THE ROLE OF NUCLEAR POWER IN CLIMATE CHANGE STABILIZATION

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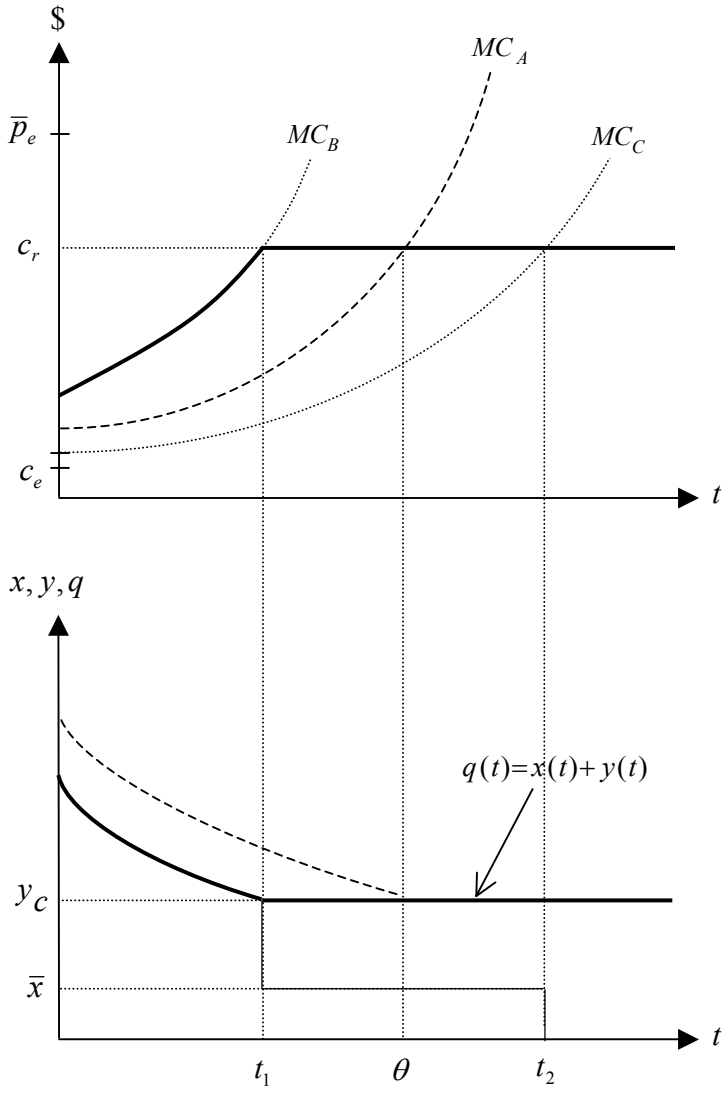
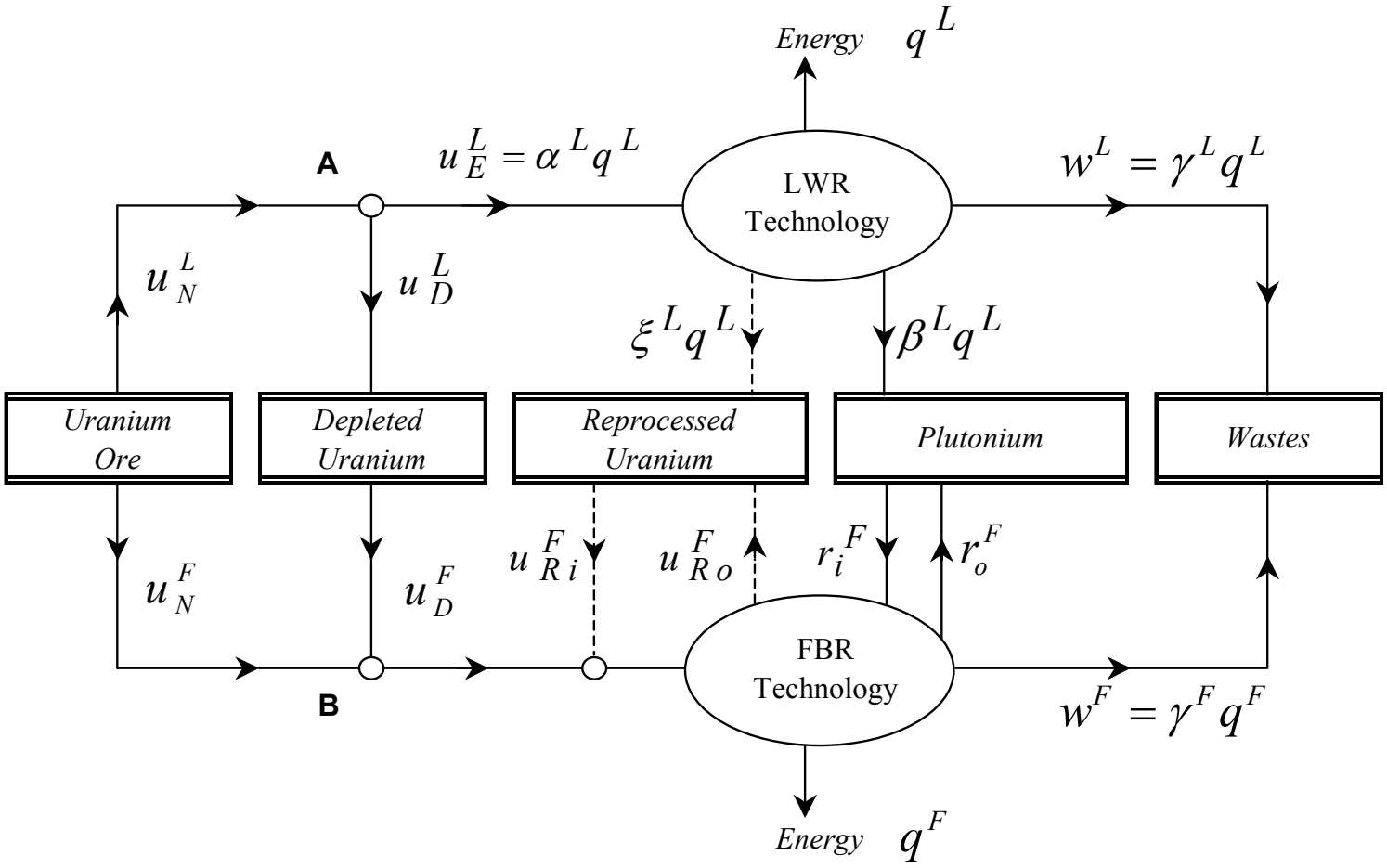
- THE IMPORTANT ROLE OF NUCLEAR POWER TODAY
- NUCLEAR ACCOUNTS FOR A SIXTH OF GLOBAL ELECTRICITY PRODUCTION
- 17 COUNTRIES DEPEND ON IT FOR AT LEAST 25% OF ELECTRICITY
- DOUBLE DIGIT GROWTH UNTIL 2000
- 30 NEW PLANTS UNDER CONSTRUCTION
- IN THE US, NUCLEAR IS KEY TO MEETING THE REQUIREMENTS OF THE CLEAN AIR ACT
- "MOST OF THE AVOIDED CO2 EMISSIONS OVER THE LAST 20 YEARS HAVE COME FROM NUCLEAR POWER," MONIZ (1999)



The Conceptual Model: Both the Polluting Fossil Fuel and the Clean Renewable are used at the Ceiling

WE HAVE AN ECONOMIC MODEL THAT CONSIDERS TWO TECHNOLOGIES

- LWR AND FBR
- CHANGING DEMAND
- MATERIALS RECYCLING
- DIFFERENT GRADES OF FOSSIL FUELS
- SCARCITY DRIVES UP PRICES
- WE IMPOSE PPM CONSTRAINTS
- A MODEL OF ENDOGENOUS SUBSTITUTION



Flow of Materials in the Nuclear Technology

ALTERNATIVE SCENARIOS

A. The Baseline Model: Fossil Fuels without a Cap on Emissions

B. The Business-As-Usual (BAU) Model*:* An Emissions Cap with Traditional Nuclear Technology

C. The Pro-Nuclear Model: An Emissions Cap with both Traditional and Modern Nuclear Technologies

D. The Pro-Nuclear Model plus Technological Change in Fossil Fuels and Solar Energy

E. The Pro-Nuclear Model with a Levelling off in the Demand for Energy

F. Sensitivity Analysis with Alternative Emission Caps:

G. Recent Runs with Sequestration and Technological Change

Initial Stocks of Nuclear Fuel and Waste Products [1]

	Initial Stock
Natural uranium $U_N(0)$	15.4
Depleted uranium $U_D(0)$	0.917
Reprocessed uranium $U_R(0)$	0
Plutonium $Pu(0)$	0.001
Waste Products $W(0)$	0.1

(1) Numbers are in million tons.

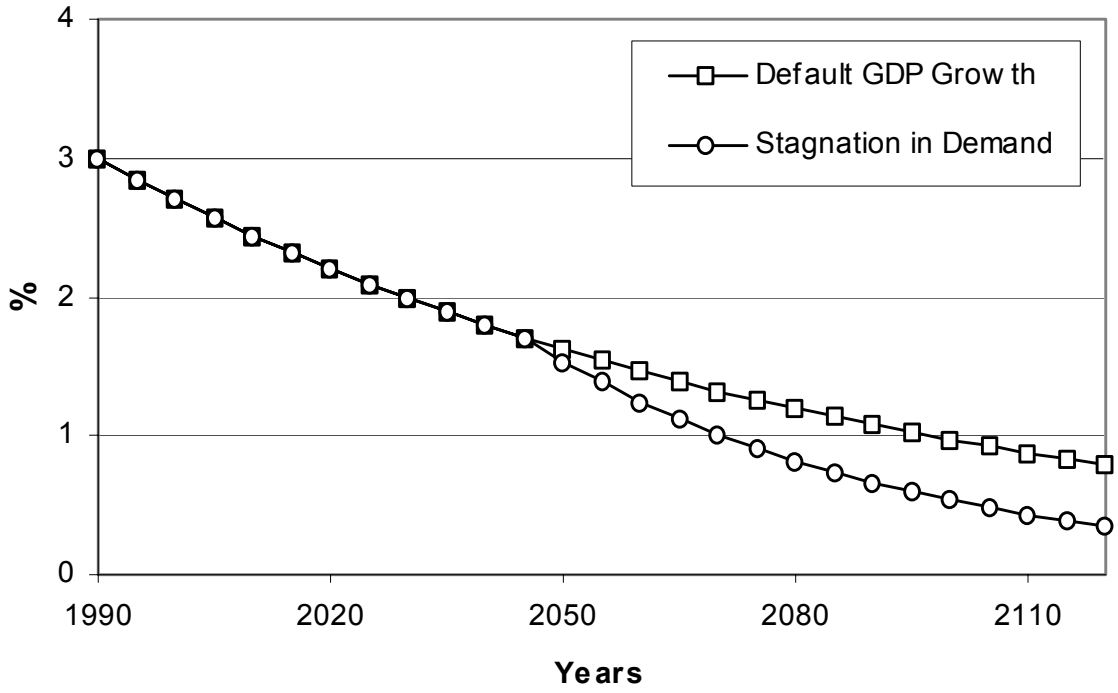
Unit Costs for the Nuclear Technology [1]

Cost parameters	*LWR*	*FBR*
Extraction $m\,m$	60	60
Enrichment m^S	76	-
Fuel Fabrication $m_f^L, m_f^F,$	305	2,600
Operating v^L, v^F	5.614	8.421
Eprocessing m_R^L, m_R^F	500	2,000
Depleted Uranium Storage s_{U_D}	3.5	-
Reprocessed Uranium Storage s_{U_R}	3.6	3.6
Plutonium Storage s_{Pu}	1,000	1,000
Waste Disposal s_W	400	400

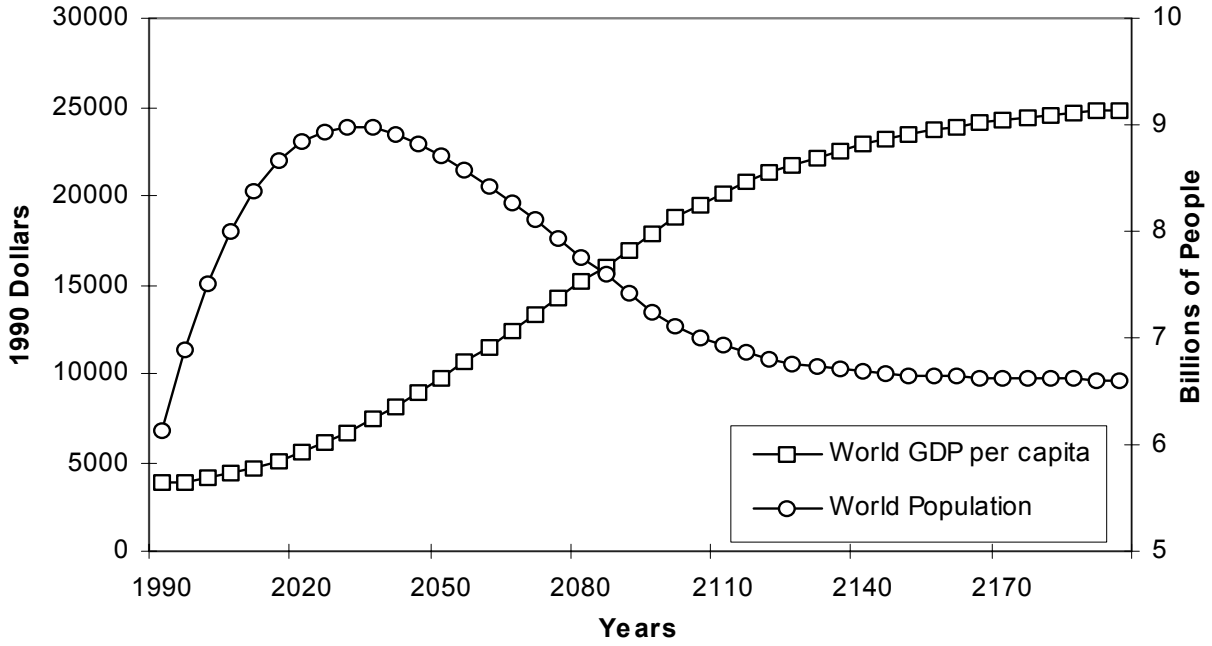
(1) All numbers are in $/kg

Sectoral Demand Parameters

Sector i	*Constant parameter* A_j	*Price elasticity* α_j	*Income elasticity* β_j
1. Electricity	0.015927	-0.65	0.92
2. Transportation	1.699235	-1.28	0.81
3. Residential / Commercial	0.006730	-0,79	1.08
4. Industry	0.091866	-0.52	0.76



GDP Growth Rate Assumptions



Stagnation in Demand Growth: GDP per capita and Population Assumptions

Resource Use in the Baseline Model with Fossil Fuel (No Nuclear)

	Baseline, Fossil Fuels, no Nuclear Power			
Decade	*Elec.*	*Transp.*	*Resid. / Com.*	*Ind.*
1990-99	Coal I	Oil I	Gas I	Gas I
2000-09	Coal I	Oil I	Gas I	Gas I
2010-19	Coal I	Oil I	Gas I	Gas I
2020-29	Coal I	Oil I	Gas I	Gas I
2030-39	Coal I	Oil I	Gas I	Gas I
2040-49	Coal I	Oil I	Gas II	Gas I-II
2050-59	Coal I	Oil I	Gas II	Gas II
2060-69	Coal I	Oil I-II	Gas II	Gas II
2070-79	Coal I	Oil II	Gas II	Gas II
2080-89	Coal I	Oil II	Gas II	Gas II / Coal I
2090-99	Coal I-II	Oil II	Gas II	Coal II
2100-09	Coal II	Oil II	Gas II	Coal II
2110-19	Coal II	Oil II	Gas II	Coal II
2120-29	Coal II	Oil II	Gas II	Coal II
2130-39	Coal II	Oil II	Coal II	Coal II
2140-49	Coal II	Oil II / Coal II	Coal II	Coal II
2150-59	Coal II	Coal II	Coal II	Coal II
2160-69	Coal II	Coal II	Coal II	Coal II
2170-79	Coal II	Coal II	Coal II	Coal II
2180-89	Coal II	Coal II	Coal II	Coal II
2190_99	Coal II	Coal II	Coal II	Coal II
2200-09	Coal II	Coal II	Coal II	Coal II
2210-19	Coal III	Coal II-III	Coal II	Coal III
2220-29	Coal III	Coal III	Coal III	Coal III
…	…	…	…	…
2260-69	Coal III / Solar	Coal III	Coal III	Coal III
2270-79	Solar	Coal III	Coal III	Coal III
2280-89	Solar	Coal III	Coal III	Coal III
2290-99	Solar	Solar	Coal III	Coal III
…	…	…	…	…
2330-39	Solar	Solar	Solar	Solar
…	…	…	…	…

Resource Use under a Carbon Target and
(a) Traditional (LWR)
(b) both Nuclear Technologies (LWR, FBR)

	Baseline, LWR, 550 ppm target			
Decade	*Elec.*	*Transp.*	*Resid. / Com.*	*Ind.*
1990-99	Oil I / LWR	Oil I	Gas I	Gas I
2000-09	Coal I / LWR	Oil I	Gas I	Gas I
2010-19	Coal I / LWR	Oil I	Gas I	Gas I
2020-29	Coal I / LWR	Oil I	Gas I	Gas I
2030-39	Coal I / LWR	Oil I	Gas I	Gas I
2040-49	Coal I / LWR	Oil I	Gas I	Gas I-II
2050-59	Coal I / LWR	Oil I	Gas II	Gas II
2060-69	Coal I / LWR	Oil I-II	Gas II	Gas II
2070-79	Coal I / LWR	Oil II	Gas II	Gas II
2080-89	Coal I / LWR	Oil II	Gas II	Gas II / Oil II
2090-99	Coal I / LWR	Oil II	Gas II	Oil II
2100-09	Coal I / LWR	Oil II	Gas II	Oil II
2110-19	Solar / LWR	Oil II	Gas II	Coal I
2120-29	Solar / LWR	Oil II	Gas II	Coal I / Gas II
2130-39	Solar	Oil II	Gas II	Coal I / Gas II
2140-49	Solar	Oil II / Sol.	Gas II	Coal I
2150-59	Solar	Oil II / Sol.	Gas II	Coal I
2160-69	Solar	Solar	Gas II	Coal I
2170-79	Solar	Solar	Gas II	Coal I
2180-89	Solar	Solar	Coal I / Sol.	Coal I
2190-99	Solar	Solar	Coal I-II / Sol.	Coal I
2200-09	Solar	Solar	Coal II / Sol.	Coal II
2210-19	Solar	Solar	Coal II / Sol.	Coal II
2220-29	Solar	Solar	Coal II / Sol.	Coal II
…	…	…	…	…
2260-69	Solar	Solar	Coal II / Sol.	Coal II
2270-79	Solar	Solar	Coal II / Sol.	Coal II
2280-89	Solar	Solar	Coal II / Sol.	Coal II
2290-99	Solar	Solar	Coal II / Sol.	Coal II
…	…	…	…	…
2330-39	Solar	Solar	Coal II / Sol.	Coal II
…	…	…	…	…

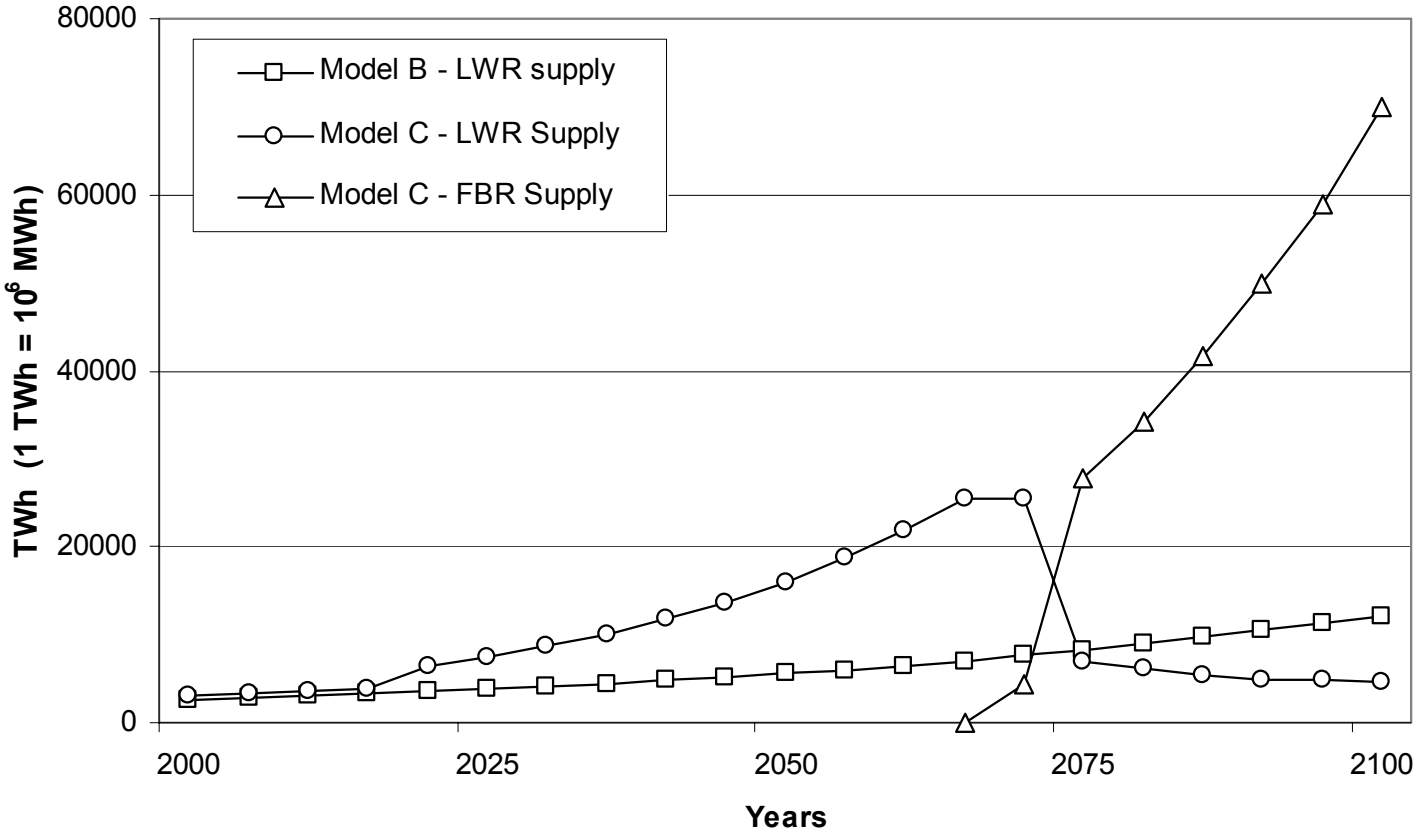
(a)

	Baseline, LWR-FBR, 550 ppm target			
	Elec.	*Transp.*	*Resid. / Com.*	*Ind.*
	Gas I / LWR	Oil I	Gas I	Gas I
	Gas-Coal I /LWR	Oil I	Gas I	Gas I
	Coal I / LWR	Oil I	Gas I	Gas I
	Coal I / LWR	Oil I	Gas I	Gas I
	Coal I / LWR	Oil I	Gas I	Gas I
	Coal I / LWR	Oil I	Gas I-II	Gas I-II
	Coal I / LWR	Oil I	Gas II	Gas II
	LWR	Oil I-II	Gas II	Gas II
	LWR / FBR	Oil II	Gas II	Gas II
	LWR / FBR	Oil II	Gas II	Gas II
	FBR	Oil II	Gas II	Gas II /LWR /FBR
	FBR	Oil II / Gas II	Gas II	Gas II /LWR /FBR
	FBR	Oil II / Gas II	Gas II / FBR	LWR / FBR
	FBR	Oil II	Gas II / FBR	FBR
	FBR	Oil II	Gas II / FBR	FBR
	FBR	Oil II	FBR	FBR
	FBR	Oil II	FBR	FBR
	FBR	Oil II / Coal I	FBR	FBR
	FBR	Coal I / FBR	FBR	FBR
	FBR	Coal I / FBR	FBR	FBR
	FBR	Coal I / FBR	FBR	FBR
	FBR	Coal I / FBR	FBR	FBR
	FBR	Coal I / FBR	FBR	FBR
	FBR	Coal I / FBR	FBR	FBR
	…	…	…	…
	FBR	Coal I / FBR	FBR	FBR
	FBR	Coal I / FBR	FBR	FBR
	FBR	Coal I / FBR	FBR	FBR
	FBR	Coal I-II / FBR	FBR	FBR
	…	…	…	…
	FBR	Coal II / FBR	FBR	FBR
	…	…	…	…

(b)

Resource Use with a Carbon Target and Exogenous Decline in Costs

	Exogenous Decline in Costs, 550 ppm Target			
Decade	*Elec.*	*Transp.*	*Resid. / Com.*	*Ind.*
1990-99	Oil I / LWR	Oil I	Gas I	Gas I
2000-09	Oil I / LWR	Oil I	Gas I	Gas I
2010-19	Oil I / LWR	Oil I	Gas I	Gas I
2020-29	Oil-Coal. I / LWR	Oil I	Gas I	Gas I
2030-39	Coal I / LWR	Oil I / LWR	Gas I	Gas I
2040-49	Coal I	Oil I/ LWR/ Sol.	Gas I	Gas I / Oil I
2050-59	Coal I	Sol. / LWR-FBR	Gas II	Oil I / Gas II
2060-69	Solar	Sol. / LWR-FBR	Gas II	Gas II
2070-79	Solar	Sol. / LWR-FBR	Gas II	Gas II / Oil II
2080-89	Solar	Sol. / LWR-FBR	Gas II	Oil II
2090-99	Solar	Sol. / LWR-FBR	Gas II	Oil II
2100-09	Solar	FBR / Solar	Gas II	Oil II / Sol.
2110-19	Solar	Solar	Gas II	Solar
2120-29	Solar	Solar	Gas II /Sol.	Solar
2130-39	Solar	Solar	Solar	Oil II / Sol.
2140-49	Solar	Solar	Solar	Oil II / Sol.
2150-59	Solar	Solar	Solar	Oil II / Sol.
2160-69	Solar	Solar	Solar	Oil II / Sol.
2170-79	Solar	Solar	Solar	Oil II / Sol.
2180-89	Solar	Solar	Solar	Solar
…	…	…	…	…

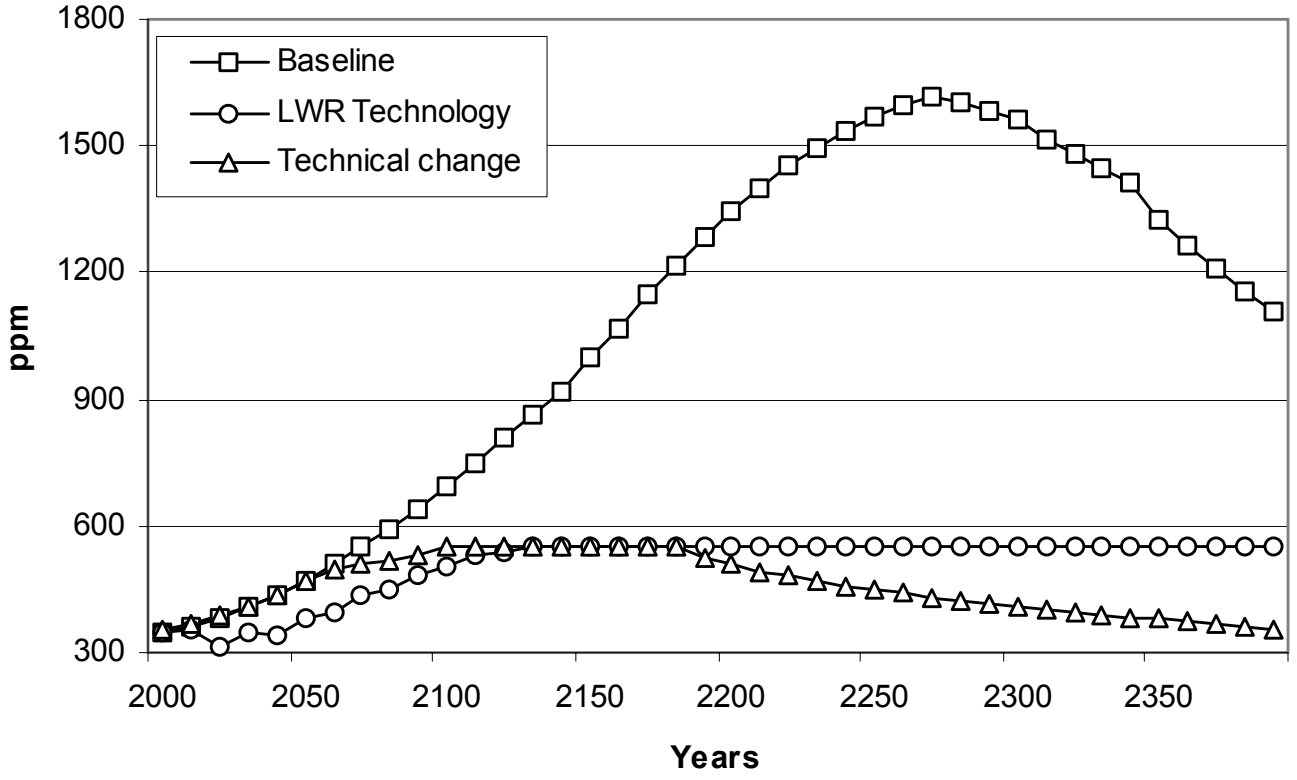


Nuclear Electricity Generation

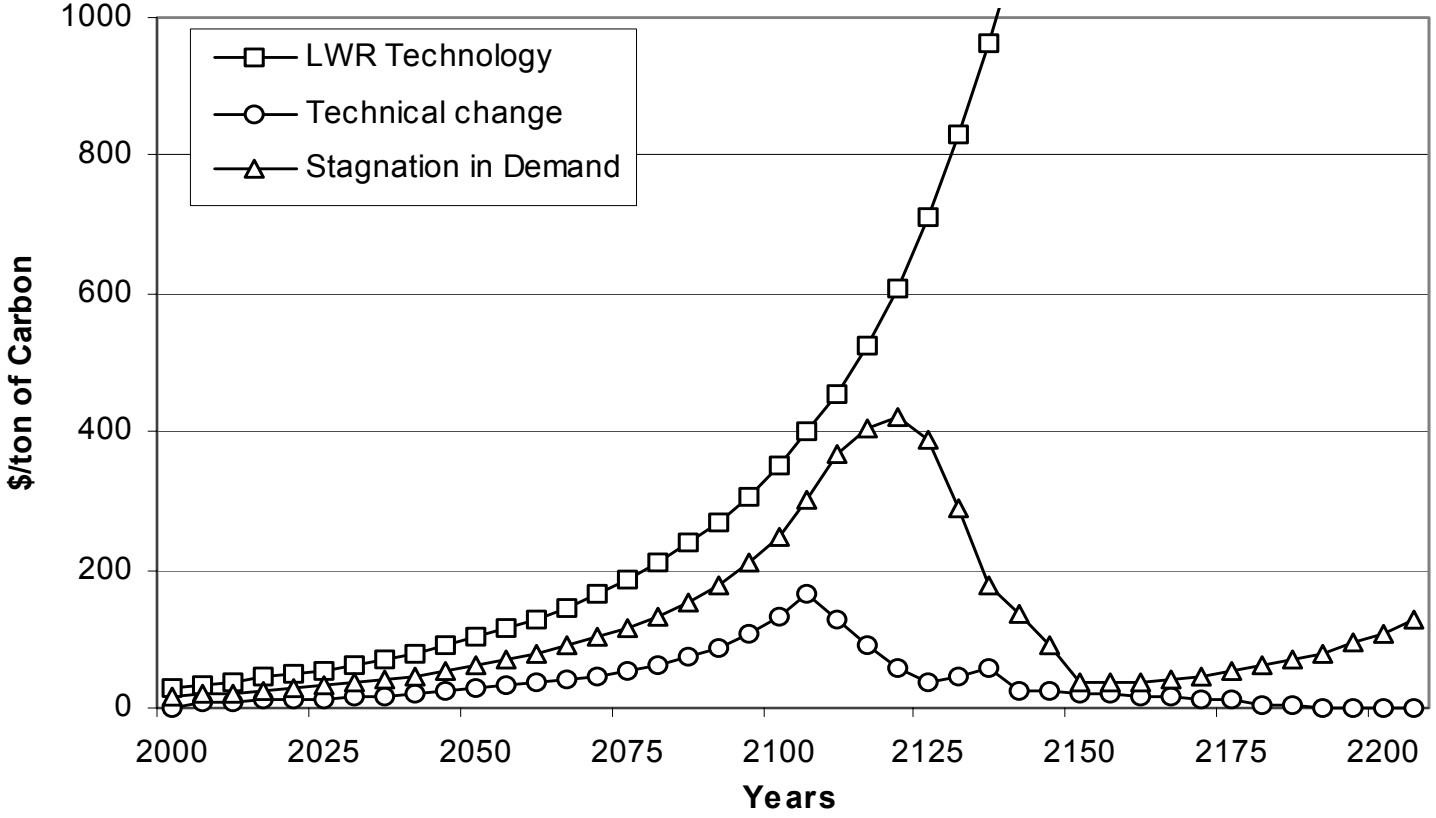
Percentage Shares of Primary Energy Supply

Scenarios	*Oil*			*Gas*			*Coal*			*Nuclear*[1]		
	2020	2050	2100	2020	2050	2100	2020	2050	2100	2020	2050	2100
Baseline	16	13	12	71	70	38	16	18	50	-	-	-
550ppm												
LWR	14	14	44	70	70	41	11	11	4	5	6	11
LWR/FBR	13	13	11	71	71	53	8	4	0	7	13	44
Tech. Prog.	23	33	6	71	37	25	0	16	0	7(0)	10(5)	5(54)
Stag. Dem.	13	13	11	72	72	51	8	4	0	7	11	38
450ppm												
LWR	43	26	22	54	55	57	0	15	0	3	4	12
LWR/FBR	27	28	0	68	62	55	0	0	0	5	10	45
Tech. Prog.	40	30	0	56	62	12	0	0	0	4	8	11(77)

(1) Solar shares are in brackets.



Time Path of Carbon Concentration

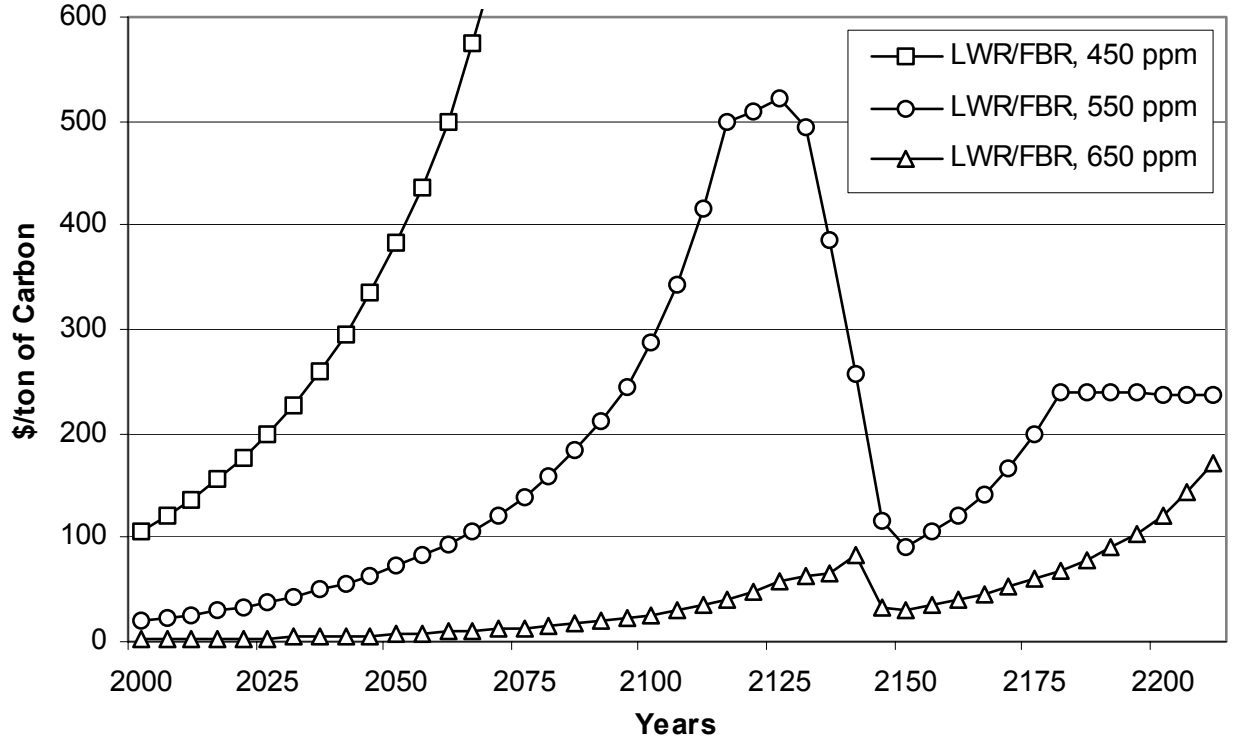


Time Path of Carbon Prices

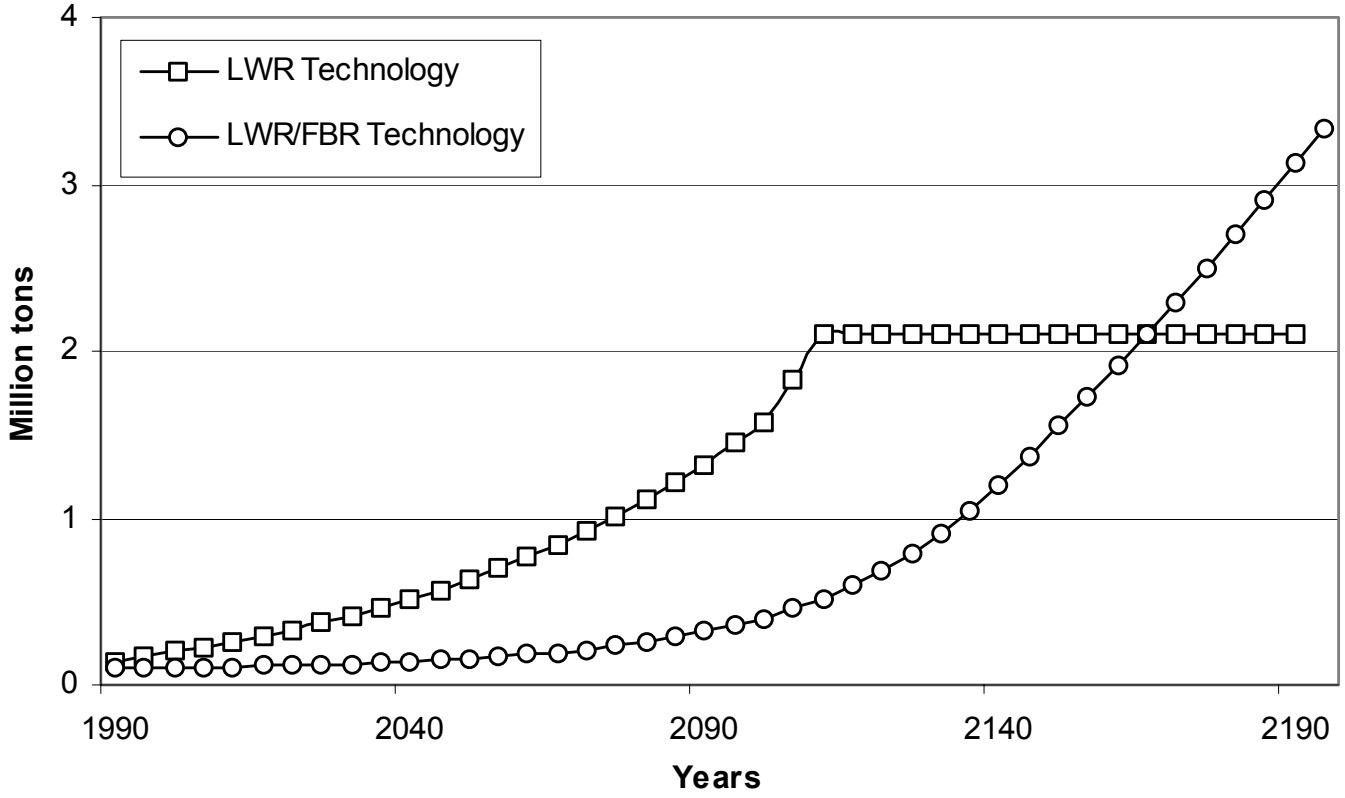
Scarcity Rent of Uranium ($/kgU) and Shadow Price of Carbon in Year 2000 ($/ton)

Scenarios	Carbon Targets (ppm)	Scarcity Rent of Uranium ($/kg)	Shadow Price of Carbon ($/ton)
LWR Technology	450	1542	87
	550	1542	40
	650	1143	21
LWR Technology and Doubling of Uranium Stock[1]	550	697	32
Both Nuclear Technologies	450	176	137
	550	160	26
	650	163	3
Both Nuclear Technologies and Technical Progress	550	17	10
Stagnation in Demand Growth	550	95	22

(1) 30.8 million tons.



The Price of Carbon under Alternative Carbon Targets



Cumulative Stock of Nuclear Waste

New Runs: Geological Sequestration of Carbon

Three costs components:

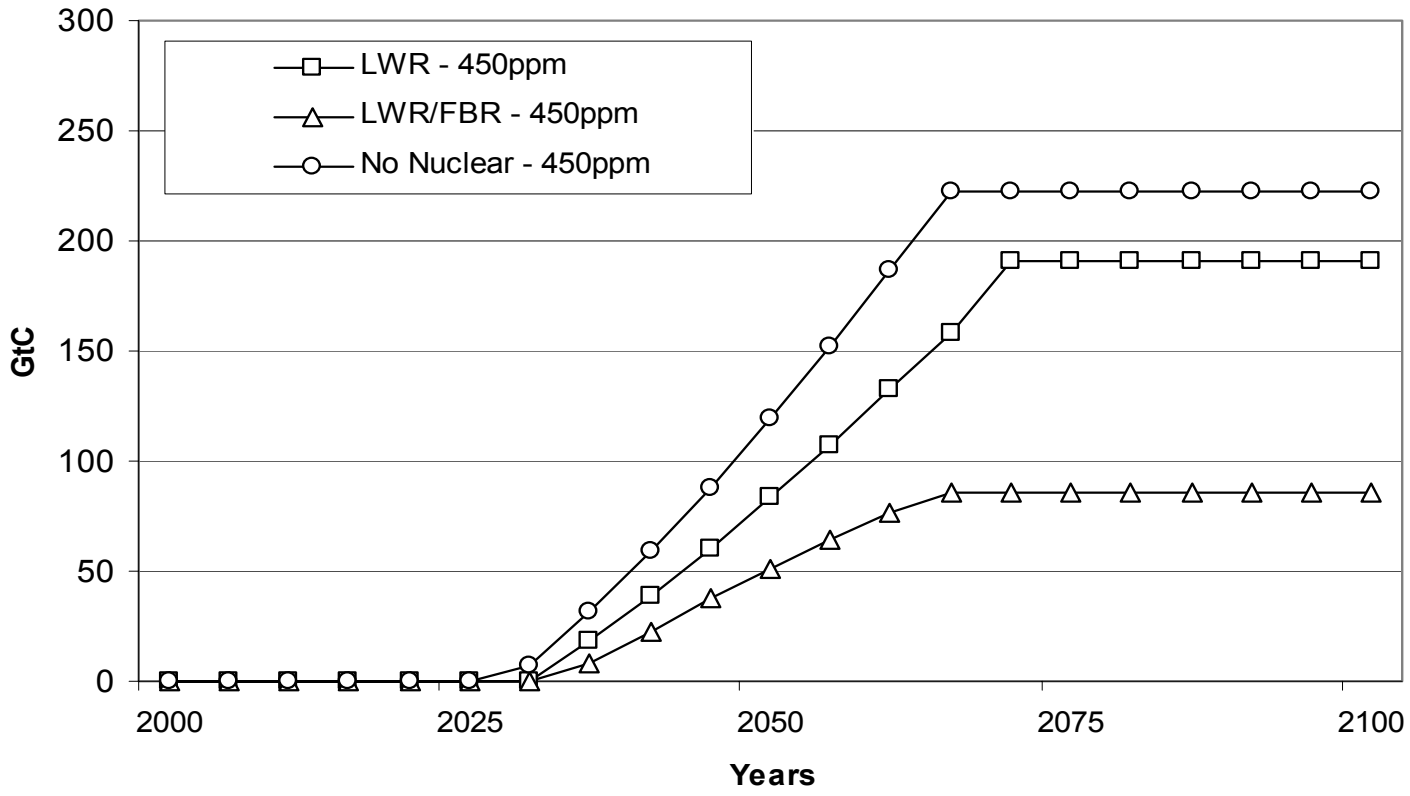
- Unit costs: 50 US$/t CO_2, assumed to decrease with time at a 1% per year rate down to 25 US$/t CO_2.

- CO_2 transport from capture location to a disposal site: 7 US$/t CO_2.

-Sequestration cost:

Geological reservoirs	Grades			
	I	II	III	IV
Oil Fields	30 (1)	40 (3)	30 (7)	30 (10)
Gas Fields	200 (4)	200 (6)	200 (8)	200 (12)
Unminable Coal seams	40 (2)	40 (8)	40 (14)	30 (20)
Deep Saline Aquifers	1000 (6)	1000 (12)	1000 (18)	1000 (24)

Geological sequestration capacity in $GtCO_2$. Numbers in parenthesis are unit sequestration costs in $/t$CO_2$.



Cumulative Carbon Sequestered

CONCLUDING REMARKS

- OIL AND GAS ARE GOOD AND ALWAYS EXHAUSTED
- COAL IS THE 800 POUND GORILLA
- LARGE SCALE ADOPTION OF NUCLEAR COULD REPLACE COAL
- HOWEVER, IS THERE ENOUGH URANIUM TO SUPPORT MAJOR EXPANSION?
- PROLIFERATION AND SAFEGUARDS
- NEW TECHNOLOGY THAT REDUCES THE RISK OF ACCIDENTS
- FBRs REQUIRE MORE HANDLING BUT LESS WASTE DISPOSAL
- THE DIFFICULTY OF COMPREHENDING LOW PROBABILITY EVENTS (NUCLEAR VS COAL)