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Emergency preparedness and response:

a review of EURATOM actions

European Commission

EUROSAFE 2019

Outline of presentation

- Potential radiological accidents: improvement and harmonization of emergency preparedness and response (EP&R)
  - From the FP7 NERIS-TP project to current methodologies implemented by FASTNET and MUSA projects
- "Practical elimination of risks" (2016 IAEA glossary): alleviation of EP&R and possible elimination of off-site consequences (evacuation of population around the plant)
  - Gen II&III operational plants (IVMR, FASTNET, sCO2-4-NPP and R2CA projects)
  - Gen III+ (European Pressurised Reactors, EPRs) under construction (SARNET networks of excellence)
  - Gen IV designs of Small Modular Reactors (SAMOSAFER and ELSMOR projects)
- Psychological impact of EP&Rs with evacuation plans following off-site contamination: need of improved communication to support "citizen science" (the quest for truth by the large public)

EURATOM research in the field of severe accident management

EURATOM target: improvement of reactor safety by understanding the phenomenology of severe accidents and reducing uncertainties

- From 1988 to 2010 the EC has been involved in the management and the scientific cooperation of the PHEBUS FP programme (largest severe accident research programme carried out in the world) with a total EC financial contribution of € 40.5 million
- Since 1992, about 100 shared-cost research projects on severe accidents and radiological emergencies have been partly funded by DG RTD with a total EC contribution of more than € 120 million
- In FP6 (2002-2006), the SARNET “Network of Excellence” has been launched to integrate research programmes and knowledge on severe accidents (continued until 2013 in FP7)

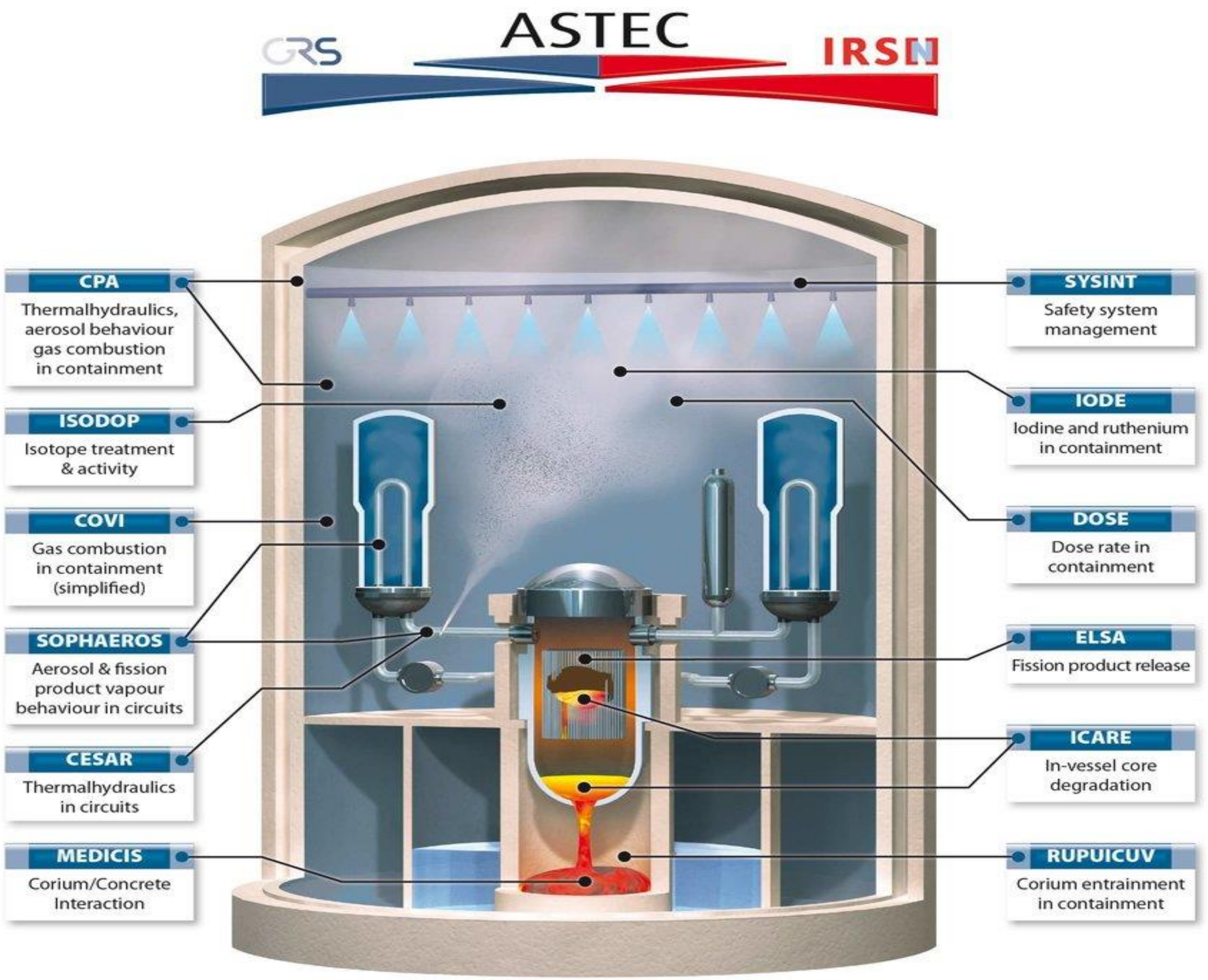
Publications Office of the EU: nuclear power, the underdog of Europe's energy mix

EURATOM SA Networks of Excellence: SARNET1 & SARNET2

SARNET: Severe Accident Research NETwork of Excellence
From 2002 until 2013 (FP6 & FP7)
Key objectives:
Improve and disseminate knowledge on severe accidents to reduce uncertainties, enhancing plant safety through experimental and modelling work (ASTEC code)

GA for SARNET1:
Total cost: € 38 937 670
Total EC contribution: € 5 750 000
Coordinated by IRSN (Fr)
About 40 equivalent full-time persons/year
22 countries from European Union, Switzerland, Canada, USA, Republic of Korea, India
43 organizations
21 research organizations
7 universities
7 industry/utilities
8 safety authorities or Technical Safety Organizations
230 researchers (+ 25 PhD)

SARNET is now a pillar of NUGENIA activities (TA2)



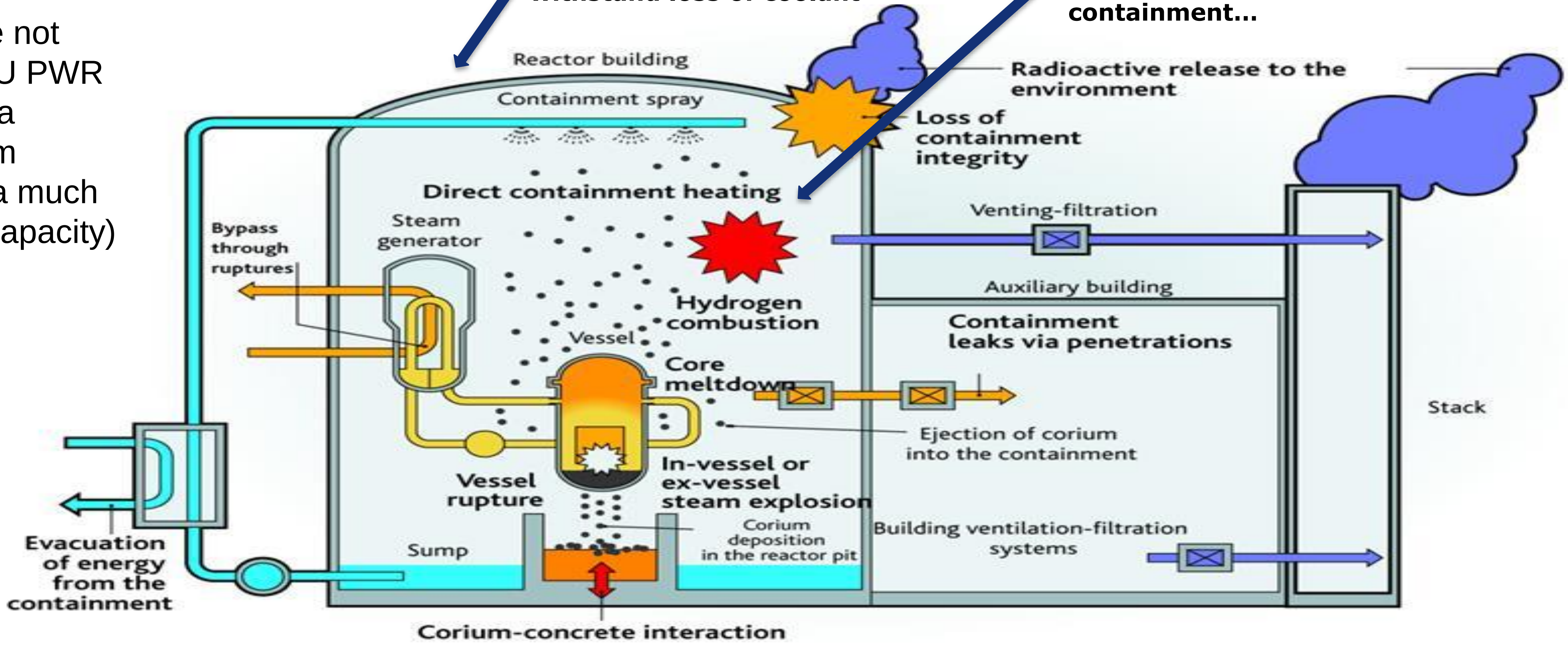
https://www.sciencedirect.com/science/article/pii/S0306454915300360

EURATOM safety improvements of “beyond-design” severe accidents: no evacuation of surrounding population for the EPR (Gen III+)

TMI would have not occurred in a EU PWR (which is using a “forgiving” steam generator with a much larger thermal capacity)

Containment designed to withstand loss of coolant

TMI operators did not even know the reason of two explosions in the containment…



35 years of EURATOM-funded research has allowed the understanding and the modelling of the accident phenomenology for all EU operating reactors: PWRs, BWRs, CANDUs as well as Russian-designed VVERs

- The EPRs (under construction in Finland, France and UK –already operational in China) is the design which has most benefitted of SARNET accident research

Examples of EURATOM FP7 Severe Accident Management Research

EC contribution with a leverage factor of 3 on total expenditure

LACOMECO – Large Scale Experiments on Core Degradation, Melt Retention and Containment Behaviour

ERCOSAM - Containment thermal-hydraulics of current and future LWRs for severe accident management

PASSAM – Passive and Active Systems on Severe Accident source term Mitigation

CESAM – Code for European Severe Accident Management ASTEC (Fukushima accidents, decision-making tool, spent fuel pond)

SAFEST – Severe Accident Facilities for European Safety Targets

ALISA – EU/ China Access to Large Infrastructures for Severe Accidents

JASMIN - Joint Advanced Severe accidents Modelling and Integration for Na-cooled fast neutron reactors

ASAMPSA_E - Advanced Safety Assessment: Extended (Fukushima-like) PSA

ASAMPSA2 - Advanced Safety Assessment Methodologies: level 2 PSA (European Best Practices L2 PSA guidelines)

A self-sustaining European Technology Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery: NERIS-TP

The NERIS-TP project has, since February 2011, combined eleven leading research organisations in the nuclear emergency management area with four SMEs and four NGOs from 13 countries

- Operation of a European platform on emergency and post-accident preparedness and management (the NERIS Platform) to improve EP&R in Europe
- Improvement of the two late phase modes ERMIN (inhabited areas) and AgriCP (agricultural production) to better deal with the request from the end-users
- Coupling of the emergency information system of the IAEA with the existing European Decision Support Systems (RODOS/ARGOS) by developing an interface and a meteorological model chain that provides meteorological data from freely available world-wide data
- Strengthening of the preparedness at the local/national level by setting up dedicated fora for the improvement/adaptation of the tools developed within the EURANOS projects
- Coupling the decision support systems with the early notification system ECURIE (the JRC’s highly reliable web-application for the creation of notifications under the 87/600/EURATOM Council Decision)

EP&R-relevant EURATOM fission projects under the NFRP 2014-2015 call

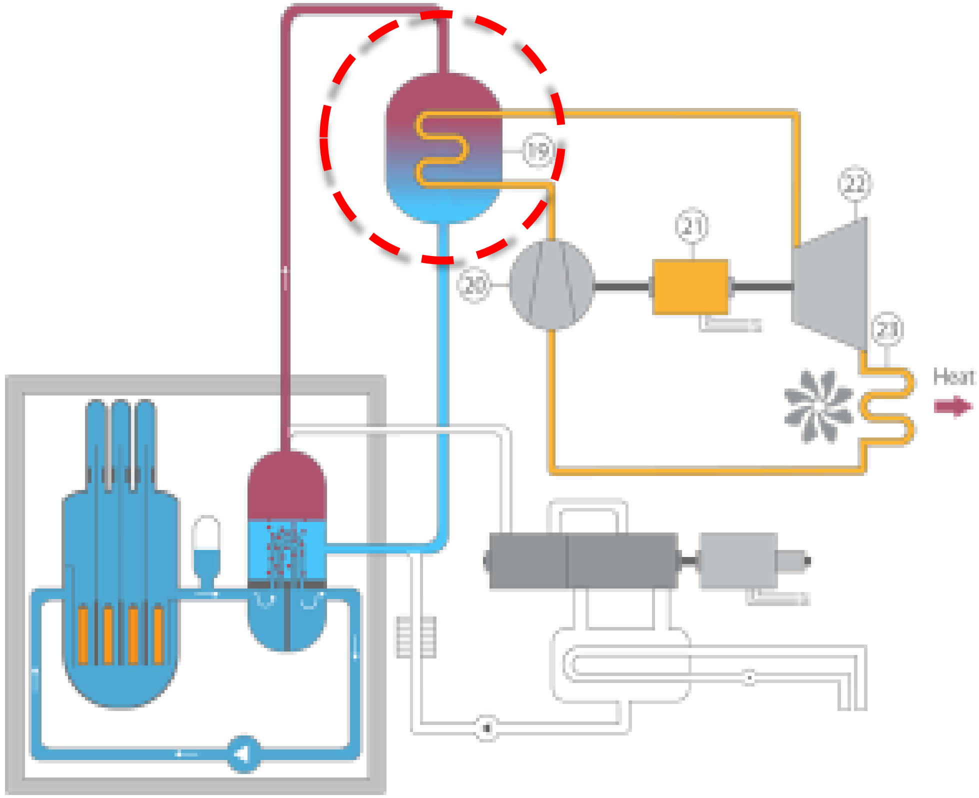
- FASTNET (FAST Nuclear Emergency Tools)
  - methodology and tools for rapid response to emergencies
  - setting-up of "Reference Accident Scenarios" (identification of main categories of scenarios) for EU LWR
  - knowledge management, dissemination and education & training through the set-up of a database of all potential SA scenarios with IAEA involvement for:
    - database extension to non-EU nuclear technologies and database transfer to emergency centres of IAEA's member countries
- IVMR (In-Vessel Melt Retention)
  - support to the implementation of the Loviisa VVER 440 "In-Vessel retention strategy" to all EU new member countries with the same Russian-designed technology
  - state-of-the-art of the IVMR concept for reactors of higher power (>600MWe) and concept development for GEN III+ designs as AP-600, AP-1000, APWR-1400, APWR-1700, BWR-1000 and ABWR
- sCO2-HeRo (supercritical CO2 heat removal system)
  - backup cooling system for the reactor core (with passive start-up in case of station blackout with loss of ultimate heat sink)

The sCO2-HeRo project

sCO2-HeRo concept

UNIVERSITÄT DUISBURG ESSEN
Open-Minded

Overall target: Prevent overheating of nuclear core

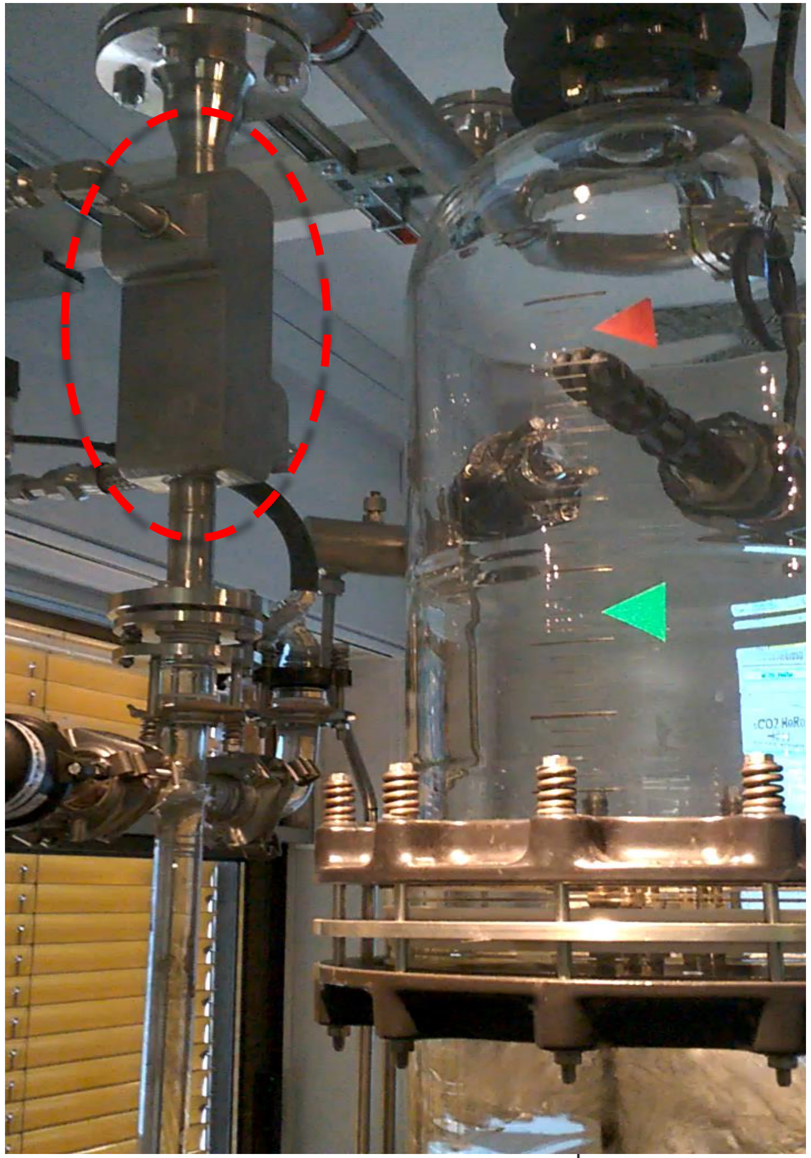


Scenario:

Loss of electricity, heat sink & infrastructure

sCO2-HeRo solution:

- **Core cooling**
  - Natural convection in primary cycle
- **Self-sustainability**
  - Simple Joule cycle running on decay heat
- **Self-starting**
- **Compactness**
  - Supercritical CO_2



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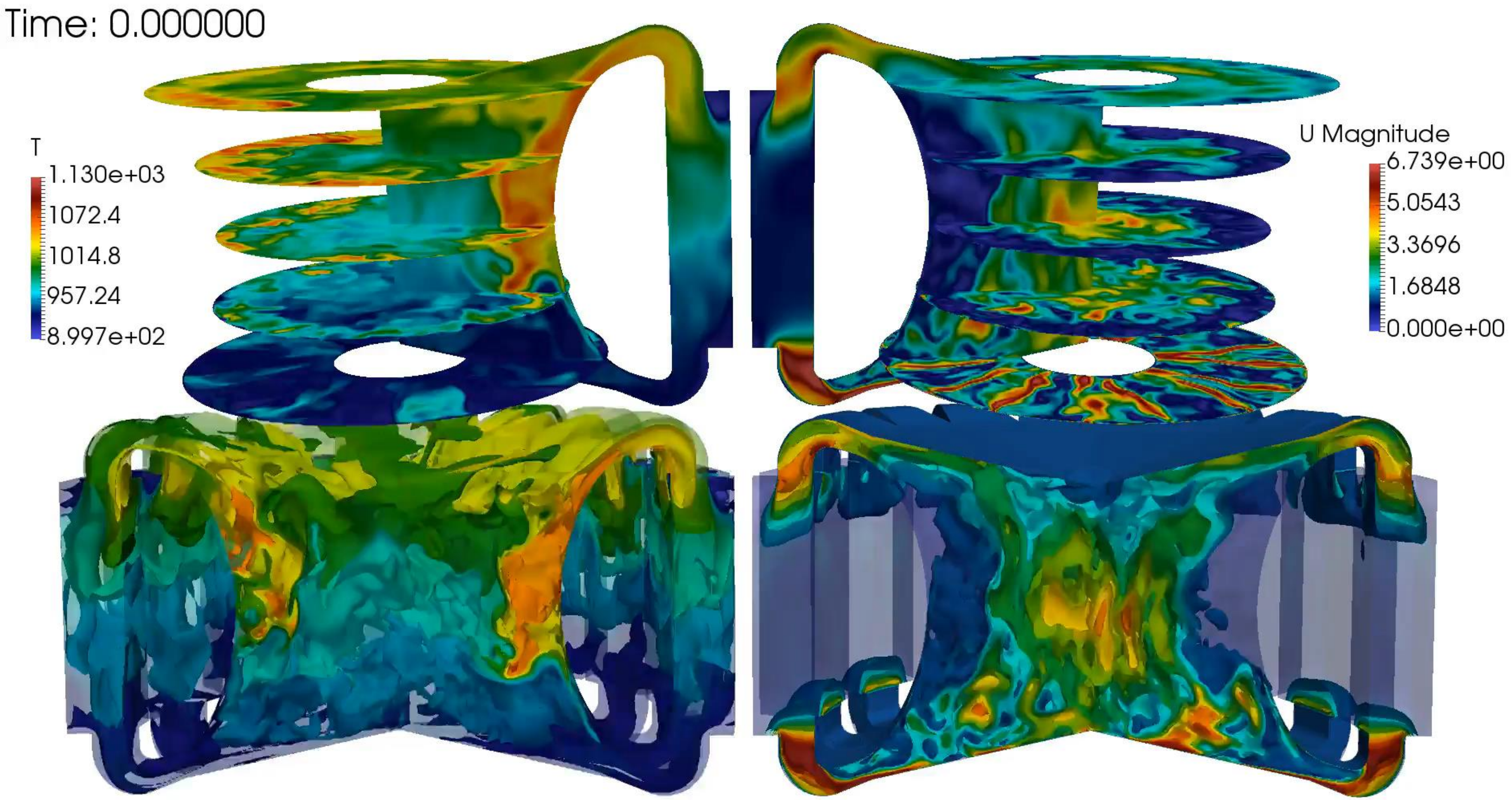
EP&R-relevant EURATOM fission projects under the NFRP 2018 call

- NFRP 2018-1: Safety assessments to improve accident management strategies for GEN II & III reactors
  - MUSA – identification of safety margins through assessment of dominating uncertain parameters (use of Uncertainty Quantification tools) and embedding accident management in SA analyses
  - R2CA - development of management approaches for the verification of new potential devices/ barriers/ optimized emergency response to reduce the burden of protection measures on population
- NFRP 2018-2: Model development and safety assessments for GEN IV reactors
  - SAMOSAFER - Development of tools for verification of safety barriers under SA conditions and demonstration of the inherent safety of the molten salt reactor
- NFRP 2018-3: Research on the safety of Light Water Small Modular Reactors
  - ELSMOR - methods and tools for the assessment and verification of the safety of light-water small modular reactors (LW-SMR)
- NFRP 2018-10: Encouraging innovation in nuclear safety for the benefit of European citizens
  - CO2-4-NPP - supercritical CO2 for heat removal aiming at solving the core cooling issue
  - PIACE – scale-up of a passive heat-removal “isolation condenser” for light water and liquid metal cooled reactors

H2020 SAMOSAFER (Severe Accident Modeling and Safety Assessment for Fluid-fuel Energy Reactors)



Multi-physics calculations for the Molten Salt Fast Reactor (MSFR) concept core with the TFM-OpenFOAM code (LES model)
@A. Laureau - PhD work under the H2020 SAMOSAFER project

2019-2020 NFRP EURATOM call (proposals under evaluation)

NUCLEAR SAFETY (Area A)

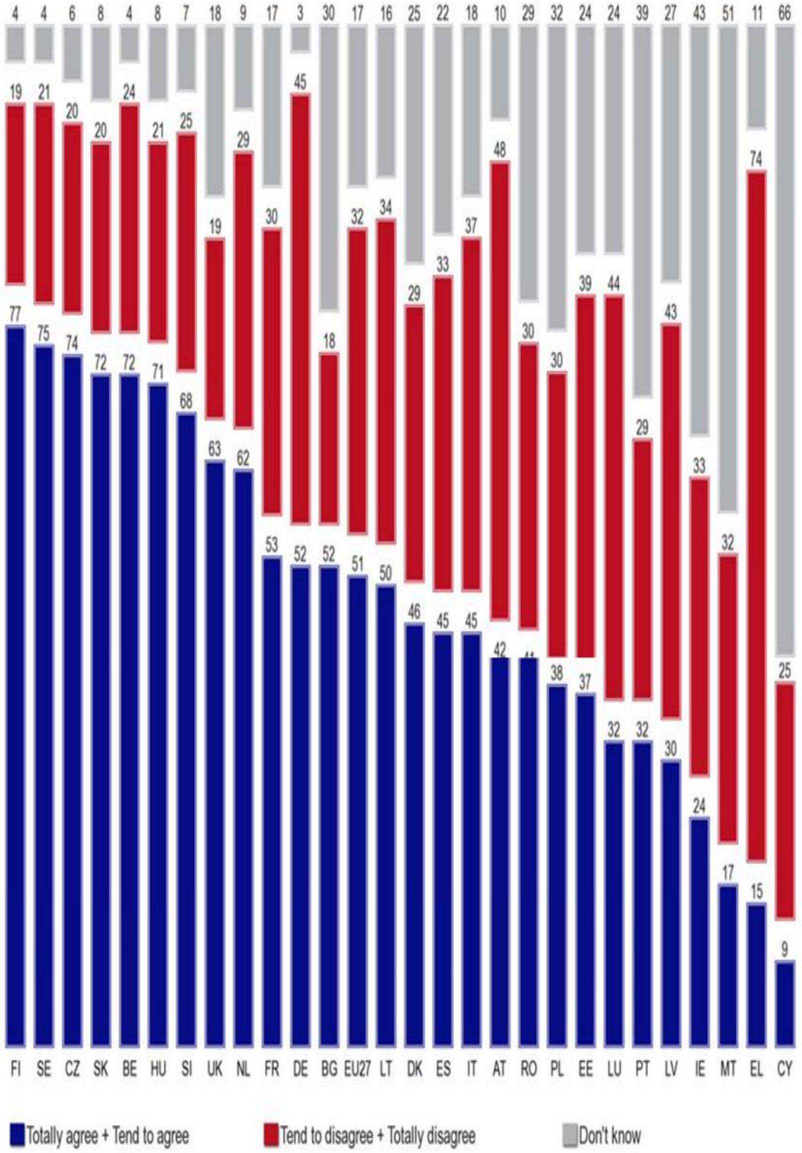
- NFRP-01: Ageing phenomena of components and structures and operational issues
- NFRP-02: Safety assessments for Long Term Operation (LTO) upgrades of Generation II and III reactors
- NFRP-03: Safety margins determination for design basis-exceeding external hazards
- NFRP-04: Innovation for Generation II and III reactors
- NFRP-05: Support for safety research of Small Modular Reactors
- NFRP-06: Safety Research and Innovation for advanced nuclear systems
- NFRP-07: Safety Research and Innovation for Partitioning and/or Transmutation
- NFRP-08: Towards joint European effort in area of nuclear materials

Fukushima lesson: EOPs with standard Emergency Mobile Equipment (EME)

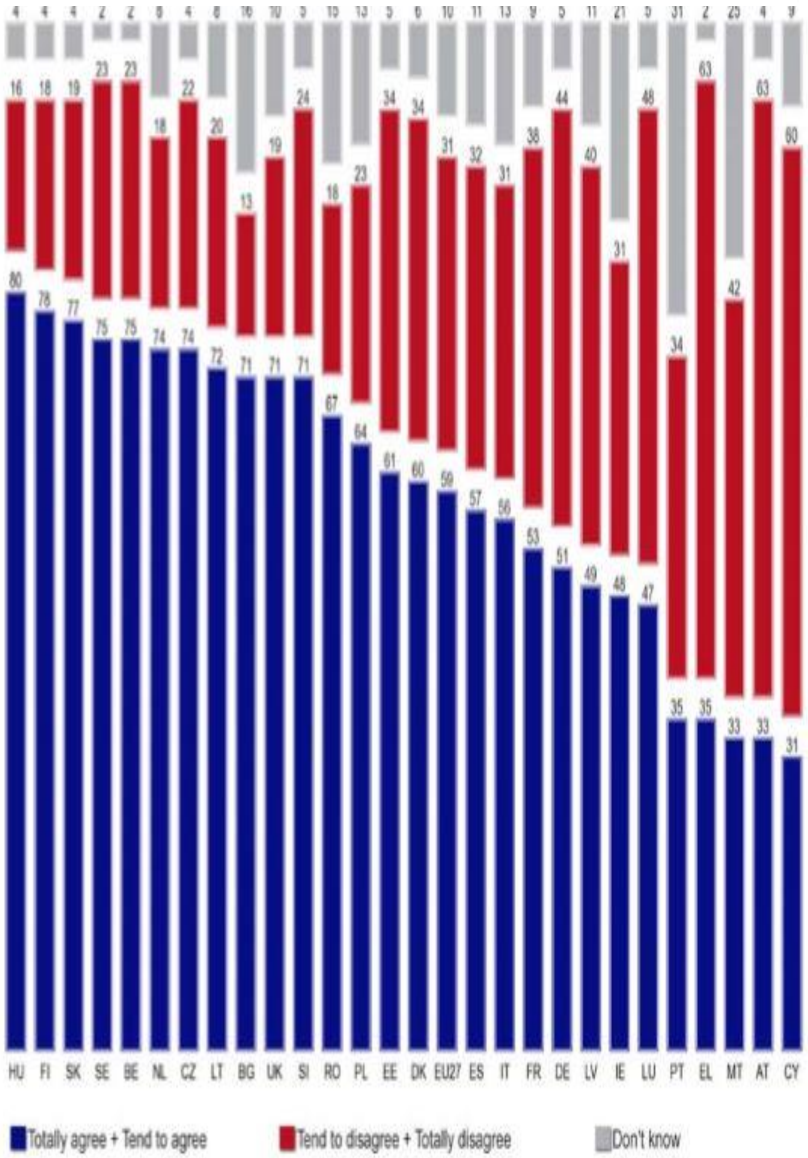
- "Practical elimination of risks": EP&Rs without evacuation of population around the plant
  - 2016 IAEA glossary: "the possibility of the potential occurrence of certain hypothetical scenarios could be considered to be excluded ("practically eliminated") provided that
    - it would be physically impossible for the relevant event sequences to occur or that
    - these sequences "could be considered with a high level of confidence to be extremely unlikely to arise"
- Topics NFRP-02, NFRP-03 and NFRP-12 (integrating Radiation Protection research in the EU) of EURATOM Work Programme 2019-2020 promote a double line of actions for GEN II & III reactors:
  - Equipment: practical elimination of off-site radiological risks by improving operational safety with e.g. passive coolant systems (as sCO_2 coolant systems), accident tolerant fuels (ATF), active and passive H_2 venting systems, scrubbers, etc..
  - Procedures/EP&Rs: adaptation of EOPs to Fukushima-like extreme challenging scenarios by use of standard Emergency Mobile Equipment (EME)

Trust to nuclear energy changes when crossing EU borders (Eurobarometer 2010)

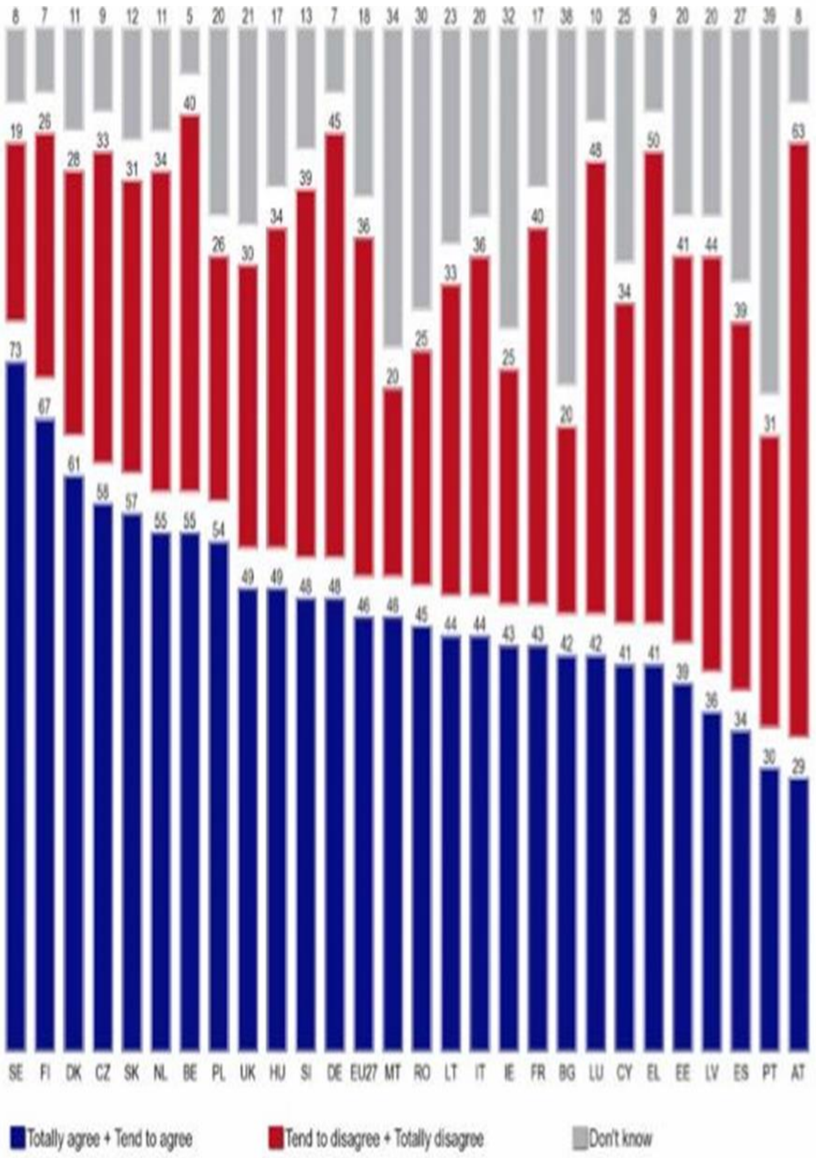
Is your national nuclear authority able to guarantee plant operational safety?



Is it possible to operate a nuclear plant in a safe manner?



Would nuclear energy be able to limit climate changes?



Low acceptance of nuclear energy: biases and “presumed knowledge” difficult to be challenged ?

- loss aversion: irrational decisions from a cognitive bias that arises from heuristics
  - the negative psychological impact we feel from a danger/ loss is twice as strong as the positive impact of a gain of a similar thing, therefore when judging a dangerous issue, rather than careful analysis, we take intuitive decisions (TED: the psychology behind irrational decisions - Sara Garofalo)
- challenge of knowledge: the more knowledgeable people are, the more polarised their attitudes become
  - thus telling people more, about e.g. genetically modified food or nuclear energy, is more likely to generate protest rather than support
  - the Monty Hall problem shows people critical attitude towards a challenge of knowledge, in this case in the field of probabilities (TED: Should I stay or should I switch doors?)

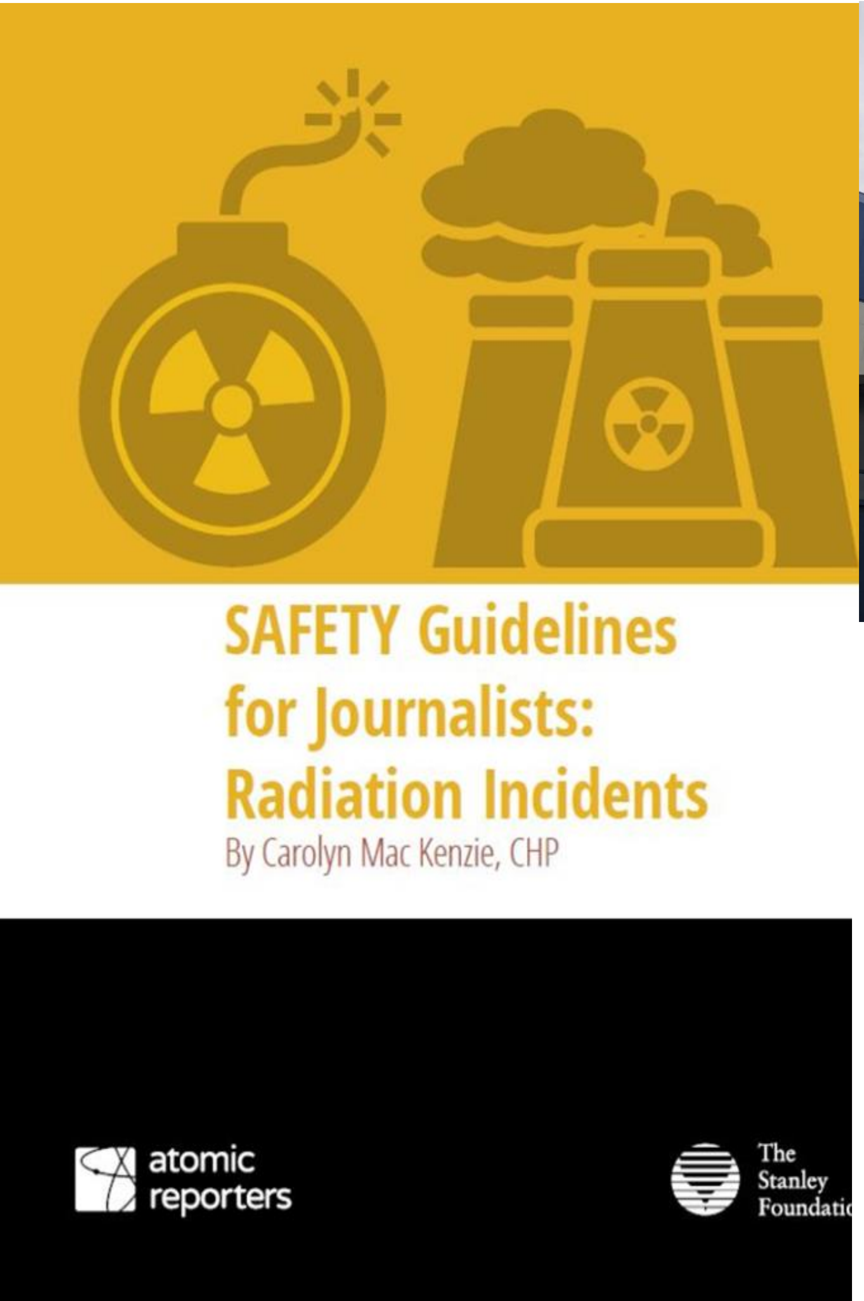
Public support for science is decreasing because of misuse of science and fake news

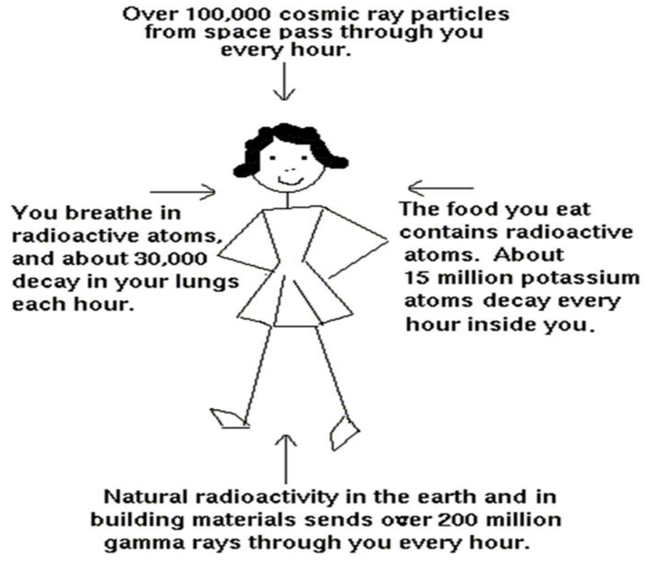
- disinformation has an increasingly adverse effect on society and democratic processes
- Pope Francis' last encyclical: need of a holistic strategy to "fight the technocratic paradigm which dominates economic and political life"
- economic and populist interests could intentionally spread disinformation in order to mislead the public and shake its trust in relevant EU strategies/ projects
- a new network against disinformation was created in 2018 within the European Commission to counteract the spread of false news and/or negative narratives related to the EU

Bridging the gap: bringing an understanding of the public to science and of science to the public

- Imperial College: “Bridging the gap: bringing an understanding of the public to science and of science to the public”
  - the “psychological irrationality” of the nuclear community has contributed to a generalized negative perception of risks
- EURATOM HoNESt project in the field of Social Sciences & Humanities (SS&H)
  - nuclear acceptance is high in countries with:
    - bottom–up public engagement (public participation to the decision process)
    - trust towards decision-makers
    - quality of communication: “only increasing the amount of engagement, if the methods employed are ineffective or unjust in the experiences of stakeholder groups, is unlikely to build knowledge, trust or support”
- EURATOM Education and Training (E&T): support “citizen science” (a quest for truth) with “scientist science” (science-based evidence)

Is current communication free from “psychological irrationality” ?





Radioactivity is all around us
The University of Waikato: www.sciencelearn.org.nz

Typical Radiation Doses (From Various Sources)

Watching television	0.01 mSv/year
Air travel (roundtrip from Washington to Los Angeles)	0.05 mSv
Medical chest X-ray (one film)	0.1 mSv
Nuclear medicine thyroid scan	0.14 mSv
Full set of dental X-rays	0.4 mSv/year
Mammogram (four views)	0.7 mSv
Average annual exposure living in the United States	3.5 mSv/year
Average annual exposure from breathing radon gas	2 mSv
Nuclear medicine lung scan	2 mSv
Nuclear medicine bone scan	4.2 mSv
Nuclear cardiac diagnostic test (technetium or Tc-99m)	10 mSv
Computed Tomography scan	10-25 mSv
Various PET studies (^{18}F FDG)	15 mSv
Tobacco products (amount for a smoker's lungs from 20 cigarettes a day)	50 mSv/year ?
Cancer treatment (tumour receives)	50,000-80,000 mSv

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Conclusions (1): EURATOM actions aiming at excluding external contamination and public evacuation

- Technical innovations for GEN II & III reactors
  - e.g. standard mobile cooling systems (EME), passive coolant systems (as sCO2 coolant systems), accident tolerant fuels (ATF), active and passive H2 venting systems, scrubbers, etc..
- Safety demonstrations of updated (post-Fukushima) accident management (EOPs and EP&Rs)
  - for all EU reactors in operation as well as future GEN IV reactors (e.g. Small Modular Light-Water (SM-LW) reactors and Molten Salt (MS) liquid reactors)
- EU common licensing procedures for “optimum” safety-based designs
  - e.g. the “run-away safe” concept for MSRs or sufficient “admissible” grace period for LWRs with EMEs

Conclusions (2): improved communication, elimination of "psychological irrationality" and preservation of EU nuclear competences

- Improved communication/ information, for example, on:
  - ability of nuclear power to play an important and non-intermittent role in a carbon reduction strategy
  - risks from low doses (from the use of nuclear energy) versus risks from high doses (nuclear weapons and criticality accidents)
  - "renewable-like" innovative nuclear technologies (e.g. Thorium-fuelled fast breeder reactors)
  - feasibility of a nuclear "circular economy" with a strong reduction of generated waste (e.g. GEN IV waste burners and improved fuel cycles)
  - technological developments, social progress and jobs creation in the field of nuclear medicine, diagnostics, space applications, etc..
- EURATOM actions in education and training (E&T) are fundamental for maintaining skills and for supporting the "science of citizens" with the "science of scientist" (bottom-up public engagement)

Will nuclear energy become a robust pillar of a sustainable future?