Nuclear Energy Ecosystems – Open Business Day 2022

Fire risk analysis of DEMO LiPb component room

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Introduction to Fire Accident Analyses

- Task WPSAE.S-04.03-T004-D001 within the framework of the EUROfusion Consortium

- Fire hazard identification & consequence assessment
- Fire accident analysis should show that
  - any releases will remain within the plant limits
  - no conditions for cliff-edge effects will occur
- Other important topics:
  - evaluation of protection of personnel and property
  - fires occurring simultaneously with other external hazards
- Primary interest: high-risk areas, such as those which include critical equipment, radioactive material inventories or large fire loads.

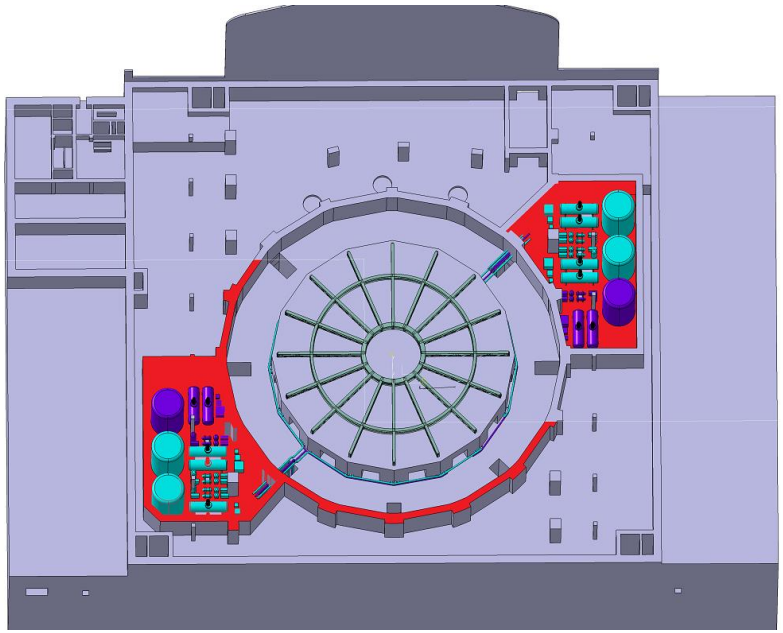
Introduction to Fire Accident Analyses

- To support the fire consequence analysis, CFD simulations are made. These enable analyzing
  - the possible propagation mechanisms of the fire
  - the effects of the fire on its surroundings
  - the possibility of the release of dangerous materials to the environment
- As an outcome, it is demonstrated that acceptable fire safety levels can be obtained with the designed fire protection systems. If necessary, modifications to the existing designs will be proposed.

Fire risk analysis of DEMO LiPb component room

Accident description

- Event: Fire in LiPb component room
- Objectives:
  - Evaluation of the potential impact of a fire on critical process equipment, based on their structural characteristics and the temperature reached.
  - Evaluation of the risk and the consequences of a release of source terms, following the failure of a critical process component.



Lithium lead component rooms, side view (marked in red)

Input data and definitions

- Room definition
- Fire load
- Fire scenarios and design fires

Room definition

Variable	Value(s)	Reference
Wall material	Concrete, thickness 1.25 m	WCLL PbLi drawings (2PFKEM) [1]
Wall leakage	$5.0 \cdot 10^{-5}$ m^2/m^2	Estimate based on [2]
Equipment material	Steel, thickness 5 mm	Estimate
Fuel (gaseous)	CH_4	Estimate
Ambient temperature	20 °C	Estimate
Room pressure	-120 Pa, VDS maintains also during a fire	Pressure value DEMO Room Book (2PCBXP) [3], operation assumption [4]
Fire damper activation	Gas temperature at damper > 70 °C or controlled by smoke/heat detector in the room ceiling	Assumption based on ITER [4]
Smoke detectors	Two in the space	Estimate based on [5]
Air change rate	1 air change/hour 10 air changes/hour	Assumption based on ITER [4]
Amount of tritium in LiPb loop	15 g	Assuming half of the mass in the total loop (based on WCLL values in DEMO BB Safety Data List (2MF8KU)) [6]

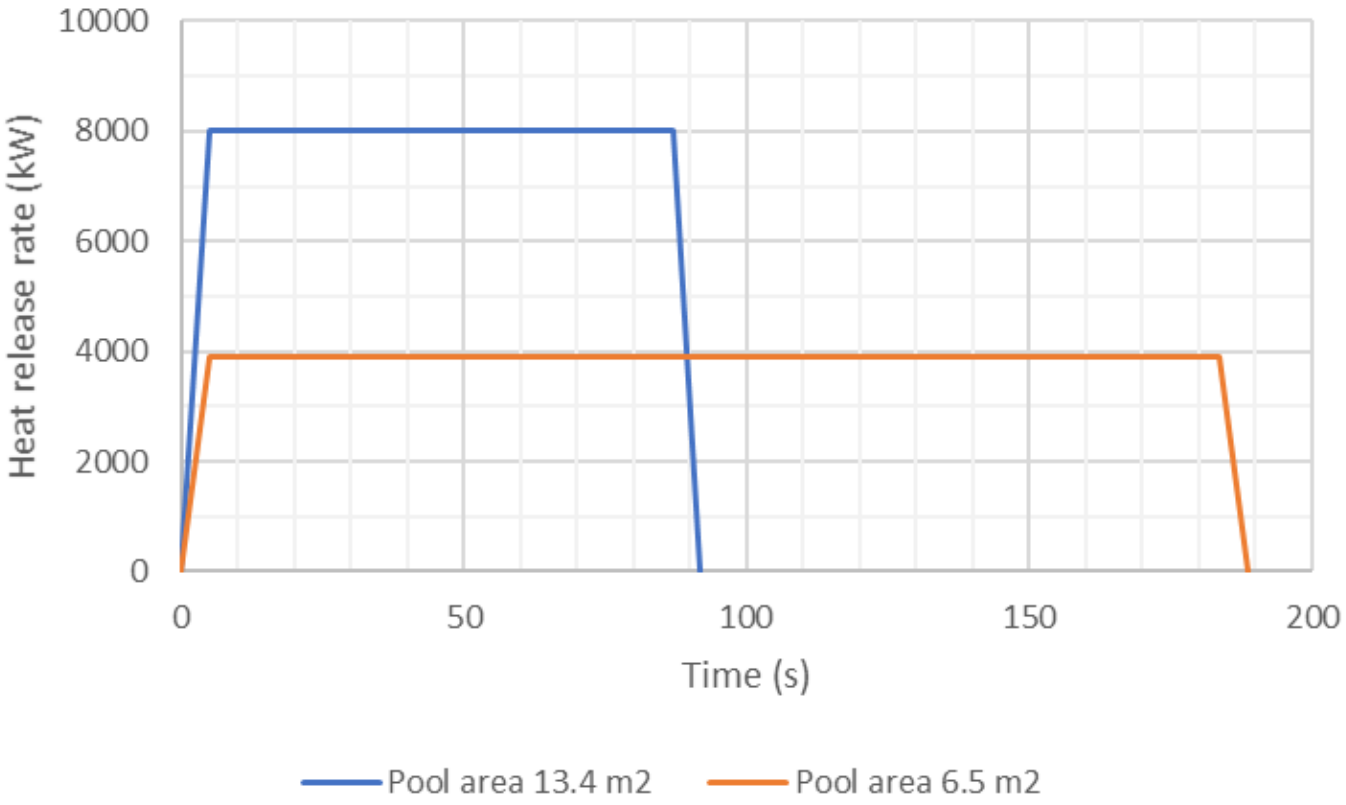
Fire load

- Mechanical pumps: oil
- Vacuum pumps: oil
- Main equipment, other combustibles per equipment
- Lamps: other combustibles
- Lamps: wiring
- Lighting switchboard
- Instrumentation device, incl. wiring
- Transmitters
- Valves: pneumatic supply
- Valves: wiring
- Power and lighting cables
- LiPb in circuit

Estimated fire load:

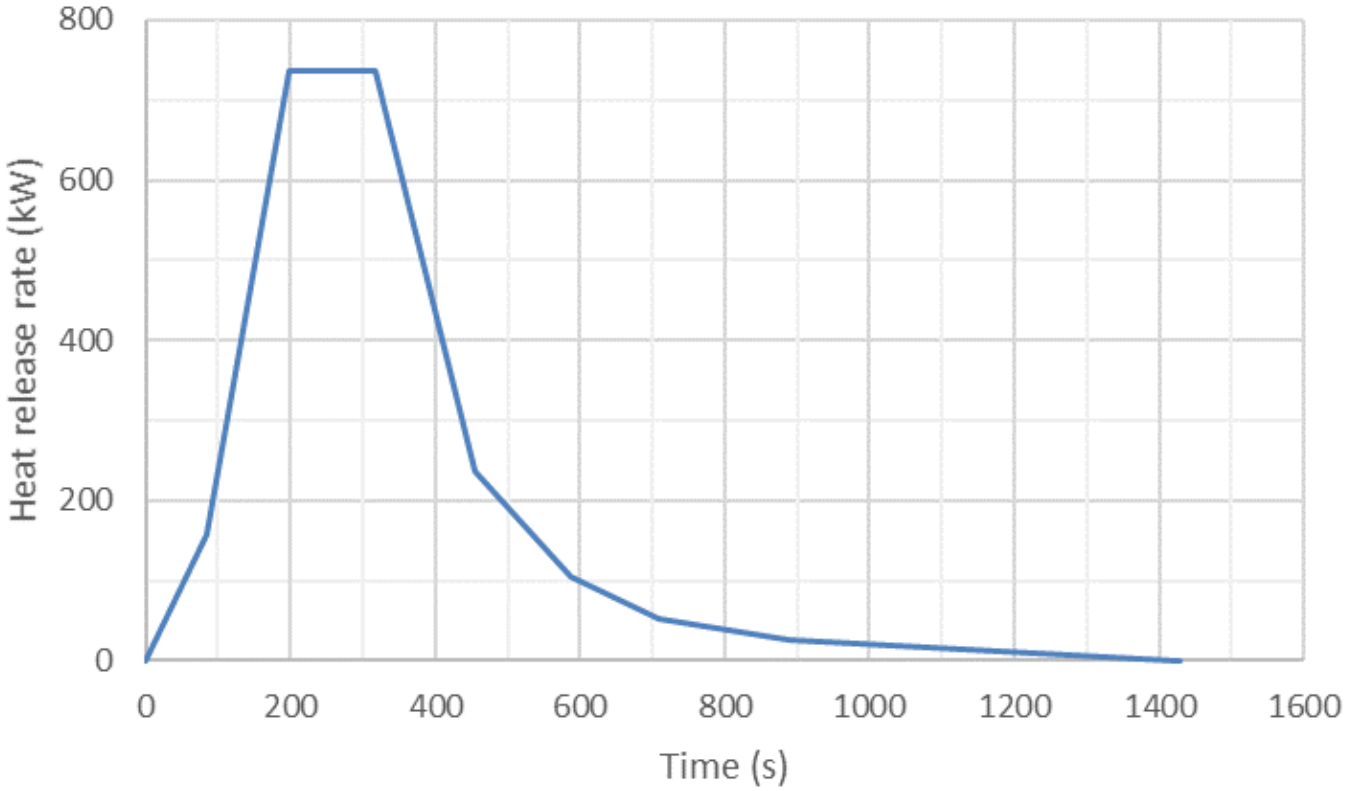
- without LiPb in the circuit 134 MJ/m^2
- LiPb included 240 MJ/m^2

Design fires



Lubrication oil fires without/with efficient spill containment

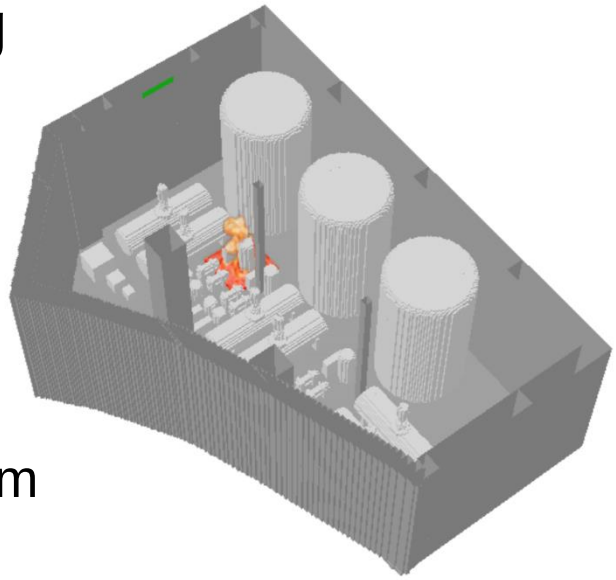
Design fires



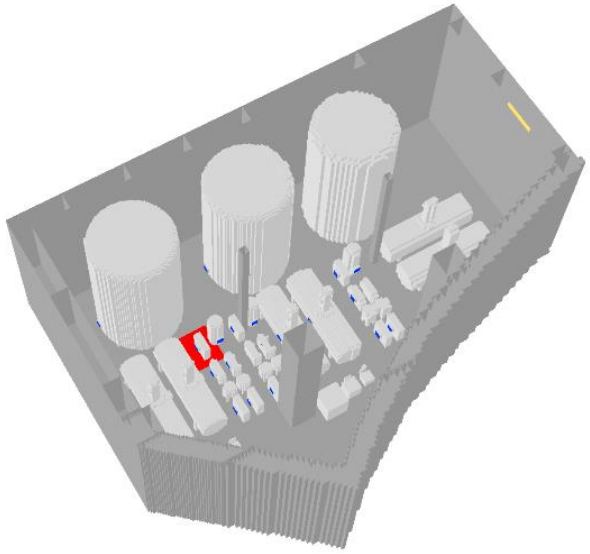
Fire of combustible parts of electrical equipment

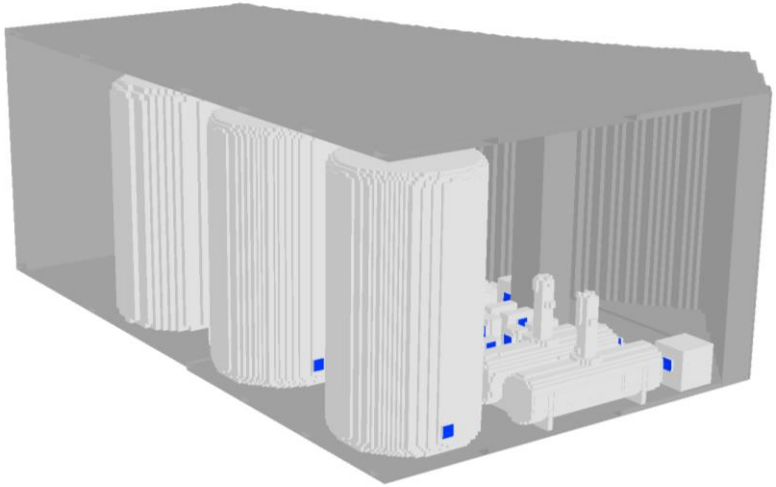
Fire simulations

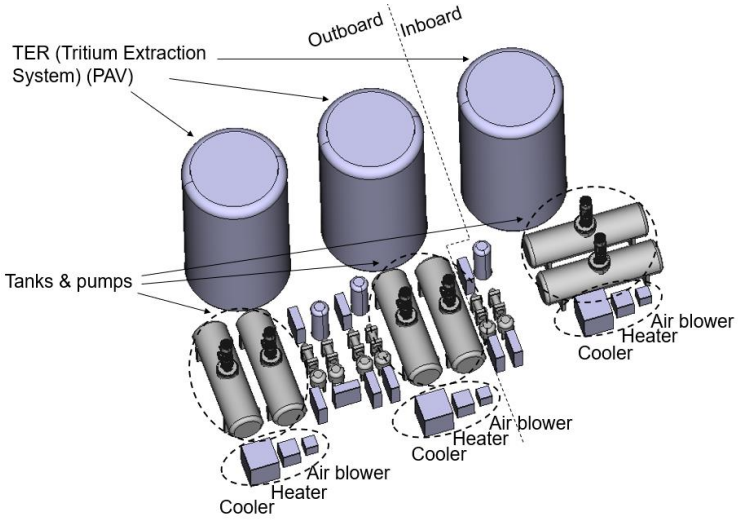
- Simulations with CFD code Fire Dynamics Simulator (FDS)
- Safety risk to equipment, cables, piping etc. assessed based on:
  - Adiabatic surface temperatures of main equipment
  - Radiation received by the equipment
  - Gas temperature in different locations
  - Pressure and gas concentrations in the room
  - Air flows in and out of the room

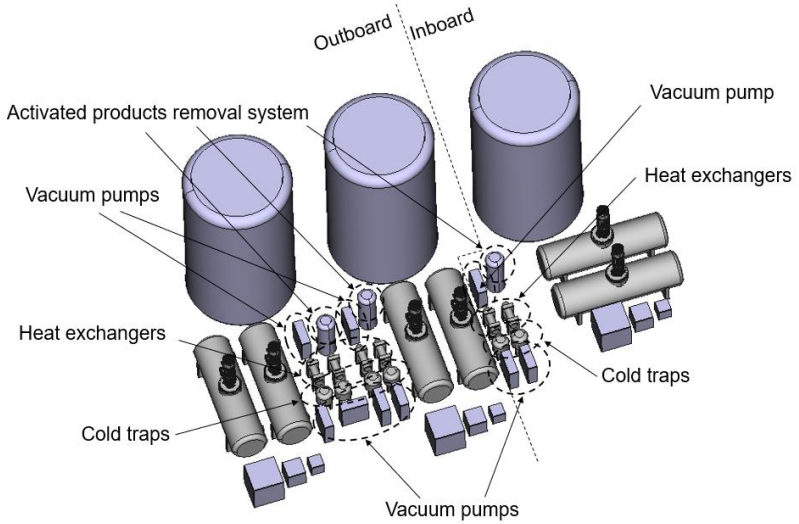


Fire simulation model





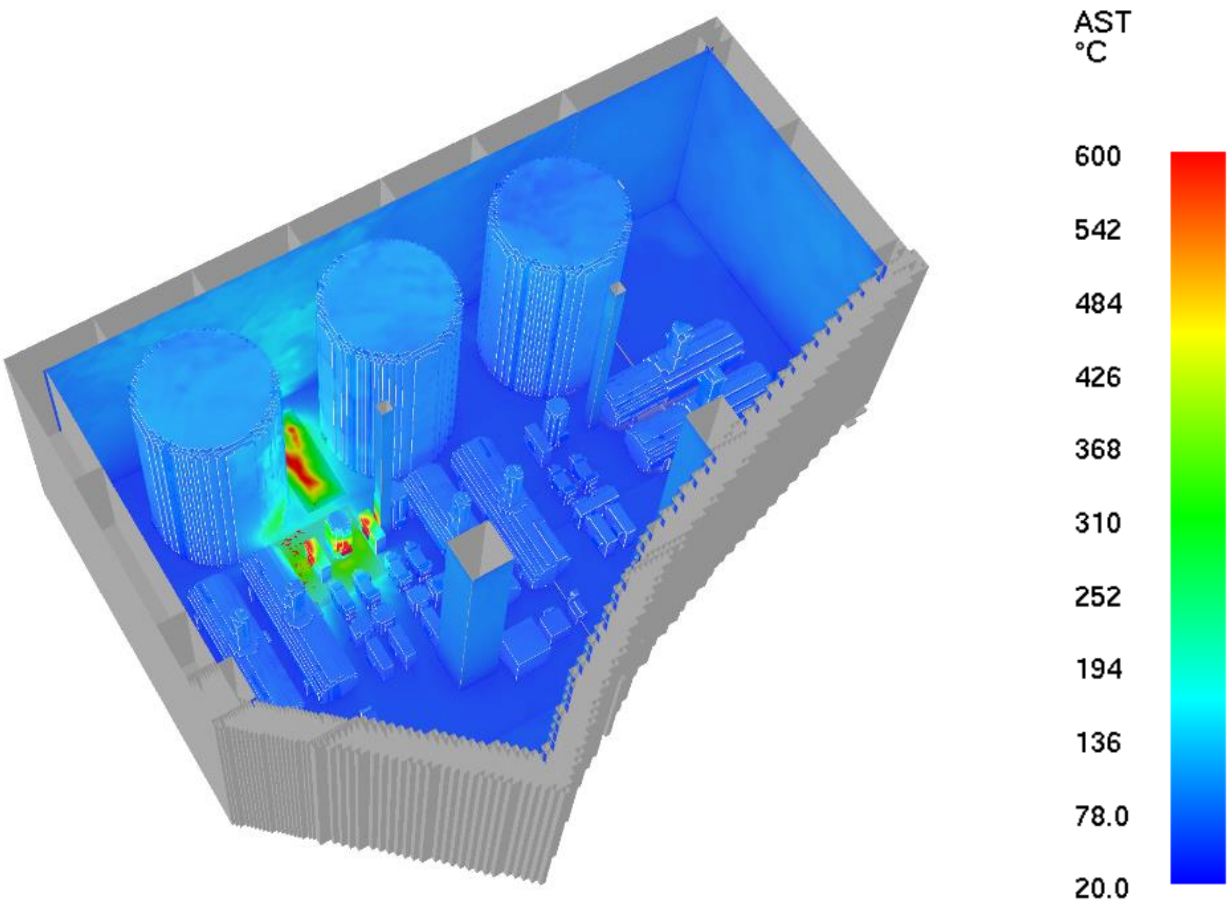




List of fire simulations

Design fire	Ventilation	Note(s)
Electrical equipment	Approx. 1 air change/hour	
Electrical equipment	Approx. 10 air changes/hour	
Small lubrication oil pool	Approx. 1 air change/hour	
Small lubrication oil pool	Approx. 10 air changes/hour	
Large lubrication oil pool	Approx. 1 air change/hour	
Large lubrication oil pool	Approx. 10 air changes/hour	
Large lubrication oil pool	Approx. 1 air change/hour	Damper closure by smoke detector
Large lubrication oil pool	Approx. 10 air changes/hour	Ventilation at constant rate
Large lubrication oil pool	Approx. 1 air change/hour	LiPb circuit rupture postulated

An example of results



Large lubrication oil pool fire with 1 ACPH and LiPb circuit rupture, adiabatic surface temperature at t = 265 s.

Summary of fire simulation results

Simulation scenario	Fire propagation	Damage by fire
Electrical equipment fire, approx. 1 ACPH	Does not occur in the simulation. Probable to any equipment located directly above fire	Severe damage (AST > 300 °C) on the piece of equipment located closest (distance approx. 0.6 m)
Electrical equipment fire, approx. 10 ACPH	Does not occur. Probable to any equipment located directly above fire	Severe damage (AST > 300 °C) on the piece of equipment located closest (distance approx. 0.6 m)
Small lubrication oil pool fire, approx. 1 ACPH	Does not occur. Probable to any equipment located directly above fire	Severe damage (AST > 300 °C) on five pieces of equipment located at oil pool edges
Small lubrication oil pool fire, approx. 10 ACPH	Does not occur. Probable to any equipment located directly above fire	Severe damage (AST > 300 °C) on five pieces of equipment located at oil pool edges
Large lubrication oil pool fire, approx. 1 ACPH	Two equipment located within the oil pool ignited. Probable to any equipment located directly above fire	Severe damage (AST > 300 °C) on twelve pieces of equipment located at oil pool edges
Large lubrication oil pool fire, approx. 10 ACPH	Two equipment located within the oil pool ignited. Probable to any equipment located directly above fire	Severe damage (AST > 300 °C) on twelve pieces of equipment located at oil pool edges
Large lubrication oil pool fire, approx. 1 ACPH, early damper closure	Two equipment located within the oil pool ignited. Probable to any equipment located directly above fire	Severe damage (AST > 300 °C) on twelve pieces of equipment located at oil pool edges
Large lubrication oil pool fire, approx. 10 ACPH, constant rate ventilation	Two equipment located within the oil pool ignited. Probable to any equipment located directly above fire	Severe damage (AST > 300 °C) on twelve pieces of equipment located at oil pool edges
Large lubrication oil pool fire, approx. 1 ACPH, LiPb circuit rupture	Two equipment located within the oil pool ignited. Probable to any equipment located directly above fire	Severe damage (AST > 300 °C) on twelve pieces of equipment located at oil pool edges and two pieces of equipment located near the LiPb pool

Conclusions

- The fire safety of the LiPb component room is considered to be on acceptable level.
- A fire originating in the room is likely to propagate to or damage only equipment which are located relatively close to the fire origin, the exact distance depending on the size of the fire.
- Elsewhere than directly above the fire, the gas temperature is probably not high enough to cause ignition or severe damage.
- The pressure increase in the room is dependent on the capacity and behaviour of the ventilation system.
- NB! The available specifications are on very early stage, and many assumptions had to be made. The scenarios should be reassessed, when more accurate and detailed information is available.

Thank you for your attention!
Questions or comments?