

# The Real Cost of Electricity Generation out of Nuclear Power Plants



# Why we should care about all costs?

- **affordable, efficient and stable provision of electricity**
- **economic efficient energy mix**
- **market failure is quite common**
- **asymmetric information**
- **public good**
- **externalities**

## **Externalities**

- **external effects affect third person**
- **classical air pollutants, greenhouse gases?**
- **electricity out of nuclear power plants is cheap?**
- **what are the externalities of Nuclear Power Plants?**

## costs @ the generation of Electricity out of Nuclear Power Plants

- **internal costs**
  - **capital costs**  
4000-5000 €/kW  
long construction period --> uncertainties
  - **operation costs**  
security and safety  
fuel costs volatile
- **external costs**
  - **waste disposal**
  - **decommissioning**
  - **accidents**
  - **insurance**



# how we can measure the external effects?

- indirect valuation method
  - travel cost method
  - hedonic pricing
- direct valuation method
  - contingent valuation
- integrated assessment model

**How an  
internalization of  
the external effects  
affect the price?**

# Integrated Assessment Model

calculate the costs of

- climate change
- effects on health

try to link

- society and economy
- biosphere and atmosphere

calculates the costs of

- climate change
- biogeochemistry, hydrology, demography, health and land use

useful way of approaching highly complex issues



# ExternE

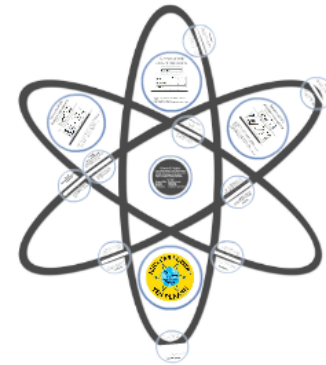
exists since 1991

50 research teams

more than 20 countries

measures all impacts of the external effects on

- economy
- ecology
- sociology
- environment



uses only quantitative figures  
monetary units

assessment of impacts based on preferences

well informed person

Impact pathway approach

external costs can be calculated

# ExternE Project

Those methods calculate monetary value of damages which are caused by releases into the rivers, seas, air and soil. Rest of the damages are calculated in response to accidents caused by transportation.

For example:

Mining and Milling  
Conversion  
Enrichment  
Fuel Fabrication

Electricity Generation  
Reprocessing  
Transportation  
LaH radioactive waste disposal

# Mining and Milling

Total costs connected with mining and milling are 0,0184 mEUR/kWh (0,0005 CZK/kWh) in 3% discount rate scenario, which is almost 20% of calculated costs.

**Monetary valuation of mining and milling in mECU/kWh. In 0%, 3% and 10% discount rate**

mECU/kWh	Short term			Medium term			Long Term			Sub-total	Sub-total In Euro	Sub-total In CZK
	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global			
<b>0%</b>	0,0148	0,0000	0,0000	0,0323	0,0169	0,0000	0,0003	0,0002	0,0000	0,0645	0,0001	0,0016
<b>3%</b>	0,0099	0,0000	0,0000	0,0056	0,0029	0,0000	0,0000	0,0000	0,0000	0,0184	0,0000	0,0005
<b>10%</b>	0,0052	0,0000	0,0000	0,0007	0,0004	0,0000	0,0000	0,0000	0,0000	0,0063	0,0000	0,0002

Source: EXTERNE. Externalities of Energy: Vol. 5: Nuclear. Luxembourg: ECSC-EC-EAEC, 1995. ISBN 92-827-5214-3., customization

What is really important in this section of generating electricity is occupational impact (almost about 50%). Remaining 50% are attributed due to air and atmospheric releases. In fact, air and atmospheric releases are in very small doses, which can experience only individuals in area with 1 000 km radius. Impact of uranium and his isotopes are almost zero.

# Conversion

Total costs of conversion are 0,0005 mEUR/kWh (1,18E-05 CZK/kWh) in 3% discount rate scenario which is almost 0,5% of total calculated costs.

Monetary valuation of conversion in mECU/kWh. In 0%, 3% and 10% discount rate

mECU/kWh	Short term			Medium term			Long Term			Sub-total	Sub-total In Euro	Sub-total In CZK
	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global			
0%	0,0006	0,0000	0,0000	0,0003	0,0000	0,0000	0,0000	0,0000	0,0000	0,0010	0,0000	0,0000
3%	0,0004	0,0000	0,0000	0,0001	0,0000	0,0000	0,0000	0,0000	0,0000	0,0005	0,0000	0,0000
10%	0,0002	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0002	0,0000	0,0000

Source: EXTERNE. Externalities of Energy: Vol. 5: Nuclear. Luxembourg: ECSC-EC-EAEC, 1995. ISBN 92-827-5214-3., customization

Conversion redound less than 1% of the total cost, which were calculated for fuel cycle. These damages are non-radiological nature, caused in the facilities (occupational impacts).

# Enrichment

Total cost from enrichment is 0,0008 mEUR/kWh (1,95E-05 CZK/kWh) in 3% discount rate scenario which is almost 1% of total costs.

Monetary valuation of enrichment in mECU/kWh. In 0%, 3% and 10% discount rate

mECU/kWh	Short term			Medium term			Long Term			Sub-total	Sub-total in Euro	Sub-total in CZK
	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global			
0%	0,0012	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0012	0,0000	0,0000
3%	0,0008	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0008	0,0000	0,0000
10%	0,0004	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0004	0,0000	0,0000

Source: EXTERNE. Externalities of Energy: Vol. 5: Nuclear. Luxembourg: ECSC-EC-EAEC, 1995. ISBN 92-827-5214-3., customization

More than 99% of the total costs are caused by occupational impacts. These damages are caused mostly by non-radiological accidents that appears in the facilities. Environmental costs are much more lower than occupational costs. Inhalation, liquid release and agricultural ingestion are much lower than external exposure. Liquid releases impacts are approximately 300 times lower than from atmospheric releases.



# Fuel fabrication

Total costs form fuel fabrication are approximately 0,0007 mEUR/kWh (1,81E-05 CZK/kWh) with 3% discount rate scenarion which is almost 1% of the total costs.

**Monetary valuation of fuel fabrication in mECU/kWh. In 0%, 3% and 10% discount rate**

mECU/kWh	Short term			Medium term			Long Term			Sub-total	Sub-total In Euro	Sub-total In CZK
	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global			
<b>0%</b>	0,0008	0,0000	0,0000	0,0011	0,0000	0,0000	0,0000	0,0000	0,0000	0,0019	0,0000	0,0000
<b>3%</b>	0,0005	0,0000	0,0000	0,0002	0,0000	0,0000	0,0000	0,0000	0,0000	0,0007	0,0000	0,0000
<b>10%</b>	0,0003	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0003	0,0000	0,0000

Source: EXTERNE. Externalities of Energy: Vol. 5: Nuclear. Luxembourg: ECSC-EC-EAEC, 1995. ISBN 92-827-5214-3., customization

This stage of the fuel cycle, do not take an important part of the total fuel cycle. The occupational impacts constitute 99% of the cost of fuel fabrication stage. These damages are mostly caused by radiological impacts. Cost from liquid damages is two times bigger than from inhalation and external exposures.



# Electricity generation

Total cost from electricity generation takes almost 0,0599 mEUR/kWh (0,0014 CZK/kWh) with 3% discount rate scenario which is about 63% of all calculated total costs.

Monetary valuation of electricity generation in mECU/kWh. In 0%, 3% and 10% discount rate

mECU/kWh	Short term			Medium term			Long Term			Sub-total	Sub-total in eurocents	Sub-total in CZK
	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global			
<b>Electricity Generation PWR 900</b>												
0% Con.	0,0337	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0337	0,0000	0,0008
0% Op.	0,0131	0,0000	0,0000	0,0528	0,0032	0,0277	0,0000	0,0000	0,3190	0,4160	0,0004	0,0103
0% Dec.	0,0000	0,0000	0,0000	0,0170	0,0000	0,0000	0,0000	0,0000	0,0000	0,0170	0,0000	0,0004
3% Con.	0,0337	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0337	0,0000	0,0008
3% Op.	0,0088	0,0000	0,0000	0,0092	0,0004	0,0018	0,0000	0,0000	0,0001	0,0203	0,0000	0,0005
3% Dec.	0,0000	0,0000	0,0000	0,0060	0,0000	0,0000	0,0000	0,0000	0,0000	0,0060	0,0000	0,0001
10% Con.	0,0337	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0337	0,0000	0,0000
10% Op.	0,0046	0,0000	0,0000	0,0012	0,0000	0,0001	0,0000	0,0000	0,0000	0,0059	0,0000	0,0000
10% Dec.	0,0000	0,0000	0,0000	0,0008	0,0000	0,0000	0,0000	0,0000	0,0000	0,0008	0,0000	0,0000

Source: EXTERNE. Externalities of Energy: Vol. 5: Nuclear. Luxembourg: ECSC-EC-EAEC, 1995. ISBN 92-827-5214-3., customization

In this case dominate (in 83% share) global public impacts. It's necessary to know, that this collective dose is combined by doses by 10 billion peoples in 100 000 years. If the global impact are not included, occupational cost adds 94% of the total costs.

# Reprocessing

In this case, total cost are 0,0145 mEUR/kWh (0,0004 CZK/kWh) with 3% discount rate scenario, which is about 15% of calculated costs.

**Monetary valuation of reprocessing in mECU/kWh. In 0%, 3% and 10% discount rate**

mECU/kWh	Short term			Medium term			Long Term			Sub-total	Sub-total In Euro	Sub-total In CZK
	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global			
<b>0%</b>	0,0030	0,0000	0,0000	0,0003	0,0096	0,1600	0,0000	0,0017	1,7400	1,9200	0,0019	0,0475
<b>3%</b>	0,0020	0,0000	0,0000	0,0001	0,0013	0,0106	0,0000	0,0000	0,0006	0,0145	0,0000	0,0004
<b>10%</b>	0,0010	0,0000	0,0000	0,0000	0,0001	0,0007	0,0000	0,0000	0,0001	0,0019	0,0000	0,0000

Source: EXTERNE. Externalities of Energy: Vol. 5: Nuclear. Luxembourg: ECSC-EC-EAEC, 1995. ISBN 92-827-5214-3., customization

To understand a large number, which is noticed in this section, it's good to know, that in the present, value of the water grows up. Due to the huge pollutions which came into the water, quality of fishes felt down. This indirectly harms health of individuals a lot. That is the reason, why monetary value of reprocessing costs is too high.

# Low and intermediate level radioactive waste disposal

Monetary valuation of LLW dispsal in mECU/kWh. In 0%, 3% and 10% discount rate

mECU/kWh	Short term			Medium term			Long Term			Sub-total	Sub-total in Euro	Sub-total in CZK
	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global			
0%	-	0,0000	0,0000	0,0000	0,0000	0,0001	0,0000	0,0000	0,0047	0,0048	0,0000	0,0001
3%	-	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
10%	-	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000

Source: EXTERNE. Externalities of Energy: Vol. 5: Nuclear. Luxembourg: ECSC-EC-EAEC, 1995. ISBN 92-827-5214-3., customization

Low level radioactive waste disposal cost approximately 0,00001 mEUR/kWh (2,12E-07 CZK/kWh) with 3% discount rate scenario.

High costs with

mECU/kWh	Local	Sh
0%	-	0
3%	-	0
10%	-	0

Source: EXTERNE. Extern

# High level radioactive waste disposal

High level radioactive waste disposal, on the other hand costs only, 6,41E-09 mEUR/kWh (1,58E-10 CZK/kWh) with 3% discount rate which is almost 0%.

Monetary valuation of HLW disposal in mECU/kWh. In 0%, 3% and 10% discount rate

mECU/kWh	Short term			Medium term			Long Term			Sub-total	Sub-total in Euro	Sub-total in CZK
	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global			
0%	-	0,0000	0,0000	0,0000	0,0000	0,0000	0,0254	0,0000	0,0000	0,0254	0,0000	0,0006
3%	-	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000
10%	-	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000

Source: EXTERNE. Externalities of Energy: Vol. 5: Nuclear. Luxembourg: ECSC-EC-EAEC, 1995. ISBN 92-827-5214-3., customization

This dose has monetary valuation about 1% of the total external cost, which ExternE project Calculated. This is very insignificant message. If 3% or 10% discount rate is used, level of waste disposal has no influence on the total external costs.

	Sub-total in Euro	Sub-total in CZK
	0,0000	0,0001
	0,0000	0,0000
	0,0000	0,0000

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cost  
t rate



# Transportation

Total costs of transpiration are 0,0003 mEUR/kWh (7,68E-06 CZK/kWh) with 3% discount rate scenario which is about 0,5% of total external costs.

**Monetary valuation of transportation in mECU/kWh. In 0%, 3% and 10% discount rate**

mECU/kWh	Short term			Medium term			Long Term			Sub-total	Sub-total In Euro	Sub-total in CZK
	Local	Regional	Global	Local	Regional	Global	Local	Regional	Global			
<b>0%</b>	0,0004	0,0000	0,0000	0,0004	0,0000	0,0000	0,0000	0,0000	0,0000	0,0008	0,0000	0,0000
<b>3%</b>	0,0002	0,0000	0,0000	0,0001	0,0000	0,0000	0,0000	0,0000	0,0000	0,0003	0,0000	0,0000
<b>10%</b>	0,0001	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0000	0,0001	0,0000	0,0000

Source: EXTERNE. Externalities of Energy: Vol. 5: Nuclear. Luxembourg: ECSC-EC-EAEC, 1995. ISBN 92-827-5214-3., customization

The main share in high of 54% is represent by public exposure, which is emitted mostly along the routes. Rest of this percent are formed by physical impacts connected with the accidents (mostly deaths and injuries). All in all this section is one of the smallest of the total external cost of all fuel cycle.

# Summary of 0% discount rate scenario

## Calculation of Total External Costs with no discount rate

Electricity production (in Gwh)	27 998
Additional external cost per kWh	0,06119648
Total External Costs (in EUR)	69 435 040
Total External Costs (in CZK)	1 713 379 047

Source: ČEZ, a. s. Výroční zpráva 2010: Skupina ČEZ. Praha: ČEZ, a. s., 2011, 306 s.; customization

## Calculation of price of 1kWh of electricity paid by consumer

Tarif D02d	before the increase	after the increase
Price per kWh in EUR	0,196	0,198
Price per kWh in CZK	4,830	4,891
Yearly consumption in kWh	2 200,000	2 200,000
Yearly consumption in EUR	430,621	436,077
Yearly consumption in CZK	10 626,000	10 760,632
Yearly payment for circuit breaker in EUR	72,945	72,945
Yearly payment for circuit breaker in CZK	1 800,000	1 800,000
Total payment in EUR	503,566	509,022
Total payment in CZK	12 426,000	12 560,632

Source: CENY ENERGIE. Ceny elektřiny 2012 [online]. 2012 [cit. 2012-04-24]. Available at: <http://www.cenyenergie.cz/nejnovjsi-clanky/ceny-elekriny-2012-cez-a-pre-zdrazi-e-on-zlevni.aspx>; customization

This scenario has not so much interpretive value because of 0% discount rate. Real cost which should be included into the cost of the ČEZ, are 69 435 040 EUR. In this case, consumer has to pay additional 6 EUR per year. The biggest influence has Reprocessing and Electricity generation.

# Summary of 3% discount rate scenario

## Calculation of Total External Costs with 3% discount rate

Electricity production (In Gwh)	27 998
Additional external cost per kWh	0,0023468691
Total External Costs (In EUR)	2 662 816
Total External Costs (In CZK)	65 707 640

Source: ČEZ, a. s. Výroční zpráva 2010: Skupina ČEZ. Praha: ČEZ, a. s., 2011, 306 s.; customization

## Calculation of price of 1kWh of electricity paid by consumer

Tarif D02d	before the increase	after the increase
Price per kWh in EUR	0,196	0,196
Price per kWh in CZK	4,830	4,832
Yearly consumption in kWh	2 200,000	2 200,000
Yearly consumption in EUR	430,621	430,830
Yearly consumption in CZK	10 626,000	10 631,163
Yearly payment for circuit breaker in EUR	72,945	72,945
Yearly payment for circuit breaker in CZK	1 800,000	1 800,000
Total payment in EUR	503,566	503,775
Total payment in CZK	12 426,000	12 431,163

Source: CENY ENERGIE. Ceny elektřiny 2012 [online]. 2012 [cit. 2012-04-24]. Available at: <http://www.cenyenergie.cz/nejnovejsi-clanky/ceny-elektriny-2012-cez-a-pre-zdrazi-e-on-zlevni.aspx>; customization

This scenario has probably the biggest interpretive value. Real costs which should be included into the cost of the ČEZ, are 2 662 816 EUR. Influence on the consumer is less than 0,2 EUR per year. The biggest influence on the total cost has Mining and Milling, Electricity generation and Reprocessing.

# Summary of 10% discount rate scenario

## Calculation of Total External Costs with 10% discount rate

Electricity production (in Gwh)	27 998
Additional external cost per kWh	0,0012132236
Total External Costs (in EUR)	1 376 553
Total External Costs (in CZK)	33 967 833

Source: ČEZ, a. s. Výroční zpráva 2010: Skupina ČEZ. Praha: ČEZ, a. s., 2011, 306 s.; customization

## Calculation of price of kWh of electricity paid by consumer

Tarif D02d	before the increase	after the increase
Price per kWh in EUR	0,196	0,196
Price per kWh in CZK	4,830	4,831
Yearly consumption in kWh	2 200,000	2 200,000
Yearly consumption in EUR	430,621	430,729
Yearly consumption in CZK	10 626,000	10 628,669
Yearly payment for circuit breaker in EUR	72,945	72,945
Yearly payment for circuit breaker in CZK	1 800,000	1 800,000
Total payment in EUR	503,566	503,674
Total payment in CZK	12 426,000	12 428,669

Source: CENY ENERGIE. Ceny elektřiny 2012 [online]. 2012 [cit. 2012-04-24]. Available at: <http://www.cenyenergie.cz/nejnovejsi-clanky/ceny-elekriny-2012-cez-a-pre-zdrazi-e-on-zlevni.aspx>; customization

This is the scenario, ČEZ have almost zero influence on the price of electricity.

Consumer has to pay 0,1 EUR per year.

The biggest influence has Mining and Milling and Electricity generation.

of the total  
y deaths and  
are formed by  
posure, which

14-3, customization





# Critics on the IEA