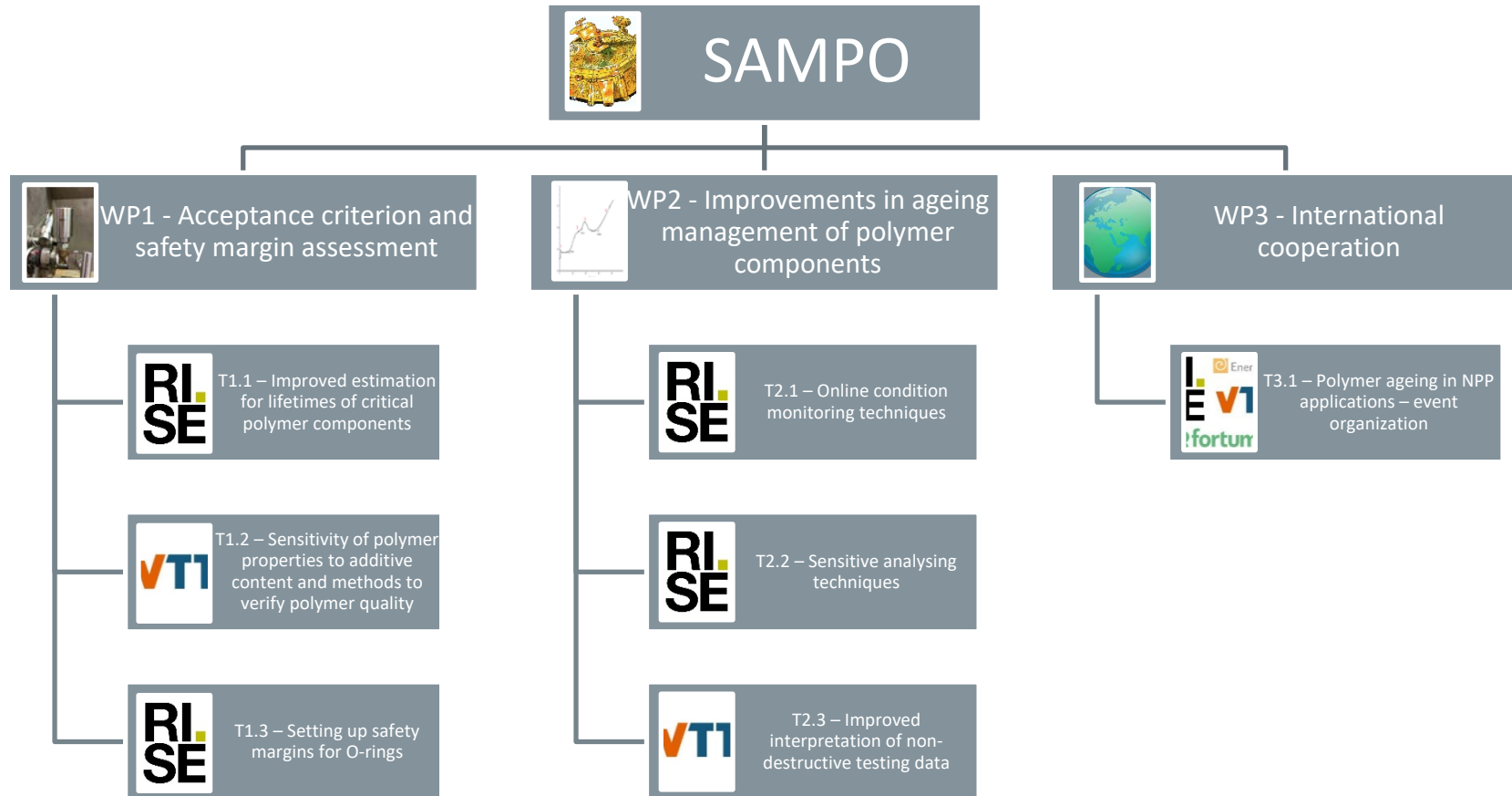


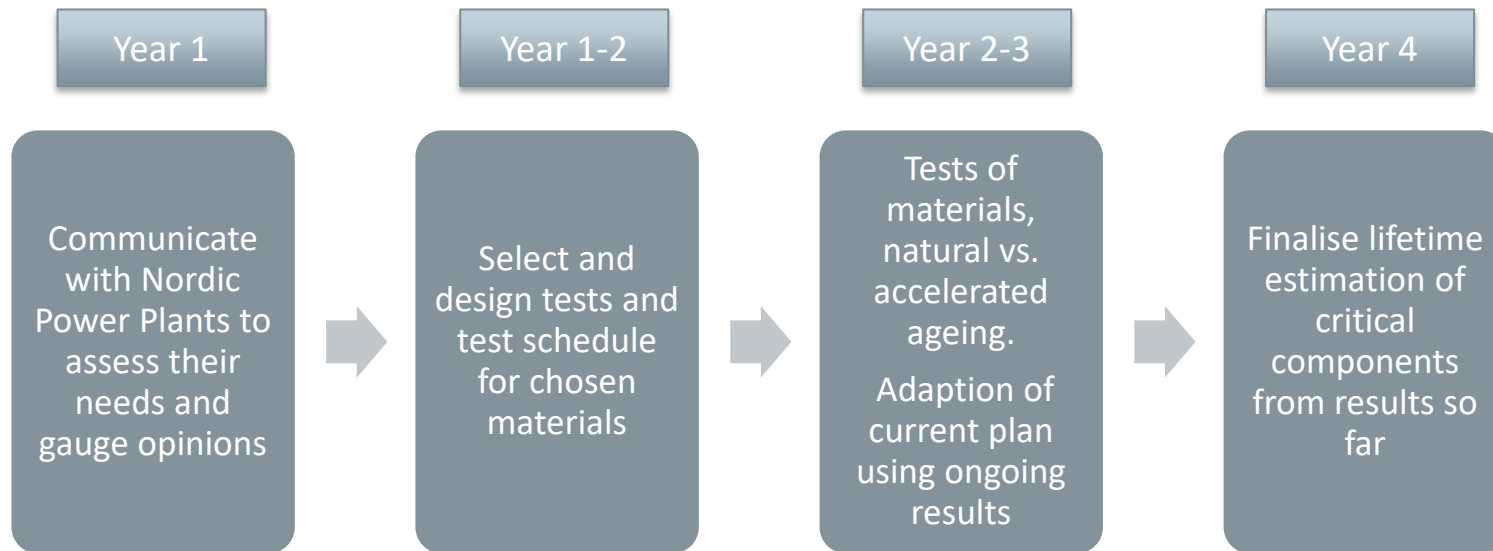
# **SAMPO - Safety criteria and improved ageing management research for polymer components exposed to thermal- radiative environments**

**Konsta Sipilä and Jason Ryan**

**Polymers in nuclear applications  
2019, Espoo, Finland 27.11.19**



# WP1 - T1.1 Improved estimation for lifetimes of critical polymer components (RISE)

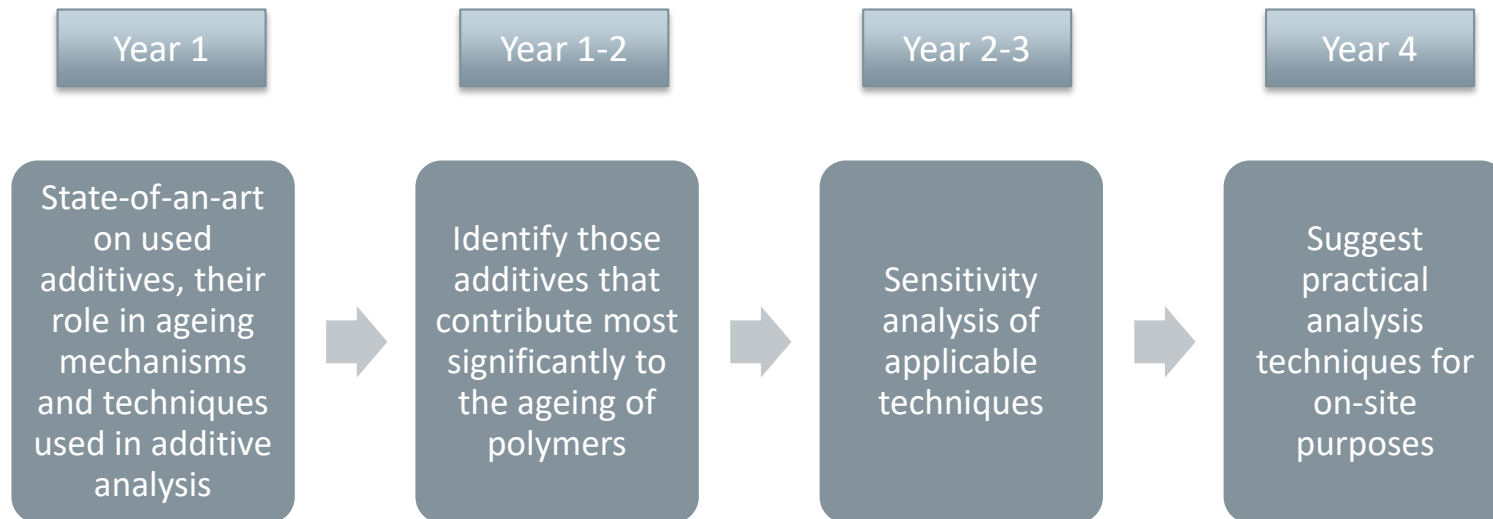


# WP1 - T1.1 Improved estimation for lifetimes of critical polymer components (RISE)

## Ringhals summary

- Cables:
  - New cables are being used (Ringhals – Nexam). More information is needed, so far knowledge is they are polyolefin and indent measurements work poorly.
  - PVC cables exist still in Ringhals 2 and would be interesting to analyse once available (R3 & R4 however have the new cables already).
- Membranes:
  - Changed relatively often – material is available to be tested at RISE.
  - Membranes more interesting than o-rings – more critical towards crisis situations.
  - Specifically, the membrane reinforcement exists as the more vulnerable part of the membranes.
- Loss of coolant accident (LOCA)
  - Materials need to be tested to LOCA specification – can be done on some already naturally aged materials from Ringhals and accelerated aged materials.

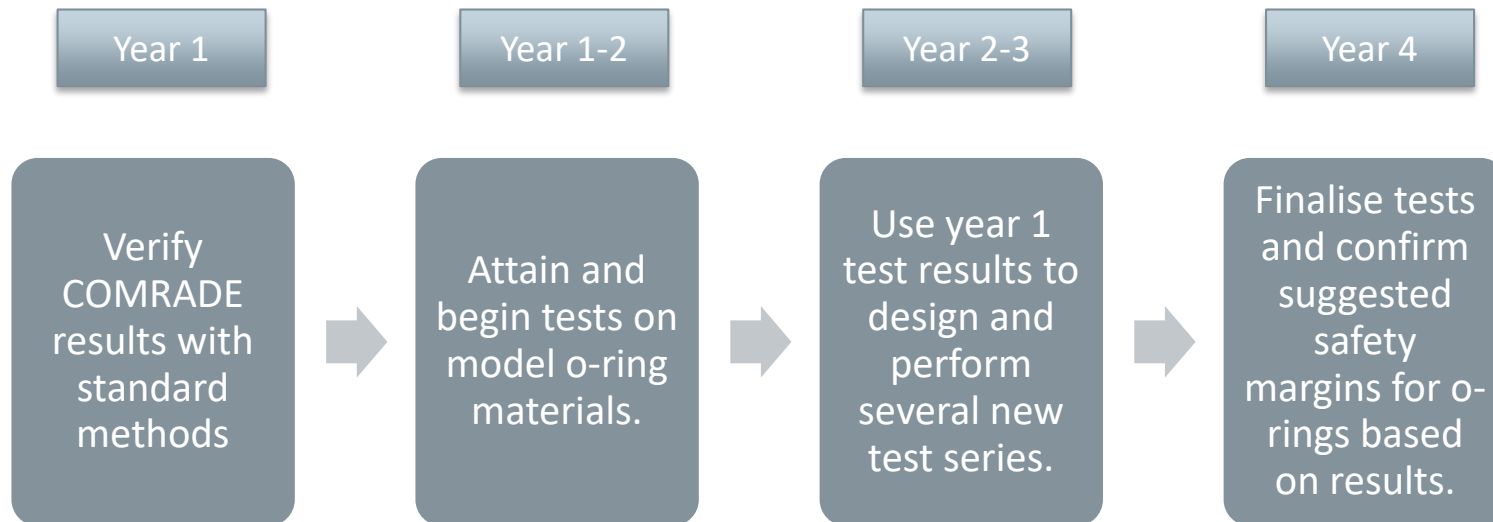
# WP1 - T1.2 Sensitivity of polymer properties to additive content and methods to verify polymer quality (VTT)



# WP1 - T1.2 Sensitivity of polymer properties to additive content and methods to verify polymer quality

- Additives can be categorized in several ways, e.g. additives used in processing, improving mechanical, chemical, surface or visual properties etc.
- Which additives contribute into the ageing process?
  - The observed effects of ageing on the macroscopic level is typically due to the degradation of the polymer backbone
  - The role of antioxidants
  - Loss of plasticisers (mostly PVC but also some elastomers)
  - Defluorination and dechlorination
- Different analysis techniques can be categorized to be
  - Chromatographic (sample preparation)
  - Organic mass-spectrometry
  - Spectroscopic (UV, IR, LS, NMR)
  - Elemental analysis

# WP1 - T1.3 Setting up safety margins for o-rings (RISE)

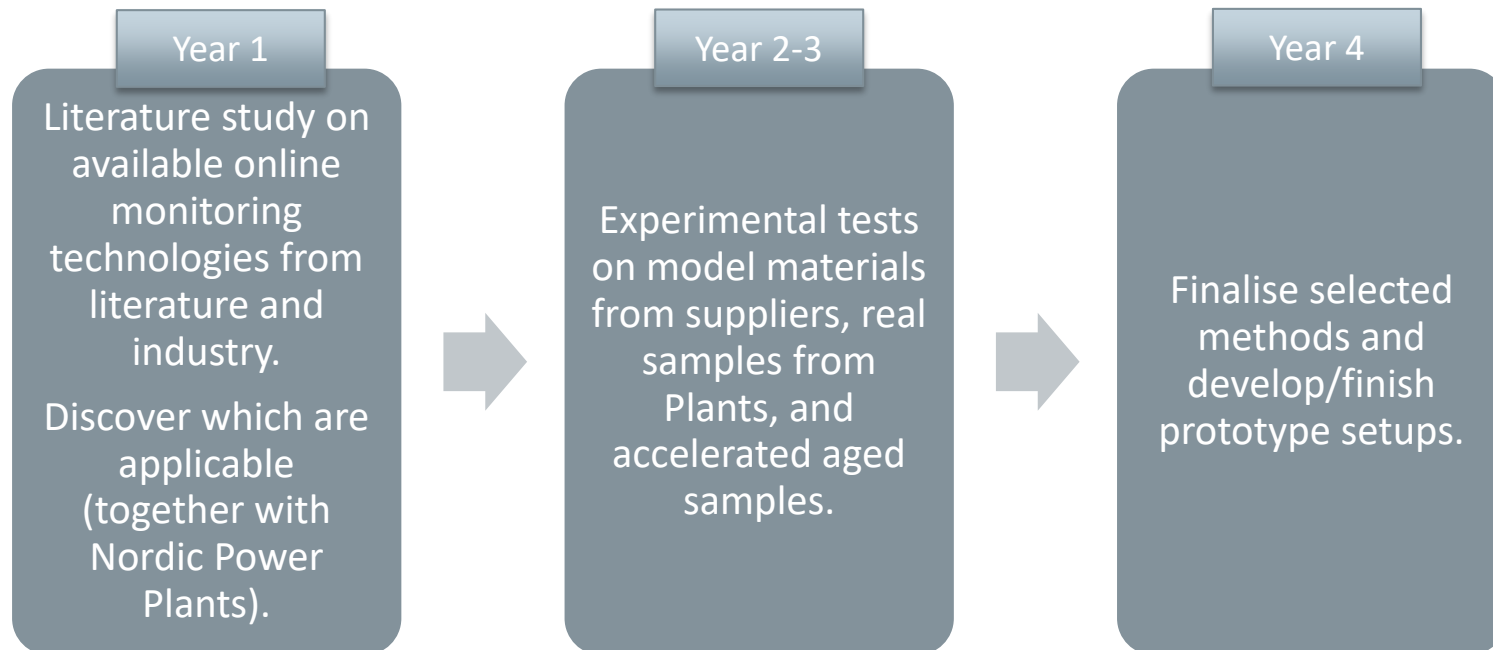


# WP1 - T1.3 Setting up safety margins for o-rings (RISE)

- O-rings:
  - COMRADE repeat tests are soon finished (Mid-December). Results will be compared to non-standardised test methods.
  - 'Disturbed' COMRADE materials are being standardised tested also.
  - Model 'bad' o-ring material is being set up to be tested, sheets arrive soon (for standardised compression-set tests). – previous COMRADE o-rings tended to not fail under any circumstance, model 'bad' material will allow the current test applicability to be confirmed.



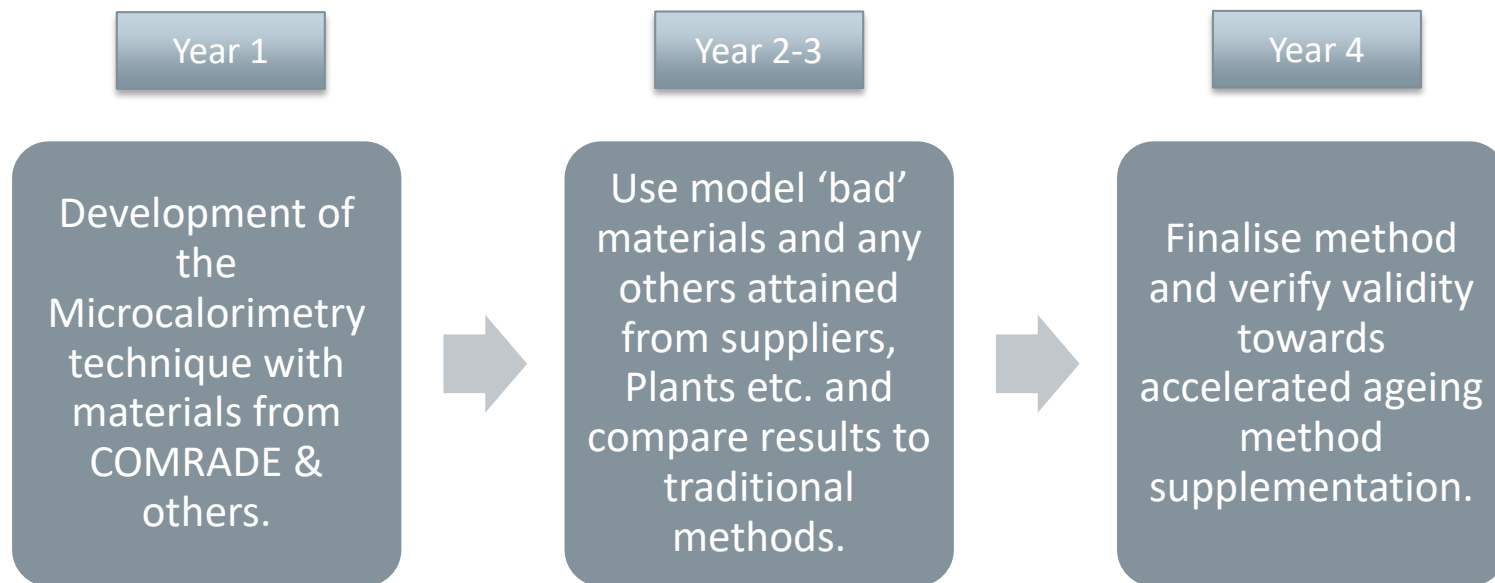
## WP2 - T2.1 Online condition monitoring (RISE)



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- Literature study:
  - In the mature stages of completion – several methods have been identified. Henrik will discuss this further in his talk.
- Ringhals technical discussion highlights:
  - Antenna sensors – properties change with ageing, RFID tags could be used for membranes.
  - Electric-length (LIRA) – already used to find hotspots, long cable lengths required.

## WP2 – T2.2 Sensitive analysing techniques (RISE)



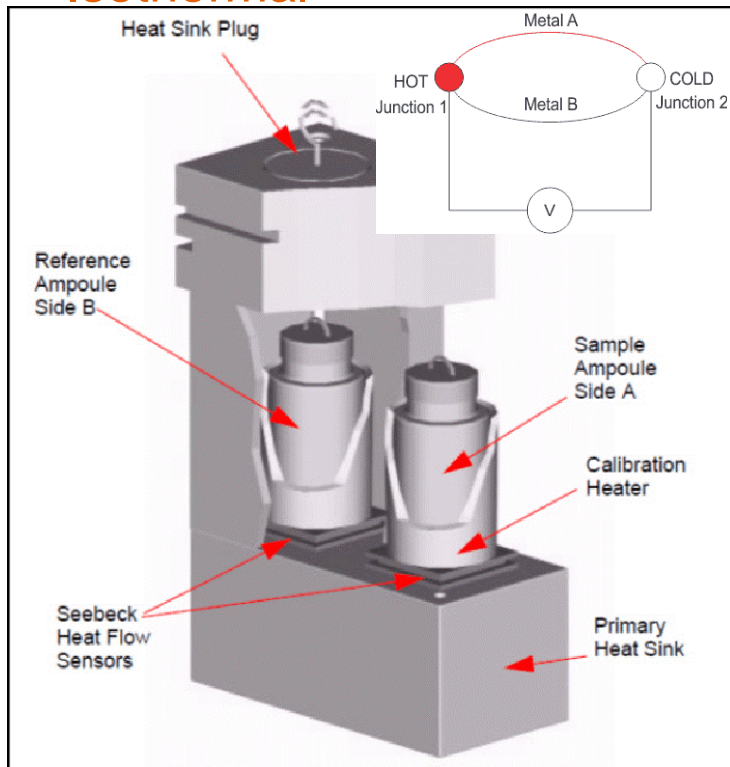
## WP2 – T2.2 Sensitive analysing techniques (RISE)

- Microcalorimetry:
  - Essentially differential scanning calorimetry (DSC) but far more sensitive.
  - Intended to detect degradation in materials via heat transfer (enthalpy).
  - Intended to analyse at closer to real-life operating temperatures for materials.
- Current work:
  - Several materials have been/are being analysed. Validity looks promising with degradation seemingly present. However, more work needs to be done to assure truth to data.
  - Temperature ranges are being screened to see if would have an affect on proposed lifetimes.

# WP2 – T2.2 Sensitive analysing techniques (RISE)

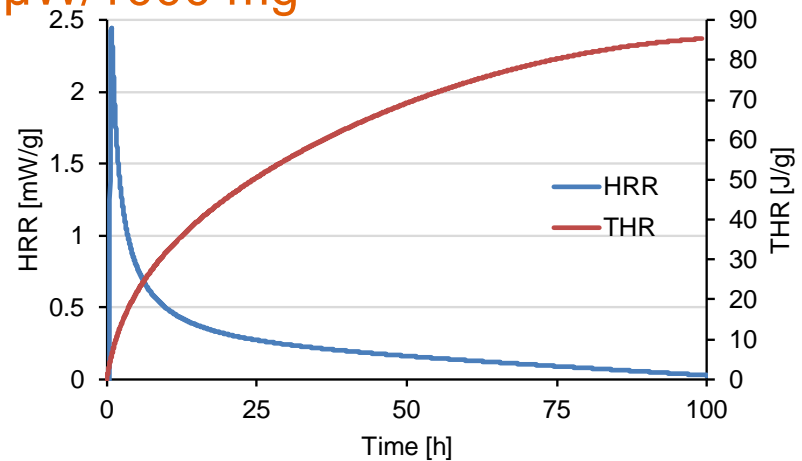
## Methodology

### Isothermal



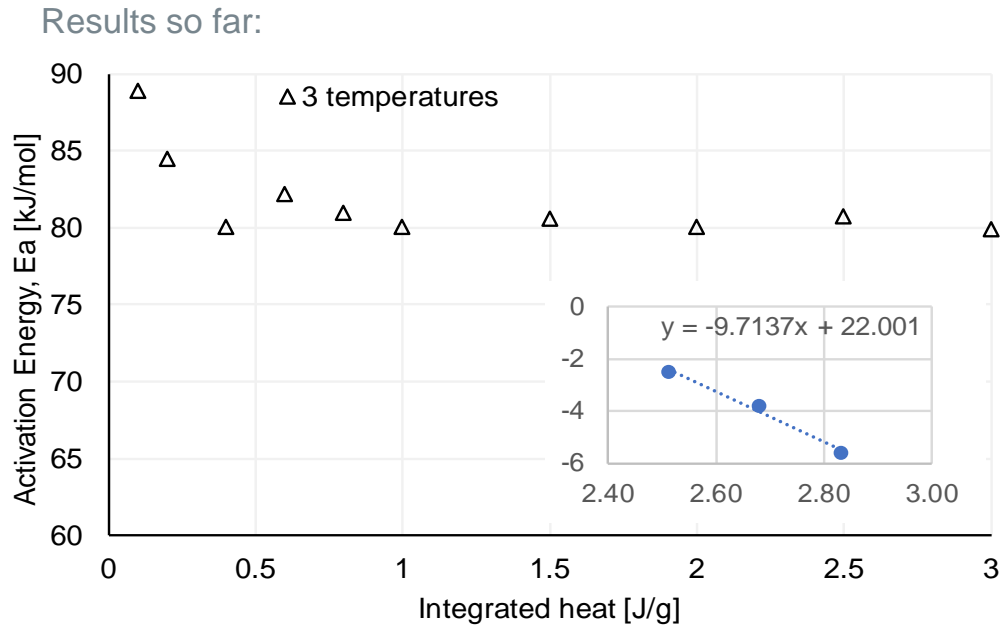
Specific sensitivity ~ 1000 times higher than DSC

DSC ~ 40  $\mu\text{W}/\text{mg}$  and IMC ~ 4  $\mu\text{W}/1000 \text{ mg}$



Normalised heat flow (mW/g) and Integrated heat (J/g) signal using IMC

# WP2 – T2.2 Sensitive analysing techniques (RISE)

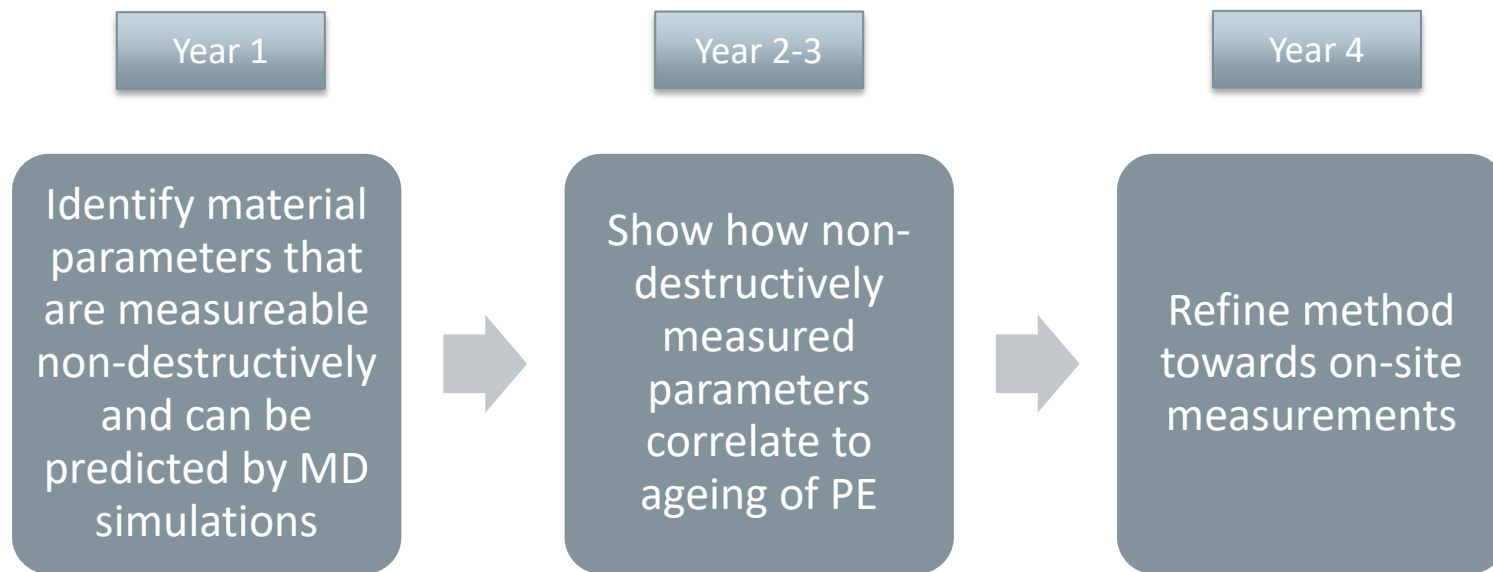


Property	Activation energy*
Elongation	103 kJ/mol
Compression set	94 kJ/mol

\*From COMRADE final report

Activation energy calculated based on the IMC measurements on EPDM conducted at 3 (80, 100, 125 °C) different temperatures.

## WP2 - T2.3 Improved interpretation of non-destructive testing data (VTT)



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Technique	Measured parameter	Applicability with MD simulations
DSC	Reaction enthalpy, specific heat capacity	Easy to moderate
IR/Raman spectroscopy	Vibrational movement of functional groups	Hard
NMR	Relaxation time (phase composition and dynamics of polymer chains)	Moderate to hard
Ultrasonic	E, $\sigma$ , and $\rho$	Easy
Dielectric spectroscopy	Permittivity, dielectric loss	Easy to moderate



## WP2 - T2.3 Improved interpretation of non-destructive testing data (VTT)

- DSC and ultrasound techniques to be further analysed
  - Reaction enthalpy can be used to determine crystallinity degree which correlates with ageing
  - Young's modulus changes as function of ageing
- Determination of crystallinity degree and Young's modulus as function of ageing (experimentally and MD calculations)
- Correlation between the degradation of the polymer chain and macroscopically (and non-destructively) measured material parameter (crystallinity degree and Young's modulus)

## WP3 – International cooperation

- Improve information exchange between between researchers, power plants, material manufacturers and regulators
- Event organization since 2016→



# bey<sup>0</sup>nd

## the obvious

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