WP3: Economic Aspects

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SAPIERR II
Implementation of European Regional Repositories, Closing Seminar, Brussels, 27 January

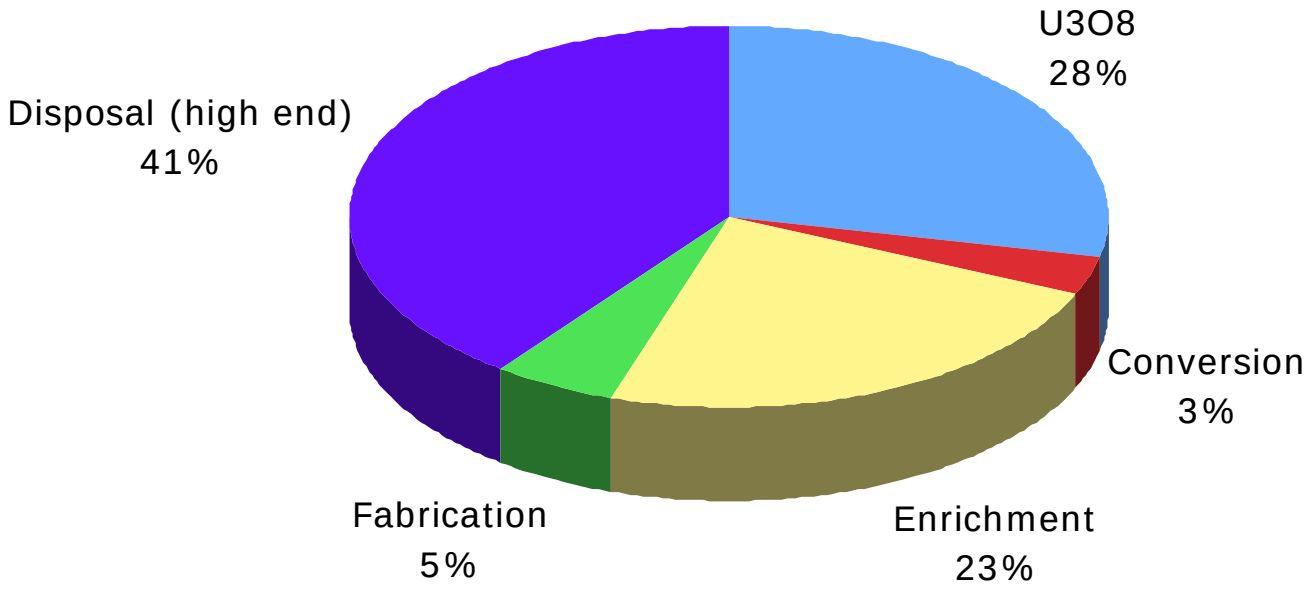
WP Objectives

- Approximate estimate of all costs of implementing and operating a complete regional disposal system
- Identify cost items most affected by national/regional decisions (e.g. number of repositories)
- Financing a regional repository project (see organisational forms and liabilities WP 1 and WP 2)
- Economic benefits for host organisations, host communities and host countries

Boundary Constraints

- Only long-lived wastes, disposed in a geological repository; spent fuel (SF), high level wastes (HLW), long lived low and intermediate level wastes (LILW-LL)
- Use reference scenarios for numbers of repositories, storage facilities and transport arrangements
- Use published European data so far as possible and relevant: main sources were
  - Finland, Sweden, Belgium, Switzerland, Slovenia, UK.
  - some data from US (mainly on transport costs)

Fuel Cycle Costs (WNA)



Assumes high-end SF disposal costs of 1000 USD/t (n.b. commercial estimates from Russia c. 1500 USD/t) and U price of 90 USD/kg

Inventory Models

- Large inventory (SAPIERR I at 2040)
  - 25,637 t SF
  - 355 m^3 vitrified HLW
  - 31,000 m^3 LILW-LL
- Small inventory (2 or 3 countries)
  - 6280 t SF
  - 6800 m^3 LILW-LL

Averages of ranges for several possible combinations giving 4700 - 7600 t SF and 6200 - 9000 m^3 LILW

e.g. B + NL; BG + RO; SL + SI + CZ

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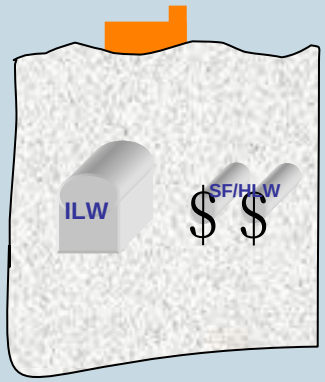
I(H)

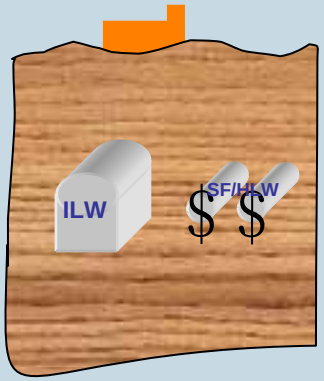


1. SKB (all waste)
2. Posiva (HLW/SF) + SKB (ILW)

II(H)

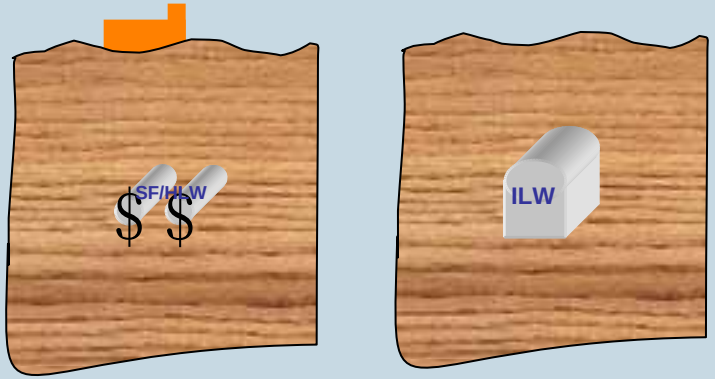
1. SKB (all waste, both repositories)
2. Posiva (HLW/SF repository) + SKB (ILW repository)

I(S)



Nagra 2001 (HLW/SF) + Nagra WLB 1999 (ILW)

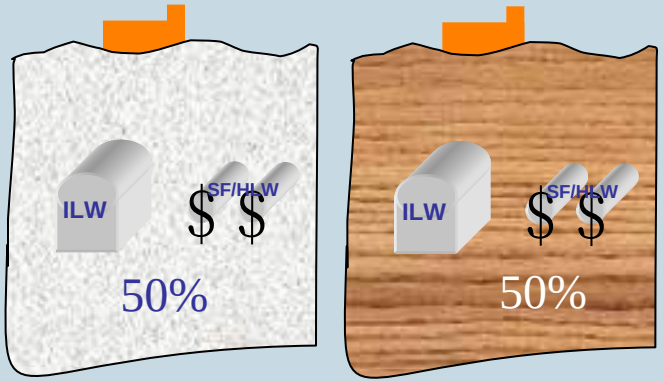
II(S)



HLW/SF repository: Nagra 2001

ILW repository: Nagra WLB 1999

IIIa



Combines I(S) with each of I(H)1 and I(H)2 to provide two costs

IIIb

Combines I(S), with no encapsulation, with I(H)1

Basis of Repository Cost Estimation

- Scaling to selected, established national cost models for the chosen scenarios on the basis of:
  - number of SF and HLW packages
  - volumes of LILW
- Scaling for each element of disposal costs
- Breakdown into fixed and variable cost items

Packaging and disposal assumptions: *read the report!*

- KBS-3V single deposition hole would hold any SAPIERR spent fuel package type (5.0, 4.3, 3.7 m): 13,246 spent fuel containers and deposition holes
- HLW in vertical deposition holes in hard rock: 5 m package contains 3 x 150 litre HLW glass casting containers: 2021 HLW containers and deposition holes
- Total HLW and SF deposition holes for hard rock scenarios: 13,920
- Horizontal disposal in sediments: no distinction between SAPIERR package sizes: scaling simply on total number of packages (13,920)
- ILW disposal scaled on waste volume, using SKB SFL3-5 data for hard rock and Nagra Wellenberg data for sediments
- Co-disposal: cavern construction, operation and closure costs of the ILW part added to those for SF-HLW repository (which include access works)
- Separate ILW repositories: construction, operation and closure costs added to siting and administrative costs of a SF-HLW repository

Fixed to variable cost assumptions

SKB data		Posiva data		Nagra data	
Cost Item	**F/R ratio**	**Cost Item**	**F/R ratio**	**Cost Item**	**F/R ratio**
Siting	100:0	Above ground* facilities	100:0	Siting	100:0
Construction	30:70	Above ground* operations	20:80	Construction	50:50
Operation	20:80	Above ground* decommissioning	100:0	Operation	40:60
Closure	0:100	Repository facilities	30:70	Closure	0:100
R&D and Admin	100:0	Repository operations	20:80	R&D and Admin	100:0
Encapsulation	10:90	Repository closure	90:10	Encapsulation	30:70

Cost component and data used to scale costs	Total Cost MEUR Dec 2006 values repository plus encapsulation plant
Swedish data: single HLW and SF repository in hard rock for 13920 containers	**8076** (5442 plus 2633)
Swedish data: single HLW and SF repository in hard rock for 6960 containers	**4910** (3547 plus 1362)
Finnish data: single HLW and SF repository in hard rock for 13920 containers. Encapsulation costs are difficult to deconvolute: an approximate estimate is that encapsulation (including all surface facilities at the repository site operating for >70 years, plus decommissioning) comprises >60% of the total.	**9597**
Finnish data: single HLW and SF repository in hard rock for 6960 containers.	**5177**
Swedish data: single repository for 31,000 m^3 ILW in hard rock	**1418** (of which, vault construction, operation and closure = 95)
Swiss data: single HLW and SF repository in sediments for 13920 containers	**7964** (5531 plus 2433)
Swiss data: single HLW and SF repository in sediments for 6960 containers	**4747** (3435 plus 1312)
Swiss data: single repository in sediments for 31,000 m^3 ILW	**627** (of which, vault construction, operation and closure = 361)

Disposal Costs

Large Inventory Model

Costs in MEUR (Dec 2006 values)		
Scenario I(H) single hard rock repository	Swedish Model	Finnish Model
	8170	**9690**
Scenario I(S) single sediment repository	Swiss Model	
	8330	
Scenario II(H) separate hard rock repositories for HLW/SF and ILW	Swedish Model	Finnish Model
	9490	**11,010**
Scenario II(S) separate sediment repositories for HLW/SF and ILW	Swiss Model	
	8590	
Scenario IIIa separate hard rock and sediment repositories, each for 50% of inventory with encapsulation plant at each	Swiss/Swedish Model	Swiss/Finnish Model
	9890	**10,150**
Scenario IIIb separate hard rock and sediment repositories, each for 50% of inventory with a single encapsulation plant (at hard rock repository)	Swiss/Swedish Model	
	9840	

Little difference between sediment and hard rock

Separate hard rock repositories add about 12-14% or 1 BEUR c.f. single repository

Seems cheaper than hard rock but issue with undifferentiated R&D costs: best estimate for both scenarios is +10%

2 repositories with 2 encapsulation plants adds c. 20%

Despite only 1 encapsulations plant, looks just like IIIa because these costs are mainly materials and operations

Separate repositories (hard rock$_{Swedish}$): MEUR

Austria	1330	Latvia	1330
Belgium	3470	Lithuania	3070
Bulgaria	3020	Netherlands	2700
Croatia	1330	Romania	3650
Czech Rep	3300	Slovakia	3060
Hungary	2840	Slovenia	2690
Italy	2700	Switzerland	3200

TOTAL 37.7 BEUR

Saving >25 BEUR

About half is on shared R&D

Even if no further R&D were needed, saving is still c. 15 BEUR

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Small Inventory Model

- Only used Scenario I(H) with single hard rock repository for all wastes
- Cost is 3980 MEUR
- Saving on two or three national repositories is about 3300 MEUR
- Implication is that each country sharing in a small partnership could save c. 500 - 1000 MEUR

Transport costs

- Not based on distance
  - main costs are capital, preparation and reception
  - we assume a single transport
- SF data available (HLW converted by mass)
  - Japan, Korea, USA, Finland, Germany, France, NEA
  - used a higher-end value of 40 kEUR/t
  - large inventory cost = c. 1065 MEUR
  - small inventory cost = c. 250 MEUR
- ILW
  - Trino NPP decommissioning data used
  - 5165 EUR/10t load
  - large inventory cost = c. 32 MEUR
  - small inventory cost = c. 7 MEUR

Transport: Comments

- Significant part (at least 10%) of back-end costs
- Moving SF to a regional repository will not cost significantly more than moving it to a national repository
- For either, considerable savings in co-locating encapsulation facility with repository

Storage Costs

- Dry storage costs less than wet storage: we assume dry storage
- Most of costs are capital; predominantly for cask purchase
- Thus,very limited economies of scale
- No compelling economic arguments for large regional storage facilities in EU
- Most countries have organised storage out to c.2040 and we assume repository start date of 2035
- Consequently, we do not include storage costs in our estimates

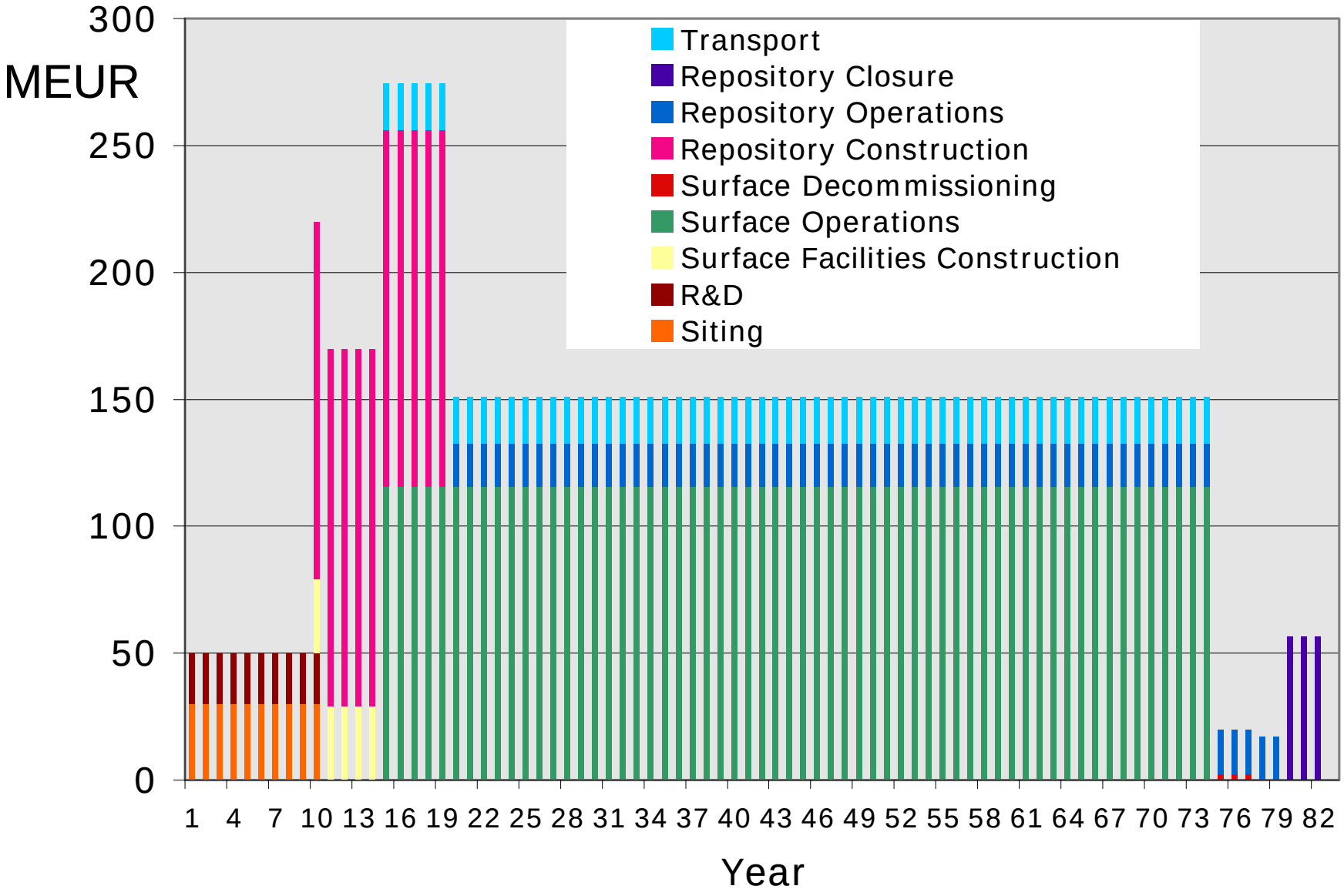
Disposal costs: overall conclusions

- Total programme disposal costs for large inventory ~ 10 BEUR
- Although savings can be made by having one rather than two repositories, they are < 25% of total programme costs
- Little overall cost advantage in having a single encapsulation plant
- Overall impact of a shared rather than numerous solo solutions ~ 15 - 25 BEUR saving to EU

Spend profile assumptions

- Scenario $I(H)_{finnish}$ plus 300 MEUR siting, 200 MEUR R&D and 1097 MEUR transport
- Total cost profiled is thus c. 11,300 MEUR
- Siting costs and all R&D costs incurred over first 10 years
- All above ground facilities constructed in Years 10-15
- Repository completely constructed in Years 10-20
- Encapsulation facility begins operation in Year 15
- Repository begins receiving waste in Year 20
- Facilities cease operation after 60 years of operation in Year 74 (encapsulation plant) and Year 79 (repository)
- Rate of encapsulation and disposal is same each operational year
- Decommissioning of encapsulation plant and closure of repository take 3 years (Years 75-77 and Years 80-82)

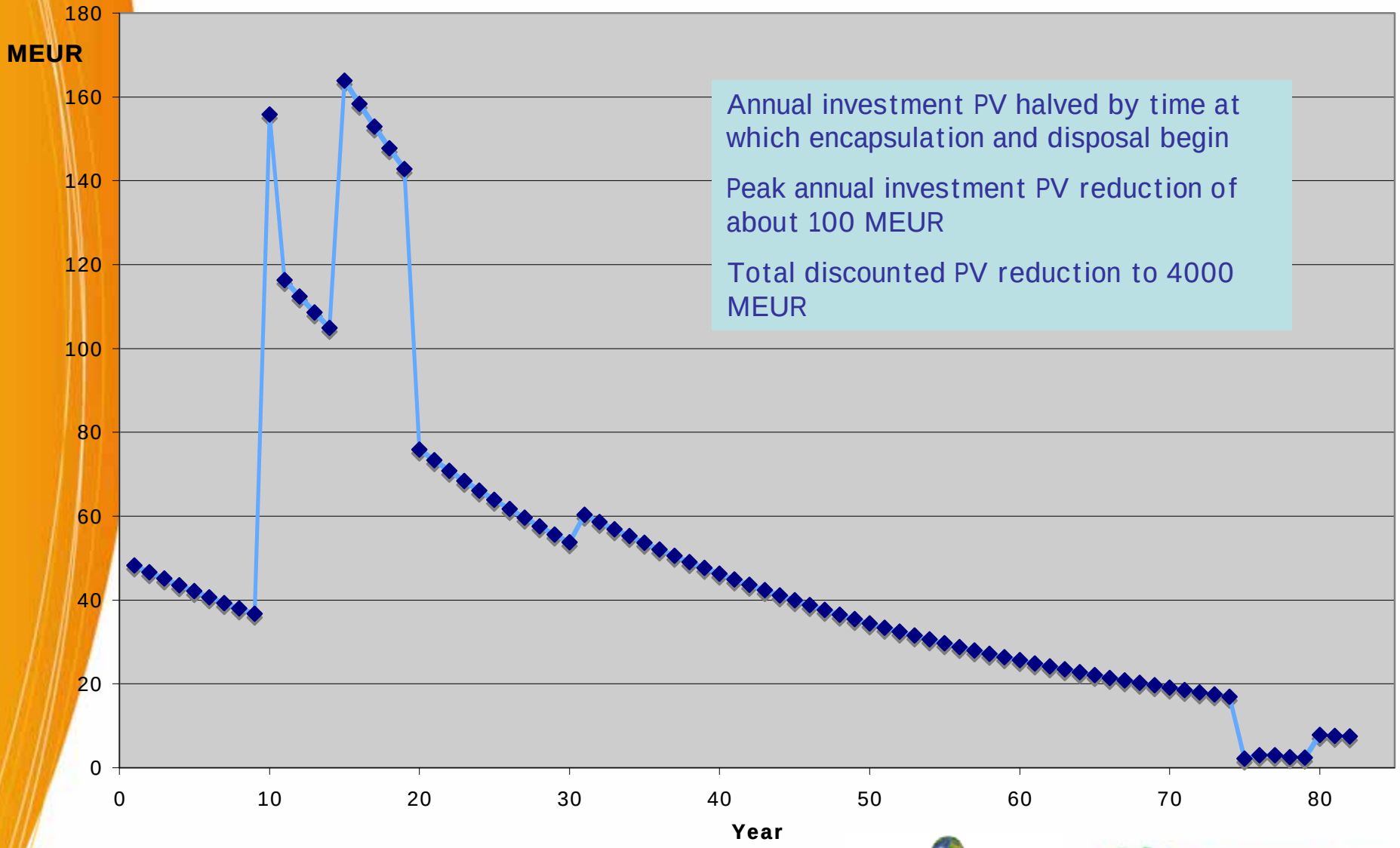
Large Inventory Spend Profile



Discounting rules

- UK Treasury Green Book suggestions for discount rates to calculate present value (PV) of future costs:
  - 3.5% for first 30 years
  - 3% to 75 years
  - 2.5% to 125 years

Discounted costs: large inventory



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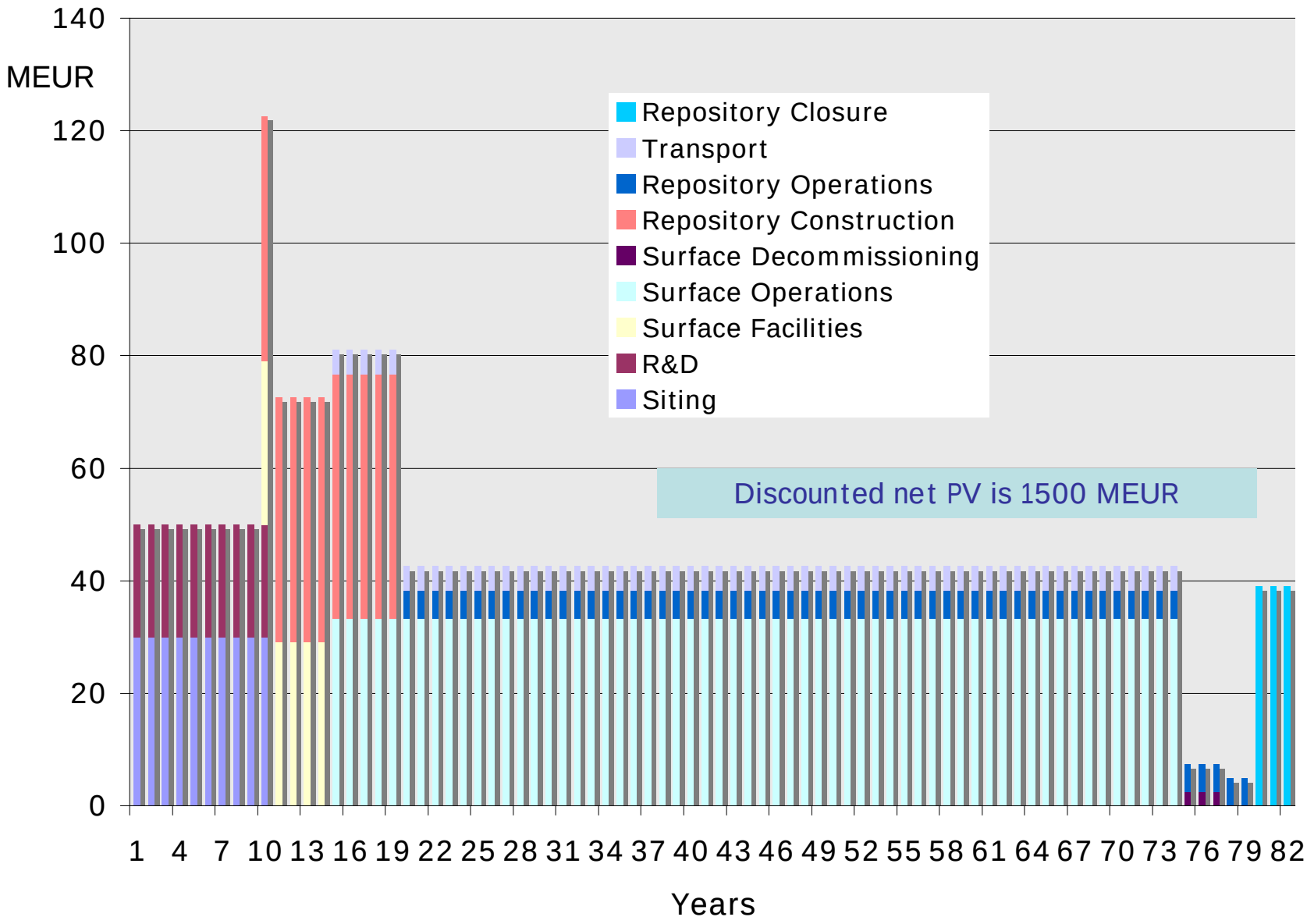
Small Inventory Spend Profile



Community Benefits: Basic Principles - 1

International experience indicates use of benefits to encourage and support participation in siting can help reduce local opposition, provided certain principles borne in mind:

- No community or country should be worse off due to accepting a site
- Should be recognition of service being provided for country or region, without any suggestion of a risk premium
- Financial and development benefits should not be used to encourage participation by poor communities or countries
- Development initiatives should come from within community/country and not be imposed externally

Community Benefits: Types of Benefit - 1

Cash

Lump sums, annual payments, expert support, tax revenue, trust funds

Social benefit

Employment, infrastructure, property value protection, integrated developments, relocation of developer, discounts

Community empowerment

Local decision making, capacity building, local partnerships, involvement support packages

Community Benefits: Types of Benefit - 2

Cash

+ve Gives a community a sense of project ownership and allows people to understand tangible benefits

-ve Can look as if poor communities/countries are being bribed to accept the unacceptable; too much money can make a community/country overdependent on the facility

Social:

+ve Helps community take responsibility for its own development and instils local confidence

-ve Can cause divisions within and between communities/countries; too much money can make a community/country overdependent on the facility

Empowerment:

+ve Gives community/country a sense of control and allows individuals to become involved

-ve Can cause local and national political disruption if not well managed

Financing models

- Surcharge on price of nuclear electricity in eventual user countries
- Amalgamation of some or part of existing national nuclear waste management funds (or government allocations) to establish the ERDO
- Providing pooled funding only for the period up to start of repository operations, then generating income based on a price per tonne of waste disposed

Surcharge Models

- MODEL 1
  - only from existing NPPs that will produce wastes from now to time of repository closure
  - only from remaining lifetimes of these plants (SAPIERR I countries in 2007, from 1 to 42 years)
  - 382 Gwe.years remaining
- MODEL 2
  - consider all of electricity that has been and will be produced
  - fairer, but can't make a historical surcharge
  - some countries already have a fund
- MODEL 3
  - include 'new build' with Model 2
  - rolling surcharge on all future nuclear electricity to cover new build and historic costs
  - a major commercial issue depending on past and future NPP financing models
  - but seems inevitable that new build wastes will be managed with existing wastes so some fund combination must eventually occur

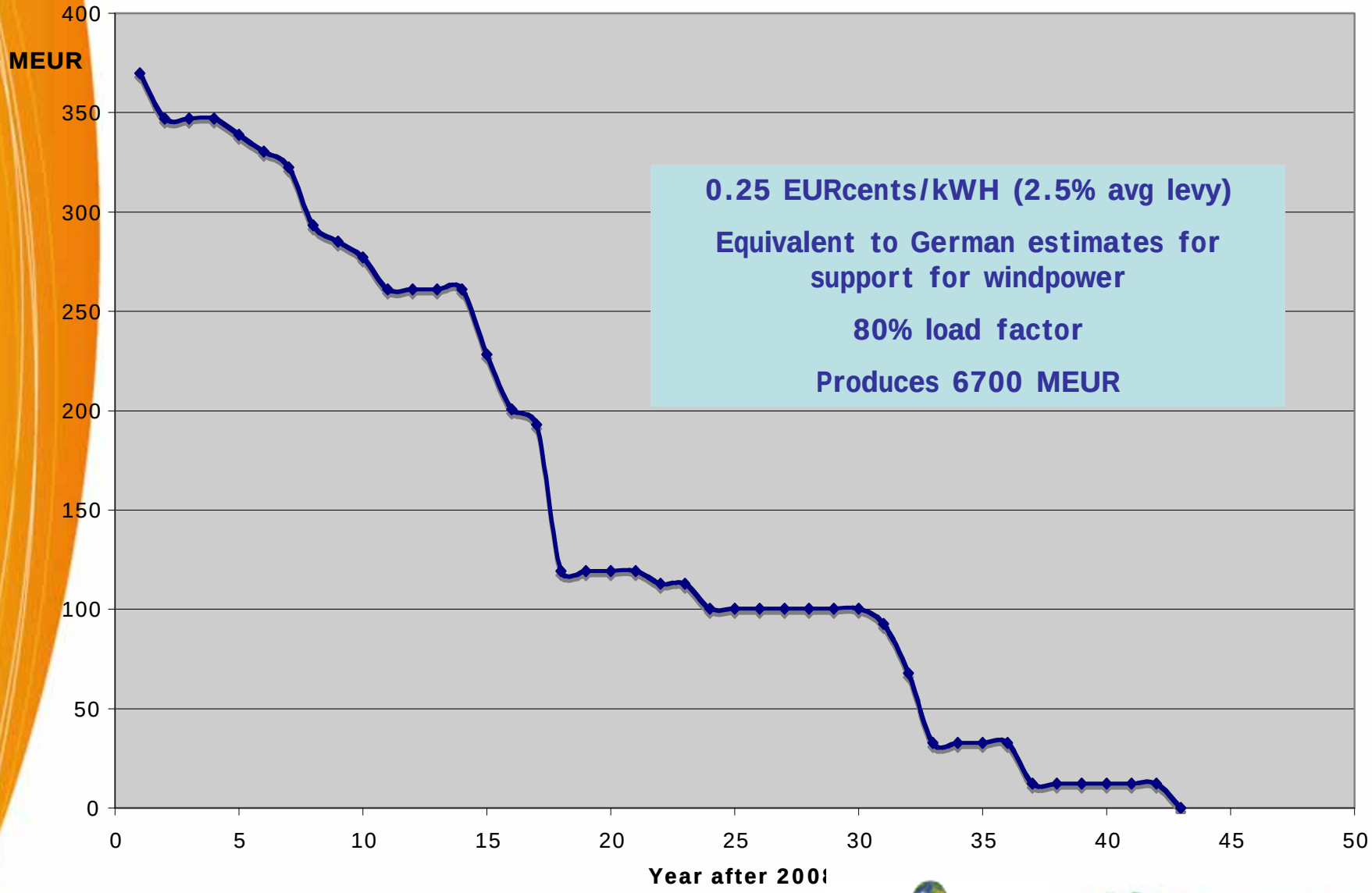
Price of EU electricity (EUR cents/kWh: Eurostat data, 2006)

Belgium	11.23
Czech Republic	8.29
Italy	15.48
Latvia	7.02
Lithuania	6.09
Hungary	8.96
Netherlands	12.07
Austria	8.94
Slovenia	8.74
Slovakia	12.16
Bulgaria	5.52
Romania	8.59

EU-25 Average Price for households; without taxes

10.78 EUR cents/kWh

Surcharge Model 1



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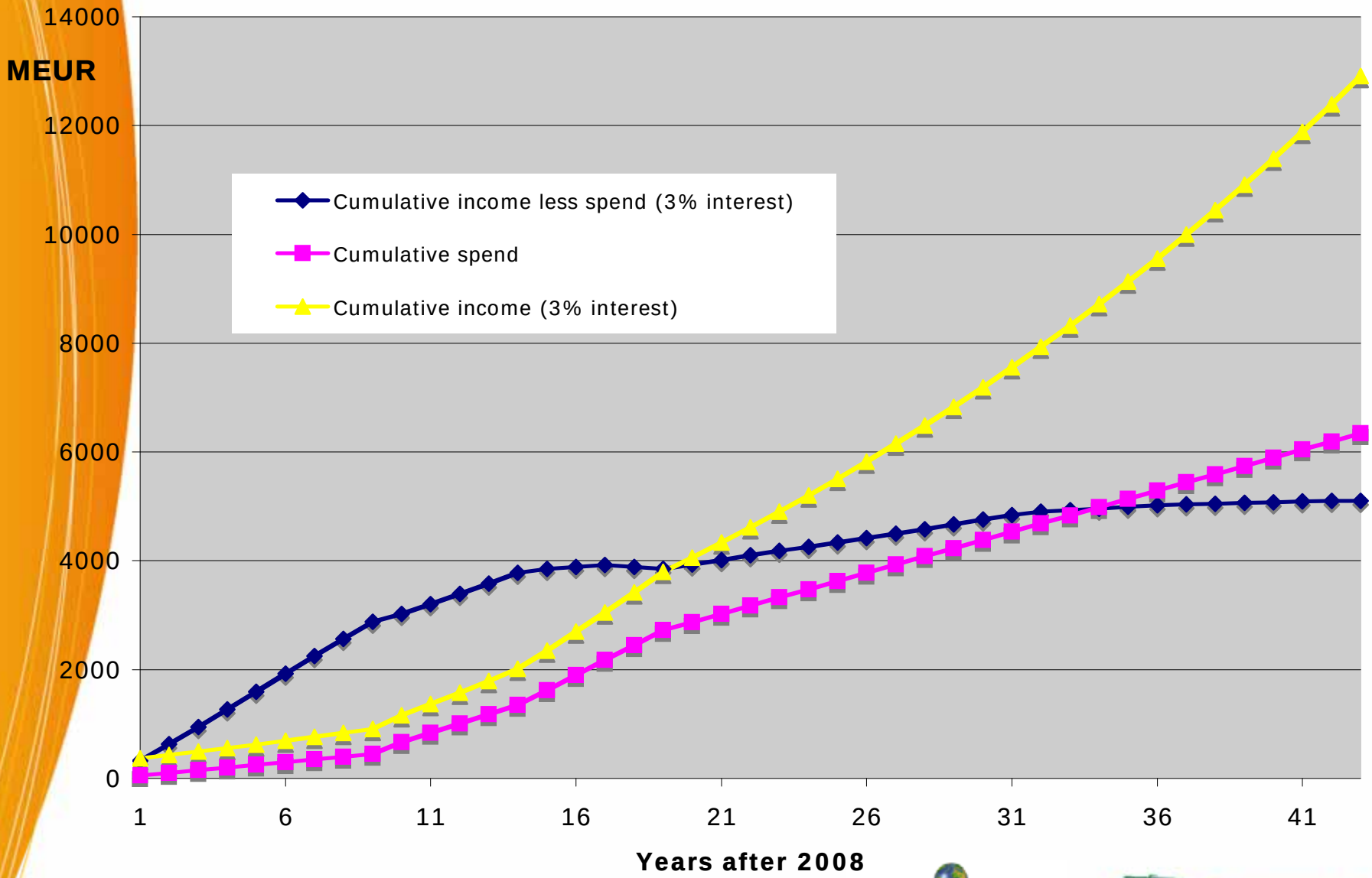
Cumulative income (with 3% interest) v. rate of spend



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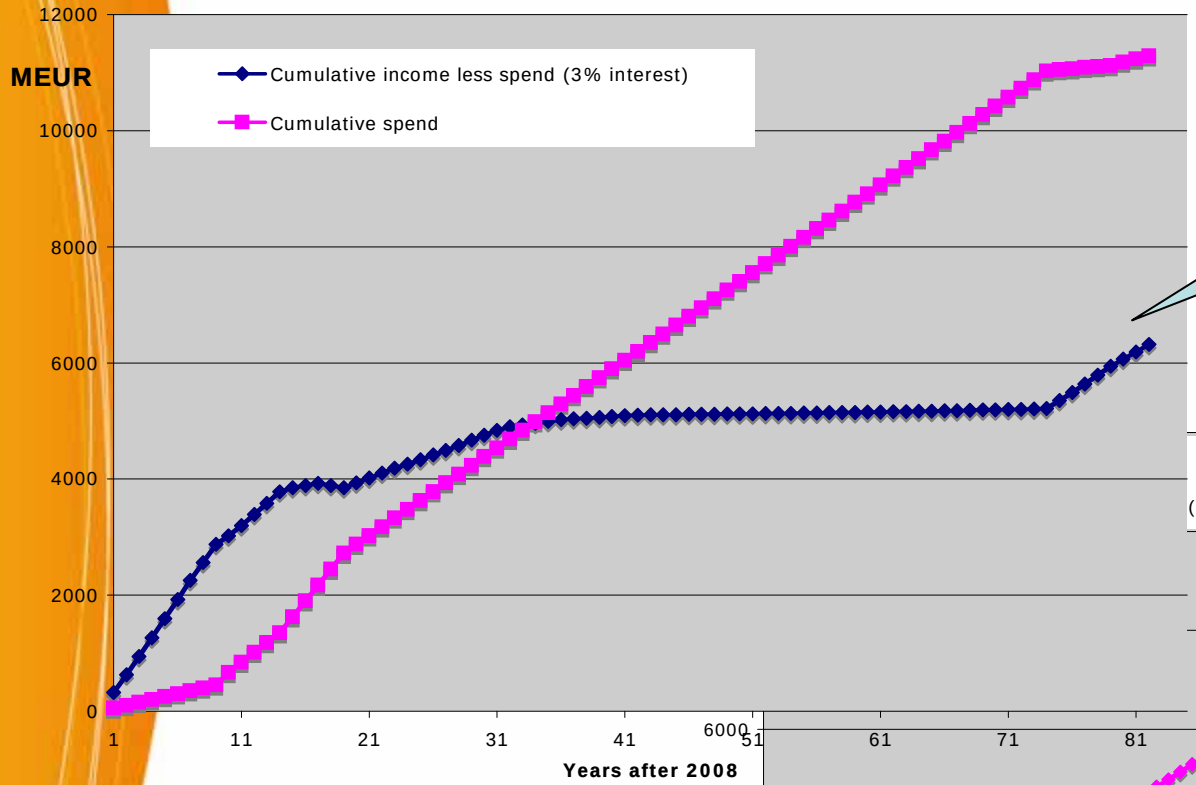
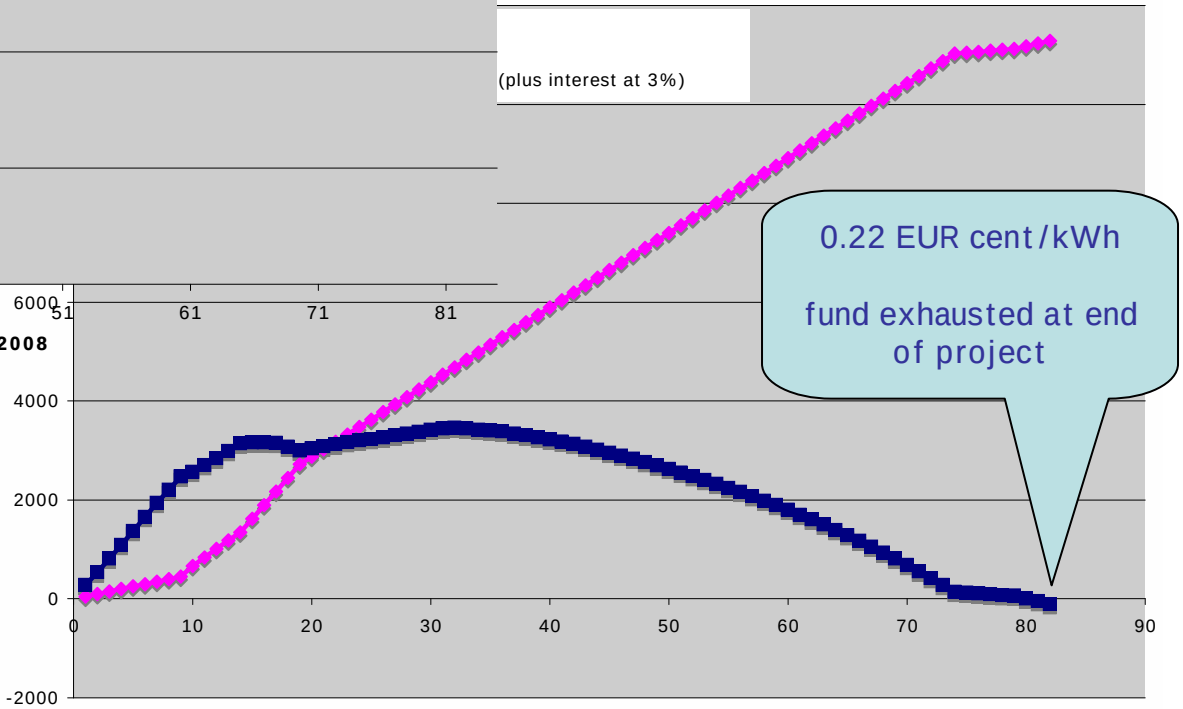
Long-range forecast: sensitivity to rate of surcharge



0.25 EUR cent/kWh

c.6000 MEUR left at end of project



0.22 EUR cent/kWh

fund exhausted at end of project

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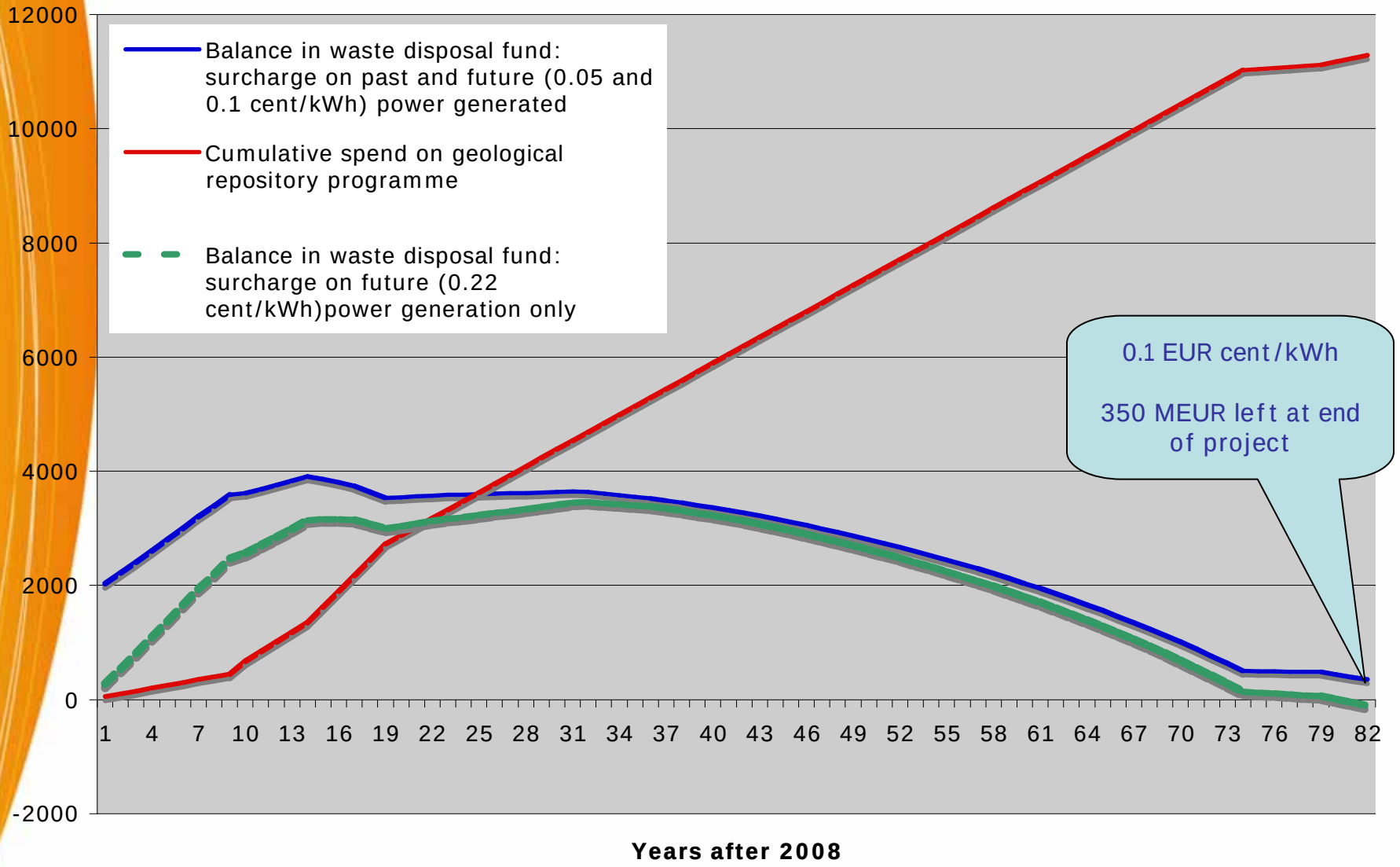
Surcharge Model 2

- ‘What if’ assumptions:
  - small proportion of cost of all electricity generated to date by NPPs in ‘large’ inventory countries had already been set aside (0.05 EURcent/kWh)
    - fund today, without interest, would be c. 1900 MEUR (enough to begin the shared programme)
    - c.f. CH has c.1350 MEUR; CZ has c. 260 MEUR in waste funds
  - a slightly greater surcharge would continue be made on all future generation (as in Model 1, but at a lower surcharge rate of 0.1 EURcent/kWh)
- With forethought: fiscally relatively painless!
- Equity between countries a big issue; tolerability of surcharge level, etc

Surcharge Model 2



Surcharge Model 3

- If future NPP generation capacity maintained at current levels
  - 0.1 EURcent/kWh surcharge would generate 185 MEUR/a - more than adequate
- If NP increases in EU
  - economies of scale will make it cheaper to dispose of all past and future wastes, up to point where more repositories are needed
  - smaller surcharge conceivable

Priced Disposal Service

- Partner countries share and cover the costs up to point of repository operation: c. 2000 MEUR for large inventory
- Non-profit transport and disposal costs for SF equivalent then charged at 0.44 MEUR/tHM
- Commercial model may also be adopted, with a price per tHM
  - NPT model for transport, dry storage and disposal in Russia
  - 1 MEUR/tHM
  - Implies potential for a large inventory profit margin of 10 - 15 BEUR

ERDO: The Formative Years

Year	Infrastructure	Main Activities	Funding (MEUR)
0	No infrastructure in this period: work managed from initial partners offices	Further discussions with potential member countries. Meetings with nominated organisations from the initial Ôcore groupÕ of countries. Administrative work leading to the establishment of the ERDO office	0.5
1	Establish small office with ~5 staff (two technical, one legal/financial. one administrative, one secretarial), possibly seconded from partner organisations. Management board set in place.	Scoping the legal and financial aspects of shared facilities. Establishing strong lines of contact with partner countries, potential users, the EU and the IAEA. Refine legal, cost and repository studies. Some of this work will be contracted out	1.5
2	Three additional staff (total 8), including one or two public communications	Establish approach to site identification and commence negotiations with potential host countries	3
3		Identify one or more potential host countries, establish national siting task forces and establish contacts with potential local communities Finalise legal and commercial basis for host countries to offer access	4
4	Two additional staff (total 10)		8
5	Five additional staff: mainly technical (total 15)	Begin initial site evaluation studies, design options work and safety studies	25
6	Establish local technical office(s) at site(s) being investigated (assume 2-3): recruit local staff to manage site investigations (total 20)	PHASE 1 Site Investigations	50
7		Parallel design, engineering and safety studies Continued evaluation and negotiation on legal and financial basis of ERO Detailed liaison with local regulatory authorities on site-specific matters Finalise legal basis for all aspects of host country provision of a site and other facilities: arrangements should be binding by this stage	50
8	Additional staff from host country or countries (total now ~25 staff).		50
9		PHASE 2 Site Investigations (completion of surface based work leading to selection of preferred site) Completion of preliminary design and safety studies and submission of first licence application to host regulators Completion of legal work and agreements to establish the ERO	50
10	Prepare for movement of all facilities to the host country and site. Recruitment of local staff to establish the ERO.		50

5 countries: 0.5 to 1 MEUR each per year