CATAPULT Offshore Renewable Energy

AiRE

Combined weathering and erosion studies on LEP materials

Stephen Jones

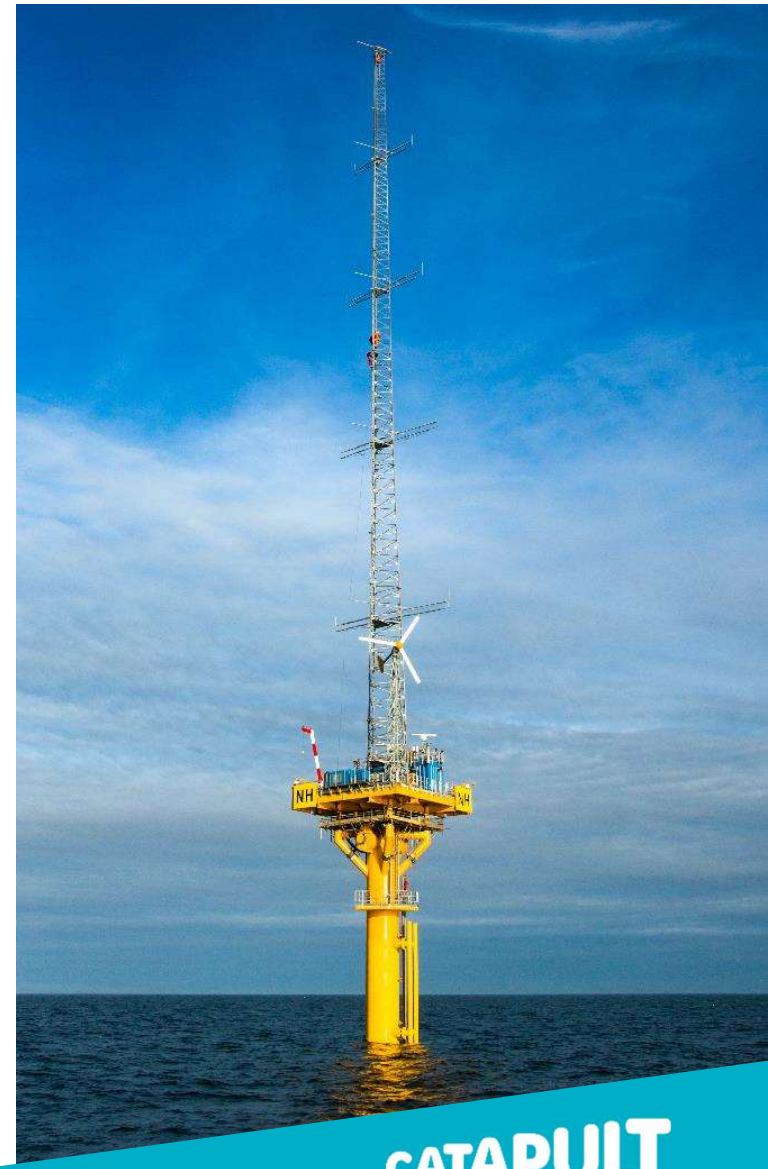
7th International Symposium on Leading Edge Erosion and Protection of Wind Turbine Blades

4th February 2026

Credit: Equinor Hywind Floating Offshore Wind Farm

Agenda

- Research motivation
- Methodology
- Preliminary results
- Next steps and take-home messages



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AIRE project (2023-2026)

AIRE European Commission

Collaborative research project to study the impact of climate conditions upon wind turbine performance

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Combined weathering/erosion test method development

Environmental analysis of wind turbine sites

Development of erosion validation models

LEP product trials at Levenmouth Demonstration Turbine

TEST TO TURBINE VALIDATION OF LEE

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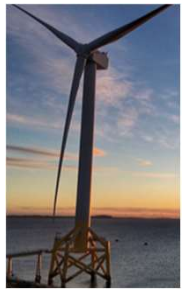
Realistic rain erosion testing

Blade rotational speed

- Wind turbine specification
  - Blade length



Environmental conditions

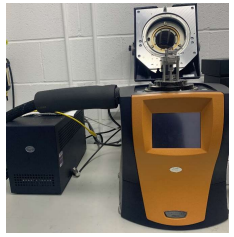
- UV irradiation
- Temperature
- Relative humidity

Application method and period

- Rate and extent of curing

Thermomechanical properties

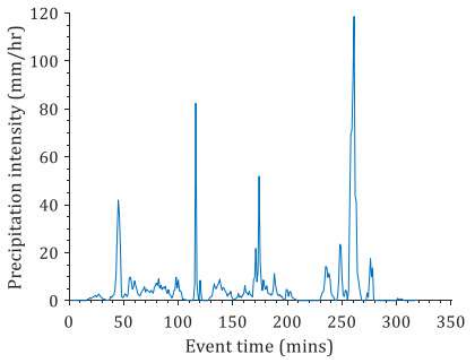
- Material composition
- Viscoelastic response



Turbine/site variables → **Realistic rain erosion test** ← **Material properties**

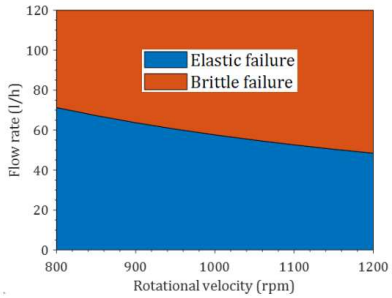
Rainfall intensity and sequencing

- Significance of 'extreme' rainfall events and low intensity periods?



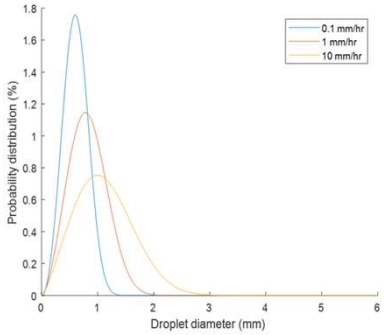
Rainfall variables

Droplet impact frequency



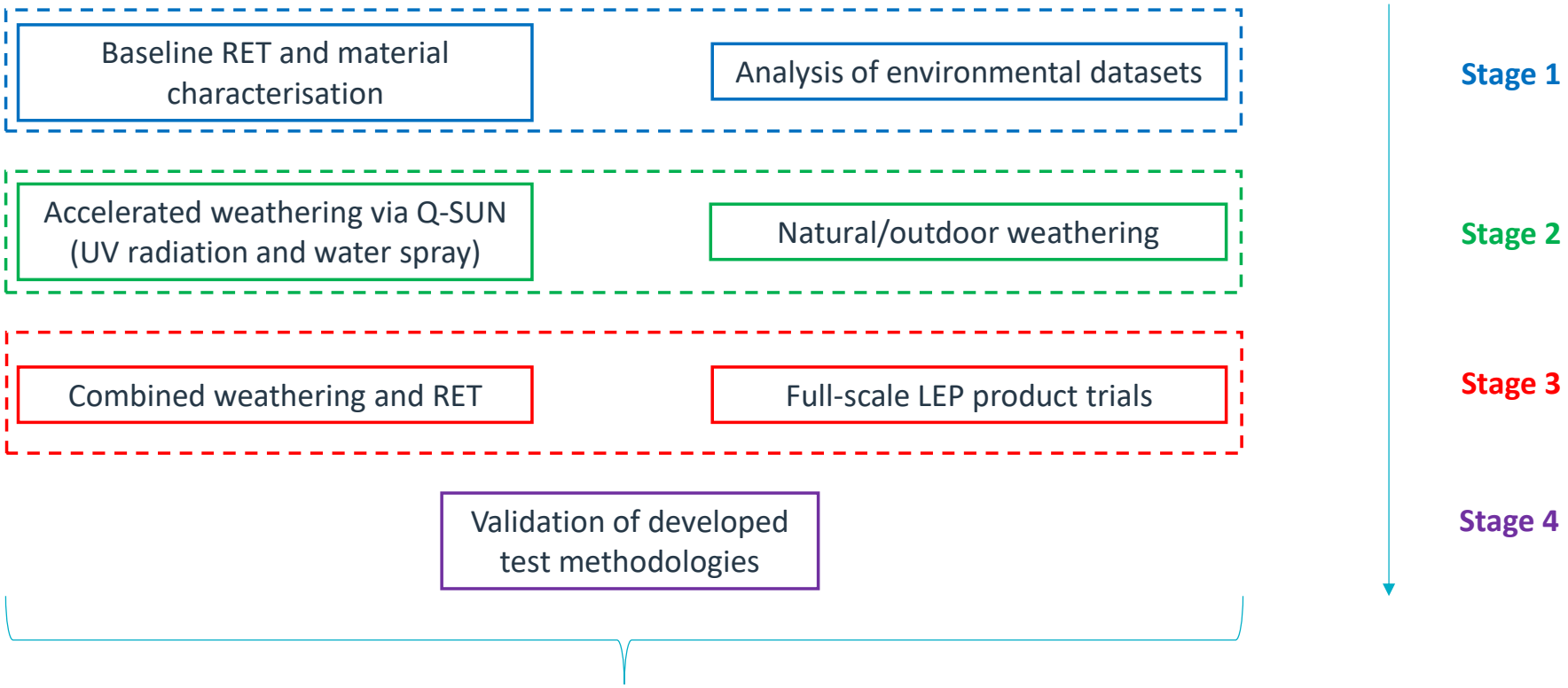
- Effect on rate of erosion and failure mode

Droplet size and distribution



P. Kinsley *et al.*, *Wind*, **5**, 2025. 3.
E. Cortes *et al.*, *AIP Conference Proceedings*, **1896**, 2017.

Methodology



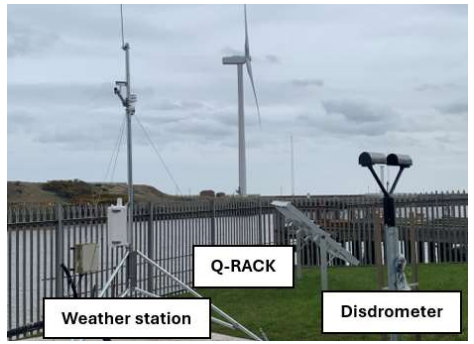
Key features of test programme

RET

- Coated leading edge test specimens using R&D A/S Rain Erosion Tester.
- Multiple LEP formulations – effect of formulation and chemical functionality.

Natural/outdoor weathering

- Flat panel test specimens at Blyth, UK.
- Weather station and disdrometer to obtain primary environmental data.



Accelerated weathering

- Flat panel and coated leading edge test specimens using Q-SUN Xe-1 equipment.
- Using existing (ISO) and developed test methods based on Koppen climate systems – effect of UV radiation, temperature and relative humidity.

Turbine trials

- Turbine trials of LEP products performed at 7 MW Levenmouth Demonstration Turbine (LDT) in SE Scotland, UK.
- On-site weathering station – additional environmental data.

Material property-erosion correlations

- Previous LEE symposium presentation (2023) and publication introduced literature correlations between LEP material properties and rain erosion resistance:

Minimise	Maximise
Ultimate tensile strength	Elongation to break
Polymer crystallinity	Tan δ
Storage modulus	Loss modulus
Glass transition temperature	Short-term recovery

- Aim to monitor material properties before/after weathering to develop understanding of weathering mechanisms and impact upon RET.

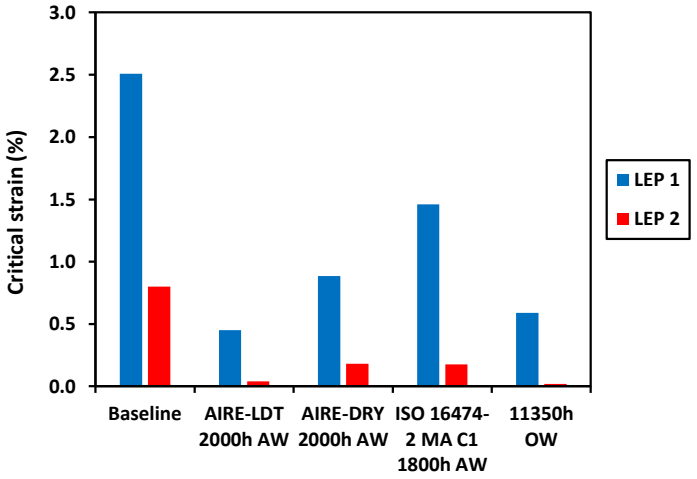
S. Jones *et al.*, *Coatings*, **13**, 2023, 1849.

Weathering of LEP materials

- Observe significant changes in material properties based on weathering type (accelerated vs. outdoor) and type of test method (changes in weathering parameters):

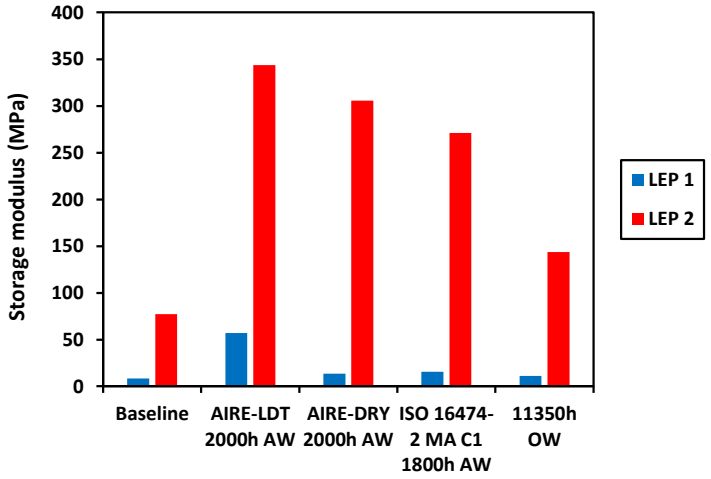
Critical strain

Reduction in value for strain at which irreversible damage occurs



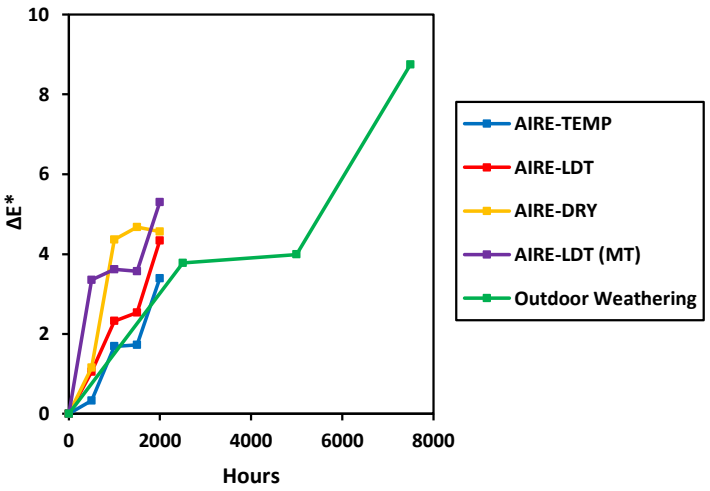
Storage modulus

Increase in stiffness



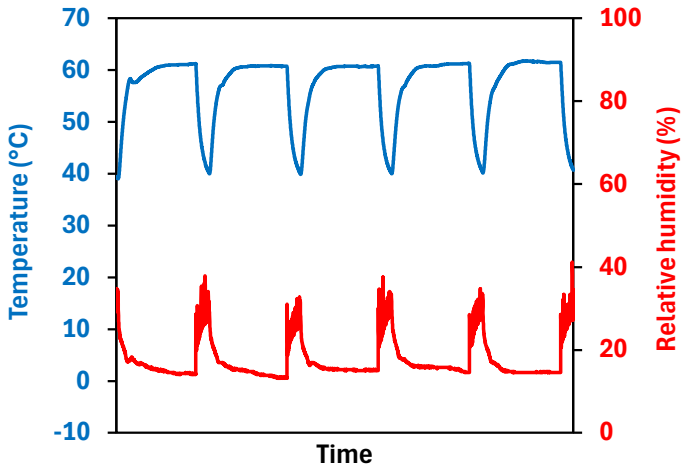
Change in colour

Indication of polymer degradation



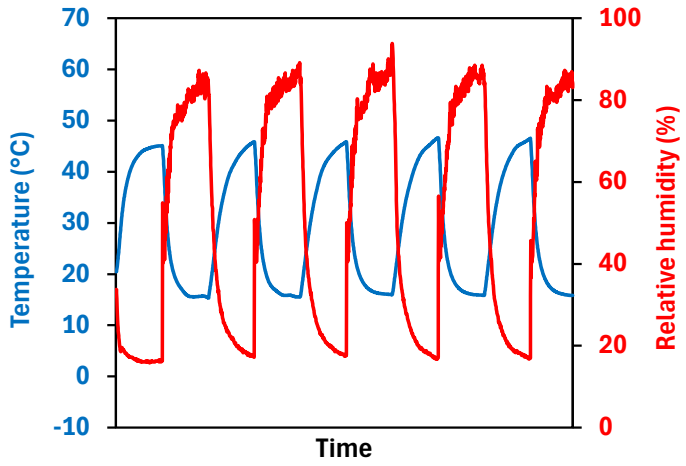
Variability in weathering methods

ISO 16474-2 (AW)



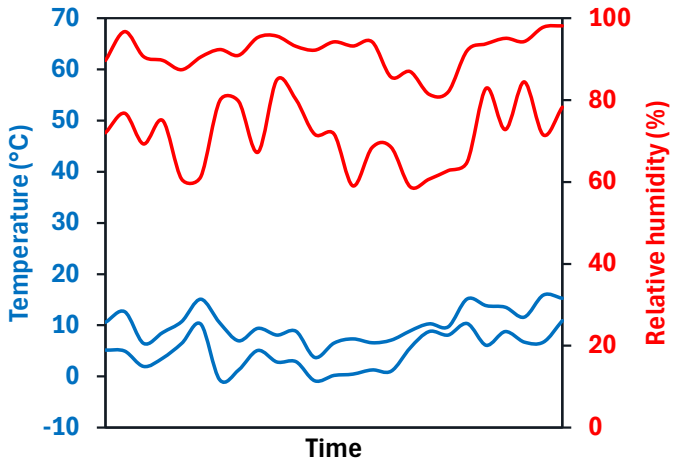
High temp. = 40-60 °C
Low RH = 15-30%

AIRE-LDT (AW)



Medium temp. = 15-45 °C
High RH range = 15-90%

Blyth (OW – Example)

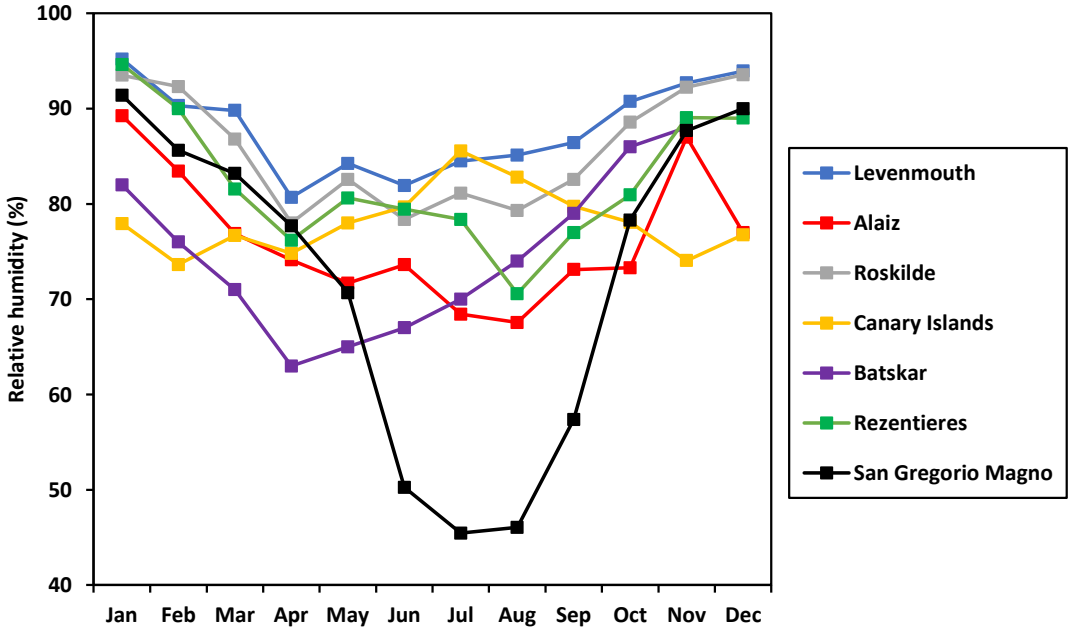


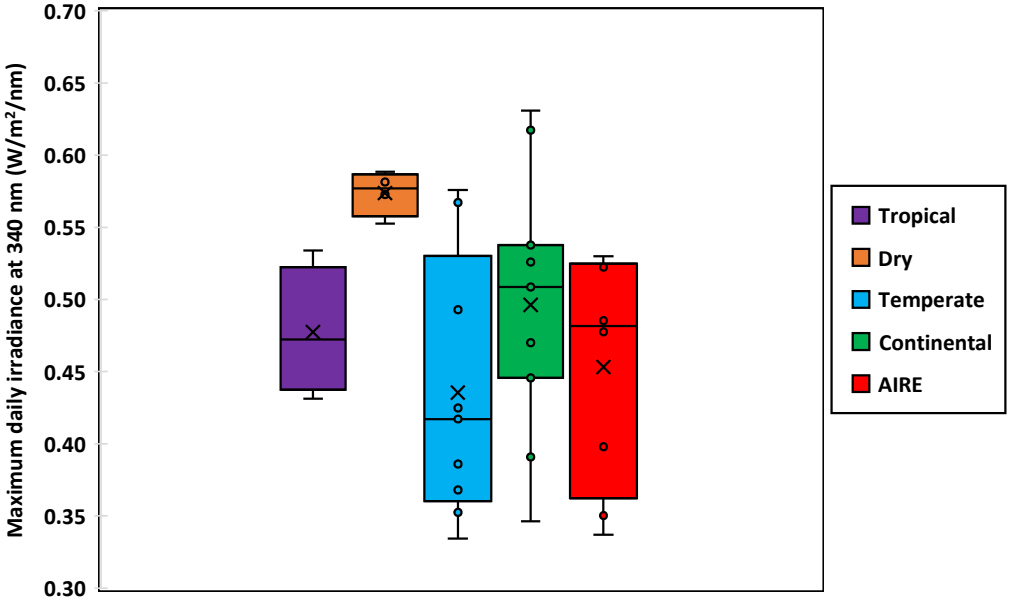
Low temp. = 0-15 °C
High RH = 60-100%

AW = Accelerated weathering
OW = Outdoor weathering
RH = Relative humidity

Importance of site location

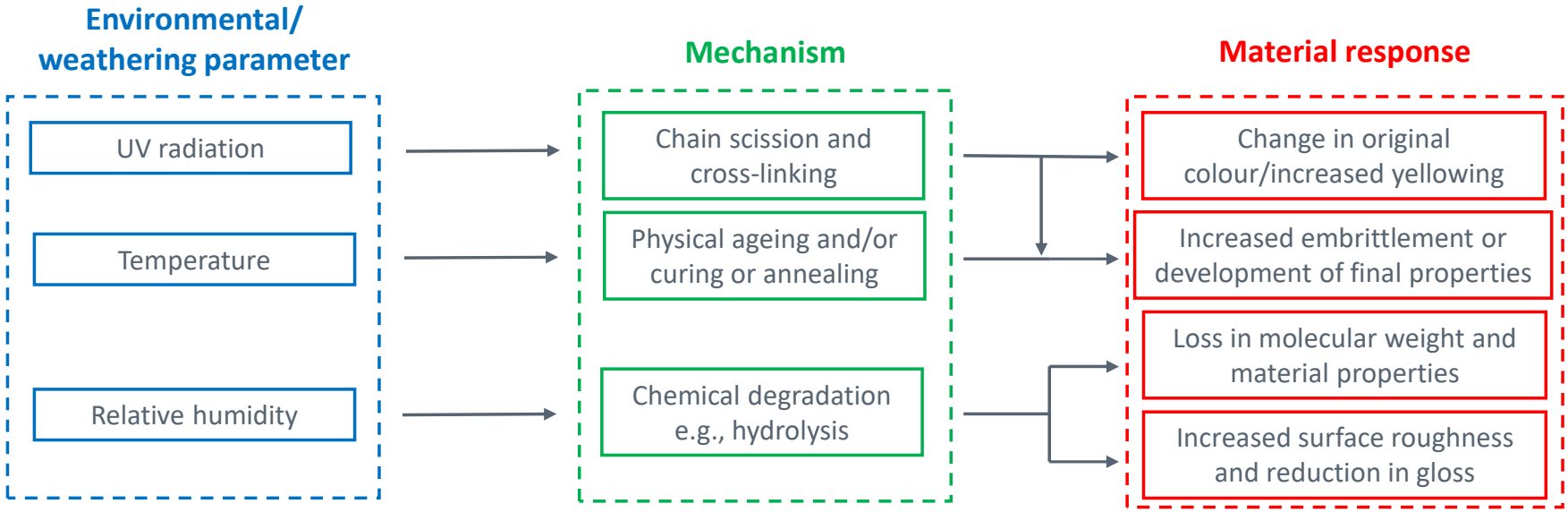
- Large variation in environmental conditions e.g., range in RH and max. daily irradiance, also expected depending on location of wind turbine – in both AIRE project and beyond.





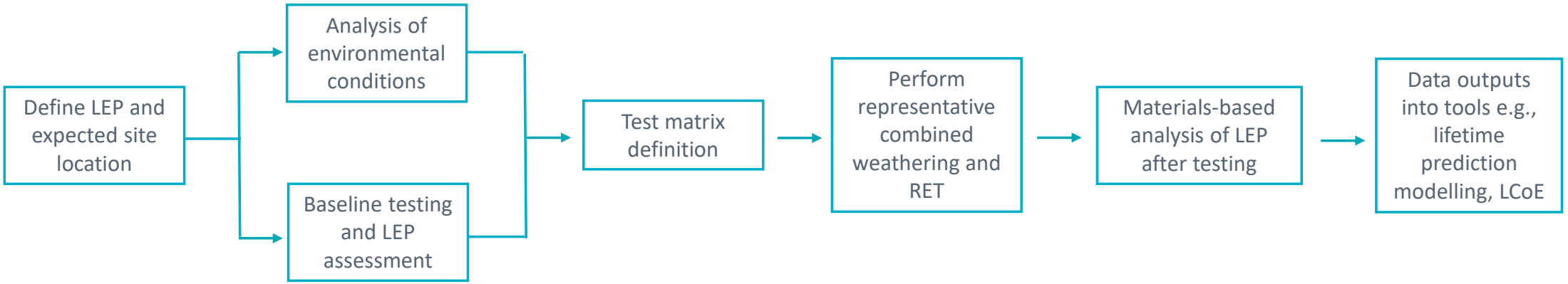
LEP material responses

- All material changes may be dependent on LEP formulation type and extent of cure after product application.
- Analysis of material properties before/after weathering enables development of example cause and effect diagrams based on environmental/weathering parameter and their relative impact upon material properties:



Next steps

- **Perform realistic combined weathering and RET** and link results to LEE model and tool development in AIRE project.
- Develop flowchart/matrix that both provides **appropriate test methods for qualification testing of LEP materials** and a **quantitative assessment of weathering for LEP solutions**.



Take home messages

- The rate of weathering for LEP products is **significantly affected** by changes in environmental conditions and product formulation type.

- Current test standards for accelerated weathering **may therefore be limited in their ability** to determine the effect of weathering for different site locations.

- **LEP material properties will change** throughout a product lifetime in-service and therefore affect rain erosion resistance.

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