DE LA RECHERCHE À L'INDUSTRIE

BACK-END SCENARIOS FOR THE FRENCH NUCLEAR FLEET

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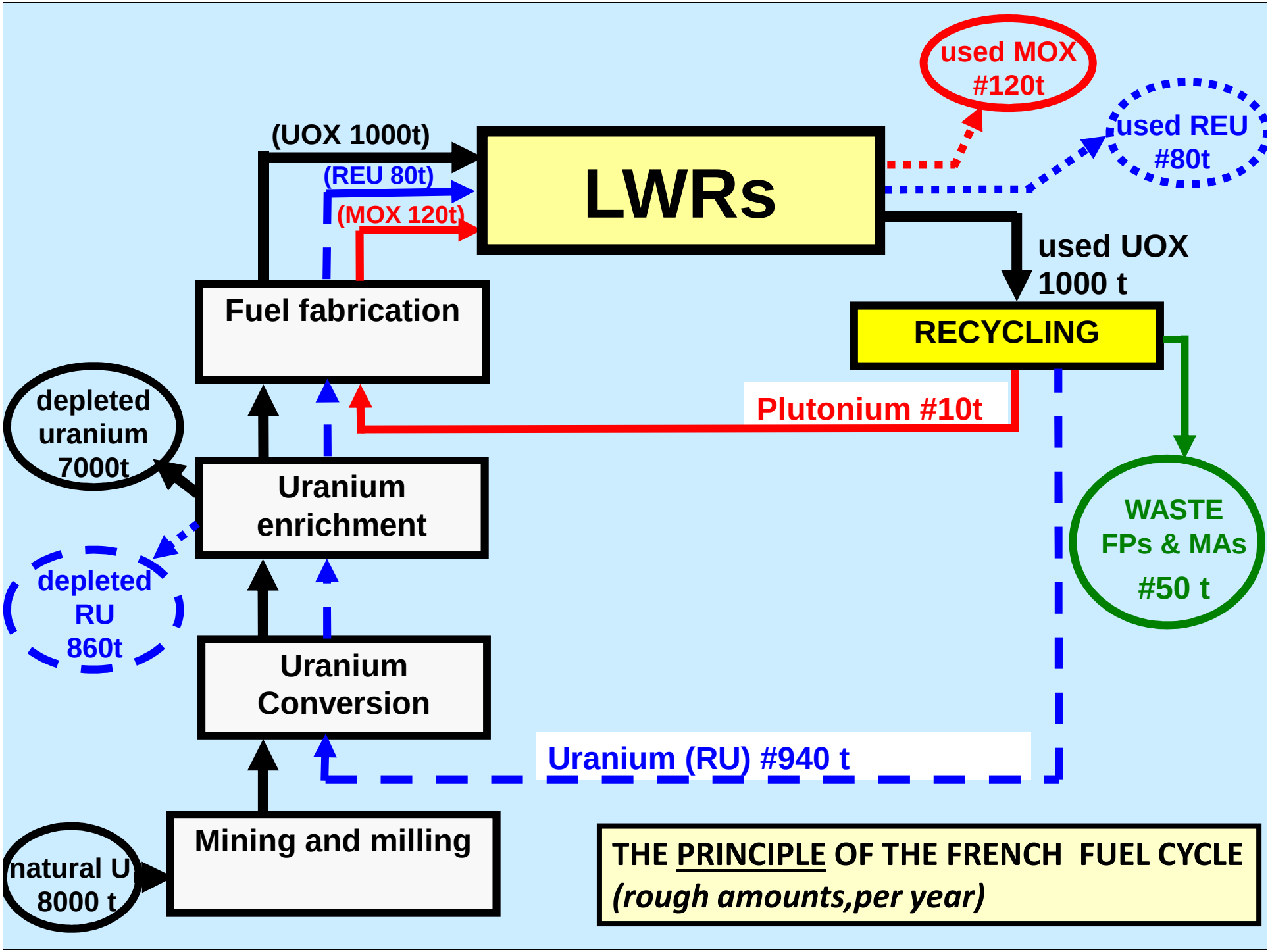
Sino-French Seminar –Building up an Advanced Back-End Industry
Beijing, 5 November 2015


used MOX
#120t
used REU
#80t
(UOX 1000t)
(REU 80t)
(MOX 120t)
LWRs
used UOX
1000 t
Fuel fabrication
RECYCLING
depleted
uranium
7000t
Plutonium #10t
Uranium
enrichment
WASTE
FPs & MAs
#50 t
depleted
RU
860t
Uranium
Conversion
Uranium (RU) #940 t
Mining and milling
natural U
8000 t
THE PRINCIPLE OF THE FRENCH FUEL CYCLE
(rough amounts,per year)

FUTURE NUCLEAR SYSTEMS :
GENERATION IV REQUIREMENTS

1 - SAFETY

2 – COST-EFFECTIVENESS

3 - SUSTAINABILITY:

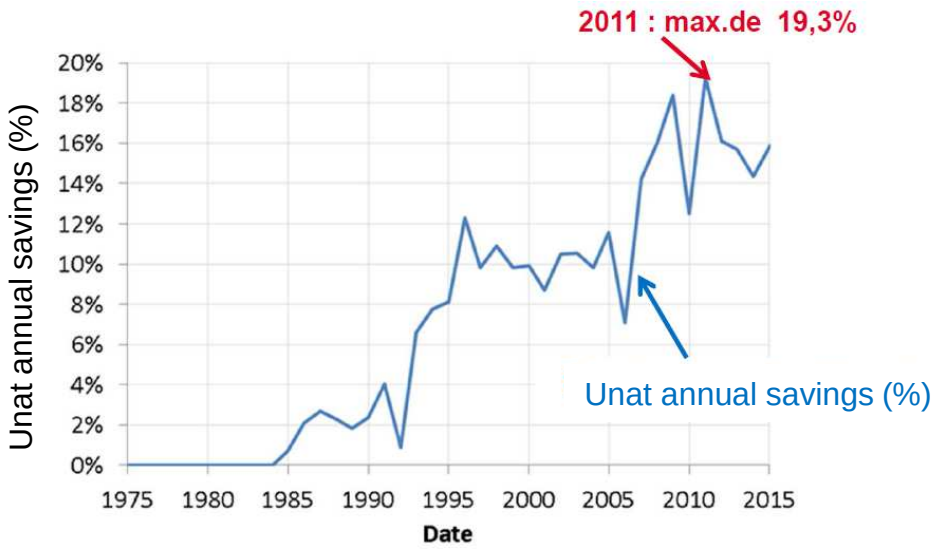
- ***NATURAL RESOURCE PRESERVATION***
- ***WASTE MINIMIZATION***
- ***PROLIFERATION RESISTANCE***

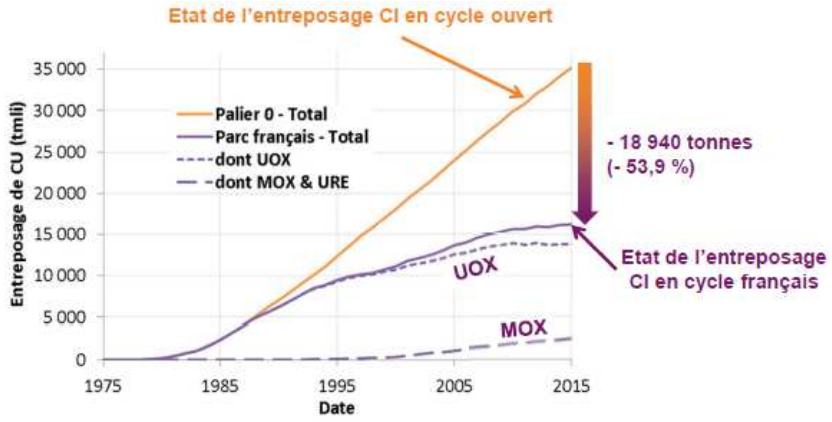
… and PUBLIC ACCEPTANCE

CURRENT RECYCLING STRATEGY:
Natural resource savings and used fuel management

- **Resource savings**
  - Valuable nuclear materials (U, Pu) are recovered and recycled
    About 15% of French nuclear electricity today from recycled materials
  - Cumulated savings (2015): 25000 tons
  - Resources kept out of the waste, available for future developments

- **Used fuel management**
  - Thanks to recycling, interim storage is reduced by 19000 tons
  - Reduction by a factor of 6 of present accumulation rate





CURRENT RECYCLING STRATEGY : *"THE NATIONAL INVENTORY", 2015 (ANDRA)*

- ***used UOX :***

  2013 : 12000 t (# stabilized)

- ***used MOX :***

  2013: 1500 tons *(increasing 120 tons/year)*

  2035 : 4000t (about # 250t Pu)

- ***used REU :***

  2013 :420 t

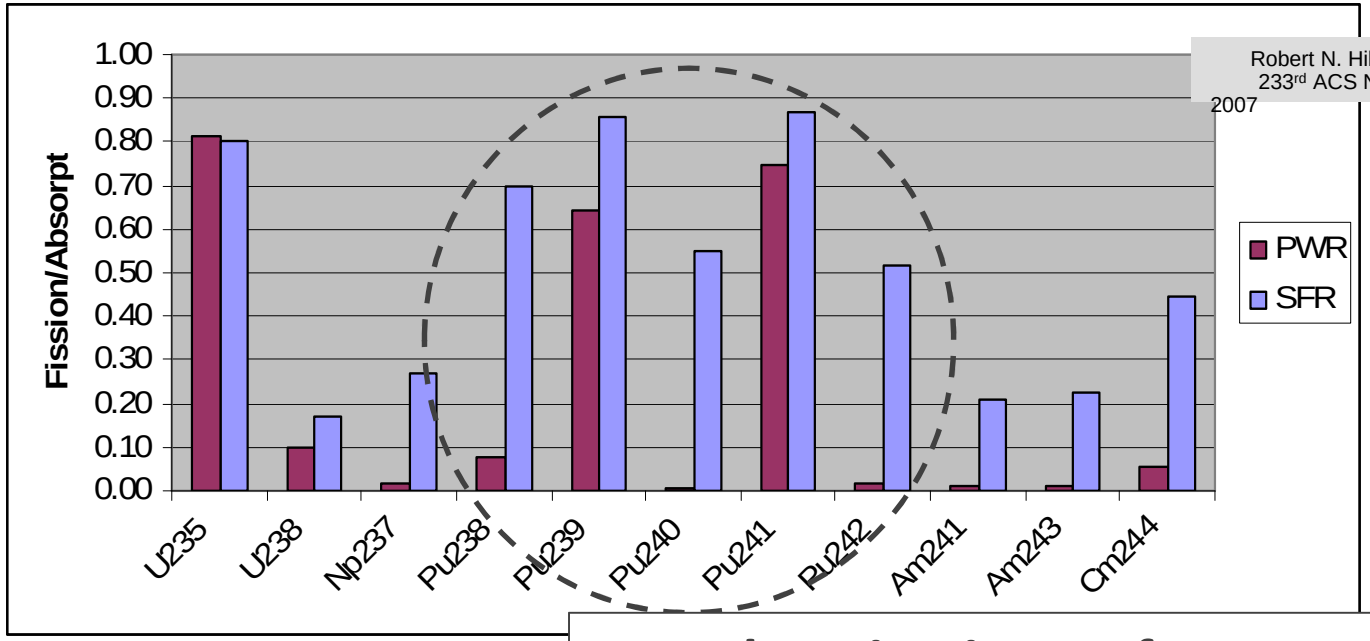
  2035 :1800 t

- ***depleted U:***

  2013 : 290 000 t

  2035: 450 000 t

WHY FAST NEUTRON REACTORS ?



Robert N. Hill
233rd ACS National Meeting – Chicago,, 2007

Pu burning in FRs favors Pu fission , allowing Pu multi-recycle

www.cea.fr

(1) **Systematic U & Pu recycle** , (2) in **fast neutron reactors**

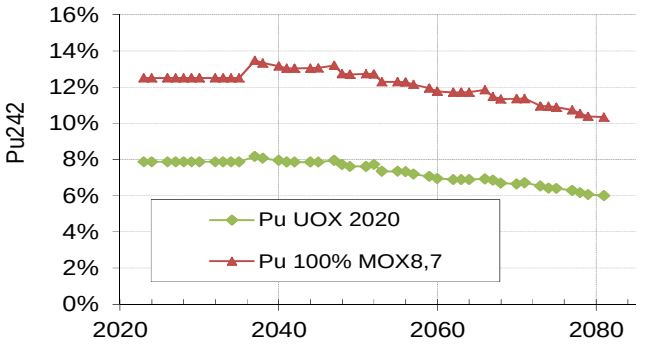
- for a sustainable management of nuclear materials & waste,
- avoiding increasing of Pu-bearing stockpiles,
- opening the way to a drastic extension of the use of U resource

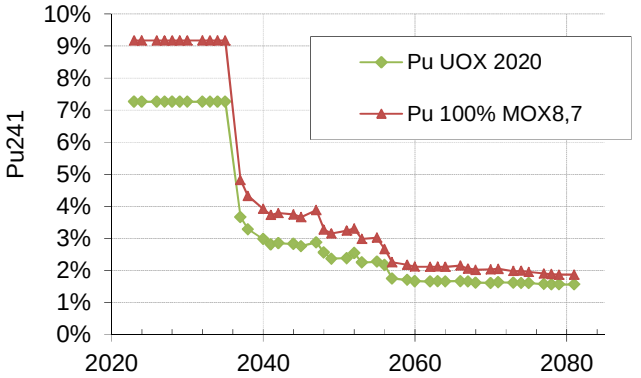
PLUTONIUM *MULTI*-RECYCLE

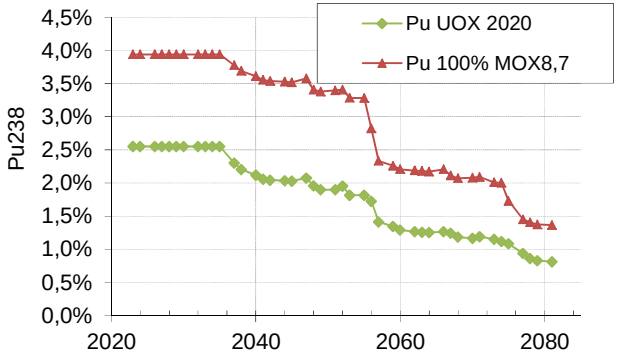
isotop	Pu fromUOX	Pu fromMOX
238	2.48	3.8
239	53.3	39.9
240	24.8	31.1
241	12.1	13.4
242	7.3	11.8

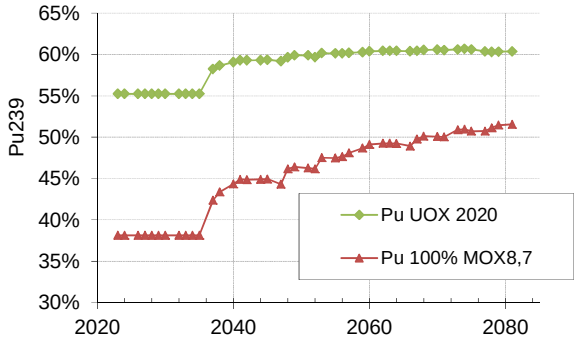
Pu recycle in LWRs

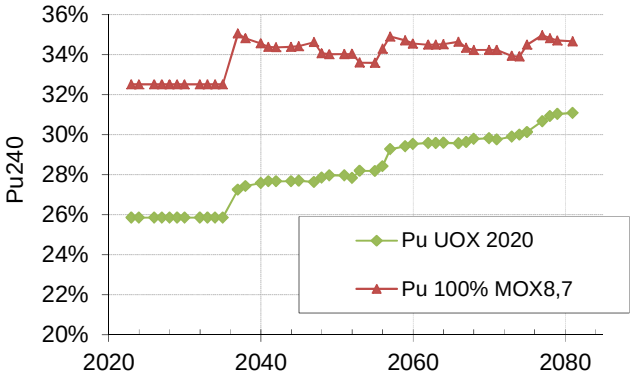
Pu recycle in FRs



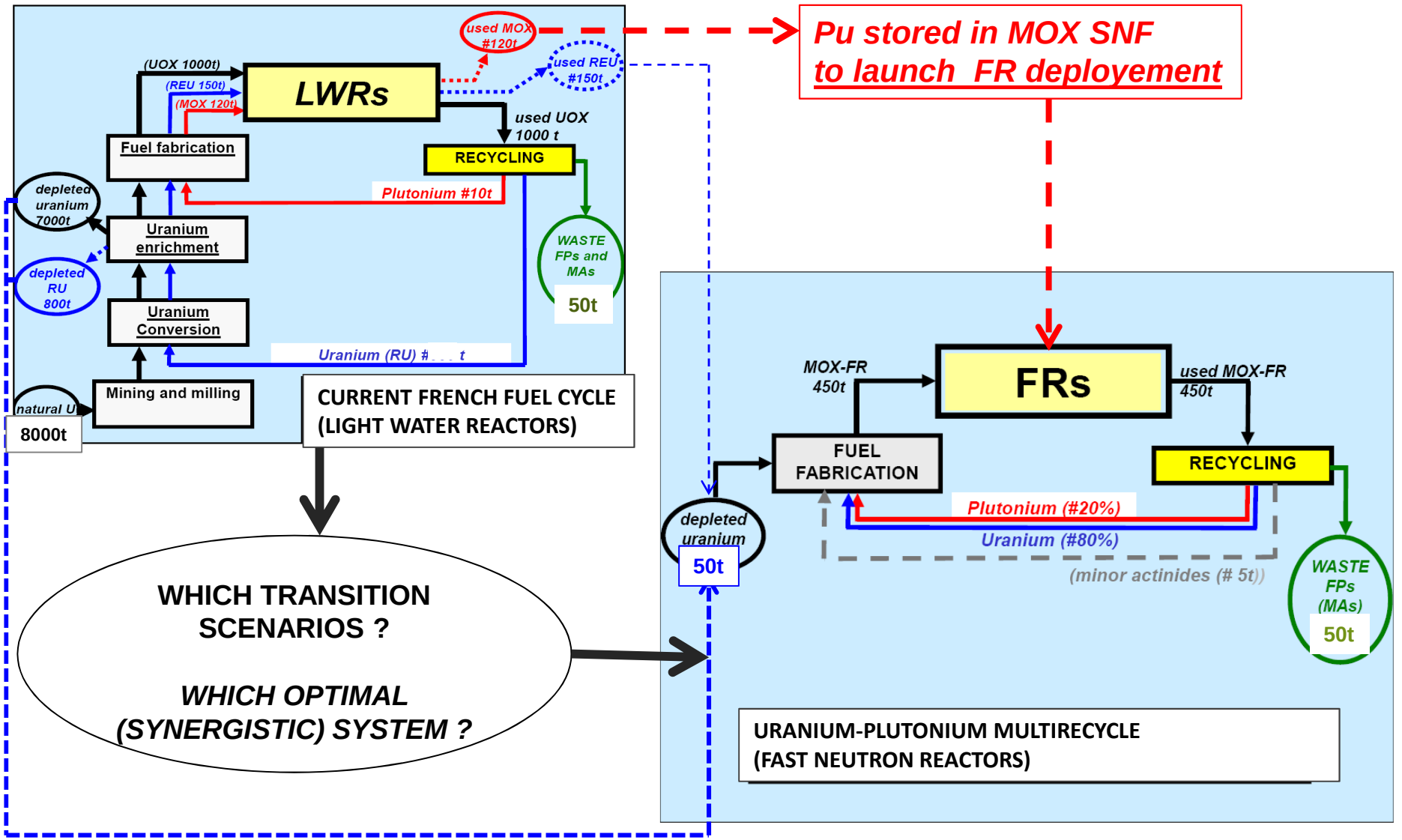




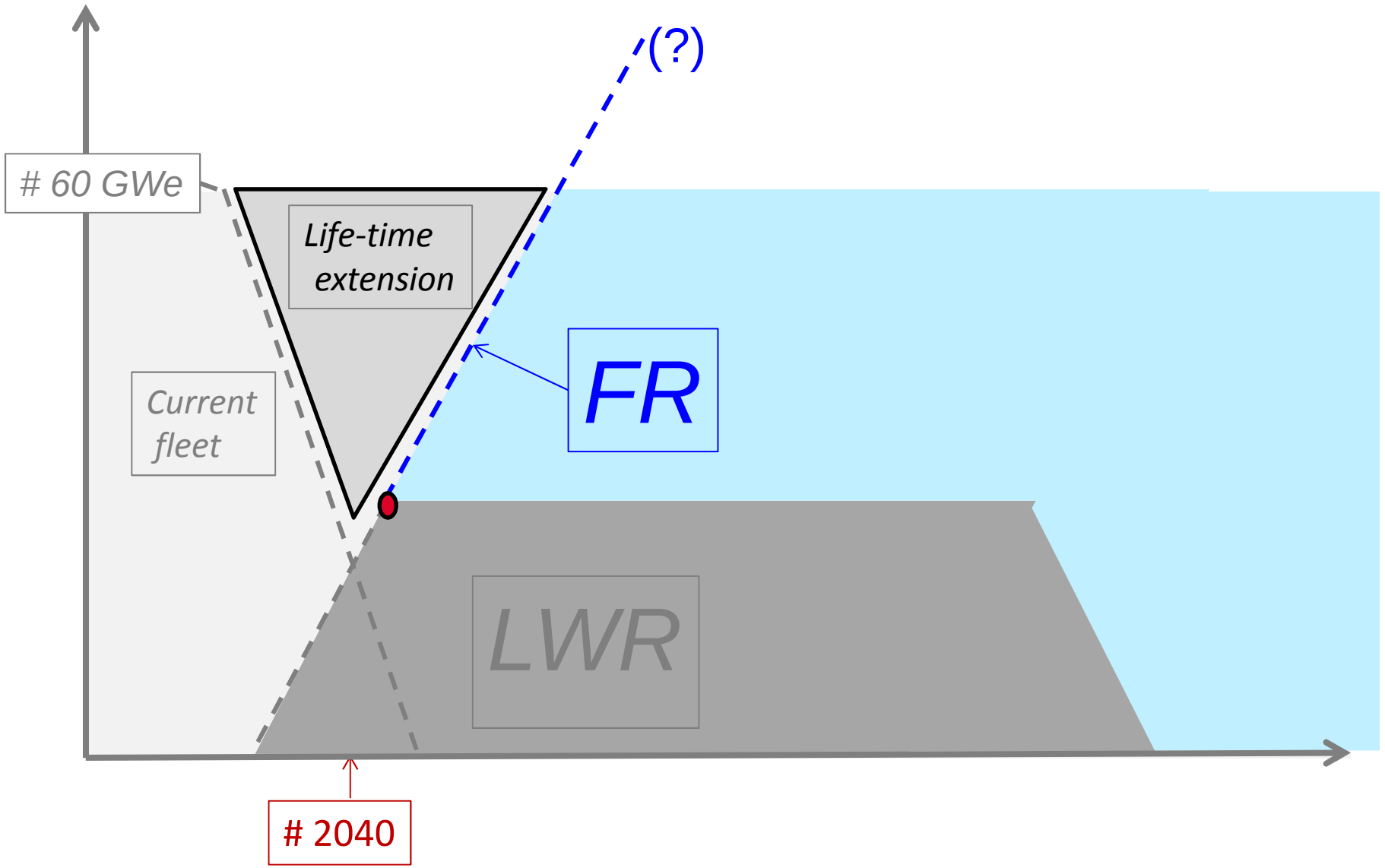




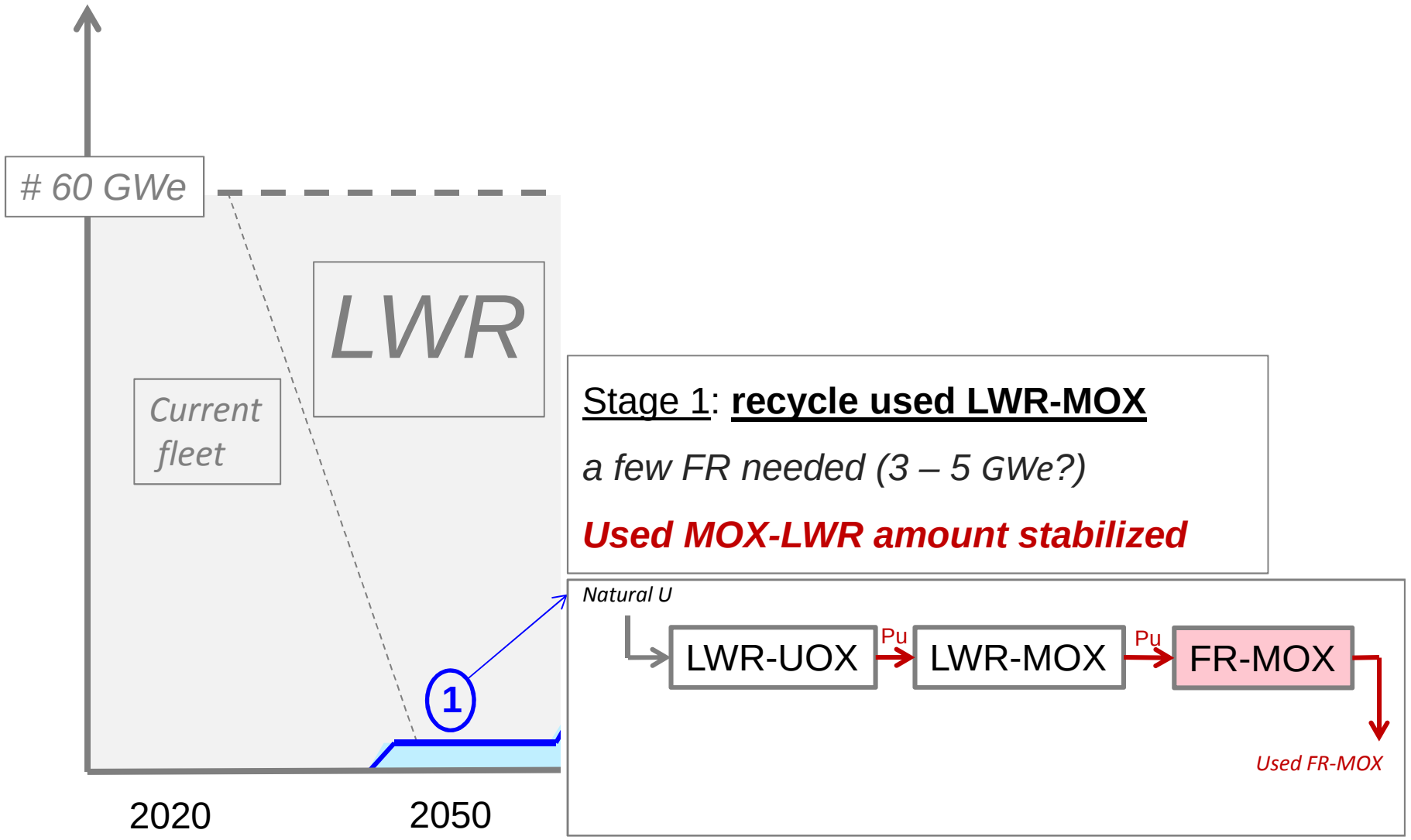
FROM CURRENT FUEL CYCLE…
TO FAST REACTORS FUEL CYCLES



FR REACTORS DEPLOYMENT : *THE FORMER VIEWS*



FR REACTORS DEPLOYMENT: *CURRENT SCENARIO STUDIES*



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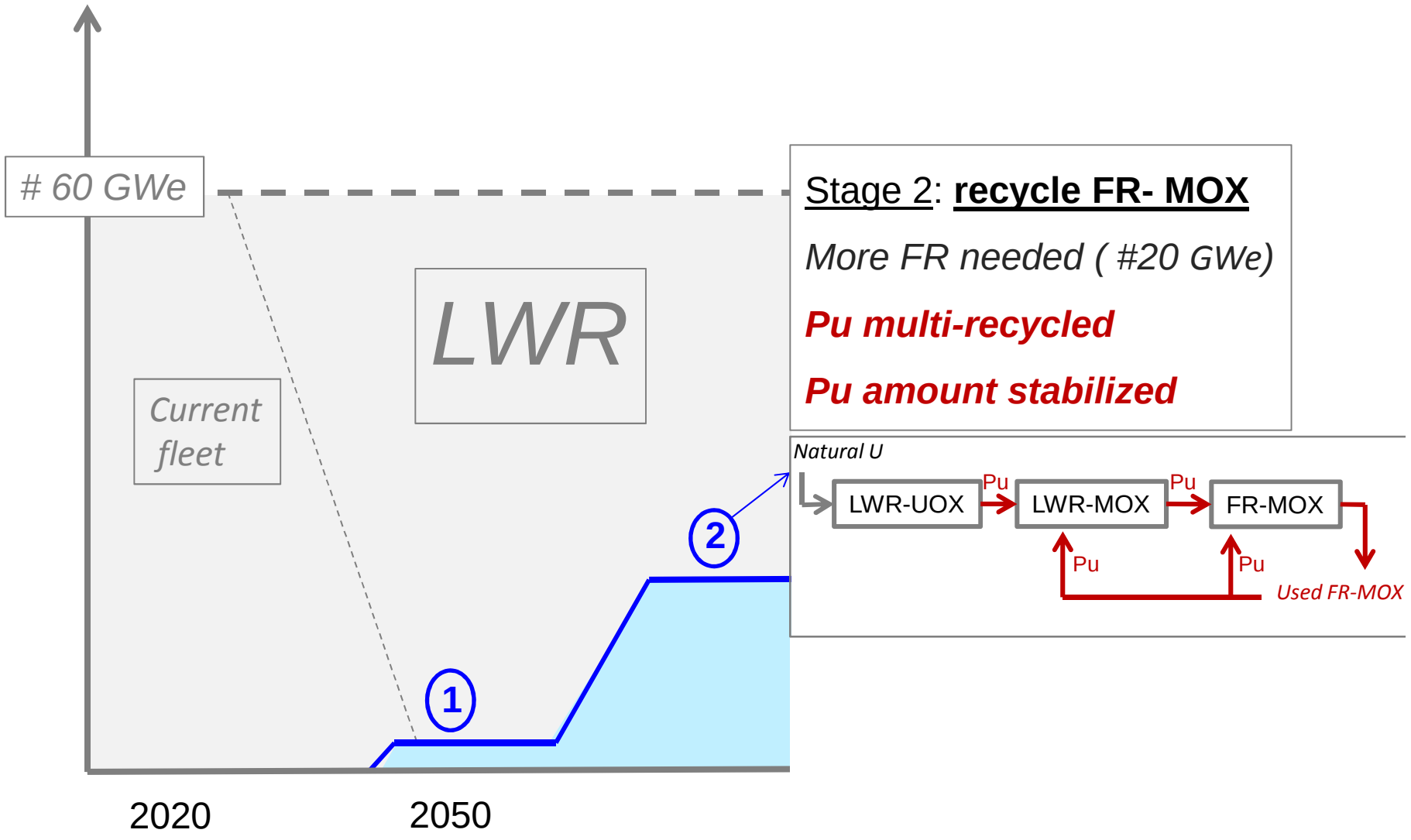

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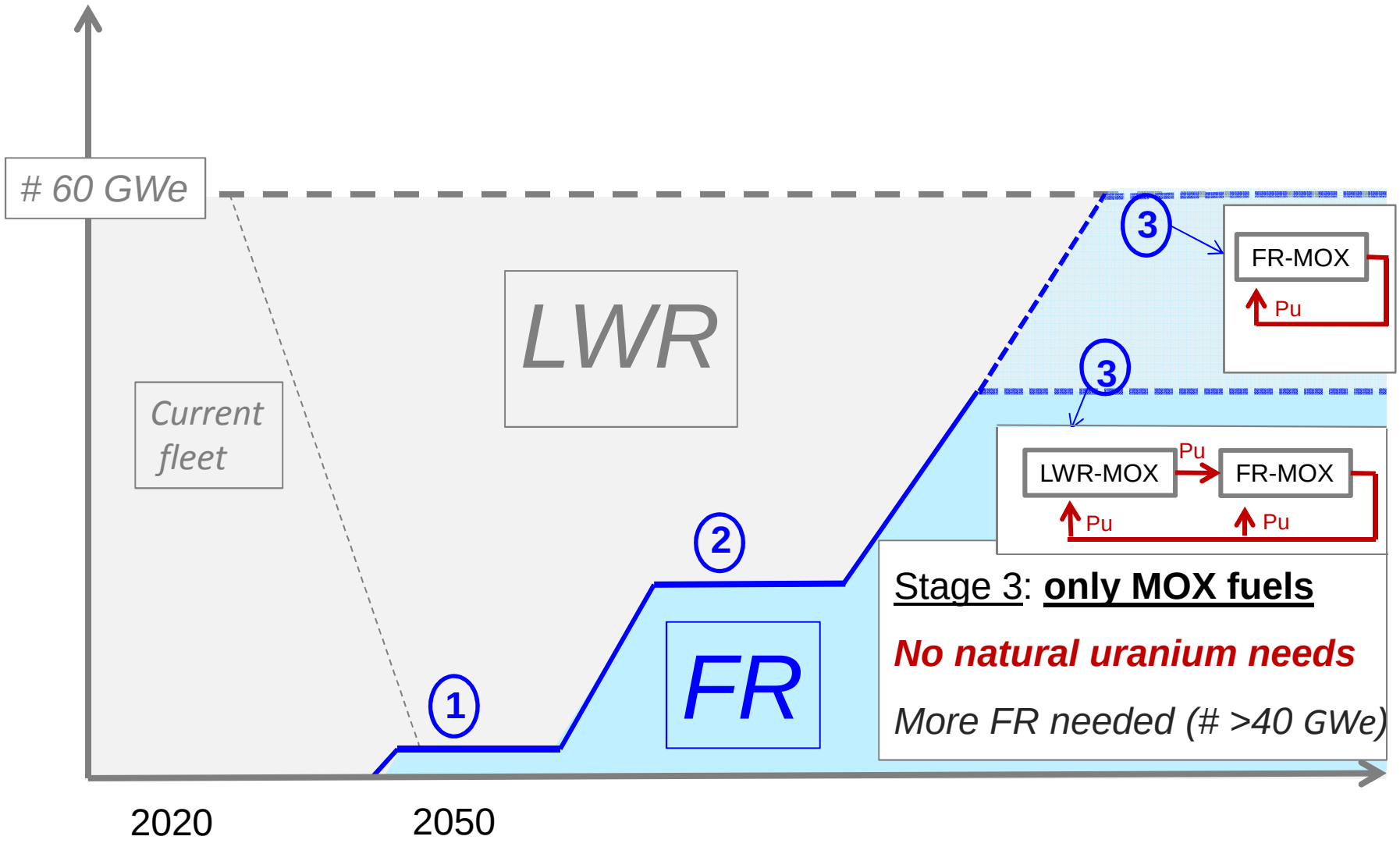
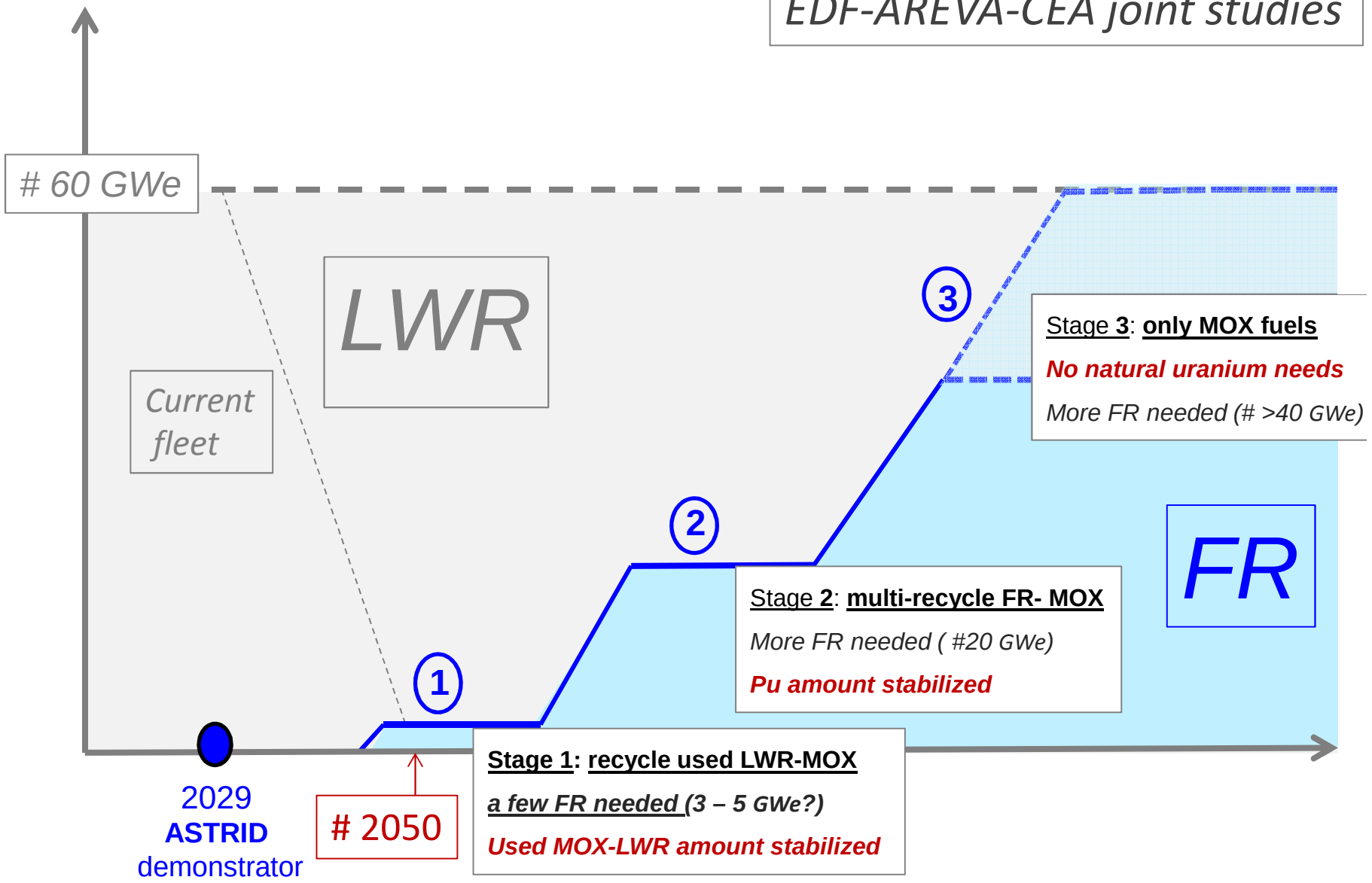


FR REACTORS DEPLOYMENT: *CURRENT SCENARIO STUDIES*

EDF-AREVA-CEA joint studies



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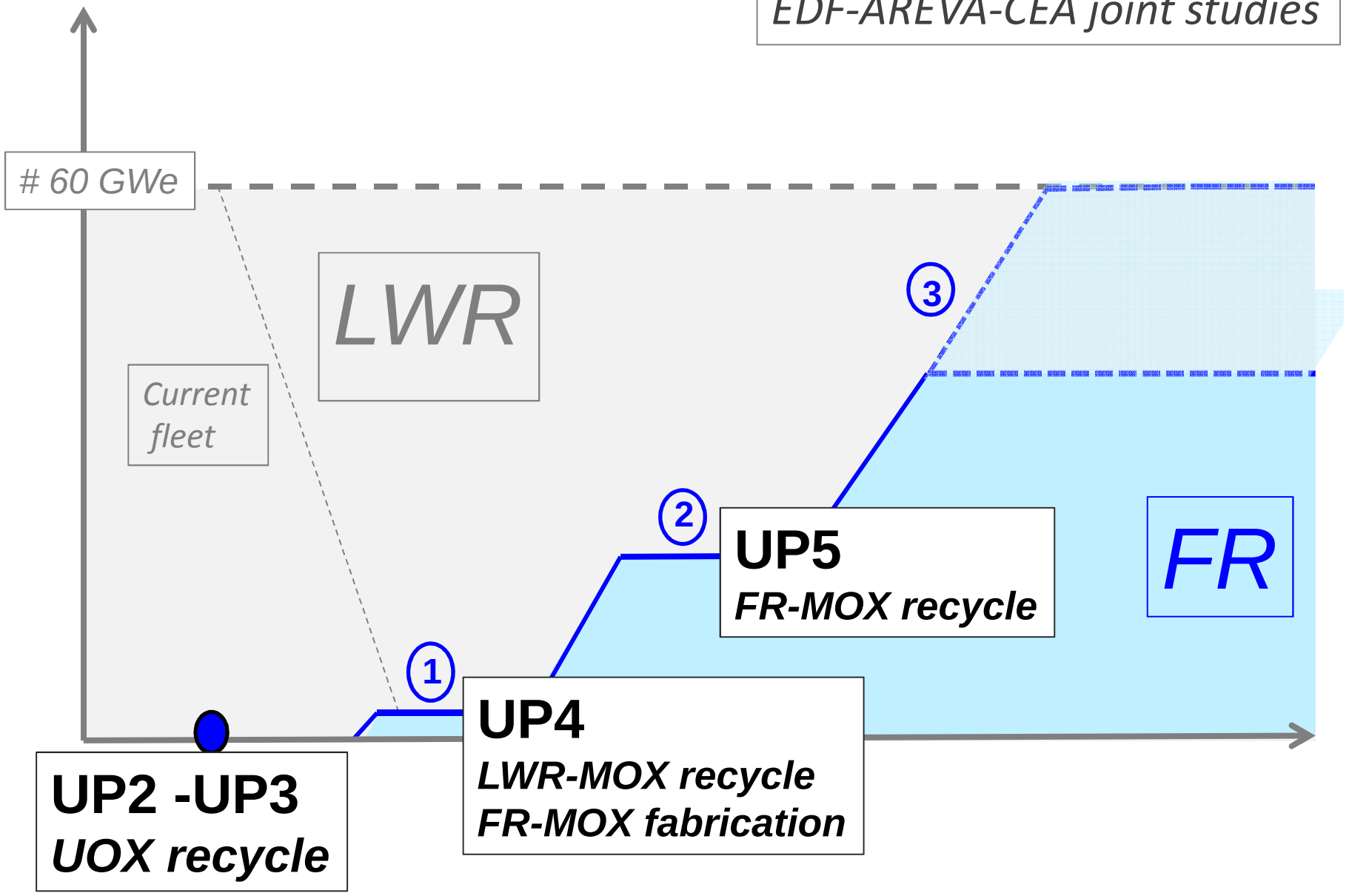


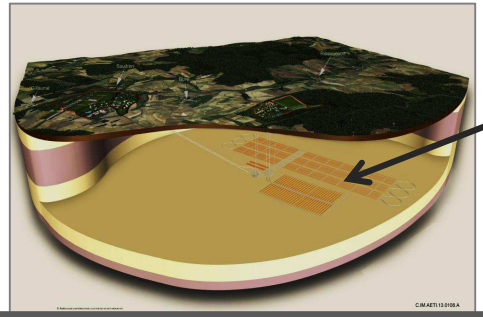
FUEL CYCLE OPTIONS PERFORMANCE ASSESSMENT
(1) NUCLEAR MATERIALS

	OPEN CYCLE	MONO-RECYCLE *LWR*	BI-RECYCLE LWR – (FR)	MULTI-RECYCLE LWR - FR	MULTI-RECYCLE no U needs FR
RNR share (GWe %)	*0*	***0 %***	***5%***	*40%*	***100%***
Natural U consumption *(t/y)*	*8000*	**6500**	**6000**	**2500**	**0**
Pu net Production *(t/y)*	*+ 10,5*	**+ 7,5**	**+ 7**	**0**	**0**
Used fuels amount *(t/y)*	*+ 1000 UOX*	**+ 160** *MOX+REU*	**+ 100** *RNR+REU*	**stabilized**	**stabilized**

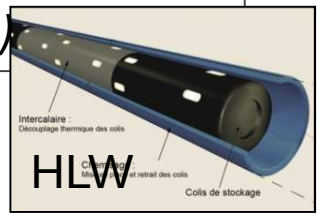
(tons / year)

CEA , report to French government , July 2015
(scenario studies,AREVA-EDF-CEA, 420 TWh/year)

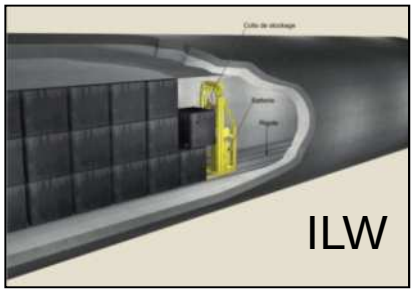
FUEL CYCLE OPTIONS PERFORMANCE ASSESSMENT
(2) REPOSITORY FOOTPRINT



REPOSITORY FOOTPRINT (HLW sockets)



HLW



ILW

	OPEN CYCLE	MONORECYCLE	BI-RECYCLE	MULTIRECYCLE	MULTIRECYCLE
	LWR	**LWR**	**LWR-FR**	**FR**	**All TRU- FR**
HLW WASTE FOOTPRINT (m^2/TWh)	490	**150**	**170**	**170**	**20**
USED FUELS POTENTIAL ADDITIONAL FOOTPRINT(m^2/TWh)	*0*	*180*	*120*	*0*	*0*
GLOBAL *POTENTIAL* FOOTPRINT (m^2/TWh)	490	**330**	**290**	**170**	**20**

CEA , report to the French government, July 2015
(scenario studies,AREVA-EDF-CEA, 420 TWh/year)
(HAVL footprint estimates from ANDRA-CEA former studies)

CONCLUSION

> Reprocessing and recycling today:

- **well-proven technologies, at commercial scale**
- **thanks to important R&D (research & industrial bodies)**
- **provides significant benefits:**
  - *natural resource savings*
  - *optimization of final waste management*
  - *mastering plutonium inventory*

> A first step towards more and more sustainable systems

- **a "step by step approach,**
- **with the progressive deployment of generation IV reactors**

(for Pu full burning, natural uranium utilization drastic increase, long-lived elements transmutation…)