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RECYCLING SPENT NUCLEAR FUELS FROM LWRS TO FAST REACTORS

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CEA

Direction for Nuclear Energy

FRANCE

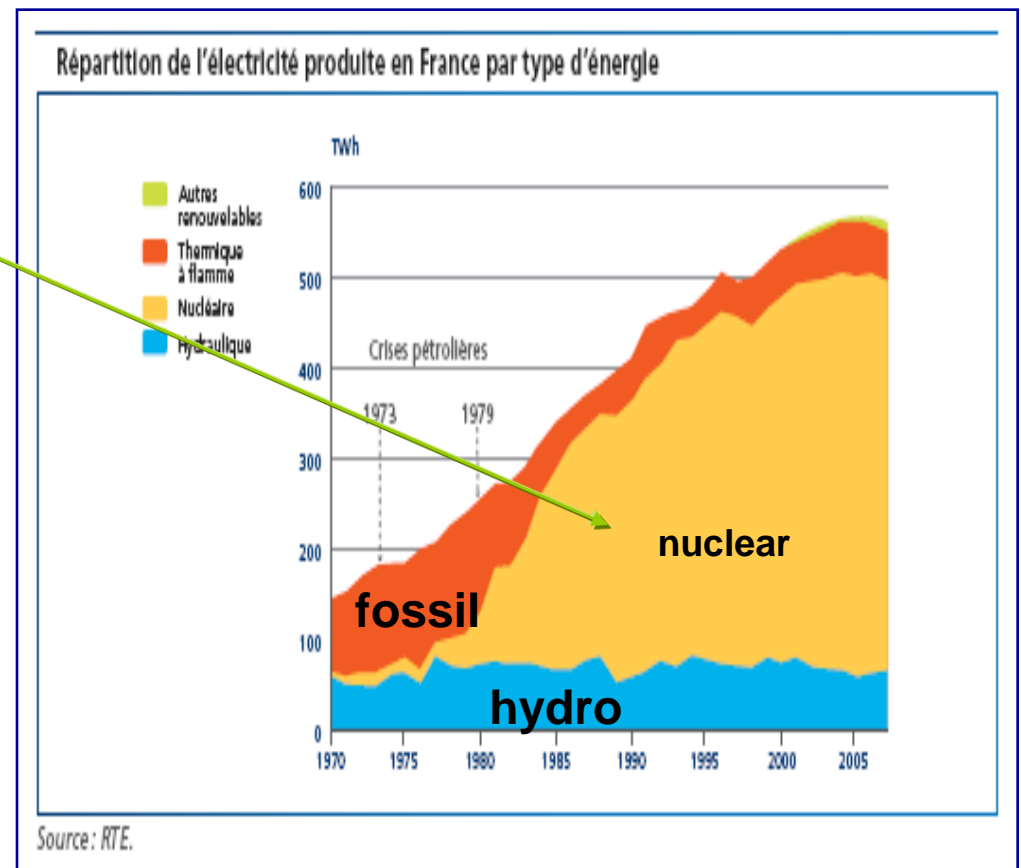
FRENCH ELECTRICITY



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NUCLEAR > 75 % OF ELECTRICITY GENERATION
LOW-CARBON ENERGY MIX : # 4G CO₂ PER KWH

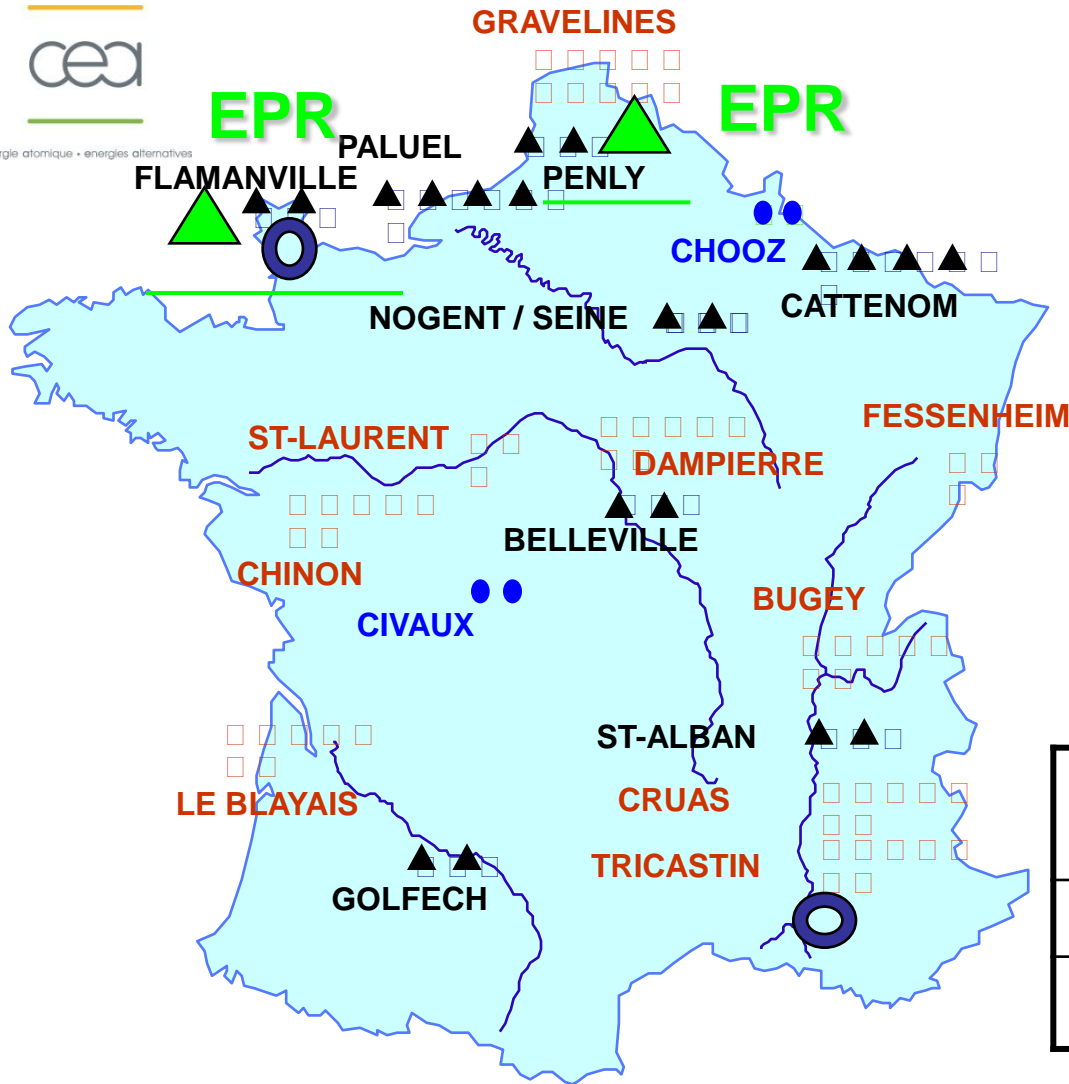
- 58 LWR units
- 63 GWe
> 410 TWh per year



The current nuclear power fleet in France



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63 GWe installed

58 PWR units

Mature cycle facilities

19 sites ; 1 single technology

A fleet :

Young: average age = 23 years old

Mature: > 1250 cumulated reactor-years

| 900 MWe | 1300 MWe | 1500 MWe | Cycle facilities |
|---------|----------|----------|------------------|
| 34 | 20 | 4 | |
| ■ | ▲ | ● | ○ |

In 2017, 60 units and 66 GWe installed

FRENCH STRATEGY FOR FUEL CYCLE



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Mines

Natural Uranium

Concentration Conversion

Enrichment

Reprocessed Uranium

Depleted Uranium

Final disposal



Vitrified HLW



compacted ILW

Storage

wastes MA, FP



Short lived L&ILW

Reprocessing plant

Spent fuel

Plutonium

MOX fuel Fabrication

UOx fuel Fabrication

Reactor

Used MOX

Interim storage

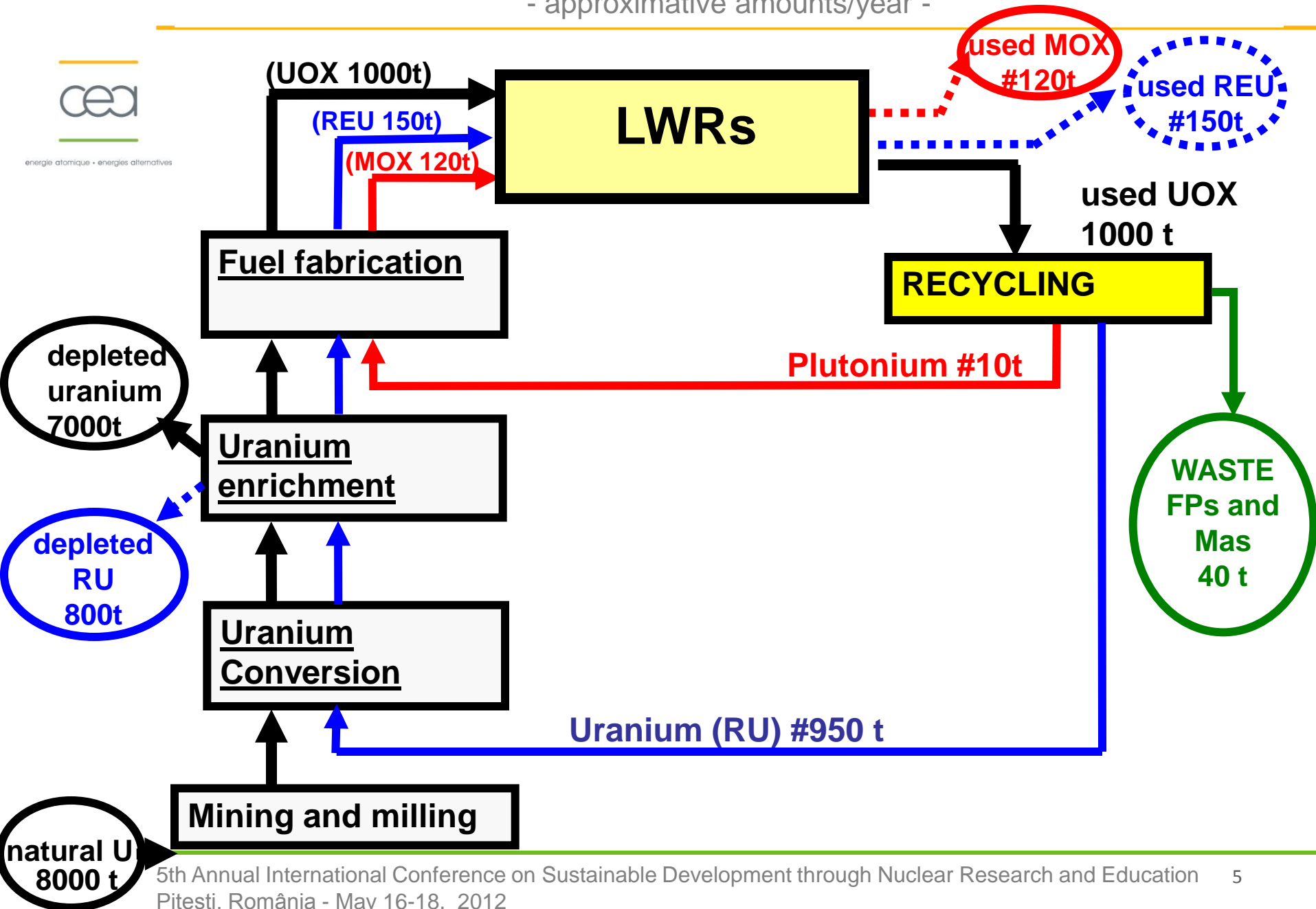


THE PRINCIPLE OF THE FRENCH CLOSED FUEL CYCLE

- approximative amounts/year -



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❑ 2005 ACT *about* ENERGY POLICY

- ✓ National self-sufficiency (*security of supply*)
- ✓ Large access to energy (*competitive price*)
- ✓ Environmental preservation (*decrease CO2*)
 - *Nuclear energy; a pillar*
 - *R&D for future generation nuclear systems*

❑ 2006 ACT *about* TRANSPARENCY & INFORMATION

- ✓ Independent Safety Authority
- ✓ High Committee for transparency & information

❑ 2006 ACT *about* NUCLEAR MATERIALS & WASTE

- ✓ Recycle (*decrease waste amounts*)
- ✓ Geological repository for final waste



□ 2012, January : “COUR DES COMPTES” REPORT

About nuclear *energy costs* :

- ✓ French electricity cost : *40% lower / other EU countries*
no « hidden costs »
- ✓ Uncertainties about decommissioning costs : *a low incidence on global costs*
- ✓ NPPs life-time extension (*beyond 40 years*) : *the main point (if not: huge investments needed)*

□ 2012, February : “ENERGIES 2050” REPORT

- ✓ Low energetic dependence, a priority
- ✓ Nuclear and renewable



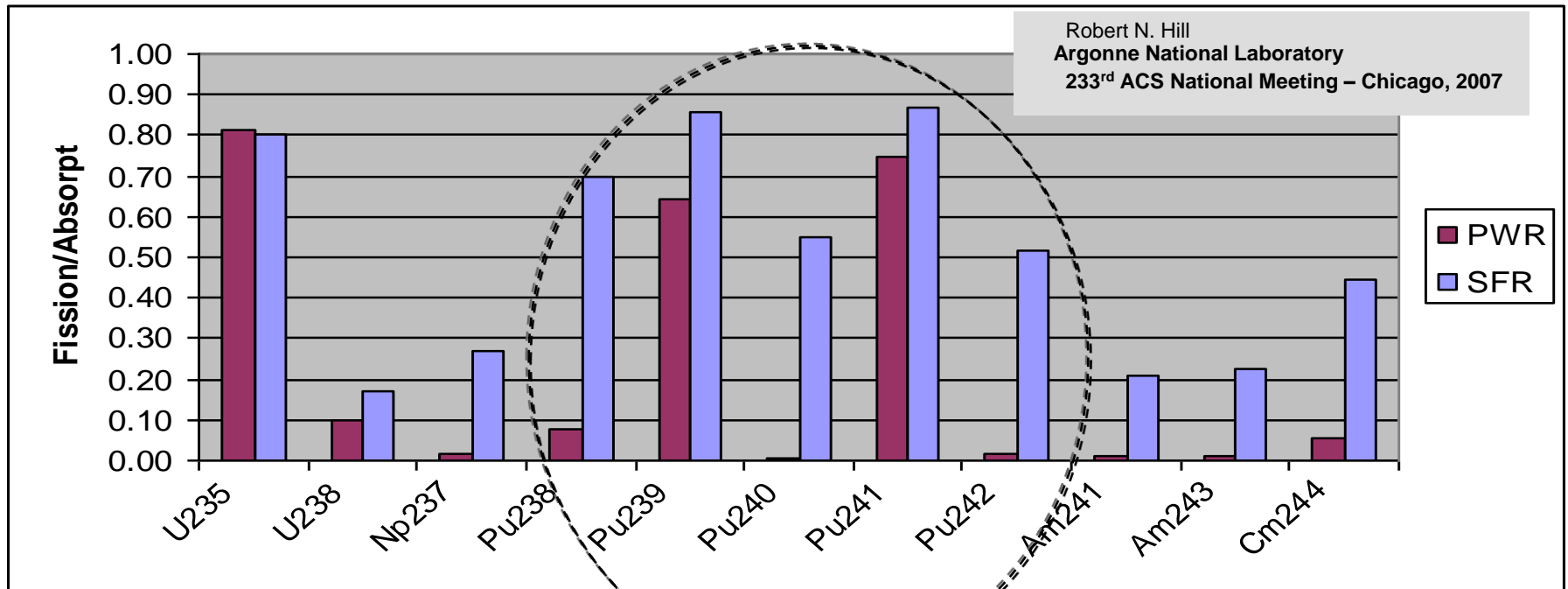
- ✓ SAVING URANIUM RESOURCES
(10% OF FRENCH NUCLEAR ELECTRICITY FROM MOX FUELS)
- ✓ MASTERING THE GROWTH OF PLUTONIUM INVENTORY
(PU FLUX ADEQUACY : PU FROM PROCESSING = PU REFUELED)
- ✓ SAFE & SECURE ULTIMATE WASTE WITHOUT PLUTONIUM
- ✓ THE PLUTONIUM AVAILABLE FOR FUTURE USE IS
CONCENTRATED IN MOX SPENT FUELS
- ✓ AN ALREADY LARGE INDUSTRIAL EXPERIENCE,
OPERATED UNDER INTERNATIONAL SAFEGUARDS
(25 000 TONS REPROCESSED, 2000 TONS MOX)



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(1) RECYCLE (2) IN FAST REACTORS...

- ✓ EFFICIENT BURNING OF PLUTONIUM,
- ✓ FULL USE OF URANIUM, EVEN DEPLETED URANIUM
- ✓ POTENTIALITIES FOR IMPROVING WASTE MANAGEMENT
- ✓ NO ENRICHMENT NEEDS

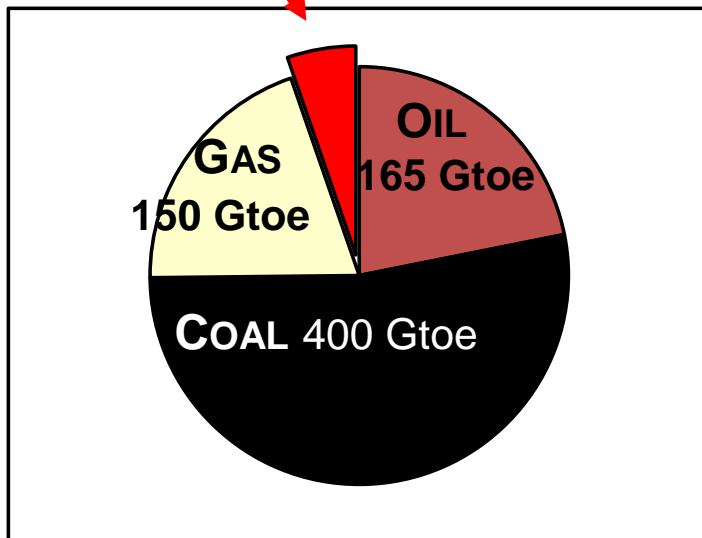


FOSSIL FUELS POTENTIAL RESERVES

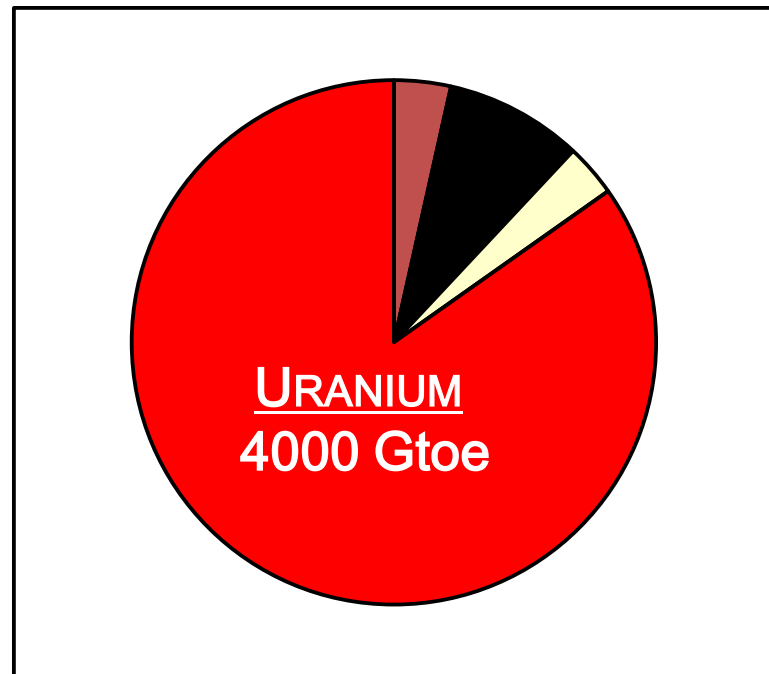


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**URANIUM
40 Gtoe**

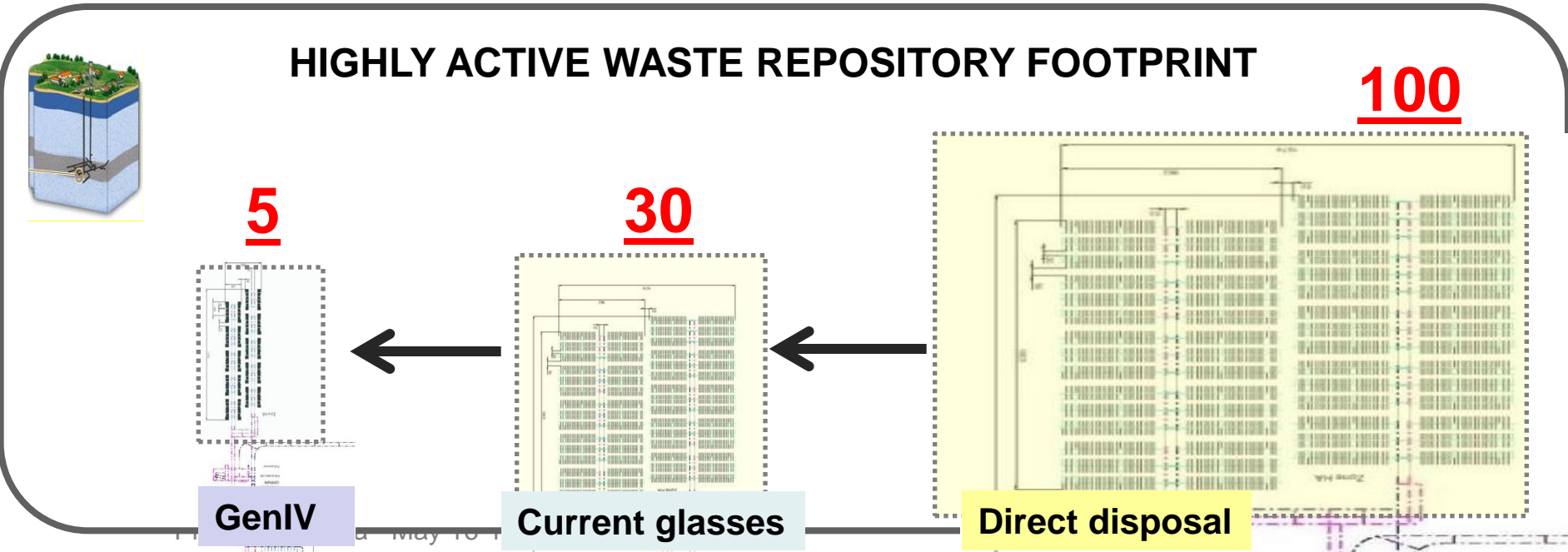
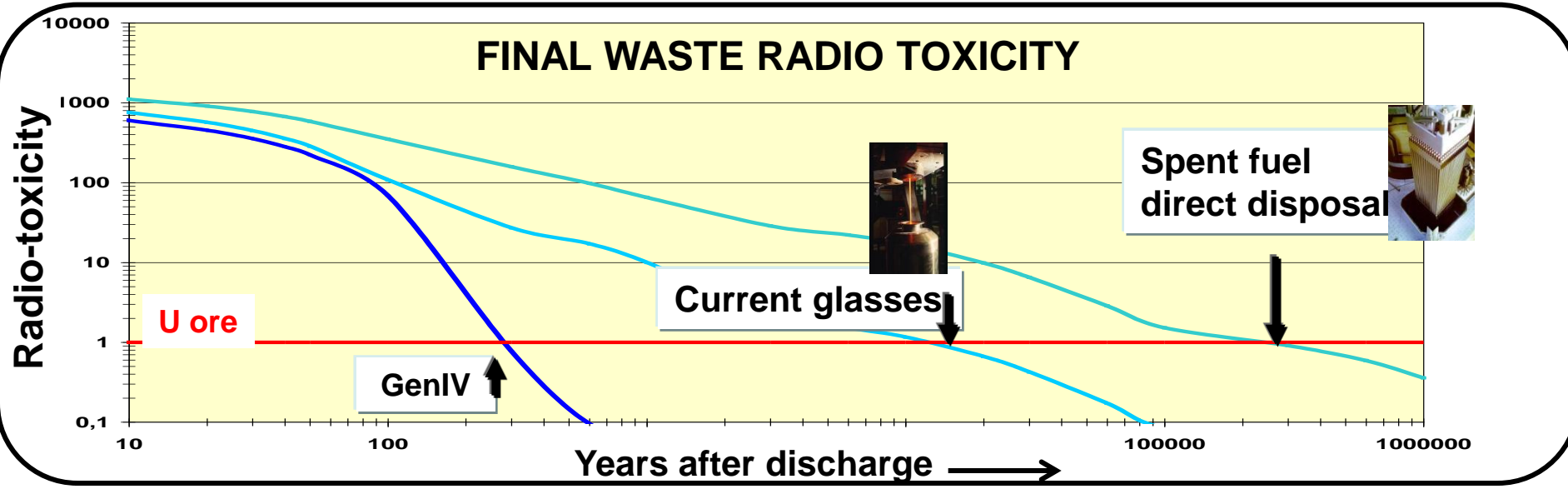


Uranium use in current reactors



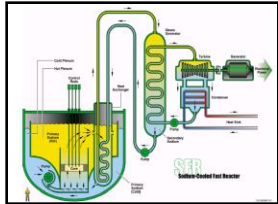
Uranium use in 4th generation reactors

IDENTIFIED CONVENTIONAL RESOURCES, GTOE
(WEC, 2010)
Oil 165 Gt, coal 826Gt, gas 180 Tm³, uranium 3,3Mt





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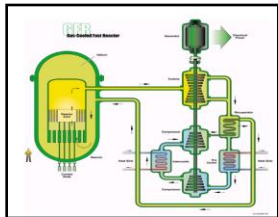


✓ **SODIUM FAST REACTOR, THE REFERENCE OPTION :** **ASTRID, THE PROTOTYPE**

- MATURITY, POSSIBLE FURTHER IMPROVMENTS (SAFETY, OPERABILITY, ECONOMICS)
- COMMERCIAL LEVEL 2040
- DEVELOPPED WITH INDUSTRIAL AND INTERNATIONAL PARTNERS

✓ **GAS-COOLED FAST REACTOR, A LONG-TERM OPTION:** **ALLEGRO, EXPERIMENTAL-SCALE PROJECT**

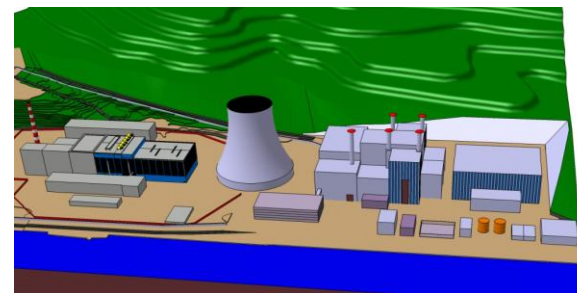
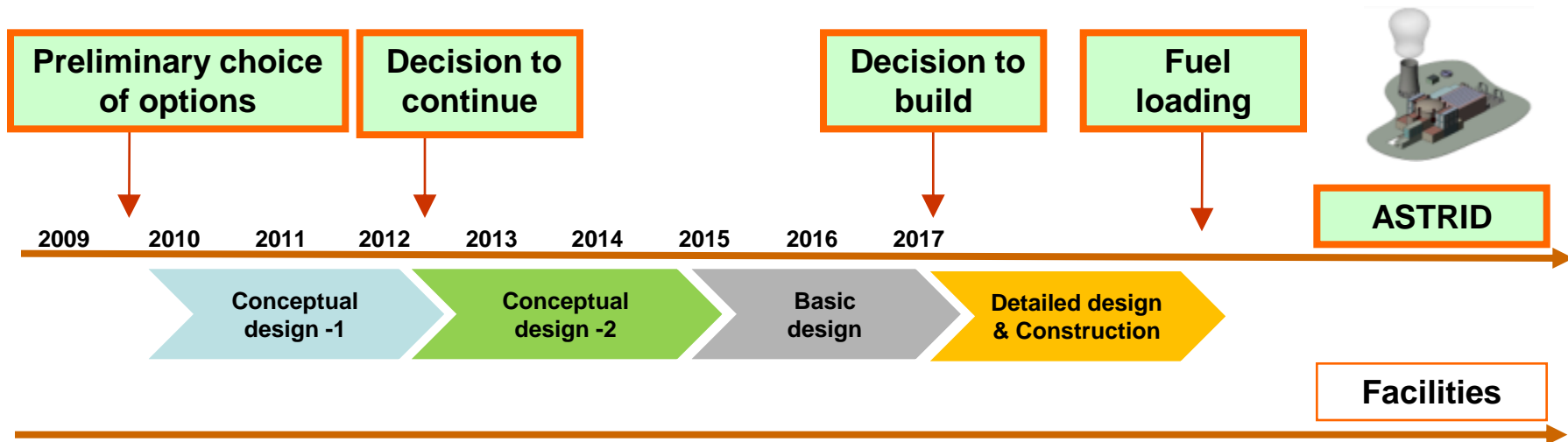
- ATTRACTIVE POTENTIALITIES
- BUT HEAVY CHALLENGES (MATERIALS, FUEL, SAFETY)
- IN EUROPE ?



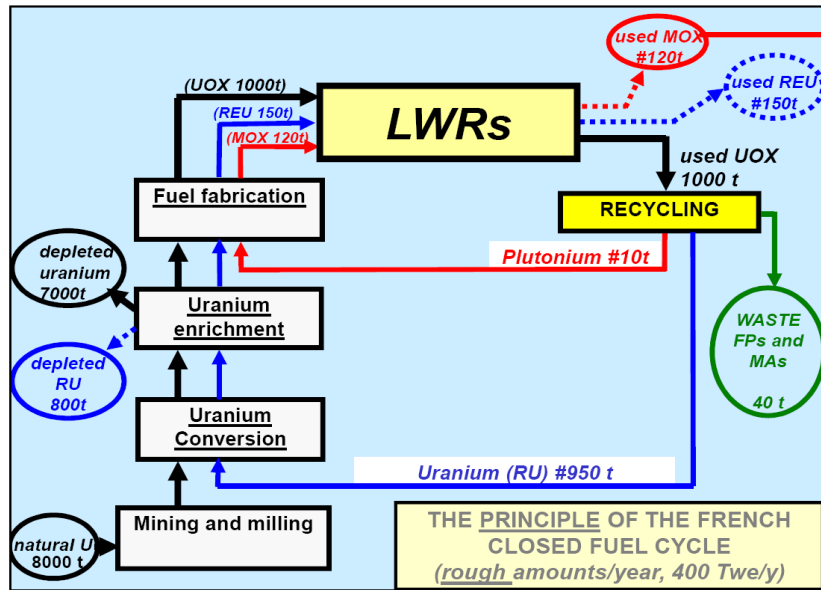
ASTRID PROTOTYPE SCHEDULE



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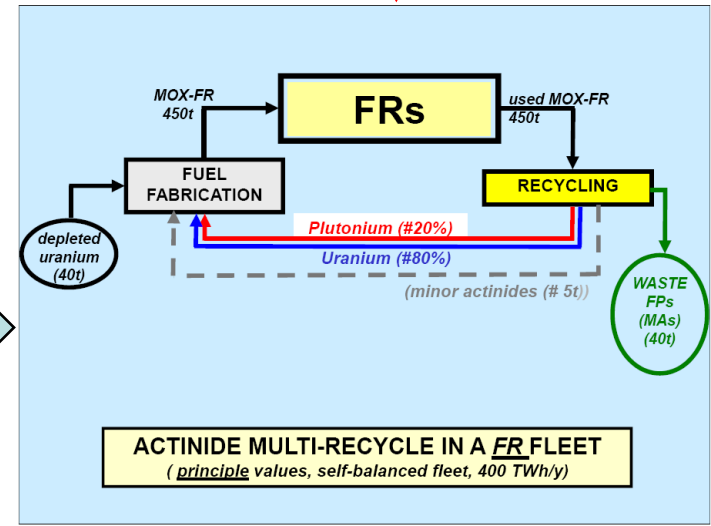


FROM LWRs RECYCLING TO SFRs RECYCLING



*Pu stored in MOX
SF recycled in
MOX SFR to start
the SFRs
deployment*

Scenarii can be flexible
Both systems can coexist
during a transition phase





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- ✓ ***U-Pu MULTIRECYCLE IN FAST REACTORS FOR SUSTAINABLE NUCLEAR SYSTEMS***

- ✓ ***THE FRENCH ROUTE : ASTRID PROTOTYPE (FROM 2020), AND THE APPROPRIATE FUEL CYCLE***

- ✓ ***COMMERCIAL DEPLOYMENT :***
 - ***FRANCE : FROM AROUND 2040, DIVERSE POSSIBLE OPTIONS***
 - ***OTHER COUNTRIES (RUSSIA, CHINA, INDIA) : PROBABLY SOONER AND FASTER***