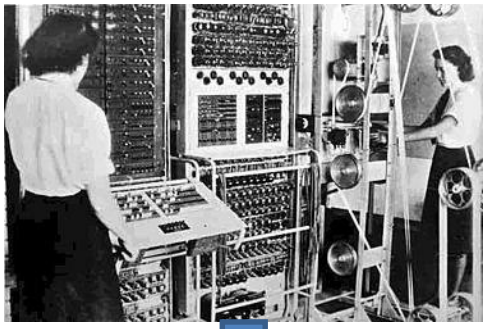
Massive population growth

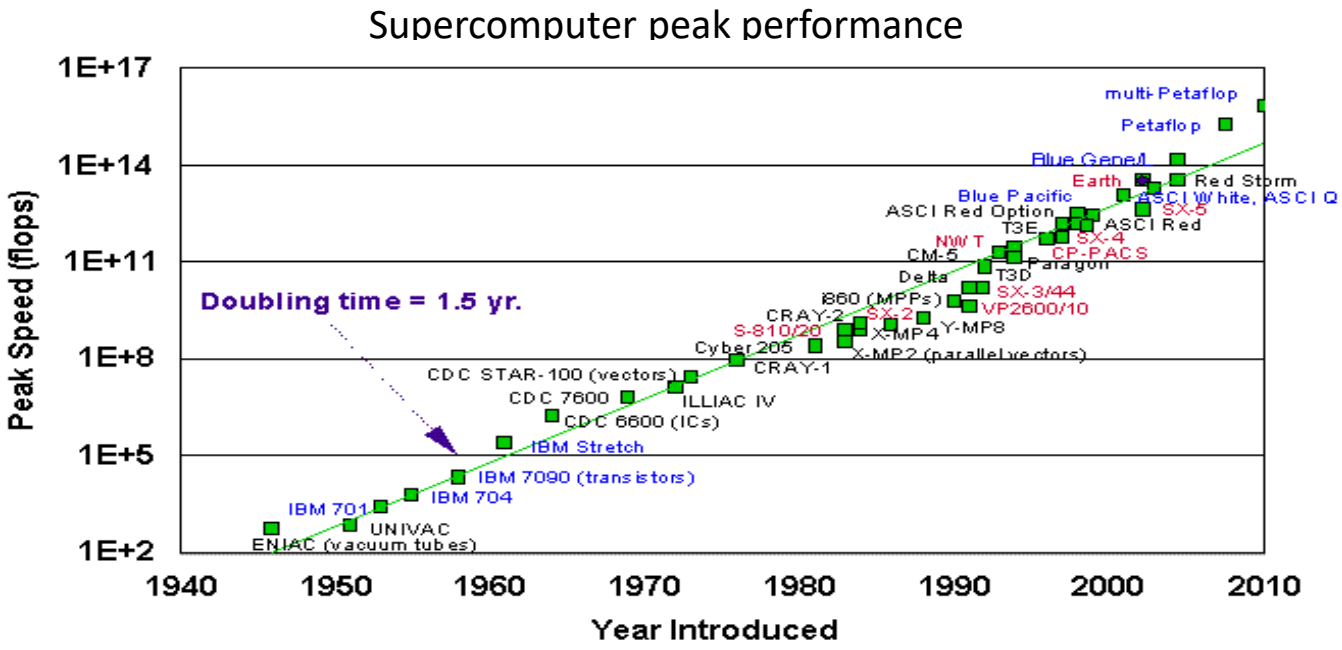
Large-scale natural resource exploitation

Substantial ecosystem service degradation

Acceleration of greenhouse gas emissions

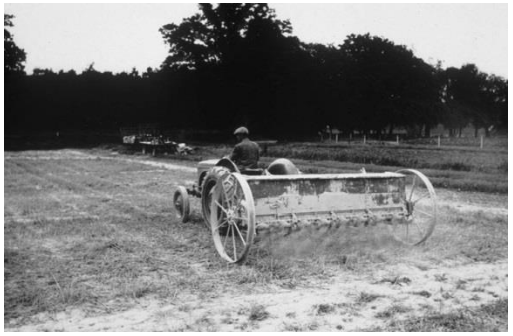
Technological Progress





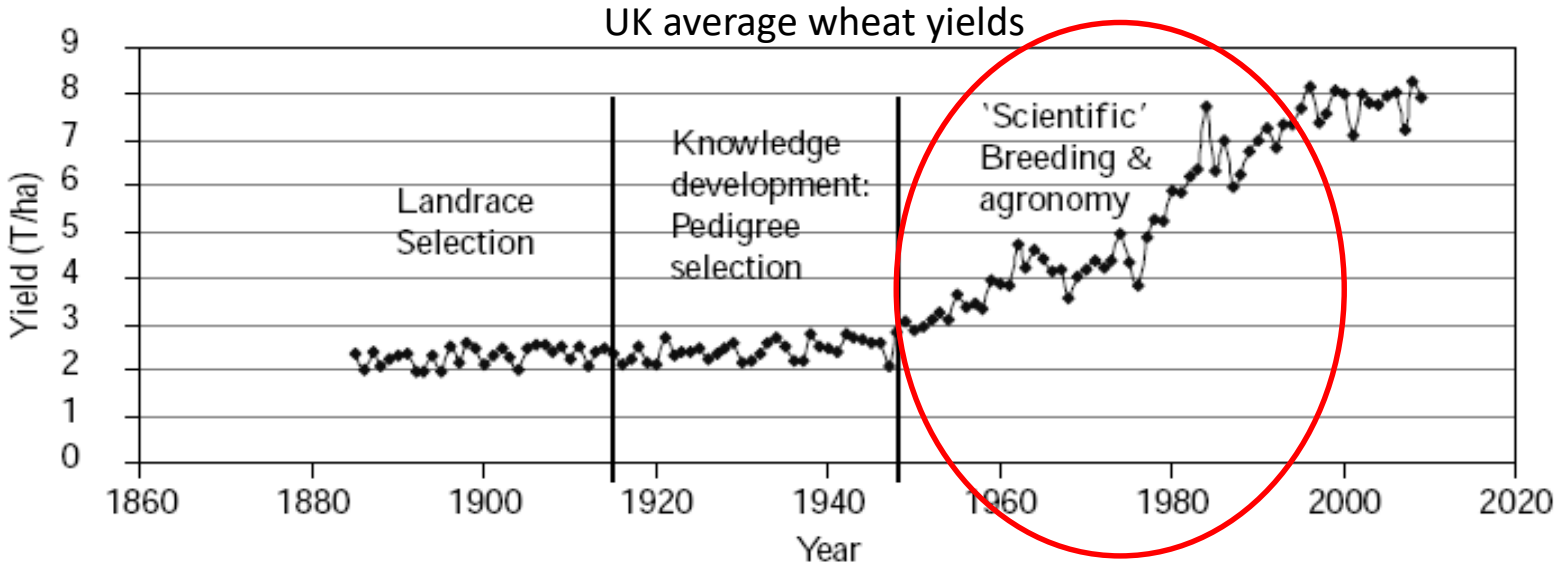
1944: ‘Colossus’, the first electronic digital programmable computer
1950s: vacuum tubes evolve into integrated circuits
1970s: Intel introduces microprocessors
1980s: first mass-produced microprocessor-based portable computers
1990s: the era of mobile computing begins

Agronomy Progress



(l) 1954 and (r) 2003: Rothamsted's Classical Experiments on wheat, grassland, barley & fallow land have been running since 1854

The Green Revolution: modern irrigation techniques, pesticides, synthetic nitrogen fertilisers



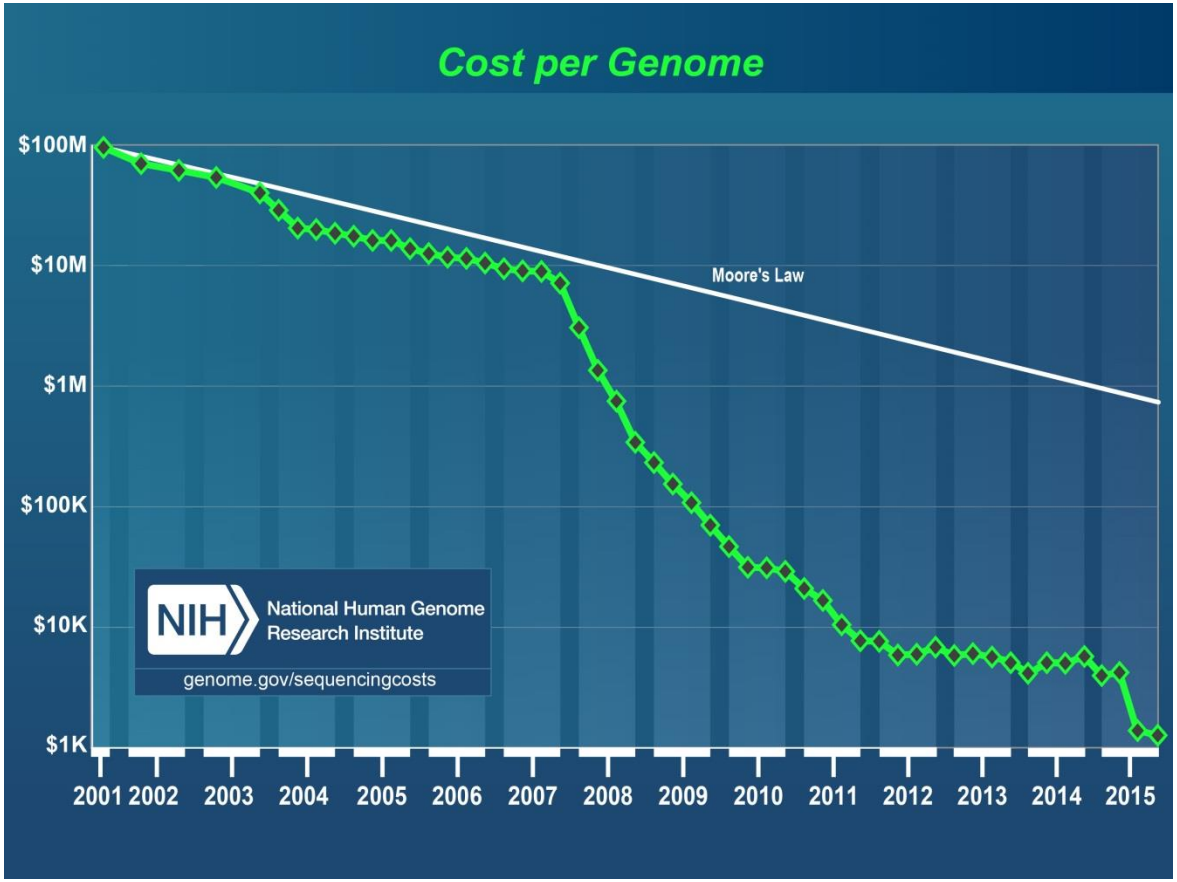
Global food production is 3x what it was in 1950

The world produces 30% more calories per person than in 1960

Biological progress

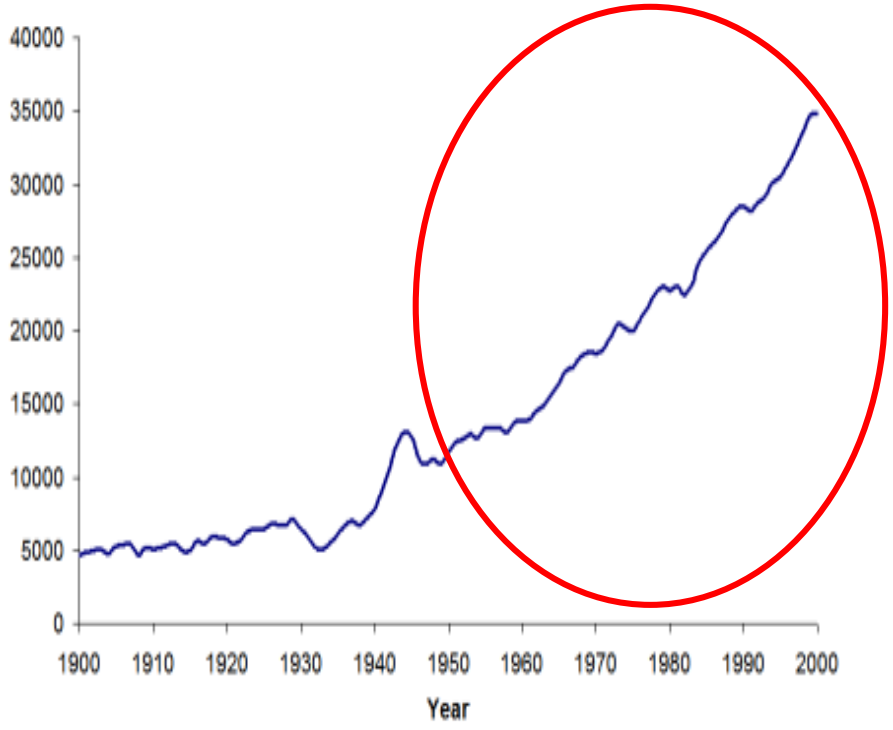
1953: DNA double helix structure mapped by Watson & Crick
1972: first recombinant DNA created
1980: first genome sequenced
1995-2014: >180 genomes sequenced

DNA Sequencing technology: faster and cheaper

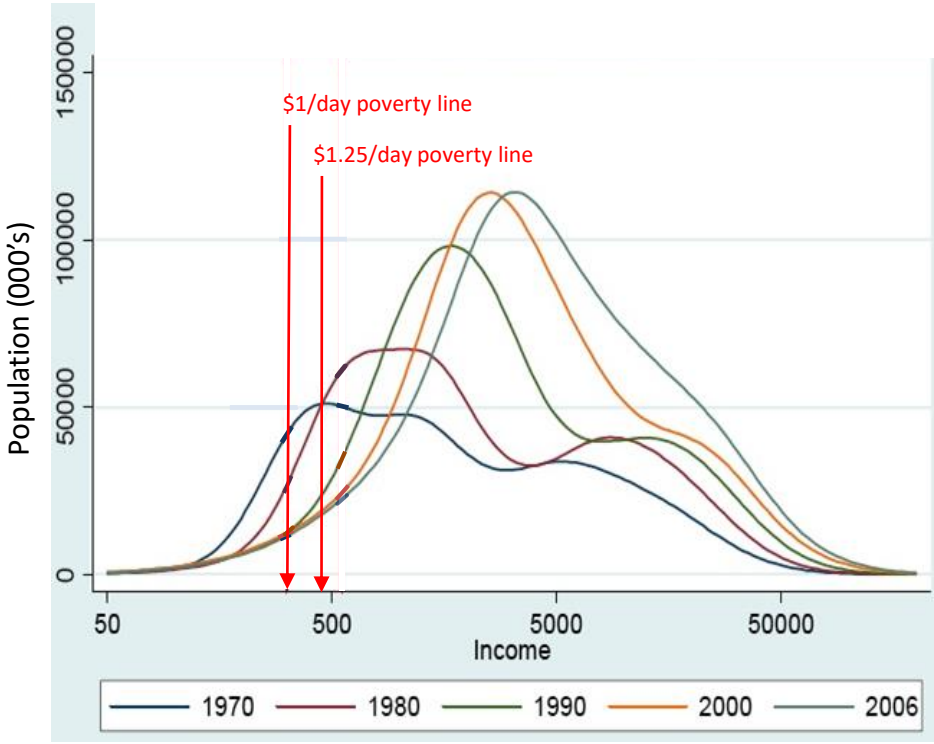


Human wellbeing indicators: wealth

Real GDP per Capita (2000 dollars)



World Distribution of Annual Income (USD)



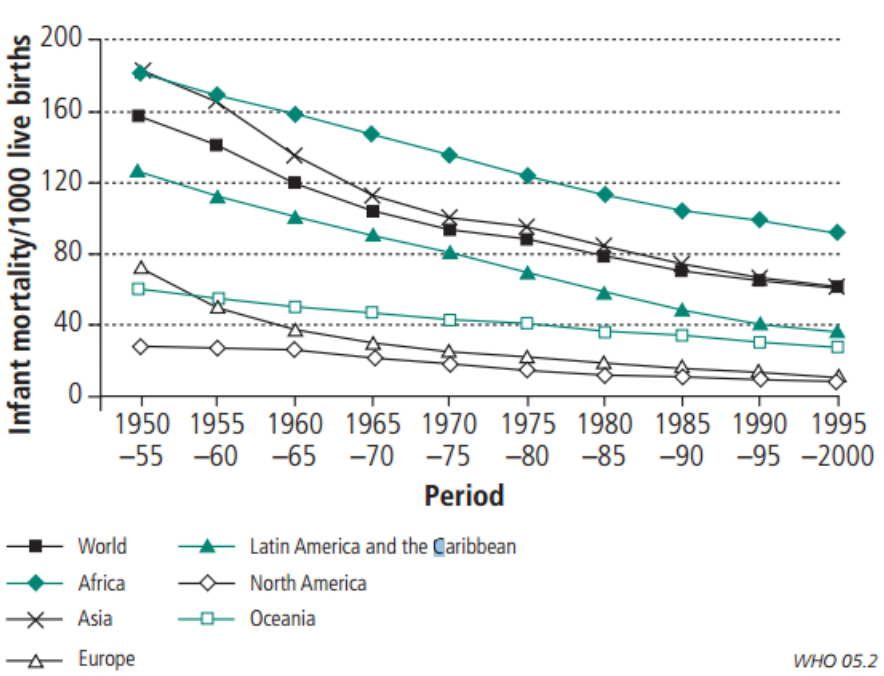
Source: Pinkovskiy and Sala-i-Martin, 2009

Human wellbeing indicators: health

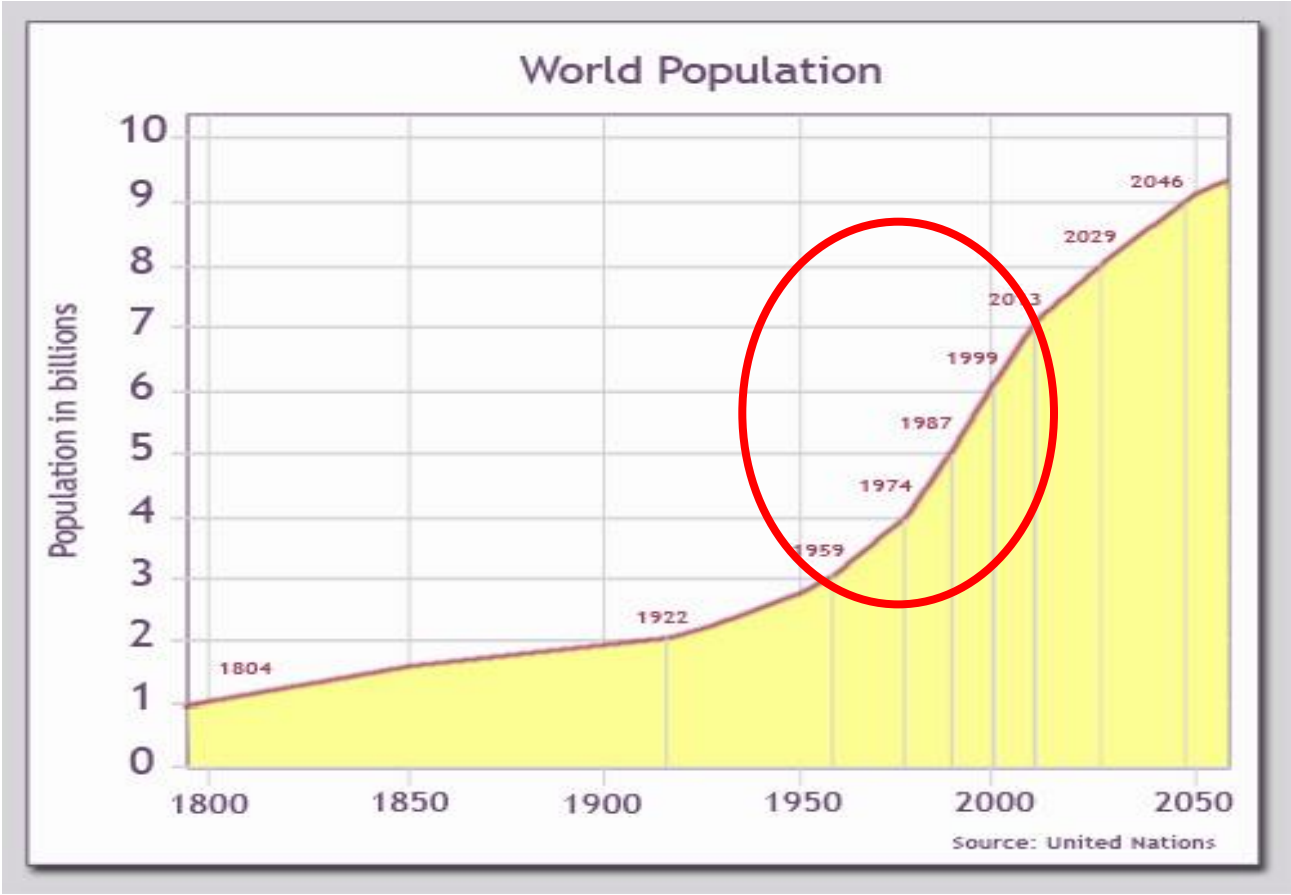
Evolution of life expectancy at birth in the world by level of development Unity: years							
	1950 - 1955	1960 - 1965	1970 - 1975	1980 - 1985	1990 - 1995	2000 - 2005	2005 - 2010
Developed countries	66	69,8	71,3	72,9	74,1	75,8	77,1
Developing countries	41,7	48,6	56,6	61	63,9	66,6	67,7
The poorest countries	36,4	40,6	44,4	48	50,4	54	55,9
World	**46,6**	**52,4**	**58,2**	**61,7**	**64**	**66,4**	**67,6**
Source : United Nations Population Division							

Global life expectancy has increased by 50% since 1950 to 70 years

Infant mortality rates have significantly improved in all regions of the world

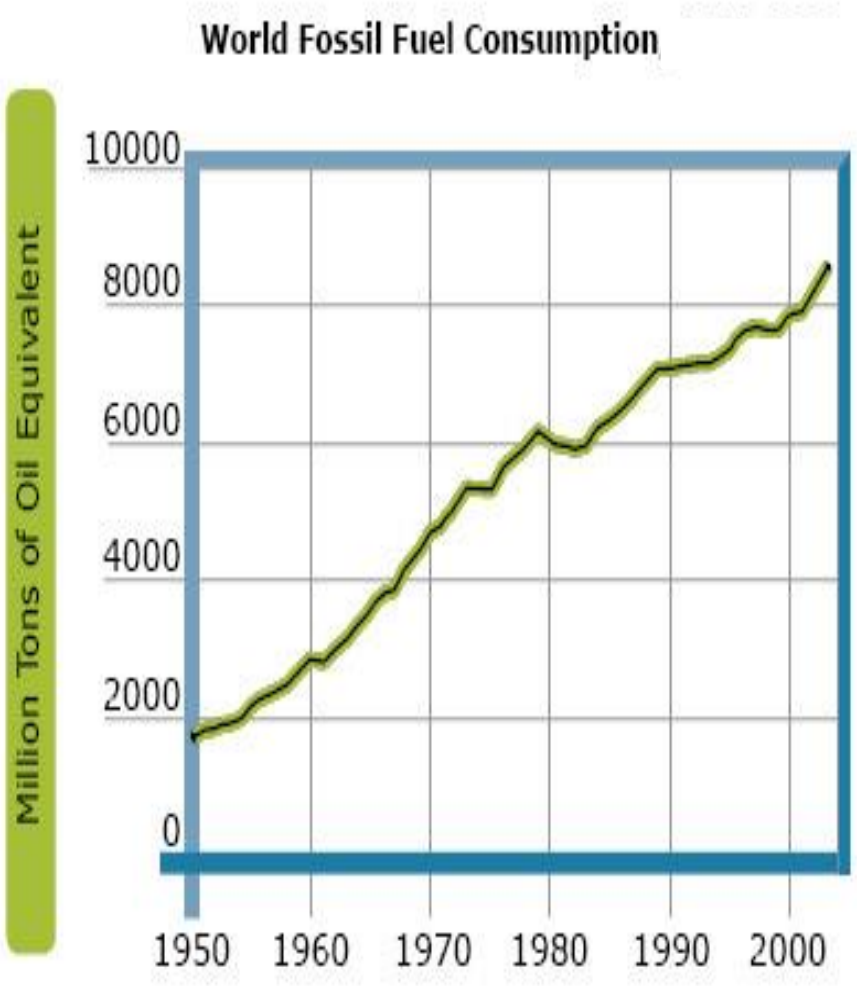


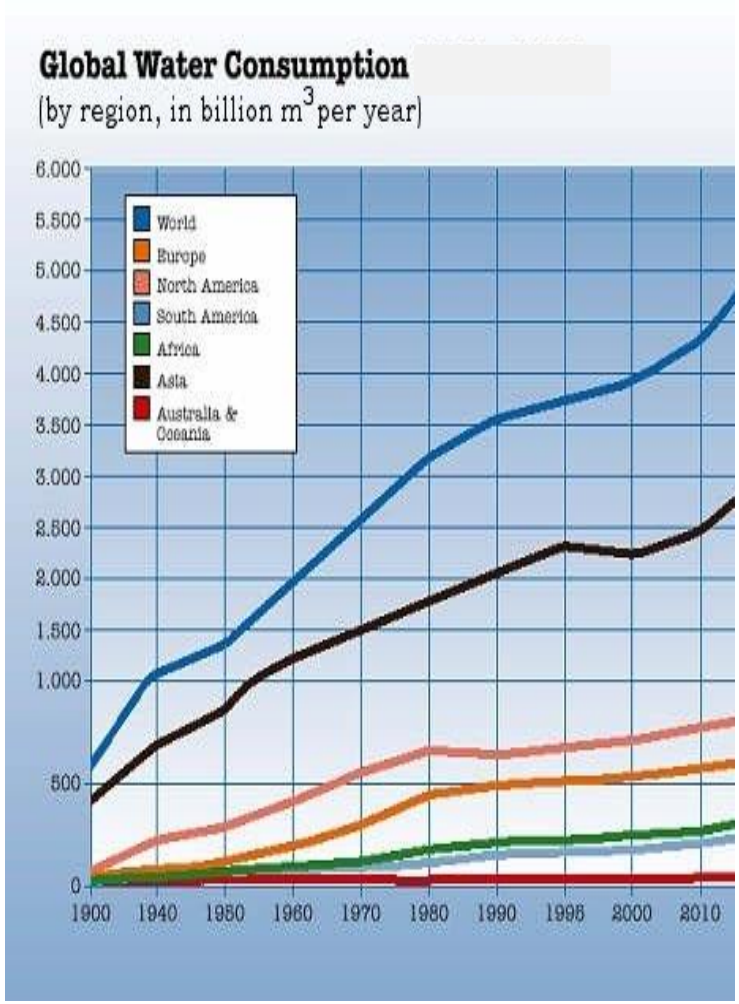
Consequences: population



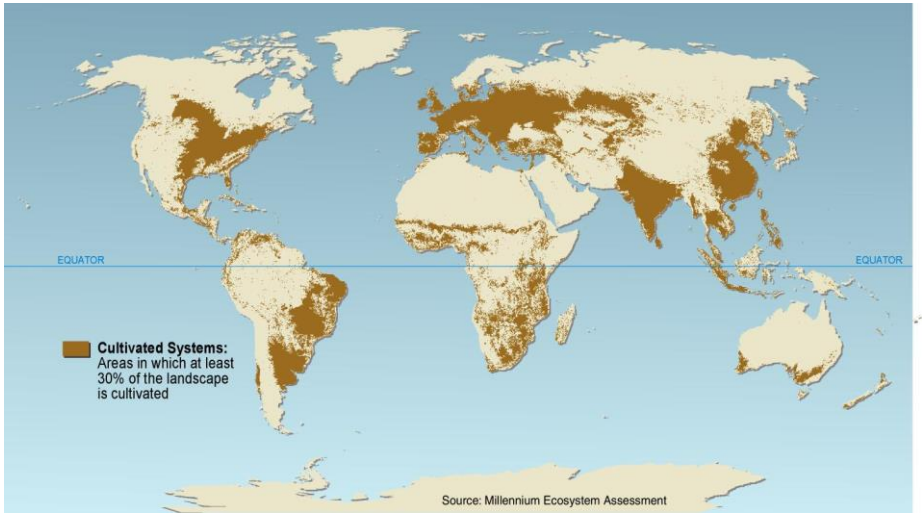
The global population more than doubled in size from 3bn in 1959 to 7bn in 2011

Consequences: resource consumption





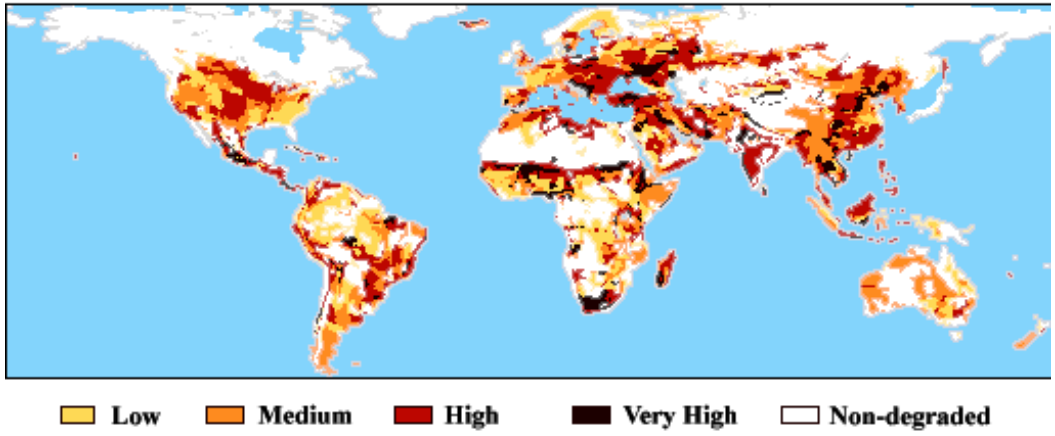
Consequences: land use change



- More land was converted to cropland in the 30 years after 1950 than in the 150 years between 1700 and 1850
- In 2000 cultivated systems cover 25% of Earth's terrestrial surface

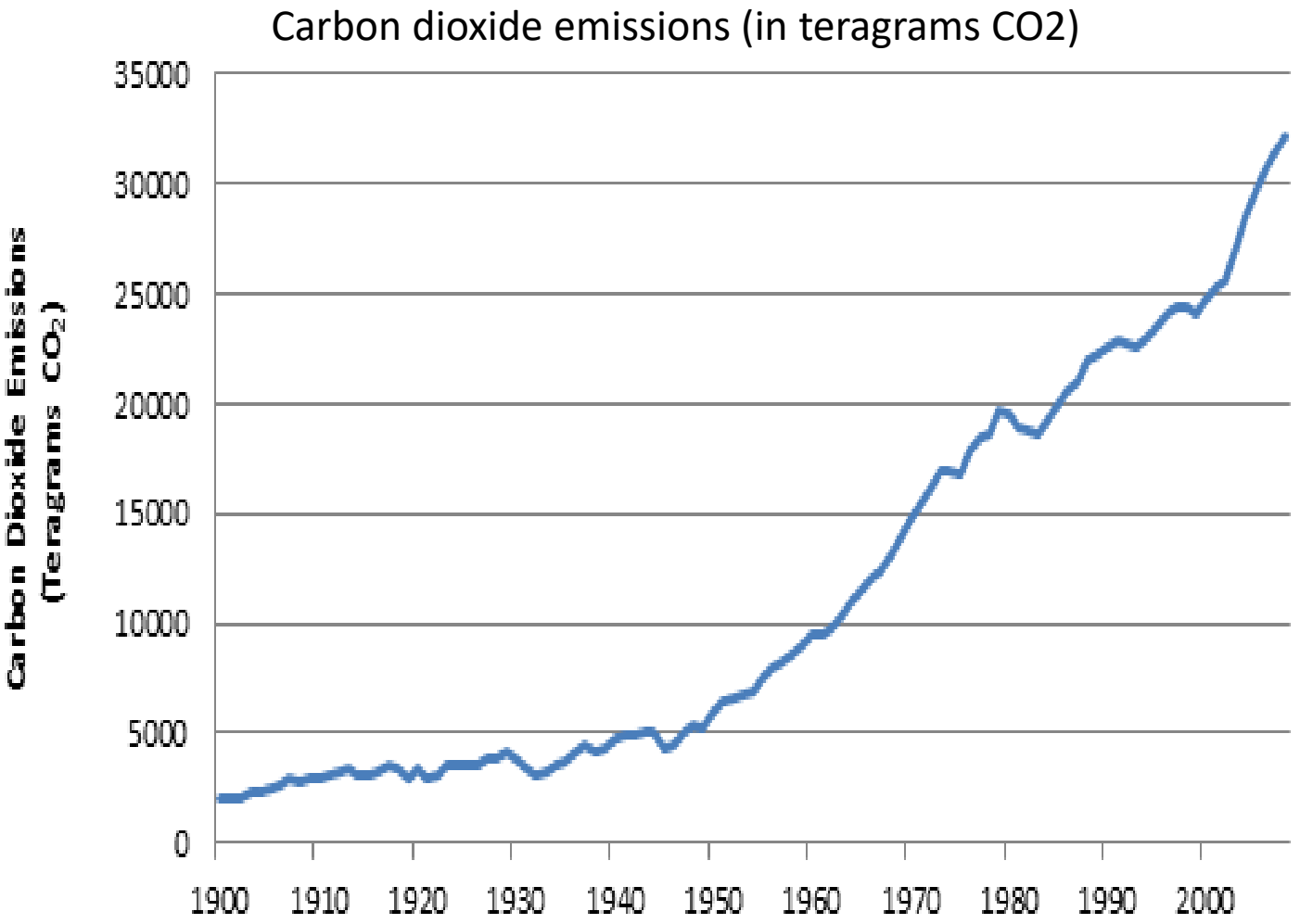
- An estimated 23% of all usable land is degraded
- 20% of the world's pasture and rangelands have been damaged
- 580m ha of forests have been degraded by logging and clearance, nearly 40% of this since 1975
- 52% of the world's biodiversity has been lost since 1970

Soil Degradation Severity



Source: Millennium Ecosystem Assessment, UNEP

Consequences: emissions



60% of the increase in the atmospheric concentration of CO_2 since 1750 has taken place since 1959

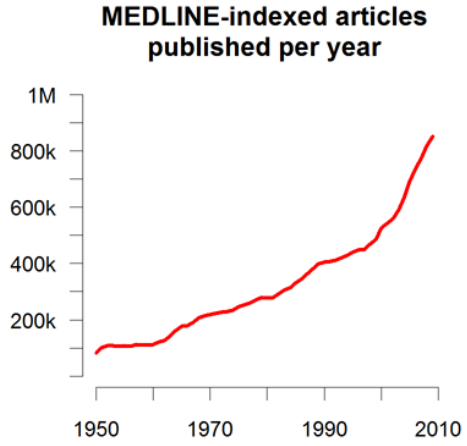
Where has the 20th Century left us?

Technological, agronomical and biotechnological progress have led to decreases in poverty and improvement in human health

Industrialisation, globalisation and urbanisation have led to significant greenhouse gas emissions

We are more informed than ever before

There are major natural and physical resource pressures



The recent global poverty transformation

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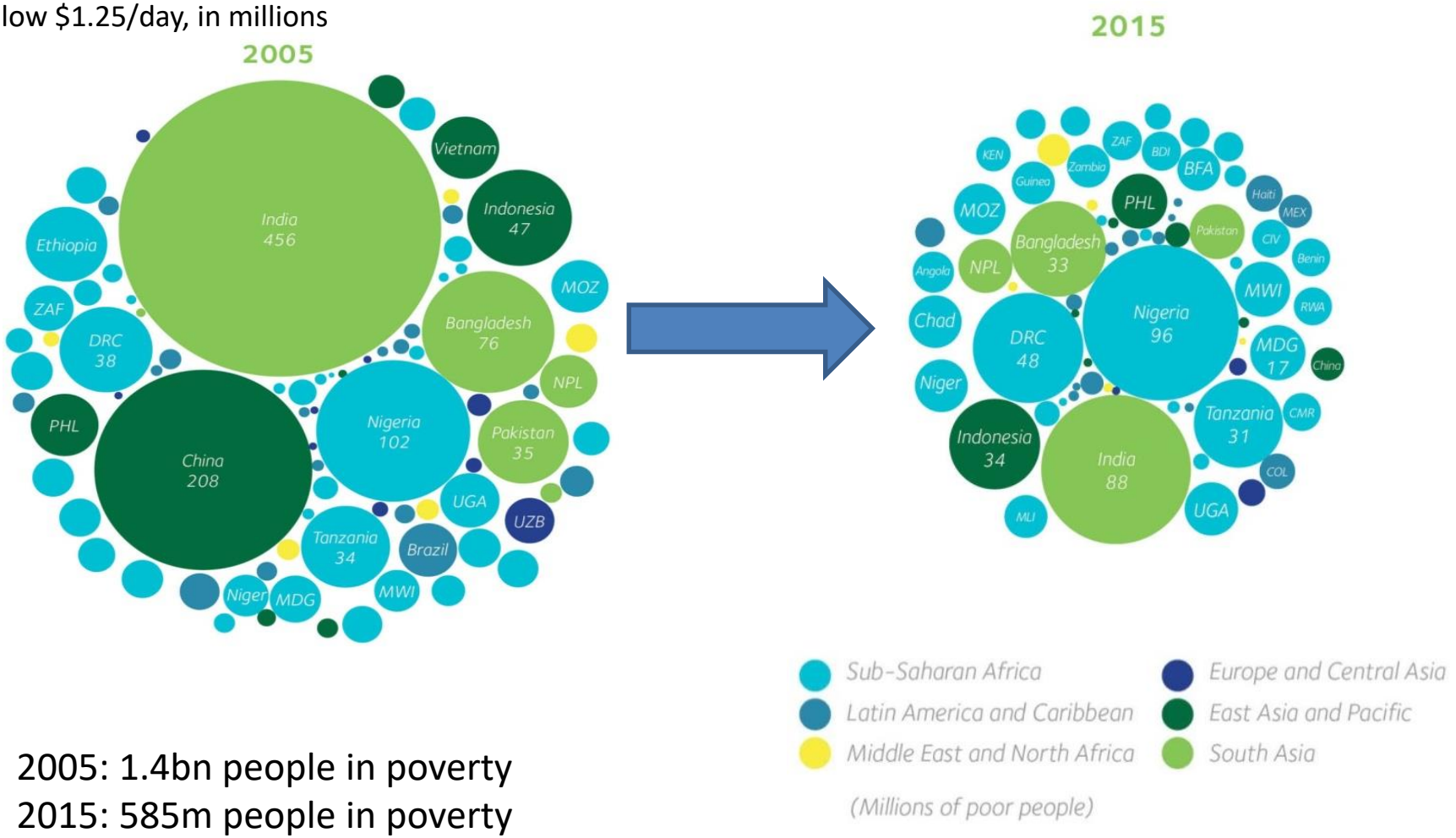
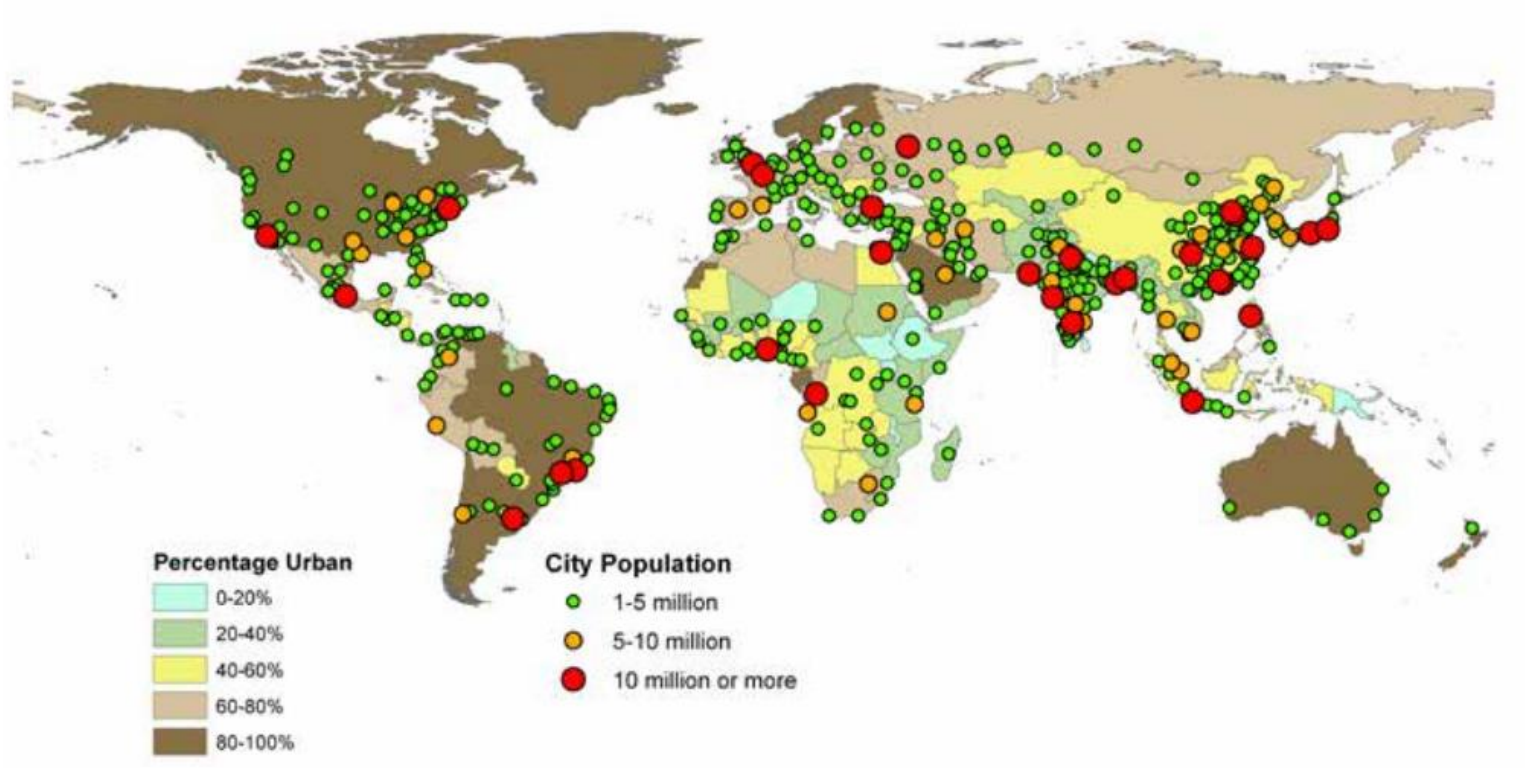
Securing the long term in national and global decision making

Numbers of individuals living below $1.25/day, in millions



2005: 1.4bn people in poverty
2015: 585m people in poverty

Urban agglomerations in 2015

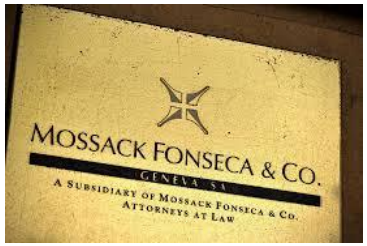


- 54% of the world's population live in urban areas, and 33% of urban-dwellers live in slums
- Nearly half of the world's urban dwellers live in relatively small cities of less than 500,000 inhabitants
- Around 1 in 8 live in 28 mega-cities with more than 10m inhabitants

Part of the Global 'In-Tray'

Climate change

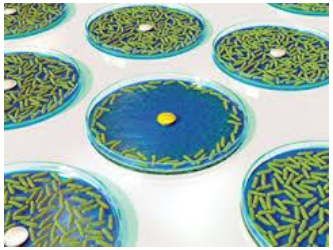
Novel biotechnologies



Inequality

Oil prices

Air pollution



Antibiotic resistance

Migrant crises

Political upheaval

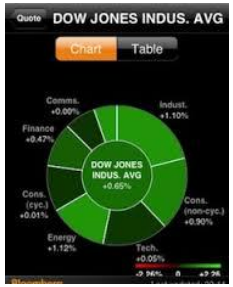
Emerging diseases

Nuclear proliferation

Terrorism

Food and water security

Cybersecurity



Financial Stability

Environmental disasters

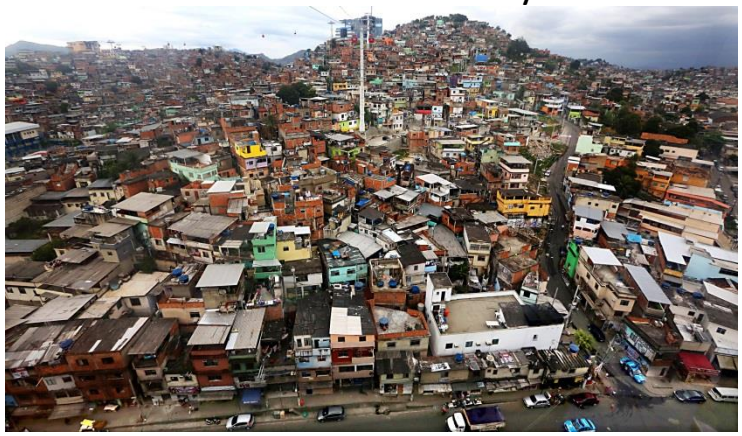
There is clearly huge uncertainty…

However, in key ways, the first part of the 21st Century is already determined

Demographic momentum:
An extra billion people by 2025

Continuing increase in overall prosperity:
Global middle class to increase to nearly 5bn people by 2030

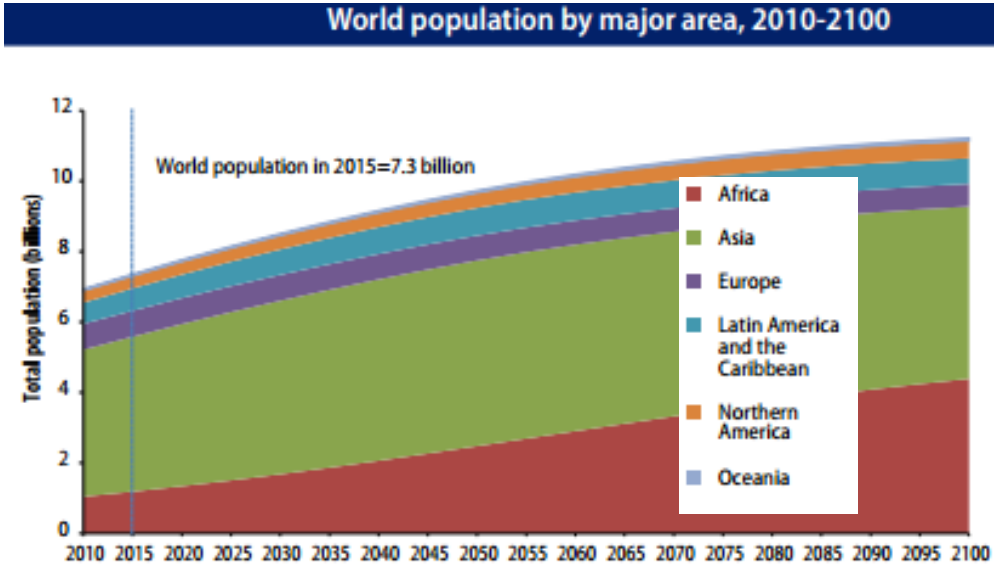
Urbanisation:
global urban:rural ratio ~58% by 2025



Alemao Shanty Town, Brazil

Climate change: (to come back to)
GHG in the atmosphere <u>now</u> will drive changes up to 2030

Global Population Predictions



Source: World Population Prospects 2015, UN

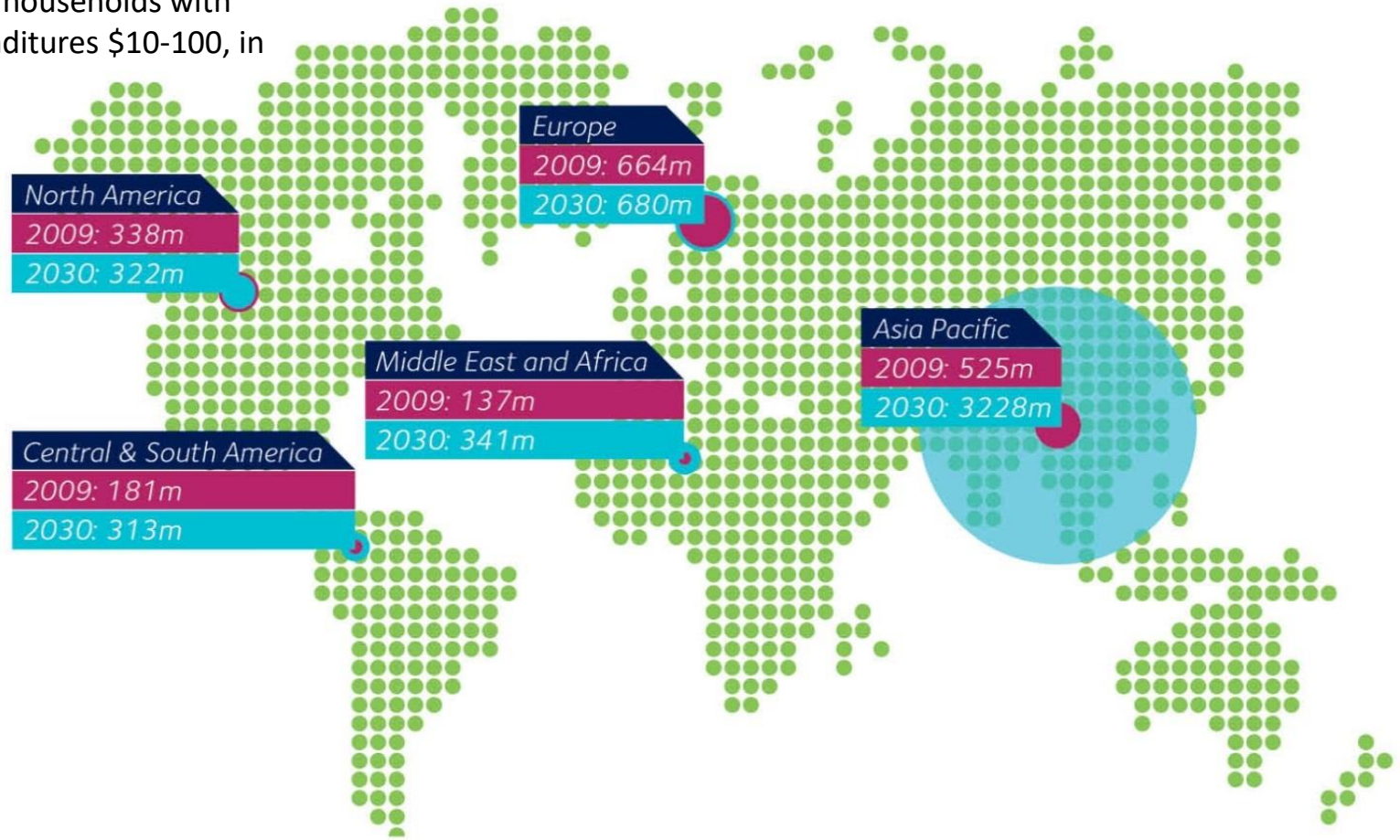
More than half of global population growth between now and 2050 is expected to occur in Africa: of the additional 2.4bn people projected to be added to the global population between 2015 and 2030, 1.3bn will be added in Africa

Historical progression of Global Population

Total Population	Year	Interval
3 billion	1959	
4 Billion	1974	15 years
5 Billion	1987	13 years
6 Billion	1998	11 years
7 Billion	2011	13 years
8 Billion	2022	11 years
9 Billion	2040	18 years
10 Billion	2055	15 years

The rise of the global middle class

Number of households with daily expenditures $10-100, in millions



2009: 1.845 billion households

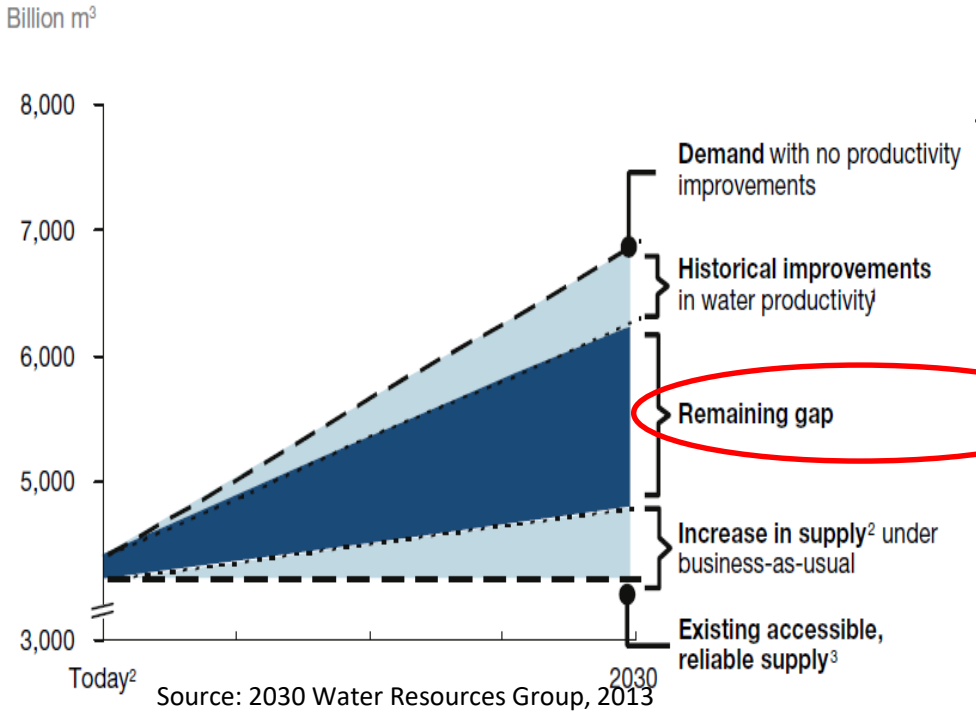
2030: 4.884 billion households

Urbanization Trends

- By 2030, the world is projected to have 41 mega-cities, with 60% of the world's population living in urban areas – another billion city dwellers
- Nearly 90% of this increase will be concentrated in Asia and Africa
- The fastest growing urban agglomerations are medium sized cities with less than 1m inhabitants in Asia and Africa

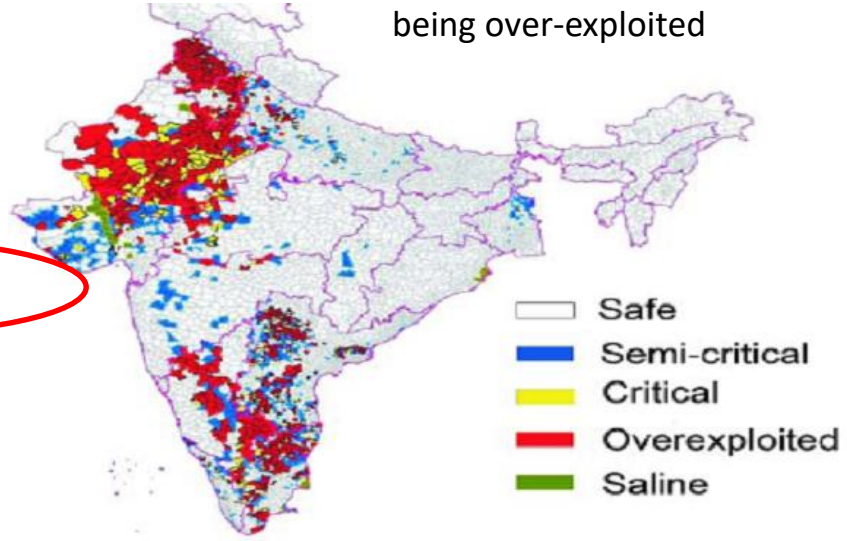
"Urbanization in Asia"
UN Photo/Kibae Park

World Water Requirements



Source: 2030 Water Resources Group, 2013

Around 20% of the world's aquifers are being over-exploited



Global water withdrawals are projected to increase by 55% through 2050, due to growing demands from manufacturing (400%), thermal electricity generation (140%), and domestic use (130%)

An estimated 30% of global water withdrawals are lost through leakage

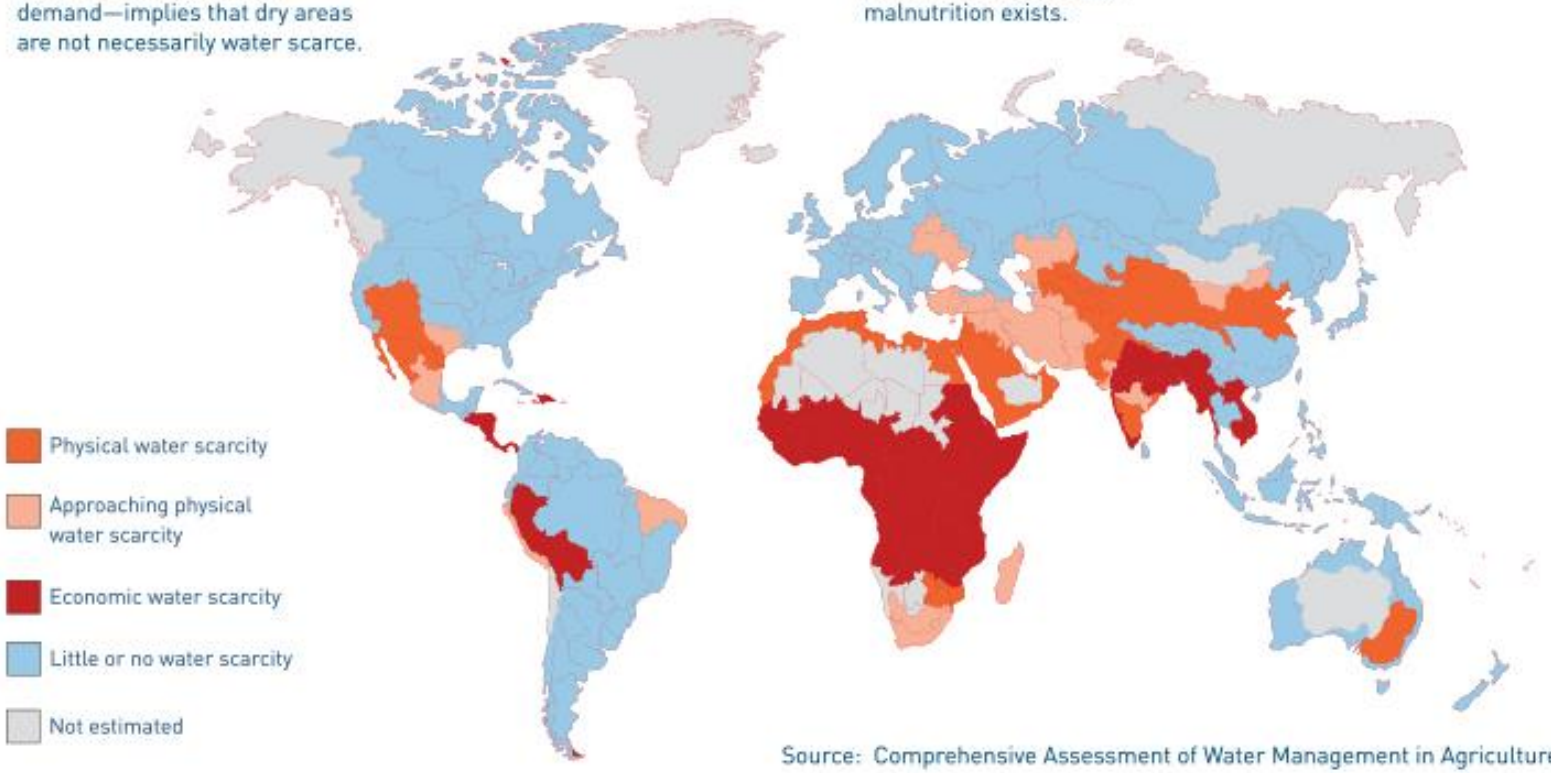
AREAS OF PHYSICAL AND ECONOMIC WATER SCARCITY

Physical water scarcity water resources development is approaching or has exceeded sustainable limits). More than 75% of the river flows are withdrawn for agriculture, industry, and domestic purposes (accounting for recycling of return flows). This definition—relating water availability to water demand—implies that dry areas are not necessarily water scarce.

Approaching physical water scarcity. More than 60% of river flows are withdrawn. These basins will experience physical water scarcity in the near future.

Economic water scarcity (human, institutional, and financial capital limit access to water even though water in nature is available locally to meet human demands). Water resources are abundant relative to water use, with less than 25% of water from rivers withdrawn for human purposes, but malnutrition exists.

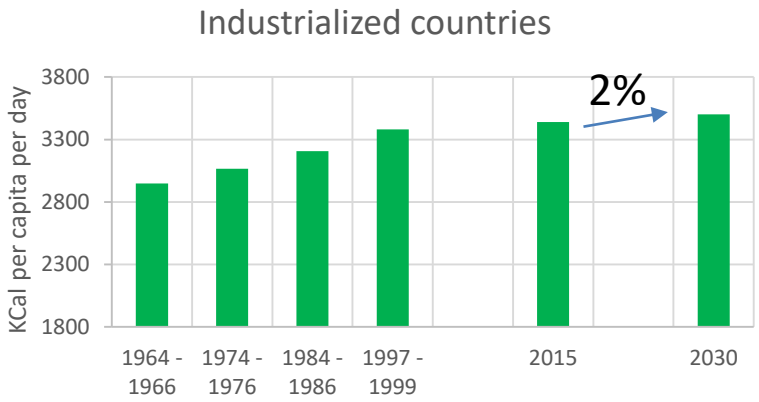
Little or no water scarcity. Abundant water resources relative to use, with less than 25% of water from rivers withdrawn for human purposes.

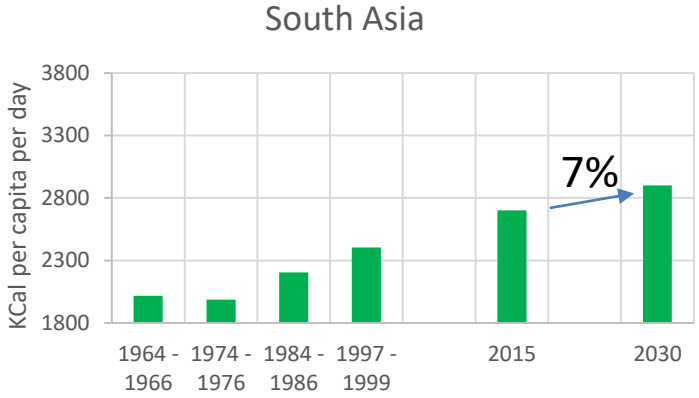


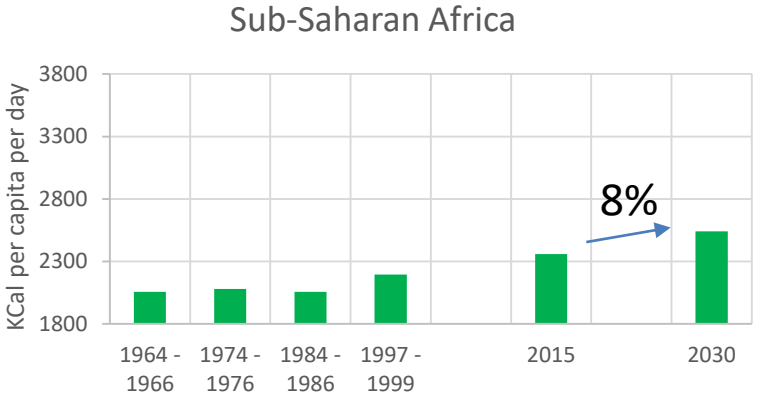
Source: Comprehensive Assessment of Water Management in Agriculture, 2007

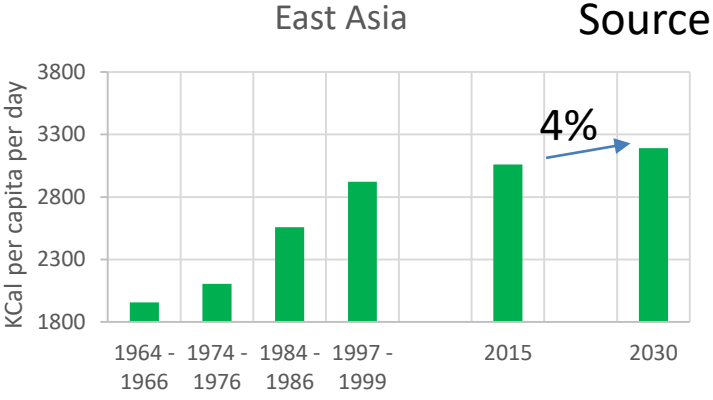
(The most recent map that we could find!)

World Food Requirements









Source: FAO, 2012

The growth in average daily calorie consumption per capita (Source: FAO, 2012)

- Food demand is determined by population growth and by changes in diet as per capita income grows
- Total global animal protein consumption has more than doubled since 1970
  By 2030, global animal protein demand is expected to increase another 60%
- Sub-Saharan Africa will account for 1/3rd of all additional calories needed in 2050
- To meet increased global food demand, agricultural production needs to increase by **~60%** by 2050

Challenges for Agriculture

OECD-FAO predicts that global agricultural production will grow at an average of 1.5% annually over the next 10 years compared with 2.1% in the last decade. Growth is expected to be slower in all crop sectors as well as in livestock production, reflecting rising costs, growing resource constraints, and increasing environmental pressures.

Increasing crop production

- increase land use
- increase yields
- increase the frequency of cropping (e.g. using irrigation)

Agriculture uses 37% of global landmass (excluding Antarctica)

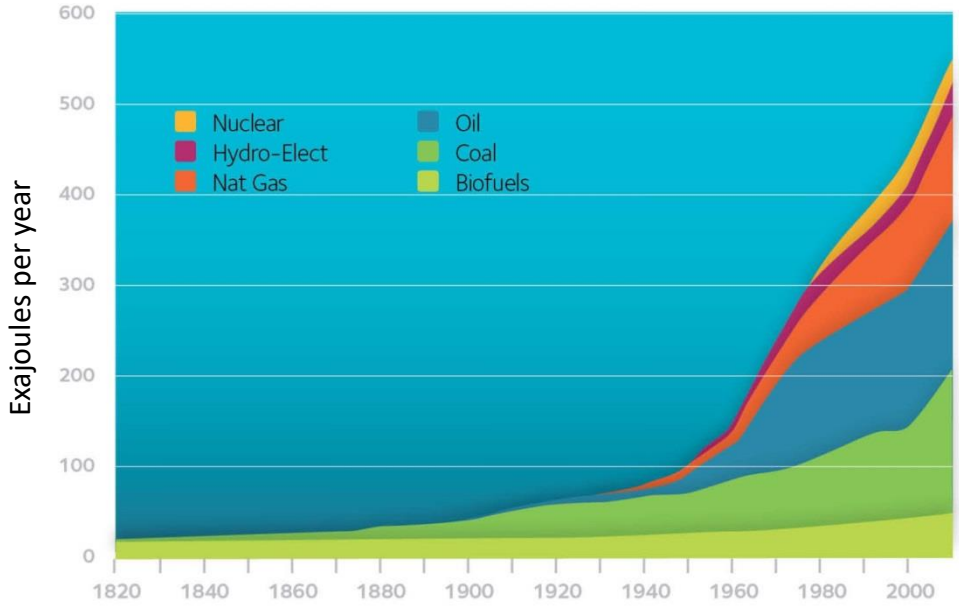
Sub-Saharan Africa currently has the world's lowest cereal yields:1.25 tonnes/ha versus developed countries, developing Asia and Latin America which all attain around 4 tonnes/ha

Agriculture accounts for 70% of all freshwater drawn from rivers, lakes and aquifers

Reducing waste

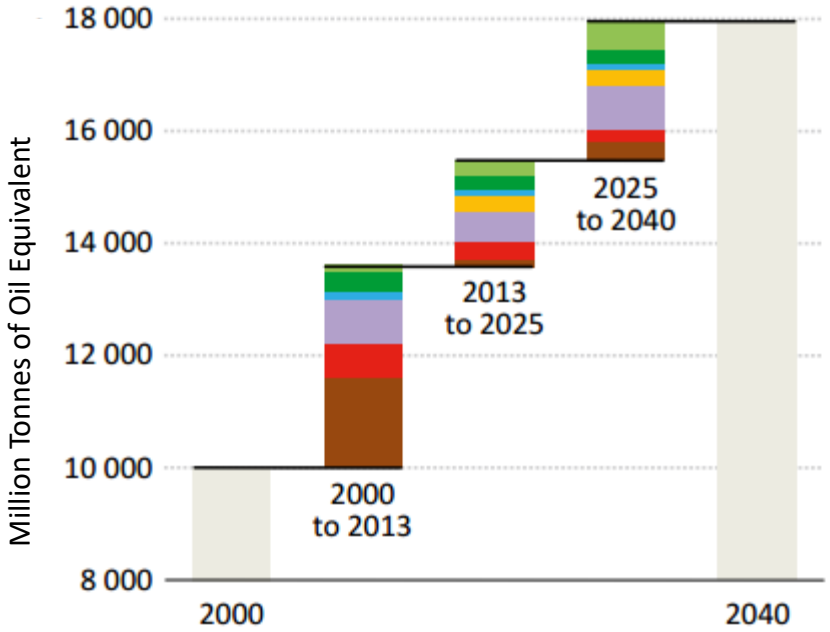
Around 30% of the food produced globally is wasted – around 1.3bn tonnes. Food waste in high-income countries is dominated by consumer waste. Food waste in developing countries is at the pre- and post-harvest and processing stages due to spoilage

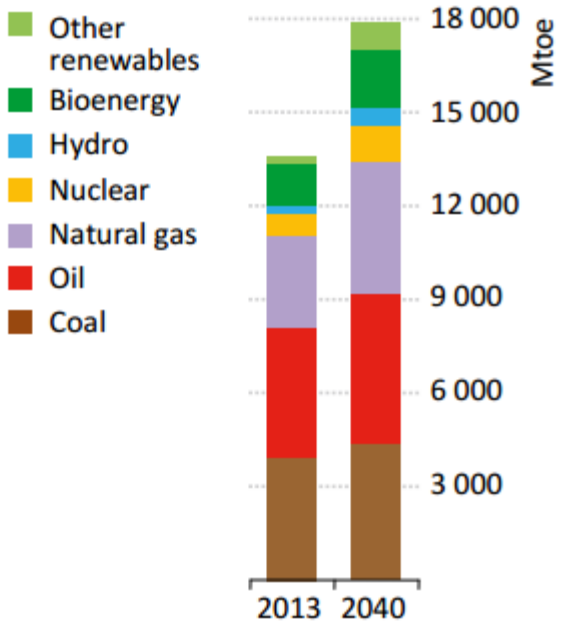
World Energy Requirements



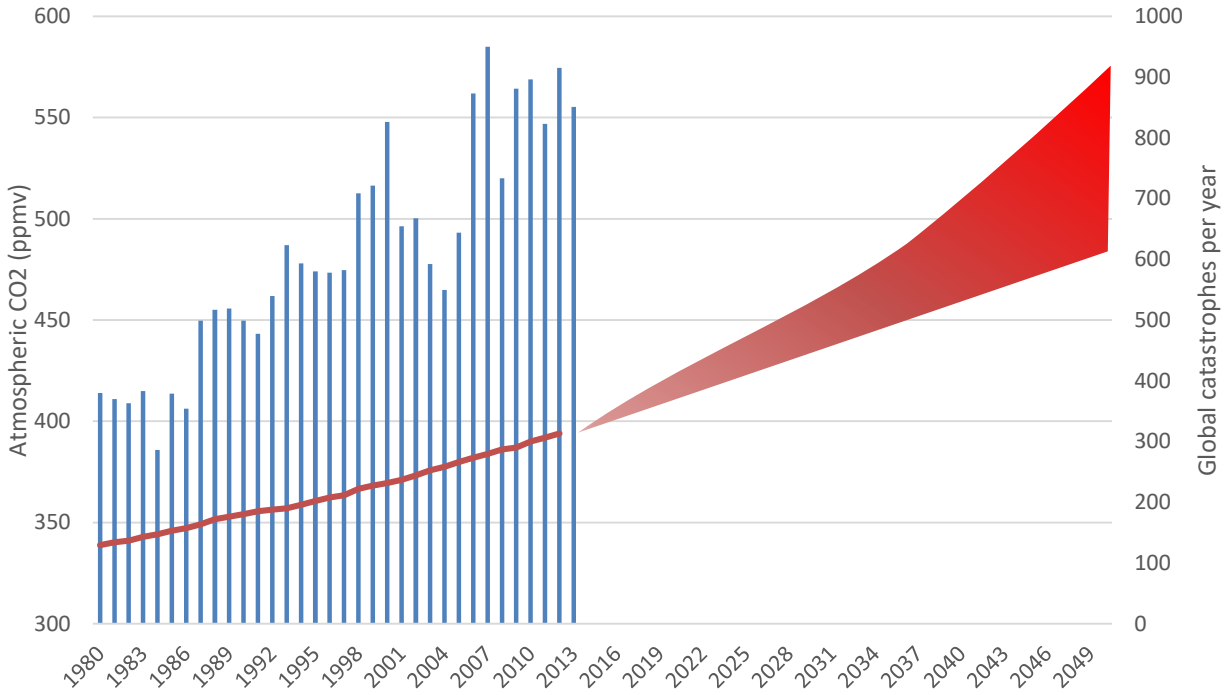
Energy demand is expected to increase by 32% by 2040, with global electricity demand growing by over 70%

Renewables are expected by the IEA to overtake coal as the largest source of electricity by the early 2030s





Future climate warming is unequivocal, and there is growing evidence that there will be increasing weather volatility



Number of natural disasters per year, as recorded by Munich Re
Atmospheric carbon dioxide concentrations (ppmv), as measured by the IPCC
Reference carbon dioxide concentration scenarios, as projected by the IPCC

- Due to climate system inertia, emissions made around twenty years ago drive the present-day climate
- There is a growing body of evidence that links human influence on climate with increasing risks of certain types of extremes, notably heatwaves (e.g. Chinese spring 2014), floods (e.g. UK winter rainfall 2013/2014), and hurricanes (e.g. Hawaiian 2014 hurricane season)

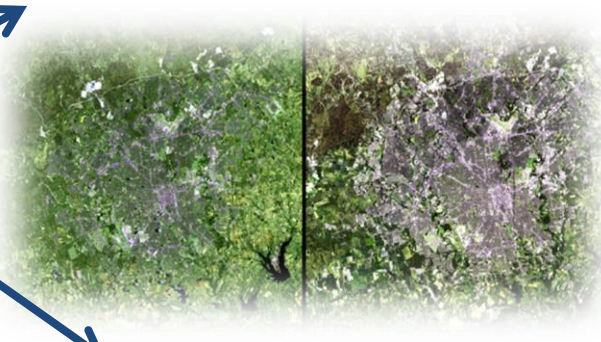
Emergent challenges of the 21st Century

Obesity and Malnutrition

Pandemics, Emerging infectious diseases and Antibiotic resistance

Sustainability of human health

Air pollution



Urban sprawl

Challenges of new technology

Automation

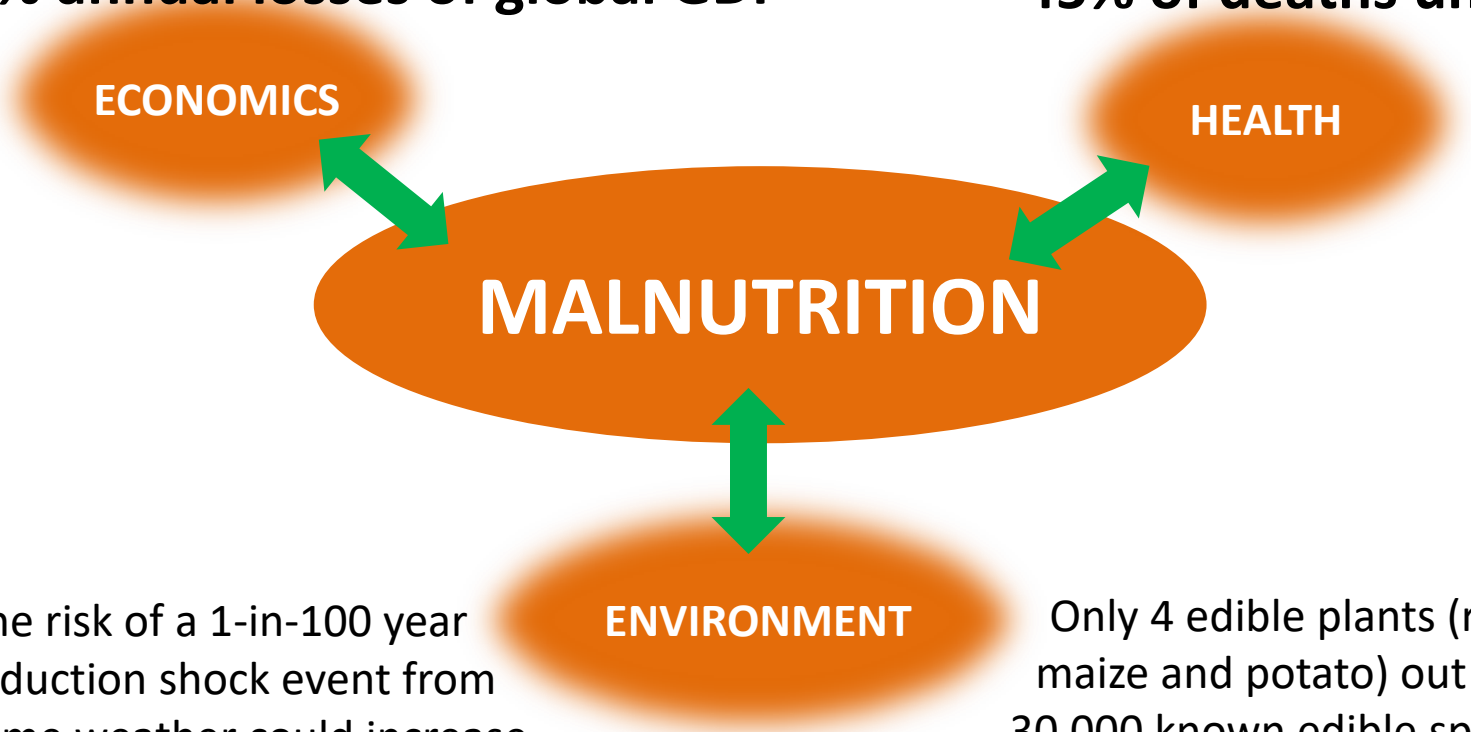
Cybersecurity

Sustainability of human health: Nutrition

Of a world population of >7bn, nearly 800m suffer from calorie deficiency…
But around 2bn people suffer from micronutrient malnutrition

10% annual losses of global GDP

45% of deaths under age 5

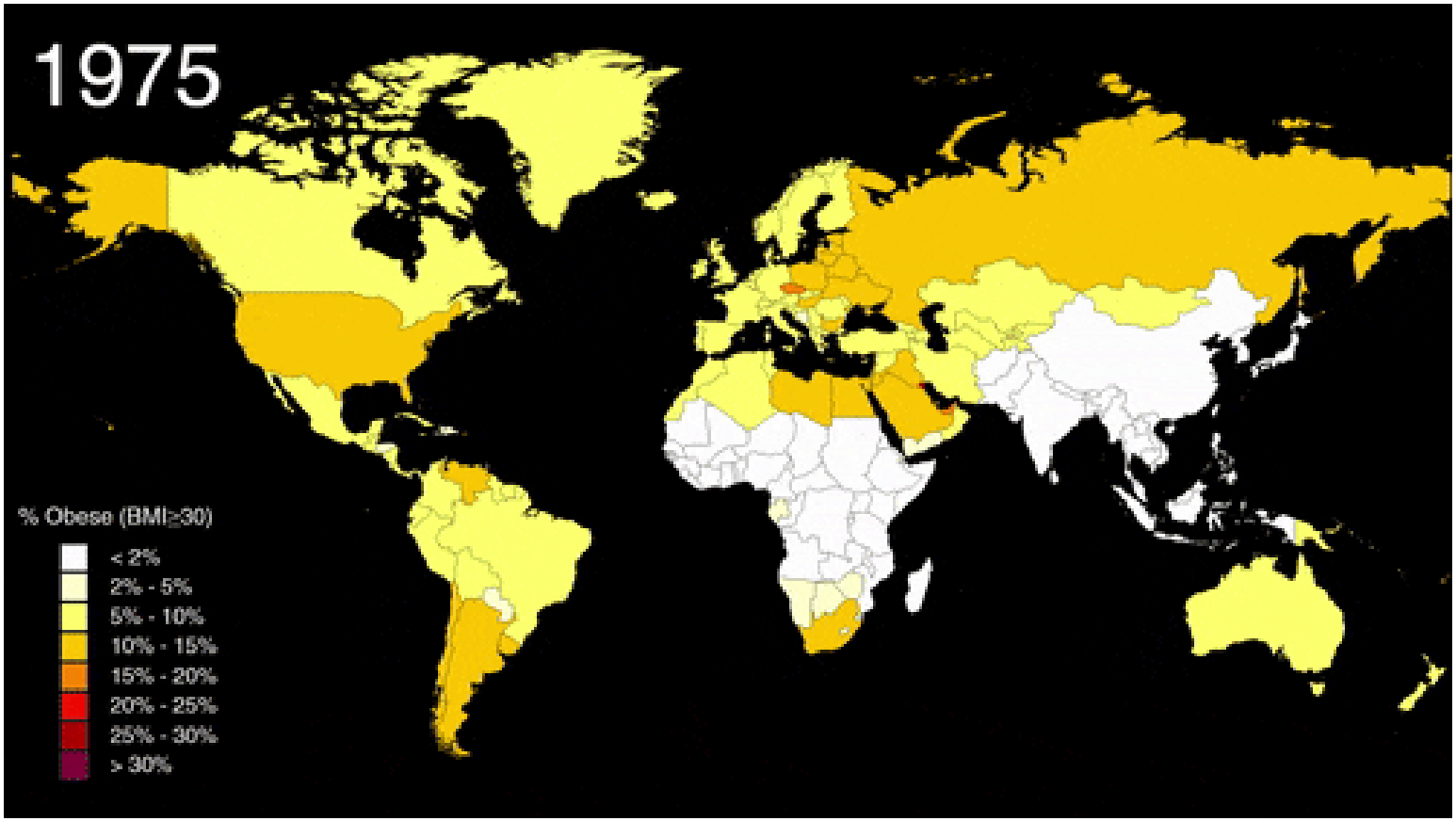


The risk of a 1-in-100 year production shock event from extreme weather could increase to 1-in-30 year or more with climate change

Only 4 edible plants (rice, wheat, maize and potato) out of a total of 30,000 known edible species provide 60% of the world's dietary energy intake.

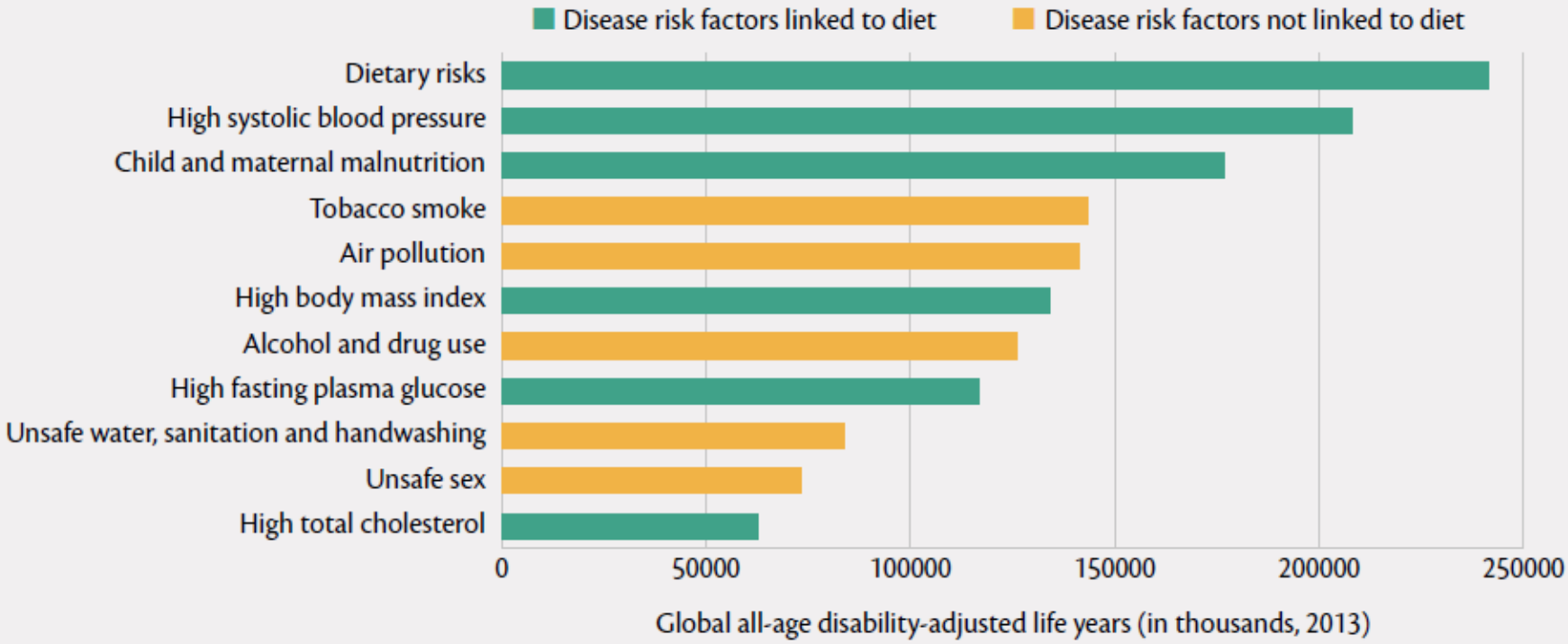
The rise and rise of global obesity

- Out of 5bn adults worldwide, nearly 2bn are overweight or obese
- 1 in 12 adults have type II diabetes



Source: metrocosm.com, using data from NCD Risk Factor Collaboration publication in Lancet vol 387, 2016

Six of the top 11 risk factors driving the global burden of disease are related to diet

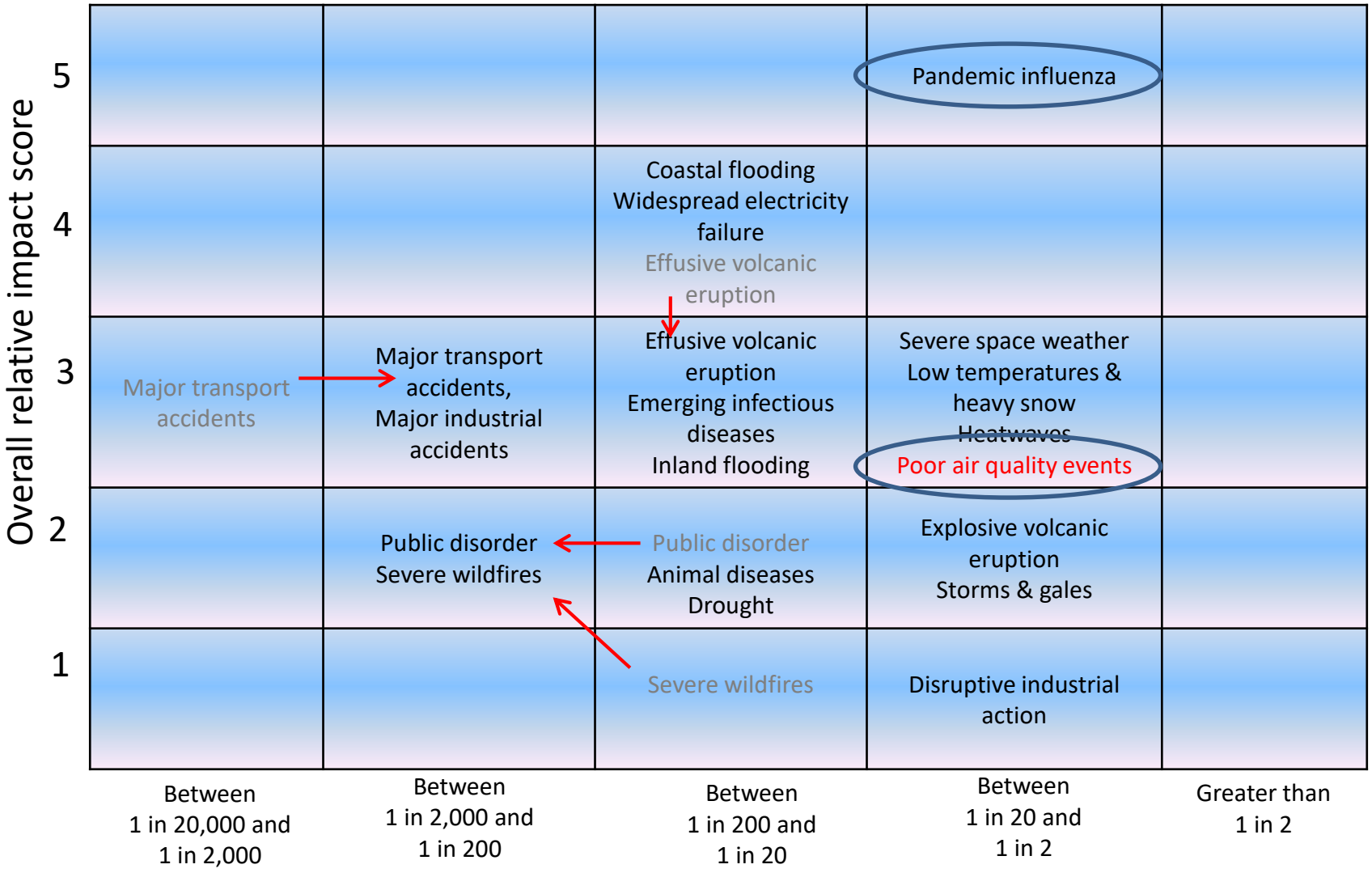


Source: Global Burden of Disease Study 2013 Collaborators (2015), Figure 5

Note: The graph shows global disability-adjusted life years (DALYs) attributed to level 2 risk factors in 2013 for both sexes combined.

UK National Risk Register: Change from 2013 to 2015

Red = new for 2015



Source: National Risk Register for Civil Emergencies, 2013 & 2015

Sustainability of human health: Pandemics

- 6 influenza pandemics in 120 years
- Approximately 65% chance of another in 20 years
- Severity highly variable

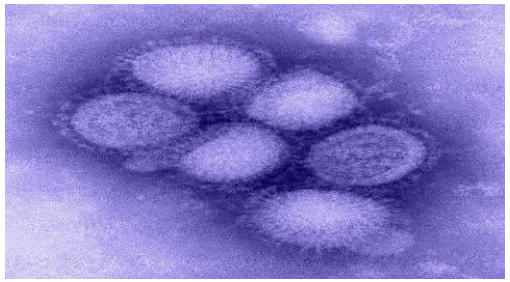
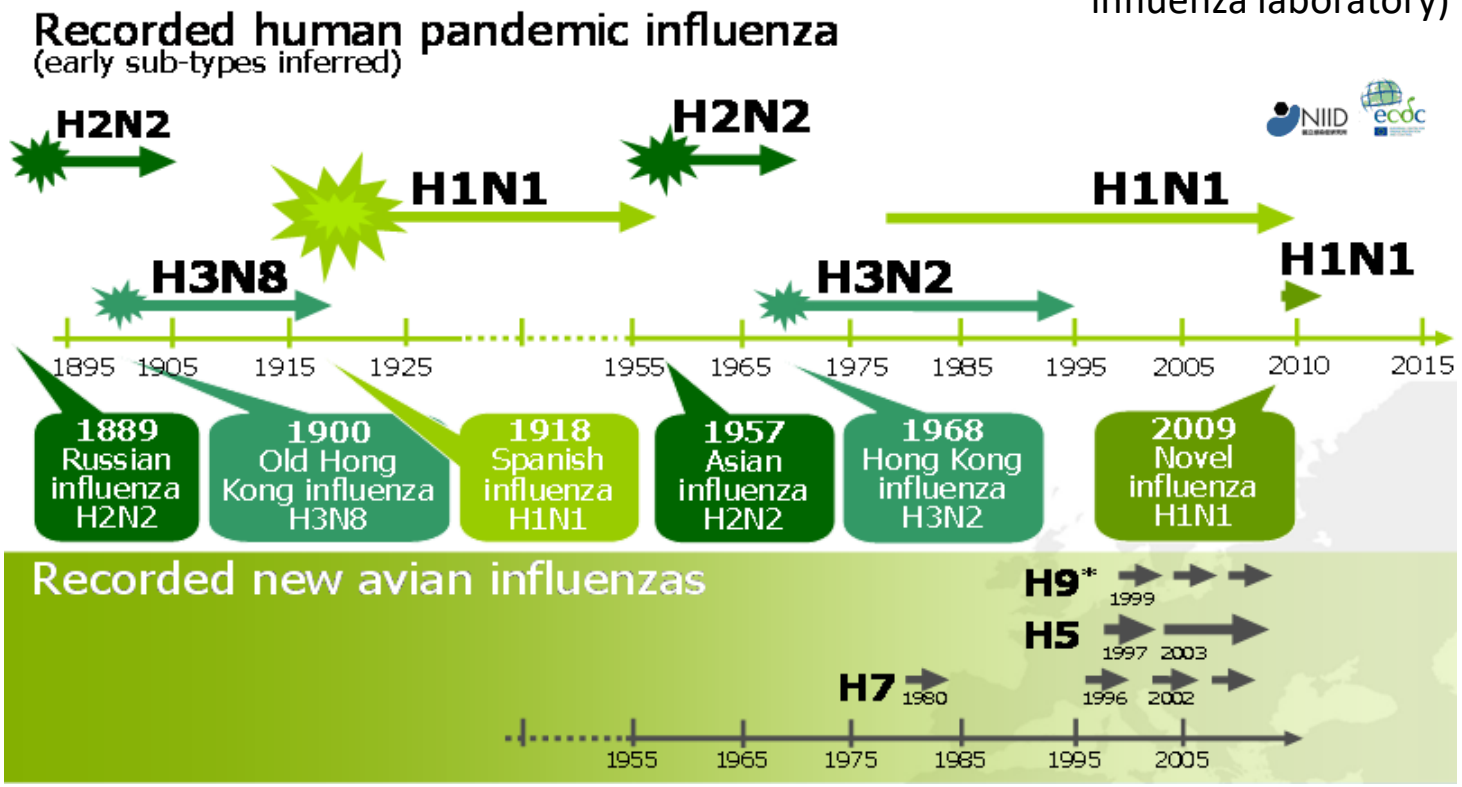


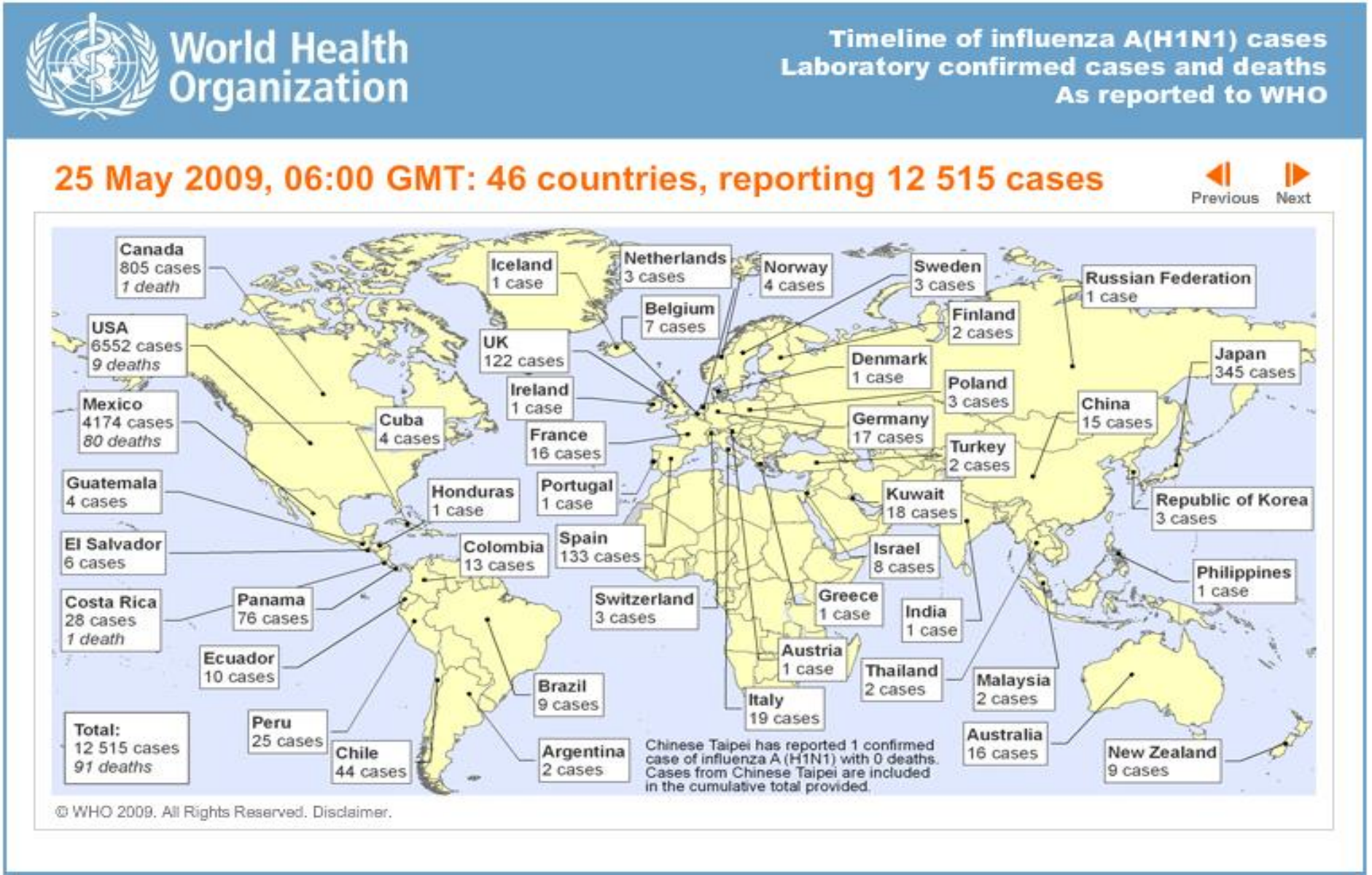
Image of HN1N virus (Source: US CDC influenza laboratory)



Recorded human pandemics of influenza

Source: NIID and ECDC 2009

2009 Novel Influenza H1N1: Day 31



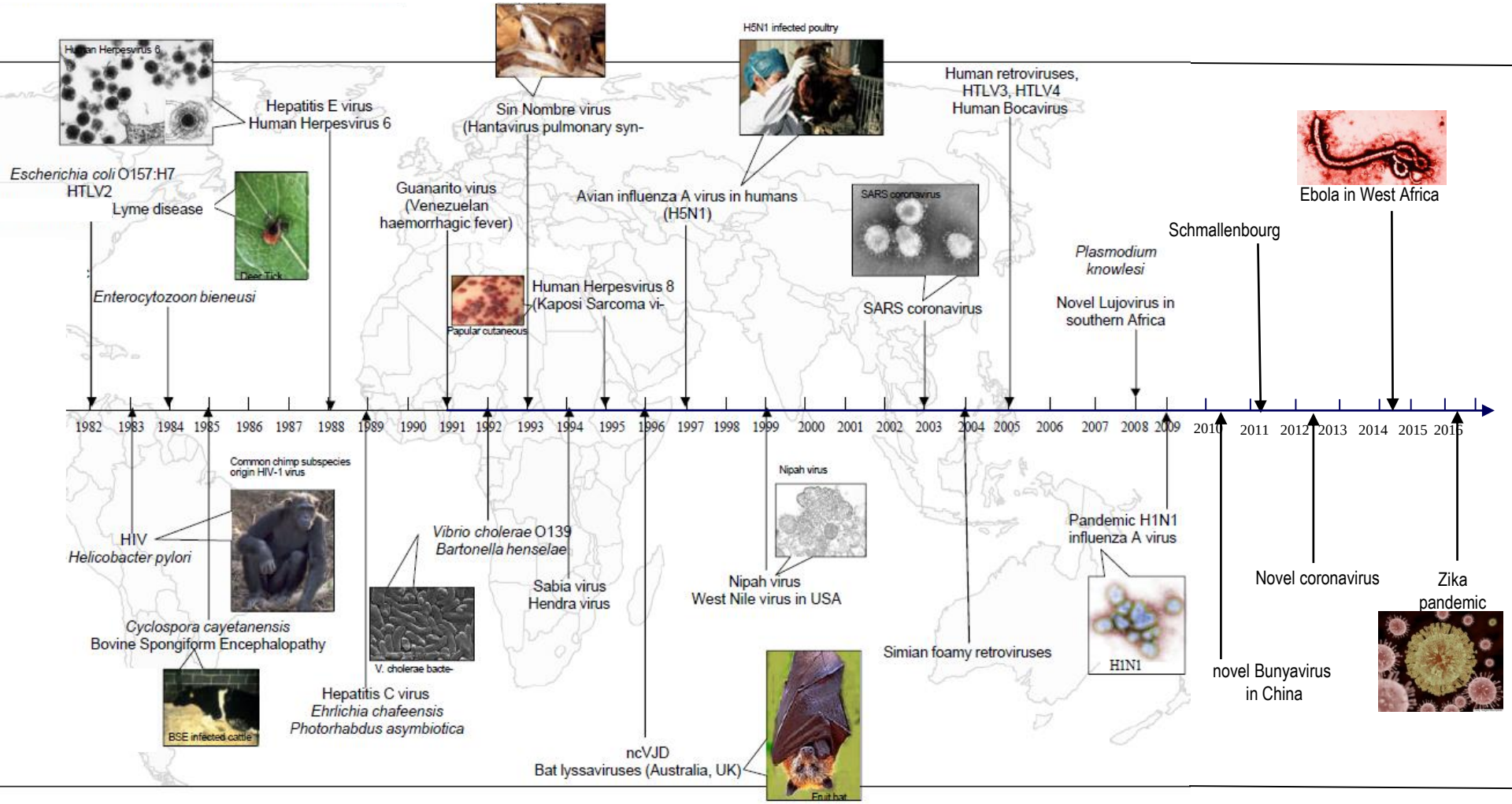
Avian flu in the context of historic influenza pandemics

Date	Strain	UK deaths	Global deaths	Age group most affected	Case fatality rate	Comments
1918/1919	A(H1N1) Spanish flu	~220,000	40-50 million	25-35yrs	>2.5%	25% of global population infected
1957/1958	A(H2N2) Asian flu	~30,000	2 million	School-children & elderly	<0.1%	
1968/1969	A(H3N2) Hong Kong flu	~30,000	1 million	Elderly	<0.1%	
2003->	H5N1 Avian flu	NA	~350	Median age of patients 18 years	60%*	Confirmed human-human transmission cases: ~3
2009-2010	H1N1 Swine flu	NA	18,000	22-30 years	0.03%	>600,000 infections

*WHO estimate that 60% of patients diagnosed with H5N1 influenza died. Analysis has indicated that under pandemic conditions, the 'real' H5N1 case fatality rate might be 14-33% Source: Li et al, 2008

WHO is currently in 'alert phase' for pandemic avian flu; nearly 40 countries have reported outbreaks in birds & poultry since November 2016

New human and animal diseases



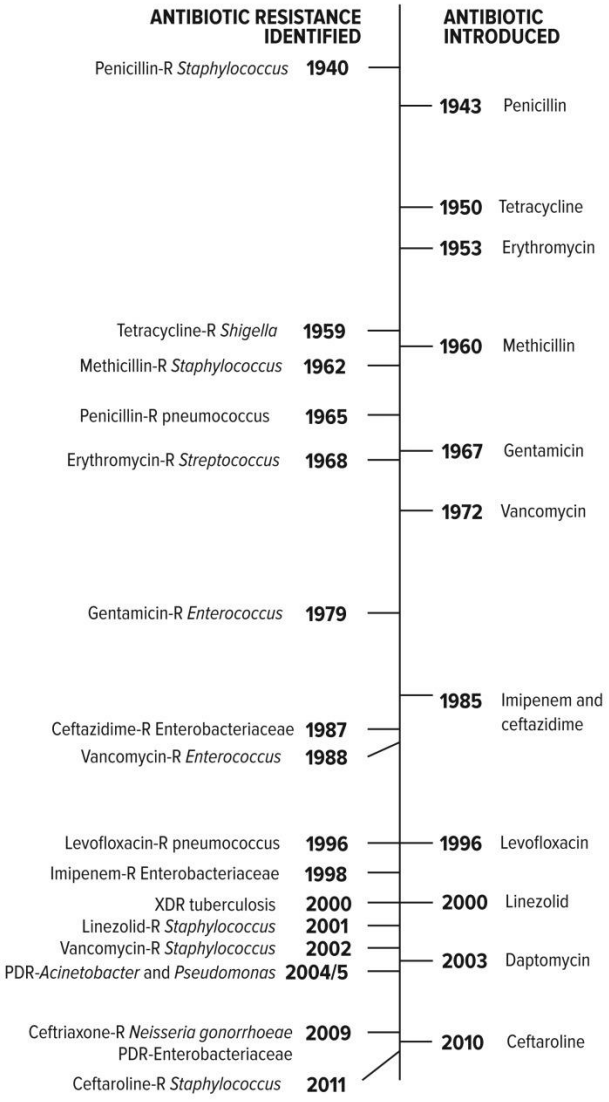
70% of the emerging infectious diseases over the last few decades have been zoonotic (passing from animal to human hosts)

Sustainability of human health: Antibiotic Resistance

- Resistance has developed for nearly all antibiotics in use
- Inappropriate prescribing and indiscriminate use of antibiotics in agriculture have a role (albeit poorly understood) in fostering antibiotic resistance
- The pharmaceutical pipeline of new antibiotics has not kept up with the rise of resistance

Source: Ventola, 2015

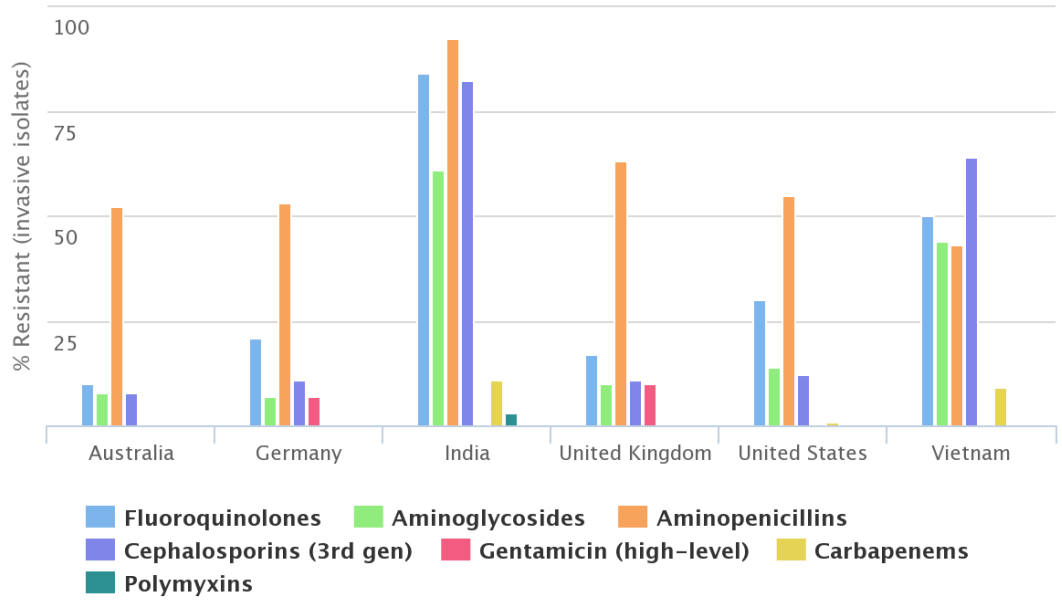
Figure 1 Developing Antibiotic Resistance: A Timeline of Key Events[5]



PDR = pan-drug-resistant; R = resistant; XDR = extensively drug-resistant

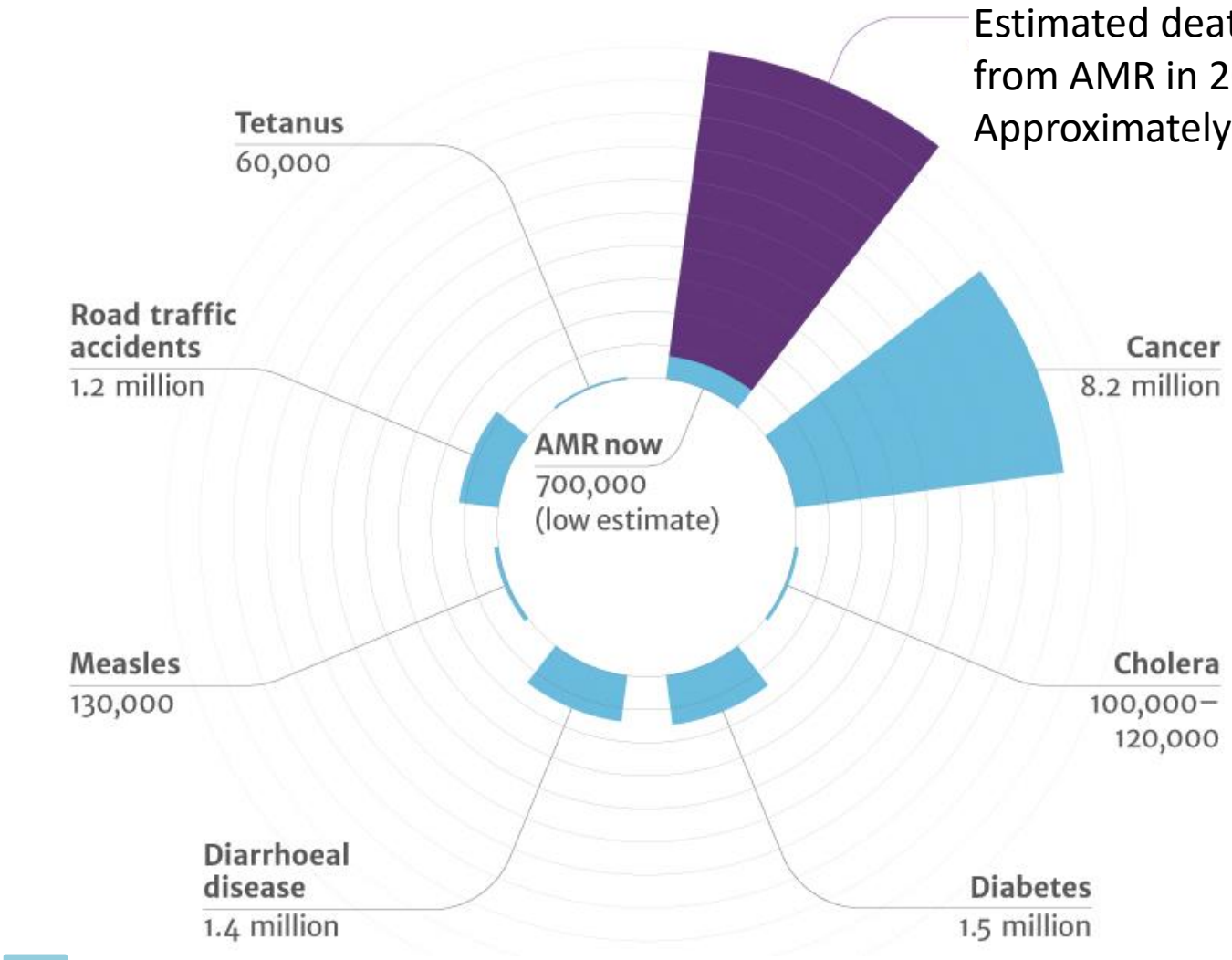
Dates are based upon early reports of resistance in the literature. In the case of pan-drug-resistant *Acinetobacter* and *Pseudomonas*, the date is based upon reports of health care transmission or outbreaks. Note: penicillin was in limited use prior to widespread population usage in 1943.

An example of the global extent of antibiotic resistance for the common bug Escherichia coli:



Center for Disease Dynamics, Economics & Policy (cddep.org)

Antibiotic resistance is a significant risk



Source: Review on Antimicrobial Resistance, Wellcome Trust/HM Govt 2016

Sustainability of human health: Urban sprawl

Source: New Climate Economy Report 2014

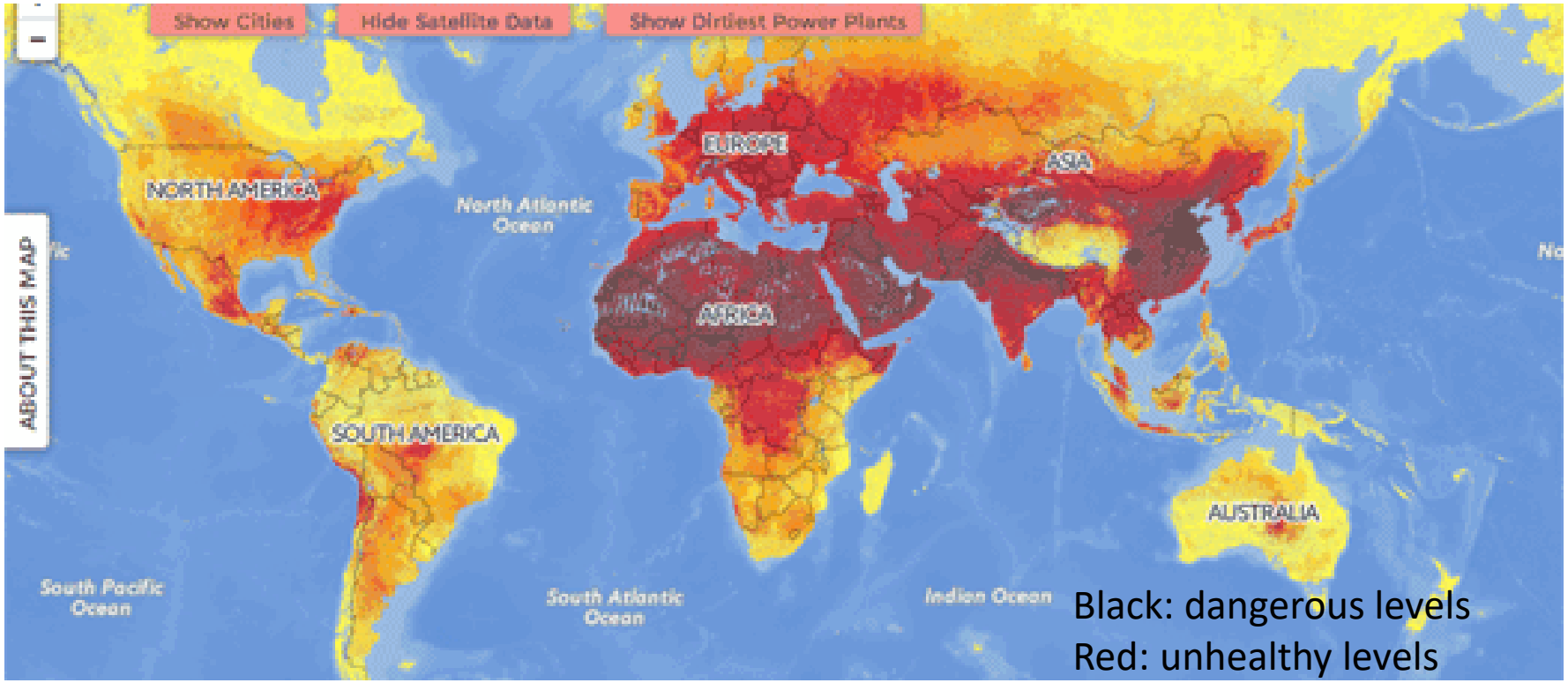
- Cities contribute 80% of global CO2 emissions
- The carbon impact of cities is not necessarily linked to population size
- Poorly designed cities have more than an emissions impact. Urban air pollution is forecast by the OECD to become the top environmental cause of premature mortality by 2050
- Urban sprawl is one of the world's most significant and least well documented market failures

Sustainability of human health: Air pollution

- 92% of the world's population lives in places where air quality exceed WHO limits
- Urban air pollution is forecast by the OECD to become the top environmental cause of premature mortality by 2050

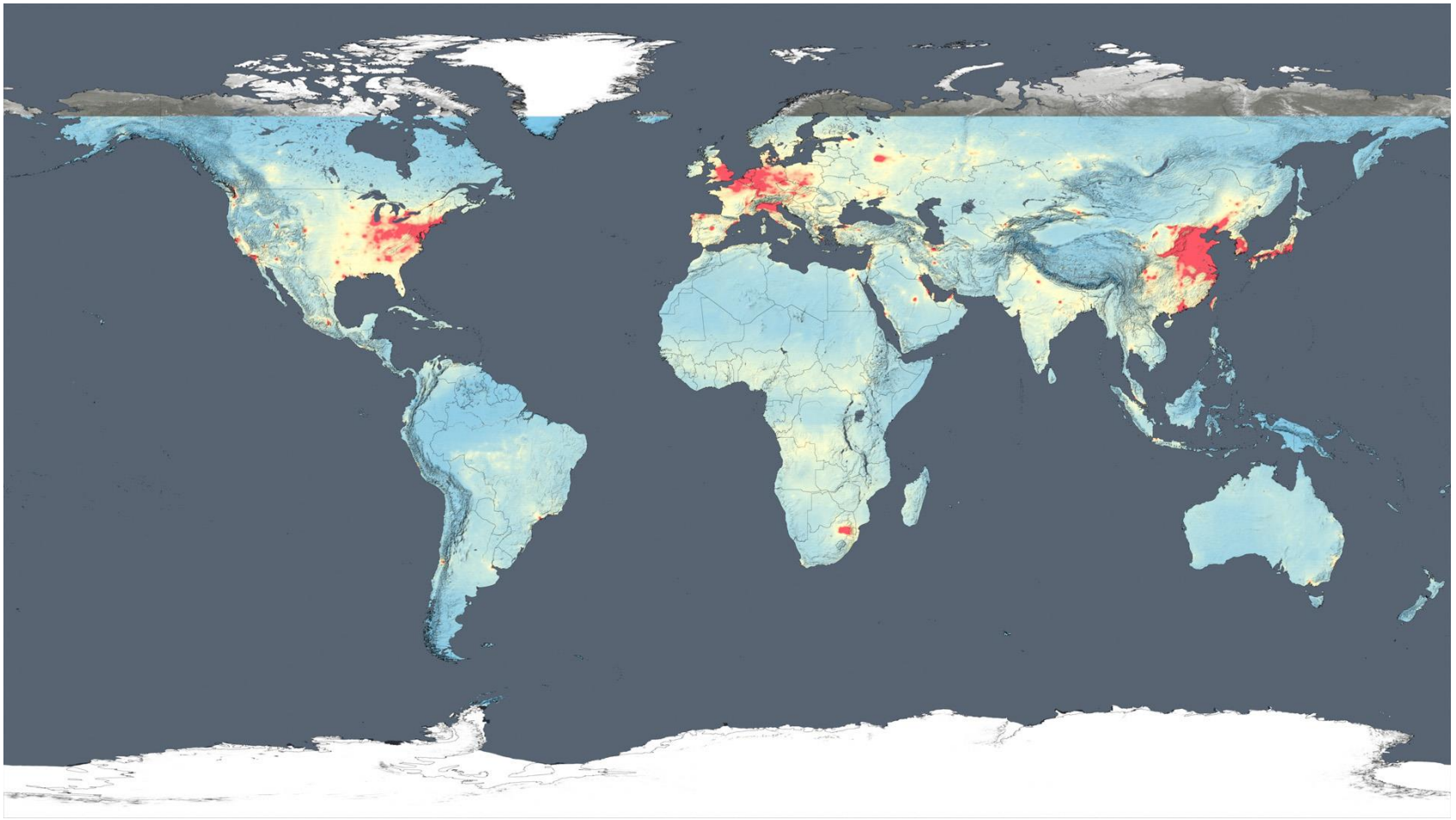
Smog in New Delhi, 9th November 2016:
1000 on the Air Quality Index (AQI), where >500 is classified hazardous

Global PM2.5 levels



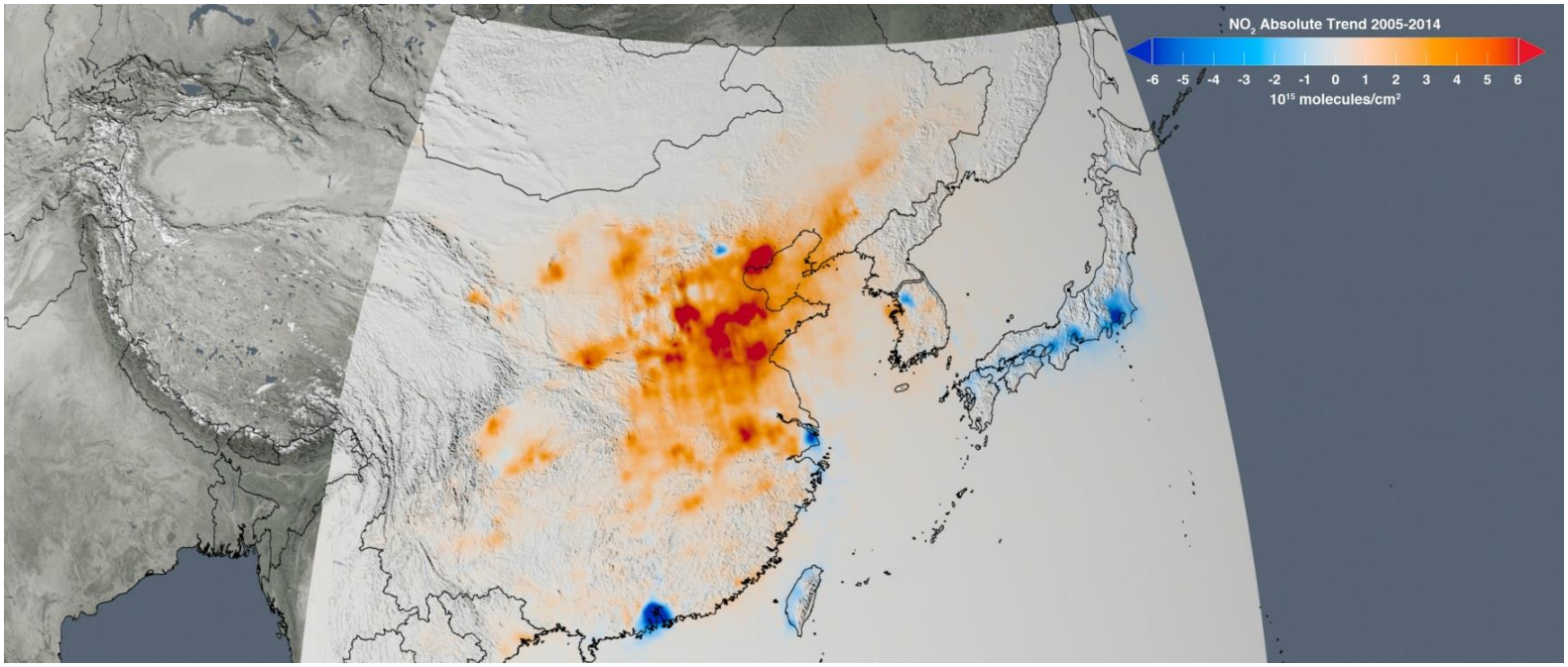
- Fine particulate matter (PM2.5): air pollutants with a diameter of 2.5 micrometers or less, small enough to invade airways and known to increase mortality risk particularly from cardiovascular disease
- Poor air quality correlates closely to population densities with the exception of desert areas where high levels of particulates are caused by mineral dust

Global nitrogen dioxide levels



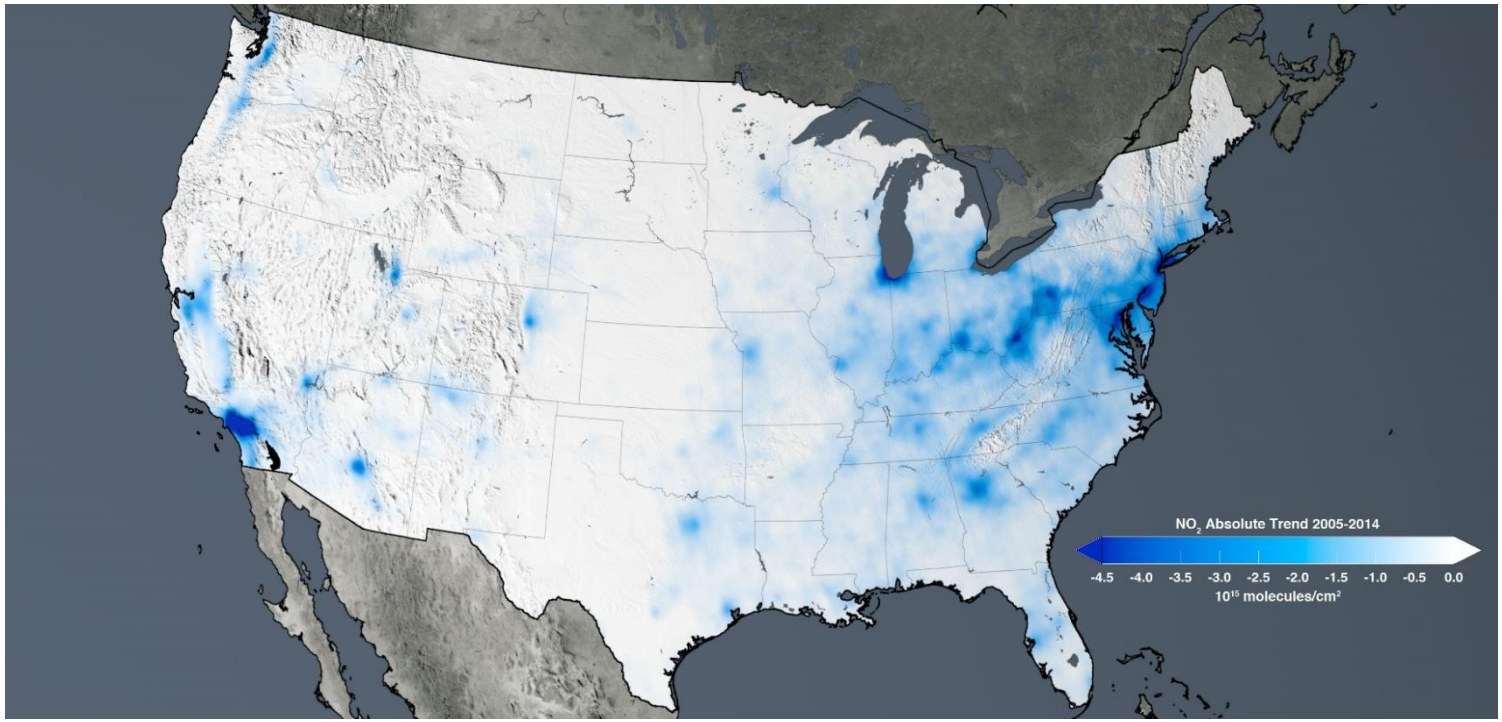
- Concentration of NO2 (nitrogen dioxide) in the atmosphere, averaged over 2014, as detected and measured by spectrometers on NASA satellites (source: NASA)
- NO2 is a pollutant originating mostly from vehicles and coal-fired power stations, which contributes to the production of ground-level ozone, a severe respiratory irritant
- Areas of the US and Europe (notably the UK) are large emitters, as is China and Japan

Trend changes in nitrogen dioxide levels: Asia

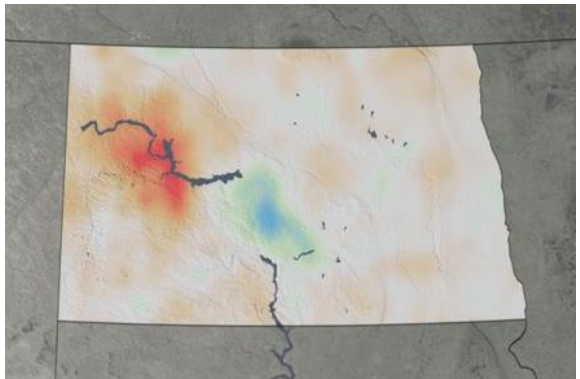


- The trend change in nitrogen dioxide concentrations from 2005 to 2014 shows the impact of both economic growth and environmental controls across China, South Korea and Japan (Source: NASA)
- The Northern plain of China became a major manufacturing hub over the time series and NO2 levels have increased 20-50% thanks to coal energy use
- Some major Chinese cities such as Beijing and China have seen improved conditions, and in Hong Kong, levels have decreased by 40% - an example of local and regional governance

Trend changes in nitrogen dioxide levels: USA

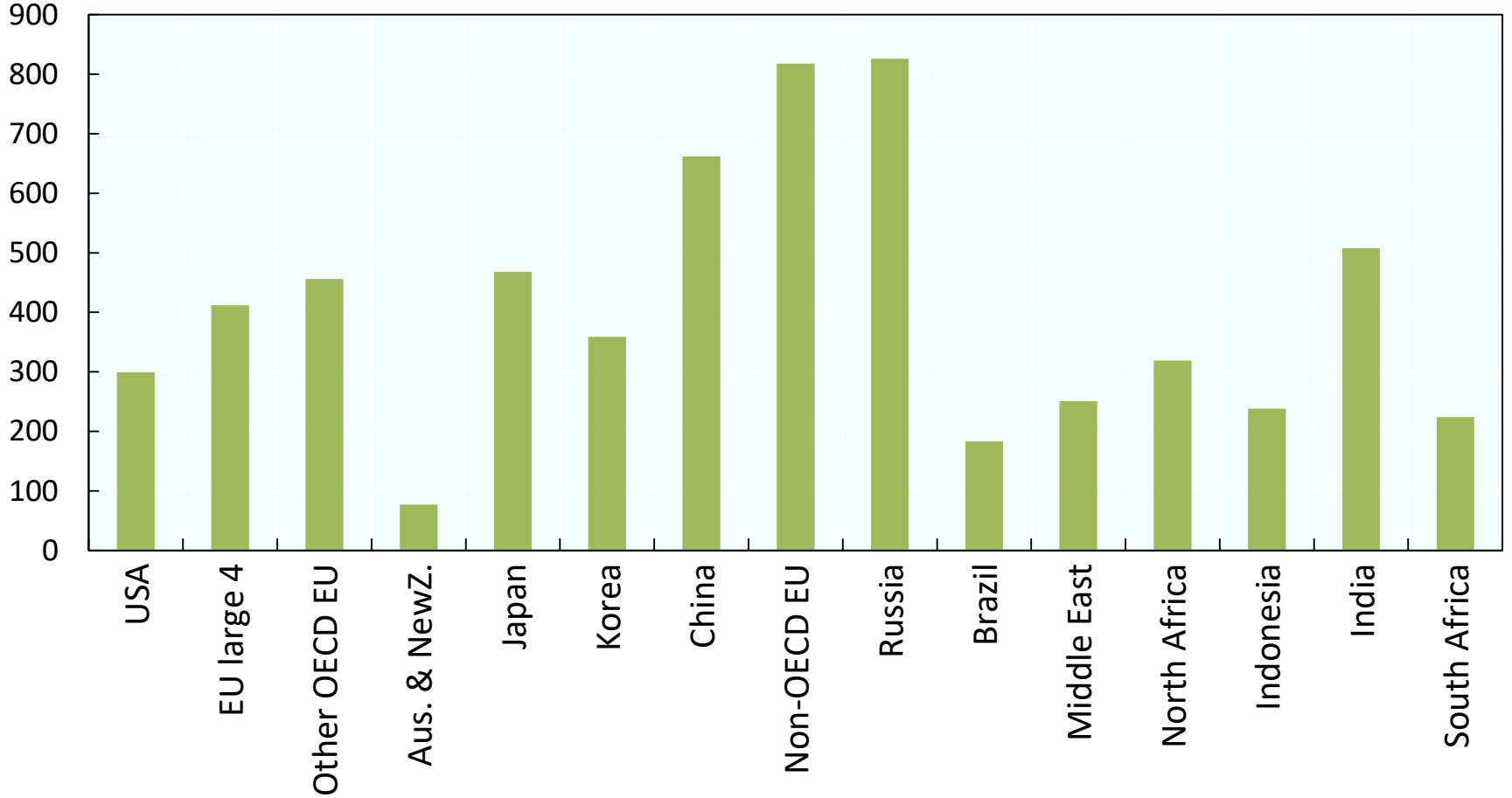


- Large decreases (20-50%) of NO2 concentrations 2005-2014 across the USA are associated with changes in environmental regulations and technology improvements (Source: NASA)
- However, focusing on North Dakota (RH chart) shows the impact on NO2 levels of heavy machinery associated with shale gas and oil exploration as well as methane flaring



Parts of Europe and Russia exceed Asian giants in air pollution deaths

Number of deaths caused by outdoor air pollution per year per million people (2010)



Global premature deaths from ozone and particulates may triple to 9m per year in 2060

(Source: OECD, 2016)

Challenges of new technology: Cybersecurity

600,000 Facebook accounts compromised every day

99% of computer users vulnerable to exploitation, thanks to Oracle Java, Adobe Reader, or Adobe Flash software flaws

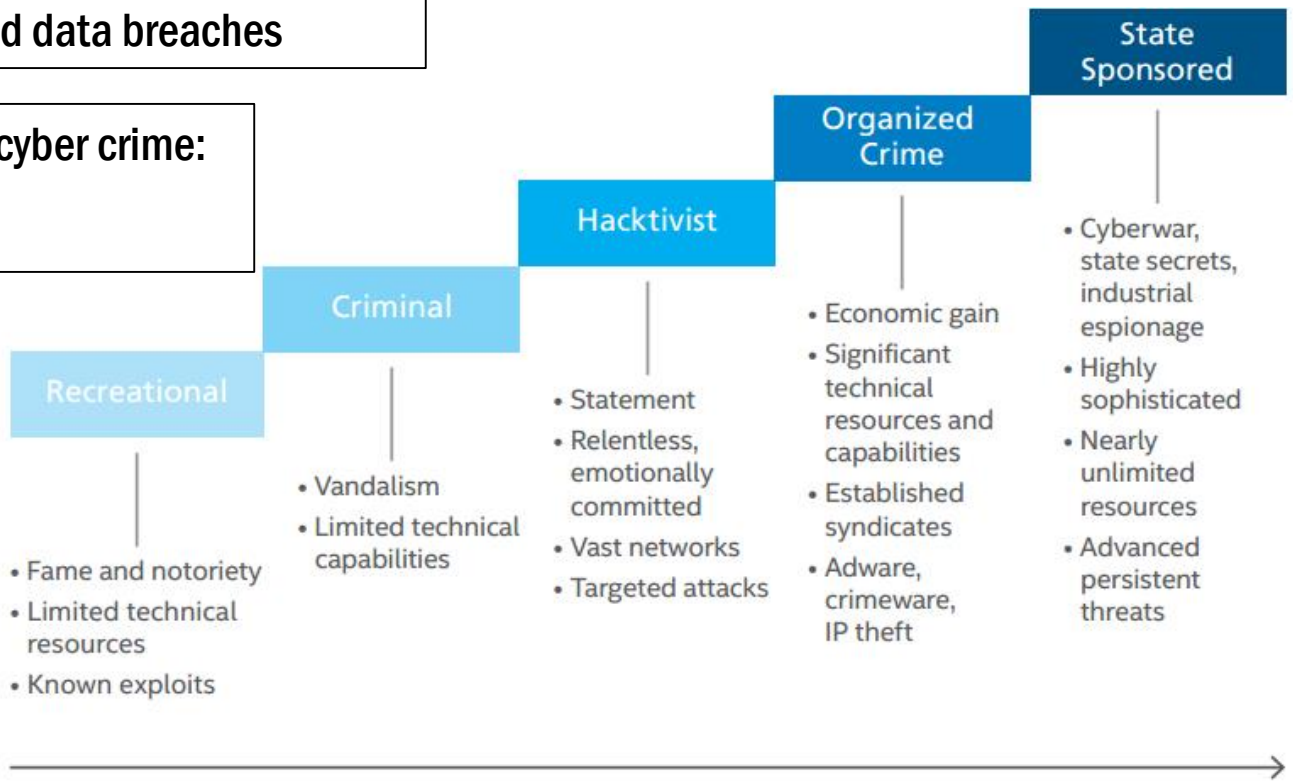
The US Navy receives 110,000 cyber attacks every hour

The Internet of Things is the perfect target for DDoS attacks and data breaches

Estimated global cost of cyber crime: $100bn

UK fraud hits record £1.1bn as cybercrime soars

(The Guardian, 24th Jan 17)

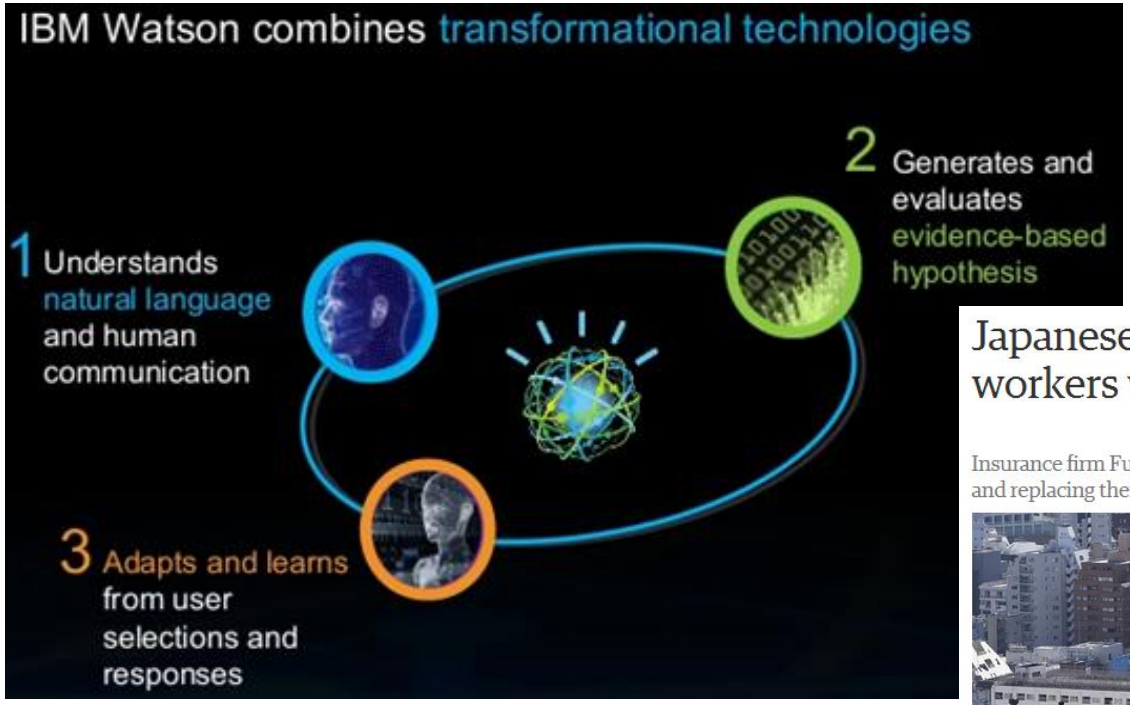


Changing attacker profiles: increasing resources and sophistication

Source: McAfee Labs Threats Report, 2015

Emergent challenges of technology: Automation

- A broad range of non-routine tasks are becoming automatable
- E.g. Work Fusion, Google Translate, IBM's Watson
- Many service occupations are now susceptible

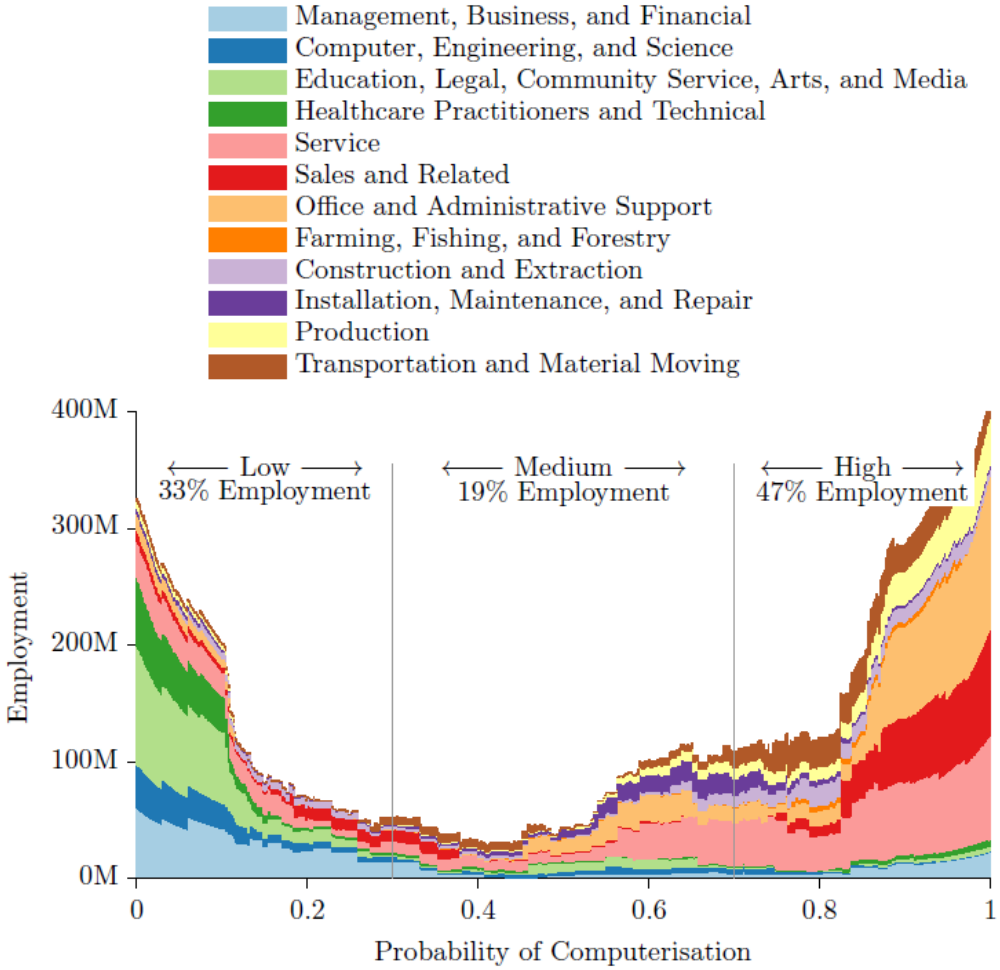


The Guardian, 5 January 2017

Japanese company replaces office workers with artificial intelligence

Insurance firm Fukoku Mutual Life Insurance is making 34 employees redundant and replacing them with IBM's Watson Explorer AI

47% of the US workforce is at risk from automation



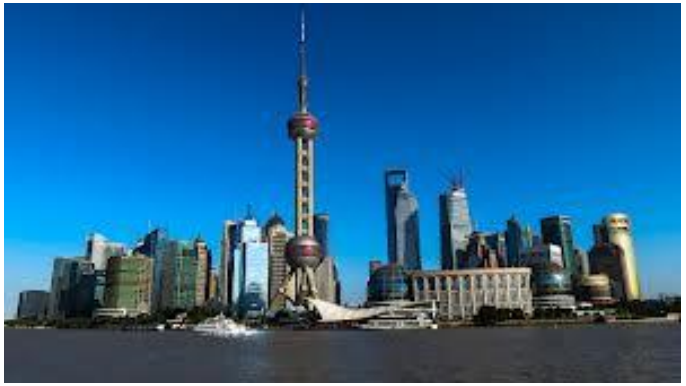
2010 occupational employment categories and the probability of computerisation . The total area under all curves is equal to total US employment (Source: Frey & Osborne, 2016)

Emerging economies are particularly at risk from automation

- 77% of the Chinese workforce and 69% of the Indian workforce is at risk of automation
- Manufacturing processes in low- and middle- income countries are more automated today than in the past, and manufacturing is becoming less labour-intensive
- Manufacturing employment in the UK peaked at 45% just before WW1; emerging economies like India and Brazil have already seen manufacturing employment peak at 15%, a so-called ‘premature de-industrialization’.

The Next 15 Years

- Population – 1 billion more people
- Urbanisation – population increase concentrated in cities
- A more prosperous world, but further strain on resources
- Complex demographic trends
- Climate change is happening – a risk multiplier
- **Increasingly complex challenges for human health and wellbeing**
- Malnutrition, obesity, pandemics, and air pollution all have the potential to provide major global public health emergencies
- **Rapid technological evolution has the potential to generate innovative solutions but there will be new challenges in the process**
- Cybersecurity and automation-related unemployment are major threats to political stability



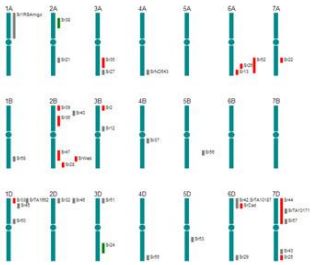
A Changing Global Balance: by 2030
Asia: 4.9bn people, 3.3bn of working age
Africa: 1.6bn people, 800m of working age
Europe: 700m people, 460m of working age

High up on the Possible Global 'In-Tray' of 2030…

1bn more people

Urbanisation

Resource inequality



Biotechnological innovation

Volatile weather

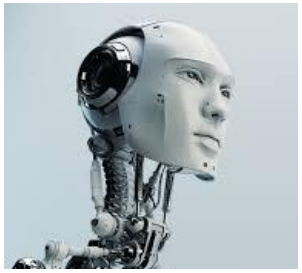
Continued prosperity?

+1'C warmer?

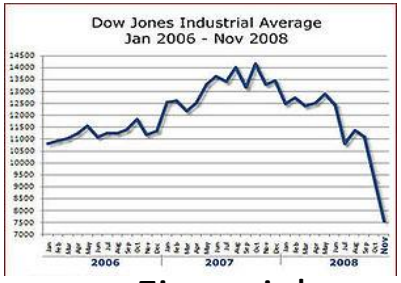
Antibiotic resistance?

A biodiversity crisis?

Pandemics?



Artificial intelligence??

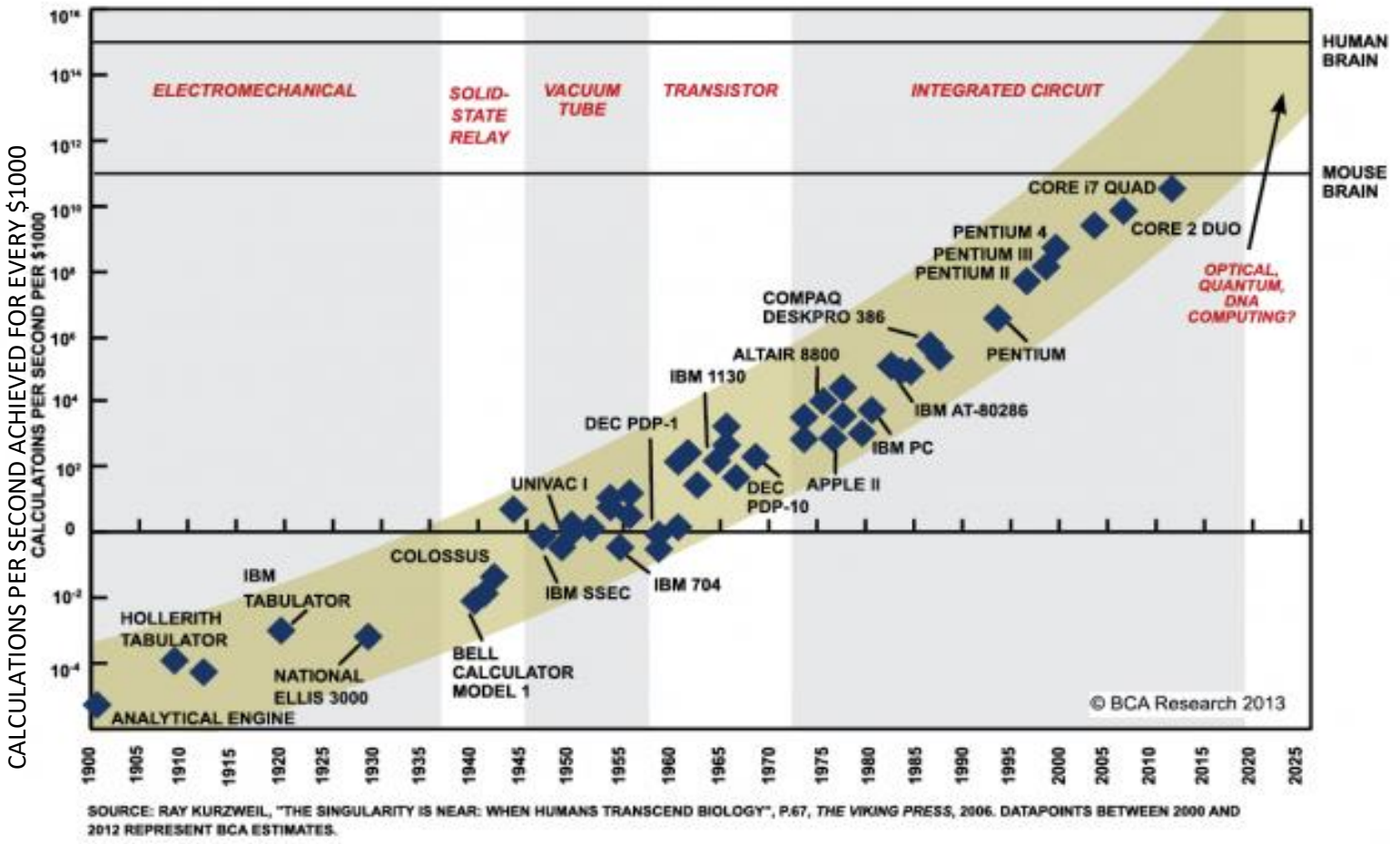


Financial instability??

Environmental disasters??

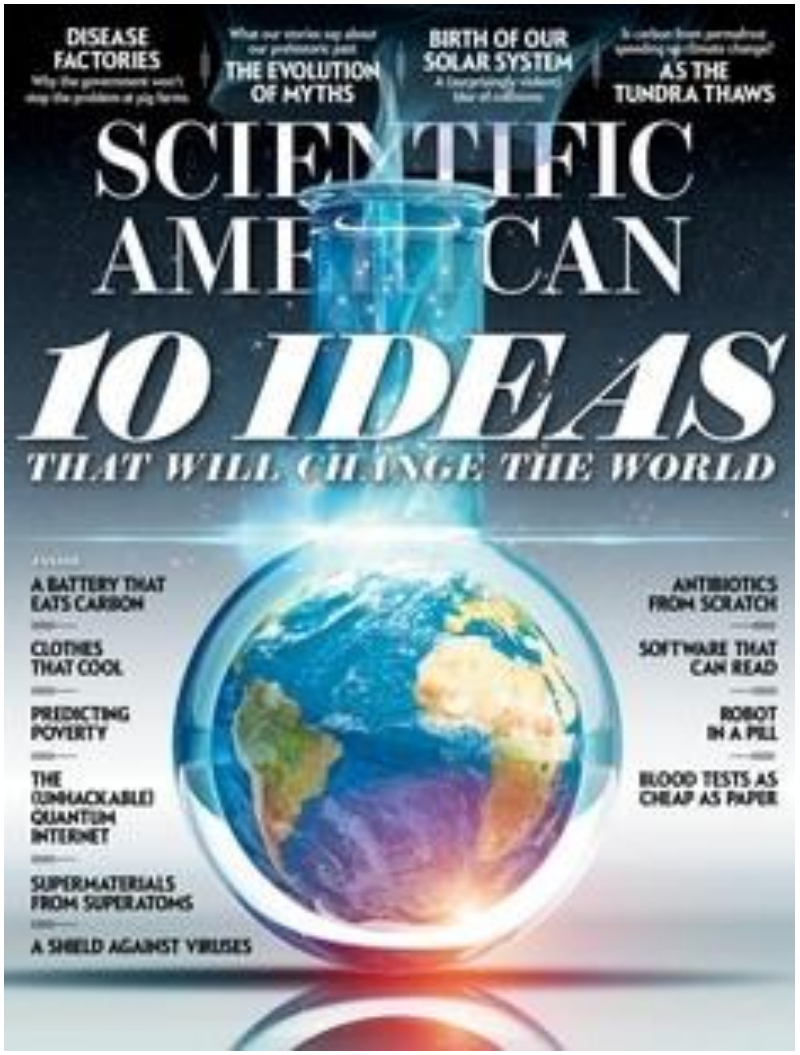
Helpful Technological Change

New materials, e.g. carbon nanotubes and graphene
Deployable and reconfigurable satellites with precise resolution
Massively increased computing power, particularly with quantum computing



SOURCE: RAY KURZWEIL, "THE SINGULARITY IS NEAR: WHEN HUMANS TRANSCEND BIOLOGY", P.67, *THE VIKING PRESS*, 2006. DATAPOINTS BETWEEN 2000 AND 2012 REPRESENT BCA ESTIMATES.

The state of the world in 2017



The 10 ideas…

Batteries that convert carbon dioxide
Novel antibiotics designed from first principle
Quantum satellites & an unhackable internet
Microscopic surgical robots
Machine learning software and satellite images
Cooling fabric made from battery material
A generic antiviral drug
Pattern-recognition advances in computers
Barefoot medical diagnostics
Supermolecules and new materials