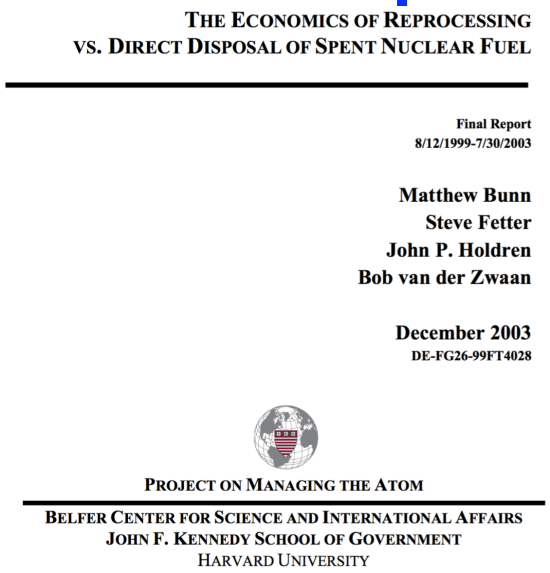
Is there a calculation error in Harvard's report in : « The Economics of Reprocessing vs. Direct Disposal of Spent Nuclear Fuel» ?



THE ECONOMICS OF REPROCESSING VS. DIRECT DISPOSAL OF SPENT NUCLEAR FUEL

Final Report
8/12/1999-7/30/2003

Matthew Bunn
Steve Fetter
John P. Holdren
Bob van der Zwaan

December 2003
DE-FG26-99FT4028

PROJECT ON MANAGING THE ATOM

BELFER CENTER FOR SCIENCE AND INTERNATIONAL AFFAIRS
JOHN F. KENNEDY SCHOOL OF GOVERNMENT
HARVARD UNIVERSITY

Adrien Bidaud[1],

& Many collaborators

1 Laboratoire de Physique Subatomique, LPSC/IN2P3/CNRS, Univ. Grenoble-Alpes, Grenoble, France
bidaud@lpsc.in2p3.fr

Grenoble, France

Grenoble, France

One of the most innovative cities in the world

World class research equipment (eg HighFlux Reactor)

Industry/research tight links (CEA/StMicro/IBM/GE Hydro…)

140 nucl. eng. master degrees / y (inc. 90 in Grenoble-INP)

Nuclear Energy Economics

LCOE = Flows (ex kg/y) * Costs ($/kg)

(YES uncertainty/un-determination are increasing)

=> look for nice references !

http://bruegel.org/wp-content/uploads/imported/events/Dhaeseleer_ppt.pdf, Nucléaire on/off (Francois Lévêque), and others

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http://drum.lib.umd.edu/handle/1903/4043 including spreadsheets !
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The data and analyses demonstrate that the margin between the cost of reprocessing and recycling and that of direct disposal is wide, and is likely to persist for many decades to come.

Sensitivity analysis is performed, showing that the conclusions reached are robust across a wide range of input parameters.

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Harvard study in 1 Slide

2 Studies

- Reprocessing in LWR
- LWR vs FBR

2 Metrics

- Differences in LCOE
- Breakeven Price of Uranium

Massive bibliography

Sensitivity (MC) study

Some refinements, ex : tail enrichment optimisation !

All figures produced by 4 spreadsheets !

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BREAKEVEN: Price of uranium at which COE of breeder equals that of LWR with direct disposal

red: back-end; blue: front-end; green: uranium; | user input

Fuel-cycle Costs		Cost ($)	Time (years) Before Loading	Time (years) After Discharge	Notes
LWR with direct-disposal					
Uranium ($/kgU)		**$134,24**	2,0		**Calculated Breakeven Price**
Conversion ($/kgU)		$6,00	1,5		
Enrichment ($/SWU)		$100,00	1,0		
LEU fuel fabrication ($/kgHM)		$250,00	0,5		
Interim storage ($/kgHM)		$200,00		4,0	Includes shipping
Geologic disposal ($/kgHM)		$400,00		0,0	NPV; includes shipping
LMR					
Difference in capital cost ($/kWe)		$0,00			
Uranium ($/kgU)	FAUX	**$6,00**	**1,0**		**price = natl U if true; DU if false**
Core Fuel Fabrication ($/kgHM)		$1 500,00	0,5		Time same as LEU
Blanket Fuel Fabrication ($/kgHM)		$250,00	0,5		Time same as LEU
Reprocessing ($/kgHM)		$1 000,00		1,0	Includes sf, Pu, U shipping, HLW storage
Geologic disposal, core ($/kgHM)		$200,00		0,0	NPV; includes shipping
Geologic disposal, blanket ($/kgHM)		$200,00		0,0	

2	**Regulated Utility**	Reactor owner (1=government, 2=regulated utility, 3=private venture); see table below
5%	**Discount Rate (%/yr)**	General discount rate for fuel-cycle services

Other Fuel-Cycle Variables					
LWR					
Design burn-up of LEU (33, 43, 53 MW-d/kg)		53			
Residence time in reactor (yr)		5			
Product enrichment (%)		4,40%			
Efficiency (net kWe/kWt, %)		33,00%			
Feed assay		0,71%			
Loss during conversion (%)		0,50%			
Loss during enrichment (%)		0,50%			
Loss during fabrication (%)		1,00%			
LMR					
Annual core loading (kgHM/MWe-yr)		11,5	11,5	9,062069	
Annual blanket loading (kgHM/MWe-yr)		25,5	25,5	1,3	
Residence time of core elements (yr)		3			
Residence time of blanket elements (yr)		3,25			
Make-up fraction in blanket (%)		2,40%			
Cost of depleted uranium ($/kgHM)		6			Use if NU = FALSE, or DU cheaper
LWR/LMR					
Construction time (yr)		6			
Interest on capital during construction (%/yr)		6,4%			set by "owner"; see table below
Interest during construction cost (% of capital)		18,9%			see calculation below
Preoperating costs (% of capital)		10,0%			
Contigency factor (% of capital)		10,0%			

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Unit costs

Flows

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All figures produced by 4 spreadsheets !

Flow Calculations

[kg/(MWe.y)]=1/BU[MWth.j/t]*365*1000/η

Ok without Blanket BUT gives 2 times more blanket flows than core flows ?

The blankets (or the driver fuel) DO NOT produce ALL the energy of the reactor !

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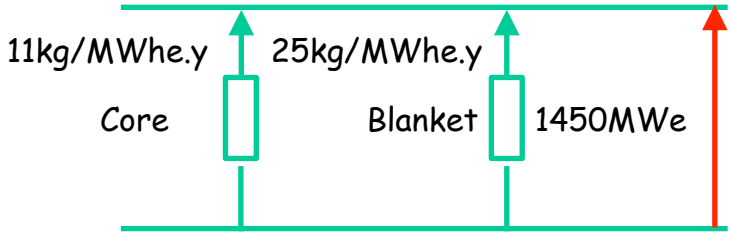

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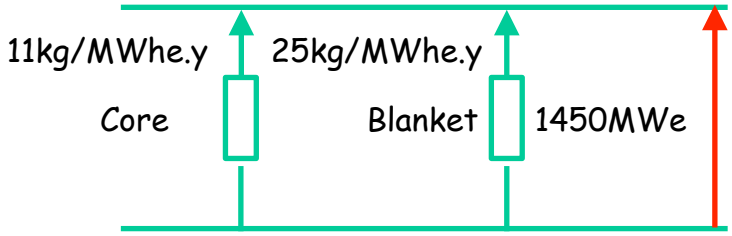
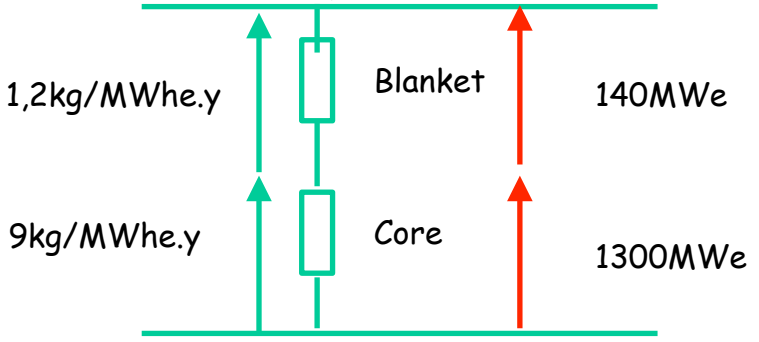
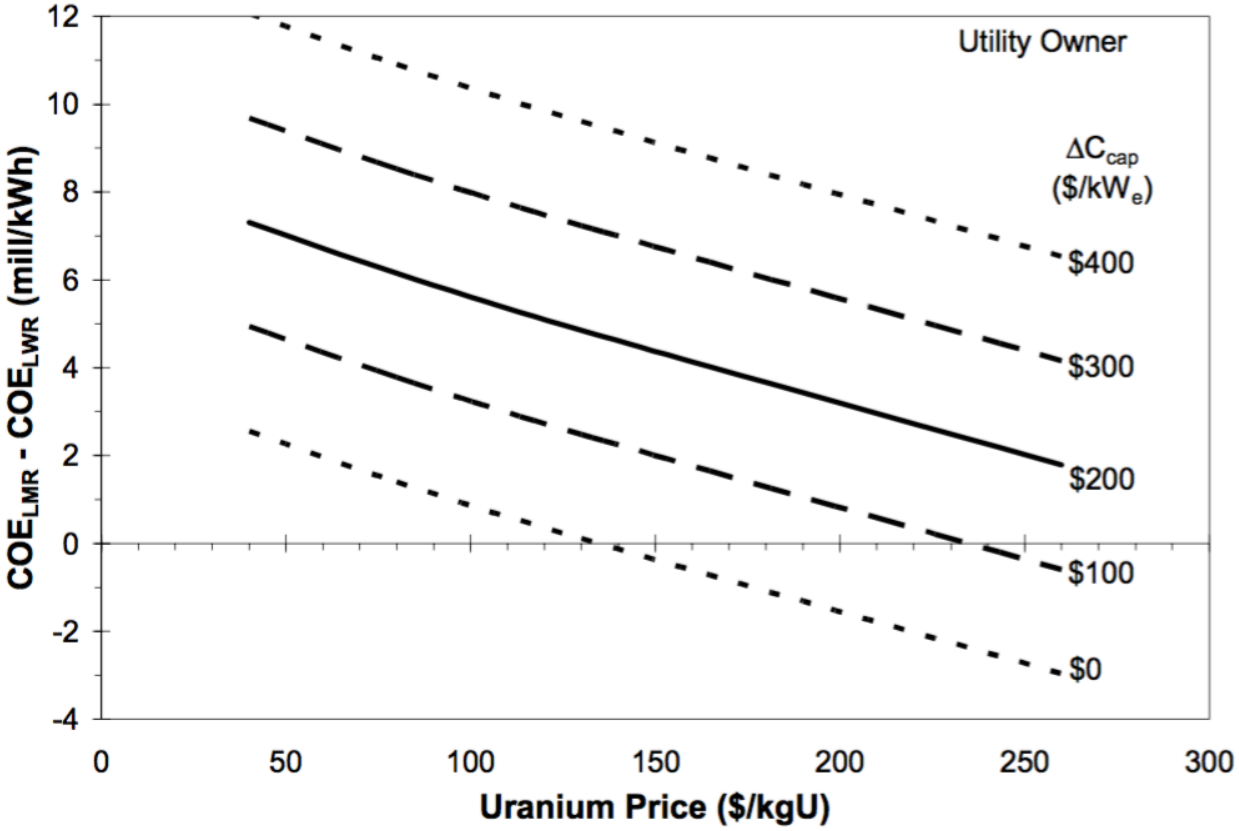
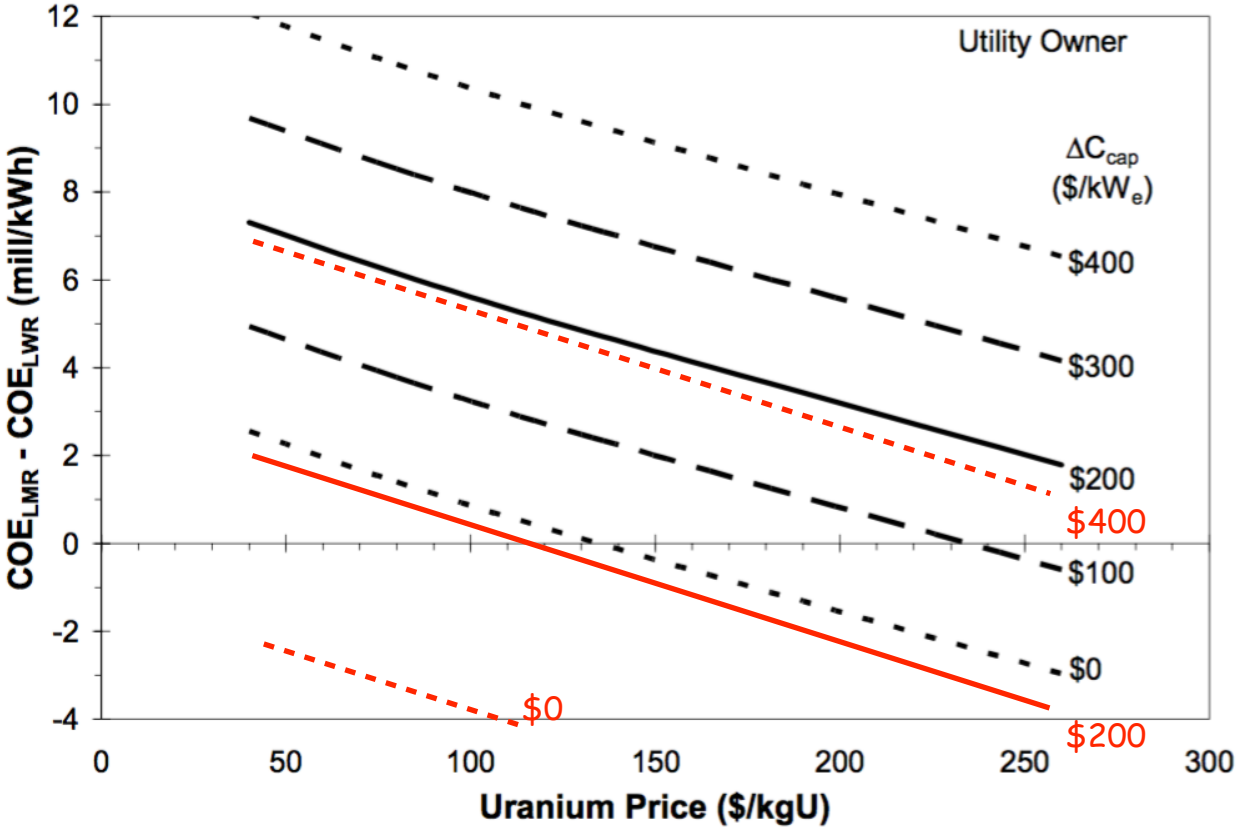




Impact ?


Utility Owner
ΔC_cap ($/kW_e)
$400
$300
$200
$100
$0
COE_LMR - COE_LWR (mill/kWh)
Uranium Price ($/kgU)
12
10
8
6
4
2
0
-2
-4
0
50
100
150
200
250
300

Impact ?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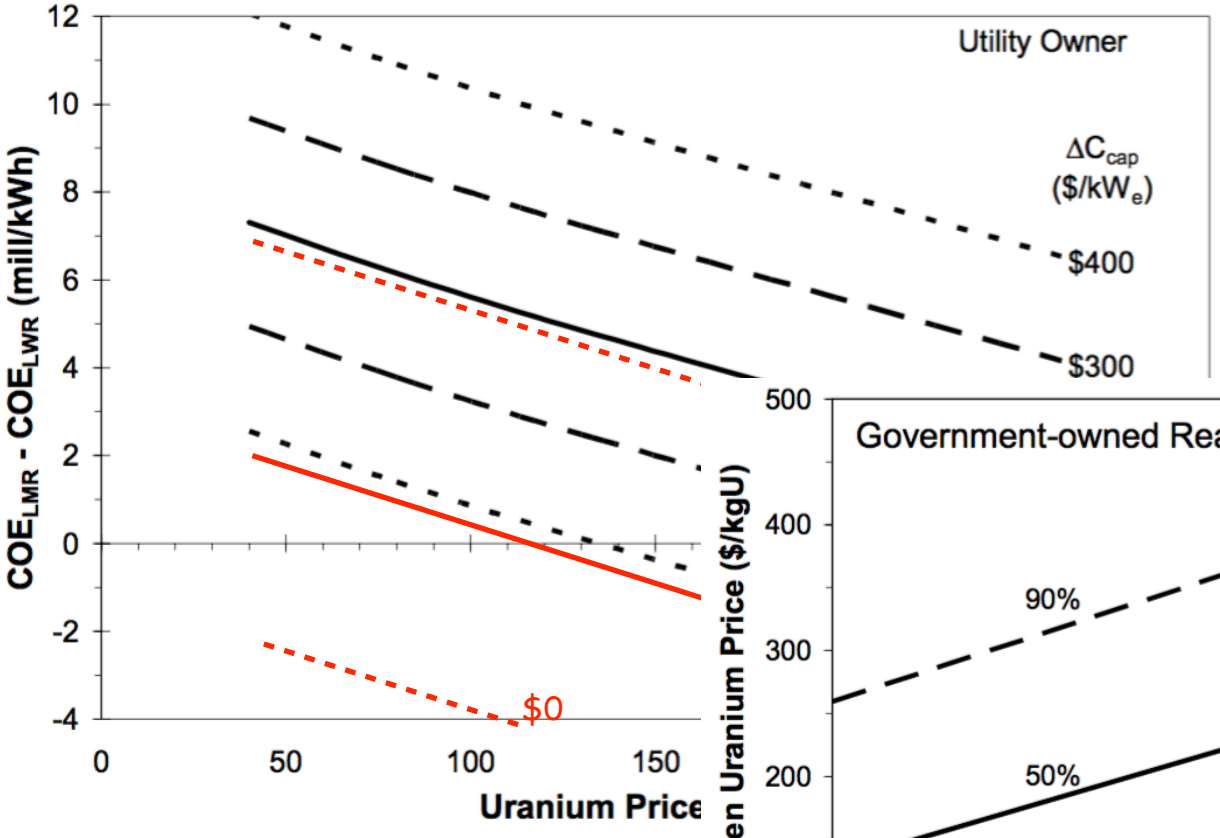
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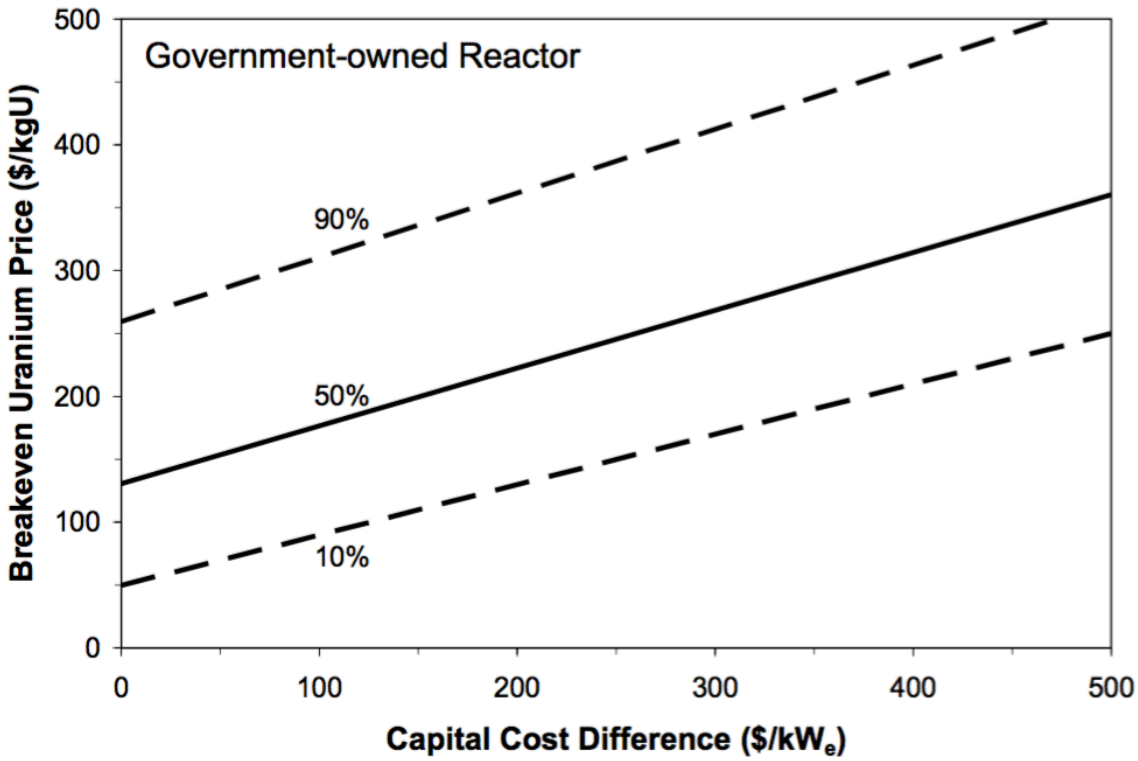
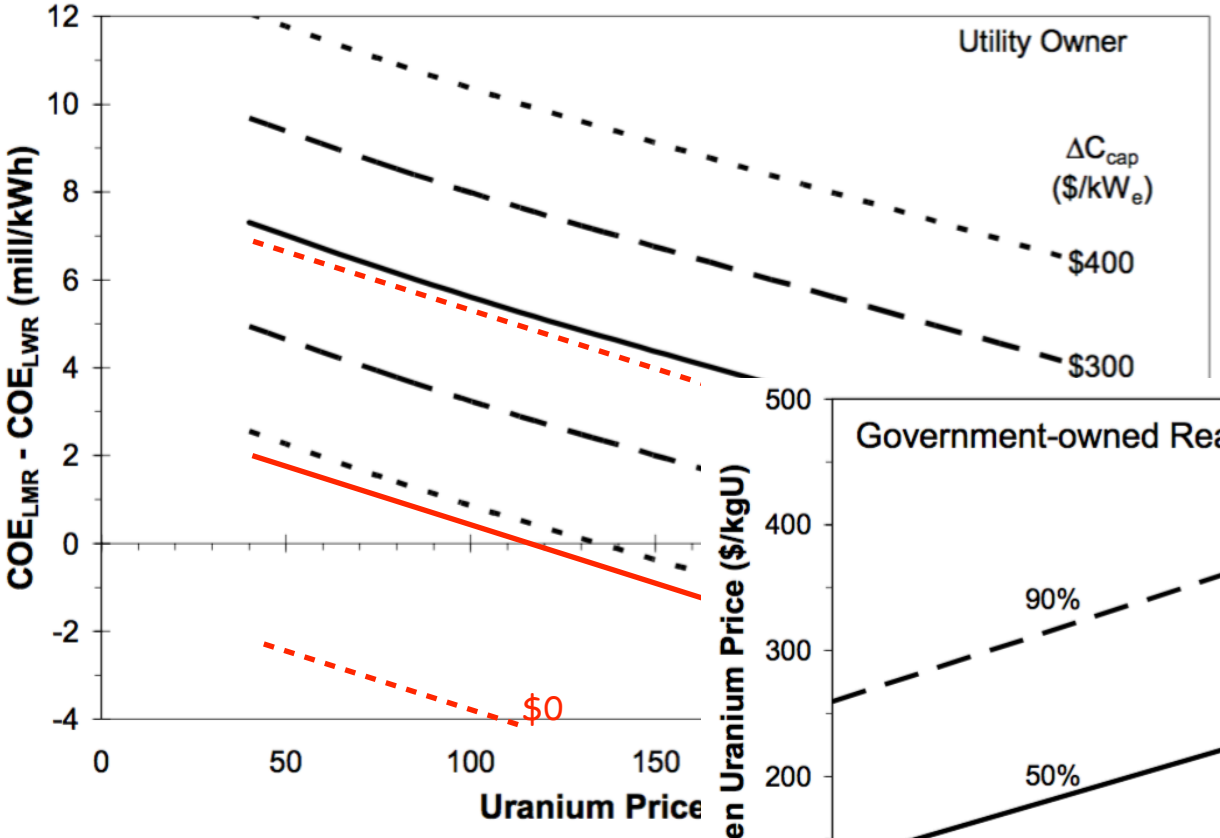

Government-owned Reactor
90%
50%
10%
Breakeven Uranium Price ($/kgU)
500
400
300
200
100
0
0
100
200
300
400
500
Capital Cost Difference ($/kW_e)

Impact ?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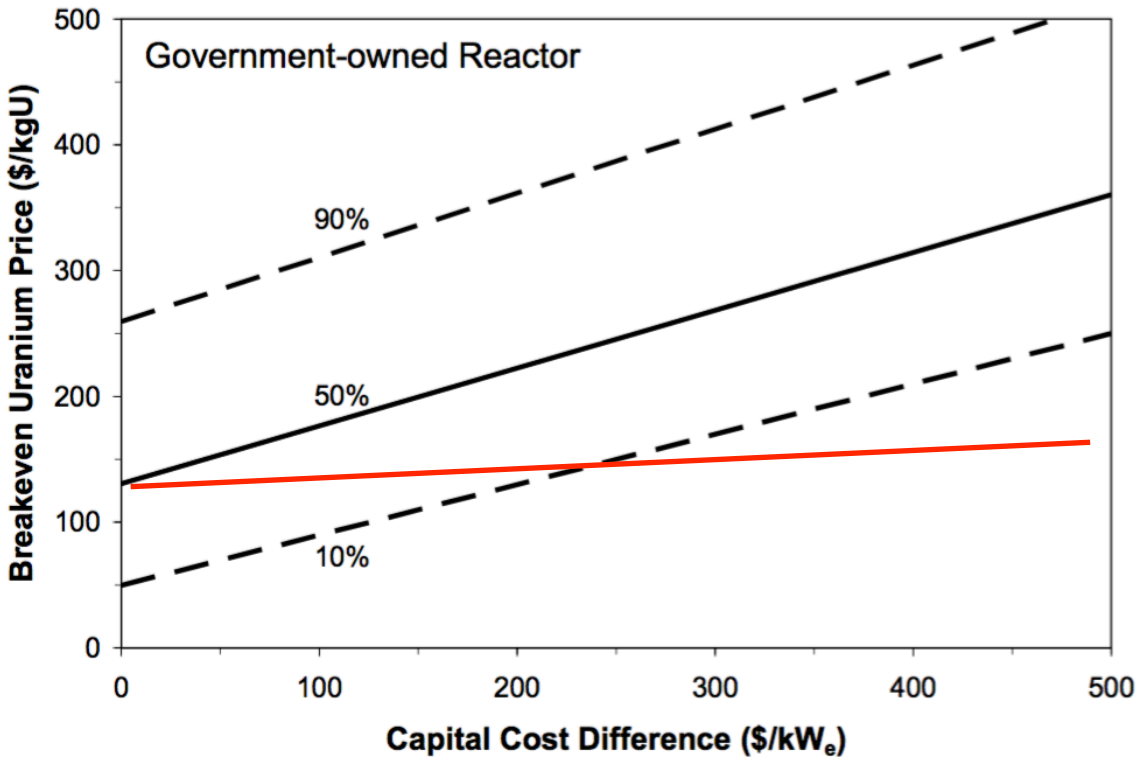
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200
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400
500

Conclusions

1/ Second part of Harvard report to be corrected ?

2/ Results should be updated : building cost increase (in western countries)

3/ Interdisicplinary studies are DIFFICULT, to run & fund

4/ Keep your codes/data/benchmarks open !

Questions

What is the cost-benefit analysis of blankets in SFR ?

Is uranium price or « visibility of its potential reduced availability » of any relevance to the debate ?

How are the uncertainties in the costs of advanced fuel cycles fuzzing the debate ?

Are economical arguments of any use for actual decision making regarding fuel cycle questions or even energy issues ?

Merci !


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cea


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ORSAY


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ENERGY
Nuclear Energy


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CARNOT
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cea


cnrs


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PAYS DE LA LOIRE
La Région
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Mission interdisciplinarité
Centre national de la recherche scientifique

EURATOM

PACEN