

Comparative risk assessment of severe accidents in the energy sector

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Content

- Key aspects of risk assessment
- Severe accidents – a controversial issue
- Energy-Related Severe Accident Database (ENSAD)
- Historical experience
- Energy chain comparisons
 - Generic results
 - EU-Project NEEDS
- Conclusions

Risk: origin and vulnerability factors

- Increase in shipping and trade at end of 16th century called for methods to describe precisely economic losses.
 → first applications of the term **risk**



- Today a variety of factors increase mankind's vulnerability towards accident and catastrophe hazards:



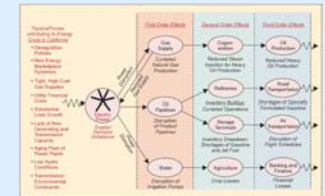
Urbanization



Industrialization



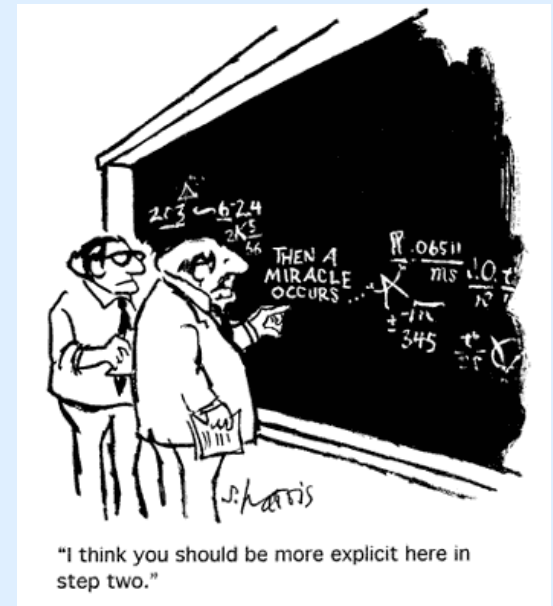
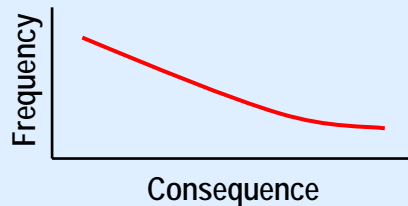
Development of coastal and other risk-prone areas



Complex inter-related infrastructures

Definition and measurement of risk

- **Risk:** potential for realization of unwanted, adverse consequences to human life, health, property, or the environment.
- **Risk assessment:** measurement of the risk, the potential loss, and the probability that the loss occurs.
- **Risk (R) = Probability (p) x Consequence (C)**
 - Estimate likelihoods
 - Estimate impacts



Severe accidents – a controversial issue



⇒ Energy-related accidents are a dominant contributor to all man-made accidents.

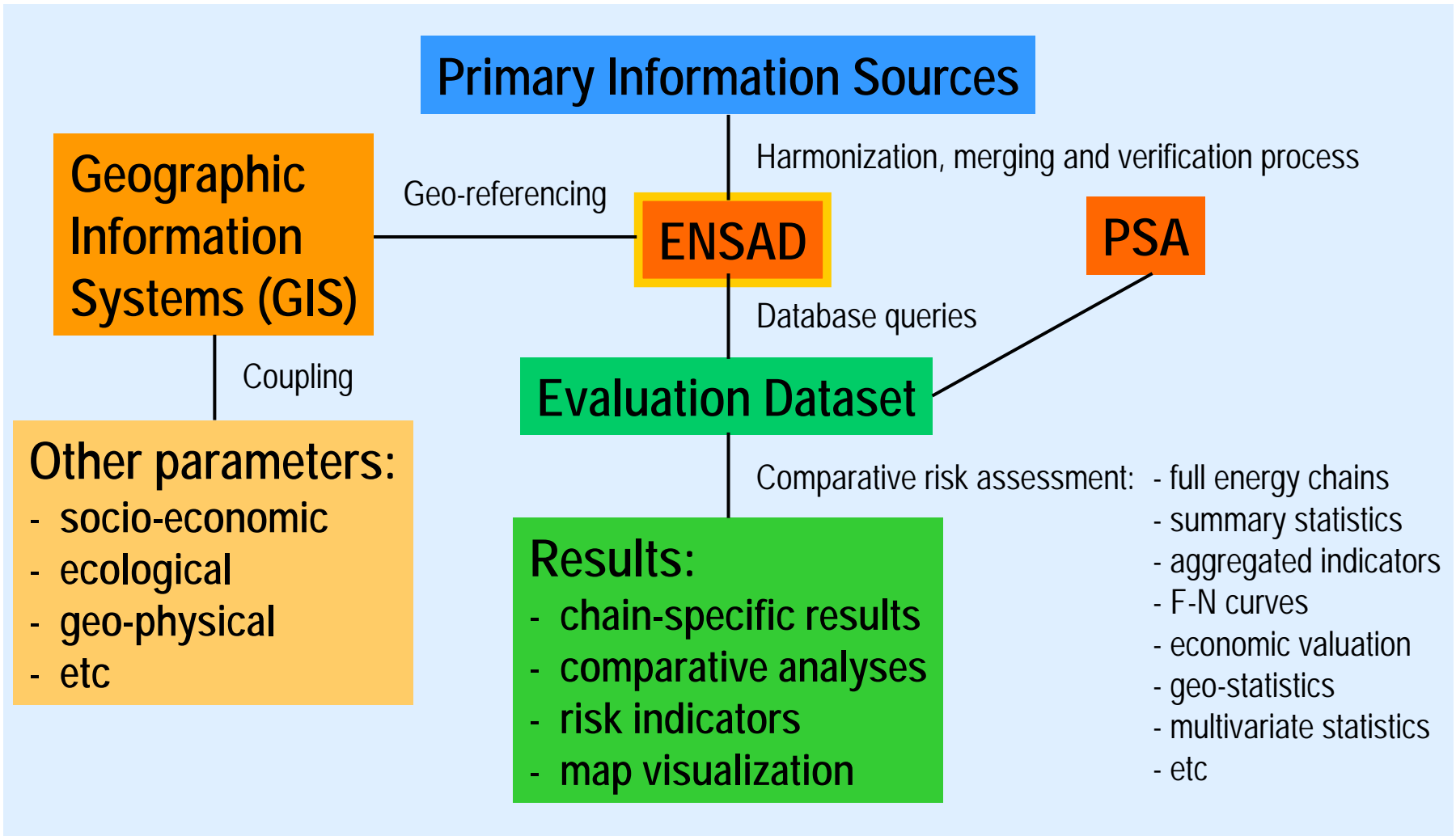
How should this problem be tackled?

- A detailed, integral and targeted analysis of accidents reveals the weak points in the energy infrastructure.
- For this reason PSI has built up ENSAD – a comprehensive, worldwide database of severe accidents in the energy sector.

Energy-Related Severe Accident Database (ENSAD)

- «*Severe accident*» *definition* that is consistently applicable to various energy chains
- *Comprehensive coverage of energy-related severe accidents*, other man-made accidents and natural disasters are less explicitly reviewed
- Coverage of *full energy chains*
- Evaluations for *fossil and hydro chains* are based on *historical experience*
- Application of *Probabilistic Safety Assessment* (PSA) for the *nuclear chain*
- Results for *renewables* are based on *accident statistics and expert judgment*
- *Chain-specific* (technical aspects) and *comparative analyses* of various energy chains
- Types of *consequences*:
 - *Health damages*: fatalities, injured persons
 - *Environmental damages*: contamination of ecosystems (e.g., oil spills)
 - *Economic damages*: loss of property
 - *Social effects*: evacuation of people in a given area

Methodological framework



Severe accident definitions

Consequence indicator	ENSAD	Sigma	EM-DAT	NatCat	WOAD
Fatalities	≥ 5	≥ 20 (dead or missing)	≥ 10	> 20	≥ 1
Injured persons	≥ 10	≥ 50	aff.	-	-
Evacuees	≥ 200	≥ 2000 (homeless)	aff.	-	-
Extensive ban on consumption of food	yes	-	-	-	-
Release of hydrocarbons	≥ 10000 t	-	-	-	≥ 1000 t
Enforced clean up of land and water area	≥ 25 km ²	-	-	-	-
Economic loss	≥ 5 million USD(2000)	≥ 82.2 million USD(2007)	-	> 50 million USD (2007)	-

Sigma: sigma insurance research (Swiss Re)

EM-DAT: The International Emergency Disasters Database (Centre for Research on the Epidemiology of Disasters, CRED)

NatCat: Natural Catastrophes Service (Munich Re)

WOAD: Worldwide Offshore Accident Databank (Det Norske Veritas, DNV)

Selected ENSAD studies and applications

EU-Projects

- **NewExt**: comparative risk assessment (CRA), external cost estimates
- **NEEDS**: CRA, trend extrapolation, risk indicators for multi-criteria decision analysis (RI-MCDA)
- **SECURE**: CRA, terrorist threat

Industry

- **China Energy Technology Program (CETP)**: CRA, RI-MCDA
- **Swiss Gas Association (SVGW)**: accident risks of natural gas
- **Sustainability of electricity generation technologies (Axpo)**: CRA, trend extrapolation, RI-MCDA

International Organizations

- **Nuclear Energy Outlook (NEA)**: CRA
- **International Committee on Nuclear Technology (ILK)**: CRA, RI-MCDA

Critical Infrastructure Protection (CIP)

- **Handbook of Science and Technology on Homeland Security**: CRA + CIP
- **Euro-Atlantic Partnership Council: (EAPC/PfP)**: energy security & severe accidents (FOCP)
- **Industrial Planning Committee (IPC) in EAPC Format**: threats and risks of CI (FONES)
- **Energy Infrastructure Security & Crisis Management (IQPC)**: CRA

ENSAD Update 2001-2005

Database:

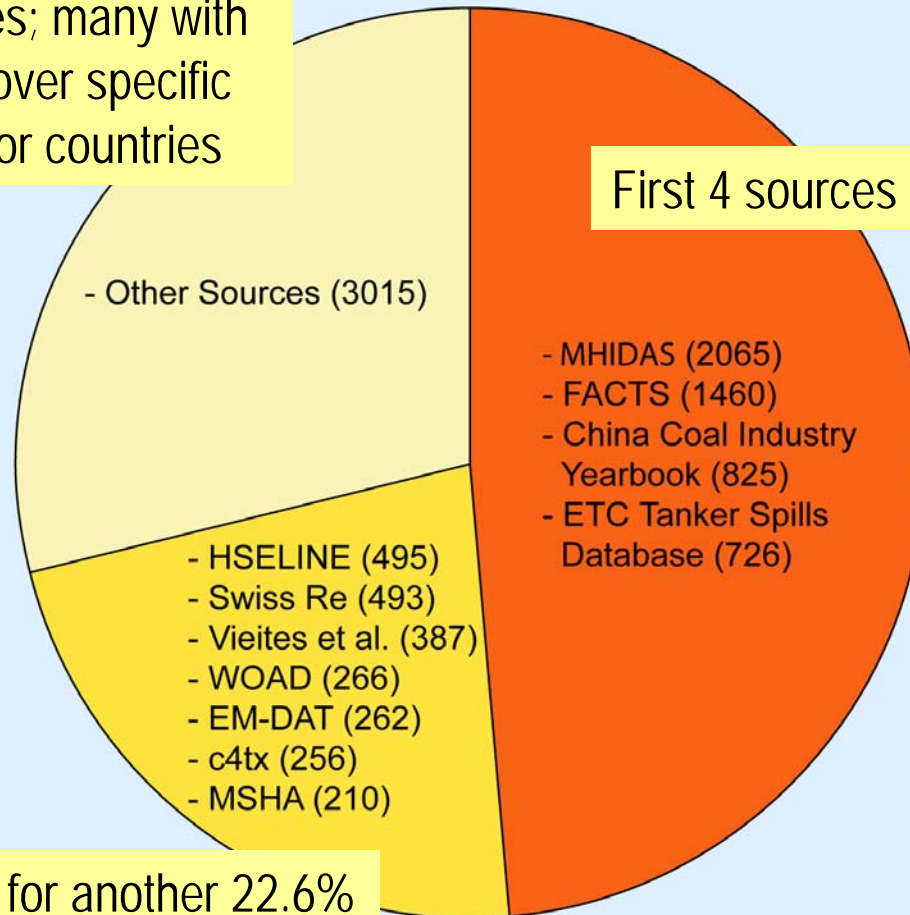
- Structural and interface design improvements of database
- Standardization of data queries, exports, and coupling with GIS and multivariate statistical analyses

Accident data:

- 30 primary and more than 50 supplementary information sources were surveyed
- Full chain update for fossil chains
- Extended review of hydropower
- New nuclear results based on simplified Probabilistic Safety Assessment (PSA)
- Consideration of new renewables, based on accident statistics, literature review and expert judgment
- In total 3024 accident records were added to ENSAD
 - 2601 classified as energy-related, and 508 of these with at least 5 fatalities

Major information sources of ENSAD

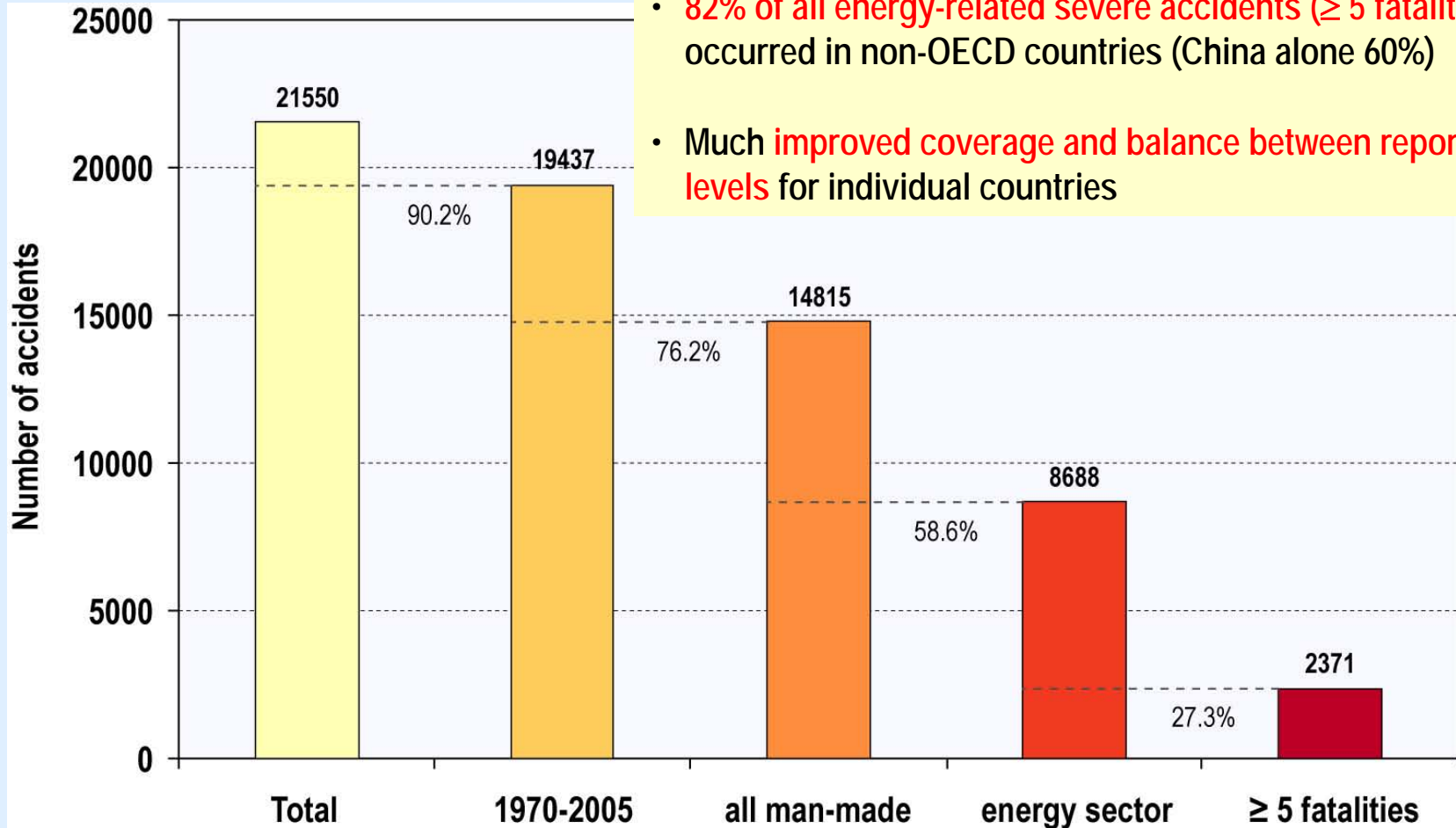
Another 170 sources; many with small shares, but cover specific energy chains and or countries



First 4 sources sum up to 48.5%

Next 7 sources for another 22.6%

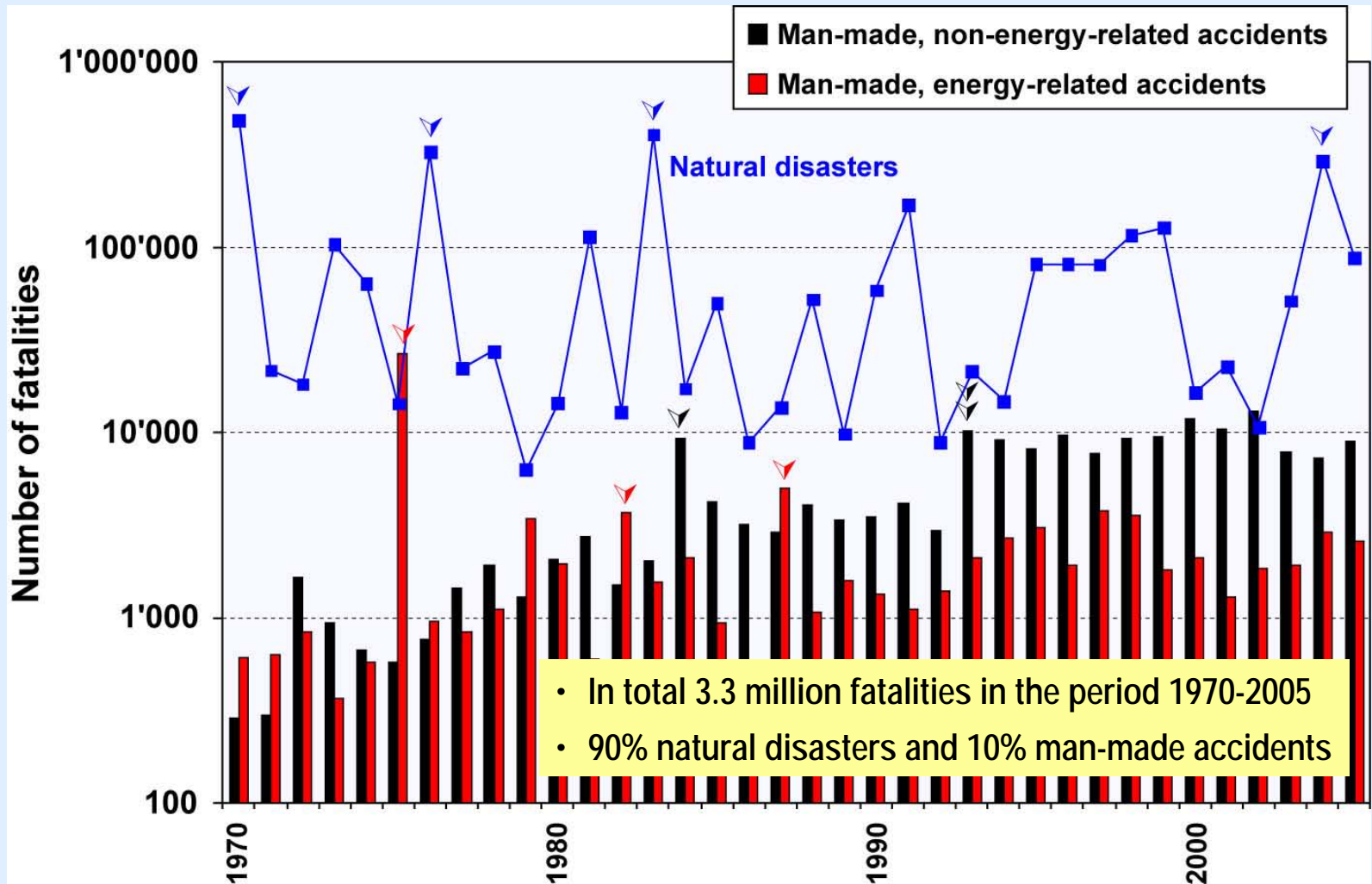
ENSAD and its merits



- 82% of all energy-related severe accidents (≥ 5 fatalities) occurred in non-OECD countries (China alone 60%)
- Much improved coverage and balance between reporting levels for individual countries

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Severe accidents and natural disasters



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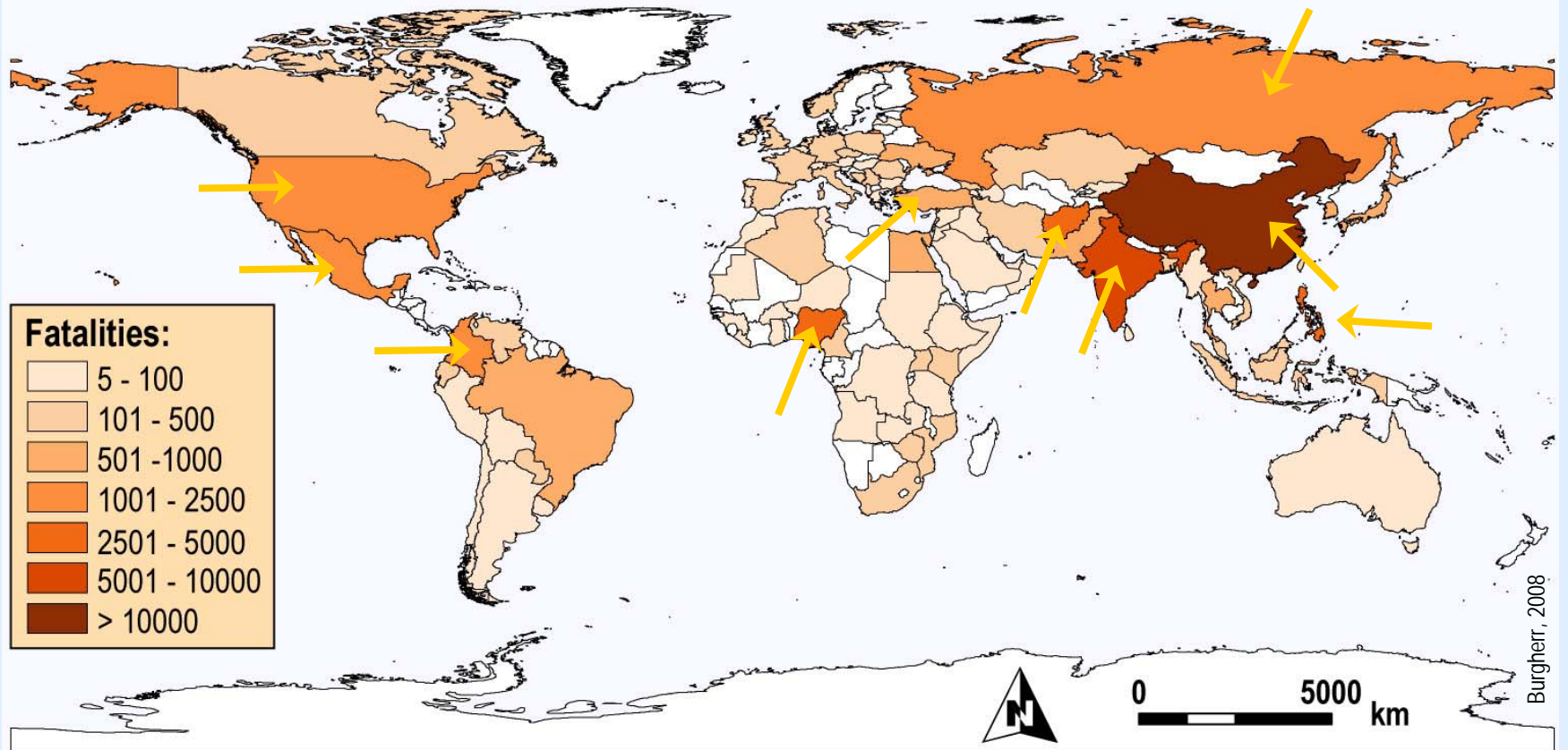
Severe accidents with at least 5 fatalities (1970-2005)

Energy chain	OECD		EU 27		non-OECD	
	Accidents	Fatalities	Accidents	Fatalities	Accidents	Fatalities
Coal	81	2123	41	942	144 1363 (a)	5360 24'456 (a)
Oil	174	3388	64	1236	308	17'990
Natural Gas	103	1204	33	337	61	1366
LPG	59	1875	20	559	61	2636
Hydro	1	14	1	116 (b)	12	30'007 (c)
Nuclear	—	—	—	—	1	31 (d)

- (a) First line: coal non-OECD without China; second line: coal China
 (b) Belci dam Romania (1991)
 (c) Banqiao and Shimantan dam failures alone caused 26'000 fatalities
 (d) Latent fatalities treated separately

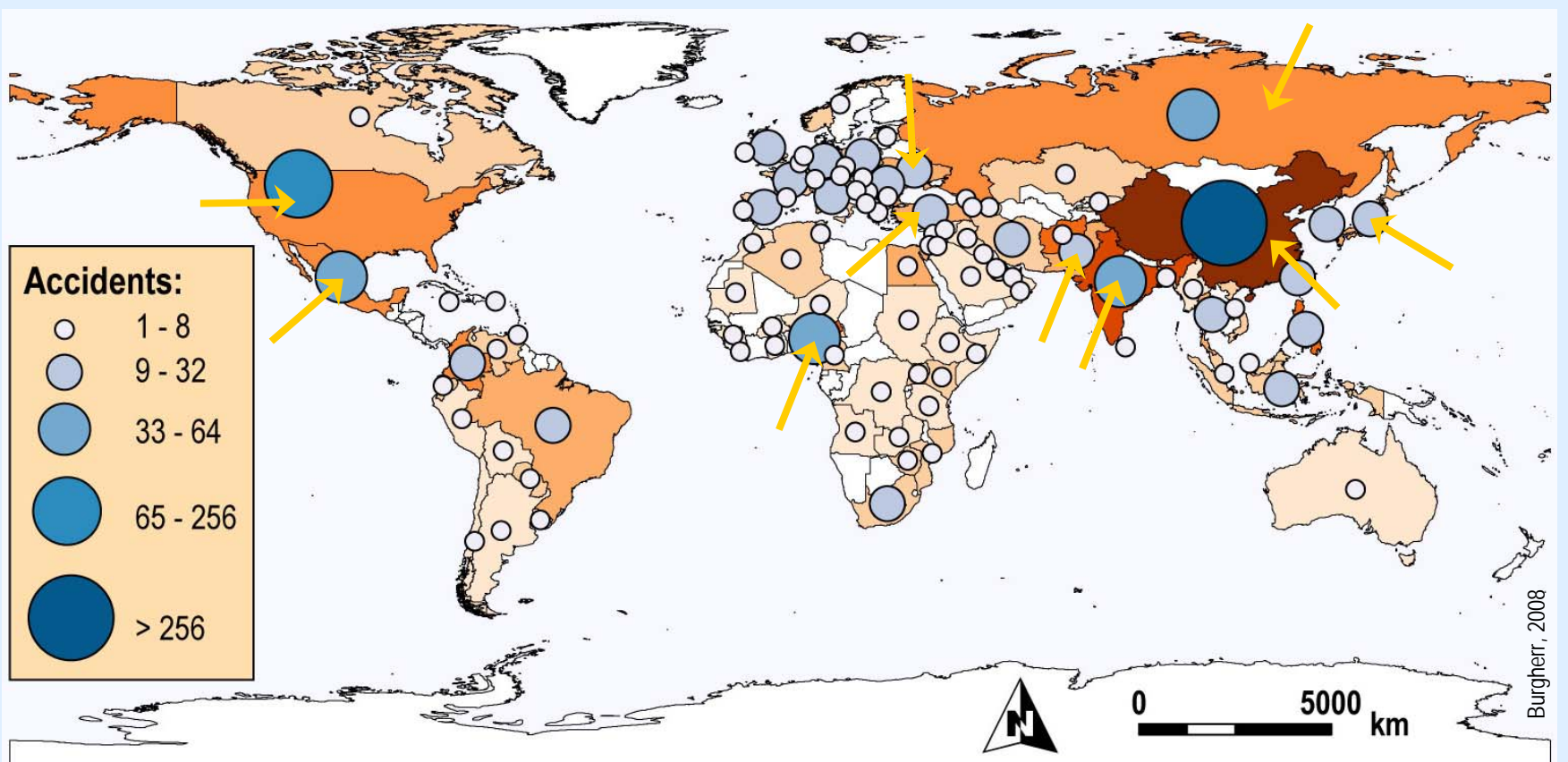
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Worldwide distribution of severe accidents



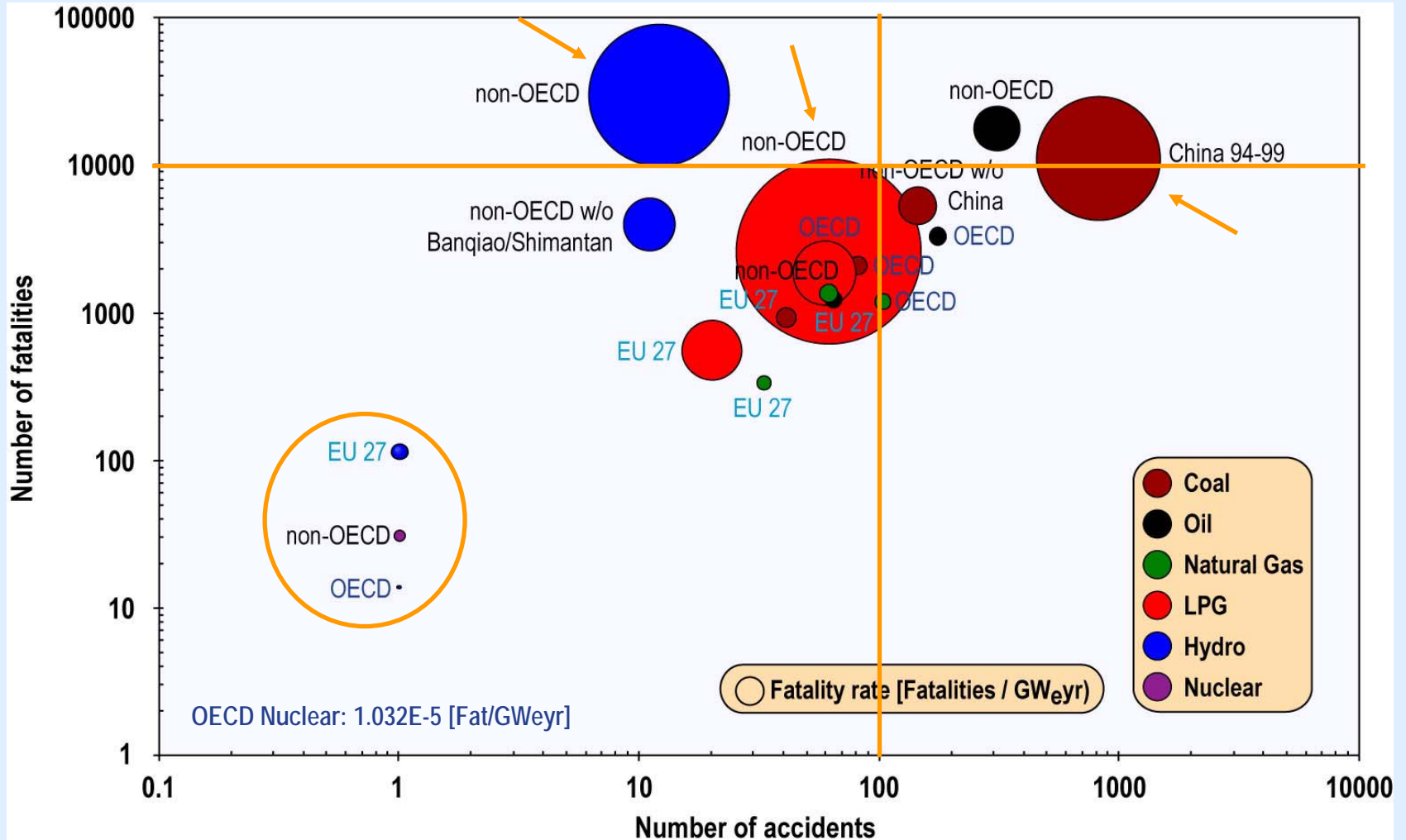
- China: almost 52000 fatalities; about 24450 in coal mine accidents; 26000 in Banqiao/Shimantan dam failure
- Philippines, Afghanistan, Nigeria, India, Mexico, Russia, Turkey and Colombia: single very deadly accidents
- USA: only few accidents with more than 50 fatalities

Worldwide distribution of severe accidents



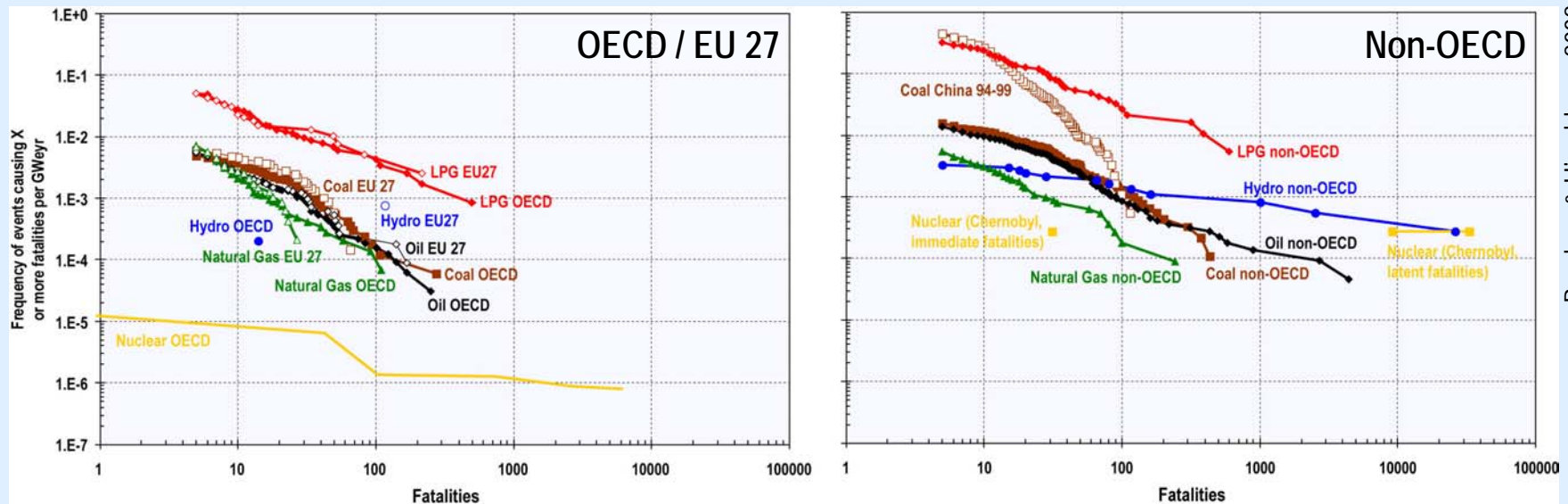
- China: 1363 of 1431 accidents in coal chain
- Nigeria (OIL), India + Japan (OIL, coal), Russia + Ukraine (COAL), Turkey + Pakistan (COAL, oil), Mexico (OIL, NG)
- USA: oil and gas chains most accident-prone (65 and 48 accidents; 149 total)

Aggregated indicators (1970-2005)



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Frequency-consequence curves (1970-2005)



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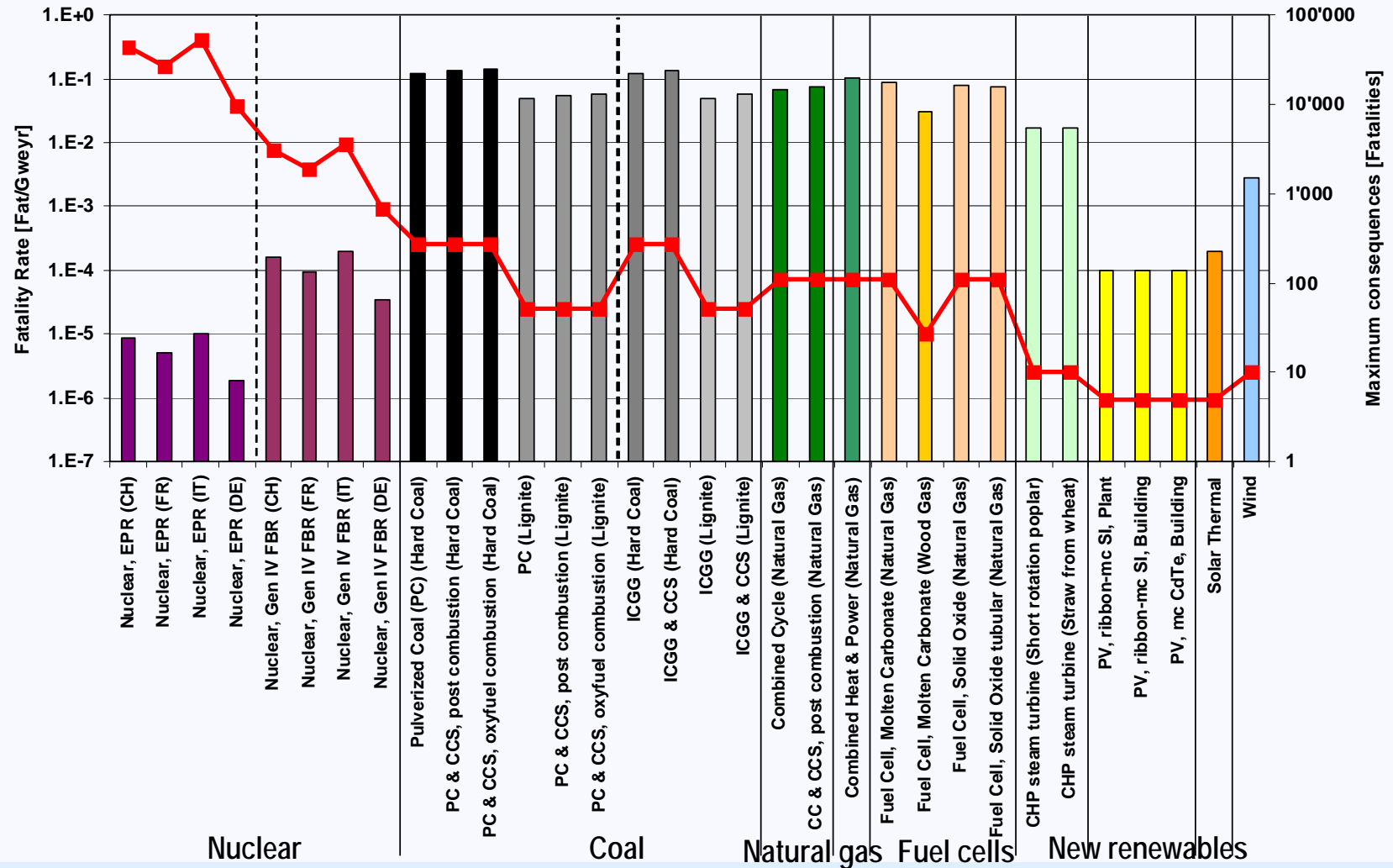
- F-N curves for OECD and EU 27 differ significantly in maximum consequences.
- Fossil chains show a similar ranking for OECD and non-OECD countries, except for the Chinese coal chain that exhibits significantly higher accident frequencies.
- Dam failures in non-OECD countries can result in thousands of victims, whereas in OECD no such accident has occurred since 1963 (Vaiont, Italy; 1917 fatalities).
- For the nuclear chain immediate fatalities are of low importance, whereas latent fatalities dominate.

EU-project NEEDS: risk indicators for 2050

- Set of 32 electricity generation technologies
- Time horizon: 2050
- Results of fossil energy chains are based on ENSAD data
- Simplified Probabilistic Safety Assessment (PSA) for nuclear
- Indicators for new renewables are calculated using ENSAD and expert-based assumptions
- Fuel origin, i.e. shares from OECD and non-OECD is considered

→ Aggregated indicators and maximum consequences

NEEDS: fatality rates and maximum consequences



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Conclusions

- The ENSAD database provides the quantitative basis for comparative risk assessment of severe accidents in the energy sector.
- Update 2001-2005: Significant achievements in database architecture & content.
- Consistent calculation of risk indicators for future technologies implemented.
- The use of ENSAD goes beyond purely scientific purposes, contributing to the formulation of energy policies, the realization of safety goals, and improved technology transfer to other countries.
- Energy-related accident risks in OECD and EU 27 countries are substantially smaller than in non-OECD countries.
- Most accident-prone are fuel extraction, refining and transportation in fossil chains, and hydropower in the less developed (non-OECD) countries.
- Expected fatality rates are lowest for western hydropower and nuclear power plants. However, the maximum consequences can be very large. The associated risk valuation is subject to stakeholder value judgments and can be pursued in multi-criteria decision analysis.

Thank you for your attention!

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In several languages risk often has the double meaning of
"chance, opportunity" and "danger, loss"

Probable origins of risk lie in the Greek word *rhiza*, meaning "root and/or cliff",
or the Arabic word *rizq* meaning "what God and fate provide for your life".

Similarly, in our everyday language we use proverbs such as
"Nothing ventured, nothing gained" or "God helps the brave",