Survey of Nuclear Politics

WNU Summer Institute 2012

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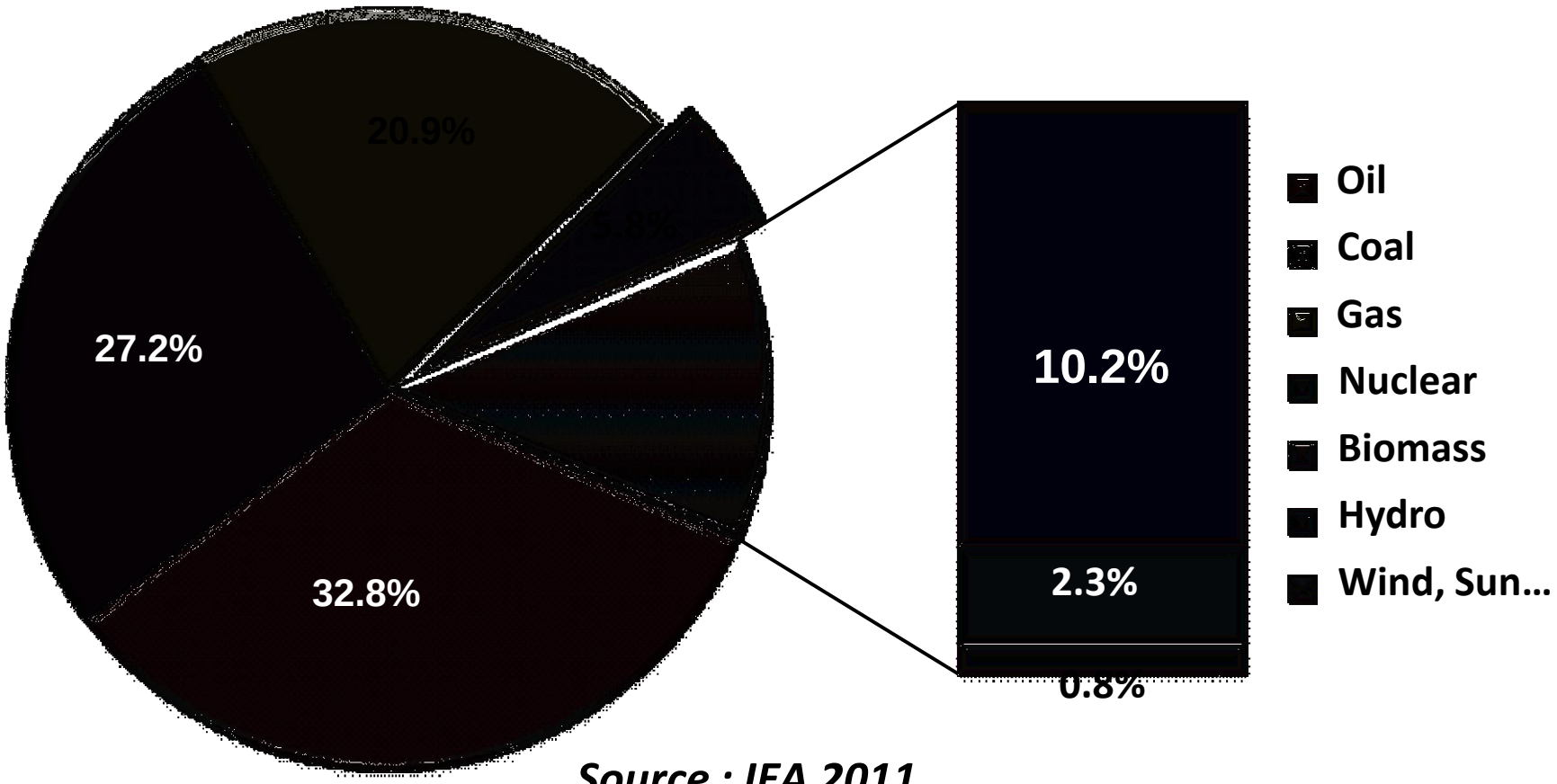
World Primary Energy Consumption 2009 (12.1 Gtoe)



Source : IEA 2011

Nuclear Power 2011-12

Country	*GWe*	TWh	Units	%Elec
USA	*102*	790	104 + 1	19
France	*63*	424	58 + 1	78
Russia	*24*	162	33 + 10	18
Japan	*45*	159	51 + 2	18
S Korea	*19*	148	23 + 3	35
Germany	*20*	102	9	18
Canada	*12*	88	17 + 3	15
Ukraine	*13*	85	15	47
China	*12*	82	15 + 26	2
U Kingdom	*11*	63	17	18
WORLD	*372*	2 518	435 + 62	13,5

58 Years of Nuclear Power

435 reactors in 30 countries*

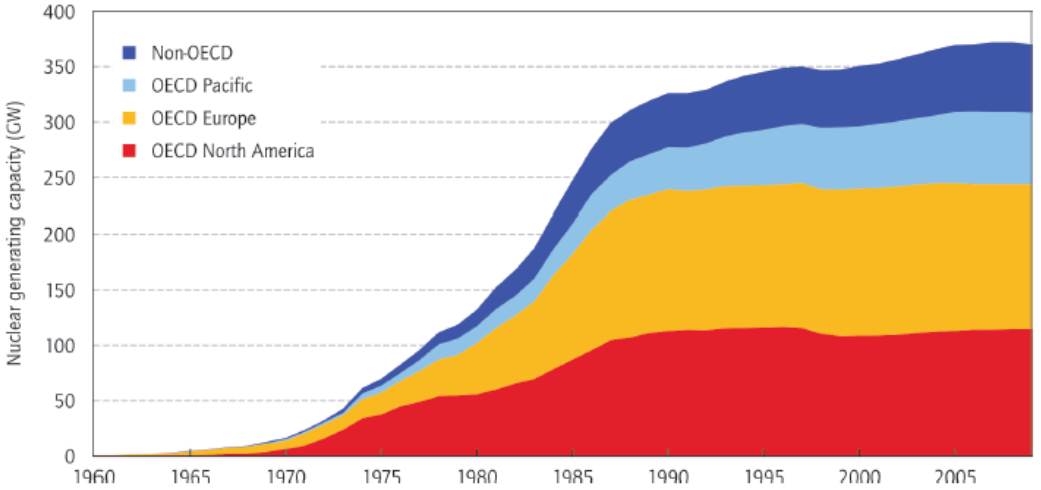
2500 billion kWh/year

<~ Hydro-power

> Saudi Oil

13.5% Electricity

Figure 2. World nuclear generating capacity, 1960 to 2009

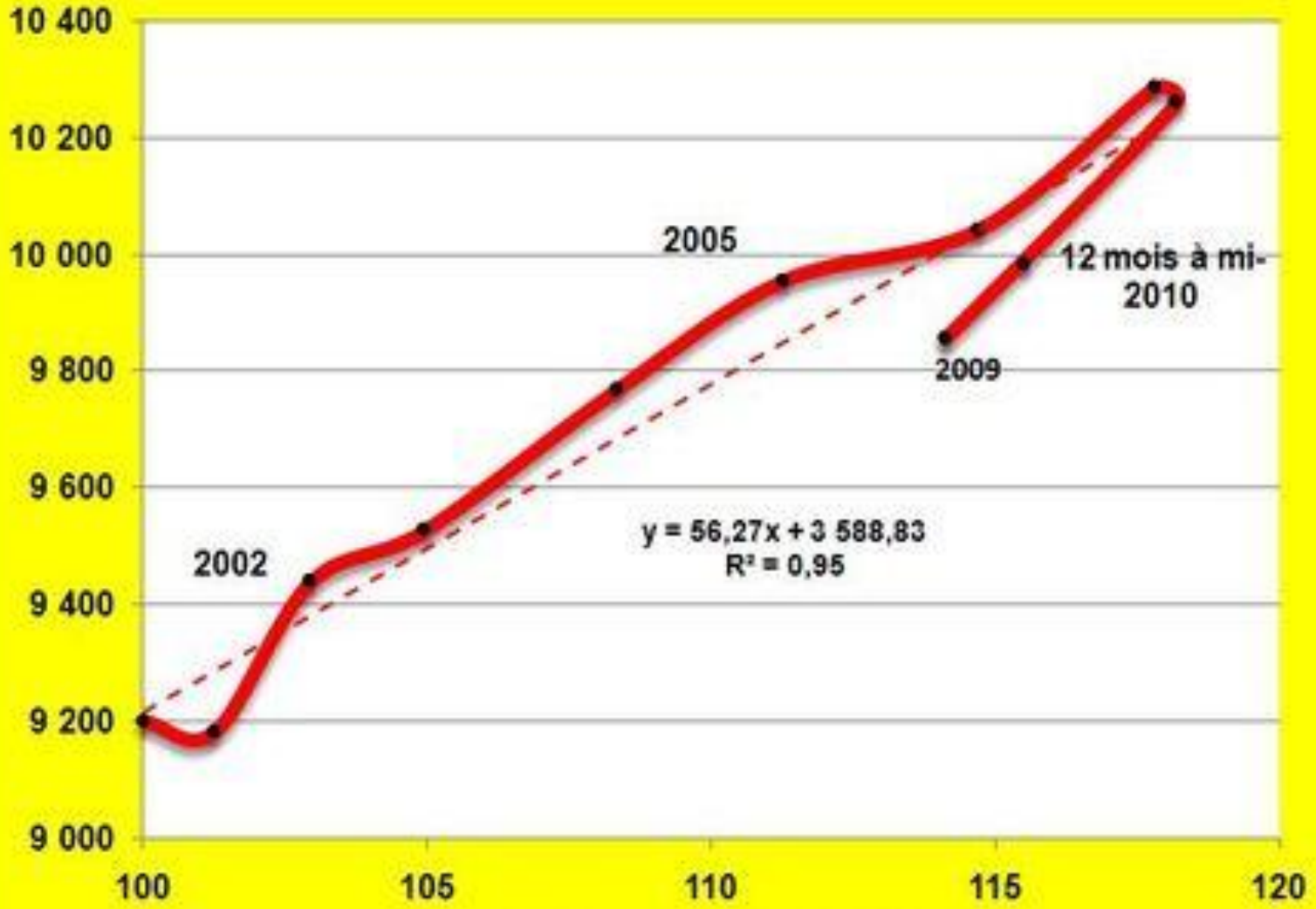


Source: IAEA PRIS.

KEY POINT: Nuclear capacity grew rapidly in the 1970s and 1980s, but much more slowly after 1990.

OECD : 10 year correlation between GNP and Electricity Consumption

TWh



GNP : Base 100 in 2000

www.undp.org

Human Development Report 2007/2008

Fighting climate change:
Human solidarity in a divided world

Climate change is the defining human development issue of our generation

Today, we are witnessing at first hand what could be the onset of major human development reversal in our lifetime.

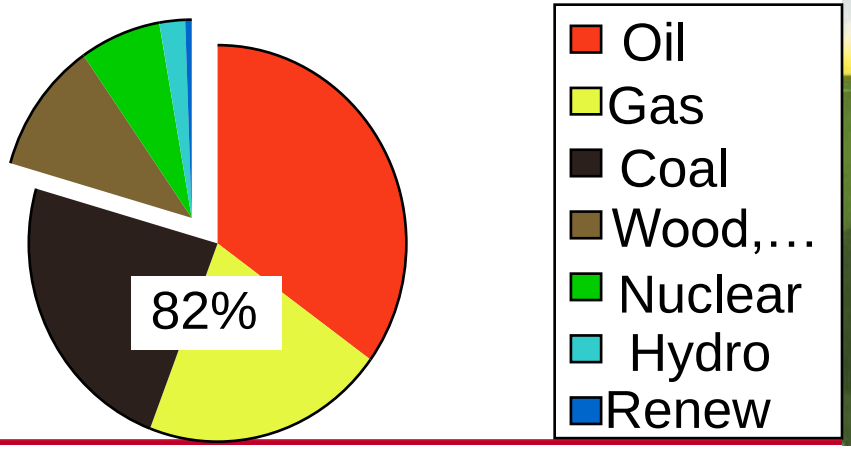
Looking to the future, the danger is that it will stall and then reverse progress built-up over generations not just in cutting extreme poverty, but in health, nutrition,education and other areas.

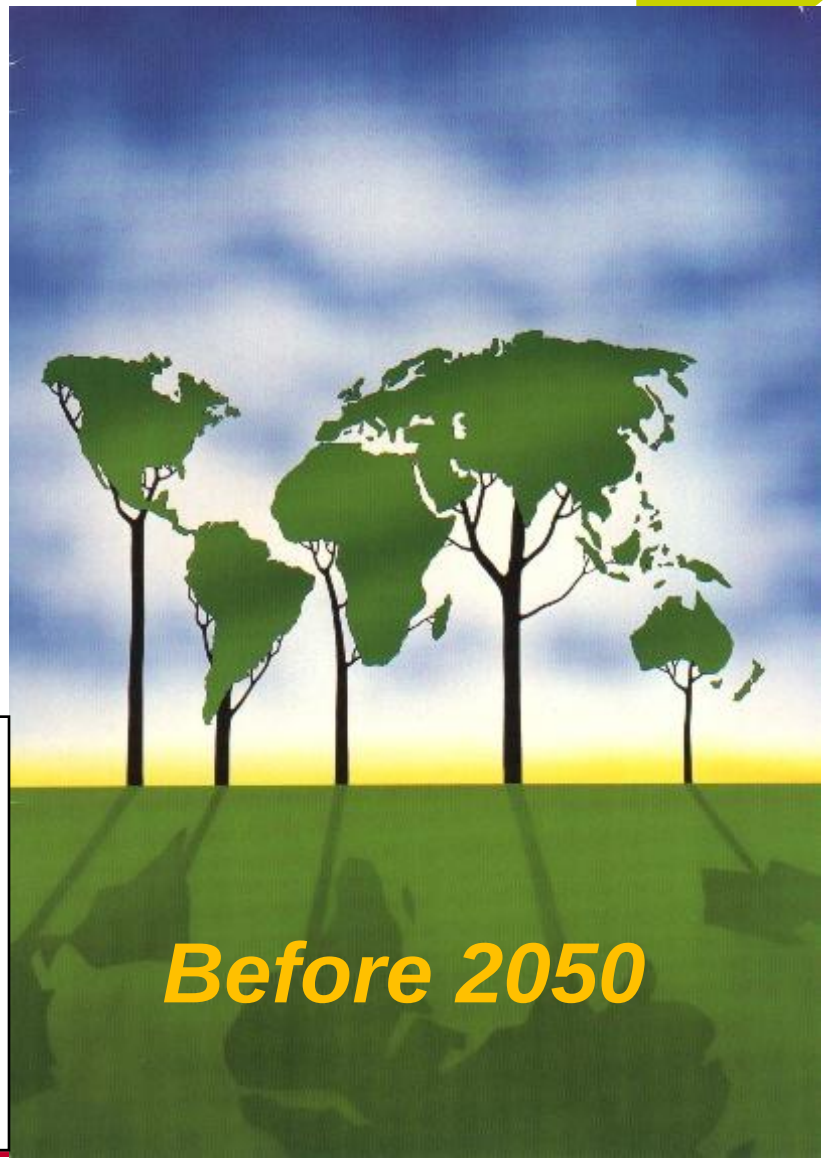
The Challenge of Global Change :

Divide by 2 world CO_2 Emissions

while

Doubling Energy Production





No Single Magic Bullet !

Challenge: to produce more energy but less CO_2

How can we accomplish this?

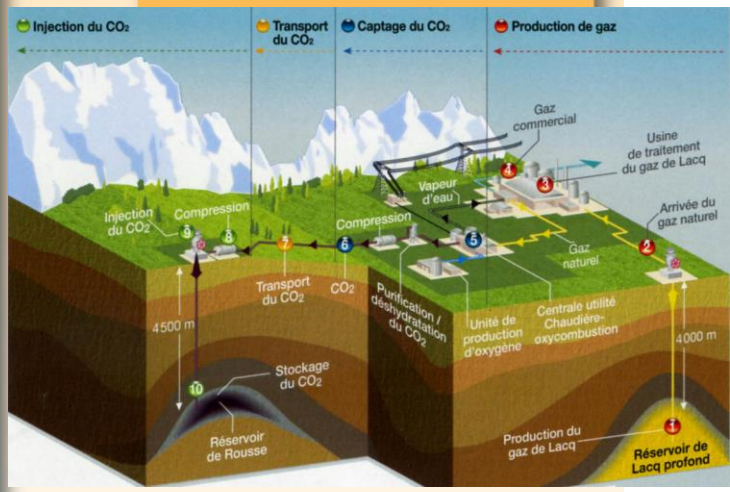
50% — **Control demand for energy**

40% — **Generate energy without producing CO_2**

> Nuclear energy

> Renewable energy

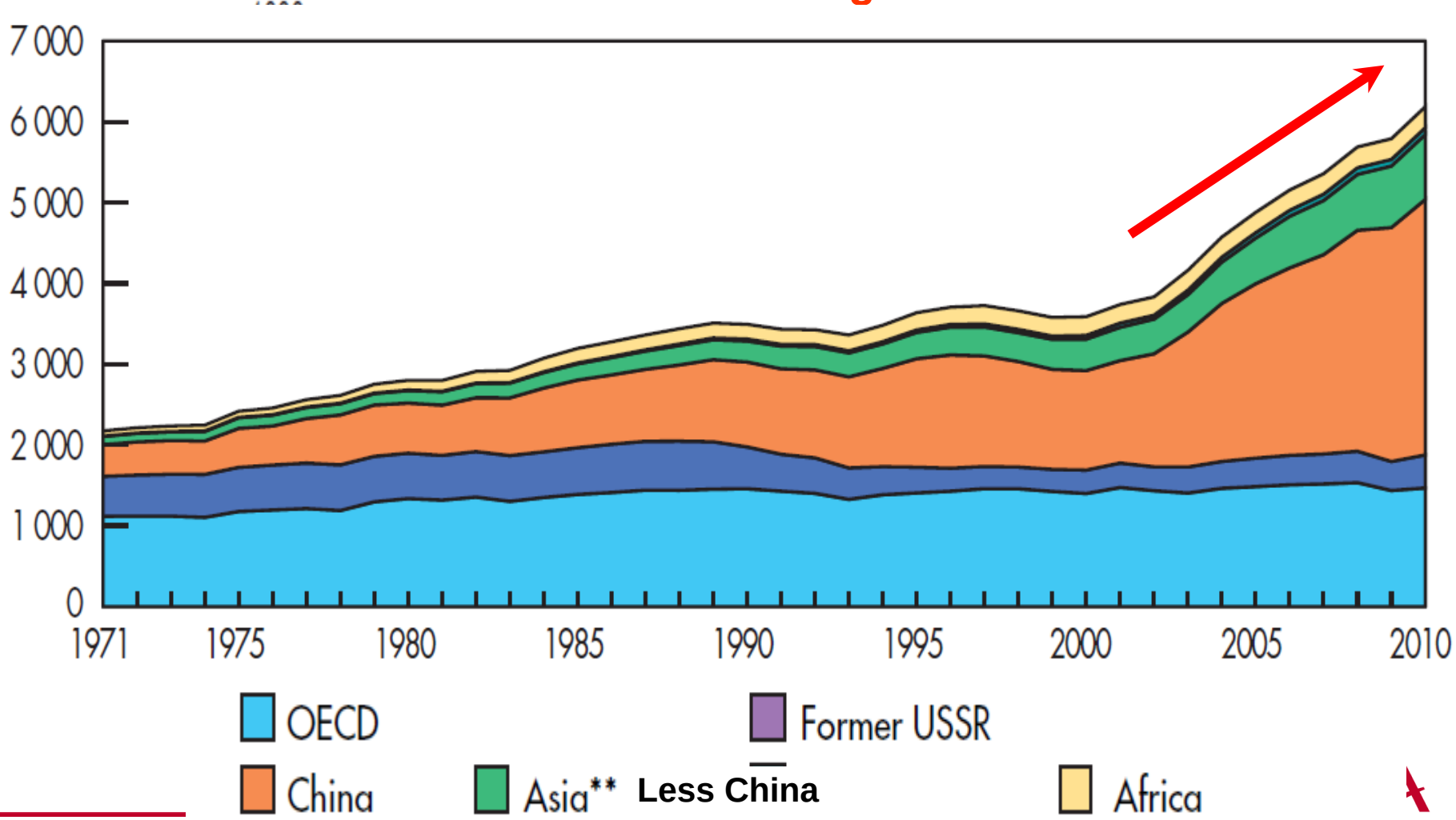
10% — **Sequester CO_2**



Coal is back !

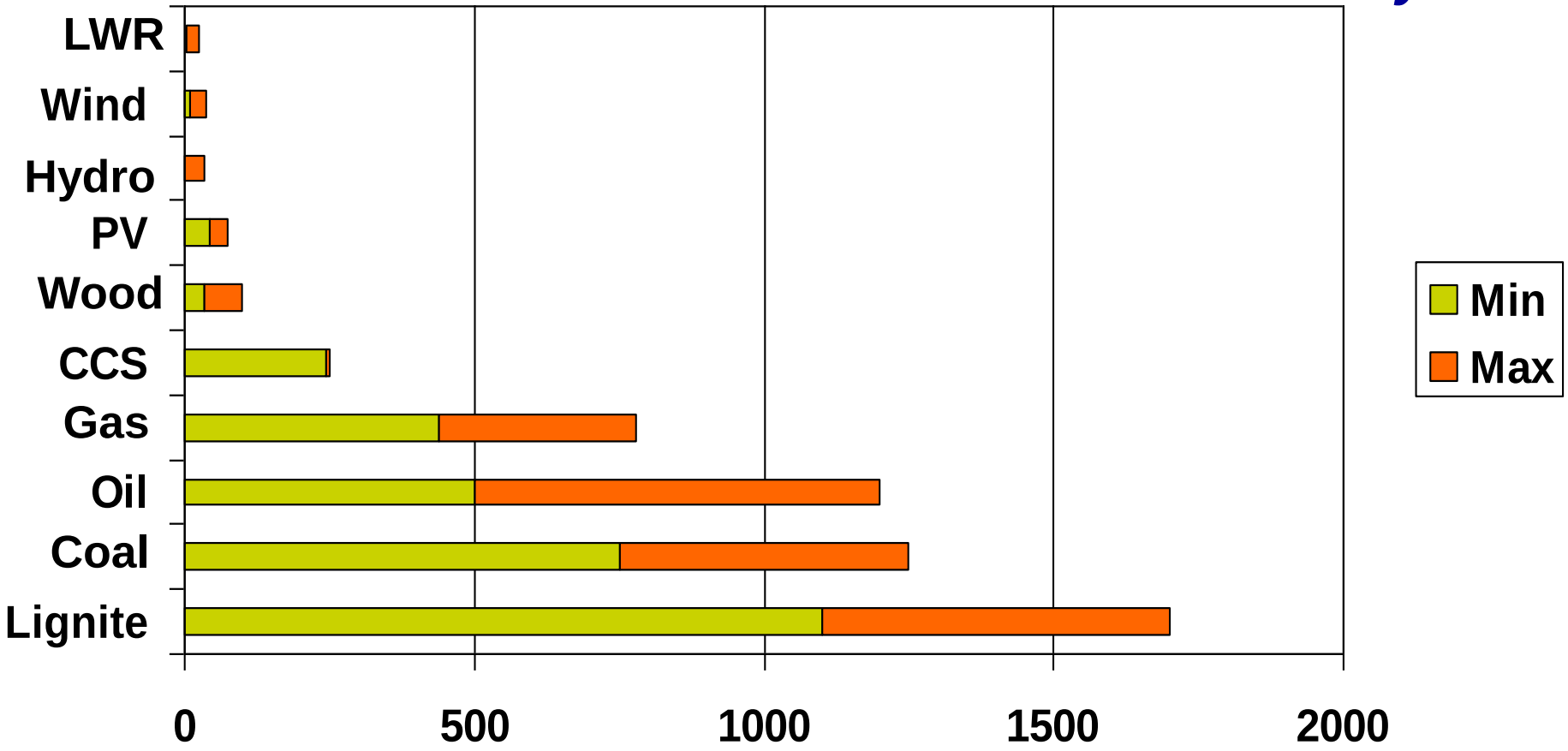
Evolution from 1971 to **2010** of hard coal* production by region (Mt)

Add 900 Mt lignite…



Life Cycle GHG Emissions, g CO_2eq per kWh_e

D. Weisser IAEA May 2006



Ranges reflect differences in assessment technology, conversion efficiency, assessment boundary, etc.

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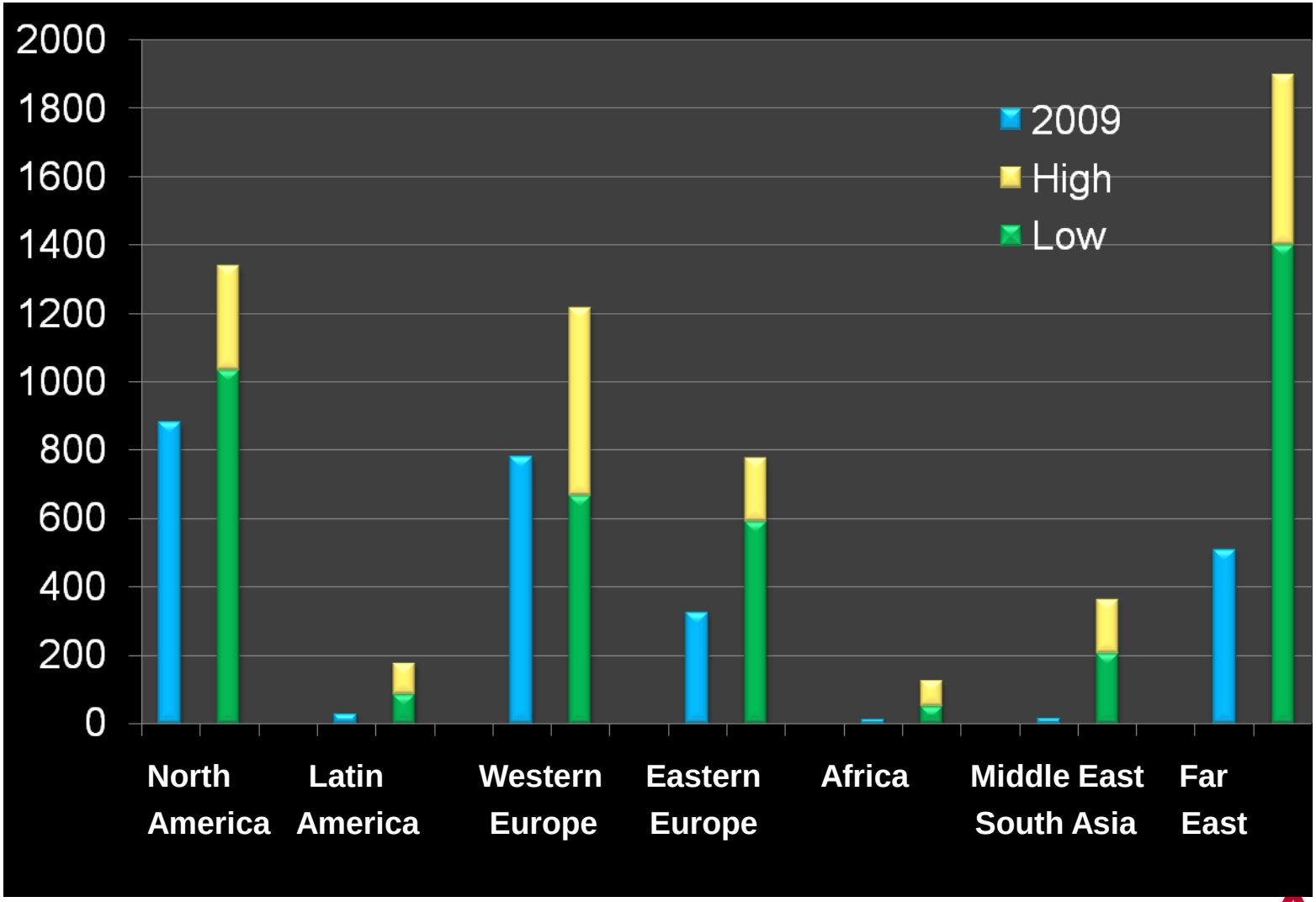
IAEA *2010* forecasts on 2009-2030 nuclear generation

TWh/y



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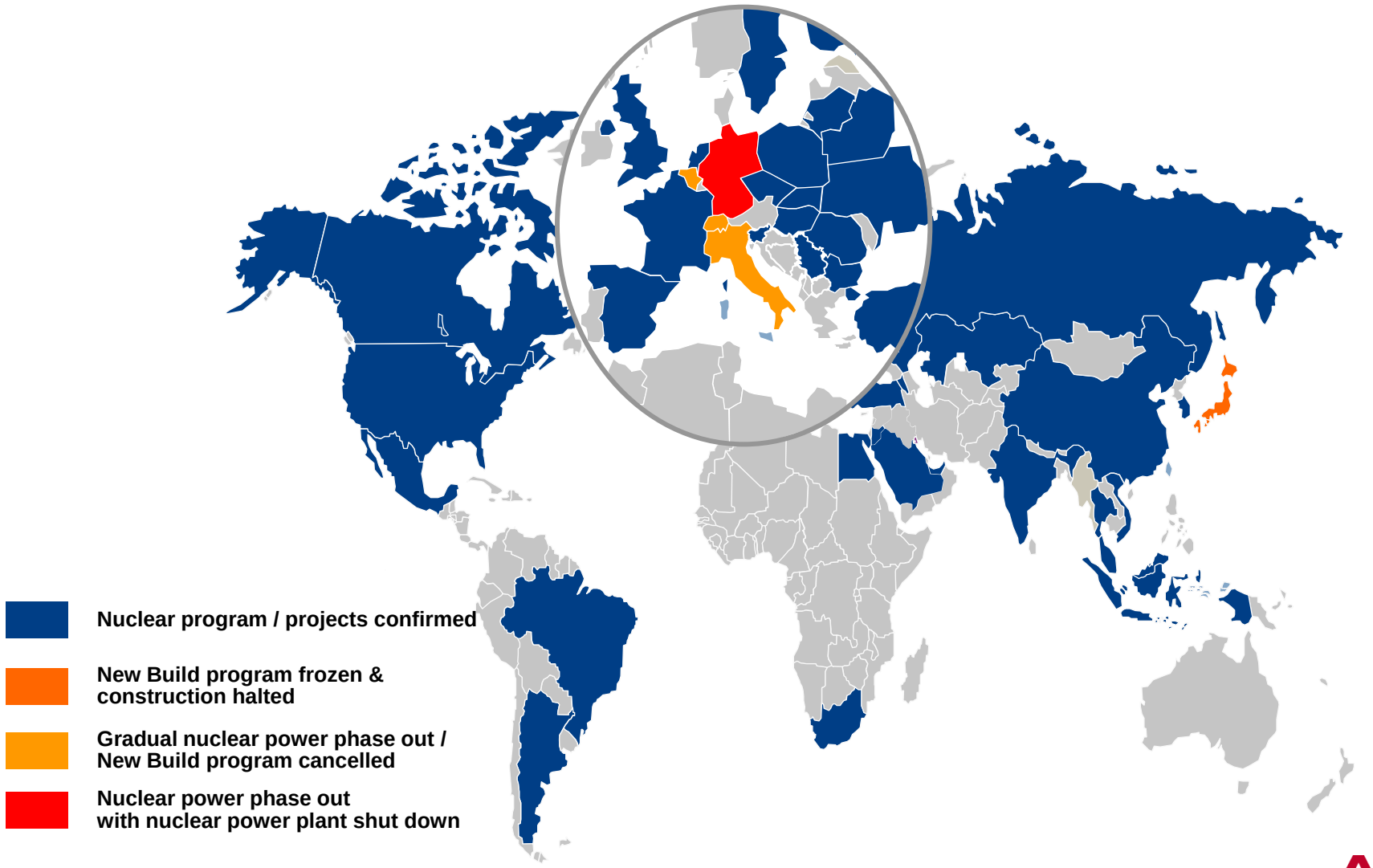
But what after Fukushima ?

Reactions all over the World (January 2012)

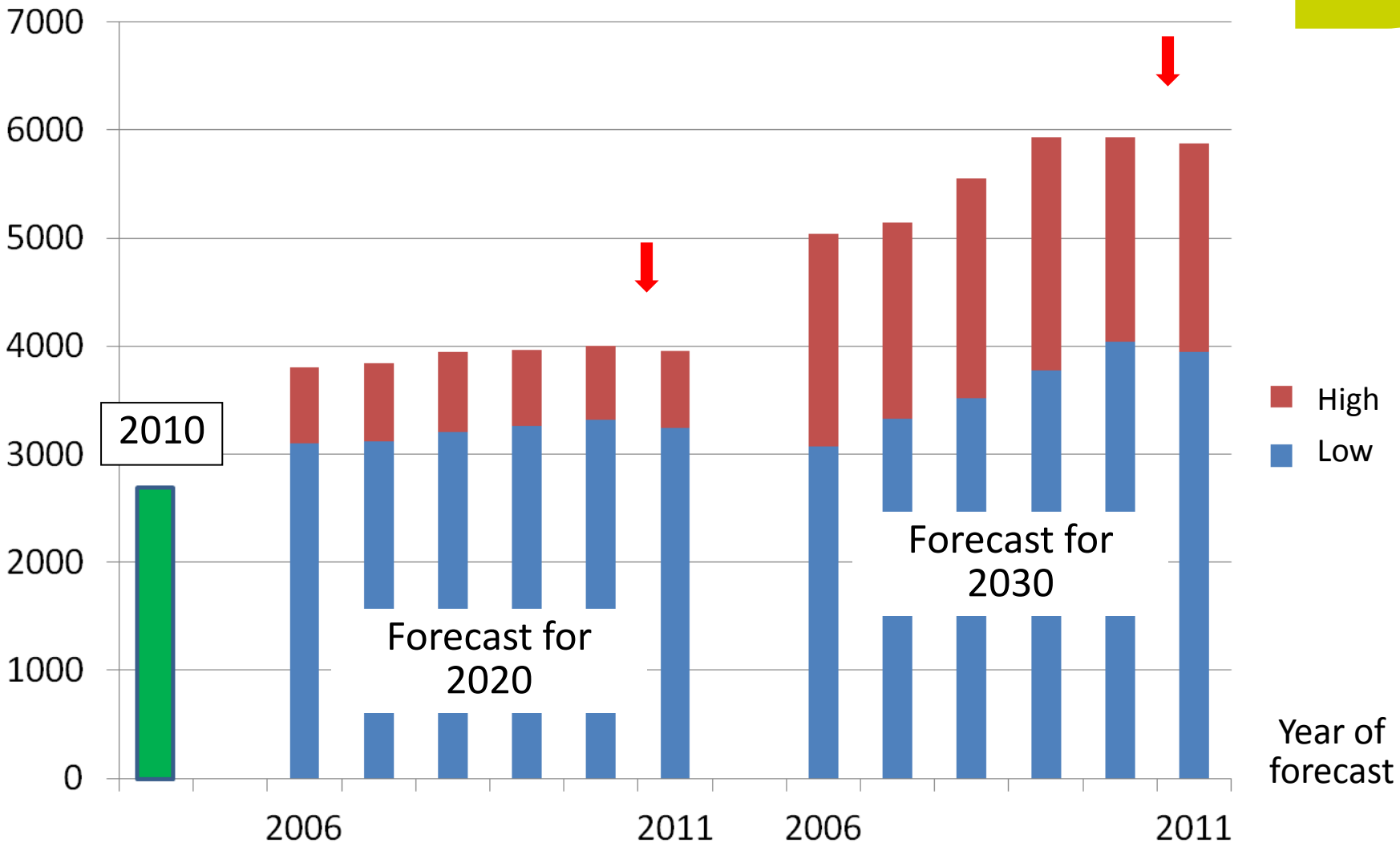
- **Phaseout Operating NPPs:**
  - **Germany**
- **Cancel Projects:**
  - **Japan, Italy, Taiwan, Switzerland ?**
- **Proceed with Nuclear Programs:**
  - **USA, Russia, China, India, UK, Finland, Poland, Czech Republic, Sweden, Slovakia, Hungary, Brazil, South Africa, South Korea, UAE,…**

+ Stress Tests in most nuclear countries

Post Fukushima : Most countries have confirmed the importance of nuclear in their energy mix



World Nuclear Generation (TWh) IAEA 2011



Oklo, Gabon

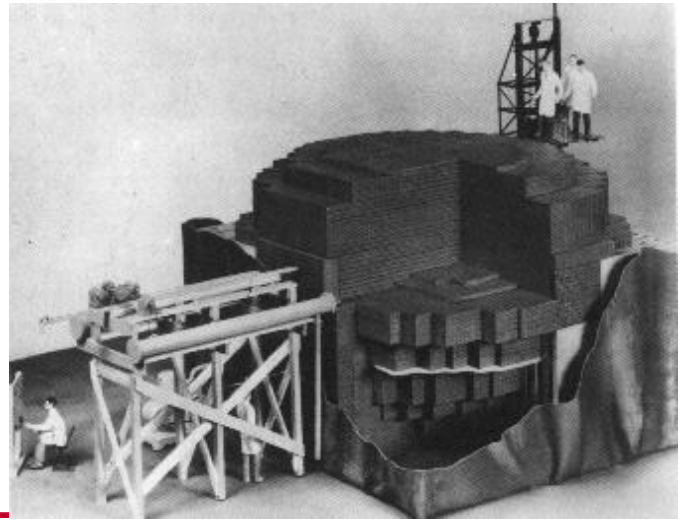
Fission 1932 - 1942

1932: Chadwick discovers neutron

1938 : Fermi plays with neutrons & U. Hahn-Meitner say «fission !»

1939 : Joliot et al. «chain reaction»

1942 : Staggs Field



The Curse on Nuclear Power

- **Because of WW2, the first application of fission was the A-Bomb**

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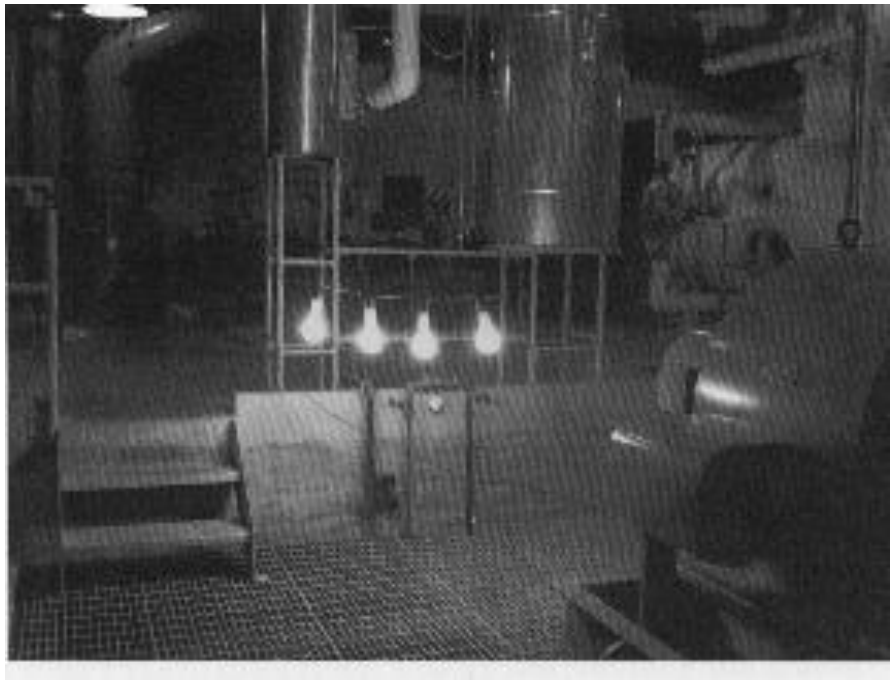
The 50s : Nuclear Electricity



1951 : EBR 1 lits its buiding

1954: Obninsk connected

1956 : Inauguration of Calder Hall by Elisabeth II

First to start a Power Programme:

- Soviet Union
- United Kingdom
- France
- United States
- Canada
- Sweden

Exports and Licenses (Japan, Germany)

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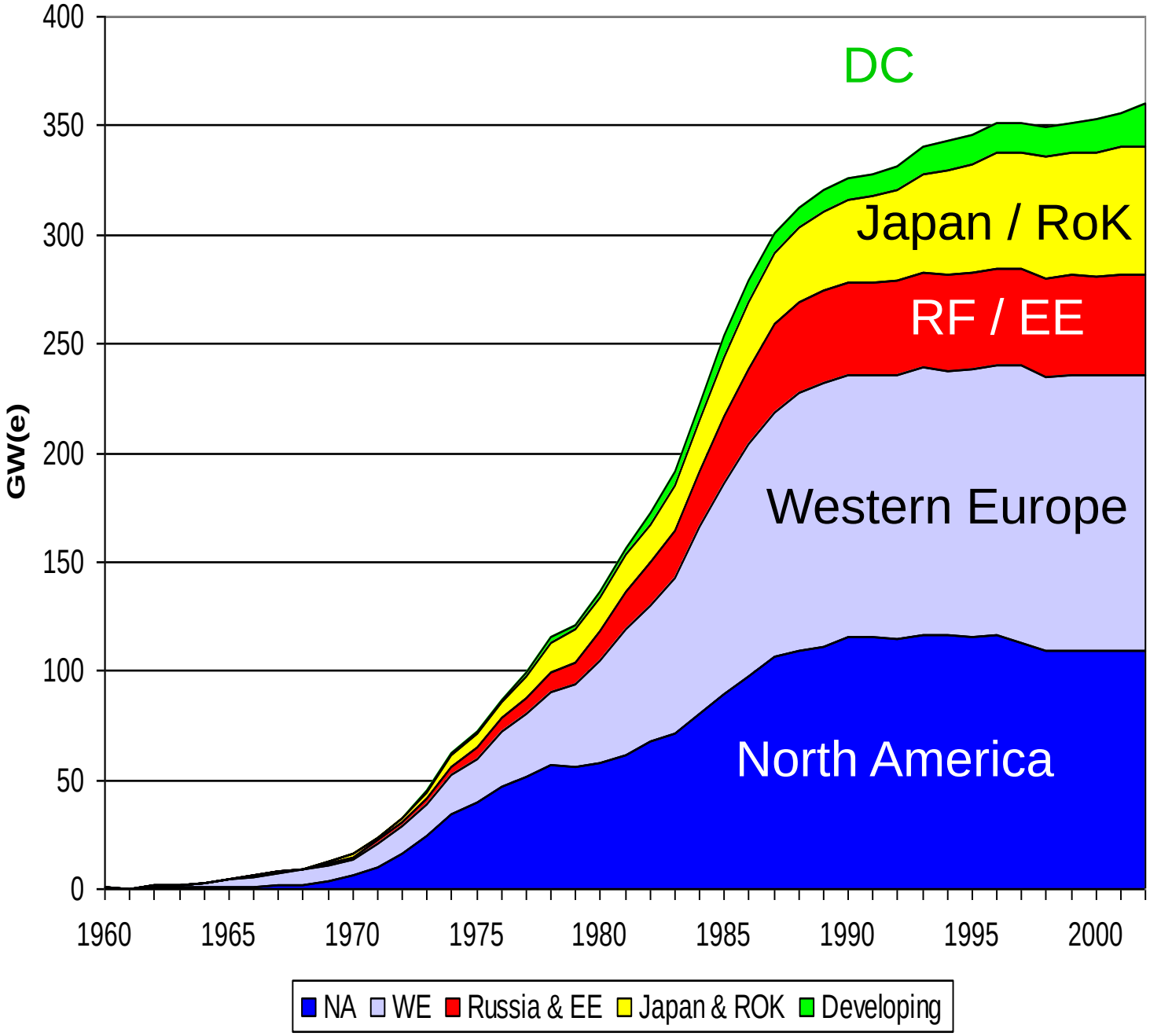
400
350
300
250
200
150
100
50
0
GW(e)
1960
1965
1970
1975
1980
1985
1990
1995
2000
DC
Japan / RoK
RF / EE
Western Europe
North America
NA
WE
Russia & EE
Japan & ROK
Developing

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Ups & Downs…
but not everywhere at the same time

- First big programs : UK, USA, Soviet Union
- Followers : Japan, Western Europe, Canada
- Relay 80s: France, South Korea
- 90s : stagnation America & Europe, growth in Asia
- Now : « second souffle », post-Fukushima

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The British Saga (1)

- Tube Alloys associated to the Manhattan Project
- 1945 AERE Harwell, military priority GLEEP 1947-90
- No D_2O, no SWU ⟶ GCRs
- Windscale production piles 1950-51
- Magnox series (Calder Hall, October 1956) : 11 sites, 26 units, 5 consortia)
- U enriched ⟶ Oxide/SS ⟶ AGR (Windscale 1962) 6 sites, 14 units

No standardization, Magnox = reprocessing

vision : Pu from Magnox to Breeders

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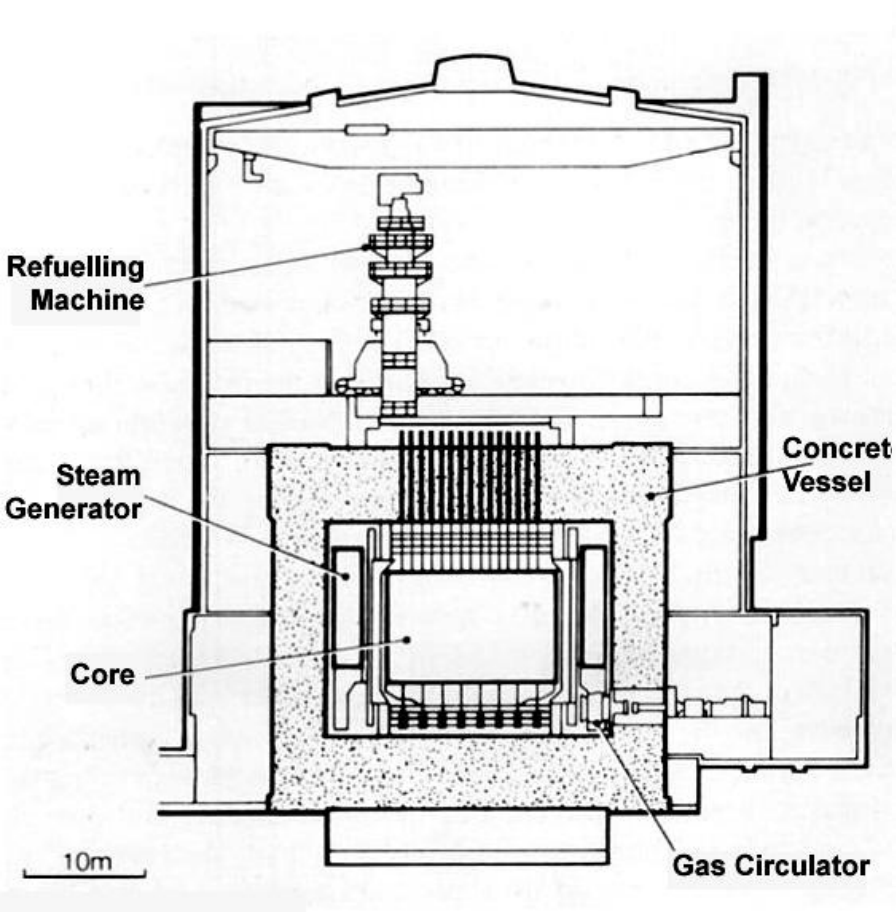
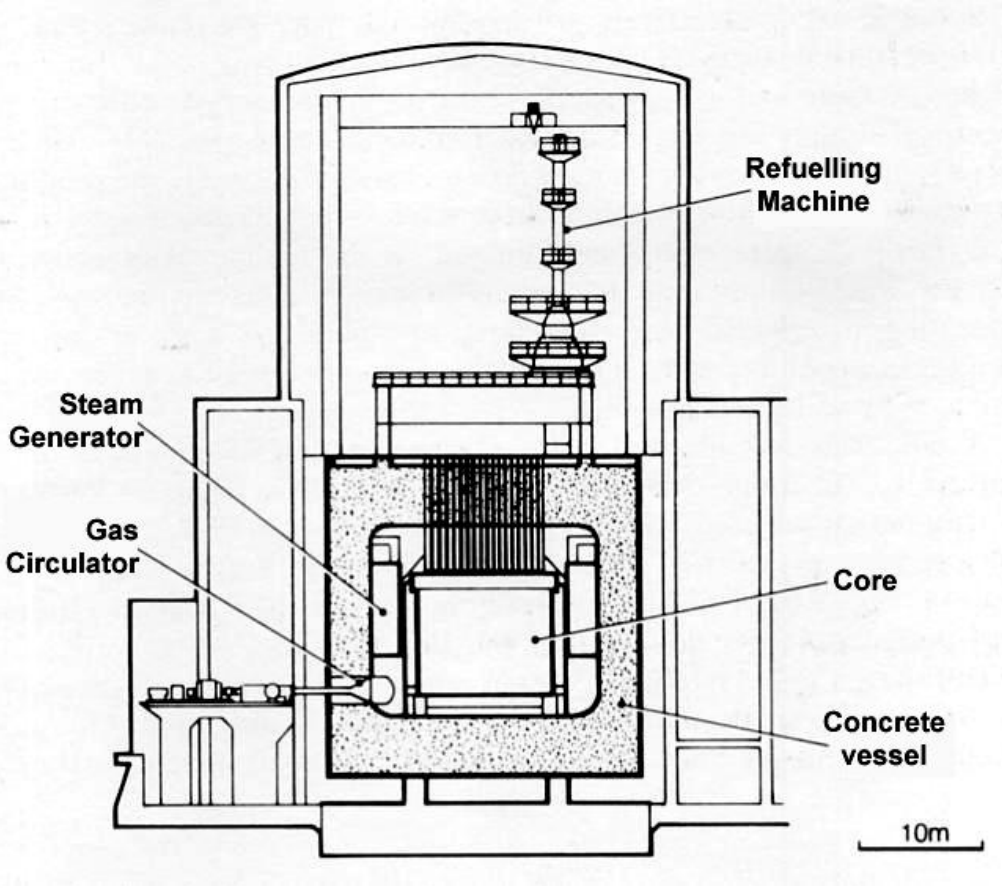
Magnox 300 MW & AGR 600 MW



Oldbury A



Dungeness B

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The British Saga (3)

- North Sea Oil & Gas (plus Coal)
- Sizewell B 1995-2035 ?

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Fuel Cycle in Britain: BNFL Saga

- BNFL separates from UKAEA 1971
- U Mines : RTZ (Ranger, Rössing)
- Enrichment : BNFL shares in URENCO
- Fuel Fabrication : BNFL
- Reprocessing : BNFL (?)
- 1996 BNFL is given the Magnox (ex-CEGB SSEB)
- 1999 BNFL buys Westinghouse from CBS
- 2000 BNFL buys ABB-CE
- 2005 Nuclear Decommissioning Authority
- 2006 BNFL sells Westinghouse to Toshiba, sells BNG/US
- 2007 BNF for sale, Magnox go to NDA, Thorp ???

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The Times November 21, 2005

Britain is ready to go nuclear

By Philip Webster, Political Editor

Blair courts controversy with power station plan

BRITAIN will start building new civil nuclear power stations under plans backed by Tony Blair, *The Times* has learnt. Less than two years after a government paper called nuclear power an unattractive option, the Prime Minister has become convinced that building nuclear power stations is the only way to secure energy needs and meet obligations to reduce carbon emissions

November 2009 : National Policy Statements (10 possible sites ?)

Nuclear Power in the United States

- **Priority to the Bomb…then to the Submarines**

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USA 1 : The Beginnings

- 1946 : Mc Mahon Act, establishes USAEC
- 1948 : Westinghouse involved in submarine design
- 1950: General Electric, ditto
- 1951: MTR, EBR1 at INEL (picture 20-12-51)
- 1953: S1W, land-based sub, ancestor PWR. Atoms for Peace Speech.
- 1954: Atomic Energy Act opens Nuclear to private industry and declassifies relevant data
- 1955-57: AEC launches Power Demonstration Program (PWR, BWR, Na-Graphite, HWR, FBR, HTGR). BORAX III lits Arco.

USA 2 : The Heydays

- 1957: Shippingport 60 MWe PWR, 1st US NPP connected (Shut down 1982, green field 1987)
- 1963-1966 : First turnkey Plants W & GE (costs overruns)
- 1966: 20 orders in the year, « truly commercial »: B&W, CE and GA join the gang, and A/E intervene
- 1972-1972 : > 40 orders/year

Shippingport 1957

Dresden 1960

USA 3 : 1974, Annus Horribilis

- 1972 West Valley shut down for refurbishing, will not restart. GE abandons Morris
- 1973: Kippour War, 1st Oil shock, Project Independance, Watergate hearings
- 1974: Series of NPP cancellations – AEC split into ERDA and NRC, JAEC dissolved – Smiling Buddah
- 1976: G Ford stops commercial reprocessing
- 1977 (April 7): J Carter kills reprocessing and FBR-ERDA becomes USDOE - INFCE
- 1978: Nuclear Non Proliferation Act. Full Scope Safeguards – End of US enrichment monopoly
- 1979 (March 29) TMI2 Accident. : National Nuclear Scare

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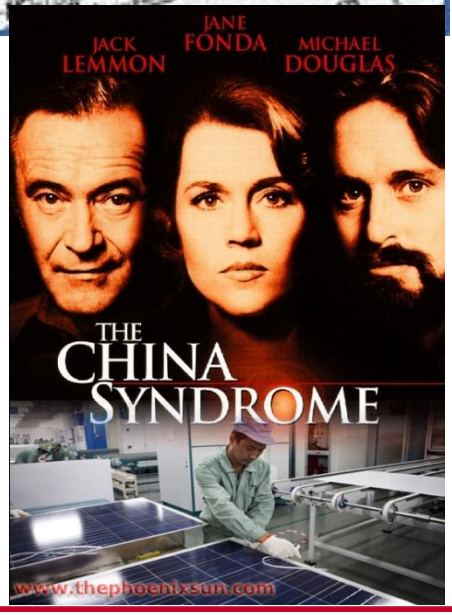
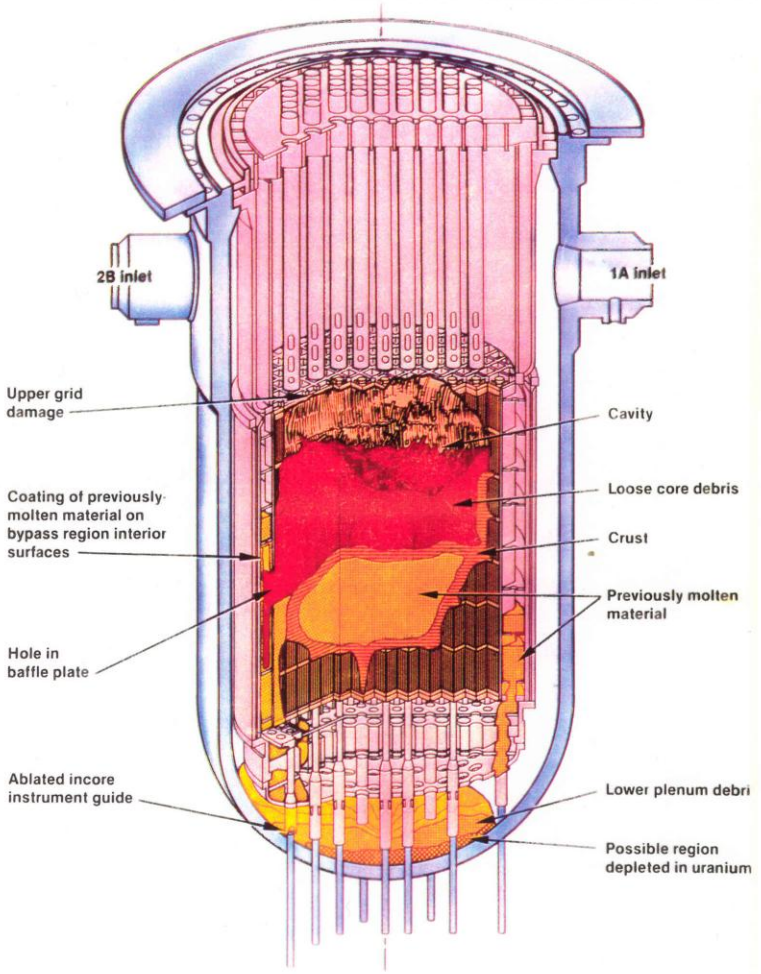
Three Mile Island





TMI-2 Core End-State Configuratio

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The USA's nuclear moratorium

1978 last nuclear plant order in US (cancelled later)

1979 last 2 construction permits issues

1993 last operating license issued

1995 last 2 orders cancelled

259 Reactors ordered

124 Cancelled orders

132 Operating licenses issued

28 Plants shut down

104 Operating plants today

36 Nuclear Engineering programs terminated

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USA 5: The long Road to Recovery

- 1981 R Reagan lifts ban on reprocessing, but no private taker
- 1982: Nuclear Waste Act, Government to take charge of spent fuel Jan 31 1998 - 1 mill/kWh
- 1985 Portsmouth CGEP cancelled (for AVLIS)
- Mid 80s: ALWR FOAK, EPRI URD
- 1986 : Chernobyl Accident (much less impact than in Europe)
- 90s: NRC licensing reform : One-step Licensing, Design Certification, Early Site Approval, COL
- 1998: WIPP receives 1st waste package

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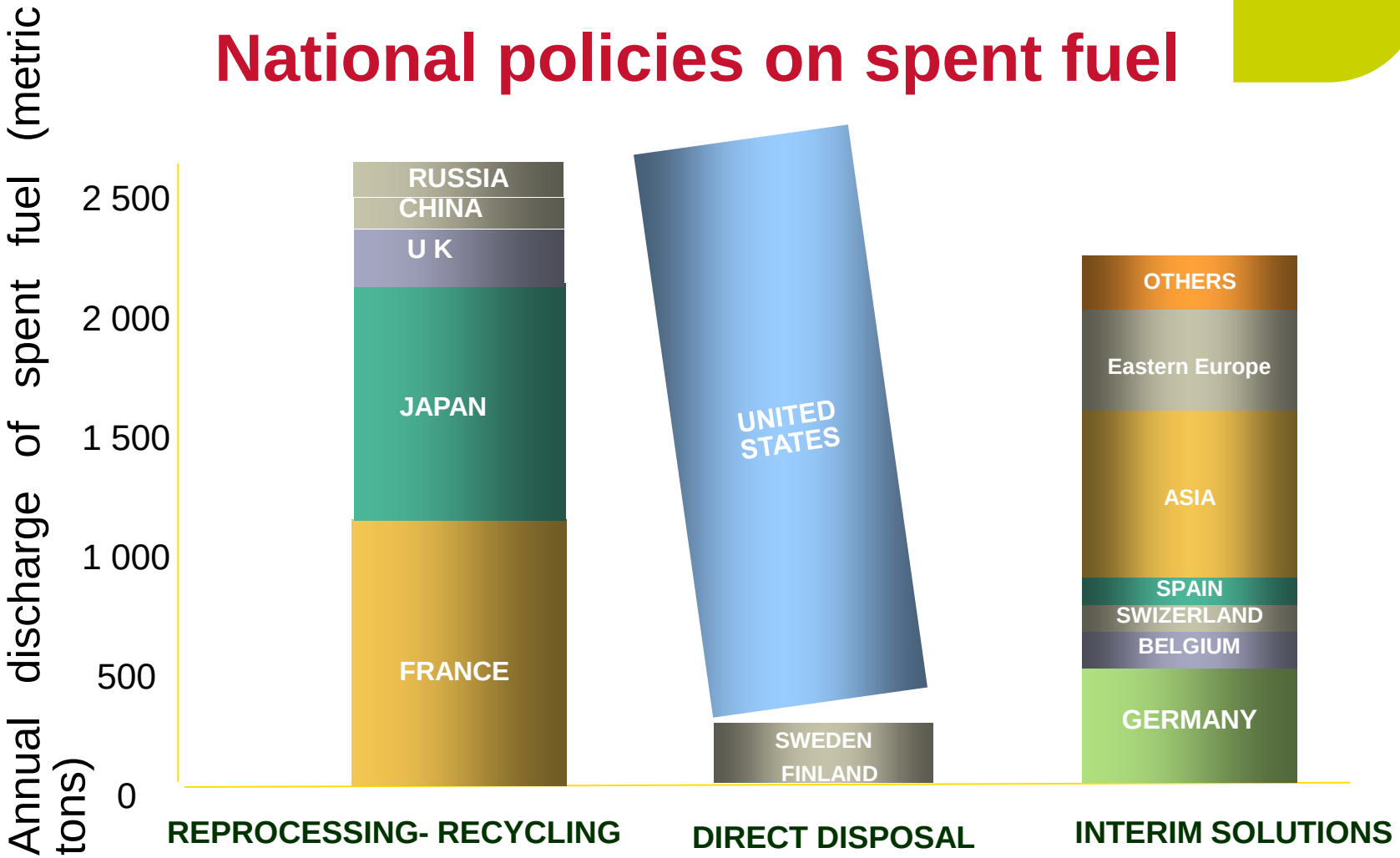
USA 6 : Prelude to Renaissance

- Late 90s: End of NPP shutdowns and Rush to License Extension – Improved Availability, uprates – second-hand market for NPPs → Nuclear « Fleets »
- 1998 : WIPP commissioned – License Renewal starts
- Progress on Yucca Mountain (…)
- Design Certification ABWR, AP600-1000, then ESBWR, EPR
- 2005 Energy Policy Act
- 2011 : Yucca Mountain ? 63 PLEX, 21 License applications
- 2012 : License to Vogtle, but shale gas at 3 $/MBTU !

National policies on spent fuel



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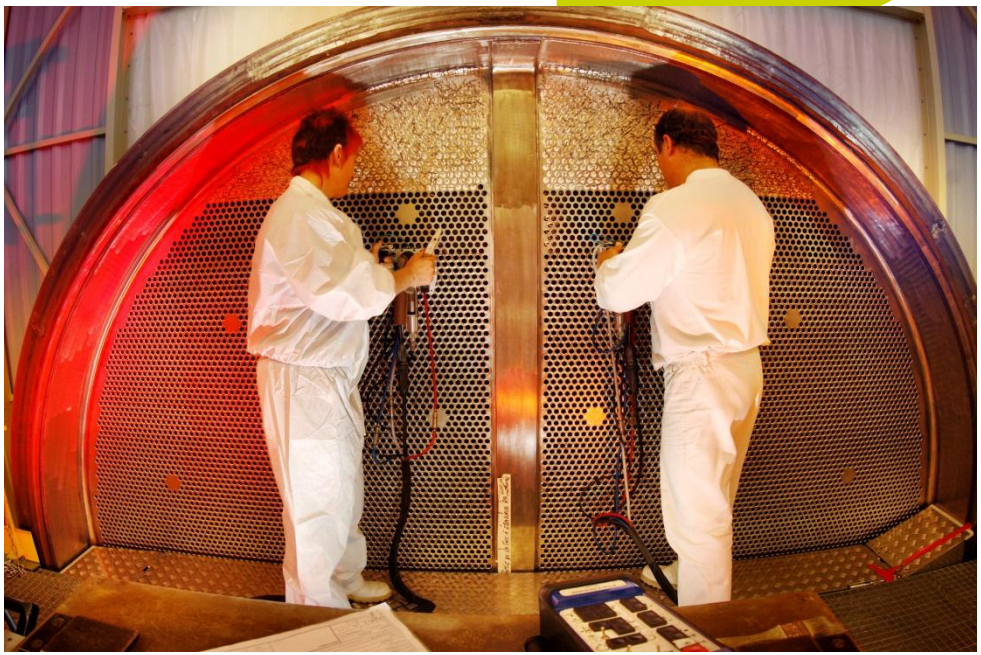
France : Standardized Series & Full Fuel Cycle



French Pionneer Scientists

Henri Becquerel 1852 - 1908

Marie Curie
(1867-1934)

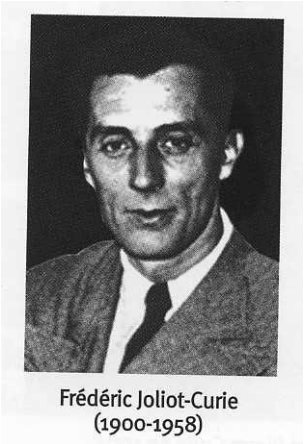
Pierre Curie
(1859-1906)

1903 Nobel

Radioactivity

1911 Nobel

Polonium, Radium



Frédéric Joliot-Curie
(1900-1958)

Irène Joliot-Curie
(1897-1956)

1935 Nobel

Artificial Radioactivity

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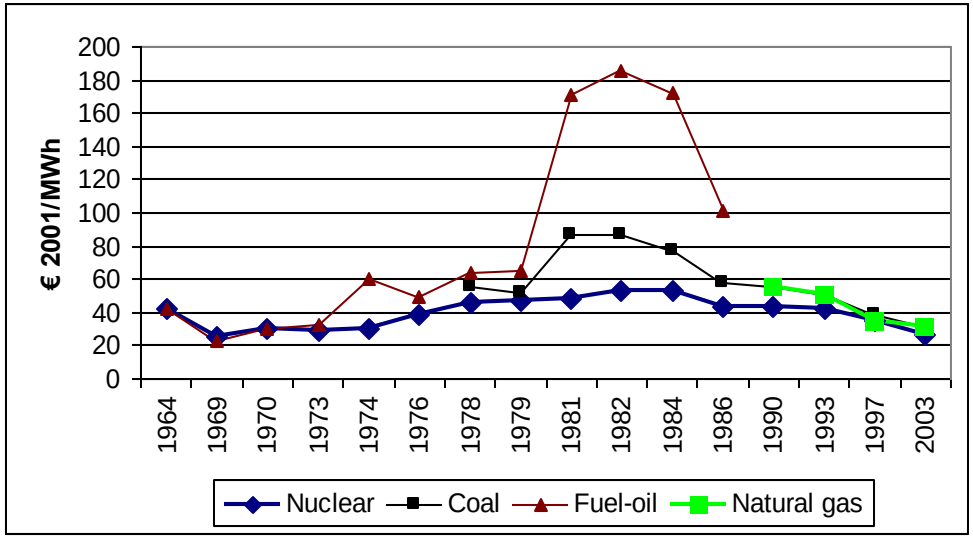
Key Dates of the French Nuclear Program

- 1945 Creation of the CEA (Commissariat à l'Énergie Atomique)
- 1948 Criticality of ZOE
- 1956 First experimental generation of nuclear electricity (G1)
- 1963 First EDF Nuclear Plant Chinon A1
- 1970 Decision to switch from UNGG to LWR at Fessenheim
- 1974 « Messmer » Program
- 1976 Establishment of COGEMA, opening La Hague UP2
- 1977 First 900 MWe at Fessenheim
- 1978 Start-up Eurodif
- 1981 End Westinghouse License : No string attached.
- 1997 Termination Superphénix
- 2000 Start-up Civaux 2, 1500 MWe N4 PWR
- 2001 Creation of AREVA
- 2006 Commitment EPR
- 2012 : Flamanville 3 under construction, GBII replaces Eurodif

The One overwhelming Motivation behind the Messmer Program

- **To reduce our Dependance from imported Oil, after the first oil crisis.***

- **Political consequences**
  - **(unstable Middle East)**
- **Financial consequences**
  - **(Energy « Bill »)**
- **Economic consequences**
  - **(End of « 3-decade Growth)**
  - **(Securty of Supply)**
  - **(Cost Predictability)**



*** « *En France, on n'a pas de pétrole, mais on a des idées* »**

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The « Messmer » Program : « Mission Impossible » ?

- **Order 34 almost identical 900 MWe plants, 6 per year, while :**
- **The first French 900 MWe PWR was still under construction**
- **Previous experience with 300 MWe Chooz A1 was only half convincing**
- **No significant series anywhere else in the western world**
- **In parallel, start untried 1300 MW series, only 3 years later**

BUT IT WORKED

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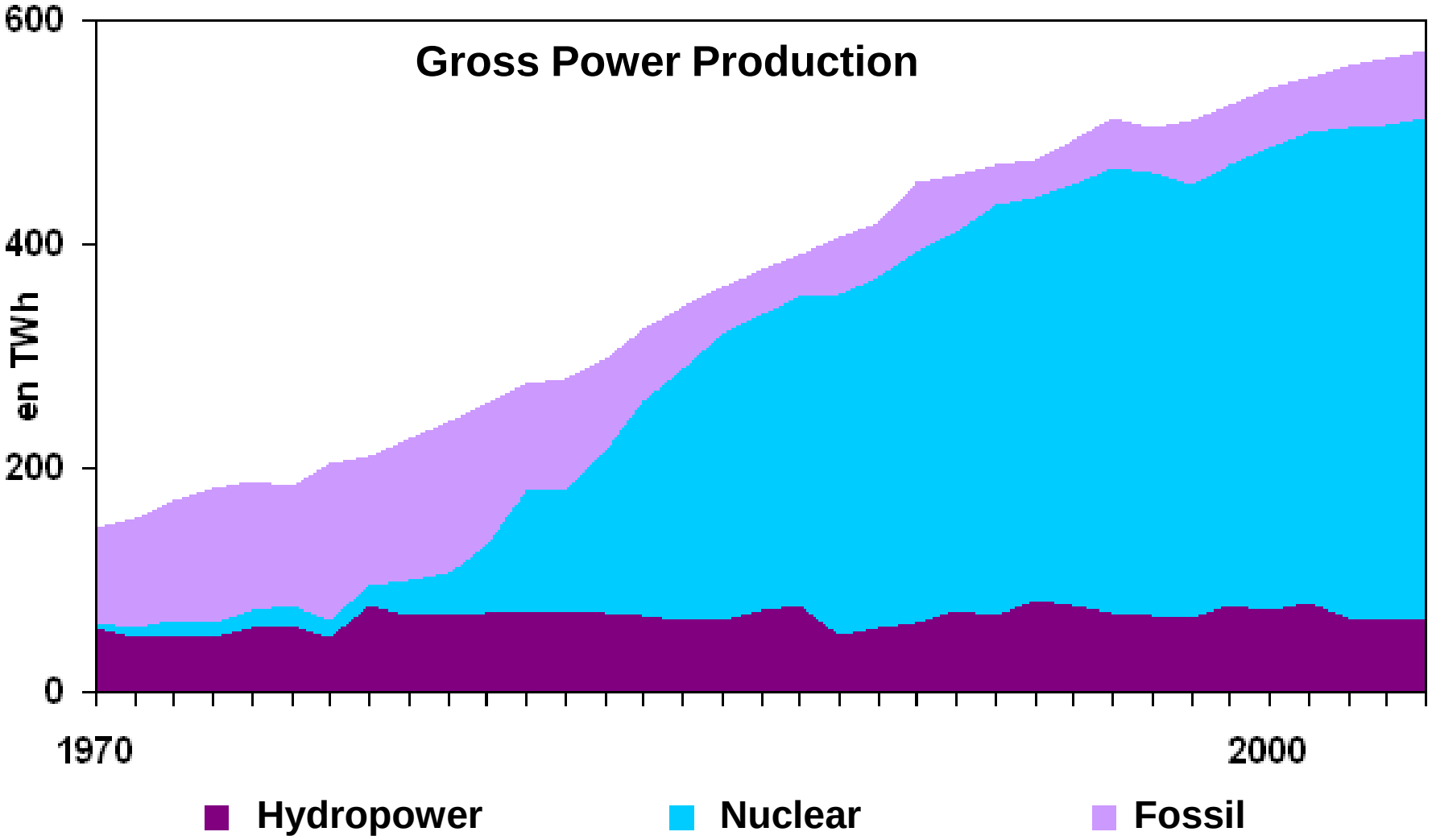
Power Generation in France 1973 - 2004



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Key Factors of Success

- A perceived need by Government and Public.
- A powerful national utilty (EDF), with engineering capability… & worldwide bank credit.
- An existing complete Nuclear Background (CEA, Industry, Safety Authority), including trained manpower.
- Standardization
- Full support by the Licensor (Proven design, Lead Plants)
- Supporting R&D (« 4-Partite Program »)
- Completeness of the scope (Fuel Cycle, waste management, emergency planing, etc.), now mastered within AREVA
- A long term Vision + Commitment (Breeders, even Fusion)
- Continuity through political changes (1981)

Some Problems along the Way

- **Standardization is basically good (Industry size, Costs, Return of experience, Training of operators … and regulators), but with some drawbacks (Common Modes : under cladding cracks, RPV Heads)**
- **Generally good Public Acceptance, but with some local exceptions (Plogoff, Le Pellerin), and some problems with foreign neighbours (Fessenheim, Cattenom)**
- **Focus points for World and/or Europe Protesters (Creys-Malville, La Hague, Bure)**
- **Brutal loss of public confidence after Chernobyl (and the Oil counter-shock). Claims of « overcapacity » = no longer Feeling of Need**
- **Bad handling of the Waste Disposal Issue in the 80s.**
- **Termination Superphénix 1997 (Political)**

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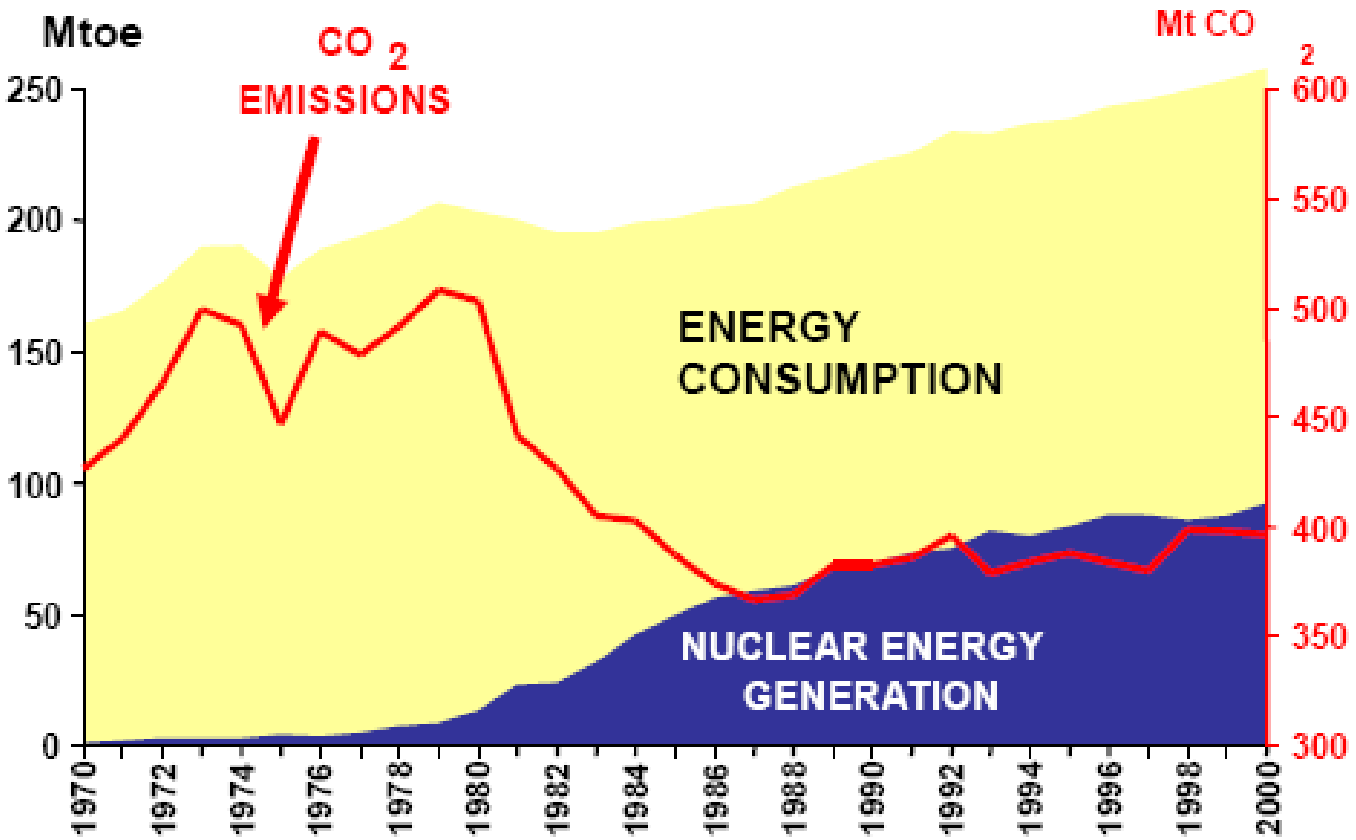
French nuclear electricity and CO2 emissions



La Hague Reprocessing Plant

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Flamanville 3 EPR May 2012

Law for the Sustainable Management of Radioactive Materials & Waste. June 28, 2006

- Spent Fuel Reprocessing + Recycle
- Interim Storage of HLW and LL-MLW …
- … followed by their reversible disposal in deep geological stratum
- Opening of the Disposal Site before 2025, after local and national consultation.
- Continue R&D on P&T within the « Generation 4 » frame
- Demonstrator in 2020 (CEA)
- Waste producers pay for everything.
- No « foreign » waste disposal in France

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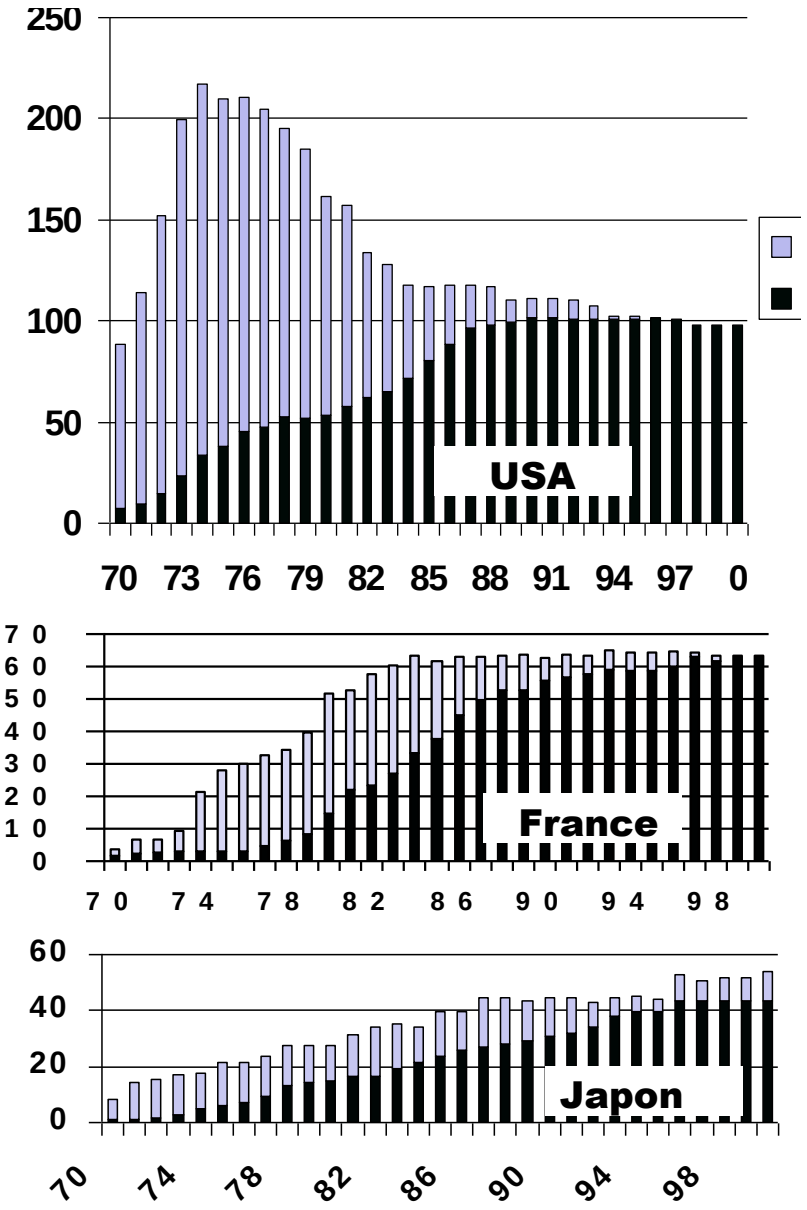
USA – France – Japan Comparison (Gwe)



Construction + Order

Operating

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Some Comments on USA & Japan

USA

- Largest program in the world
- Invented LWR technology
- No domestic order completed since 1974
- Side effect of : Oil shock, overordering, small utilities, Pricing mechanism, TMI, non-standardization
- Drastic improvement in operating plants performance
- Regaining lost vision
- First new projects launched

Japan

- *Was* 3rd program in the world
- Very continuous effort, and long-term vision
- Technology transfer from USA
- Too little standardization
- High costs
- Series of mishaps have severely shaken public confidence
- Safety Authority perceived too weak
- Fukushima Daiichi

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Japan 1

- 1963 – 1976 : JPDR, first nuclear electricity
- 1966: 1st commercial NPP, Tokai Magnox (1998), imported from UK
- 1970: Mihama 1, PWR 340 MWe, Kansai
- 1971: Fukushima 1, BWR 400 MWe, Tepco

9 Utilities + JAPC :

5 Utilities BWR (Hitachi, Toshiba from GE license)

4 Utilities PWR (MHI from Westinghouse license)

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Japan 2

- 1997: 1st ABWR Kashiwasaki-Kariwa 6
- Long-term = FBR. Joyo Monju
- ATR Fugen shut down, no successor
- 30 MWt HTTR first to produce nuclear hydrogen ?
- Centrifuge Plant Rokkasho
- Reprocessing plants Tokai, Rokkasho
- « Pluthermal » MOX
- 2006: Completion Rokkasho –Toshiba acquires Westinghouse - GE and Hitachi get closer, MoU between MHI and AREVA

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Japan's trump cards in Generation 4

HTTR

Monju

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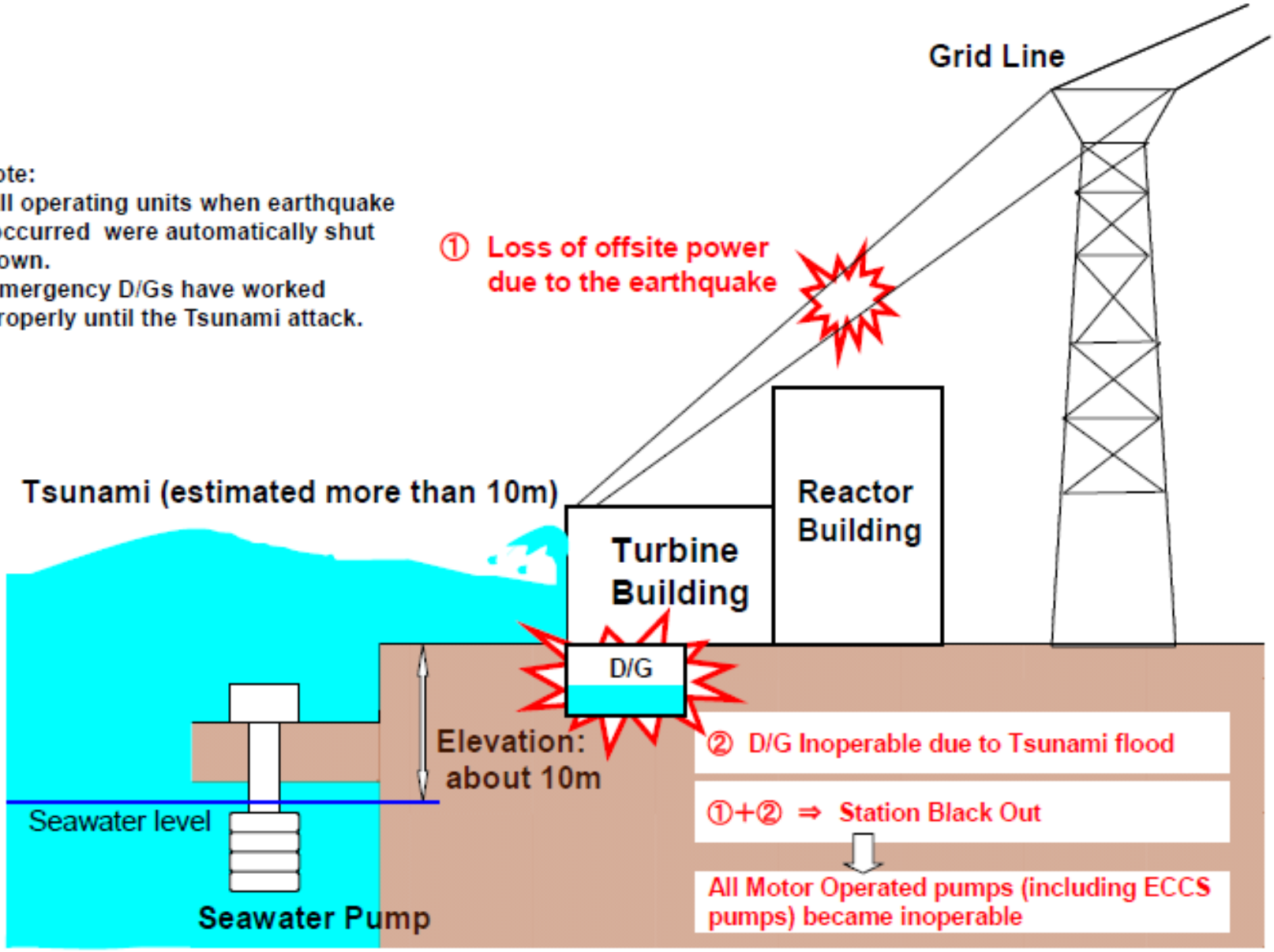
3-2. Major root cause of the damage



Current Status of the Nuclear Power Plants in Japan

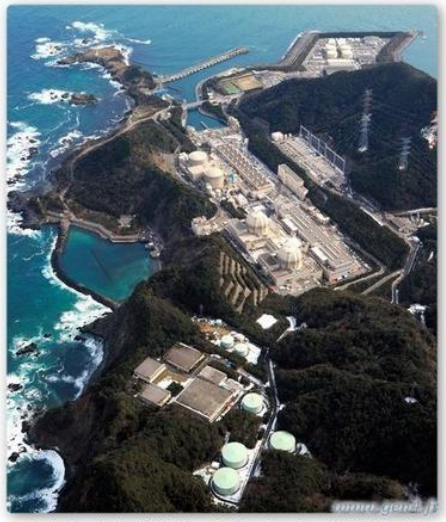
(as of May 28, 2012)

: **In operation**
(0 unit, 0GWe)

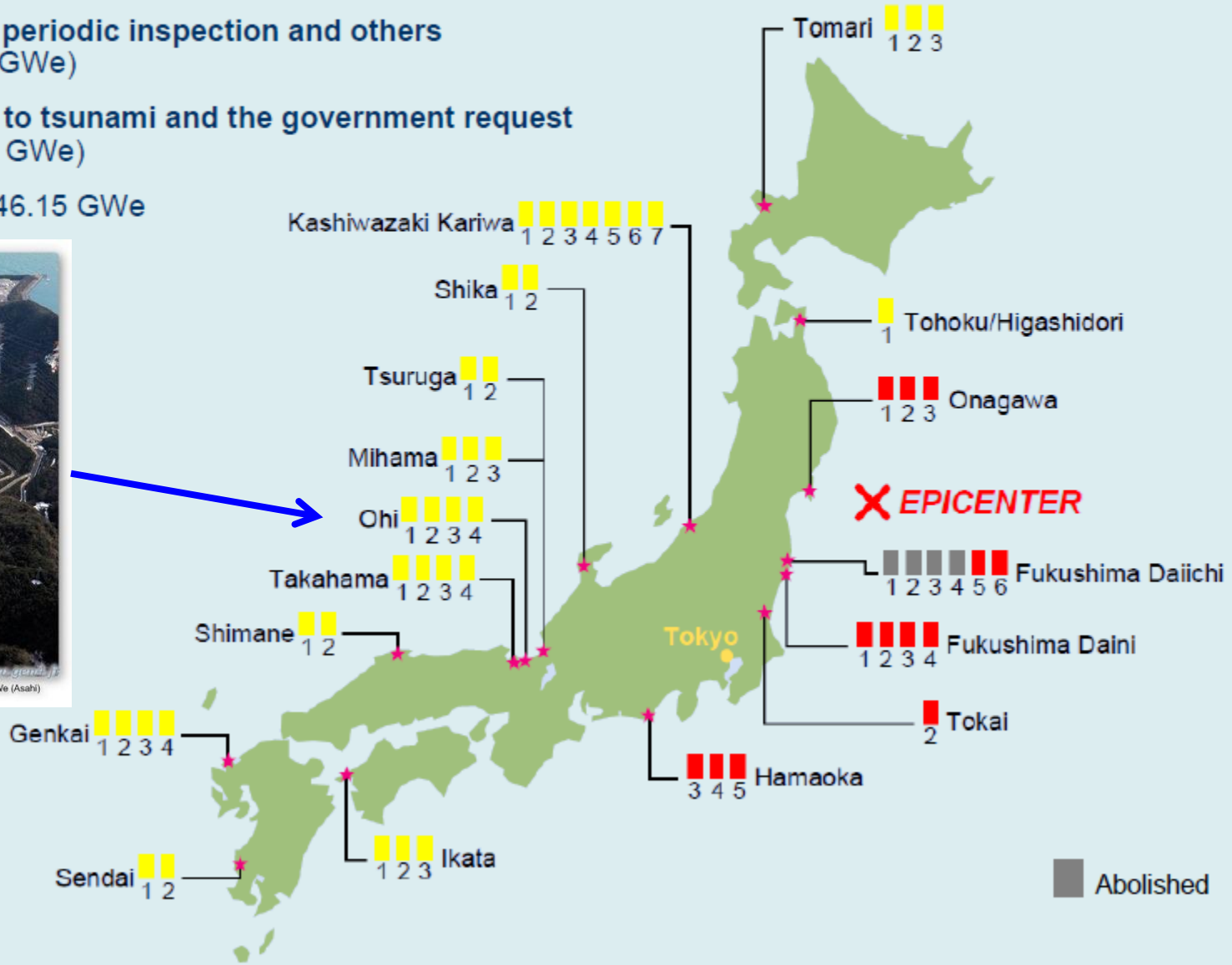
: **Outage for the periodic inspection and others**
(37 units, 32.97GWe)

: **Shutdown due to tsunami and the government request**
(13 units, 13.18 GWe)

TOTAL : 50 units, 46.15 GWe



Le site de production d'Ohi à l'Ouest de Tokyo, 4 tranches, 4400 MWe (Asahi)



Pause

Soviet Union 1: The Beginnings

- 1946: F1 at Kurchatov Institute = CP1, still operational
- 1954: Obninsk APS1 5MWe connected, ancestor RBMK
- 1964:Beloyarsk 1, 100 MWe RBMK and Novovoronezh 1, 210 MWe VVR + B2, NV2

  « Dual Purpose » RBMKs restricted to SU proper, while VVR exported to satellites (except Yugoslavia & Romania) + Finland, with spent fuel return
- First generation (1973-79) = 12 units, 5.8 GWe, 4 VVR 440/230, 4 RBMK 1000 and 4 Cogen Bilibino
- FBR units BOR 60 and BN 350 (desalination)

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Soviet Union : Generation 2

- In Russia : 18 units, 16,5 GWe: 7 RBMK, 2 VVR 440/213, 7 VVR 1000, 1 FBR BN600
- In Ukraine, Lituania : 4 RBMK 1000, 2 RBMK 1500, 2 VVR 400, 13 VVR 1000
- April 26 1986: Accident at Unit 4 Chernobyl
- 1990: End USSR

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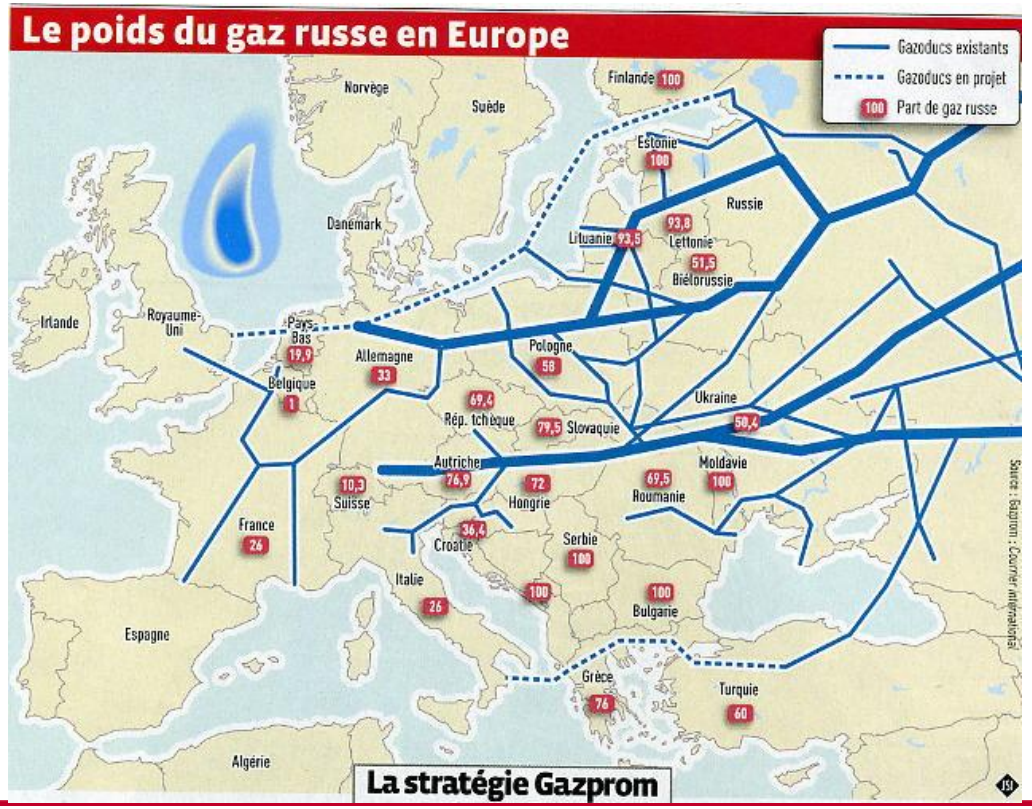
Russia is Back

- 2001: Commission Rostov 1
- Exports NPP: China, Iran, India – Export SWUs
- Putin Program : 2 units/year after 2010

Develop Nuclear for domestic needs to save natural gas for exports



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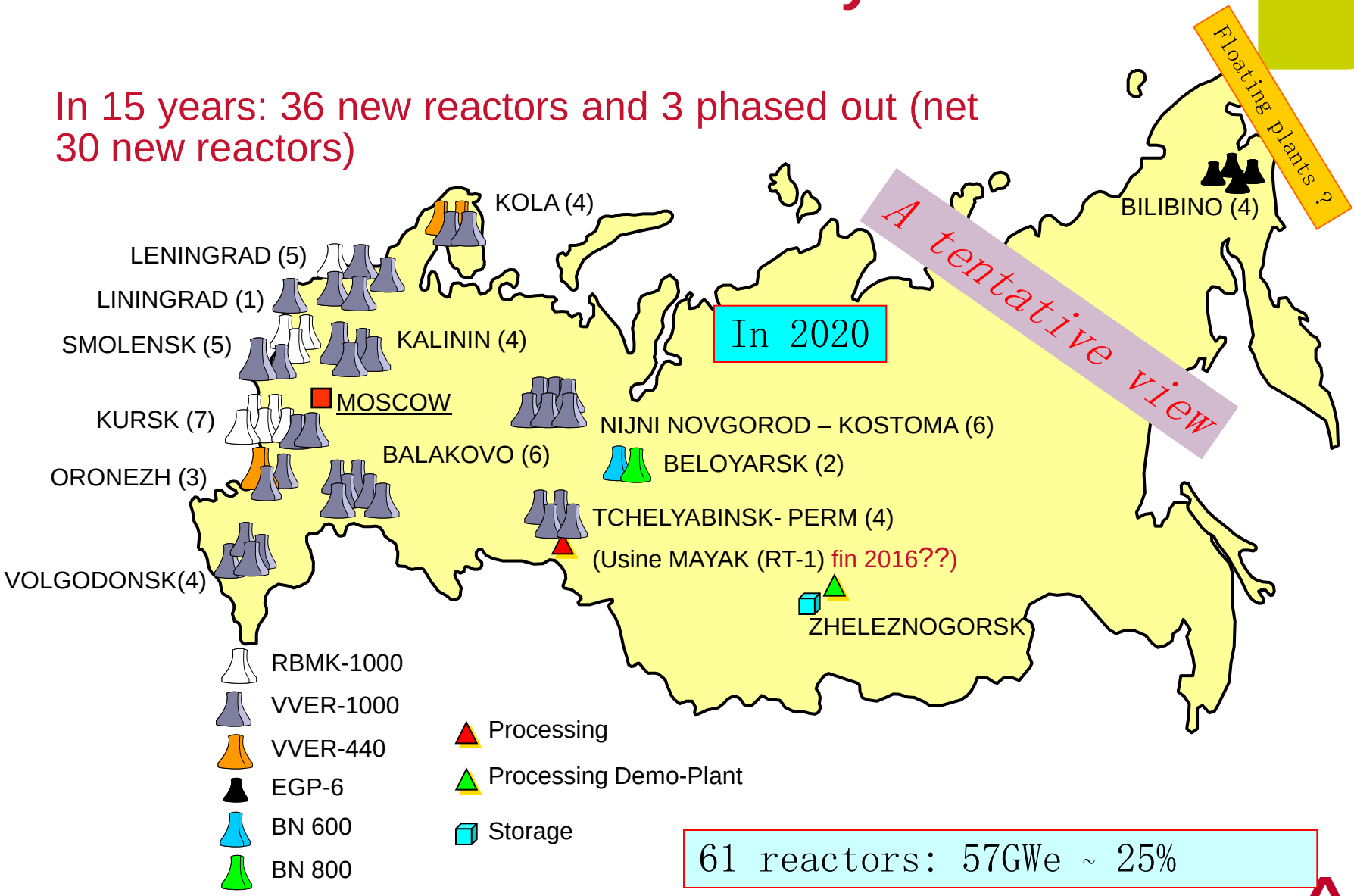
Russian Nuclear industry around 2020

In 15 years: 36 new reactors and 3 phased out (net 30 new reactors)



61 reactors: 57GWe ~ 25%

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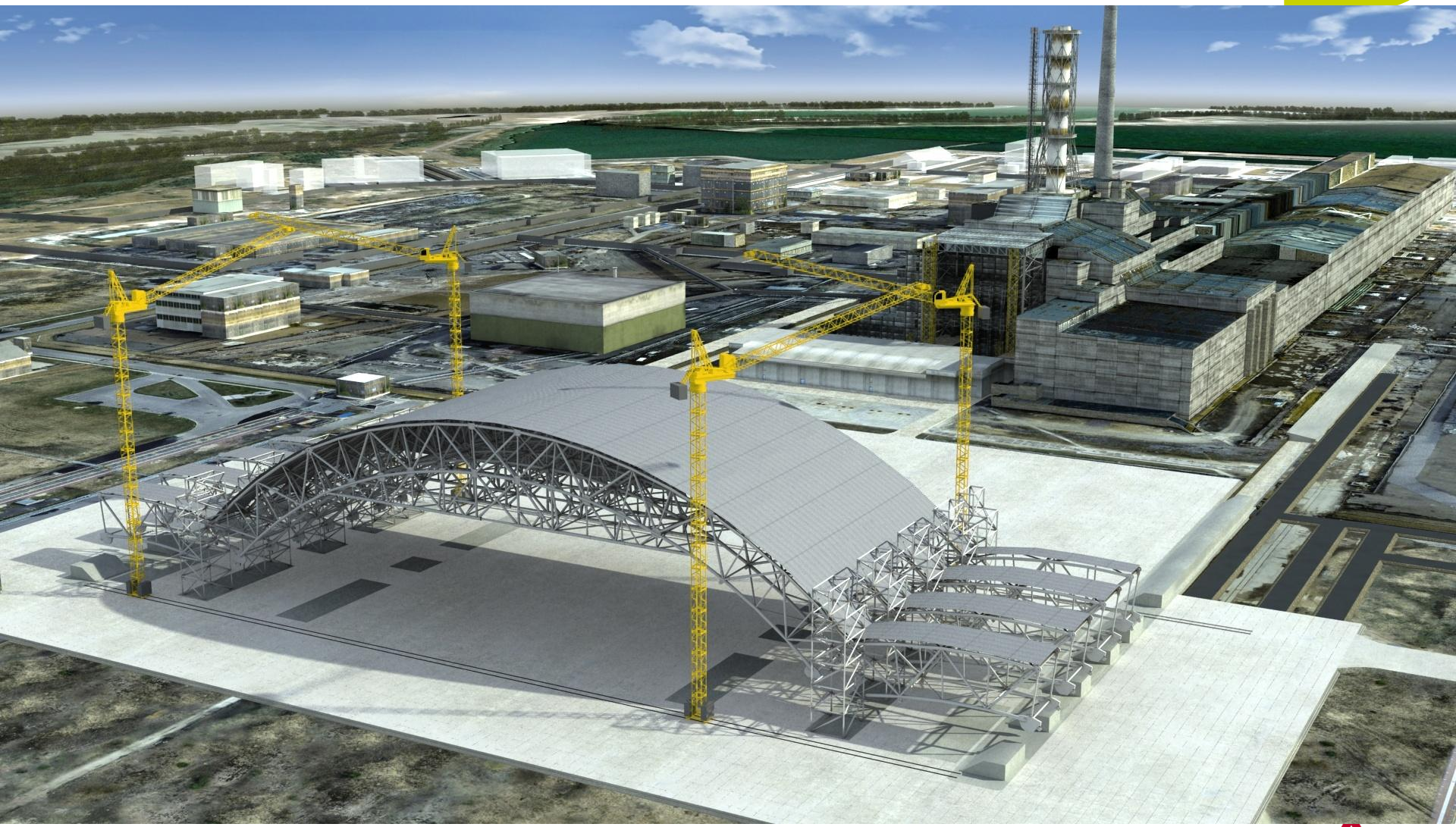
New Safe Containment



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Canada

- September 1945 : ZEEP, first nuclear reactor outside USA
- 1947 NRX
- 1952 AECL (Chalk River)
- 1962 NPD 25 MWe PHWR (AECL, GE, Ontario Hydro) first nuclear electricity
- 1966 Douglas Point 200 MWe CANDU
- 1973 : Pickering, 4 x 800 MWe CANDU (largest nuclear station) + KANUPP + Rajasthan
- 1974 Indian explosion

CAMECO 2nd largest Uranium Producer. 3rd world U reserves

Exports to Argentina, China, India, Pakistan, Romania, South Korea

Latest AECL design, ACR 1000, uses light water cooling and LEU, but still heavy water moderation (not so for ECR)

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Bruce Site

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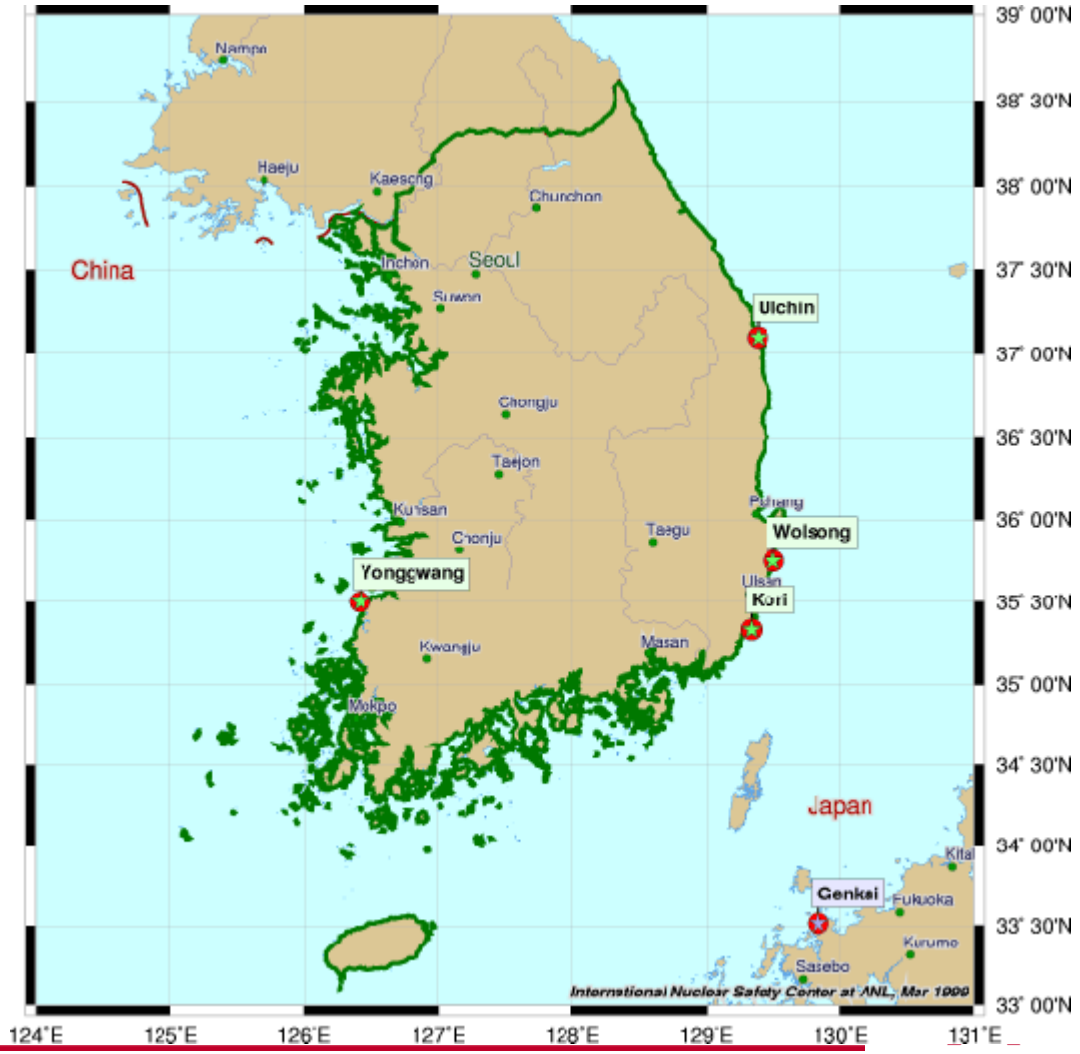
South Korea : on Fast Track

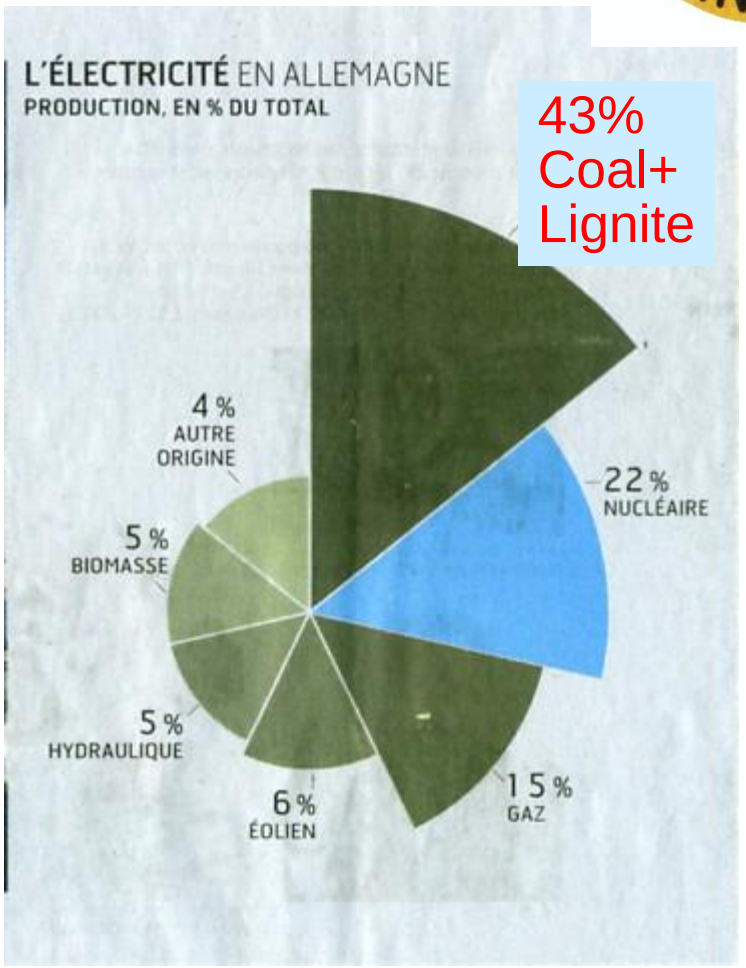
- 1978, 1st electricity Kori 1.
- PWRs (W, Fra, CE) + 4 Candus (Dupic).
- Full technology transfer from Combustion Engineering at the origin of indigeneous KSNP
- 2009 : 4 APR400 sold to UAE
- 2011 : 23 NPP in operation, 3 NPP under construction, 34.6% nuclear electricity



Germany : Off, On and Off again…

- Both PWR & BWR.
- 2001 : SPD-Grünen Coalition decrees nuclear Phaseout by 2021
- Siemens Nuclear merged into AREVA NP
- 2009 : Siemens opts out of AREVA NP
- 2010 : Angela Merkel decides to postpone NPPs shutdown by 8 to 14 years
- March 2011 : Between Fukushima and Bade-Würtemberg election, immediate shutdown of 7 NPPs
- May 2011 : Back to Phaseout in 2022…


ATOMKRAFT ?
NEIN DANKE


L'ÉLECTRICITÉ EN ALLEMAGNE
PRODUCTION, EN % DU TOTAL
43% Coal+ Lignite
4 % AUTRE ORIGINE
22 % NUCLÉAIRE
5 % BIOMASSE
5 % HYDRAULIQUE
6 % ÉOLIEN
15 % GAZ


LES RÉACTEURS NUCLÉAIRES ALLEMANDS
RÉACTEURS ARRÊTÉS À TITRE PROVISOIRE APRÉS FUKUSHIMA
BRÜNSBUTTEL
BROKDORF
UNTERWESER
KRÜMMEL
EMSLAND
BERLIN
GROHNDE
ALLEMAGNE
BIBLIS A
BIBLIS B
GRAFENRHEINFELD
PHILIPPSBURG 1
PHILIPPSBURG 2
NECKARWESTHEIM 1
NECKARWESTHEIM 2
ISAR 1
ISAR 2
GUNDREMMINGEN B
GUNDREMMINGEN C

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Italian Référendum June 13

- All Nuclear Power stopped overnight in 1987
- 2011 : 94% voters against nuclear Revival

NO AL LEGITTIMO IMPEDIMENTO

REFERENDUM 12 GIUGNO 2011: vota SI'

RIPRENDI IL TUO DIRITTO

ALL'AMBIENTE, ALLA SALUTE, ALL'ACQUA PUBBLICA E ALLA LEGALITA'

neuroniattivi.blogspot.com

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A Quick look at some other Countries

- **Belgium : pionneer in MOX. 7 PWR, 54% electricity from nuclear power. 1963 first MOX in 11 MWe BR3. 2003 phaseout Law… unless security of supply threatened. 2009 PLEX for the oldest**
- **Sweden: 1980 is forgotten ! 2 small plants, too close to Denmark, shutdown, but phaseout phased out.**
- **Ukraine : All RBMKs shutdown**
- **« Eastern » Europe : Czech Republic, Slovakia, Bulgaria : VVRs**
- **Slovenia : PWR, Romania : Candus**

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European Union : A Strange Puzzle

- 13 Without Nuclear Power : Austria, Cyprus, Denmark, Estonia, Greece, Italy, Ireland, Latvia, Lituania, Luxemburg, Malta, Poland, Portugal
- 14 With Nuclear Power : Belgium, Bulgaria, Czech R, Finland, France, Germany, Hungary, Netherlands, Romania, Slovakia, Slovenia, Spain, Sweden, UK

One third EU's electricity from nuclear plants - No accident since 1957 - Strong GHG reduction Commitments – Fossil fuels dependance 50% ↑70%

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China : Major Program Underway

- **China : diversify from coal.**
- **1st generation, shopping around with localization + Own PWR development.**
- **Small FBR & HTR Demos.**
- **Biggest construction program by far !**

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SIBERIA
RUSSIA
KAZAKHSTAN
MONGOLIA
HEILONGJIANG
JILIN
INNER MONGOLIA
KYRGYZSTAN
XINJIANG UYGUR
AUTONOMOUS REGION
NORTH KOREA
HEBEI
Beijing
Hongyanhe 4
Weihai 2
Hongshiding 2
Haiyang 8
GANSU
SHANXI
PAKISTAN
SOUTH KOREA
Tianwan 2 1 1
QINGHAI
CHINA
SHAANXI
Ningde 4
Fuqing 4 2 5
HUBEI
SICHUAN
ANHUI
Sanmen 2
TIBET
NEPAL
HUNAN
JIANGXI
INDIA
GUIZHOU
TAIWAN
GUANGDONG
Taishan 6
YUNNAN
Ling Ao 2 2 2
Yangjiang 6
Daya Bay 2
VIETNAM
Lufeng 6
Yaogo 2
MYANMAR
LAOS
LUZON
Power reactors in mainland China and on Taiwan:
16 In operation
7 Under construction
54 Planned

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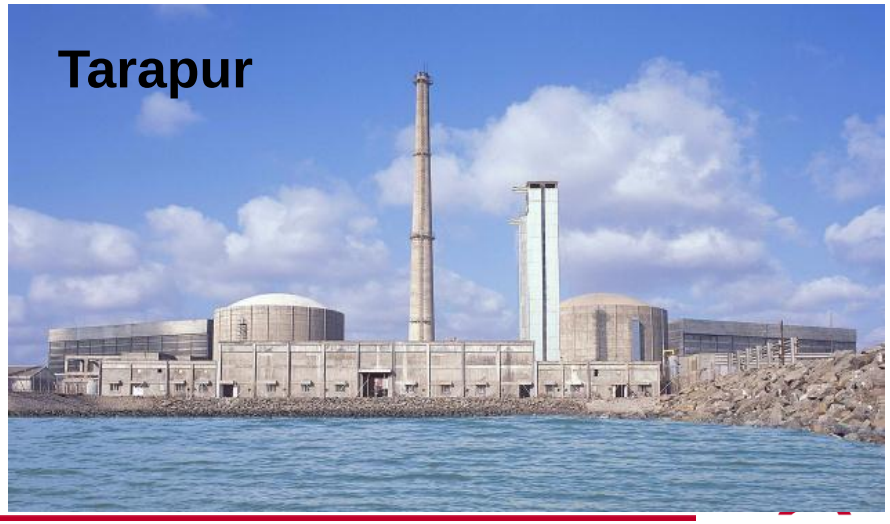
Gen III in China (2012)

EPR in Taishan

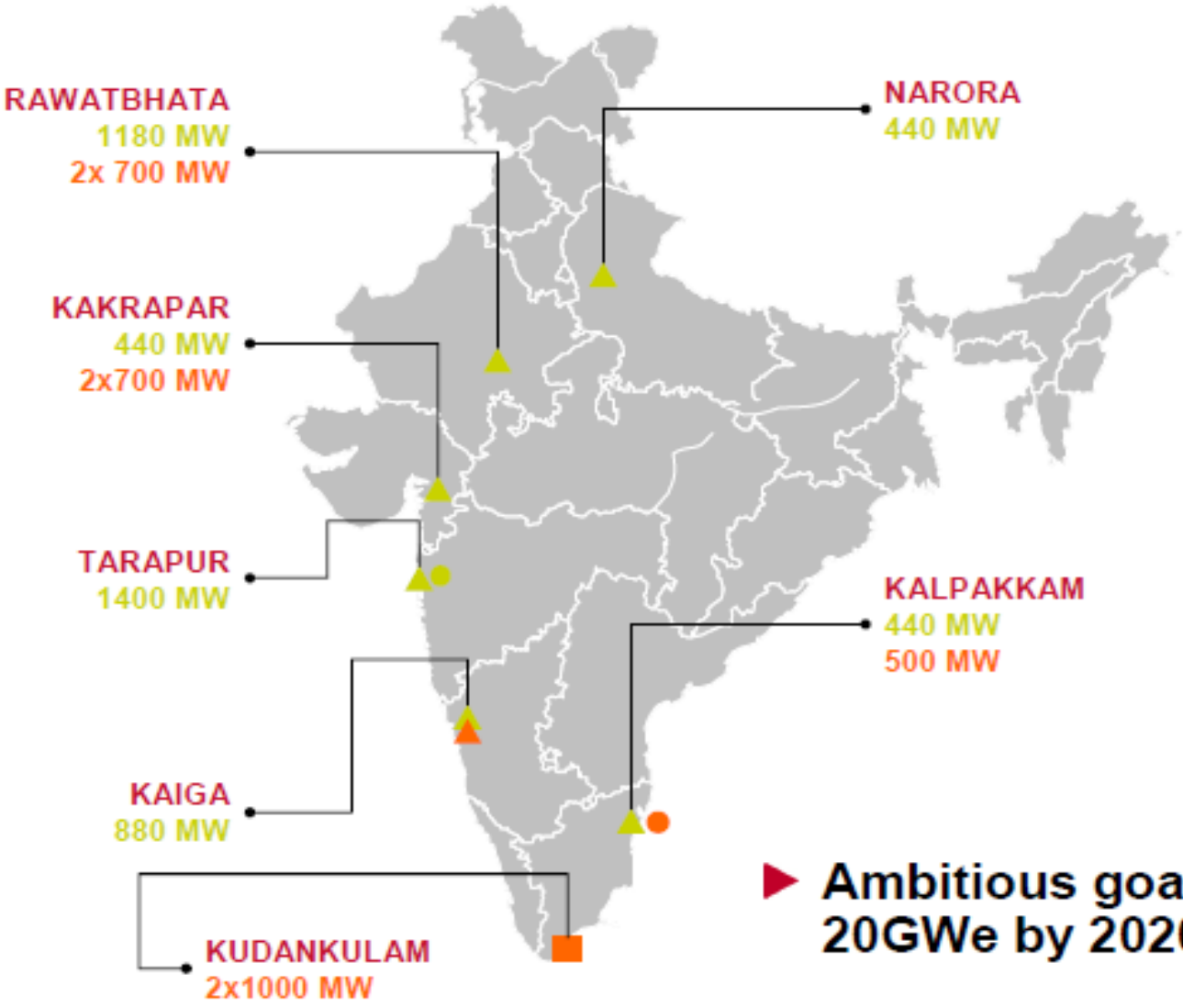
AP1000 in Sanmen, Hayang

India : Homi Bhabba's 3 Phasaes

- After 1974, India on its own – PHWR deployment.
- India: 2009 = Back into international community.
- Now, PWR imports
- Phase 2 : FBR deloyment.
- Phase 3 : Thorium ?



Nuclear in India today: 20 reactors in operation and 7 under construction



- Current gross capacity: 4,780MWe

Reactors in operation

- 2 BWRs (320 MW)
- 18 PHWRs (4,460 MW)

Reactors under construction

- 2 VVERs (2,000 MW)
- 4 PHWR (2,800 MW)
- 1 FBR (500 MW)

- Ambitious goal: reach 20GWe by 2020

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PFBR in India

Fig. 1 Overall view of nuclear building

Fig. 2 Erection of main vessel of PFBR

Fig. 3 Intermediate heat exchanger

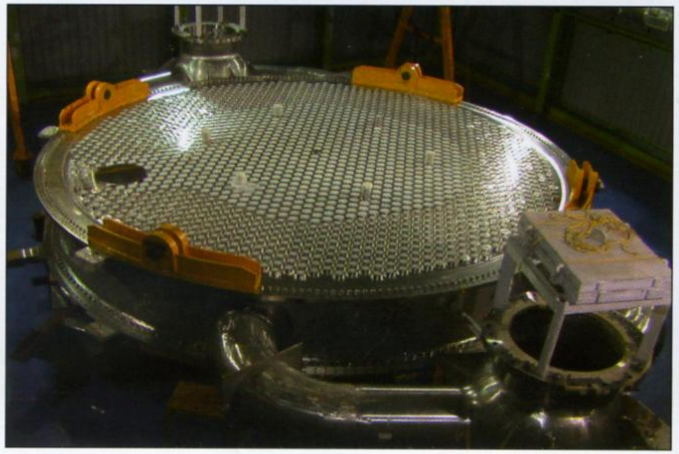

Fig. 4 Integration of grid plate with primary piping

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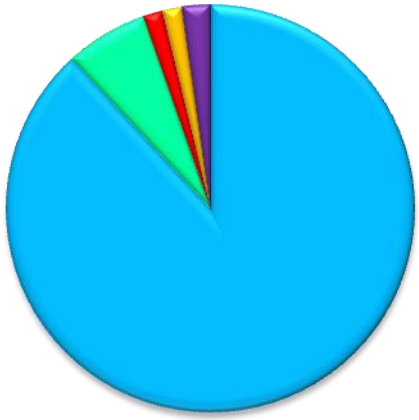
GWe Installed in the World, June 2012

Operating: 435 Units, 370 GWe

Reactor Types

- PWR*
- BWR
- GG
- RBMK
- Candu
- FBR

**VVR included*



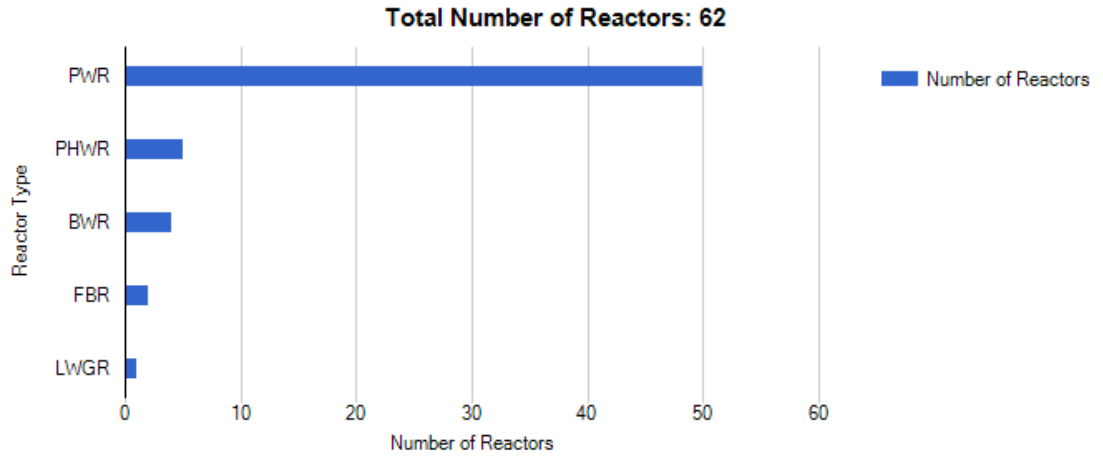
Under Construction:

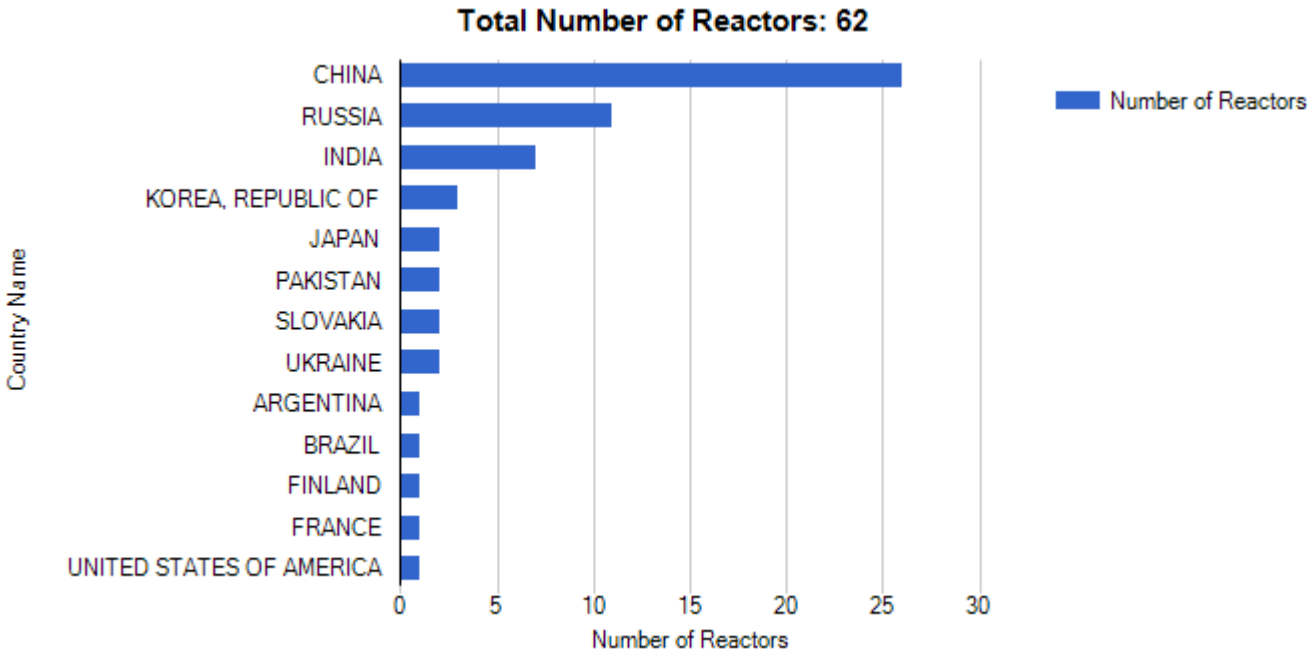
62 Units, 59 GWe

50 PWR+VVR

Source: IAEA PRIS

Reactors under Construction (June 2012)



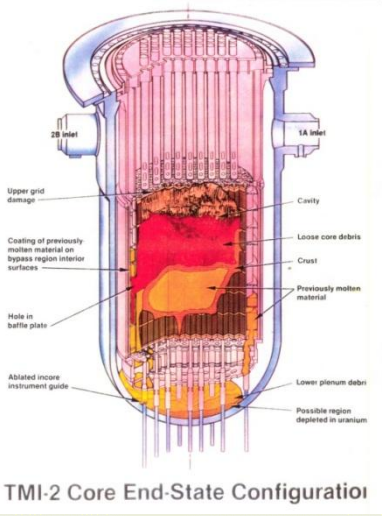


LWR Evolution

March 1979 : TMI (representation error)

- Man/machine Interface
- Alarms Hierarchization
- Take time to think
- INPO (→ WANO)

→ *Improvements to Generation 2*

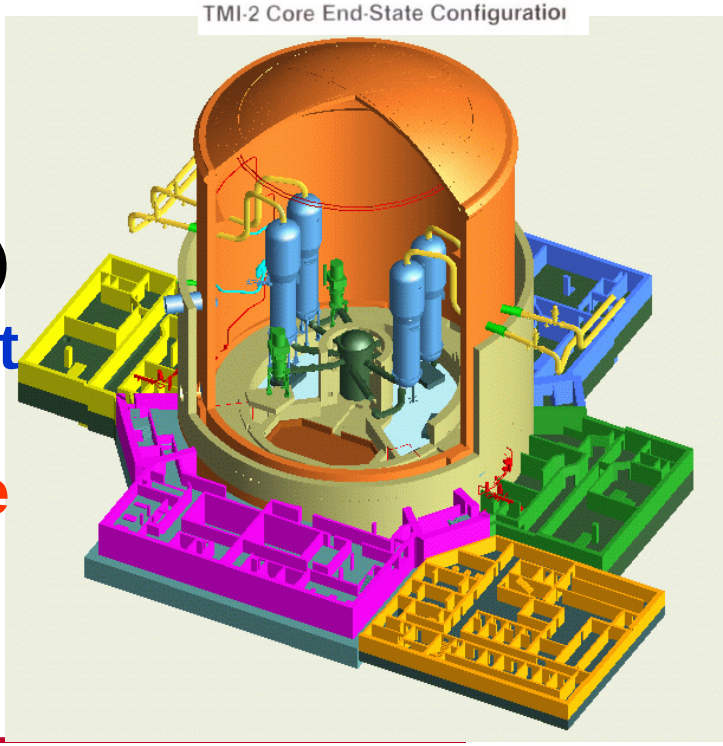


TMI-2 Core End-State Configuratio

April 1986 : Tchernobyl (meltdown)

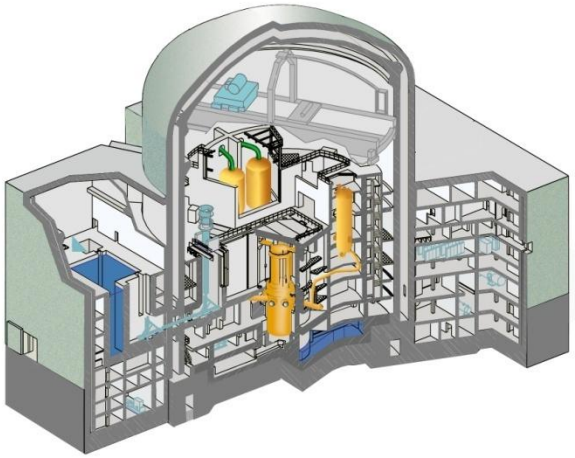
- Importance of the Containment
- Protect it against corium, H2
- Massive Release unacceptable

→ *Generation 3*



Generation III PWRs

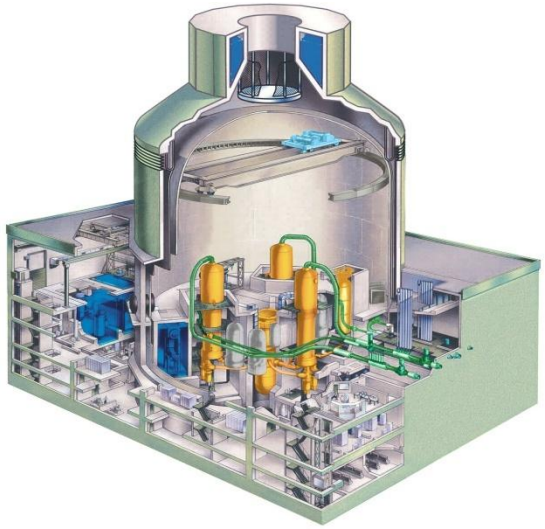
EPR Areva



APR1400 S Korea

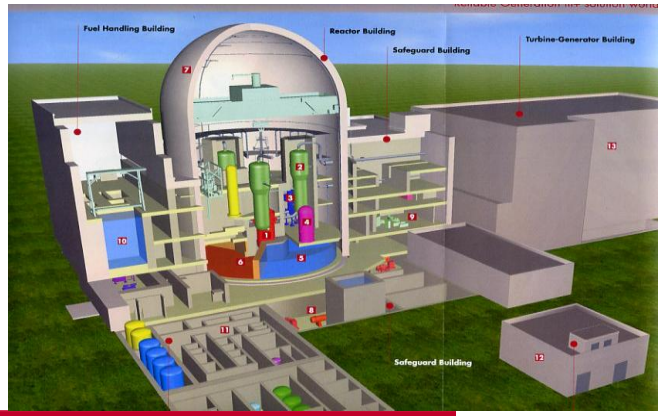
APWR MHI

AP 1000 Toshiba-W



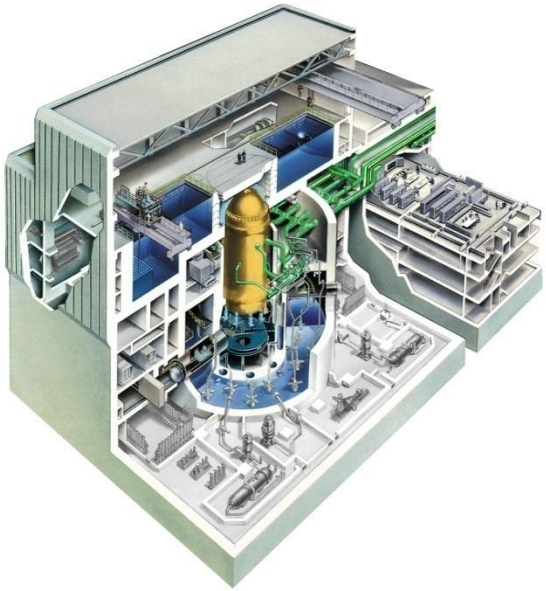
AES 92 Russia

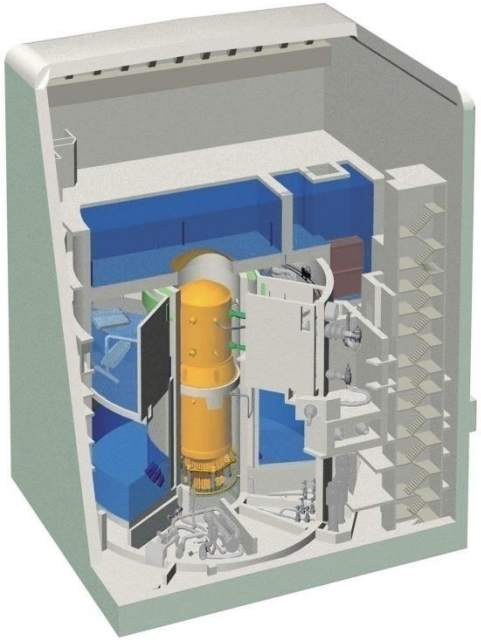
ATMEA Areva-Mitsubishi



Generation III BWRs

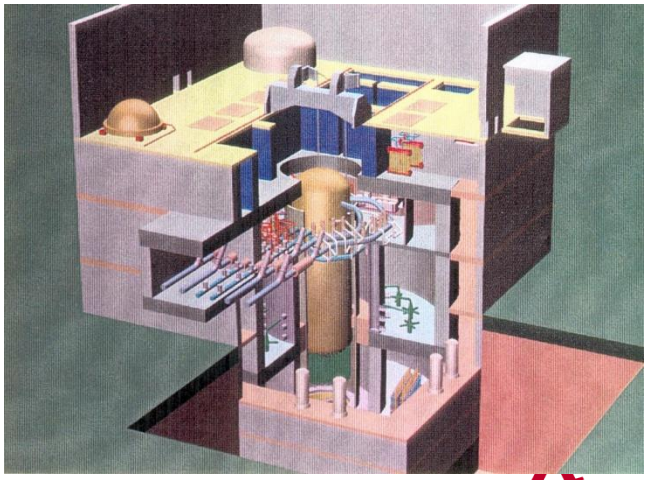
ABWR GE-Hitachi





KERENA Areva

ESBWR GE



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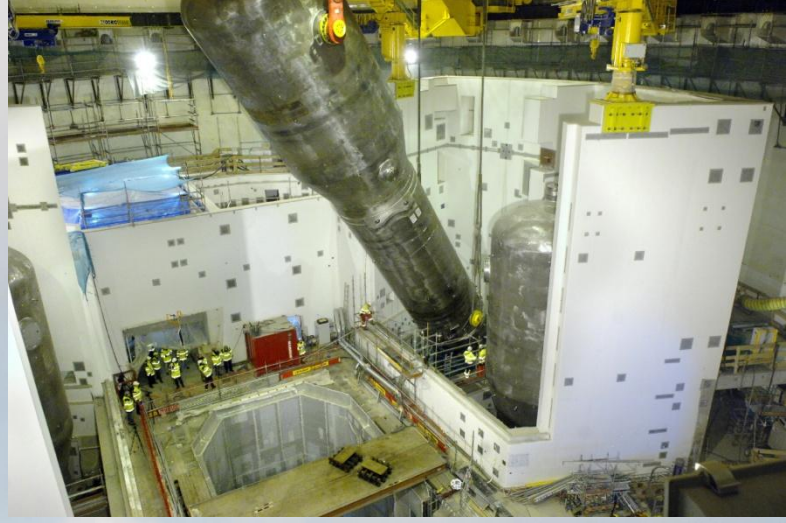


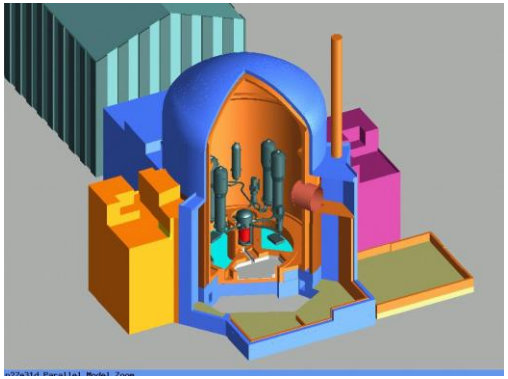
Olkiluoto 3 2012

Nuclear reactors « Generations »

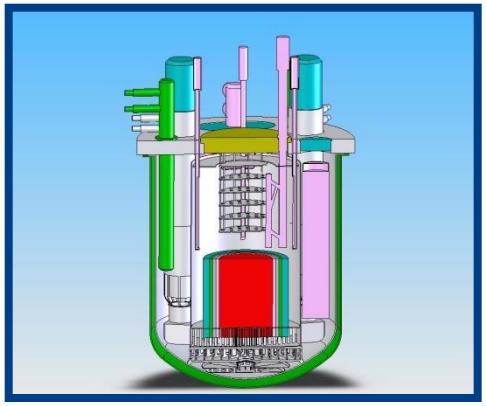
Pionner Facilities

Operating Reactors

Advanced Reactors



Future Nuclear Systems



1950 1970 1990 2010 2030 2050 2070 2090

Generation I

Generation II

Generation III

Generation IV

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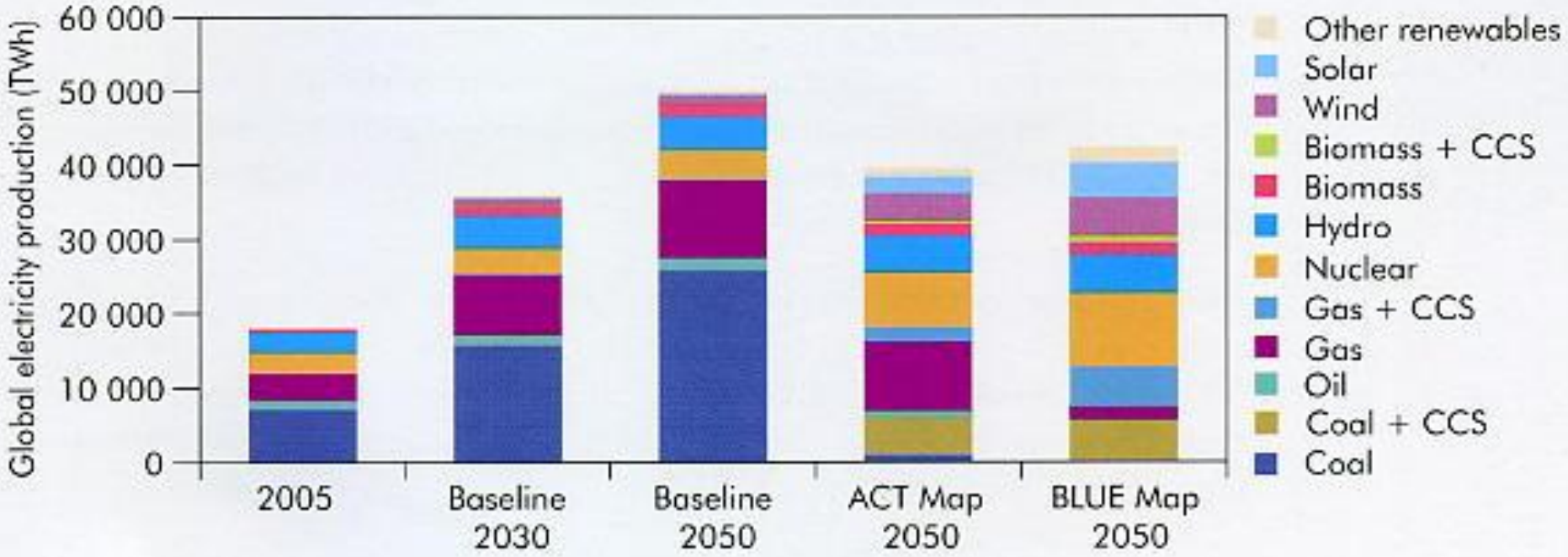
World Power Production 2050

Figure 2.15 ▶ Global electricity production by fuel in the Baseline, ACT Map and BLUE Map scenarios, 2005, 2030 and 2050



Key point

There is a major shift from fossil fuels to carbon-free alternatives in the ACT Map and BLUE Map scenarios.

Prim En. 11.4 23 15.7 Gtoe

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Year	Country	Proliferation	Non-Proliferation
1945	USA	First ABomb	
1949	URSS	A Bomb	
1952	UK USA	A Bomb First H Bomb	
1953	URSS USA	H Bomb	Atoms for Peace
1957	United Nations UK	H Bomb	IAEA
1960	France	A Bomb	
1963	USA/USSR/UK		Moscow Treaty (Tests limitation)
1964	China	A Bomb	
1967	China	H Bomb	
1968	France UN	H Bomb	Non-Proliferation Treaty NPT
1974	India IAEA Suppliers	« Peaceful » A test	« Trigger list», Zangger Commitee London Club NSG
1976	France		6 points – CPNE – Stop Pakistan repro

Year	*Country*	*Proliferation*	*Non-Proliferation*
1990	Iraq	Clandestine Program	Gulf War
1991	South Africa		Weapon dismantling, NPT
1992	France, China Suppliers (NSG)		NPT : all NWS parties. Full Scope Safeguards
1995	CIS IAEA		Return of warheads to Russia Extension NPT, CTBT
1997	IAEA		Additional Protocol
1998	India	H Bomb	
1999	Pakistan	A Bomb	
2003	Pakistan, Libya, Iran,NK North Korea	« Bazaar » A Q Khan NPT withdrawal	
2006	Iran North Korea	Enrichment Crisis A Bomb (?)	
2007	Syria	????	

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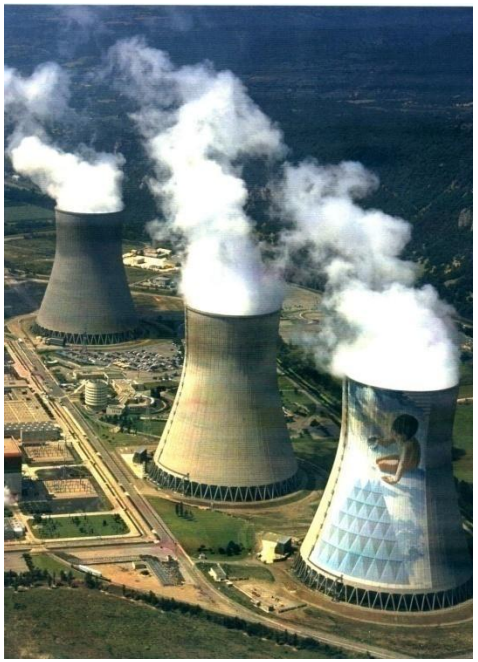
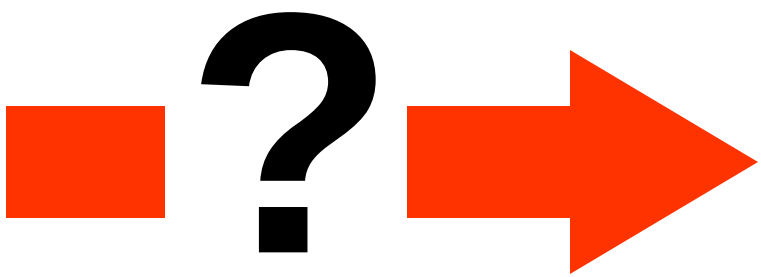
Non-Proliferation





»**Proliferation did and does exist whithout any Nuclear *Power* : see all weapons States, Israël, Irak, North Korea…**

»**So far, the number of potential proliferators has decreased (Sweden, South Africa, Argentina, Brasil, Ukraine, Khazakstan, etc. vs no new entrant)**

»**Does the development of Nuclear Power increase *or decrease* the risk of Proliferation ?**

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Civilian Nuclear Power & Proliferation Risks

- Dissemination of knowledge, some disciplines identical, not all
- Increase inventories of fissile materials (not w-grade, but…)
- Possible duplication of facilities
- Possible Short-cut to weapon-usable materials
- Legal possibility to terminate NPT with advance notice

- NPT & NSG constraints
- Safeguards & inspections : high likelihood of detecting clandestine production
- Deterrent of termination of techology transfers (India)
- Energy security & diversification of supply decreases motivations to proliferate
- Safer technology than indigeneous or…
- Burning w-grade materials

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A Final Word from our Sponsor…

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