Carbon vs Nuclear Energy

Comparative Large Scale Risks and Management by Market Instruments

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AMU

« Indian Point » : the Tradoff

Mr Cuomo's dilemma :

No nuke + no fracking = more coal burning

The NIMBY syndrome !

Nuclear and carbon risks cannot be dissociated when time comes for decision

Energy: Demand & Supply

First half of the 21st century

The demand side

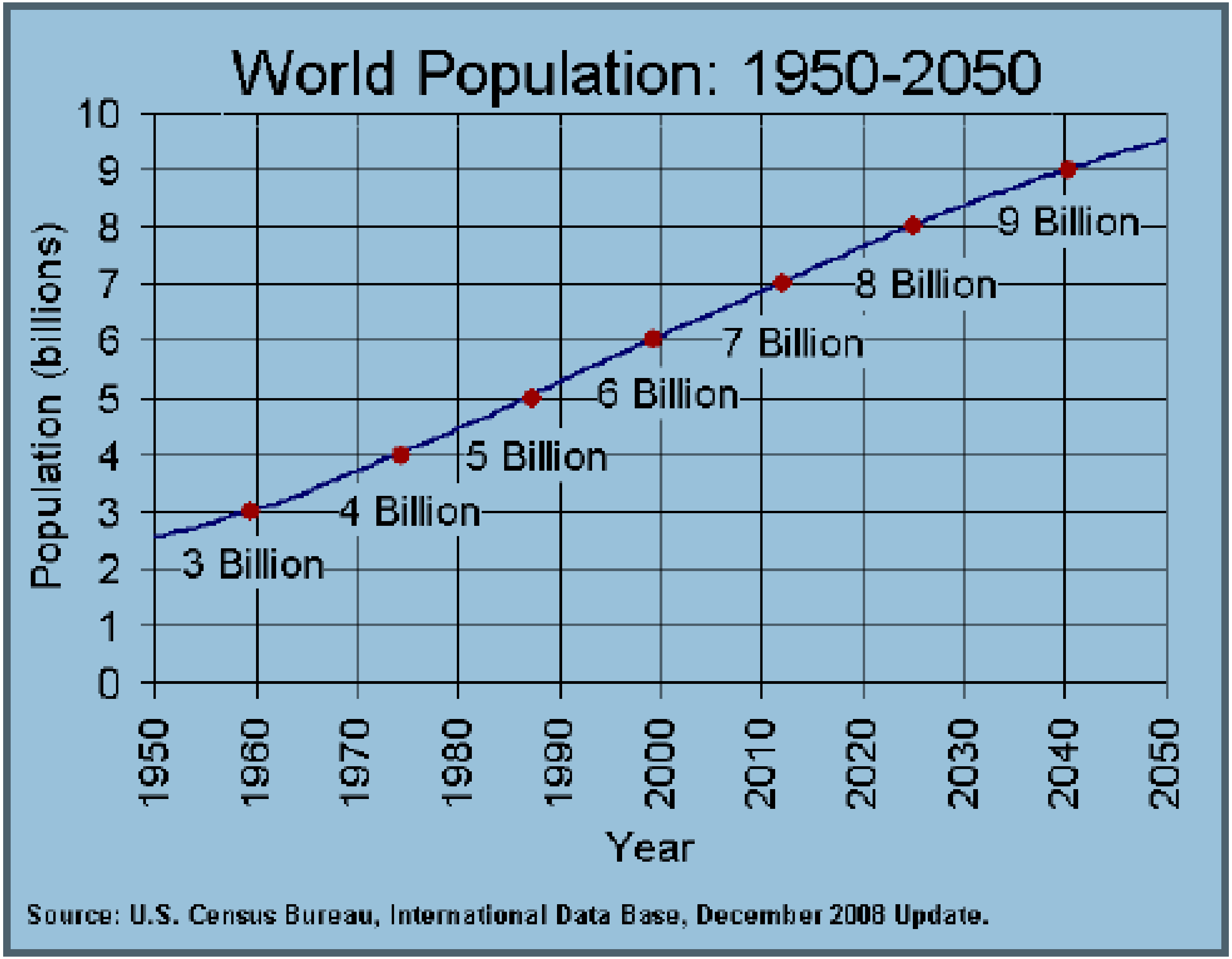
- demographic factors
- economic factors

The supply side

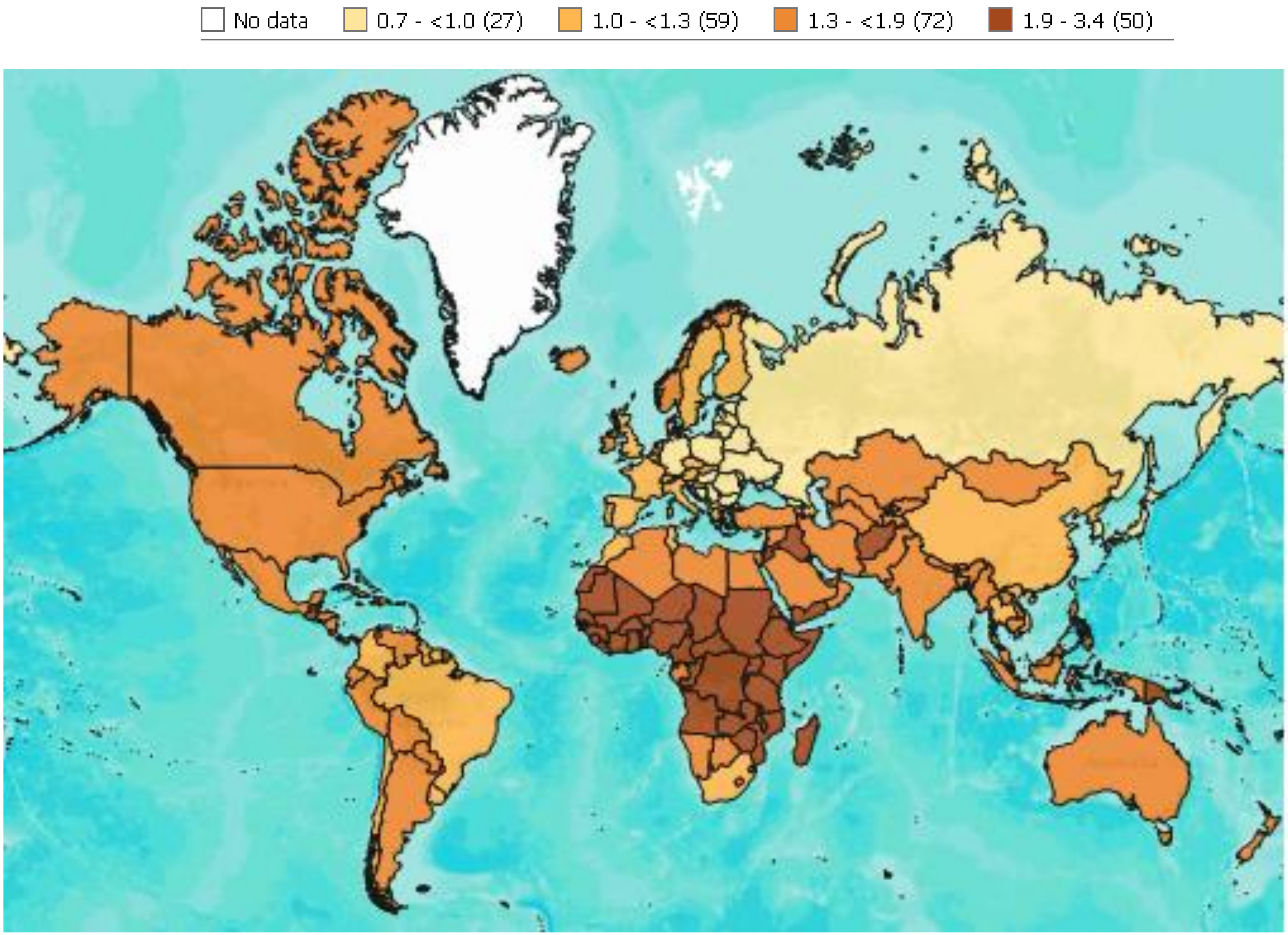
- energy production solutions
- energy efficiency

Long term prices variation : great uncertainty

No market for future energy

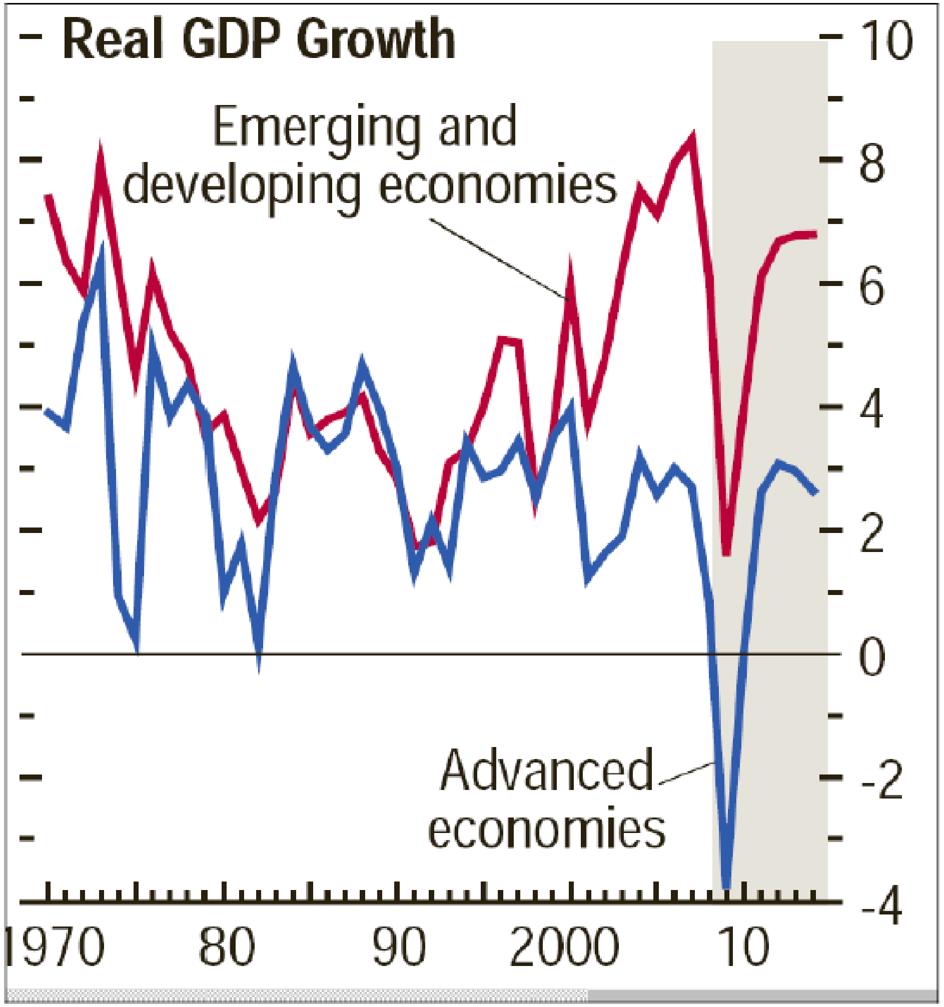

World Population: 1950-2050
Population (billions)
0
1
2
3
4
5
6
7
8
9
10
3 Billion
4 Billion
5 Billion
6 Billion
7 Billion
8 Billion
9 Billion
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
Year
Source: U.S. Census Bureau, International Data Base, December 2008 Update.

Population growth to 2050



Source:
PRB 2011
World Population
Data Sheet

Demand side: demographic and economic factors

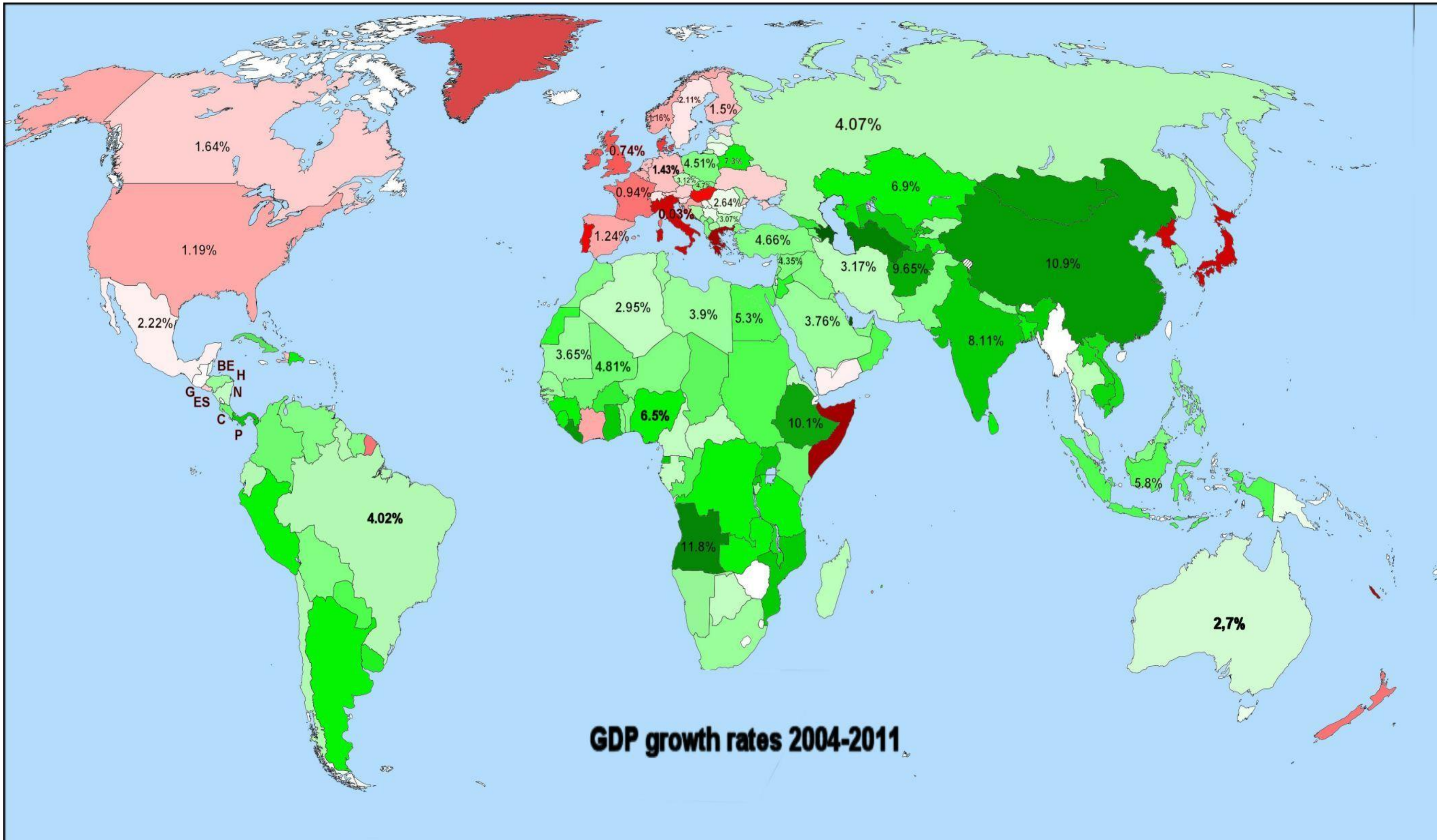


Source: International Monetary Fund (IMF), World Economic Outlook: Crises and Recovery, April, 2009

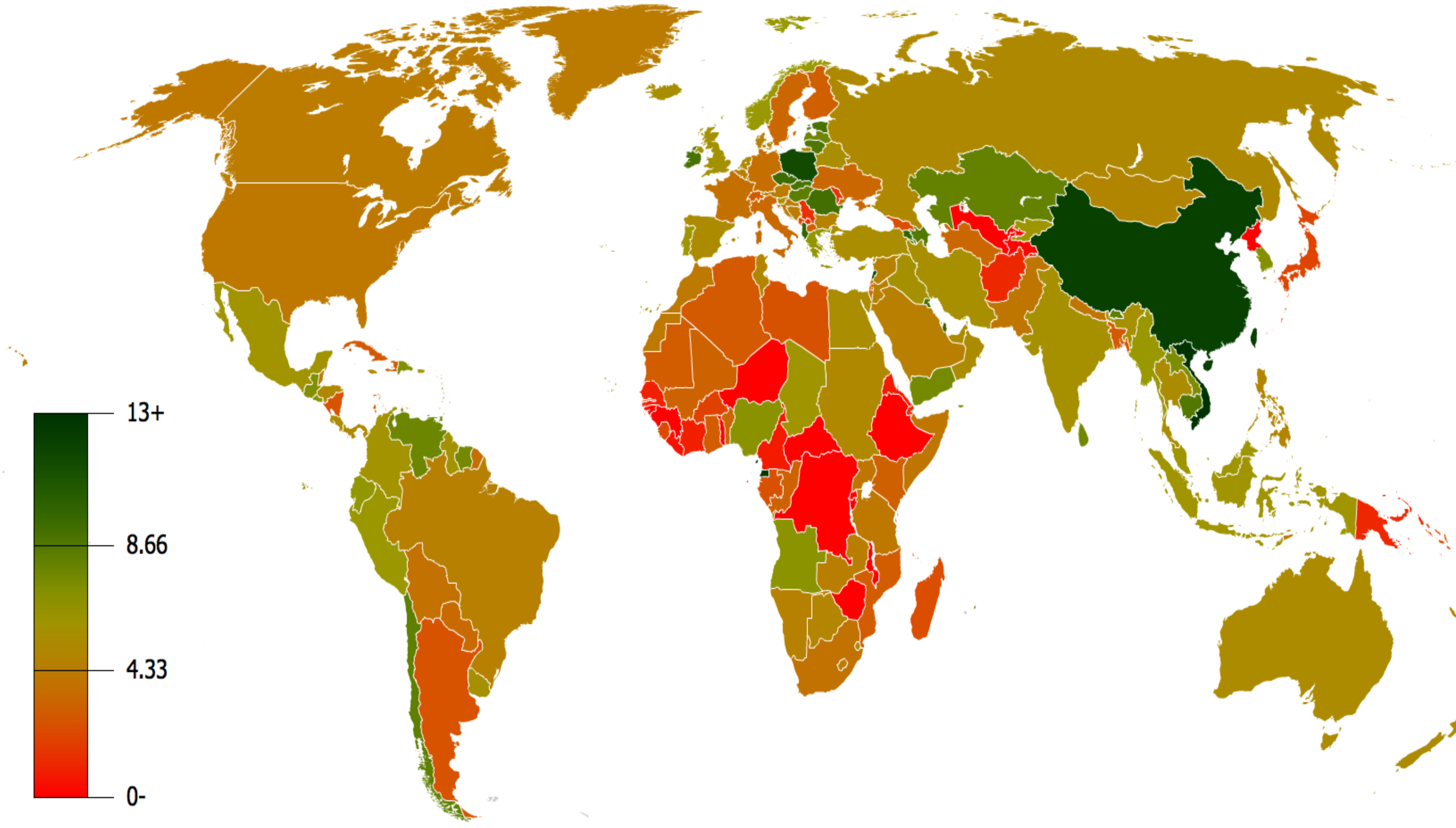
Global Picture of Growth

Source : map by PB from OECE data

Green light to dark : 3%-15%   pink to red : weak growth to recession



GDP per capita 1990-2007
(UN data)



Variations of CO_2 emissions 1990 – 2009

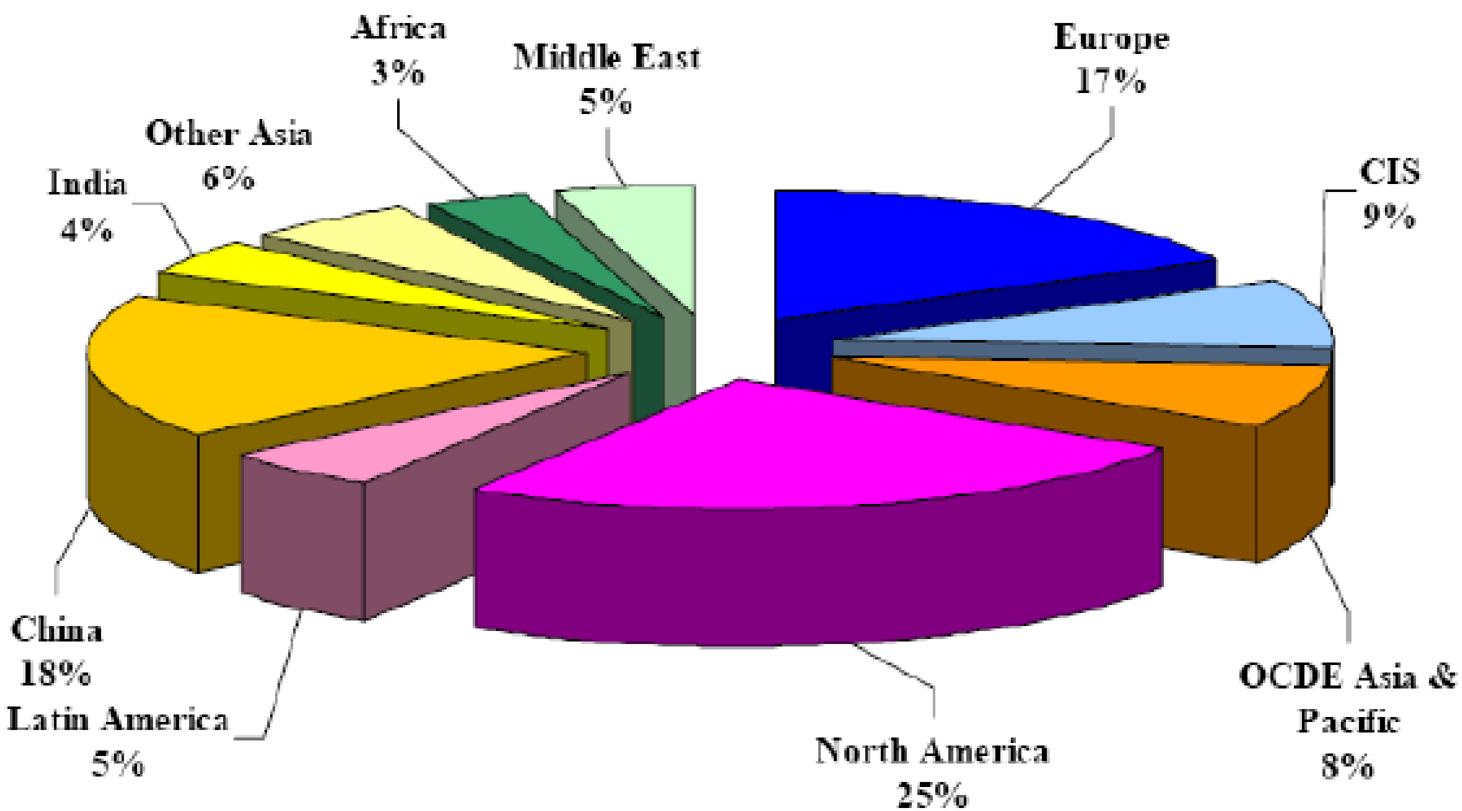
Strong relationship between growth and emissions

Kyoto targets -4,7%

Europe	-4.9%
Russia	-30%
North America	+20%
Usa	+6.7%
Canada	-6%
Africa	+70%
China	+206%
Asia –RPC	+144%
Middle East	+171%
Latin America	+63%

Source
TRENDS IN GLOBAL
CO_2 EMISSIONS
2012 report
Eu and netherland EAA

Distribution of CO^2 emissions from energy use 2006



Source: WEC, 2008-EE

Table 2.1: World Total Energy Consumption in 2005 and the three Scenarios for 2050 (Mtoe/yr)

	2005	Baseline	ACT Map	BLUE Map
Total end-use	7,748	15,683	12076	10553

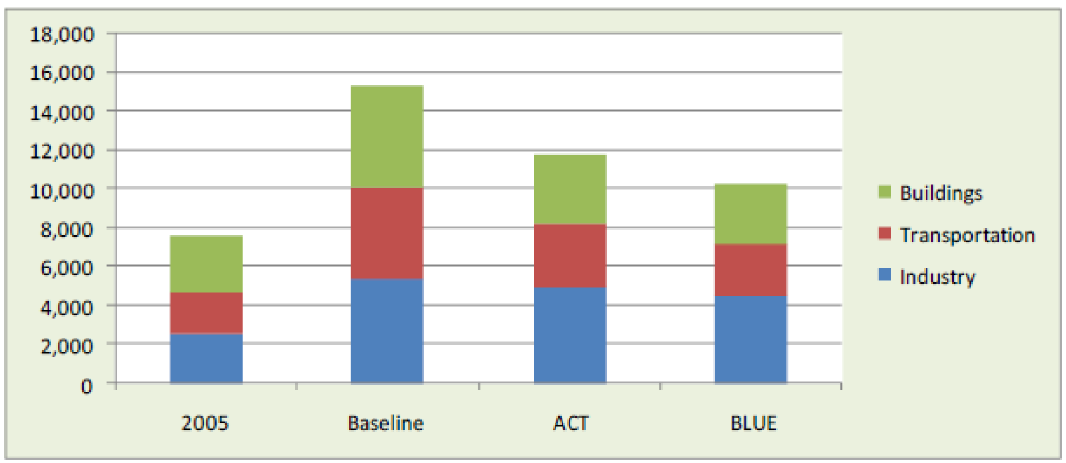
Table 2.2: World Energy Consumption growth rate (%/yr)

Sectors	Baseline	ACT Map	BLUE Map
Industry	1.7	1.5	1.3
Transportation	1.8	1.0	0.5
Buildings	1.3	0.4	0.2
Non-energy use	1.9	1.9	1.4
Total end-use	1.6	1.0	0.7

World Energy Scenarios to 2050
Hameed Nezhad
Metropolitan state university
Minneapolissept 2009

Energy demand will continue to grow in all sectors between now and 2050. The highest growth rate will be in transportation, followed by industry and buildings as shown in Figure 2.2.

Figures 2.2: Energy Consumption by Sector for 2005 and the three scenarios (Mtoe/yr)



Supply side

Coal
Oil
Biomass
Gaz

Carbon

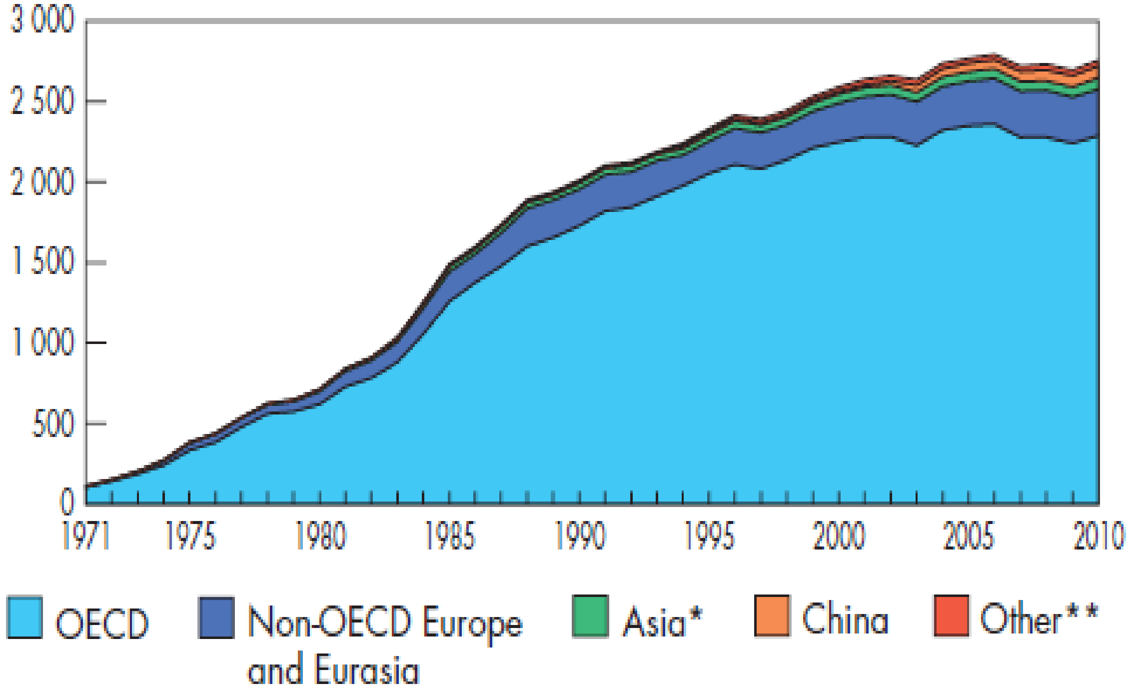
Nuclear

Strategic decision for several emerging and developed countries

Hydro
Wind
Solar
Geo
Tide
…

Nuclear Production

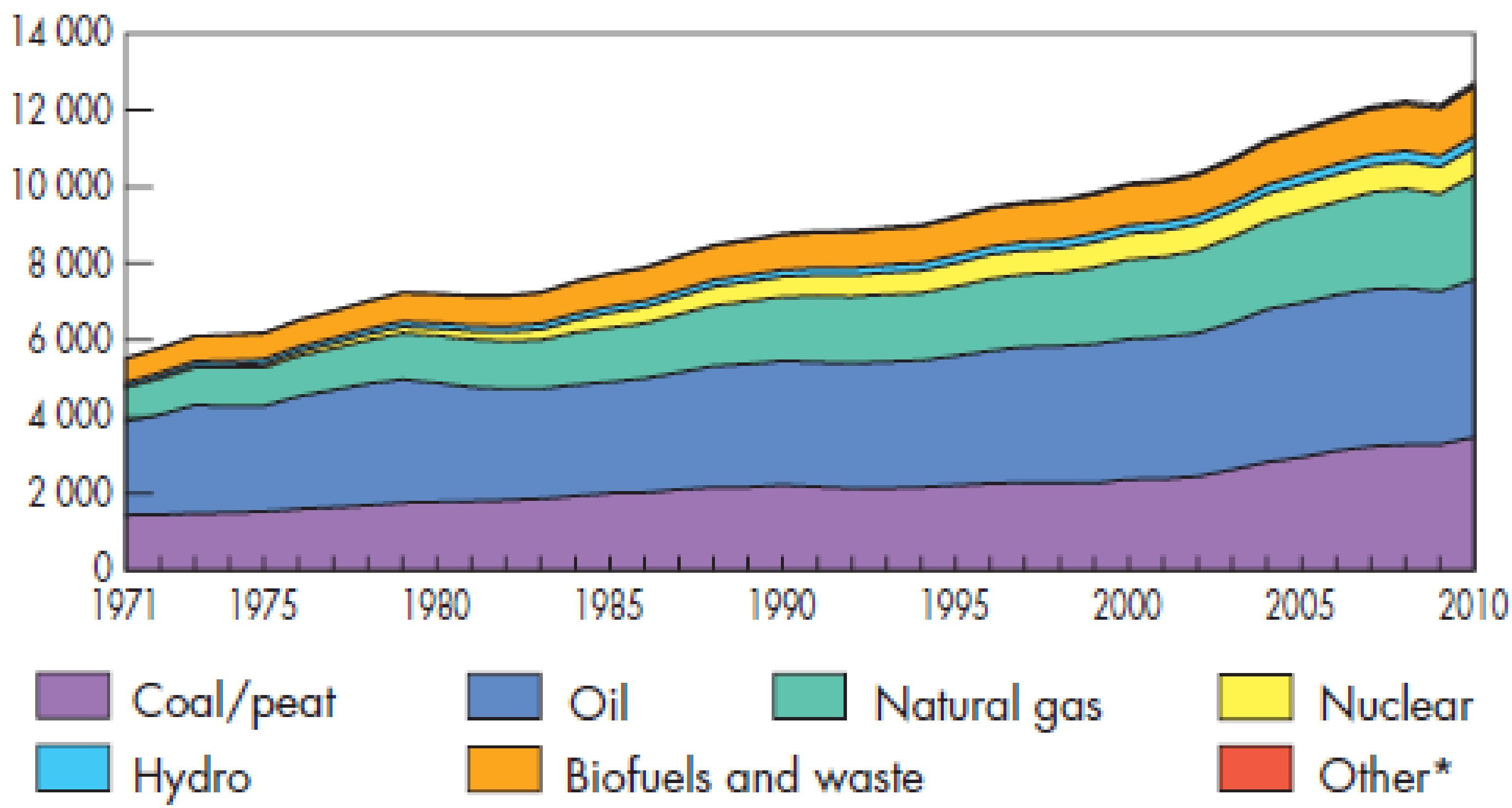
Nuclear production from 1971 to 2010
by region (TWh)



IEA 2012 World Energy Key Statistics

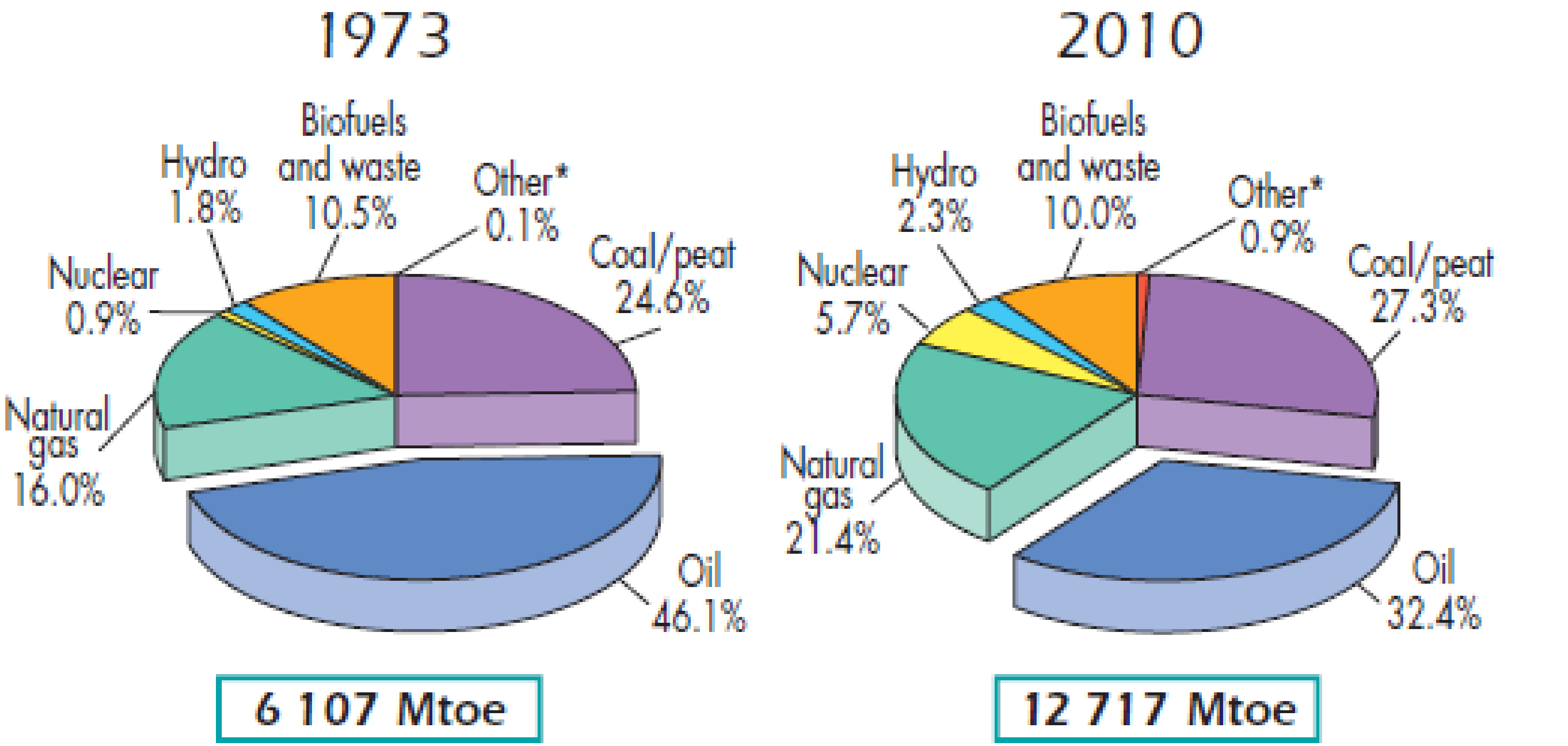
World

World total primary energy supply from 1971 to 2010 by fuel (Mtoe)

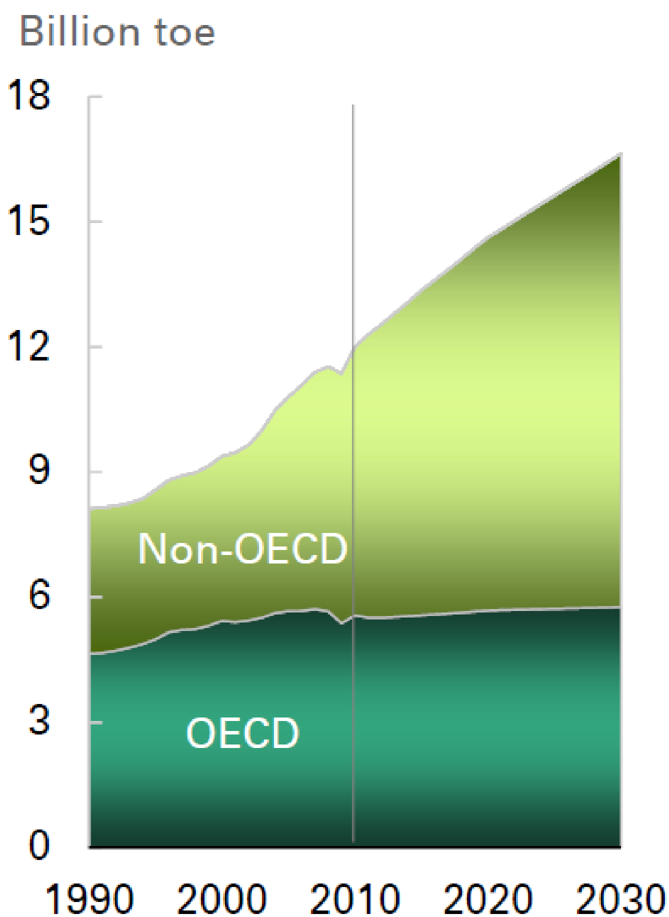


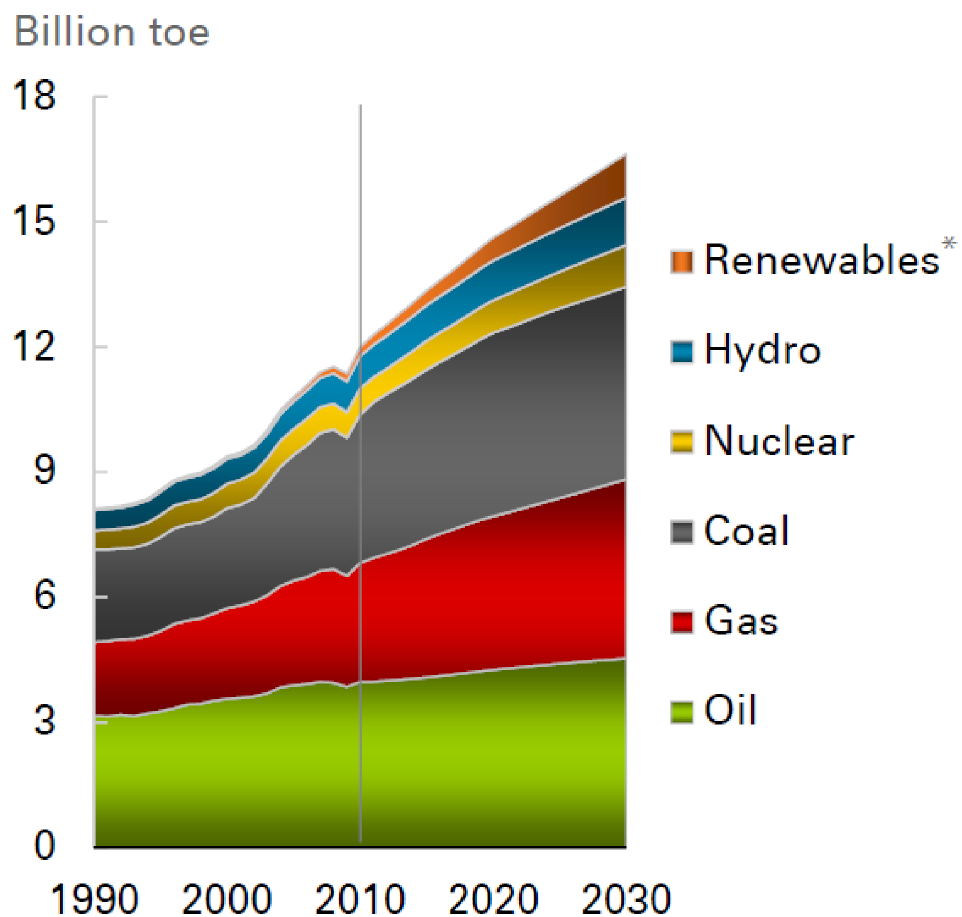
IEA 2012 World Energy Key Statistics

1973 and 2010 fuel shares of TPES



IEA 2012 World Energy Key Statistics

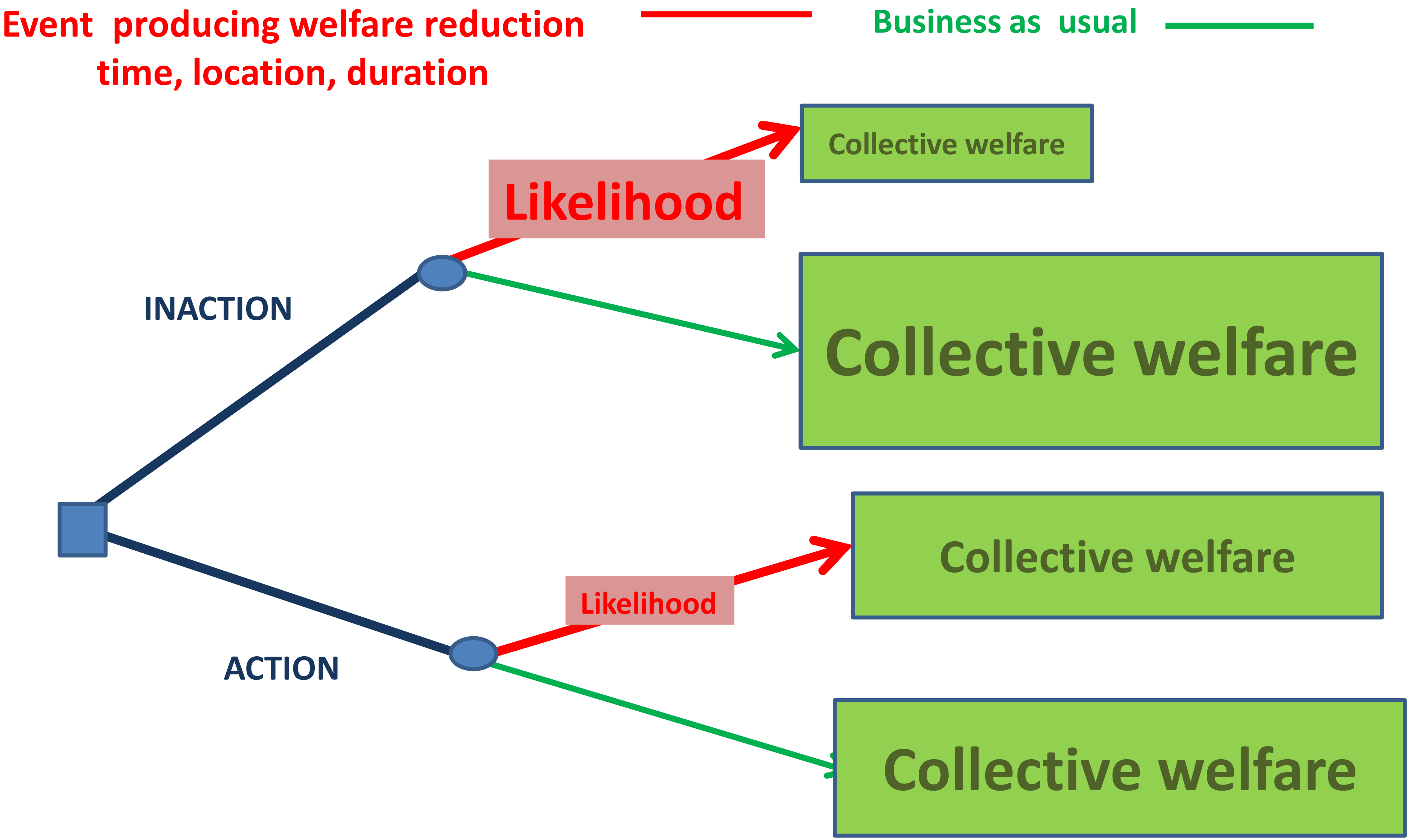




*Includes biofuels

Risk
Theoretical Background

Basic Risk Model



Measuring Welfare

1- Individual welfare

2- Aggregate welfare : Bentham's tradition (utilitarianism)

3 - Which welfare ? Present or future generations' welfare or mixture ?

Q: how to know welfare parameters of future generation?

Thesis A : we borrow the earth to our descendants and must redeem it in the state we have found it. (*Saint Exupery)*

Remark : we'll legate to our descendants <u>much more</u> than we have received and it has been the case of all generations for the last 300 years.

Thesis B : the cost of repairing the damages will be lighter for the future generation than it is for the present one. So the burden of the damage must be « shared » partly or postponed (e.g. why pay today for avoiding cancers in 30years if cancer is to be vainquished before that date?)

Thesis C : The planet deserves to be saved for itself (for its biodiversity) and not for mankind alone. What about living creatures' welfare ?

Assessing Likelihood

Uncertain worlds vs Probabilisable worlds

The founding arguments are in:

Frank Knight : *Risk Uncertainty and Profit (1921)*

(Knightian profit : premium for taking non insurable risks which is the case of the « entrepreneur »)

Uncertainty : no possible insurance

(Although many modern insurance contracts bear on events that Knight would have termed « uncertain »)

Decisions

- Assessing likehoods : questionning scientists and experts for improving the informational background of assessment

- Influencing significantly the likelihoods by monitoring the event-generating process : (technological advances and management system)

- Influencing the scope of damages : prevention

- Influencing people's welfare assessment: training people for resilience and adaptation

Quotations

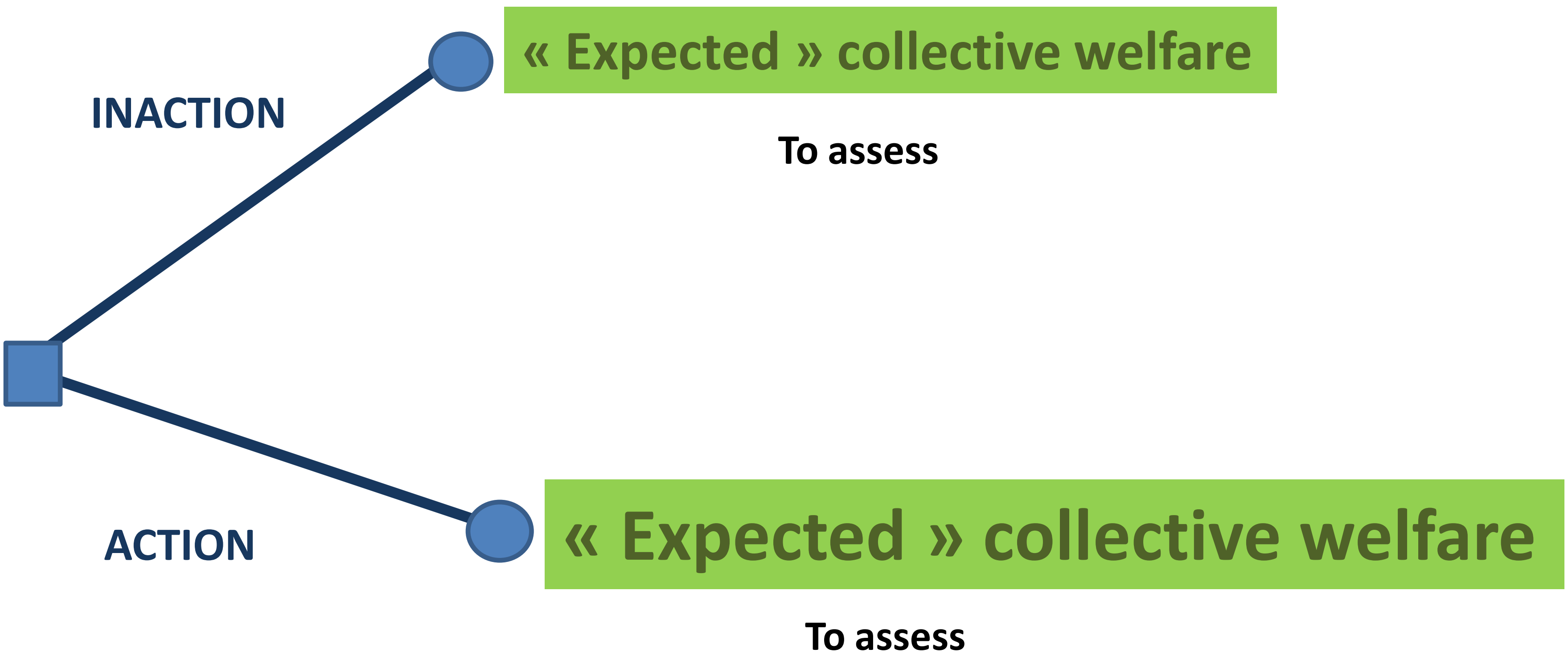
"Under uncertainty there is no scientific basis on which to form any calculable probability whatever…Nevertheless, the necessity for action and for decision compels us as practical men to do our best to overlook this awkward fact and to behave exactly as we should if we had behind us a good Benthamite calculation of a series of prospective advantages and disadvantages, each multiplied by its appropriate probability waiting to be summed."

(John Maynard Keynes, General Theory, 1937)

"It is the greatest happiness of the greatest number that is the measure of right and wrong"

(*Jeremy Bentham 1776, On Government*)

Decision under Uncertainty
Keynes & Bentham' heritage



Subjective Probability Tradition

Bernouilli (modelling risk aversion)
Keynes (use probabilities, utilities and compute expected values)
De Finetti (define subjective probability)
Savage (formal axiomatic of subjective probability)
Marschak (anotehr axiomatic)
Statistical decision theory s (e.g. Girschik) : the statistician is a decision maker who cannot dissociate statistical assessment from the cost of error, which is the usual « mistake » of the Fischerian statistics used by mots scientists)
Bayesian school : combining ex ante subjective probability with new data.

<u>All « real events » are assessed through subjective probability</u>

Subjective probability reflects the state of information
It is a combination of:

- **Knowledge of the event-generating model**
- **Information about its parameters**
- **(limited) statistical background**
- **Experience of the assessor**

Is tossing a coin a Bernouilli process with p=1/2 ?

If you were to use a sophisticated e and fast enough machine to capture the parameters of the trial, together witha good model of the dynamic of the throw, your subjective probability of « heads », before the coin reaches the ground, might become close to zero or one. The reason why you bet ½ usually is lack of information other than your statistical culture.

If you choose tails and you know that the coin is tossed by a smart crook, would you bet ½ ?

« Collective » Subjective Probability
Does it Make Sense?

- Wide dispersion of information among experts and scientists (Both in carbon and nuclear energy risks)

- Strong asymmetry of information, i.e. much disagreement about likelihoods

- Can we aggregate individual subjective probabilities ?

Auman's ghost looming around (Agreeing to Disagree 1972)

(Suppose you sell your Facebook stocks because you think they will ineluctably loose value, and you learn that your buyer is a prominent G&S trader with an MBA from Wharton, do you think you have got a good deal?)

But eventually, politicians and managers make decisions and we want them to be as « rational » as possible.

After Fukushima : Attitudes Revelation of Risk Assessments

The passive Bayesians: We have learnt « *a posteriori* » that nuke is more dangerous than « *a priori* » assessed. So let us stop it!

The active Bayesians: We know more about nuclear risk and this will allow us reducing it by technological advances. So let us increase ou efforts and investment!

The Markovians: the accident-generating process is markovian (no memory process). It is a Poisson process (possibly with non stationary lambda) and our engineers know its parameters. So Fukushima does not bring any new information and there is no new reason to stop.

Carbon and Nuclear Risk as Externalities

- A (negative) externality is an effect which you generate and which affects the welfare of other agents without having to pay a market price (because there is no market).

  It looks like a « free lunch » to the emittor of the externality
- When the consumption of a resource is market free, the resource is overexploited (*Harding : the tragedy of the commons*, 1966)
- Models : Harding, Prisoner's dilemma, Ostrom…
- Treating externalities

Carbon and nuclear emission of risk are externalities

Dealing with Externalities

- Regulation
- Taxation (à la Pigou!)
- Market systems for « internalizing » the externality
- Risk transfer (when the externality is a risk)

To date, the emission of « **carbon risk** » is much less « regulated, taxed or market-internalized» than the emission of « **nuclear risk** » (which is essentially « regulated »).

N.B. *You do not pay for the risk you place on future generations with the CO^2 of your car (I predict that ETS systems will be generalized before 2030 for individual cars and you'll have to buy permits if you want to trespass your allotment.)*

N.B. nuclear and carbon risks cannot be fully insured for several reasons : remote in time consequences, correlation of risks, scope of damages, moral hasard and informational asymmetries.

Carbon Risk

Factors of uncertainty

- about the scope of damages
- about the location of damages
- about the timing of damages

Main sources of information to assess risk

- Earth scientists (climate, ocean ...)
- Social scientists (economists, sociologists…)

Why ? because the event-generating process is guided by parameters that are essentially **publicly** observable

So « competitive » science can do its job without corset and according to scientific positivism and ethic, and independantly of vested interests.

Information Processing

- IPCC reports
- Stern’s report
- Efforts of probabilistic assessment

Stephen H. Schneider*†‡ and Michael D. Mastrandrea*, Probabilistic assessment of “dangerous” climate change and emissions pathways

*This contribution is part of the special series of Inaugural Articles by members of the National Academy of Sciences elected on April 30, 2002.

Nuclear Risk : Scope and Location of damages

Figure 12.1 • Nuclear reactor construction starts, 1951-2011

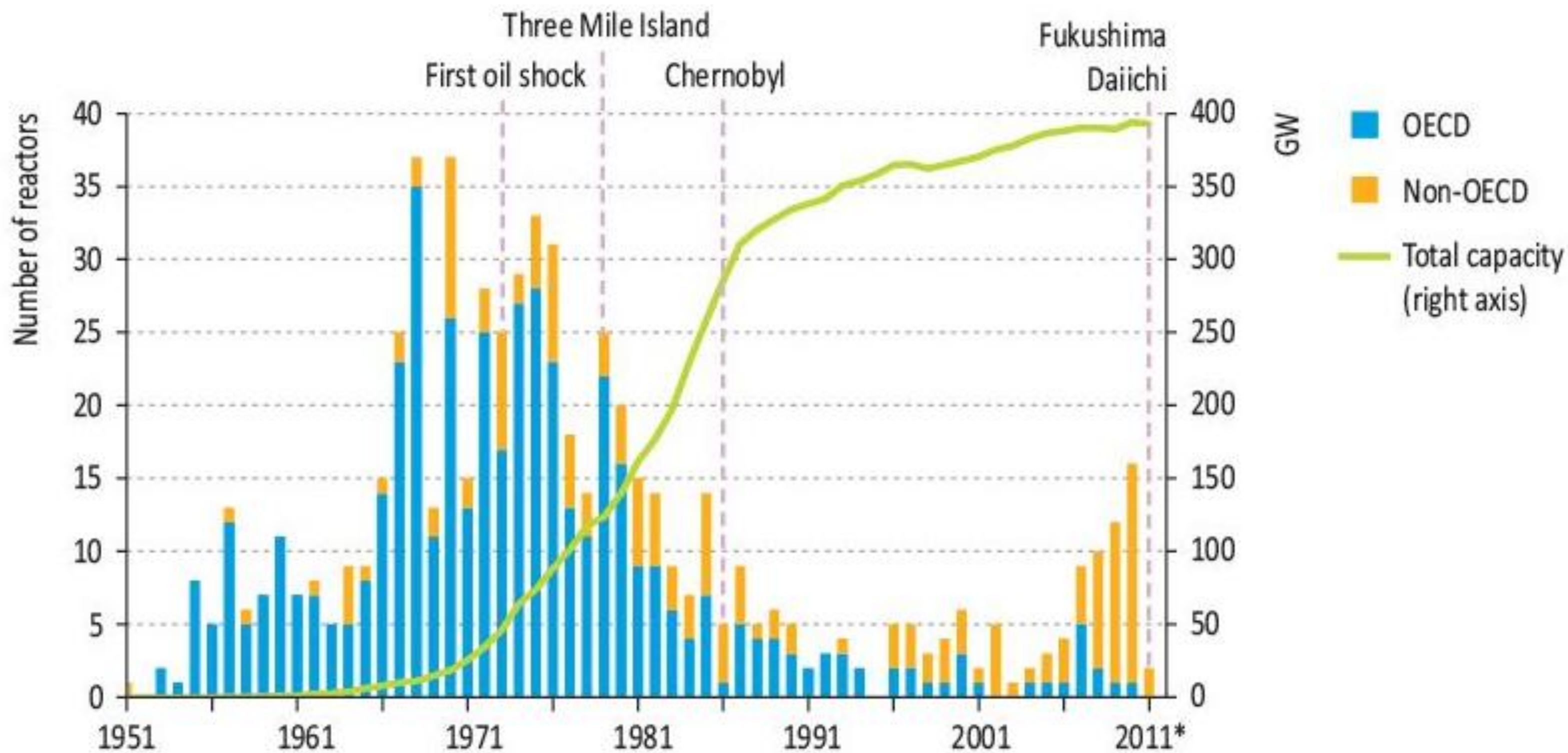
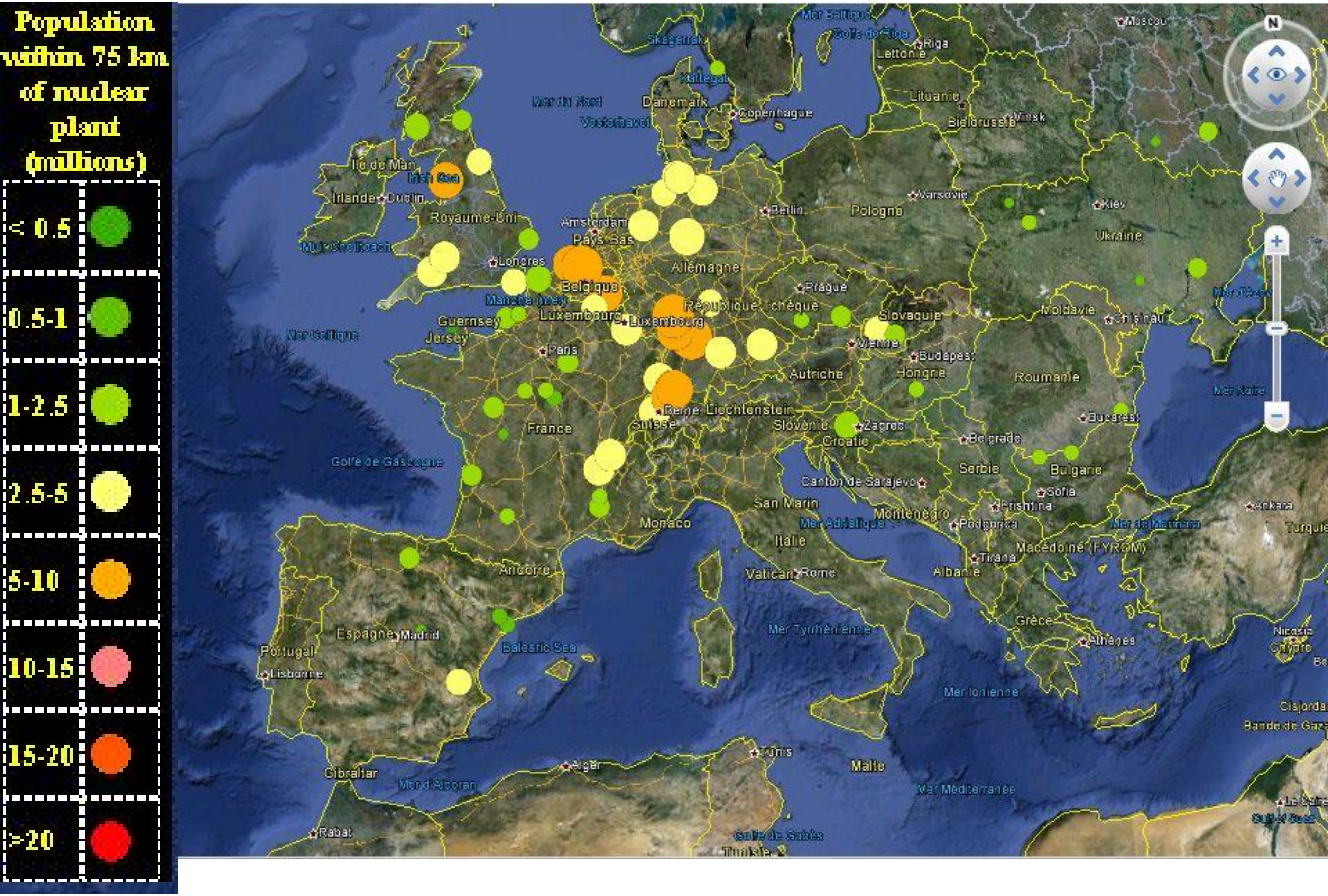


Table 12.1 • Key nuclear power statistics by region, end-2010

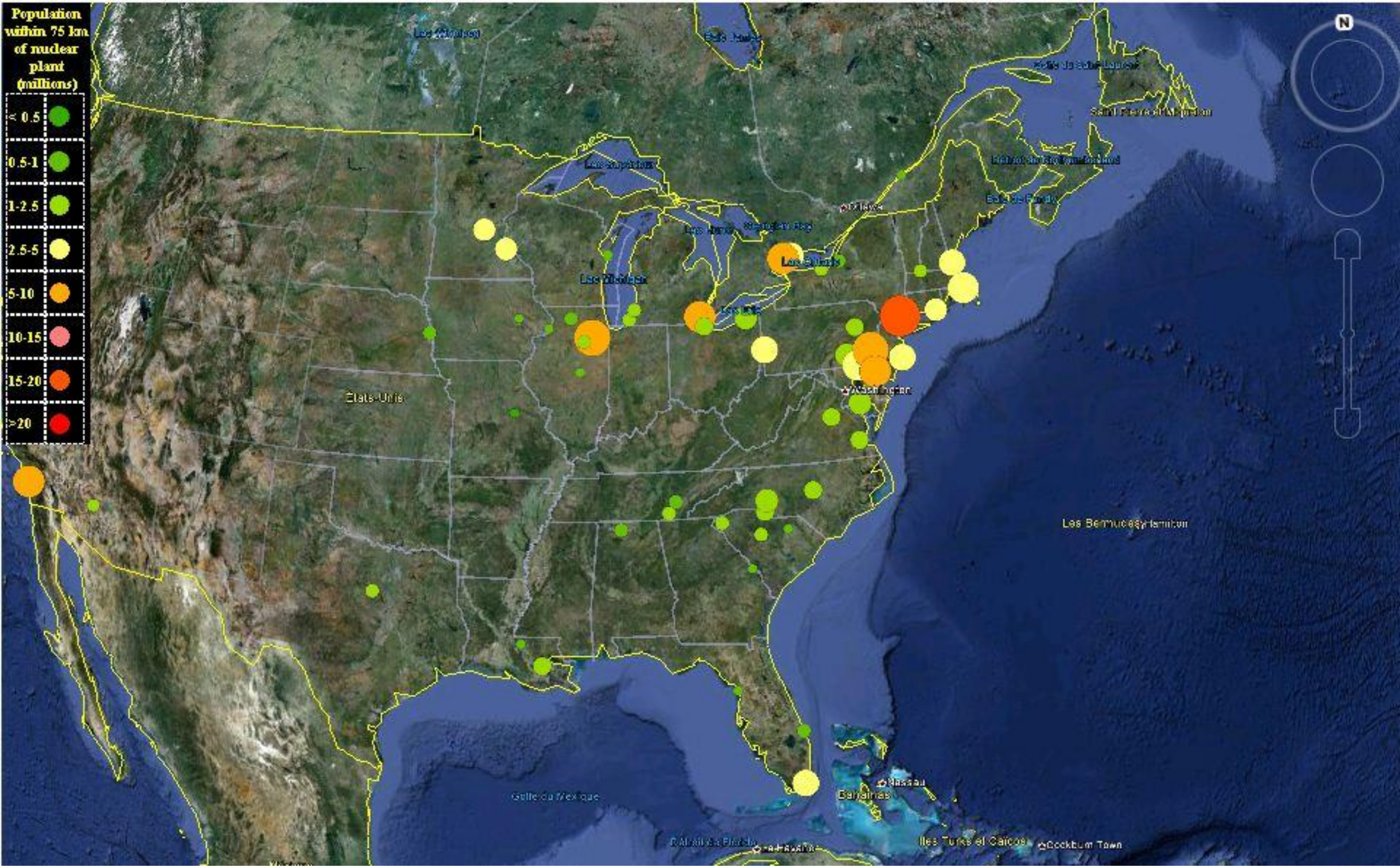
	Operational reactors	Installed gross capacity (GW)	Average fleet age (years)	Share of total generation	Reactors under construction
OECD	343	326	27	21%	12
United States	104	106	31	19%	1
France	58	66	25	75%	1
Japan	54	49	25	27%	2
Germany	17	21	28	23%	0
Korea	21	19	17	31%	5
Canada	18	13	26	15%	0
United Kingdom	19	11	29	16%	0
Other	52	40	28	24%	3
Non-OECD	98	68	21	4%	55
Russia	32	24	28	15%	11
Ukraine	15	14	22	48%	2
China	13	11	8	2%	28
India	19	5	17	3%	6
Other	19	14	24	9%	8
World	441	393*	26	13%	67

*393 GW of gross capacity is equivalent to 374 GW of net capacity.

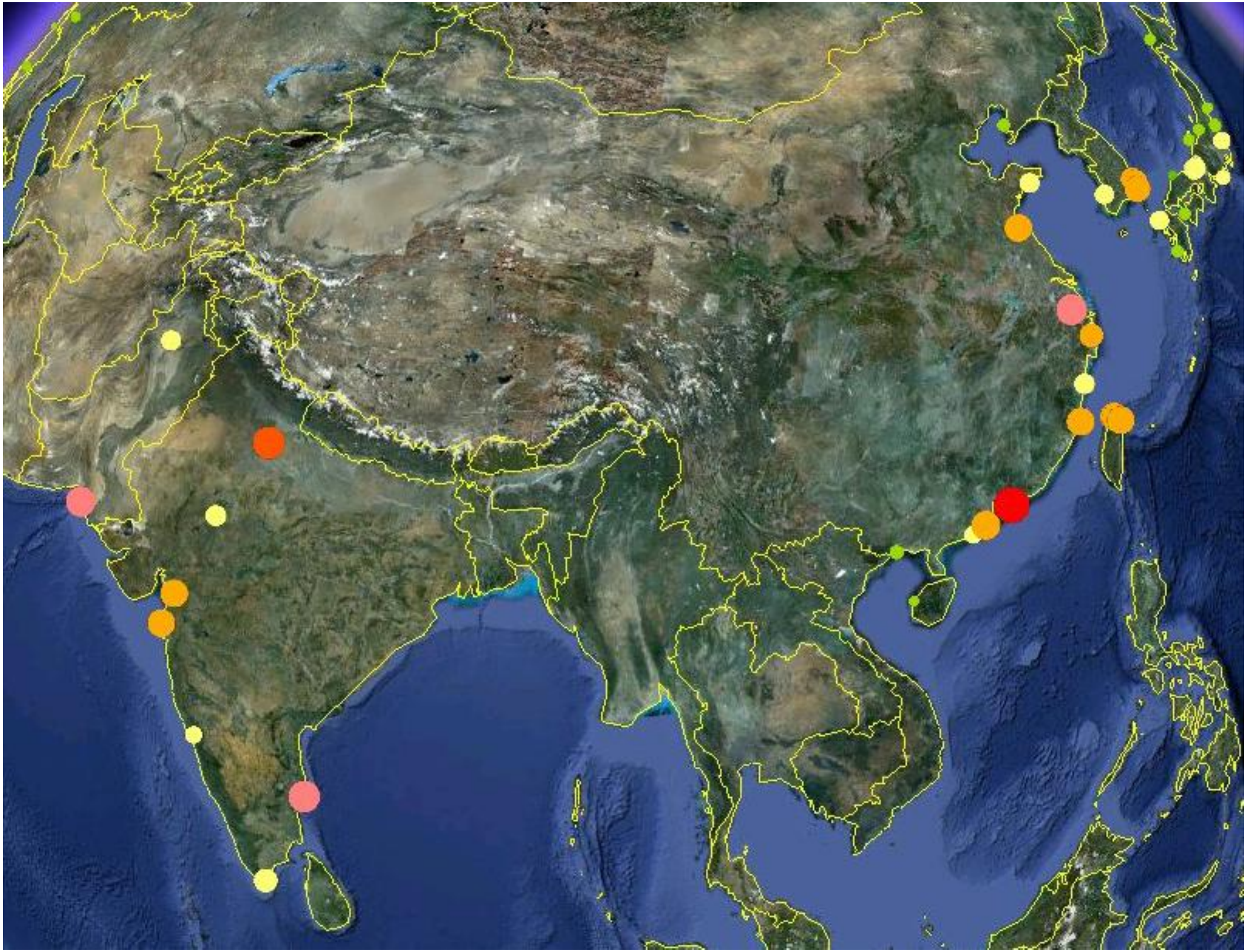
Sources: International Atomic Energy Agency Power Reactor Information System; IEA databases.



Google Earth



(Google Earth)



Google Earth)

French case

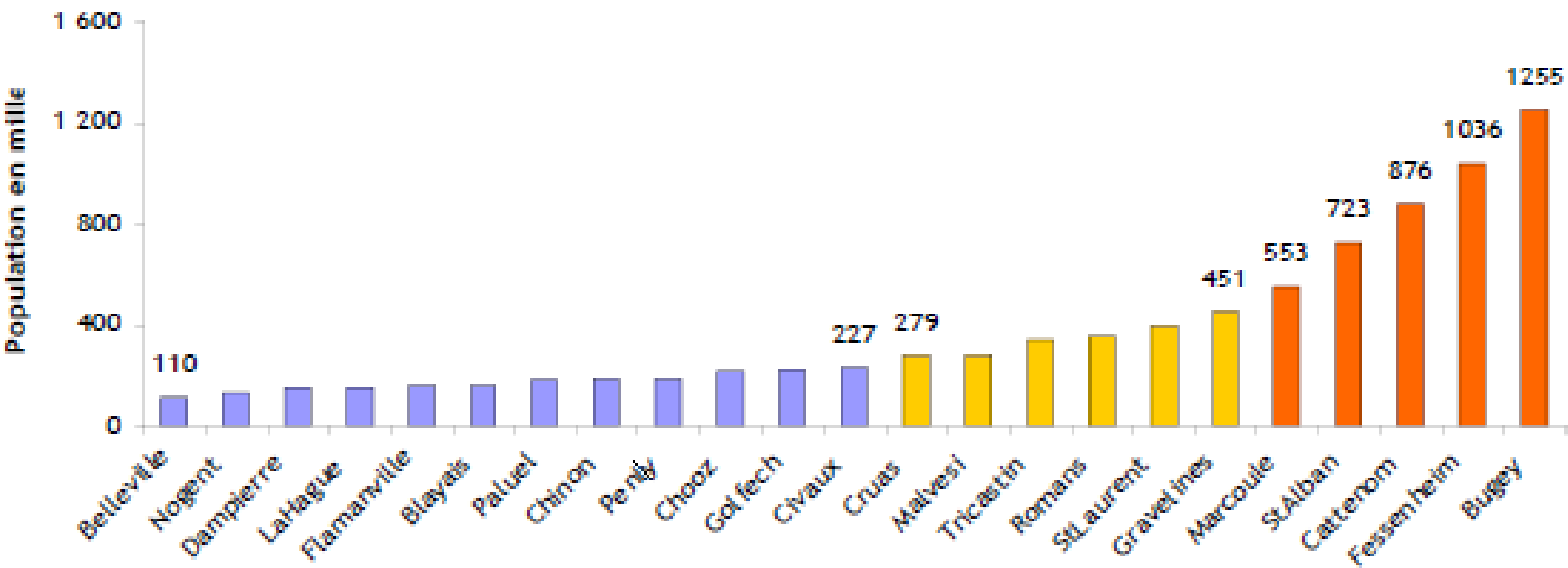


Figure 1 : Population dans un rayon de 30 km

Nuclear Risk : Features

-Localised source and diffusion with decay

-Heterogeneity of the source (the emittors use different technologies and different management systems)

-Secretive tradition (not separable from the dissemination issue and targets for big scale terrorism.)

-Proprietary (private or government owned) operations as source of risks (agency problem, moral hazard))

Central Issue : Information that Underlies Probabilistic Assessments

(my main point !)

The **main distinguishing feature** between carbon and nuclear risks for future generation dwells in the fact that the mechanism of carbon risk generation is ***exogenous*** **to the production of energy** and can be therefore assessed **outside the arena of vested interests** while the generation of nuclear risk is ***endogenous*** **to the production system** so that its assessment cannot be fully separated from this system since many relevant pieces of information underlying this assessment are in the hands of the operators themselves, i.e. **much more dependant on vested interests.**

Managing Nuclear Risk
French Principles

… Un cadre spécifique a été dessiné en s'appuyant sur les principes suivants :

- Cadre juridique supranational ;
- Canalisation de la responsabilité sur l'exploitant d'installation nucléaire ;
- Limitation du montant de la responsabilité de l'exploitant (comme contrepartie de la canalisation) ;
- Garanties financières apportées par le biais d'une collaboration public-privé ;
-Création d'organismes **spécifiques et indépendants** pour mesurer et auditer les risques.
 (N.D.L: *Yes but relying on information provided by the operators i.e. agency problem and moral hasard at work*)

Ainsi, le dispositif de gestion des risques apparaît fort et cohérent, et beaucoup pensent qu'il figure une sorte de modèle pour la gestion des risques complexes, qu'ils soient industriels ou financiers.

Gilles Bénéplanc

Risques n° 86 / juin 2011 - Rubrique Risques et solutions

Managing Carbon Risk through Market Systems

Trade markets for emission permits

-Pollutants
-CO^2

Why CO^2 ? Because of a scientific consensus on CO^2 volume of emission as an accurate **« proxy »** for assessing carbon risks for future generations.
CO^2 by itself is not the problem, but the chain of well studied phenomena which link carbon dioxide to climate change and human consequences.

Europe : the Emission Trade System : restricted to « industry»
China : a system of permits as of 2013
America : Obama's move towards more environmental concerns
may be an ETS before the end of the mandate

Extension of market systems to transportation and building before 2025

ETS
N. Stern's Perspective

UK economist Sir Nicholas Stern's review of the economic impact of climate change has a stark and simple conclusion: action to tackle climate change might be expensive, but not as expensive as suffering the consequences. Mr Stern concludes that tackling climate change and limiting <u>CO_2 in the atmosphere to less than 550ppm will cost 1% of the world's GDP, but allowing CO_2 to rise above this level will be far more expensive - up to 20% of world GDP.</u>

Refreshingly, Mr Stern also sets out a vision of how the world tackles climate change from an economic perspective. A key leg of his strategy is to develop a global, liquid traded market for carbon**<u>. He also forecasts a price of $85/tonne as able to drive investment in low-carbon infrastructure by pricing carbon-intensive infrastructure out of the market. He cites the EU Emissions Trading Scheme (ETS)</u>** - along with other carbon trading schemes such as the soon-to-begin Regional Greenhouse Gas Initiative in the Northeast US - as providing the starting point for a global carbon market. **Currently, the EU ETS is not liquid, and is highly volatile and low in price – presently around E11/tonne.**

According to analysts from Deutsche Bank**, EU CO2 allowance (EUA) prices could fall below €5 per ton** if the set aside proposal is not agreed between EU law makers. Indeed, at the beginning of the month, **prices fell to €6.14,** prompting calls from Members of the European Parliament for the EU to intervene and **reduce the supply of carbon allowances**. Further to this, Gunther Oettinger, the EU's Energy Commissioner publicly announced, at a European Wind Energy Association conference, that the European Commission needs to prepare a proposal **to drive EUA prices up and encourage investment,** as requested by the Parliament.

Statement by Commissioner Hedegaard
IETA press release June 2012

Market System for Nuclear Risks

Three different but related questions:

1) Is it possible to design tradable instruments which would provide a more independant and aggregate assessment of nuclear risk (at the plant level as well as at the national and global level) ?

2) Is it possible to design tradable instruments which allow an efficient allocation of risks, given the huge amount of damages incurred in a highly asymmetric way by diverse populations.

3) Is it possible to design tradable instruments which induce operators to invest more in safety, together with reducing the global emission of risks ?

Risk Assessment through Financial Instruments

Remark : financial markets provide an assessment of the risk of default by a government via the spread required on government debt. This assessment is <u>*independant*</u> *of the action of governments since they cannot draw directly on the central bank to reduce the spread (at the expense of future inflationary risks.)*

My model (in progress) : Consider a (public) entity issuing **« perpepuities »** (infinite duration, similar to stocks) with **annual coupon C** and the condition that **in case of a nuclear accident (single plant in a simple model) the fund is cancelled and the proceeds serve for compensating the victims of the disaste*r***

Technically, this can be done via **a « closed-end » fund** which invest the proceeds of the issuance in a portfolio of « low risk » bonds (OAT, Long term G-bonds…)
The issuance method is **by auction** and a price **P°** is formed.
Next the instruments are traded on a continuously quoted market. Since the value of the **portfolio B** can be known at evert quotation day t**, the spread Pt – Bt** is known (it can be either a discount or a premium depending on whether Pt is larger than Bt or the reverse). The time series will serve as background information for assessing nuclear risk, its evolution , and its price.

N.B A coupon is not necessary but the risk of financial bubble is higher without it)

2) Risk transfer

The previous system provides part of the solution to question 2 since the burden of the risk is transfered to investor who make free decisions to bear the risk. It provide also a partial solution for financing the compensation of the damages.

3) Monitoring the emission of nuclear risks

The issue here is more complicated because of the absence of a **clear « proxy »** (i.e. an observable and verifiable indicator) which can be related through models to nuclear risk variation. The output of the previous market could serve as a benchmark for authorities to determine the total amount of permits to issue. However determining the maximum allowances for each plant would again rely on proprietary information.

Conclusion

Need for research : (liquidity, volatility, portfolio effects, diversification)

- Modelisation of markets to deal with nuclear risks

- Simulation

- Experimentation

voila