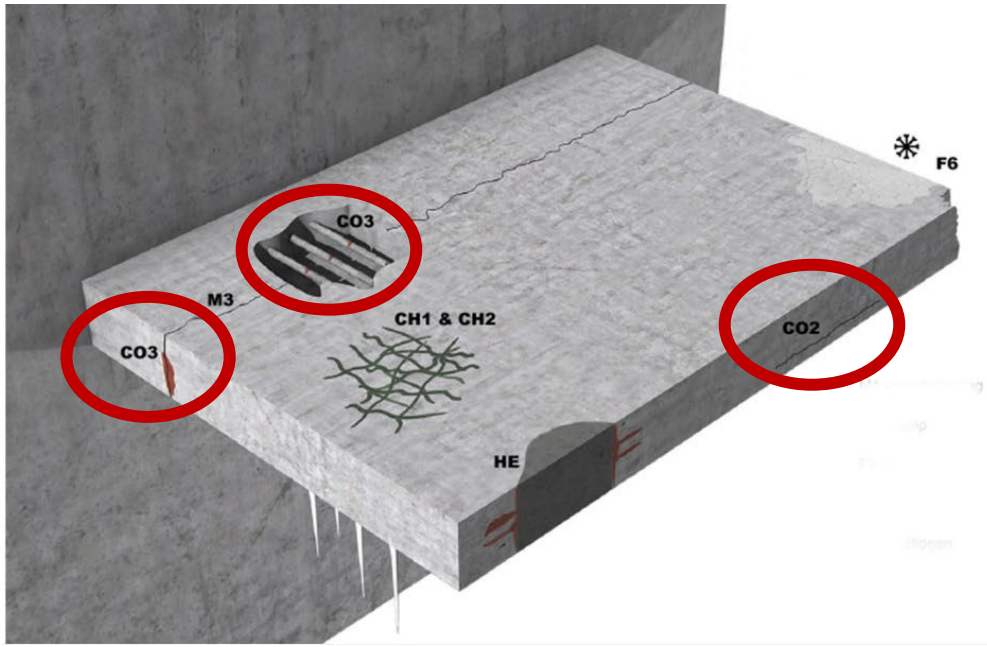
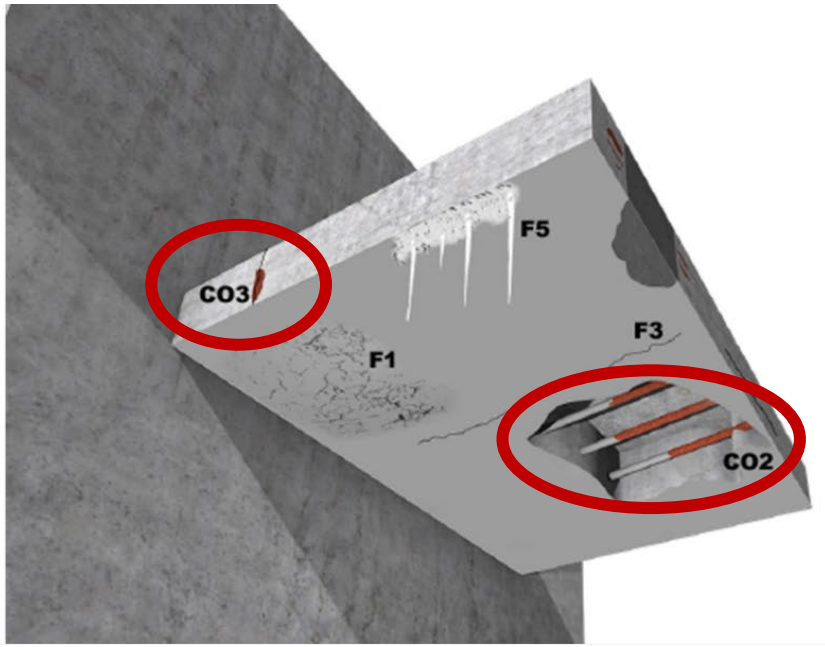
EMIB
Energy & Materials in Infrastructure & Buildings
University of Antwerp

The **environmental impact** of service life-extending **repair** for **corrosion damaged reinforced concrete balconies**: a case study in a **coastal** context

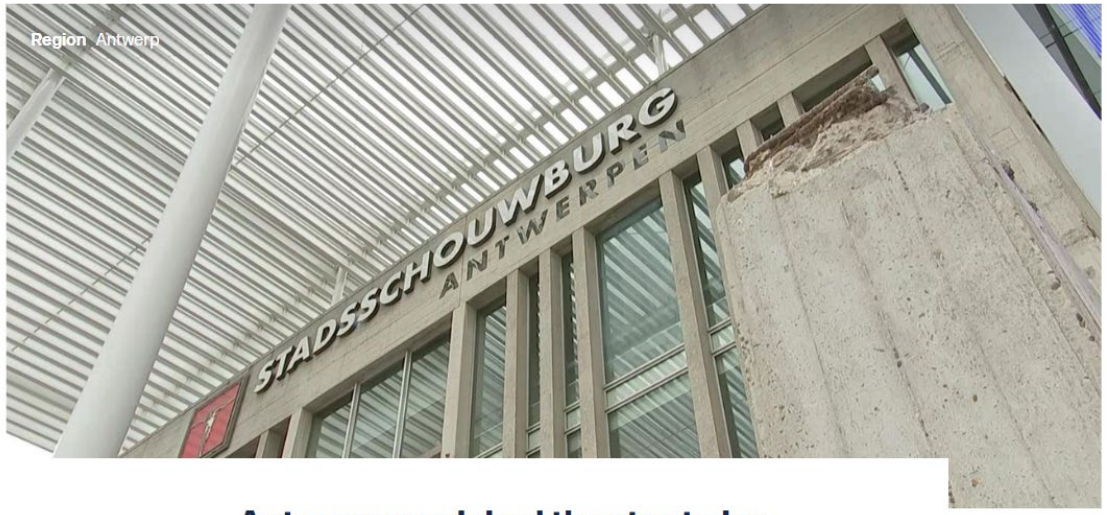
Neel Renne, Bart Craeye, Matthias Buyle and Amaryllis Audenaert





Four killed after balcony collapses during housewarming party in France

Terrace terror as concrete balcony falls off Beijing apartment building

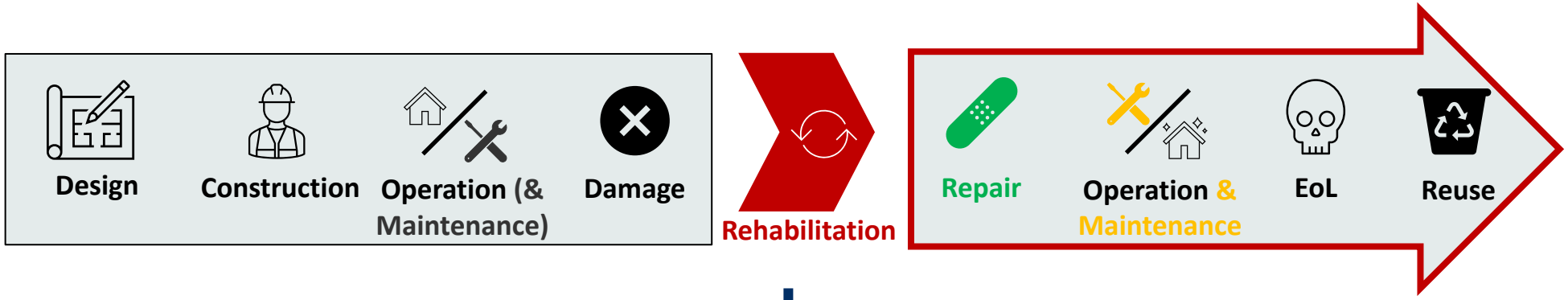


Antwerp municipal theatre to be demolished

Mon 16 May 13:59

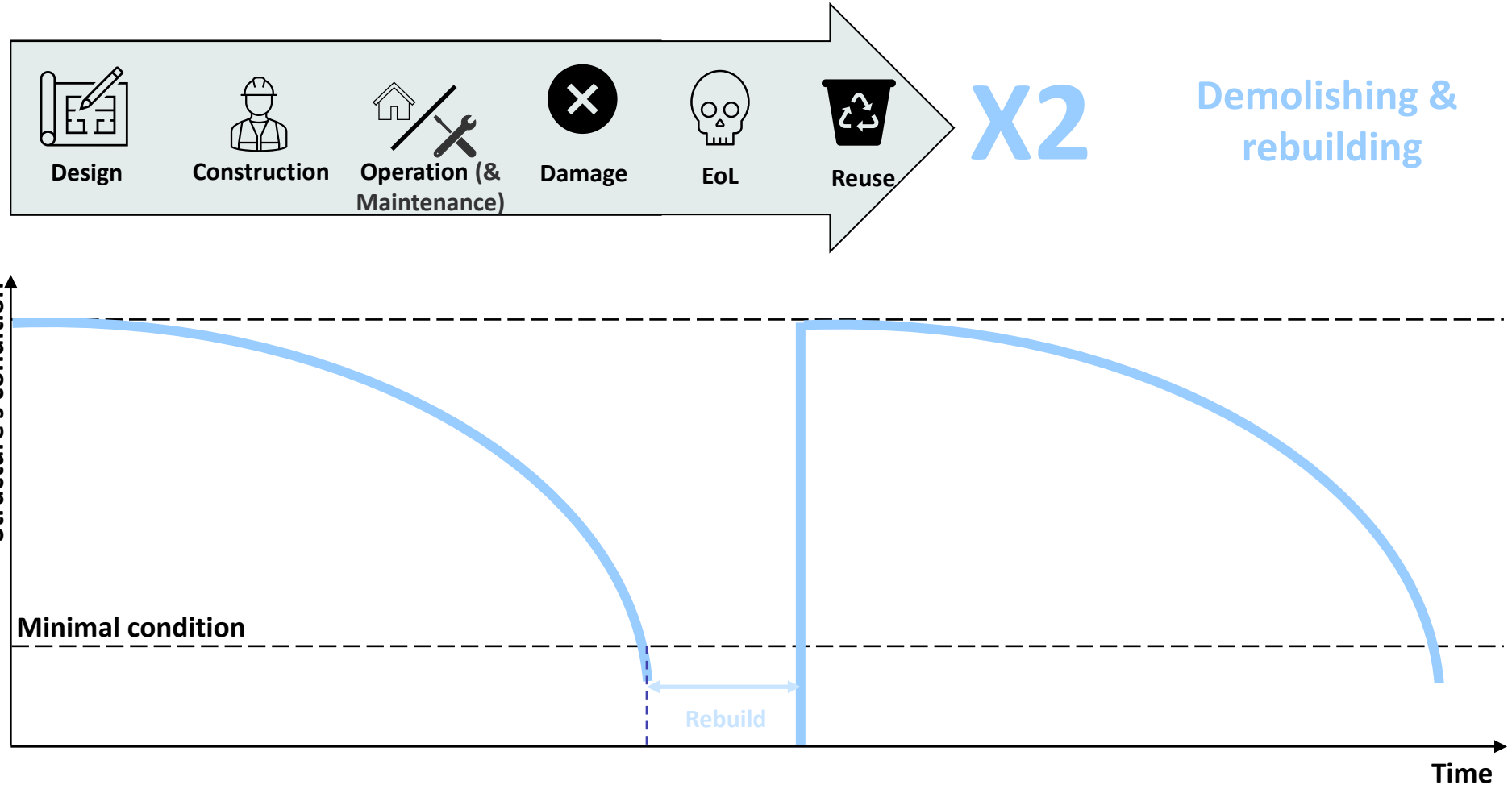
Damage -> Concrete repair

Service life extension

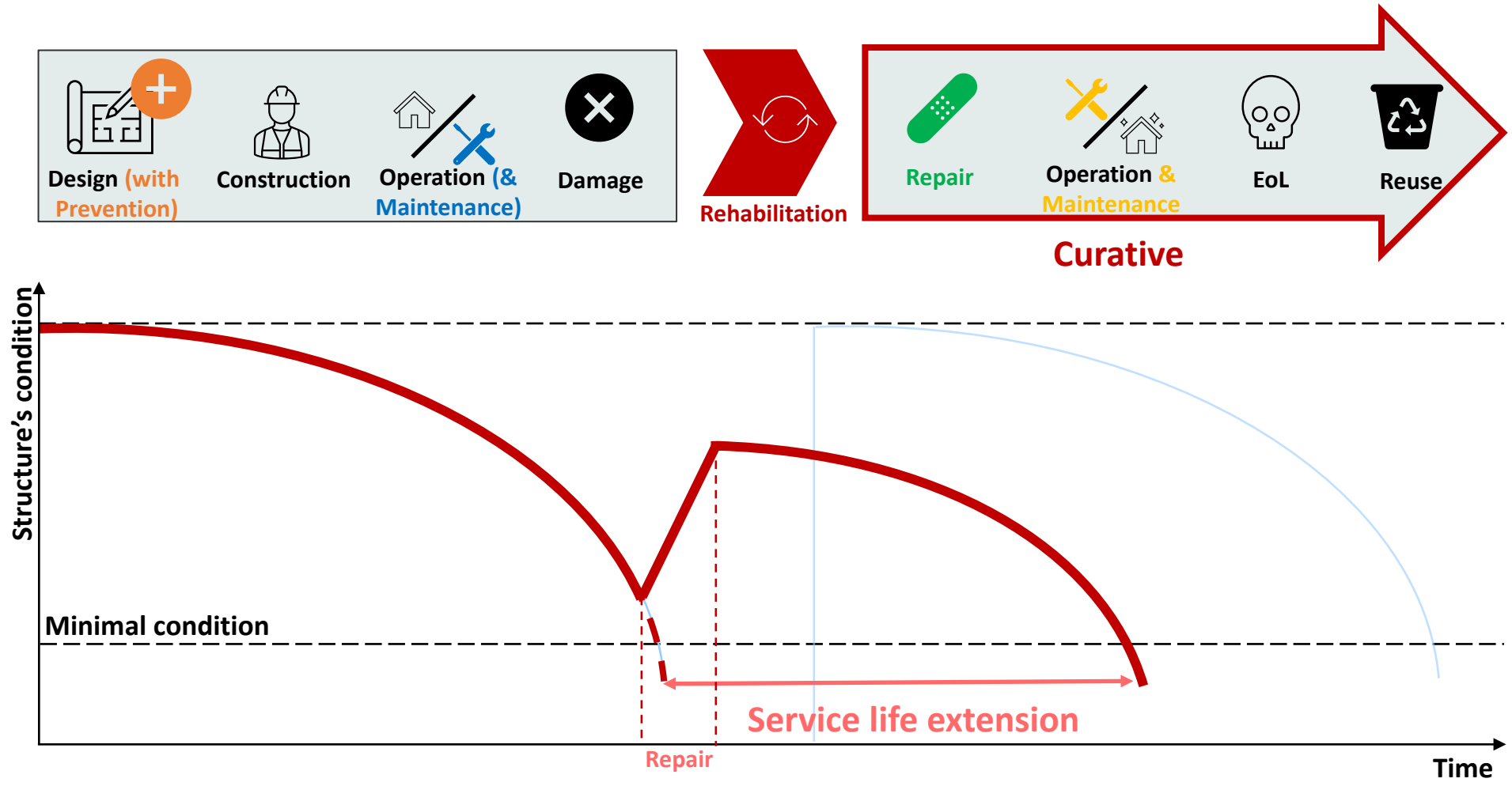


Environmental cost?

Demolishing and rebuilding



Service life extension



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State-of-the-art

- **Very limited research: sustainability assessment of concrete**
- **Lack of LCA results of service life-extending concrete maintenance and repair**
- **Studies comparing repair for RC structures**

Reference	Type of structure	Rating (from less to most beneficial)
Andrade and Izquierdo [11]	General	Electrochemical treatment - inhibitors - cathodic protection - hydrophobic agents - patching
Årskog et al. [12]	General	Patch repair - hydrofobic treatment
Navarro et al. [13]	Bridges	Stainless steel - galvanized steel - organic inhibitor - migratory inhibitor - ICCP - sealant product - hydrophobic treatment
Habert et al. [14]	Bridges	Conventional repair - UHPFRC solution
Wittocx et al. [15]	Balconies	FU-5y.: New – ICCP – conventional repair – GCP - patch repair FU-20y.: New – Patch repair – ICCP – conventional repair - GCP FU-40y.: New – ICCP – GCP – conventional repair

Goal

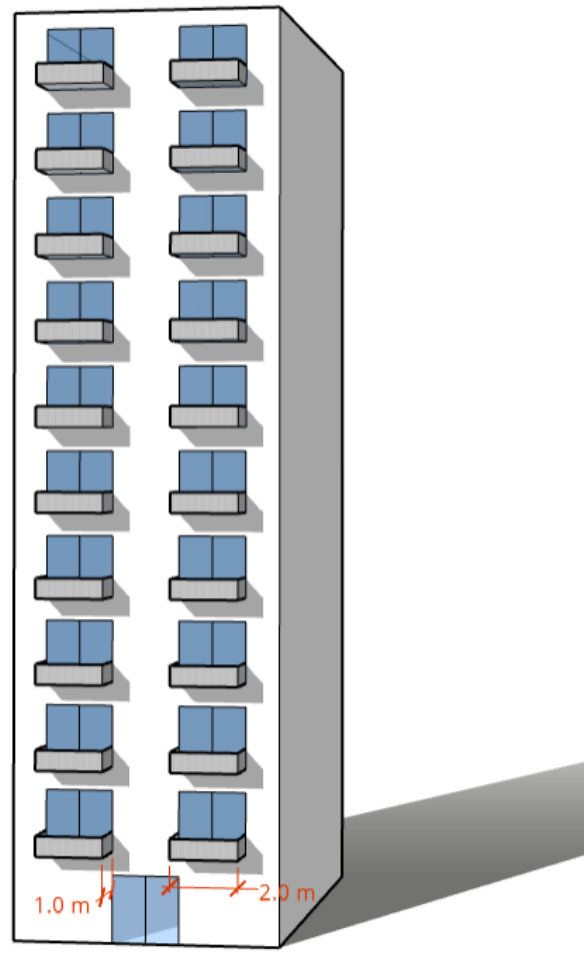
- **Environmental impact -> Life cycle assessment (LCA)**
- **Corrosion damaged reinforced concrete balconies**
- **Frequently used repair techniques:**
  - Patch repair (PR)
  - Conventional repair (CR)
  - Galvanic cathodic protection (GCP)
  - Impressed current cathodic protection (ICCP)
  - Total replacement of the element (NEW)





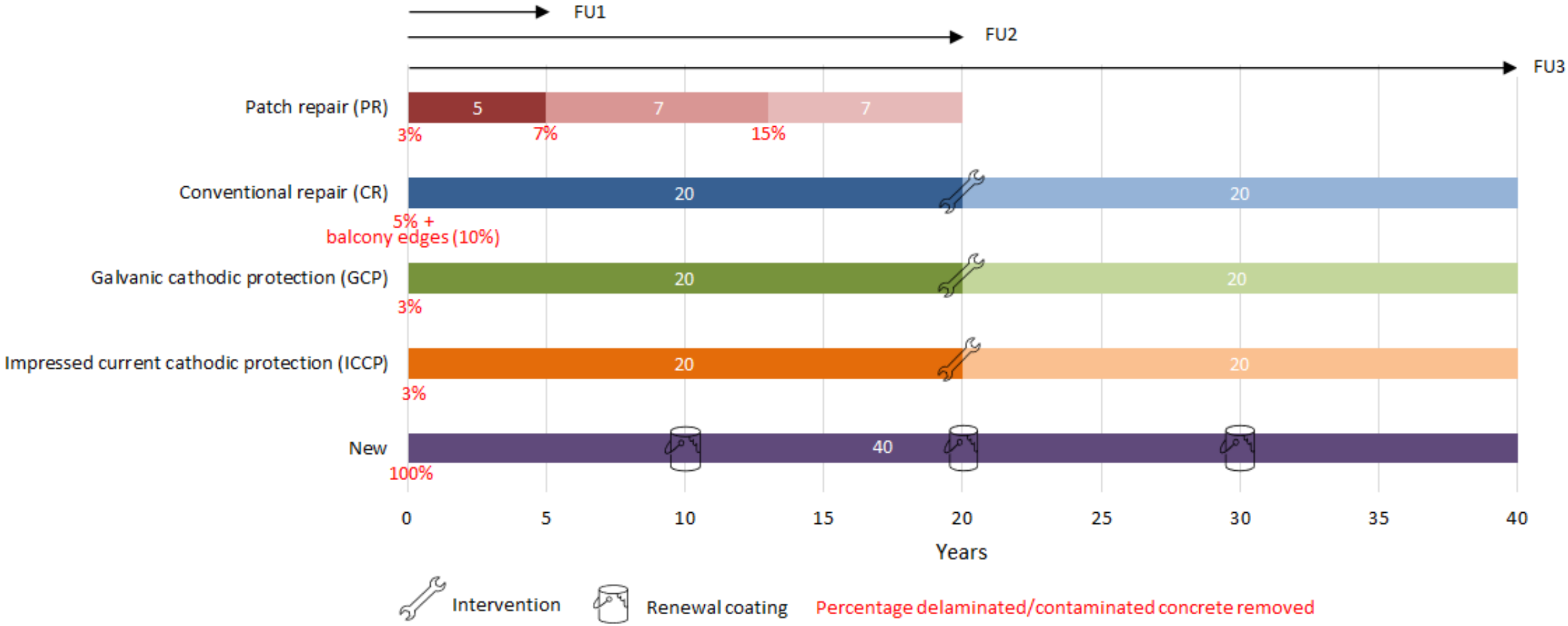
Methodology

- **Corrosion:** propagation started, without affecting load bearing capacity
- **Intensity damage:** rating cfr. paper B. Craeye ICCRRR*
- **3 Functional units (FU):** the service life extension of 20 balconies for 5, 20 and 40 years
- **Building:** 10 floors with 2 individual balconies on each floor
- **Dimensions:** 1 m x 2 m × 0.1 m & a double steel mesh 8/8/150/150 mm
- **Consequential approach:** flows described as response to possible decisions
- **Ecoinvent database v3.5**
- **ReCiPe 2016 v1.04 method:** midpoints & endpoints

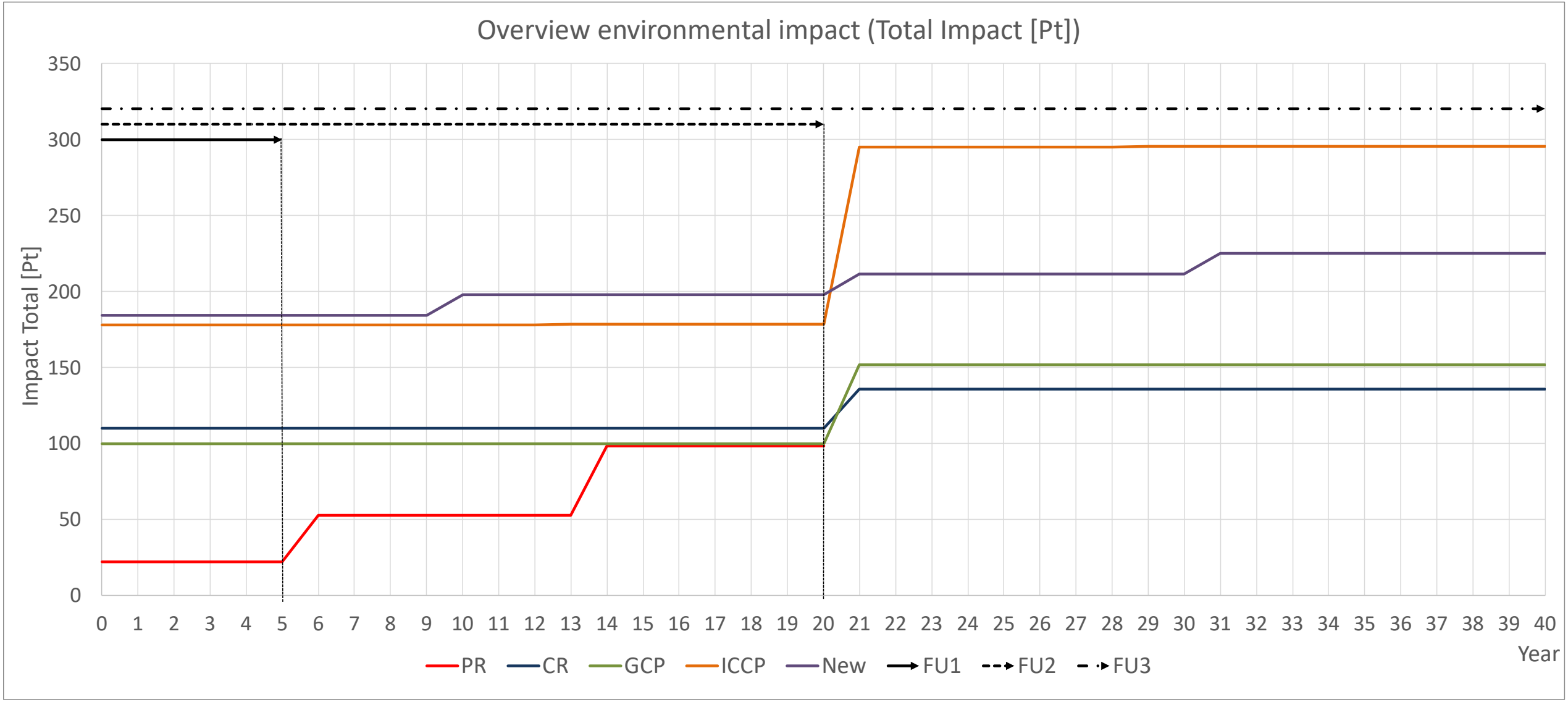


(*) Assessment of cantilevered concrete balconies by means of practically oriented evaluation tools - B. Craeye, L. Wittocx, P. Minne, R. Caspeele

Methodology



Main scenario



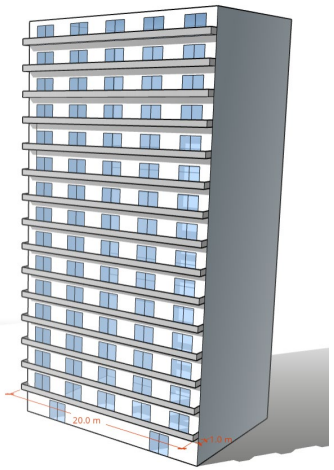
Sensitivity analysis

- **SA1: Balcony configuration and construction volume**
- **SA2: Intended service life extension**
- **SA3: Repair mortar composition**
- **SA4: Composition and application of coating/waterproofing**

SA1: Balcony configuration and construction volume

Bigger building

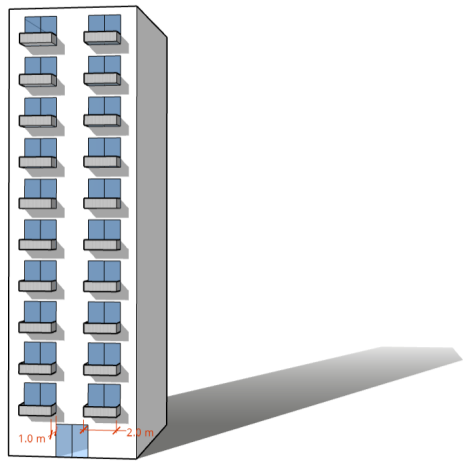
- 15 continuous balconies: 1,1 m edges/m² balcony area
- Less concrete coating
- CR: fewer side as balcony nose
- ICCP: number electronic components not linearly increasing



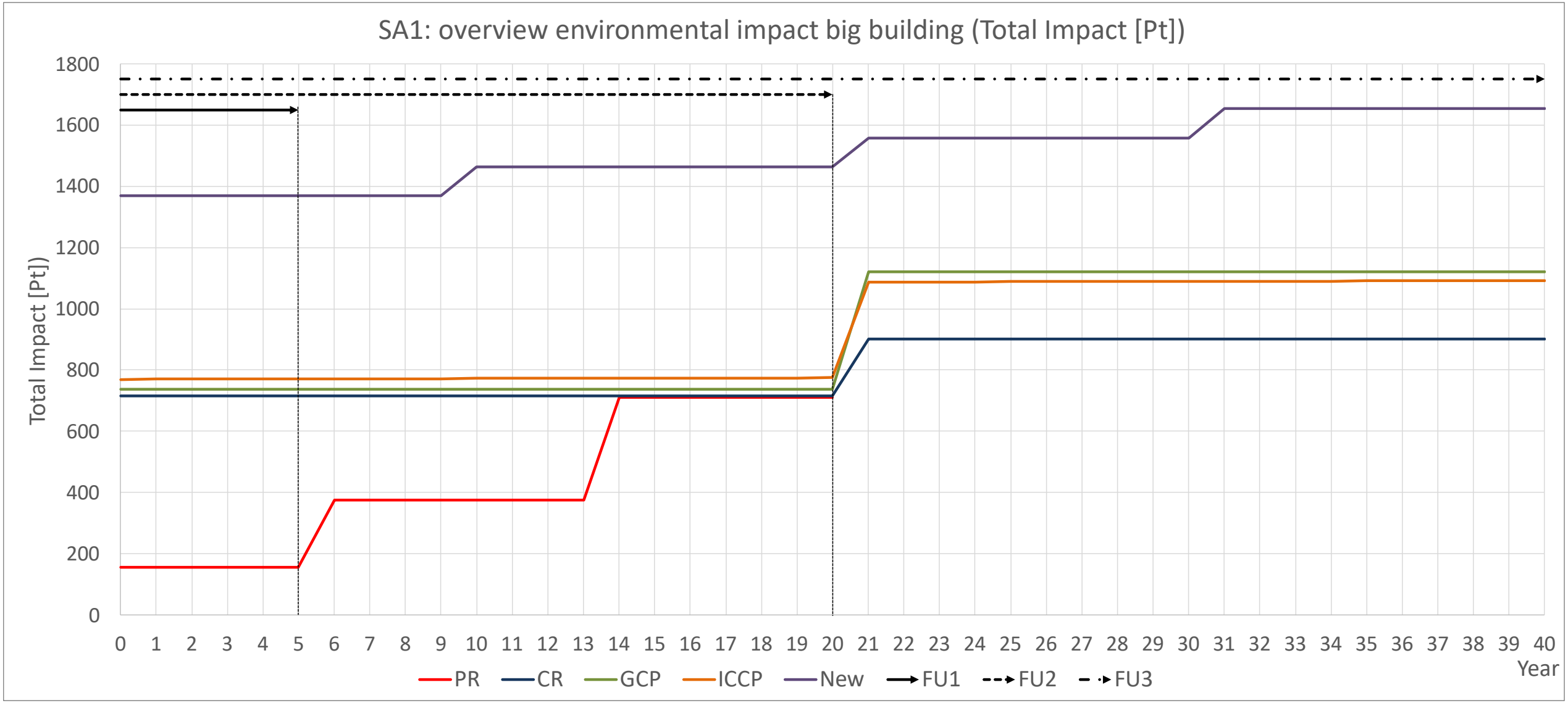
VS

Main scenario

- 20 individual balconies: 2,0 m edges/m² balcony area



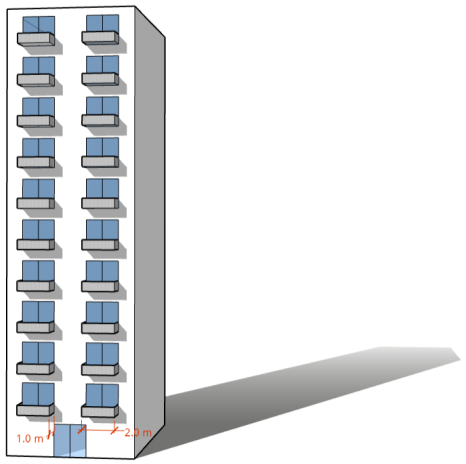
SA1: Balcony configuration and construction volume



SA2: Intended service life extension

SA2

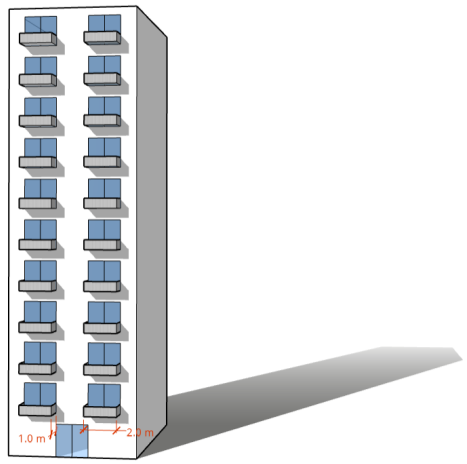
- Service life extension:
  - PR: 5 years
  - GCP: 14 years



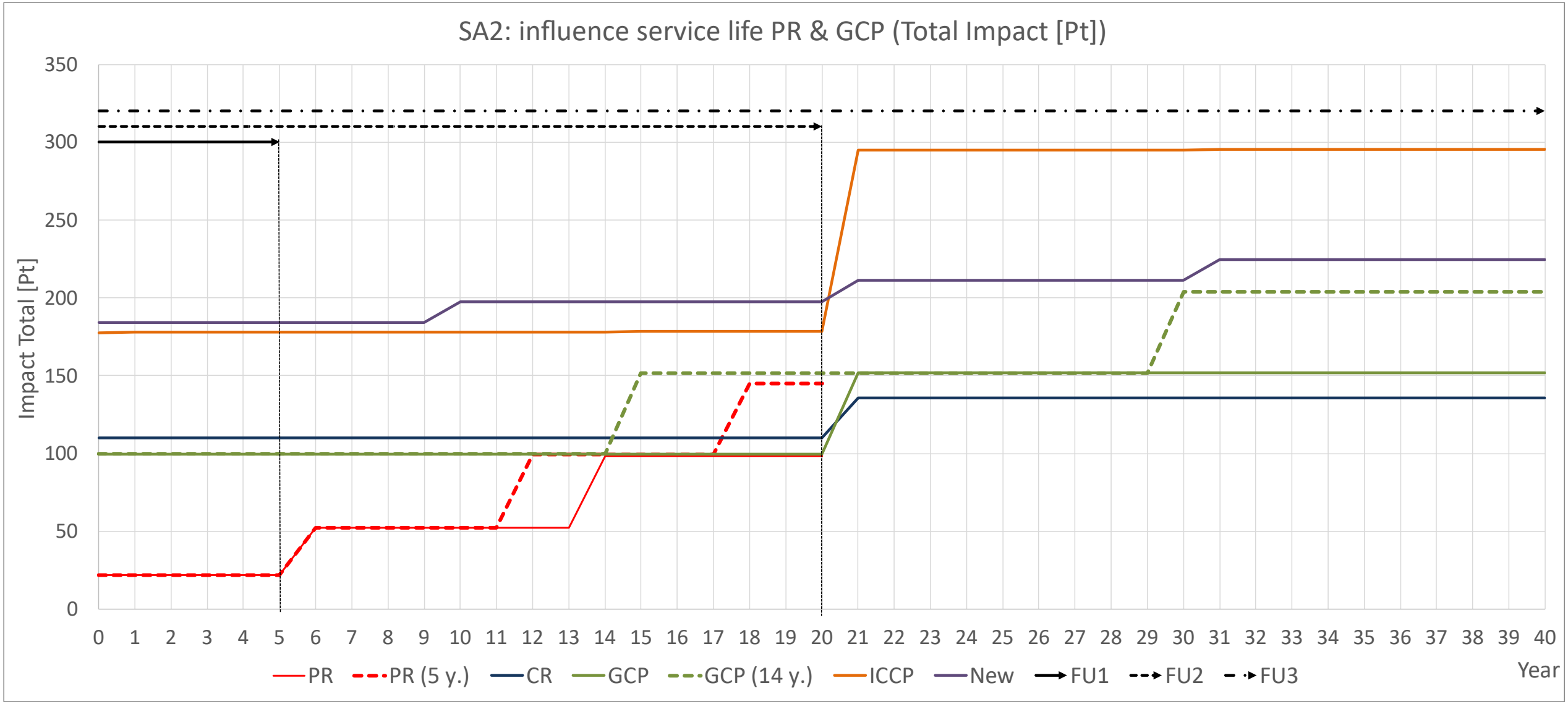
VS

Main scenario

- Service life extension:
  - PR: 5 & 7 years
  - GCP: 20 years

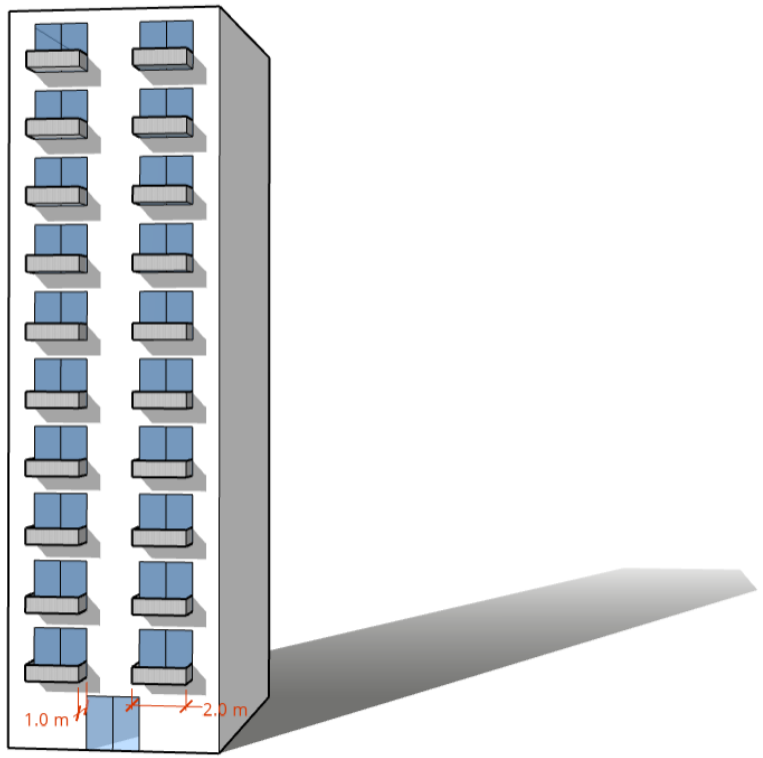


SA2: Intended service life extension

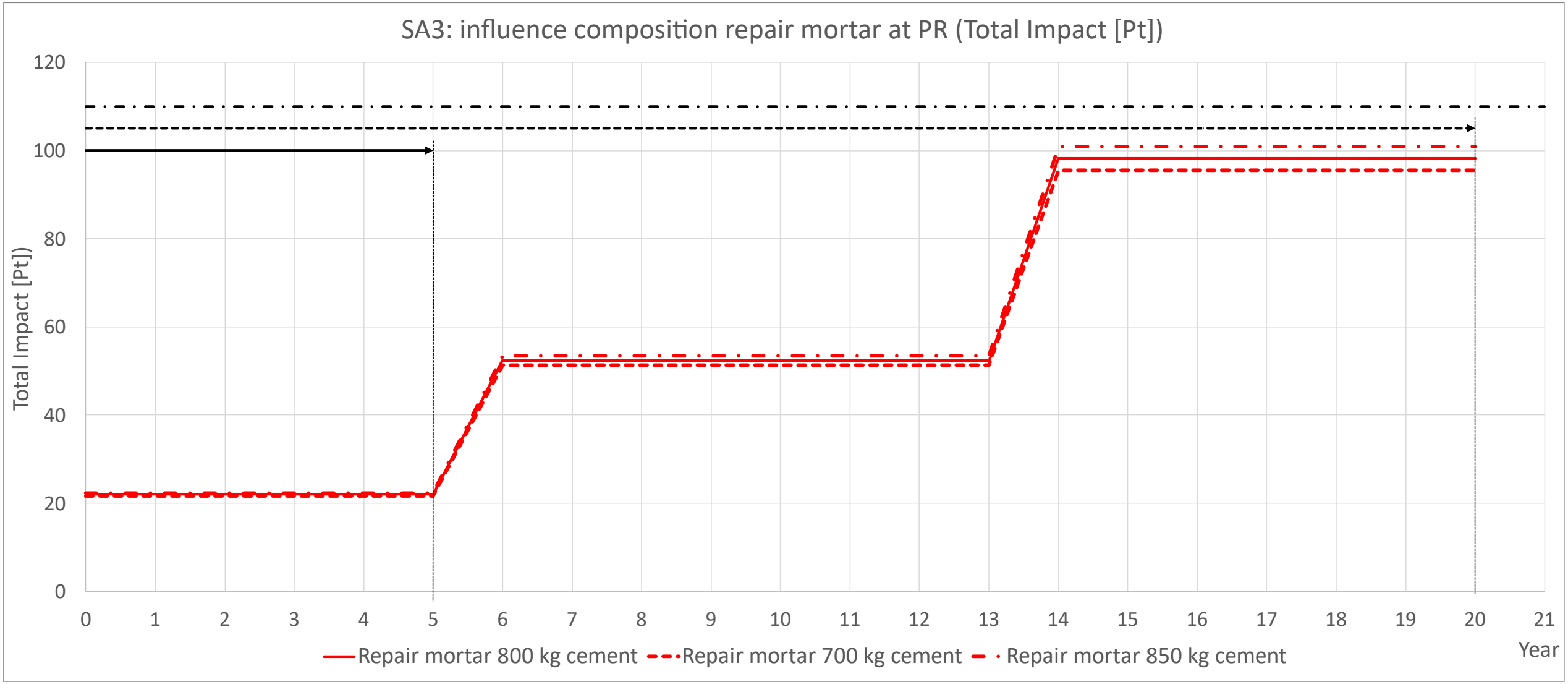


SA3: Repair mortar composition

- **Composition not generally known because suppliers won't give detailed information about their products**
- **Kg cement/m³ repair mortar**
  - 800 (reference)
  - 700
  - 900



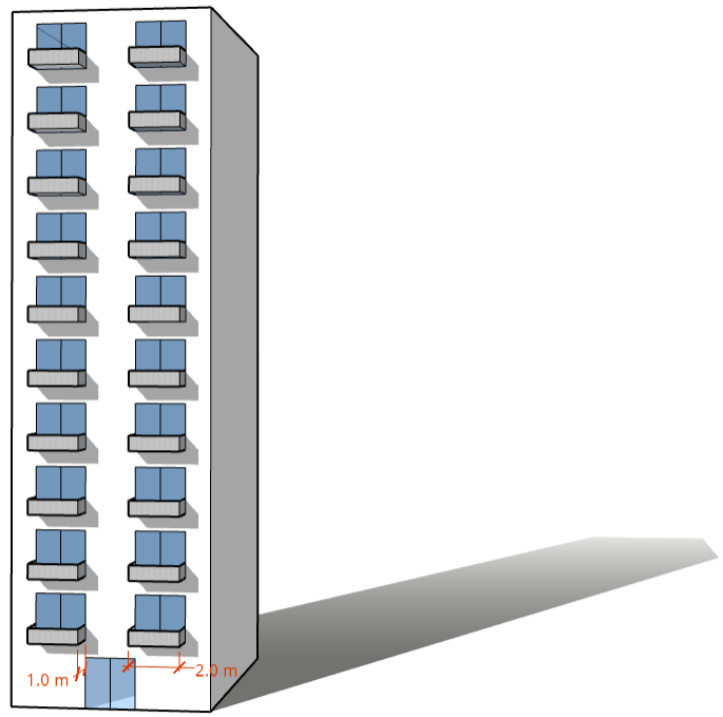
SA3: Repair mortar composition



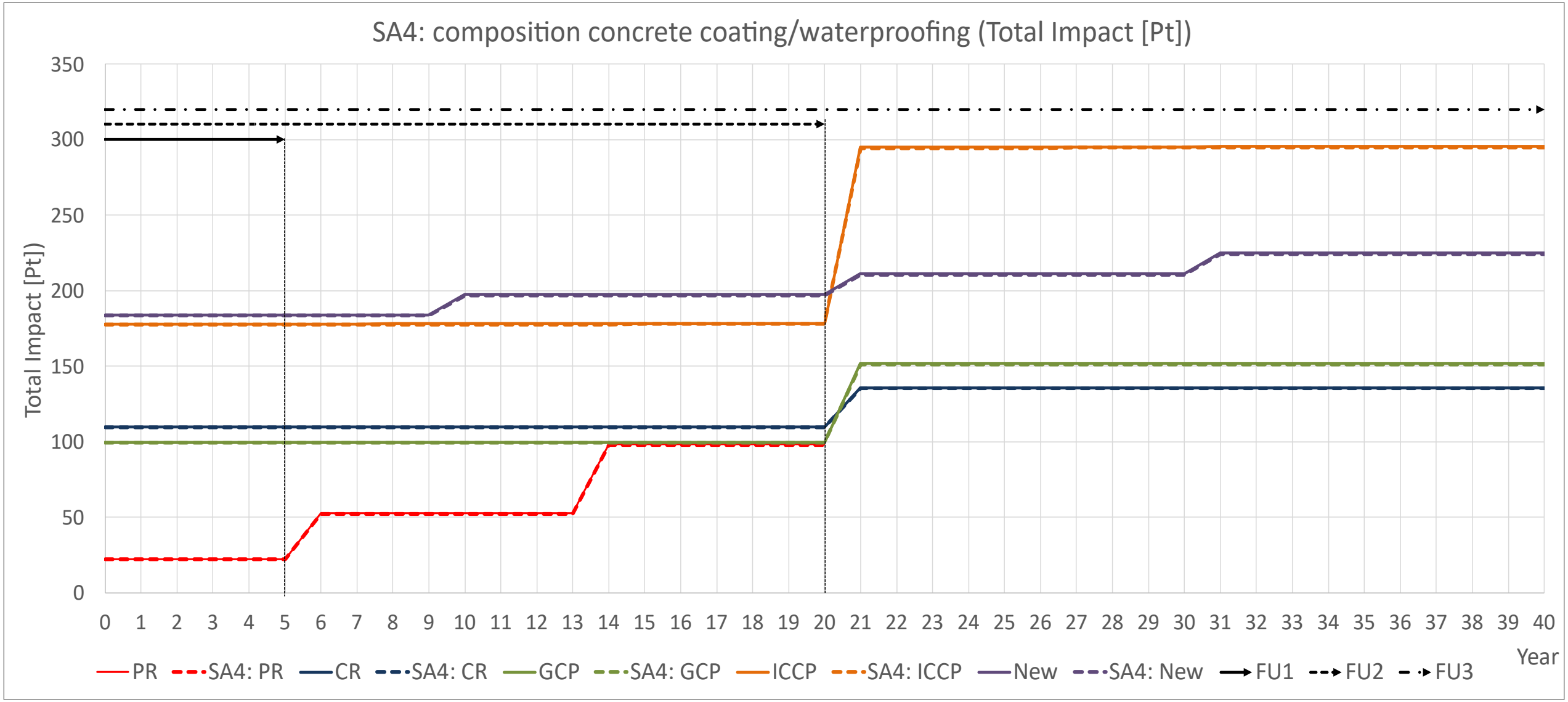
SA4: Composition and application of coating/waterproofing

- **Biggest impact: finishing i.e. coating, screed, primer, waterproofing and reinforcement mat**
- **3 sensitivities:**

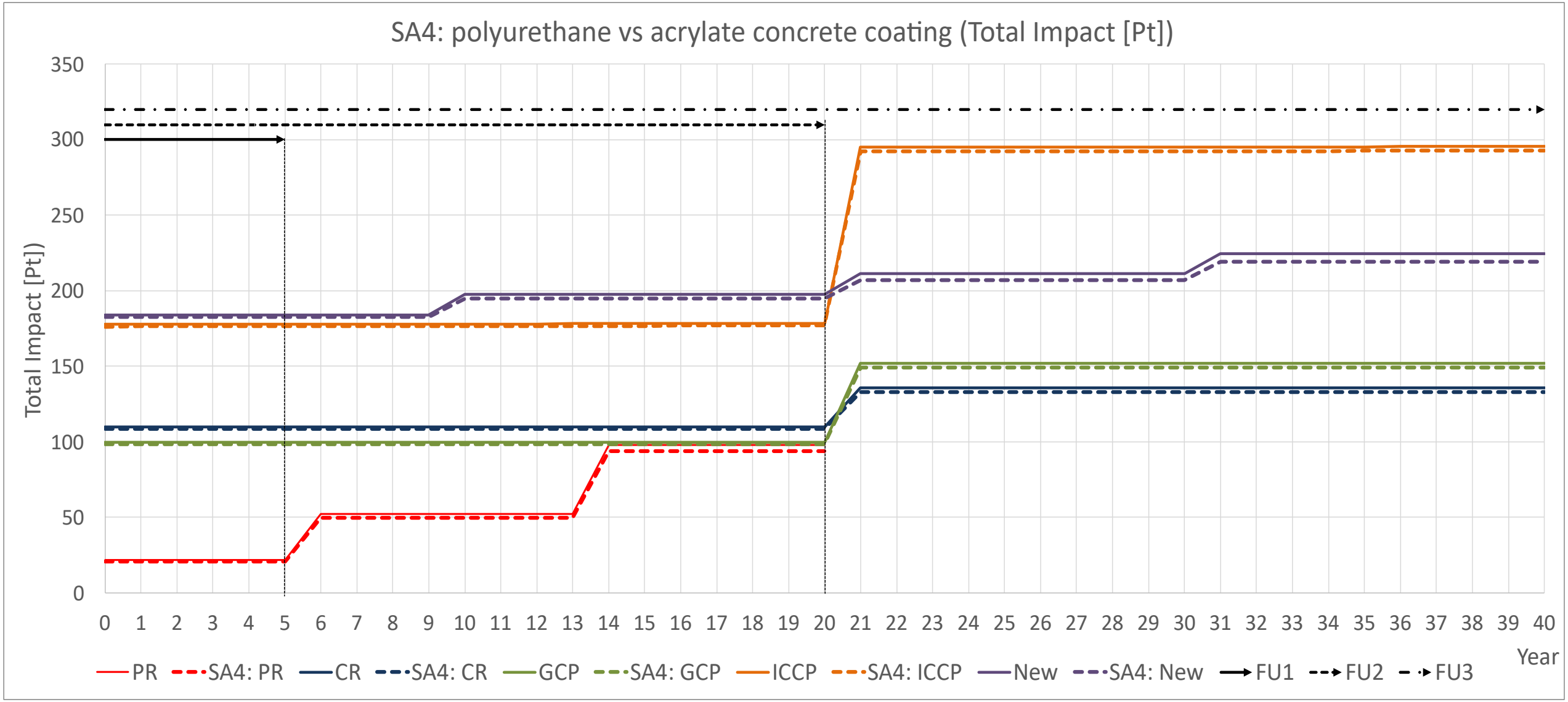
1) **Coating and waterproofing: hard segment composition, 21 % to 18 % & 30 % to 25 % respectively**
2) **Acrylate based coating instead of polyurethane**
3) **No coating for GCP and ICCP**



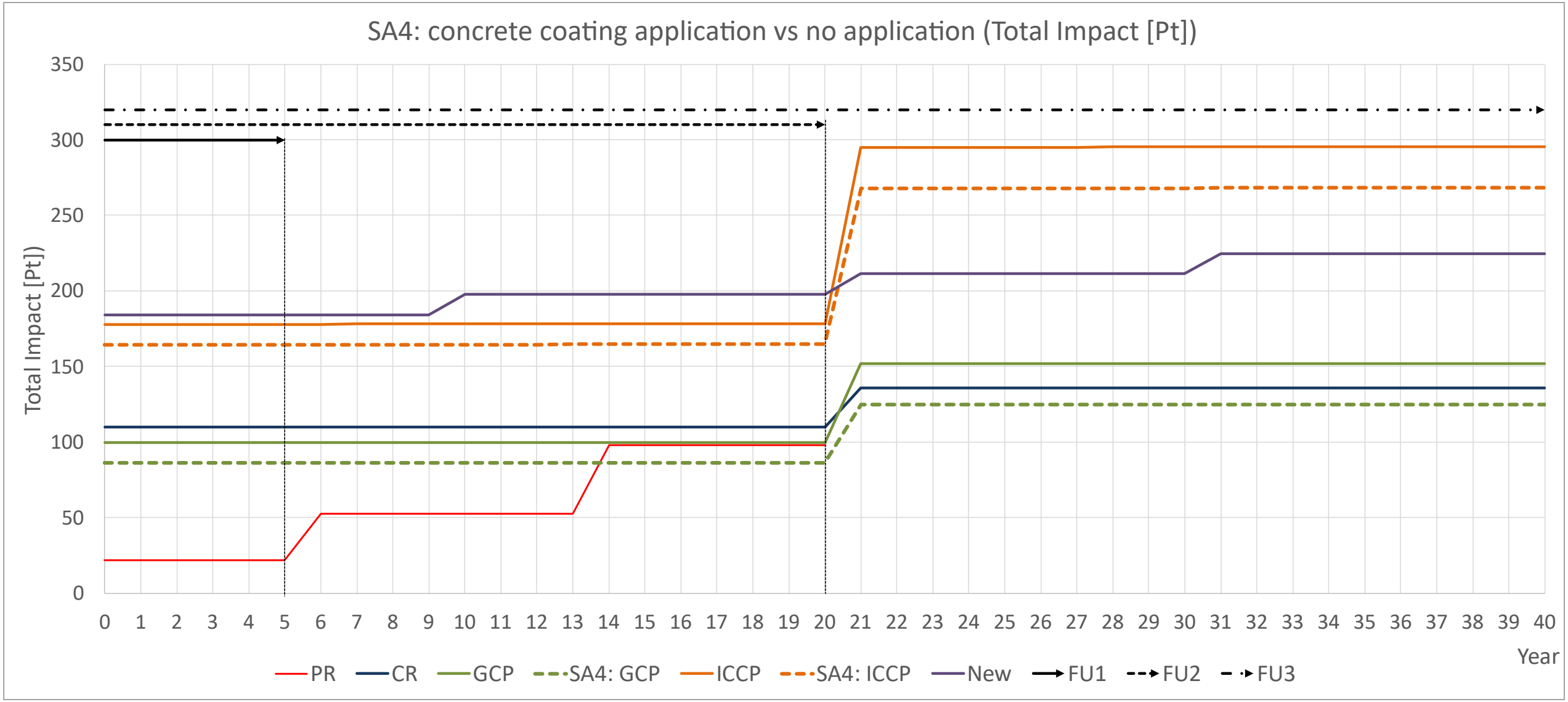
SA4: Composition of coating/waterproofing



SA4: Acrylate coating



SA4: No application of coating for GCP & ICCP



Conclusion

- **LCA -> key factor for reducing the environmental impact**
- **FU1: PR by far best option**
- **FU2: PR still the favorable option, closely followed by GCP**
- **FU3: CR**
- **Total replacement (NEW) very high impact**
- **ICCP not environmentally effective for small components/volumes**
- **Further research:**
  - Composition of repair materials e.g. repair mortar and coatings
  - Service life extension of repairs

Thank you for listening

Questions?

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