

# Quantification of health and environmental impacts of a nuclear accident

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Approaches to estimation of the costs of nuclear accidents  
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- Assessment of the external costs of the accident within the ExternE project in the 90's
- Based on available models (COSYMA) and assumptions on source term and dose-effect relationship
- Taking into account the social costs of an accident and application of a set of countermeasures

## Assumption adopted for the severe accident

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- Reference reactor: PWR French Reactor – 1300 MW
- Source term: derived from OECD/NEA-CEC inter-comparison study
- Core melt probability: French Probabilistic safety analysis
- Conditional probability for environmental releases: US NUREG-1150 report
- Collective dose: calculations on local area (100 km radius) and regional (3000 km radius) over 200 years

# Sensitivity analysis on source term and associated probabilities

Release category	Release fraction of the core inventory						Conditional probability
	Noble gases	I	Cs	Te	Alk. Earth metals and noble metals	Metal oxide	
ST2	1	0.1*	0.1	0.1	0.01	0.01	20 %
<b>ST21</b>	<b>0.1</b>	<b>0.01</b>	<b>0.01</b>	<b>0.01</b>	<b>0.001</b>	<b>0.001</b>	
ST22	0.01	0.001	0.001	0.001	0.0001	0.0001	
ST23	0.001	0.0001	0.0001	0.0001	$1.10^{-5}$	$1.10^{-5}$	80 %

# Estimation of health impacts

Source term	Collective dose (person.Sv)	Nb of fatal cancers	Nb of non fatal cancers	Nb of severe hereditary effects	Nb of early diseases	Nb of early deaths
ST2 local regional	59 200 232 000	2 962,0 11 575,0	7 108,8 27 780,0	592,4 2 315,0	138,0 -	9,0 -
<b>ST21</b> <b>local</b> <b>regional</b>	<b>8 200</b> <b>50 100</b>	<b>410,0</b> <b>2 505,0</b>	<b>984,0</b> <b>6 012,0</b>	<b>82,0</b> <b>501,0</b>	<b>2,4</b> <b>-</b>	<b>0,0</b> <b>-</b>
ST22 local regional	1 280 10 900	63,9 544,0	153,2 1 305,6	12,8 108,8	0,0 -	0,0 -
ST23 local regional	213 1 630	10,6 81,5	25,5 195,6	2,1 16,3	0,0 -	0,0 -

# Types of costs considered

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- **Cost of countermeasures**
  - Evacuation and relocation of population
  - Restriction and agricultural countermeasures
  - Decontamination
  
- **Cost of radiation-induced health effects**
  
- **Indirect economic costs**

# Monetary evaluation (ExternE)

Source term	Total cost of health effects (M€)	Total cost of agricultural restrictions (M€)	Total cost of evacuation and relocation (M€)	Sub-total (M€)
<b>ST2</b> local regional	11 044,1 43 059,0	824,4 26 809,6	1 515,2 -	<b>83 252</b>
<b>ST21</b> <i>local</i> <i>regional</i>	<b>1 525,2</b> <b>9 318,6</b>	<b>330,7</b> <b>5 820,0</b>	<b>98,1</b> -	<b>17 093</b>
<b>ST22</b> local regional	237,5 2 023,7	86,0 978,0	13,5 -	<b>3 339</b>
<b>ST23</b> local regional	39,6 303,2	13,7 63,6	10,9 -	<b>431</b>

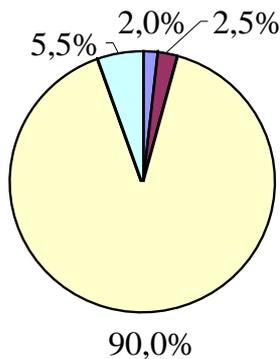
# External cost of accidents (ExternE)

Source term	Probability of core melt (reactor .y <sup>-1</sup> )	Conditional probability	Total cost (M€)	External cost - (m€ per kWh*)
<b>ST2</b>	1 E-05	0.19	83 252	0.023
<b>ST21</b>	<b>1 E-05</b>	<b>0.19</b>	<b>17 093</b>	<b>0.0046</b>
<b>ST22</b>	1 E-05	0.19	3 339	0.0009
<b>ST23</b>	<b>1 E-05</b>	<b>0.81</b>	<b>431</b>	<b>0.0005</b>

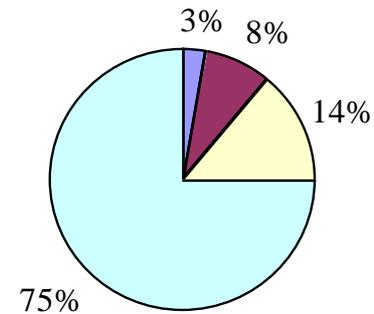
\* 7 TWh/reactor.y<sup>-1</sup>

# External costs of the nuclear fuel cycle

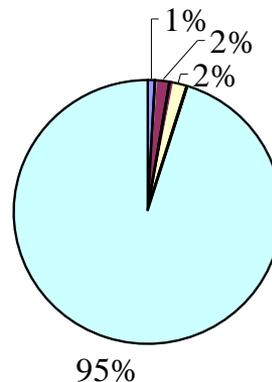
Sub-total = 2,52 mEURO/kWh  
No discount rate



Sub-total = 0,098 mEURO/kWh  
Discount rate = 3%



Sub-total = 0,054 mEURO/kWh  
Discount rate = 10%



■ Public local    
 ■ Public regional    
 ■ Public global    
 ■ Occupational

■ External cost of accident without aversion: 0.005 m€/kWh

## Indirect costs of nuclear accidents (1)

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- **Negative effects on the regional economic activity**
  - impacts on employment
  - Impacts on the regional added value
  - modification of exchange with other regions
  
- ↙ Evaluation from the individual loss of income  
(Input-output exchange matrix)

## Indirect costs of nuclear accidents (2)

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- Indirect costs represent about 10 % of the local gross domestic product during the first two years
- Similarly, it represents about 0.2 % of the national gross domestic product
- Indirect costs lead to an increase of 25 % of the direct external costs of a nuclear accident

**The main criticism on the monetary evaluation of the consequences associated with a nuclear accident on the basis of probabilistic approach:**

- There is a discrepancy between the global and social acceptability of the risk and the average monetary value which corresponds in principle to the compensation of the consequences for each individual of the population affected by the accident

## Risk aversion (2)

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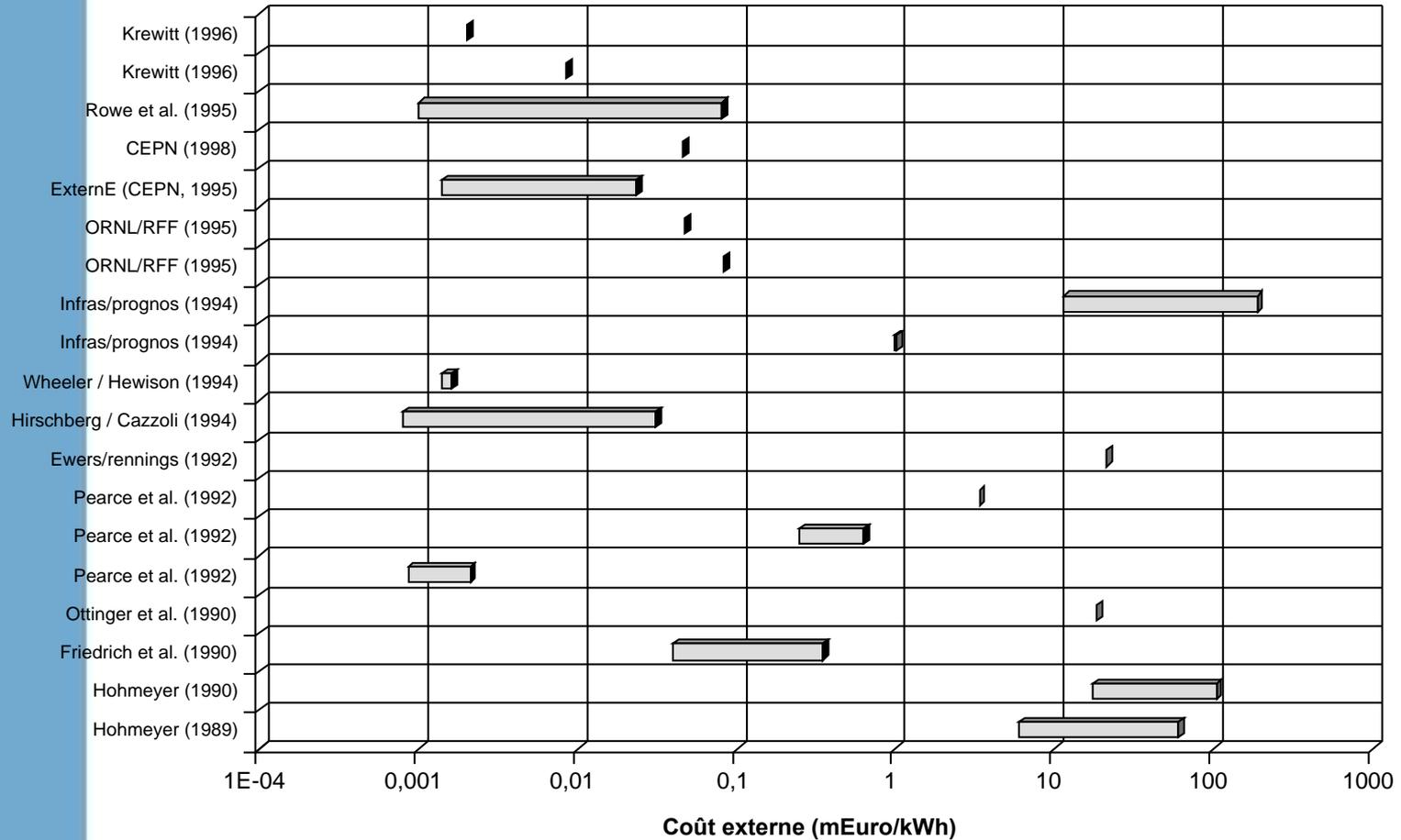
- Adoption of a risk aversion coefficient around 2 for the specific case of nuclear accident
- Application of multiplying coefficient of about 20 (for a release of about 1 % of the core)

**The external cost of the nuclear accident would be about 0.1 mEURO/KWh, instead of 0.005 mEURO/KWh without taking into account risk aversion**

- Sensitivity analysis

Relative Risk-Aversion (Ar)	Coefficient (K)	External cost of accident (m€/kWh)	% of total external cost of nuclear fuel cycle (without accident)
1.2	3.3	0.02	1 %
2	19.7	0.1	4 %
2.5	81.7	0.4	16 %

# External costs of accident from different studies



# Some complexities related to the evaluation

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- Scientific and technical dimensions
- Health uncertainties
- Environmental issues
- Socio-economic impacts

# Scientific and technical dimensions

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- Uncertainties associated with the definition of the source term and long term behaviour of the contamination in the environment
  
- Large dependency on the efficiency of the countermeasures
  - Efficiency of sheltering, agricultural restrictions...
  - Efficiency of decontamination programme
  - Management of waste

- Limited knowledge on the long-term health effects
  - In the case of Chernobyl, under-evaluation of the Thyroid cancers
- Difficulties to estimate the long-term collective dose
  - which time and space dimensions?
  - Which efficiency of self-help protection in the long term?
- Debate on the calculation of collective risk at low doses
- Debate on the non-cancer effects

- Uncertainties on the long-term consequences for the ecosystem
- Existence of interactions between environmental consequences and human activities inducing a transport of radioactivity in the environment
- Difficulties to assess the long-term depreciation of the environmental quality

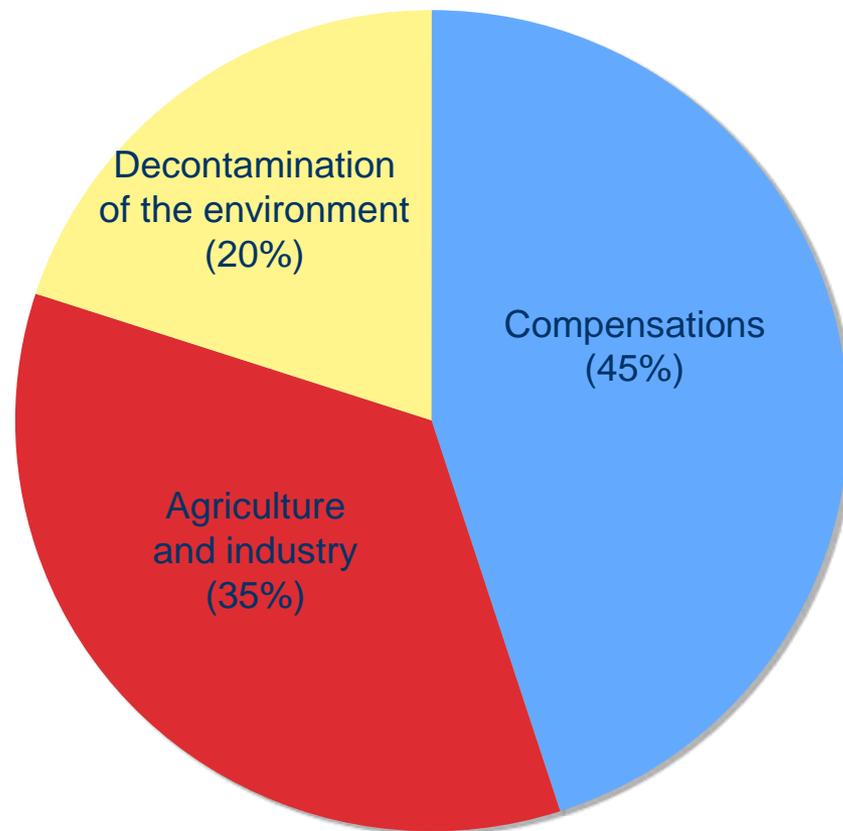
# Socio-economic impacts

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- Large disturbance on long term of the social life
  - Necessity to re-organise the day-to-day life in affected territories
    - Occupational activities, economic activities, social activities
    - Modification of habits
  - Depreciation of patrimony
    - Economic, cultural and environmental
- Depreciation of economic products from the region
- Deployment of long-term countermeasures

# Structure of estimated costs in Belarus following the Chernobyl accident (1996-2015) (1)

Three main areas...



## Structure of estimated costs in Belarus following the Chernobyl accident (1996-2015) (2)

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- Limited evaluation of the economic consequences for the industry (mainly agricultural activities)
- Cost of health consequences limited to the health surveillance and medical treatments (< 1% of total cost)
- No consideration of attributable risk associated with exposure
- Estimation of the total cost of the accident for Belarus Republic on 30 years (1986 -2015) : 235 billion US \$ (i.e. in average 10% of the national budget per year)

## Concluding considerations on the long term consequences

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- Living in a contaminated environment is a **complex situation generating a lot of questions and concerns** among the affected population
- Exposures are driven by **individual behaviours** and the **socio-economic situation** in the affected areas
- The main objective is the **rehabilitation of living conditions**, not the contaminated environment
- National resources must be mobilized **to support community projects** and local producers to improve living conditions in the areas affected instead of being mainly used for compensations