Can we recycle CO_2? Technical considerations

Alain Bucaille (AREVA)

Jordan, Sharing Knowledge across the Mediterranean

March 1-3, 2010

AREVA

Coal and nuclear: the two main solutions for baseload electricity

- **Base-load electricity (production twenty four hours a day) is often confused with other types of electricity. It is not possible to generate this electricity from intermittent sources (there is no sunshine at night, there is not wind every day).**

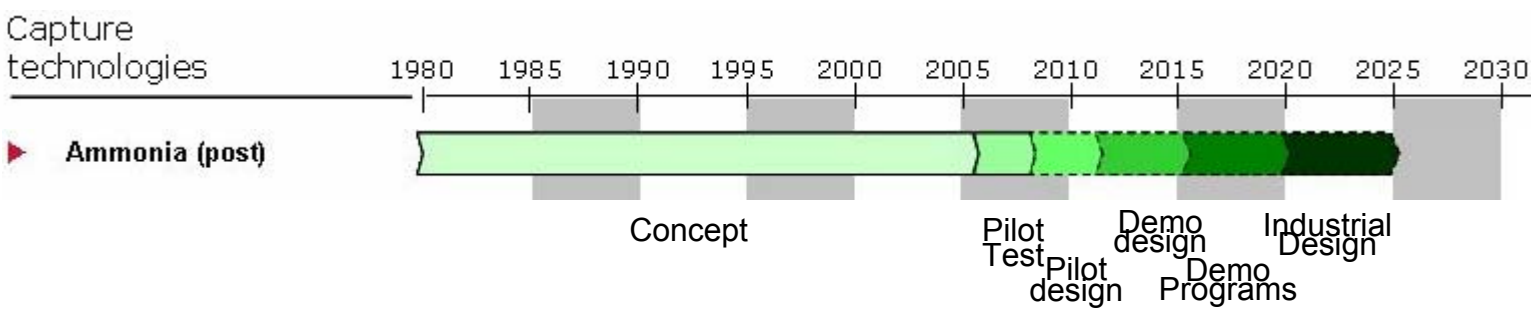
- **As far as reserves are concerned, for the top 50 or 60 economic powers in the world, the choice for base-load electricity comes down to coal or nuclear.**

- **…. And we will need all we can get.**

- **Only countries which enjoy a lot of sunshine and where the available space is big or endowed with a lot of hydraulic will be able to avoid this dualistic choice.**

CCS, a question of timing and a matter of costs

- Capture and CO_2 storage is one of the possible and feasible technology to reduce CO_2 emissions on a long term perspective. However, industries studying these technologies do not forecast significant deployment before 2025 and describe technologies that still need validation.
- The impact of the CCS is virtually nonexistent before 2025 and CCS coupled with coal power plants would avoid less than 20% of CO_2 emissions in 2035.
- Finally, CCS is expensive (over 100 €/t of CO_2 in future demonstrations, 80 €/t of CO_2 later?) and negatively impact the performance of coal power plants



AREVA

Difference in between continents

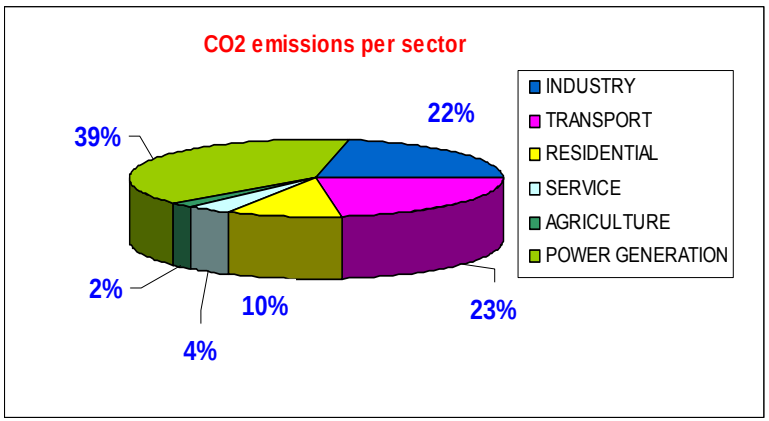
- If North America has plenty of potential sites, if Europe has many geological potential but an urban, agricultural, tourism geography, the situation is more difficult for Asia which is in a very different position.
- CCS is impossible in Japan on the islands, it would be excessively costly in the oceans.
- In India, all around the continent, the seismicity is unfavorable, inside the continent it is more feasible.
- Finally, in China, there where it is economically feasible, the country is not half "economically developed".
- Whatever the progress of the CCS technology, Asia will therefore not consider it as a universal solution.

Why considering the CO_2 issue?

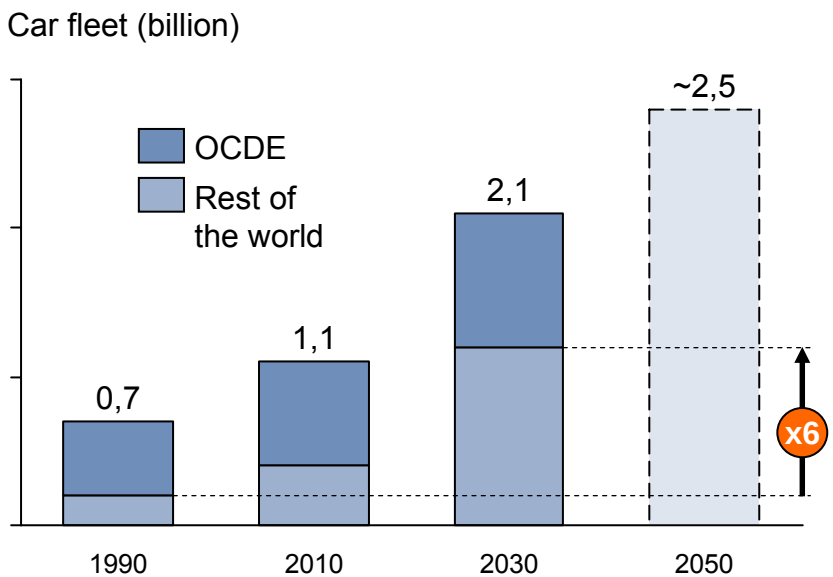
Strong energetic and environmental constraints for car and oil industries

Transport sector is the second largest emitter of CO_2 behind the sector of power generation

- **23% of CO_2 emissions in the world and ~ 30% in OECD**



Car fleet multiplied ~2,5 between 2010 and 2050



The worldwide car fleet growth is driven by developing countries growth

The decarbonization of the transport sector is a key issue to mitigate climate change

AREVA

Self-understanding figures

- **For cars**
  - **7 liters per 100 km**
  - **15 000 km/year**
  - **1,5 billions of car potentially in ~2025 (0,8 today)**
  - **~ 4 Gt of CO_2 emissions per year**
- **For planes**
  - **If the whole CO_2 produced by today's cement plants was recycled into kerosene, the current consumption of the existing plane fleet could be largely covered for less than 30% extra cost to air transport consumers.**

The specific aviation dilemma

- **Strong growth to be anticipated with the emerging countries growth**
- **Aviation requires high energy density and easy handling fuels. There is no match for liquid fuel such as kerosene.**
- **Such CO_2 free kerosene (-CH_2- chain) is indeed feasible if**
  - **Its carbon is taken from renewable biomass while the hydrogen is provided both by the biomass and water electrolysis powered by CO_2 free electricity (Hydraulic, Nuclear, Renewable)**
  - **The CO_2 released during engine operation contains the same CO_2 that was synthesized into biomass during the photosynthesis.**

Mastering the CO_2 releases

- **A) Avoid use of fossil fuels when substitutes exist:**
  - **Maximize use of hydraulic resources**
  - **Use nuclear for electricity or process heat where it makes sense**
  - **Use renewable biomass resources**
- **B) Where fossil use is unavoidable :**
  - **Optimize its efficient use**
  - **Consider Capture and Storage of CO_2 where convenient**
  - **Alternatively consider recycling CO_2 into useful products such as methanol which is at the basis of numerous chemicals**
- **C) Where fossil material is converted:**
  - **Optimize its conversion yield, usually with externally provided H_2 from electrolysis, so that all carbon molecules end up into the final product, not in CO_2 in the conversion process**

An alternative that is still underestimated

Until now, we have only considered eliminating CO_2 by capture and storage deep underground.

However, today we see the possibility of transforming it into oil using electricity, with the mass-production of hydrogen.

The critical path is as follows:

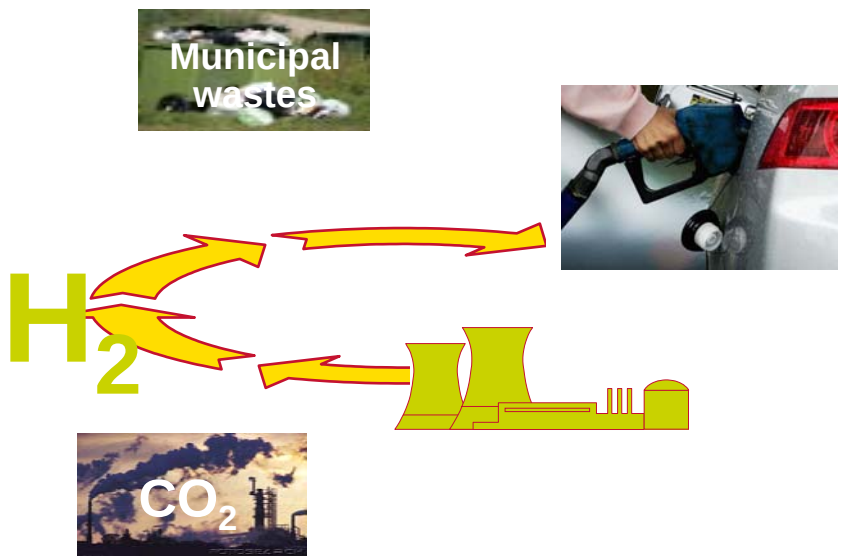
CO_2 + H_2 + electricity ➔ CO + H_2 ➔ C_8 H_{18} (gasoline)

Patents are being filed for this, which leads us to believe that such a transformation could be achieved at a cost of around $150 per barrel, if it is to take place using nuclear power during off-peak times, and considering a monetary rate of less than 5%.

Carbon-based materials are numerous

- **Biomass, indeed**
- **But also:**
  - **Municipal wastes without halogens heavy metals**
  - **And naturally CO_2!**

~22 kg H_2/bbl



~55 kg H_2/bbl

AREVA

This is worth it!

- For synthetic fuels production (kerosene $C_{10}H_{22}$ to $C_{14}H_{30}$, diesel $C_{16}H_{34}$, gazoline C_8H_{18}, DME CH_3-O-CH_3, methanol CH_3OH)
- For gas production (methane CH_4)

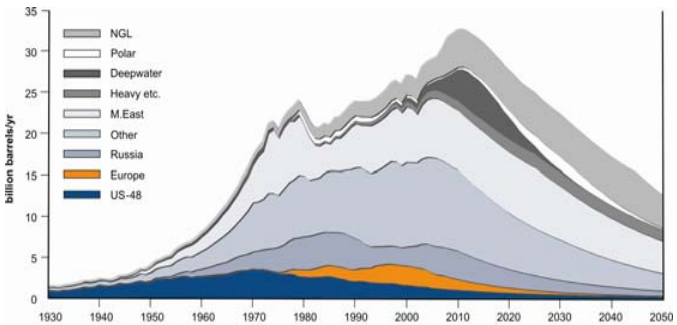
- And at a price between $150 and $200 per barrel

AREVA

Fossil fuel reserves and price uncertainty open a door to alternative fuels?

Fossil fuels are becoming scarce

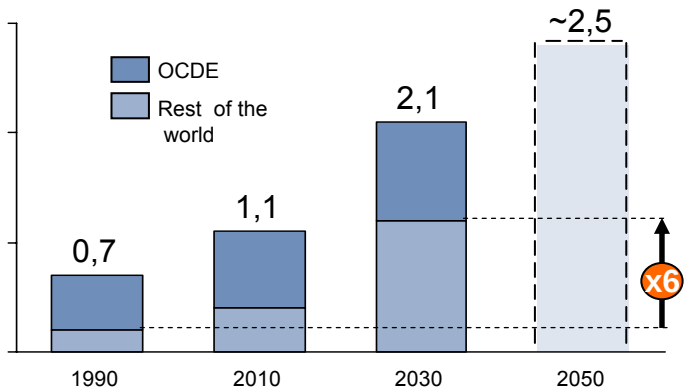
Production de gaz et pétrole (Gboe/an)



"The globe will see oil production peak in 2020 about a decade earlier than most official government predictions[1]"

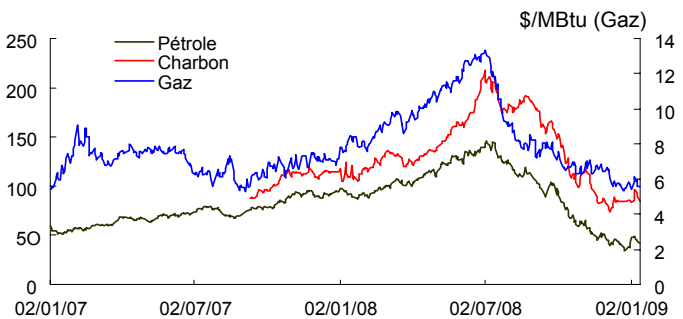
Car fleet multiplied ~2,5 between 2010 and 2050

Car fleet (Billion)



Prices are becoming volatile

$/t, $/bl



Alternative fuels offer a solution to cope with growing demand and with environmental constraints

[1] **August 2009 – Birol : Chief Economist IEA**

Sources slide: Association Study of Peak Oil & Gas, 2007 et BP statistical review 2008

AREVA

Lets focus : a classical CtL Plant (1/6)

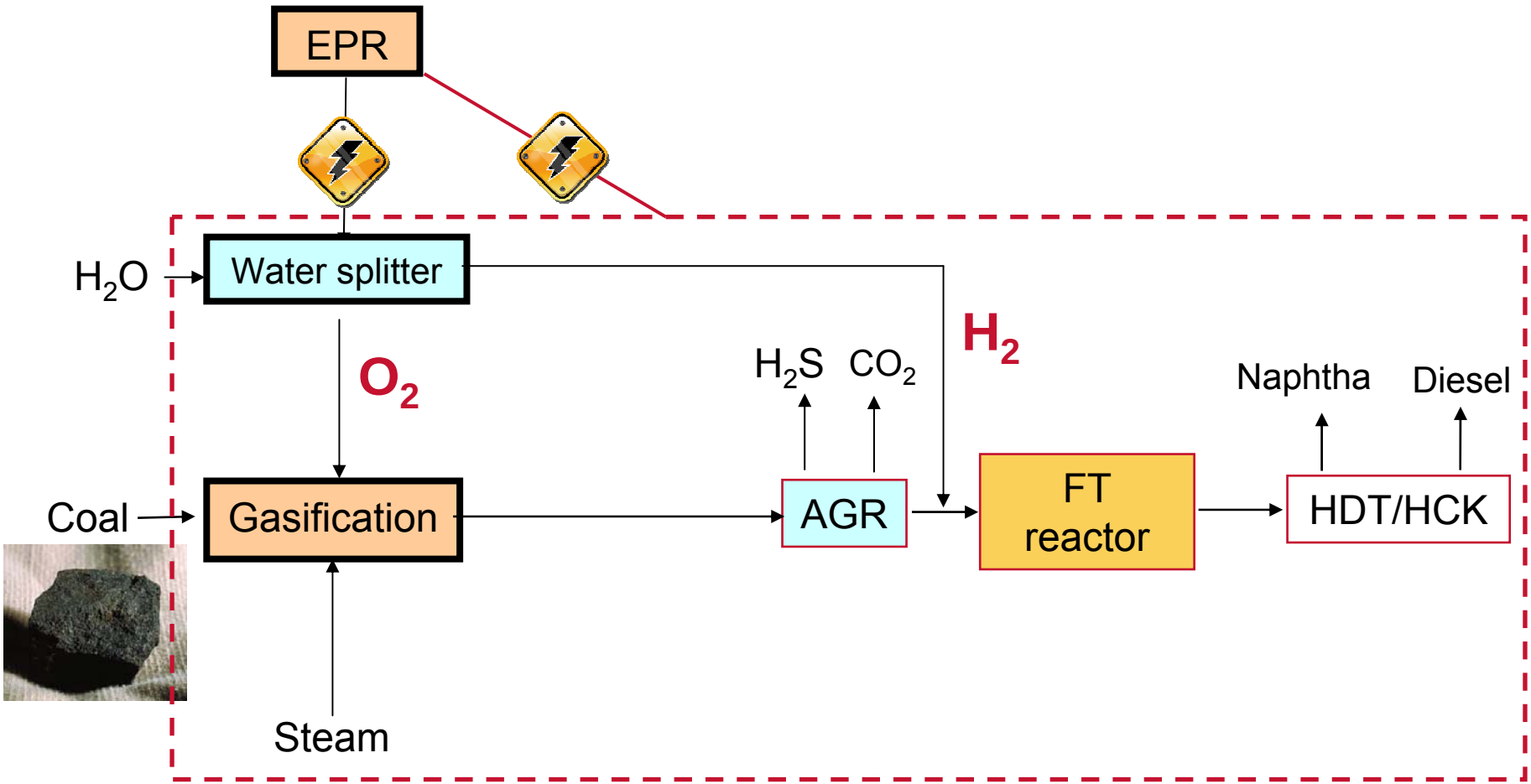
ASU: Air Separation Unit
AGR: Acid Gas Removal
HDT: Hydrotreatment
HCK: Hydrocracking

AREVA

CtL with no major impact on the environment imply to be able to mass-produce CO_2 free H_2 (2/6)

- **Reducing the environmental impact of CtL production requires a massive production of clean hydrogen, which water electrolysis technology can offer:**
  - **In water electrolysis, electricity enables breaking water molecules into its elementary components: hydrogen and oxygen,**
  - **In the case where the electricity is produced free of CO_2 emissions, hydrogen is also produced CO_2 free.**
- **In a generic way, the challenges which the oil industries are facing can be dealt by using nuclear power, via:**
  - **The use of hydrogen stemming from water electrolysis as a replacement to hydrogen stemming from fossil raw material or from methane,**
  - **The use of the co-produced oxygen,**
  - **And the direct use of electricity and\or nuclear heat in petrochemical processes.**
- **These generic interfaces are applicable in all of the oil industry processes: synthesis of fuels, refining, and heavy oil production. As a result, clean massive hydrogen production is a technology enabling substantial CO_2 abatements in the oil industry.**

From a classical CtL Plant to a nuclear integrated one (3/6)



ASU: Air Separation Unit
AGR: Acid Gas Removal
HDT: Hydrotreatment
HCK: Hydrocracking

AREVA

From a classical CtL Plant to a nuclear integrated one (4/6)

	Baseline Non-Nuclear CTL Plant	CTL Plant with Nuclear Integration	CTL Plant with Recycle & Nuclear Integration	Smaller CTL Plant with Recycle & Nuclear Integration
Coal Feed (tons/day)	17051	17051	17051	5260
Liquid Fuel Produced (bbl/day)	26,000	58,200	84,672	26,000
Conversion (bbl liquids per ton coal)	1.38	3.09	4.49	4.49
Yield of Liquid Fuel (% of carbon input)	29.5	65.8	95.7	95.7
Added Hydrogen needs t/d # EPR	0 0	2568 3.45	3260 4.38	1006 t/d 1.35
CO_2 release (tons/day)	17 000	~ 8 500	1 157	357

AREVA

From a classical CtL Plant to a nuclear integrated one (5/6)

Nuclear integration

Provides H_2 and O_2

- Water gas shift removal and more CO available
- AGR size reduction
- ASU removal

General process simplification

Resulting plant performance

- Up to 3-fold improved conversion ratio (bbl/t of coal)
- Quantity of H_2 needed ~ 40 kg/bbl
- ~ 1800 kWh/bbl and 1 EPR™ for a 20 000 bbl/d production
- CO_2 reduction: cut down to 1/40

Conclusions

- **Even with no process heat to provide, very sensible process improvement achievable**
- **Re-opens CtL option for the future as it drastically reduces its CO_2 footprint**

The technologies are available and can be coupled to any CtL plants (6/6)

Light Water Reactor

- No need for any specific reactor for H_2 application
- Use of electricity only
- EPR™ is AREVA's reference

Alkaline Water Electrolysis technology

- H_2 production capacity: 760 Nm^3/h, ~1,64 t/day per module
- Operating pressure: 32 barg (no need for additional compressor to bring H_2 to CtL process pressure)
- Life time: ~15 years
- Electric consumption: 4,3 to 4,6 kWh/Nm^3 of H_2

CtL plant

- CtL plants are already operating and some are under construction

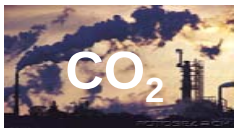
It would be technically possible to reopen CtL route and massively decarbonize fuels

AREVA

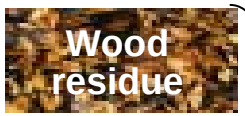
The same conversion as CTL can be applied, with some modifications, with a full range of carbon species to produce chemicals or synfuels

Raw Materials	Preparation	Process	Further Processing	Final products

C anthropogenic source



C neutral source



Capture

Electrochemical reduction

Methanol conversion

RWGS

Methanol Synthesis

Dowstream synthesis

Chemicals:
Ethylene
Propylene
MTBE
Acetic Acid
Formaldehyde
Acrylic acid/Acrylate

Hydrocarbons:
DME
Diesel
Gasoline
Etc.

Gasification Syngas production

Torrefaction

Pyrolysis

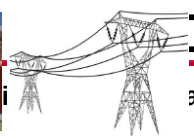
FT Synthesis

Refining

Hydrocarbons:
Wax
Diesel
Gasoline
Liquid gas
Gas
Etc.

CO_2 free H_2 production is at the basis of many clean energy conversion processes

Electrolyzer



Biochar

Soil amendment
C sequestration

AREVA know how and patents

- **AREVA identified the CO_2 mastering and/or conversion early as a potential means to minimize releases but also to convert massive nuclear energy into liquid fuels as a means to "store" excess production capacity at some times into fuel via hydrogen.**
- **To that effect, internal developments led to patents:**
  - **On high performance electrolyzers:**
    - Design
    - Component materials, electrodes, electrolytes, etc.
  - **On carbon to liquid plant design with added flexibility of operation to adapt its operation to cheap electricity availability,**
  - **On CO_2 conversion processes to hydrocarbons.**

AREVA

Nuclear assisted XtL available between $150 and $200 per barrel

- **Nuclear assisted XtL processes already enables:**
  - **CO_2 emission abatement,**
  - **High conversion ratio for XtL,**
  - **Reasonable costs due to**
    - **Process integration and simplification,**
    - **O_2 ex electrolysis valorization,**
    - **Savings on raw materials.**
- **However, 70 % of XtL barrel cost is H_2 cost of which 80% is kWh cost.**
- **To optimize CO_2 free H_2 cost:**
  - **One of the main lever is to use the cheapest and the most predictable CO_2 free electricity,**
  - **Another one is to improve existing electrolysis technologies (alkaline one) and develop breakthrough electrolysis technologies (High Temperature one).**

The SMR issue H_2 production

- The worldwide H_2 consumption was 630 billions Nm^3, in 2006, of which:
  - 50% was used to process fossil fuels,
  - 34% was used for ammonia production.
- More than 95% of consumed hydrogen is commonly produced from fossil through mainly natural gas steam reforming (Steam Methane Reforming) and crude oil partial oxidation and coal gasification.
- These H_2 production processes are extremely polluting, as an example:
  - The production of 1 t of H_2 via SMR emits ~ 9 t of CO_2,
  - In a life cycle assessment, the production of 1 t of H_2 via SMR emits ~90 t CO_2 equivalent, including CH_4 GHG effect.
- In a world where oil industry will require massively H_2 in refinery processes and even more to lighten heavier and deeper oils emitting even more CO_2, the production of H_2 is a major issue.

AREVA

Fatal CO_2 emitters

► **Cement, steel and glass industries, for example, are large CO_2 emitter and emit unavoidable CO_2 however, these industries have to reduce or deal with their CO_2 emissions.**

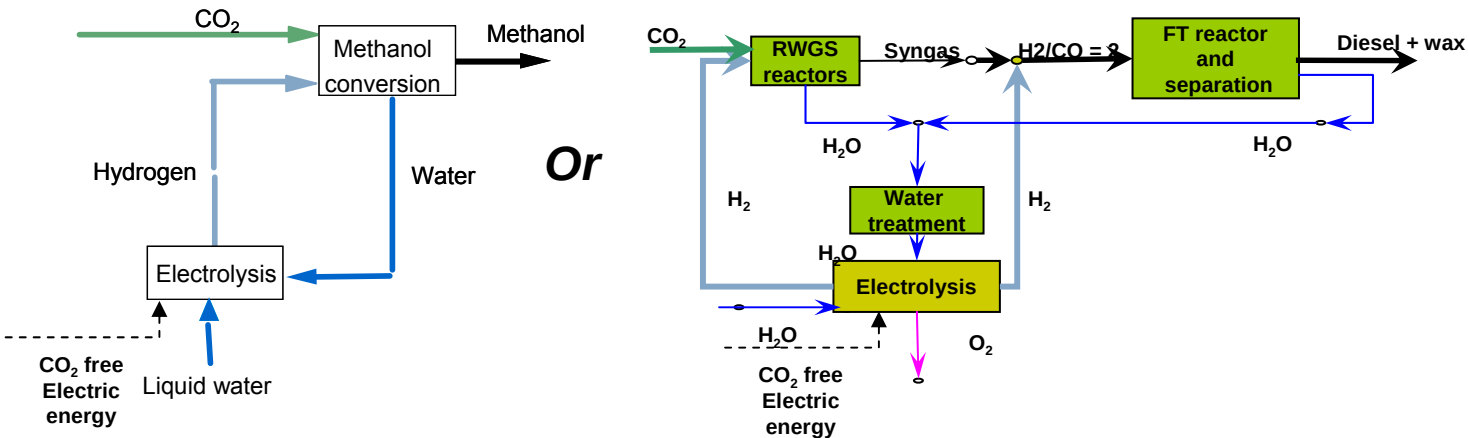
► **Regardless of the adopted transformation path, CO_2 can be recycled into a high added value product such as fuels thereby decreasing the carbon balance of such large industrial emitter, the net release being overall divided by 2.**

► **Combined with electrolytic (carbon free) hydrogen addition, CO_2 can be recycled into methanol (1) or into Fischer Tropsch products (2):**

$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$ (1)

$CO_2 + H_2 \rightarrow CO + H_2O$ then $nCO + 2nH_2 \rightarrow (-CH_2-)n + nH_2O$ (2)

$(-CH_2)n$ is an hydrocarbon like gasoline, diesel or kerosene



► **CO_2 recycling is an alternative or a complement to CCS.**

AREVA

A focus on cement industry

- **Fatal CO_2 emitters such as cement industry need to deal with their CO_2 emissions**
  - **Cement production is an important source of CO_2 emissions, accounting for ~1,8 Gt CO_2 in 2005. Half of cement process CO_2 emissions are due to the chemical reaction in cement clinker production. These process emissions are not affected by energy efficiency measures.**
  - **An increasing demand of cement …**

Demand for Cement in Million Tons	2005	2010	Growth rate
North America	170	200	2.9%
Western Europe	208	236	2.2%
Asia/Pacific	1500	1900	5.2%
Other Regions	405	500	4.7%
WORLD Cement Demand	2283	2836	4.7%

Source: Globalisation cement industry, 2007

  - **A small size cement factory emitting 1MtCO_2/year would require ~150 kt H_2/year for the CO_2 to be converted into synfuel and would produce 7000 bbl/day.**

AREVA

Possible change of paradigm

If two or three of the following were to occur:

- **Automobile manufacturers speed up the changes in their models,**
- **Economic growth takes off again,**
- **The cost of oil products increases once again,**
- **The absorption capacity of the oceans drops,**
- **Worldwide climate negotiation becomes a reality,**

It could be said that the requirements of the automobile and air transport industries would lead:

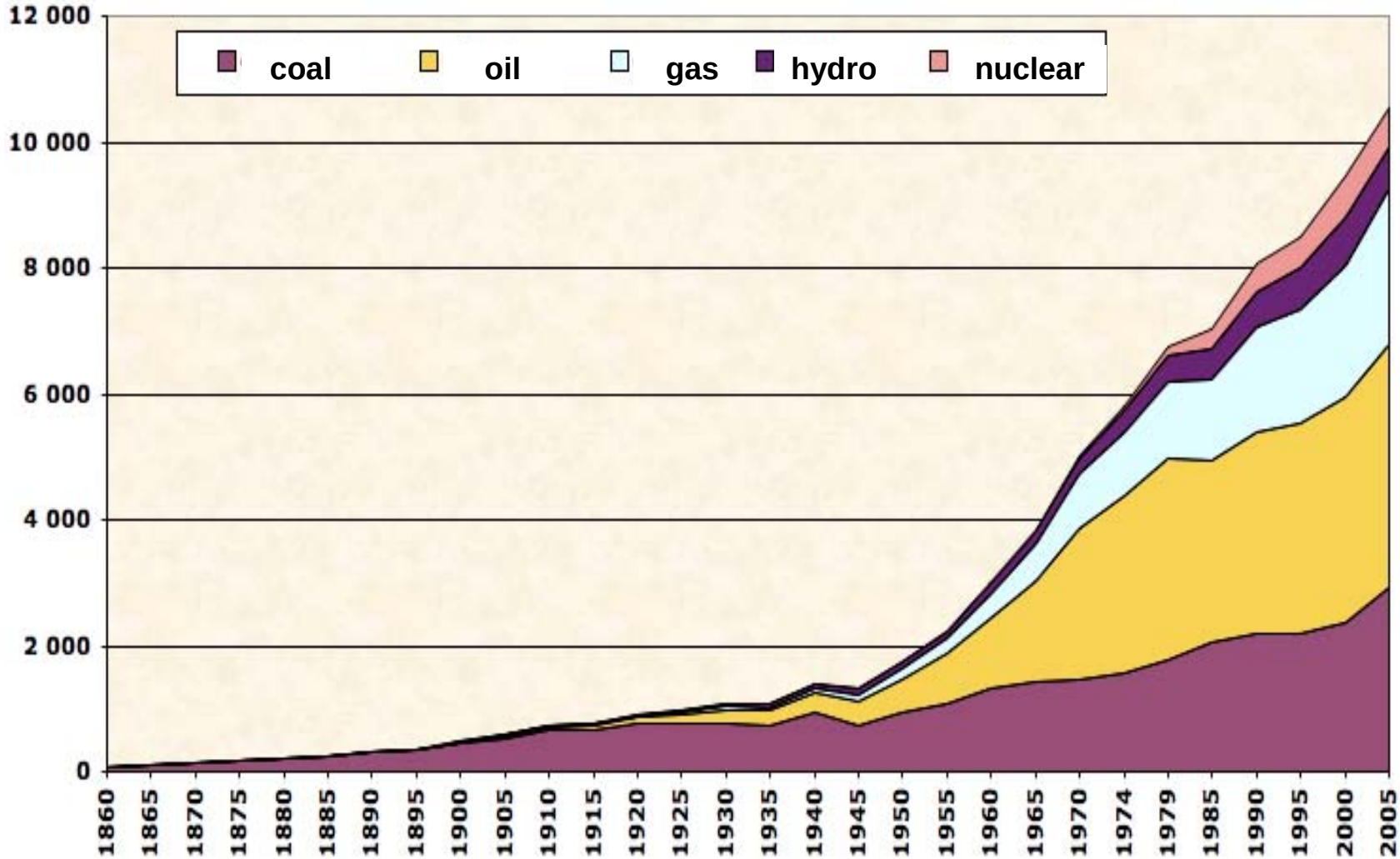
- **to having nuclear power plants operate at off-peak times**
- **to offer lower rates and baseload operation as much as possible – allowing electricity to be stored in cars and/or airplanes.**

Some thoughts on climate change

Alain Bucaille
Senior VP Reseach and Innovation AREVA
Jordan - Sharing knowledge across the Mediterranean
March 1-3, 2010

AREVA

Global primary energy consumption since 1860 (excluding conventional biomass)



Source Schilling & al + Observatoire énergie

AREVA

Demography and Economy

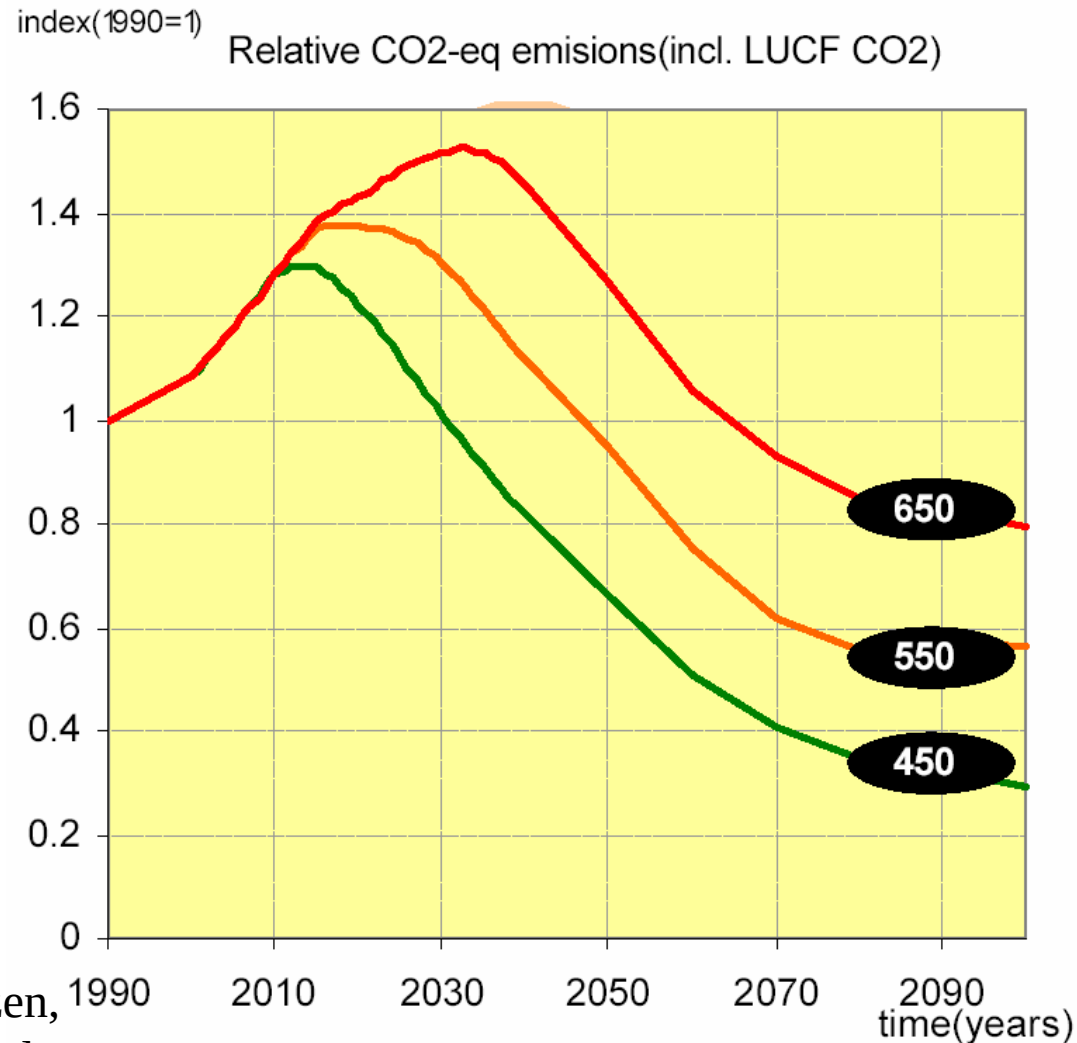
- **World population is growing as never before:**
  - **3 Billion in 1960**
  - **6.5 Billion today**
  - **9 Billion probably by 2050**

  Even though it is possible that we reach stabilization, or even decrease, later on

- **….. And already today 1.5 billion people have no access to electricity.**

AREVA

CO_2 and scenarios

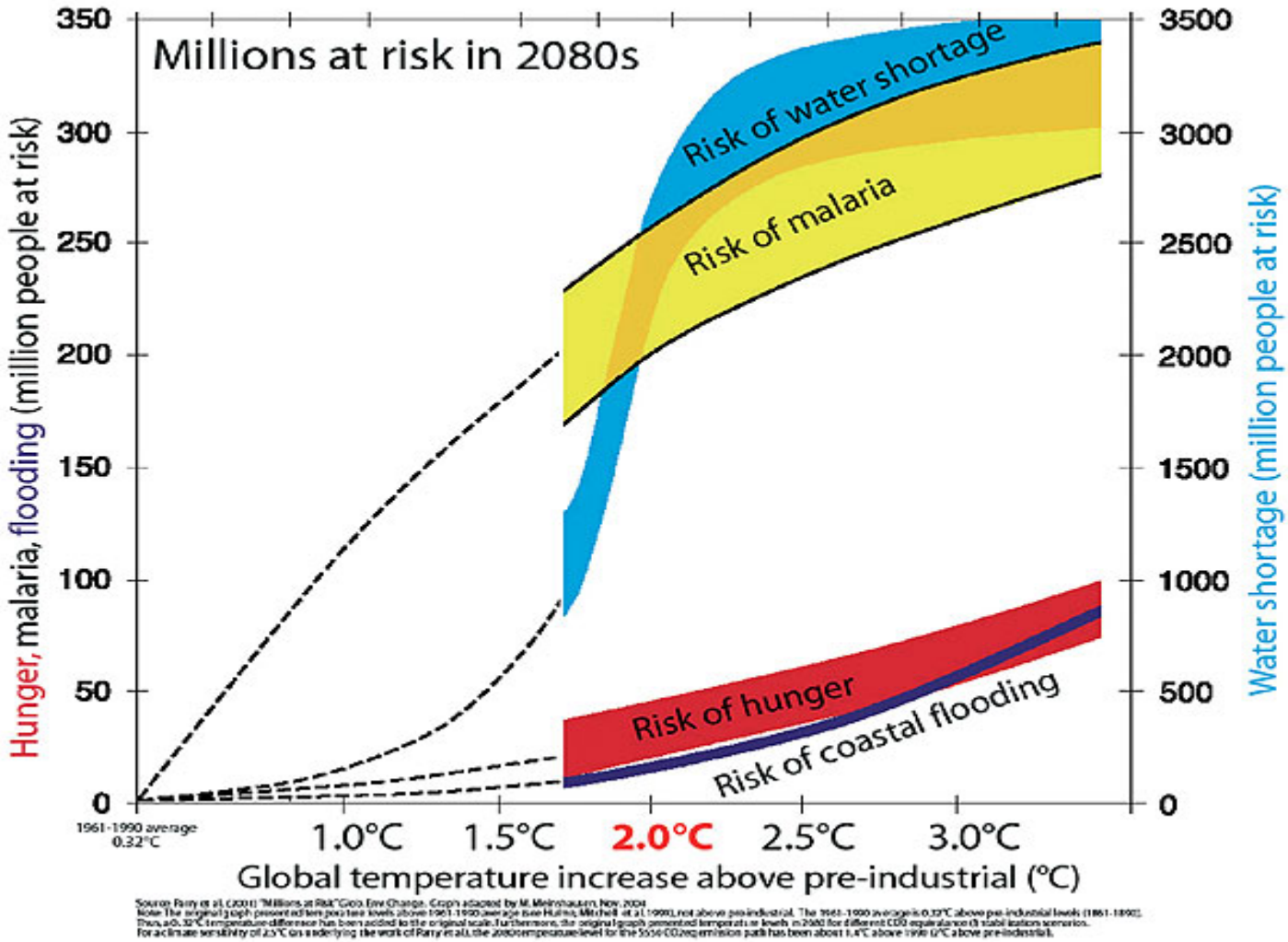


Equilibrium concentration vpm

Source: den Elzen, Meinshausen and van Vuuren, 2006

AREVA

Some thresholds not to be crossed: Millions of people at risk due to a global temperature increase above pre-industrial levels (source Parry et al., 2001).



AREVA

The frightful inertia of phenomena

- **Once in the atmosphere, a CO_2 molecule will not be destroyed by light: it will only disappear in the upper layer of the oceans by transformation into carbonate.**

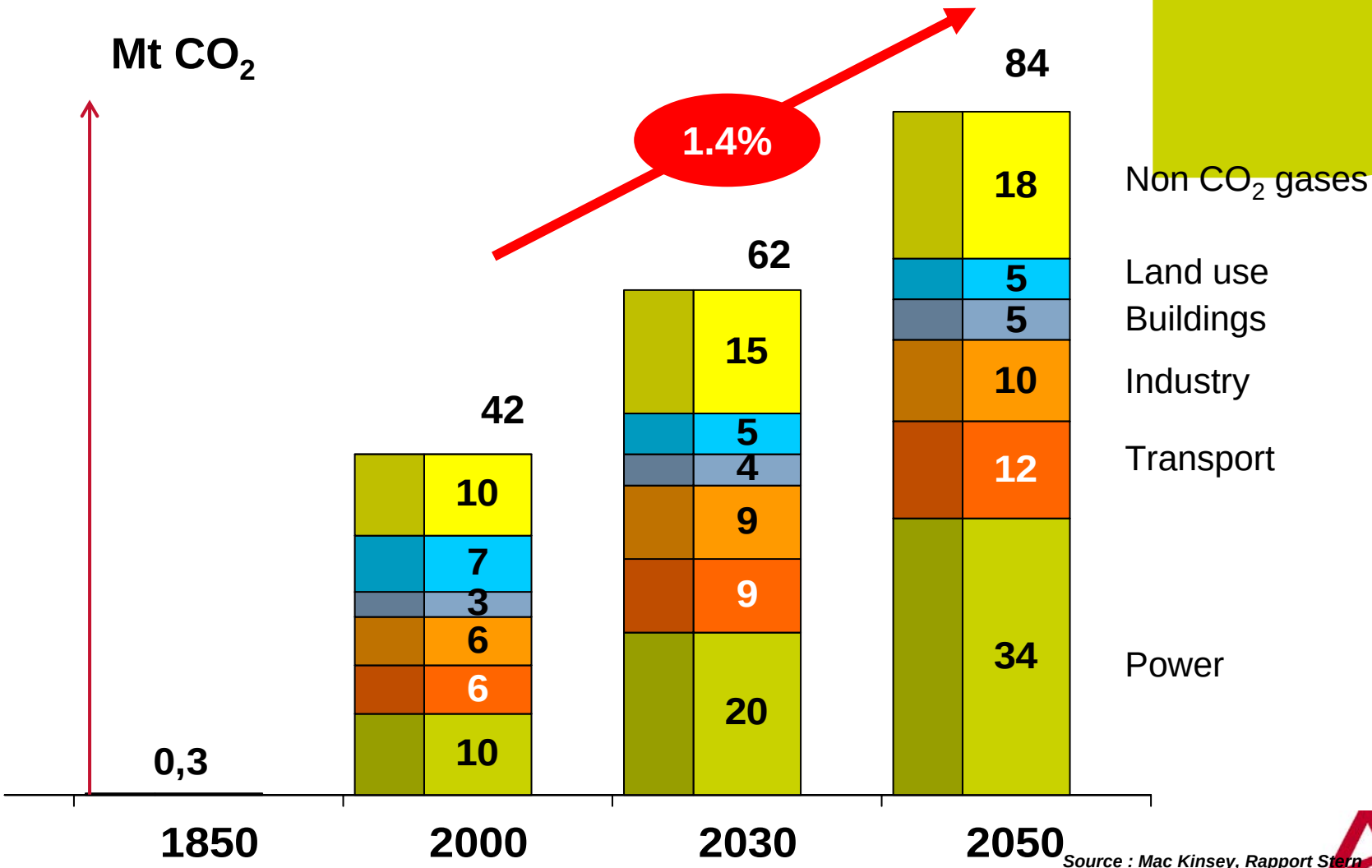
  This mechanism is very slow. The average lifetime of CO_2 in the atmosphere exceeds one century.

- **Even after the peak *of emissions* and as long as they have not decreased below 3 GtC/year, the amount that oceans and biosphere are able to absorb, CO_2 concentration will continue to grow.**
- **This phenomenon could even become irreversible (at a human scale) if the absorption capacity of oceans and lands were to decrease.**
- **It is therefore paramount to start decreasing the emissions as soon as possible.**

  The states, the financial community and public opinion must convince themselves that this can be done as early as 2025.

AREVA

Many areas are concerned: Emission growth forecasts, per sector



Source : Mac Kinsey, Rapport Stern

AREVA

Coal and nuclear: the two main solutions for baseload electricity

- **Base-load electricity (production twenty four hours a day) is often confused with other types of electricity. It is not possible to generate this electricity from intermittent sources (there is no sunshine at night, there is not wind every day).**

- **As far as reserves are concerned, for the top 50 or 60 economic powers in the world, the choice for base-load electricity comes down to coal or nuclear.**

- **…. And we will need all we can get.**
- **Only countries which enjoy a lot of sunshine and the available space is big will be able to avoid this dualistic choice.**

AREVA

Gas in the very long term

- **Opinions differ as to when the conventional gas peak will occur: 2045, 2055 at the latest.**
- **If demand were to grow by more than 2.5% per annum, the peak would occur before 2050…. and the competition between global regions would quickly become even fiercer than it is today … especially if Russia were to put more emphasis on prices than volume.**
- **We sometimes hear about methane resources in hydrates, but this is not much more realistic than getting uranium from seawater.**

AREVA

Three kinds of thoughts

1. If you guess for a base-load electricity
   - 50% nuclear
   - 25% clean coal plants
   - 25% clean coal plants with carbon capture and sequestration and/or hydro-electricity.
2. And for other kinds of electricity ;
   - ¼ heat
   - ½ Renewable
   - ¼ fossil fuels
3. **Then you divide by 5 to 6 the present emissions in terms of CO_2 / KWh (700 ➔ 120g CO_2 / KWh).**

AREVA

7.5% of electricity to be replaced by heat in OECD countries?

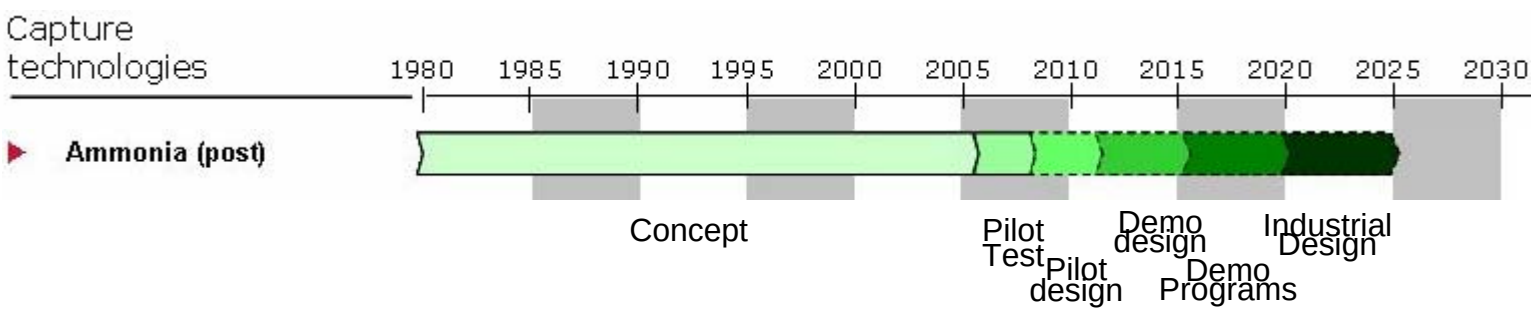
Nothing would seem to stand in the way of such an objective **or its evaluation by the IEA based on OECD-specific methods (examination by an international team based on national contributions and resulting in public reports).**

Subject to verification, any substitution should be encouraged, taking carbon at less than 50€/t CO_2

AREVA

CCS, a question of timing and a matter of costs

- Capture and CO_2 storage is one of the possible and feasible technology to reduce CO_2 emissions on a long term perspective. However, industries studying these technologies do not forecast significant deployment before 2025 and describe technologies that still need validation.
- The impact of the CCS is virtually nonexistent before 2025 and CCS coupled with coal power plants would avoid less than 20% of CO_2 emissions in 2035.
- Finally, CCS is expensive (over 100 €/t of CO_2 in future demonstrations, 80 €/t of CO_2 later?) and negatively impact the performance of coal power plants



AREVA

Difference in between continents

- If North America has plenty of potential sites, if Europe has many geological potential but an urban, agricultural, tourism geography, the situation is more difficult for Asia which is in a very different position.
- CCS is impossible in Japan on the islands, it would be excessively costly in the oceans.
- In India, all around the continent, the seismicity is unfavorable, inside the continent it is more feasible.
- Finally, in China, there where it is economically feasible, the country is not half "economically developed".
- Whatever the progress of the CCS technology, Asia will therefore not consider it as a universal solution.

AREVA

The shape of change for road transport

In Europe and Japan, we have clearly entered a new era combining:

- **lighter cars,**
- **developments in electric town vehicles,**
- **developments in rechargeable hybrid vehicles.**

All of the major automakers are predicting that markets will possibly develop in this direction. Obviously, those that perform less well or are less likely to keep up with the new requirements will suffer as environmental concerns increase.

The challenge of eco-driving is also far from secondary. Tests carried out in these fields have shown that these practices, especially in or around cities, enable customers to save 20-30% in fuel.

AREVA

Self-understanding figures

- **For cars**
  - **7 liters per 100 km**
  - **15 000 km/year**
  - **1,5 billions of car potentially in ~2025 (0,8 today)**
  - **~ 4 Gt of CO_2 emissions per year**
- **For planes**
  - **If the whole CO_2 produced by today's cement plants was recycled into kerosene, the current consumption of the existing plane fleet could be largely covered for less than 30% extra cost to air transport consumers.**

AREVA

An alternative that is still underestimated

Until now, we have only considered eliminating CO_2 by capture and storage deep underground.

However, today we see the possibility of transforming it into oil using electricity, with the mass-production of hydrogen.

The critical path is as follows:

CO_2 + H_2 + electricity ➔ CO + H_2 ➔ C_8 H_{18} (gasoline)

Patents are being filed for this, which leads us to believe that such a transformation could be achieved at a cost of around $150/barrel, if it is to take place using nuclear power during off-peak times, and considering a monetary rate of less than 5%.

It is thus possible to technically win this challenge on climate

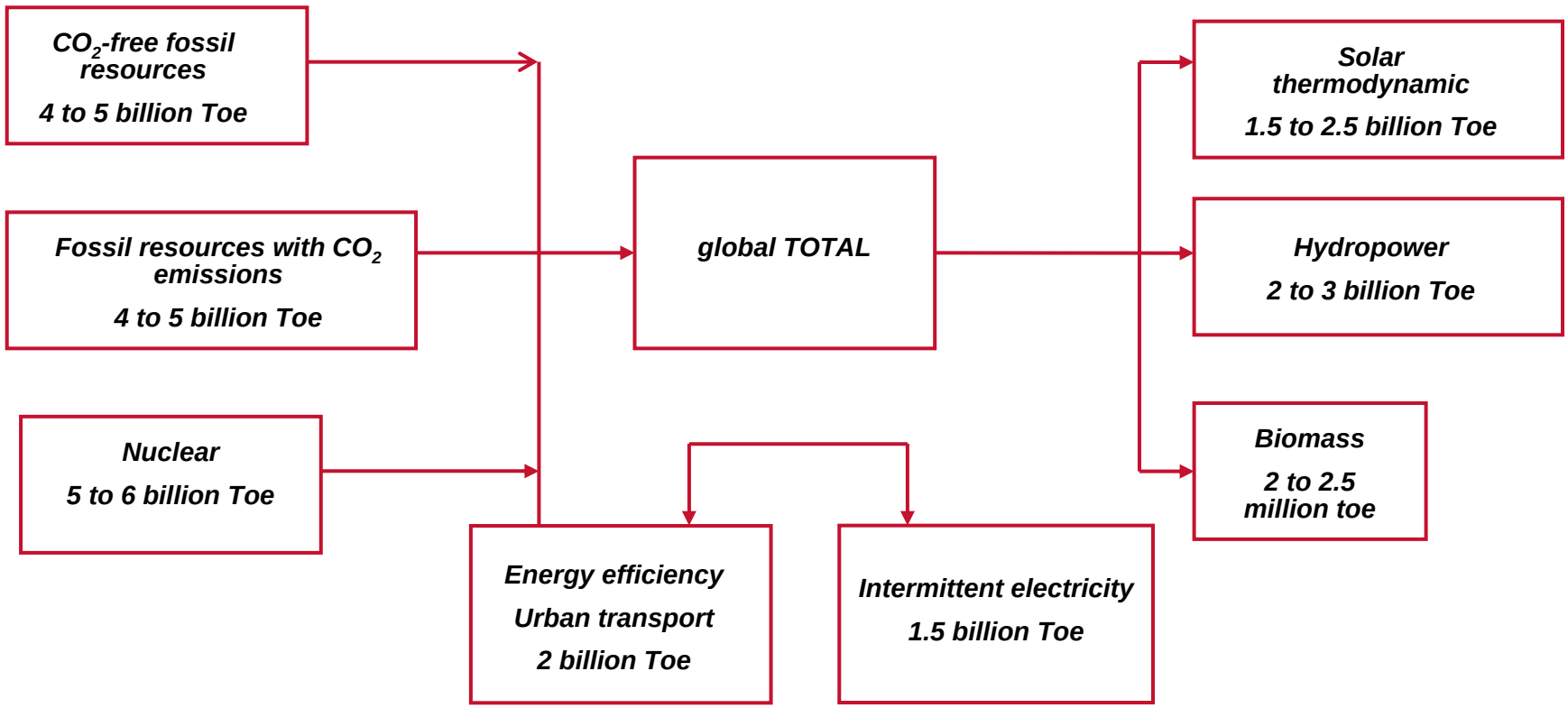
It is easily feasible to put in place regulations which do not curb economic growth or which even stimulate a new type of growth leading to the following in the G20+:

- **15% lower emissions by promoting energy and heat savings by 2015**
- **Stabilizing emissions due to electricity generation between 2017 and 2020 before reducing them by at least one third if not by half**
- **Triggering a virtuous circle for transport which should mean that emissions due to these activities would not have to increase beyond 2020**

AREVA

And so what?

Looking forward…. to a date we cannot quite pinpoint (2060, 2070?), the scenarios we have just seen could result in the following:



AREVA

Technologies exist to meet this challenge (1/6)

Technologies to rise to these challenges already exist or are highly likely to exist by 2015; the proposed climate pact offers the possibility of implementing them:

- **Technologies for coal-fired plants which reduce emissions by one third exist already but no-one is forced to implement them. Even before 2015 it is possible to have coal-fired plants which emit 600 g CO_2/KWh as opposed to 1000 for plants sold since 2000.**
- **The average car emissions vary from area to area from 160g CO_2/km to 280 g CO_2/km, yet we already know how to manufacture five-seaters which generate less than 110 g CO_2/km.**
- **All the necessary technologies (roofing, insulation, glazing) to reduce the demand for heating and cooling by at least 35% in old housing.**

We know how to cut lighting consumption tenfold without losing more than 3% in brightness.

Technologies exist to meet this challenge(2/6)

- **Heat pump/solar water heating are used by two thirds of the planet to provide up to 50% of heating requirements from solar power and earth heat. Wood heating and/or electric heating could improve this figure even more.**
- **Hydro-electric power is only used to 30% of its potential and where there is wind onshore wind turbines are of a major interest for the coming years. Geothermal power has also been used very little up until now.**
- **Experimental technologies to capture/sequester CO_2 will exist by 2020; regulatory constraints are what is delaying the financing of any large scale operations. On the other hand, geology alone is preventing CO_2 capture and sequestration in at least half of Asia.**

Technologies exist to meet this challenge (3/6)

- **Technologies to produce synthetic fuels at less than 150$/barrel exist but with a 5% interest rate on investments, which nobody is discussing.**
- **Long-distance electricity transportation technologies (HVDC and AC) will exist by 2010.**
- **If we would recycle nuclear used fuels on a large scale, we would easily counter the limited availability of uranium ore to develop reactors which have proven themselves in terms of safety to meet an increasing demand for nuclear energy. Fast breeders are another likely technology.**
- **Concentrating solar thermal power cost less by 2020 than 150, possibly 120€/MWh in areas that receive a lot of sunlight.**
- **Electric trains could be developed extensively.**

Technologies exist to meet this challenge(4/6)

- **The technology already exists to manufacture cars (high performance thermal engines for light vehicles and more especially rechargeable hybrids) which can travel at the same speeds and give off at least three times less pollution than current cars which account for 15% of the world problem.**
- **If 30% of the world's baseload electricity is provided by coal-fired plants with the best available technologies (600 g $C0_2$/KWh), 30% by nuclear, 30% by coal-fired plants with CCS, and 10% from hydroelectricity and renewable energies, and if semi-baseload and peak electricity which makes up 40% of total electricity is increased to 50% by renewables, $C0_2$ emissions due to electricity would be divided by four per KwH produced, compared to now. And this accounts for 40% of the world problem.**

Technologies exist to meet this challenge (5/6)

- **Agroforestry which represents at least 15% of the issue in the longterm is a matter of organization and not technology.**
- **We can assume that we can manufacture natural gas and synthetic oil by recycling carbon materials. Finetuning such technology is not a major problem.**
- **In so-called polluting industries which use a lot of heat, electricity could technically replace fossil fuels. This is a matter of relative cost.**
- **On the other hand 15% of the topics are dependent on national situations and public willingness to rise to the challenge, in particular to make energy savings in old buildings and to develop collective transport.**

  Leading the average citizen to believe that the development of long-term technology is the indispensable but uncertain condition for meeting these challenges amounts to deceit.

False ideas regarding technology (6/6)

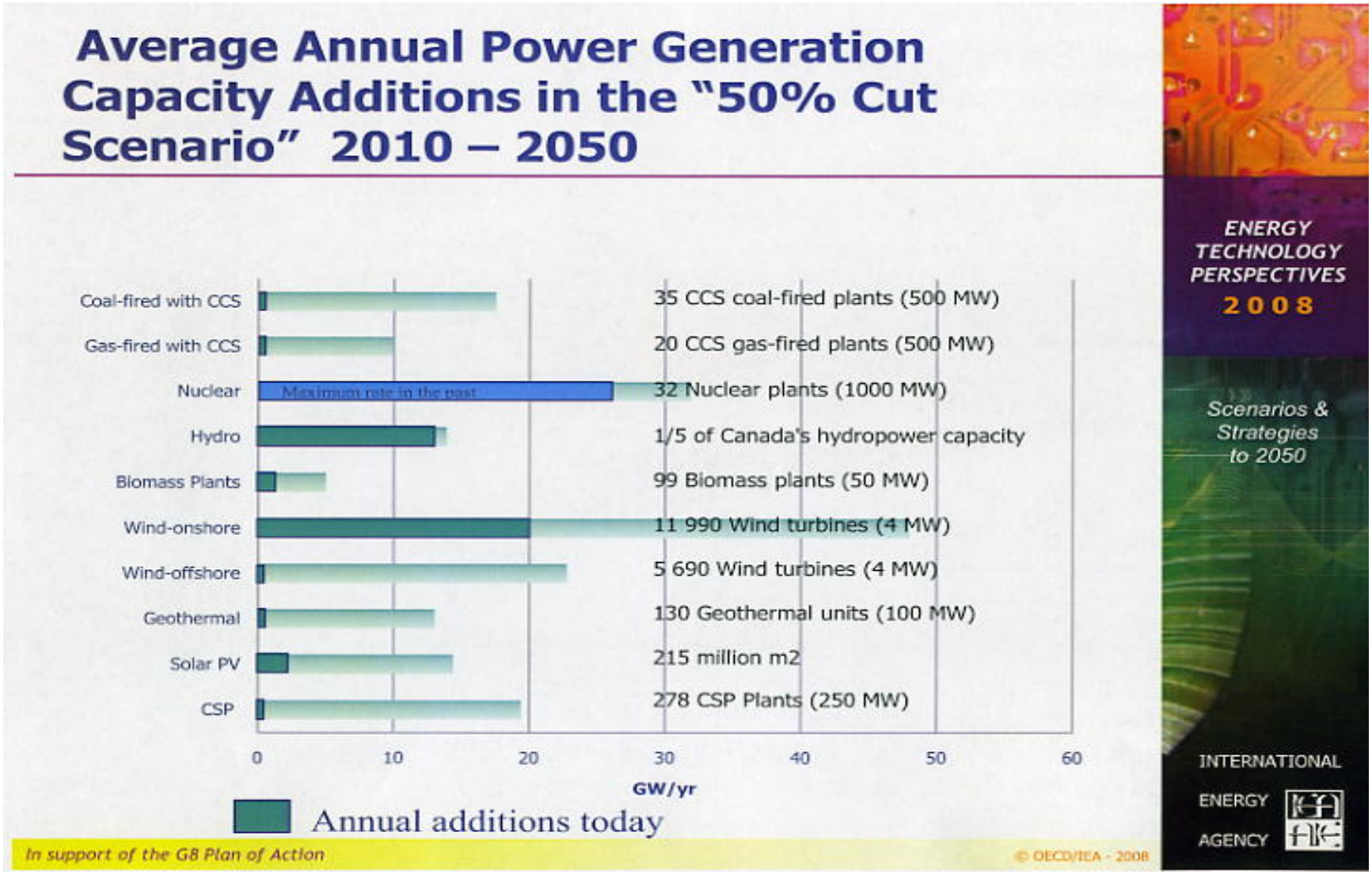
Some believe that technology, by its very nature, will progress in leaps and bounds and save the day. Unfortunately this is wrong or wishful thinking :

- **Technical progress will likely help solar power to progress but it won't make the sun shine at night!**
- **We may be able to travel 200 km in electric cars by 2015, but we have no scientific knowledge which allows us to hope to mass store enough electricity to cover the needs of several days of consumption in a country.**

Other key topics have been identified in the technological roadmaps of the major countries but success depends more on how quickly things are put in place on an industrial level than on new breakthroughs in fundamental research.

Pretending or presuming that the opposite is true amounts to weakness or carelessness.

The IAE is saying something very similar



That is exactly why we need to know how to define the best framework to achieve this

The basics of our proposal (1/4)

Our solution is both technical and economical; it involves the introduction of a legal and administrative framework that is compatible with market economy and which truly provides hope of stabilizing CO_2 emissions by 2030 and halving them by 2050. It aims at truly innovative governance, taking what we have learned from the past into account.

This solution provides an original way of involving the general public and companies in all major countries, making it much more than a government initiative. It moves away from conventional negotiations between governments and beyond cap and trade. It will lead to a right to interfere in how countries are managed.

The framework includes four types of measures. All of this combined makes up a *world climate pact* :

1 The introduction of a common environmental law for the biggest countries in the world (*) which would be enshrined into their constitutions. These countries would be obliged to adhere at the risk of being excluded from the WTO. Under its constitution each major country has to include the notion of failure to assist an endangered mankind, which will increase awareness across the planet.

Other countries would have the choice of adhering or not, depending on their own good judgment.

(*) For the purposes of our presentation we will refer to these core countries as the G20+. The 18 biggest countries alone account for over 70% of emissions.

Imperial College London

The basics of our proposal (2/4)

2. **Conventional regulations provide a framework for market economics through long-term provisions that enable industrial companies to adjust their strategies and industrial offerings. This is a long-term vision but a conventional one with specific impacts on base-load electricity, road transport and energy for buildings and housing.**

3. **Listed stock companies in these core countries (G20+) could freely adhere to this world climate pact. Ensuing rights would be valid for a period of seven years and could be renewed, if the companies so wish.**

   The corresponding mechanism would be put in place within a few years to allow companies the time to fully work their decisions through with regard to introducing a flexible system of solidarity between developed and emerging countries.

4. **Very simple mechanisms for stimulating public opinion and higher education to create the kind of effective mobilization that is essential to the overall success of this fight against climate change.**

Why a legal framework? (3/4)

- **Economic activity can be managed either by financial incentives or by laws. We need to combine them and not to oppose them.**
- **Negotiations between countries have not made much headway sofar and by nature can only lead to a consensus imposed by the weakest countries and as always dictated by their prospects for the next five to seven years.**
- **On average it takes more than twenty years to get new production, transport or construction projects off the ground. This is why we need to draw up the legal frameworks now for the new direction we want to take in several decades' time.**
- **If it can benefit from indications on what to expect in 10-15 years, the economy can pace its R&D without dwelling too much on return on investment.**
- **If we are objectively failing to assist human beings in danger, it is a legal matter. Montesquieu and Locke would have agreed in their time.**
- **Building awareness and a sense of responsibility can progress at several levels as part of a whole. We will illustrate this throughout our presentation.**

Imperial College London

An innovative proposal for structuring politics, the economy, regulation techniques and mobilizing people (4/4)

For a long time now, we have tried to reduce the topic to two issues:

- **Choosing the best way of giving a value to carbon,**
- **Getting governments to negotiate, and especially the major world governments.**

We believe that the topic should be extended to include:

- **<u>Bringing public opinion on board,</u> beginning with OECD members. Otherwise we will not successfully rise to the challenge.**
- **<u>Obliging various key countries,</u> outside of their political specifics, to integrate their commitment into their constitutions.**
- **<u>Getting economic and financial circles</u> in all sectors <u>involved</u> if they wish to do it.**
- **Admitting that <u>emissions permits and carbon taxing are only part of what is required</u>.**

Involving companies through an original mechanism (1/2)

The extent of the challenge and the issues related to solidarity between nations call for a unique form of proactive involvement from businesses. The following innovation should therefore be implemented :

- **Private companies in the G20+ would be invited to adhere to the climate change pact by 2012. Those who do shall commit 0.5% of their added value as of 2014, to one of the following:**
  - **Financing R&D**
  - **The funds dedicated to modernizing homes**
  - **Half of CCS costs**
  - **The reforestation plans.**

  At least half of their expenses should be outside the OECD.
- **Companies' commitment to the climate change pact should take the form of seven-year renewable periods.**

  This argument is also required so that populations do not consider that the economy has unburdened itself of likely challenges to be overcome.

Imperial College London

The public opinions stimulation (2/2)

It is impossible to succeed without mobilizing public opinion. There is no denying that governments will only be credible if the public opinion, in developed countries at least, is seen to be mobilized in a comparable manner.

Beyond the notion of failure to assist an endangered mankind, the spirit of our proposal lies mainly in the following measures:

- **Interest-free loans for housing projects that halve CO_2 emissions (something we all understand).**
- **Cars scrapped after 2025 if they emit more than 110g of CO_2/km.**
- **Companies involved in the global climate pact (it's not only individuals that will have to pay).**
- **Right to refer to the sustainable development boards of the G20+ (a type of parliamentary office) if a petition has 500,000 signatures and 1% of the population from within a particular country (offices can refuse to investigate); regular televised progress report every five years in G20+ countries broadcast in all other countries.**
- **Regular surveys of public opinion.**
- **NGO-type measures of solidarity for companies penalized in the G20+.**

The proposed system (1/2)

Our initiative boils down to a clear set of governmental measures and a global constitution which complements and binds them. The main measures we have suggested and which structure our proposal relate to the following:

- **A common environment law proposed within the G20+ and which forms a constitutional element shared by major countries.**
- **A potential link between all these measures and WTO regulations.**

Or in more concrete terms:

- **Incentives for energy savings in buildings, with a view to reducing global demand by 10%.**
- **Regulating baseload electricity within the G20+ not by an energy mix but through emission objectives in grams of CO_2/KWh with a view to reducing emissions by 2025 and further reducing them between 2030 and 2040.**
- **A clear and strong statement on the role of renewables at least for semi-baseload and peak electricity (at least half of these two forms of electricity by 2025 or even 2020).**

The proposed system (2/2)

- **Eliminating the sterile opposition between renewables and nuclear, so that civil nuclear can be developed safely.**
- **Technological progress objectives in particular for road travel (otherwise this topic alone would derail the others), with a view to compensating as of 2020 growth in the automobile fleet by technical progress.**
- **Capture and sequestration/transformation of CO_2, combined with a move towards electricity in road transportation (hybrid rechargeable cars, electrical cars) could help to dedramatize the issue of the Middle East.**
- **Inviting private corporations to voluntary adhere to the fight against climate change with the possibility of allocating up to 0.5% of their added value (tax free). This is essential in forging solidarity between old industrialized nations and new upcoming powers, in particular India and China.**
- **A double initiative for reforestation (support for ambitious plan, possible sanctions for any deviations in the form of international loans).**

Imperial College London