Reducing Water Footprint of building sector: concrete with seawater and marine aggregates

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Presentation outline

Introduction

- ❑ Water stress and freshwater consumption in the building sector
- ❑ SEACON project

Goal of the study

Materials and methods

- ❑ Scope of the LCA
- ❑ Life Cycle Inventory
- ❑ Life Cycle Impact Assessment

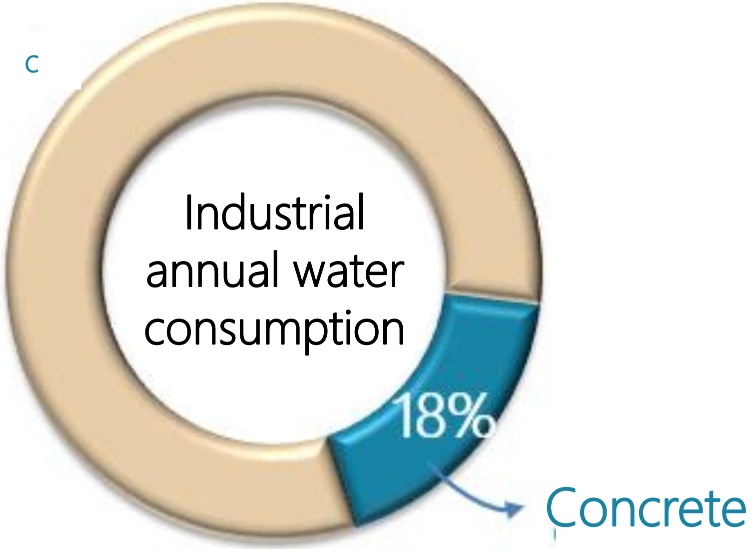
Results

Conclusions and further investigations

Introduction

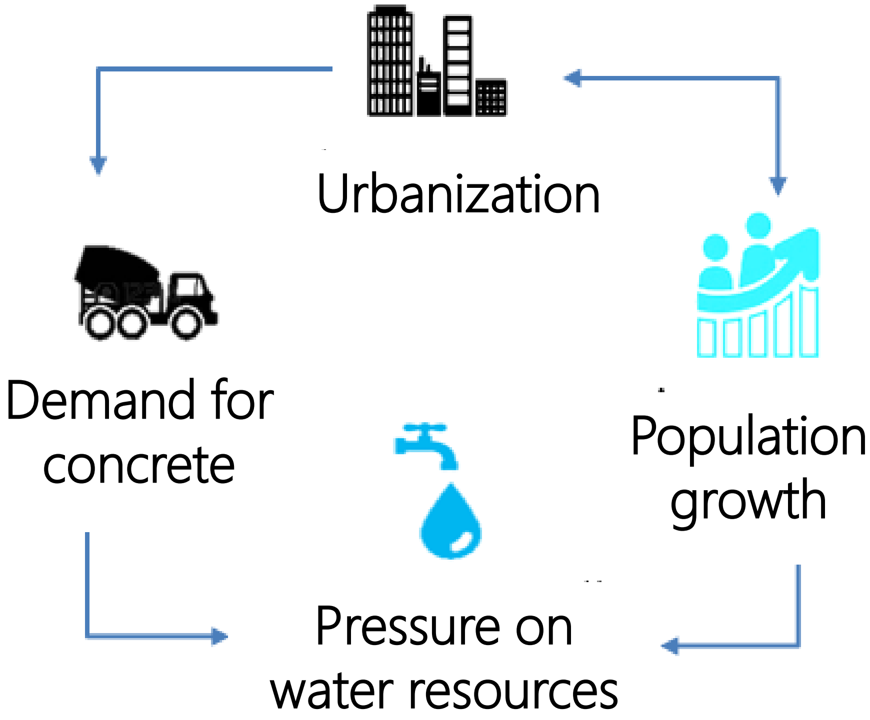
- ½ of the **global population** live in areas potentially **scarce in water** at least one month per year [a]
- Concrete is the building material with higher rate of growth [b]

[c]



Annual global water consumption for concrete = 16.6 billion m^3

Annual domestic use of **145 million US residents** [c]



[a] WWAP 2018 *The united nations world water development report 2018: Nature-based solutions for water* (Paris, France: UNESCO).
[b] Miller et al. 2016, *Readily implementable techniques can cut annual CO_2 emissions from the production of concrete by ove 20%*. ERL, 11(7)
[c] Miller et al 2018, *Impacts of booming concrete production on water resources worldwide* Nature Sustainability 1 69-76

SEACON project

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- Sustainable concrete using seawater, salt-contaminated aggregates
- Non-corrosive reinforcements: Glass Fiber Reinforced Polymer (GFRP), Stainless steel

Goal of the study

Assess the water footprint of concrete and investigate whether the use of **seawater** and **marine aggregates** could reduce it

LAFW
- ❑ Land-won Aggregates (LA)
- ❑ Fresh-Water (FW)

LASW
- ❑ Land-won Aggregates (LA)
- ❑ Sea-Water (SW)

MASW
- ❑ Marine Aggregates (MA)
- ❑ Sea-Water (SW)

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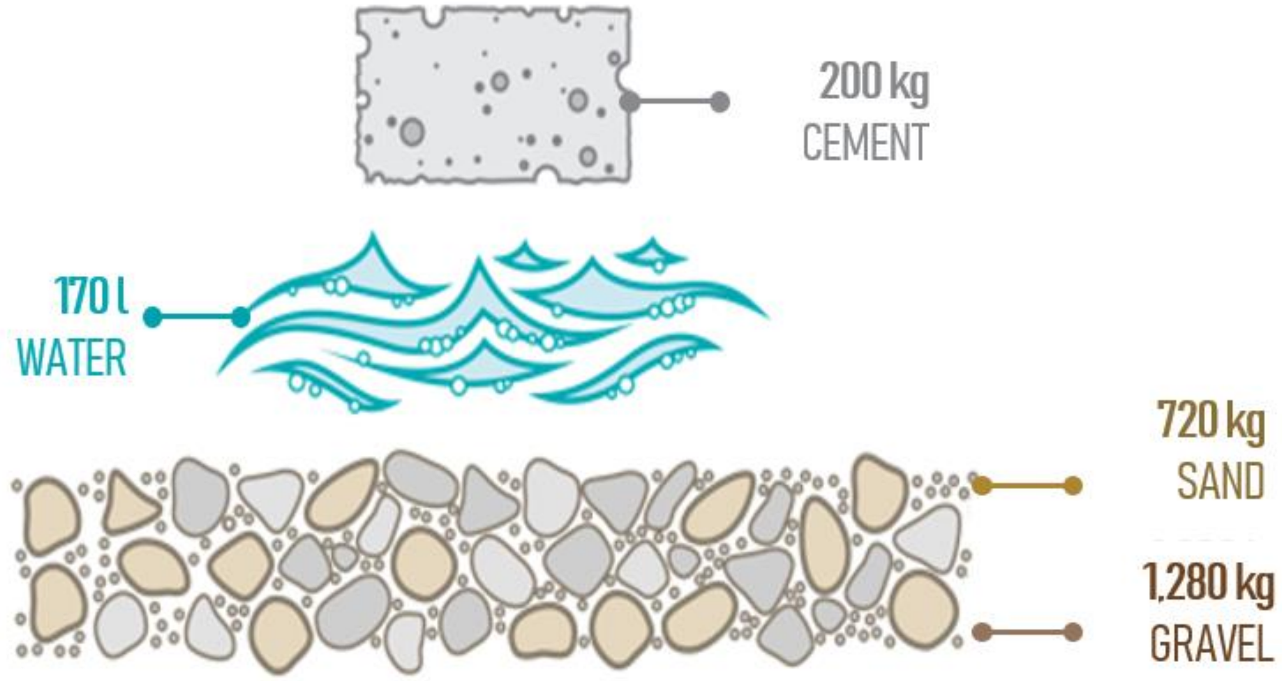
ArcGIS

Scope
Declared unit

1 cubic metre of unreinforced fresh generic concrete **delivered to the construction site** [a]

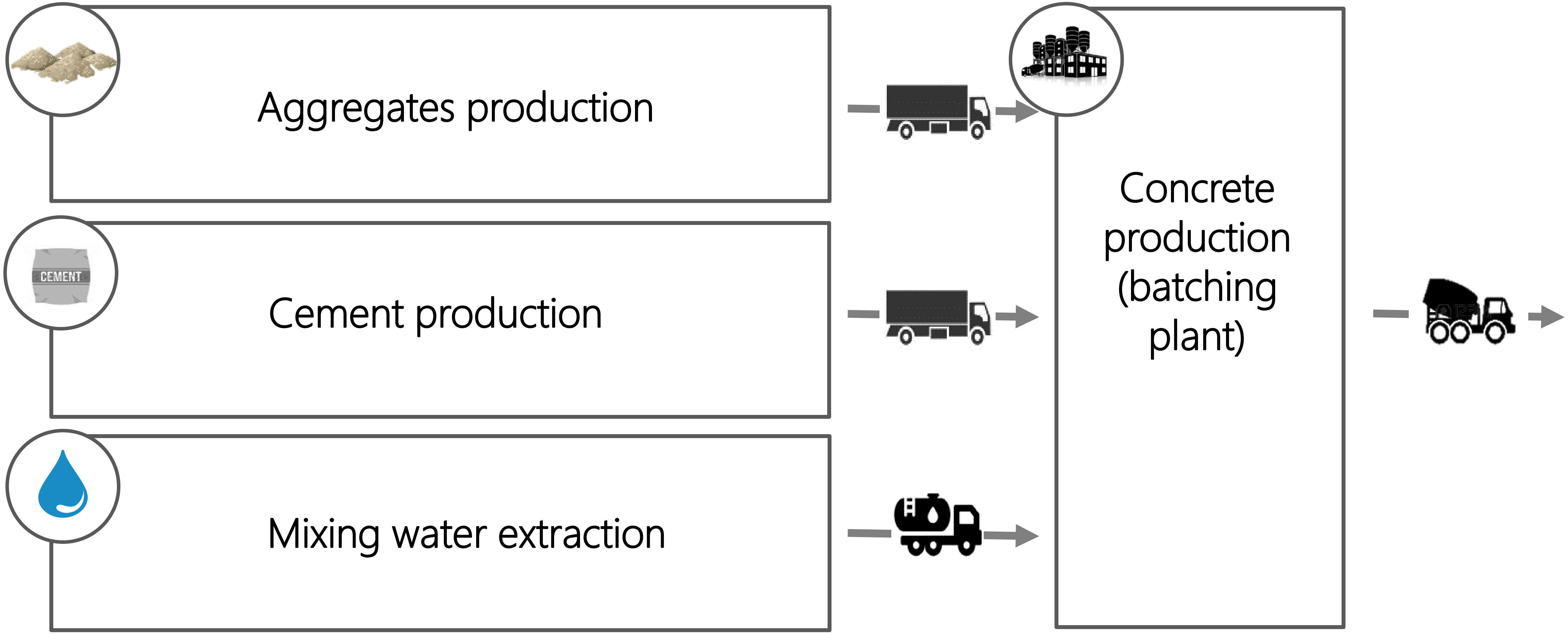


[a] Ecoinvent, dataset "*Concrete, normal {CH}, unreinforced concrete production with cement CEM/IIA*"

Scope

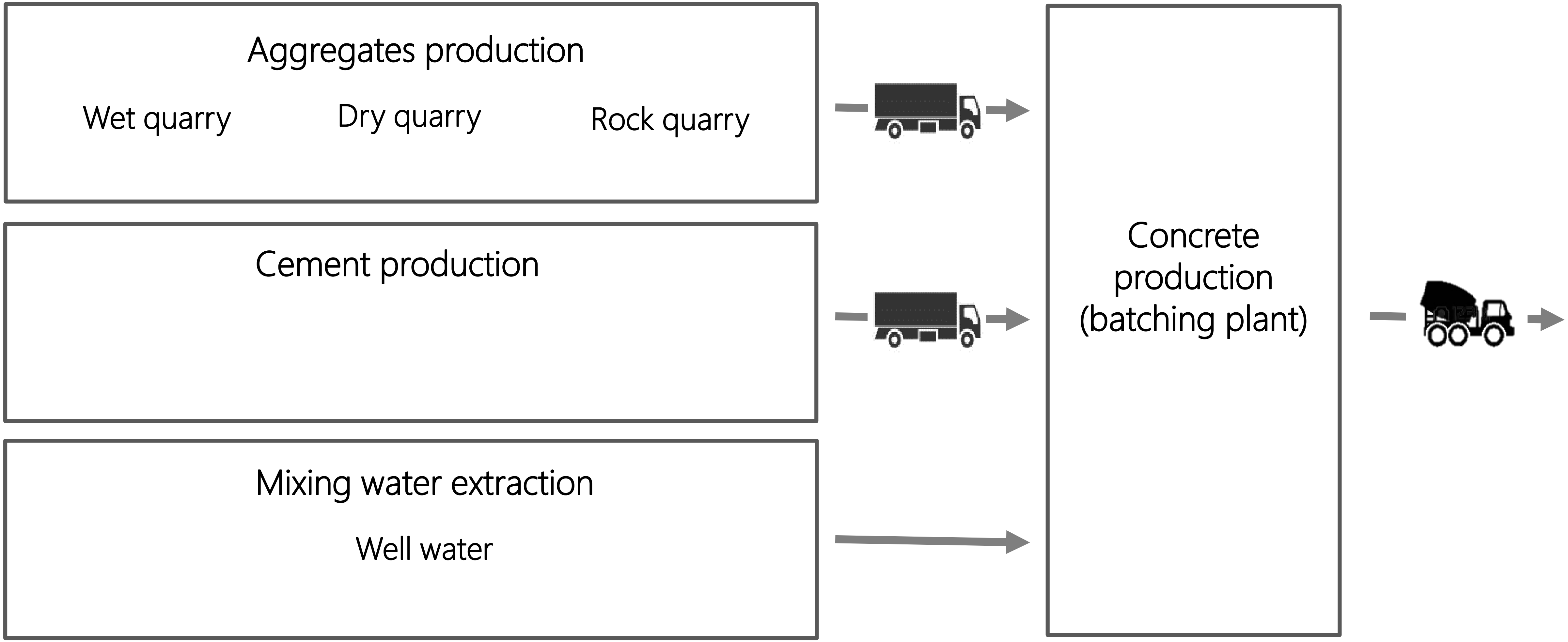
System boundaries

Cradle-to-gate analysis



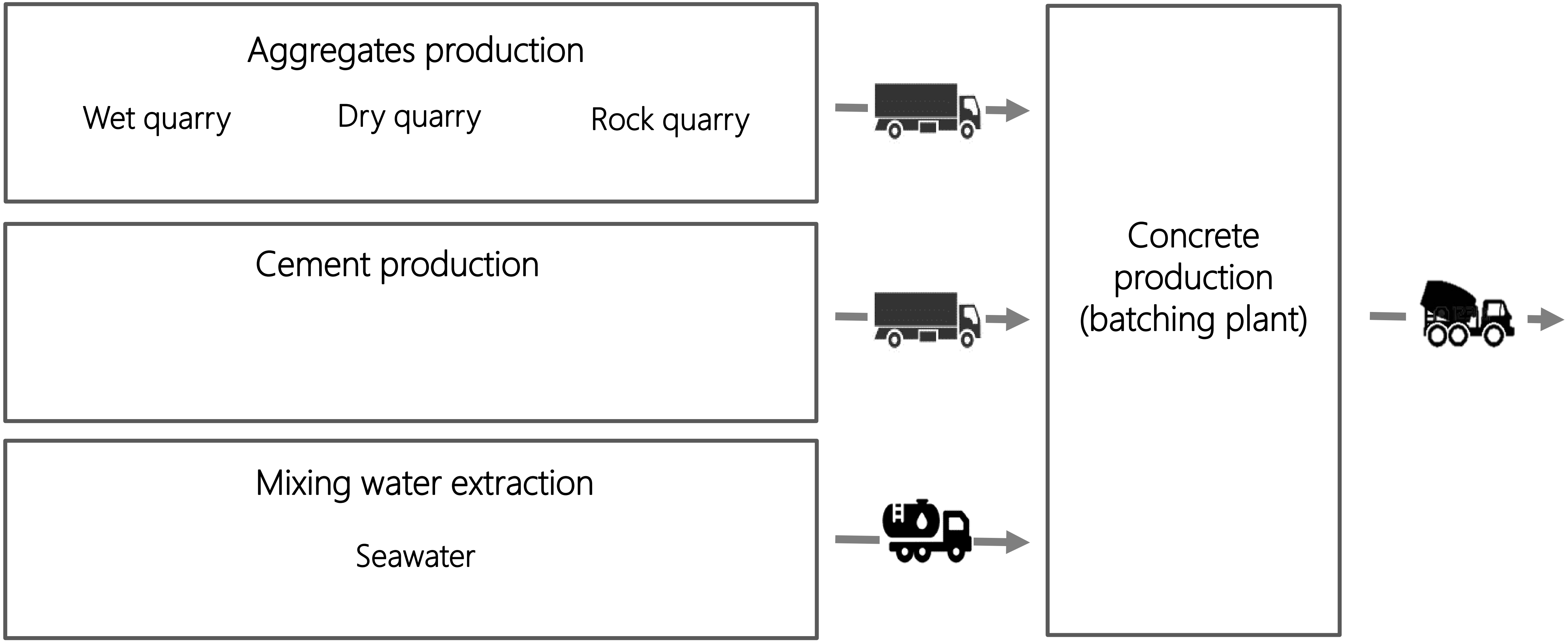
Scope
System boundaries

LAFW



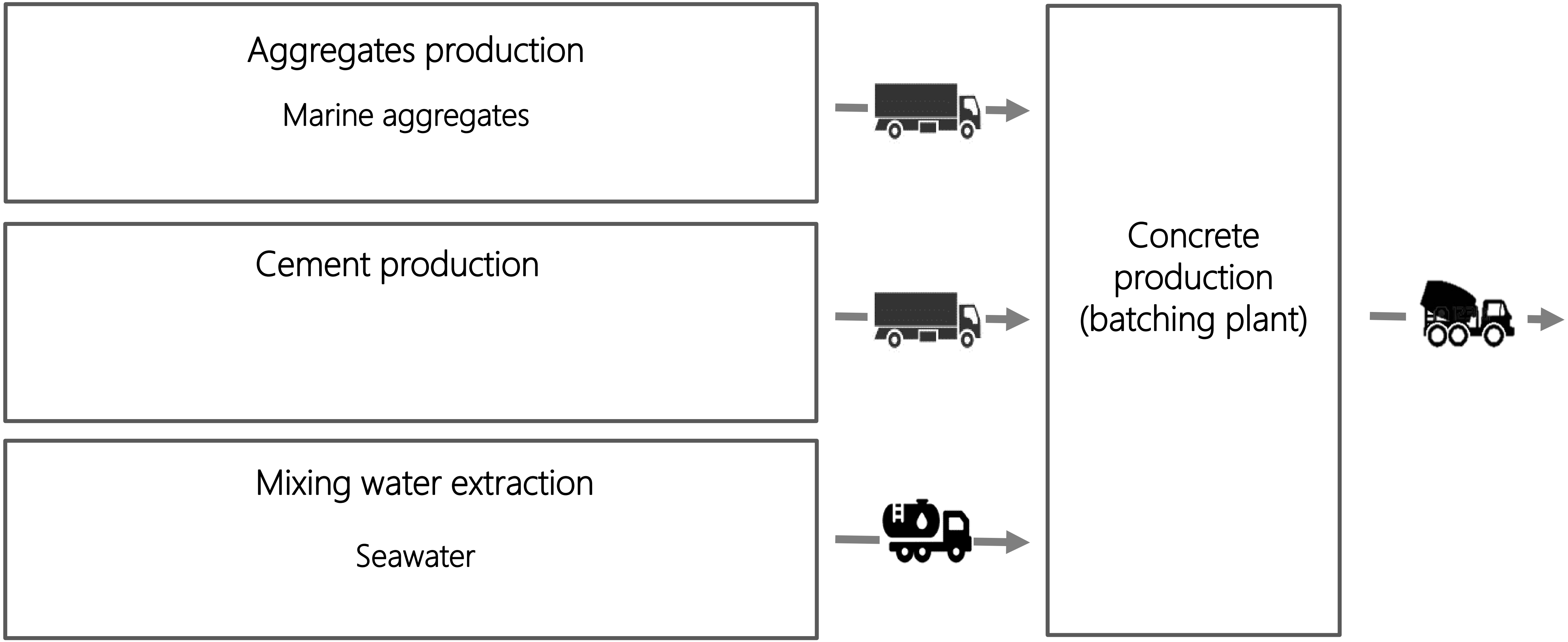
Scope
System boundaries

LASW



Scope
System boundaries

MASW

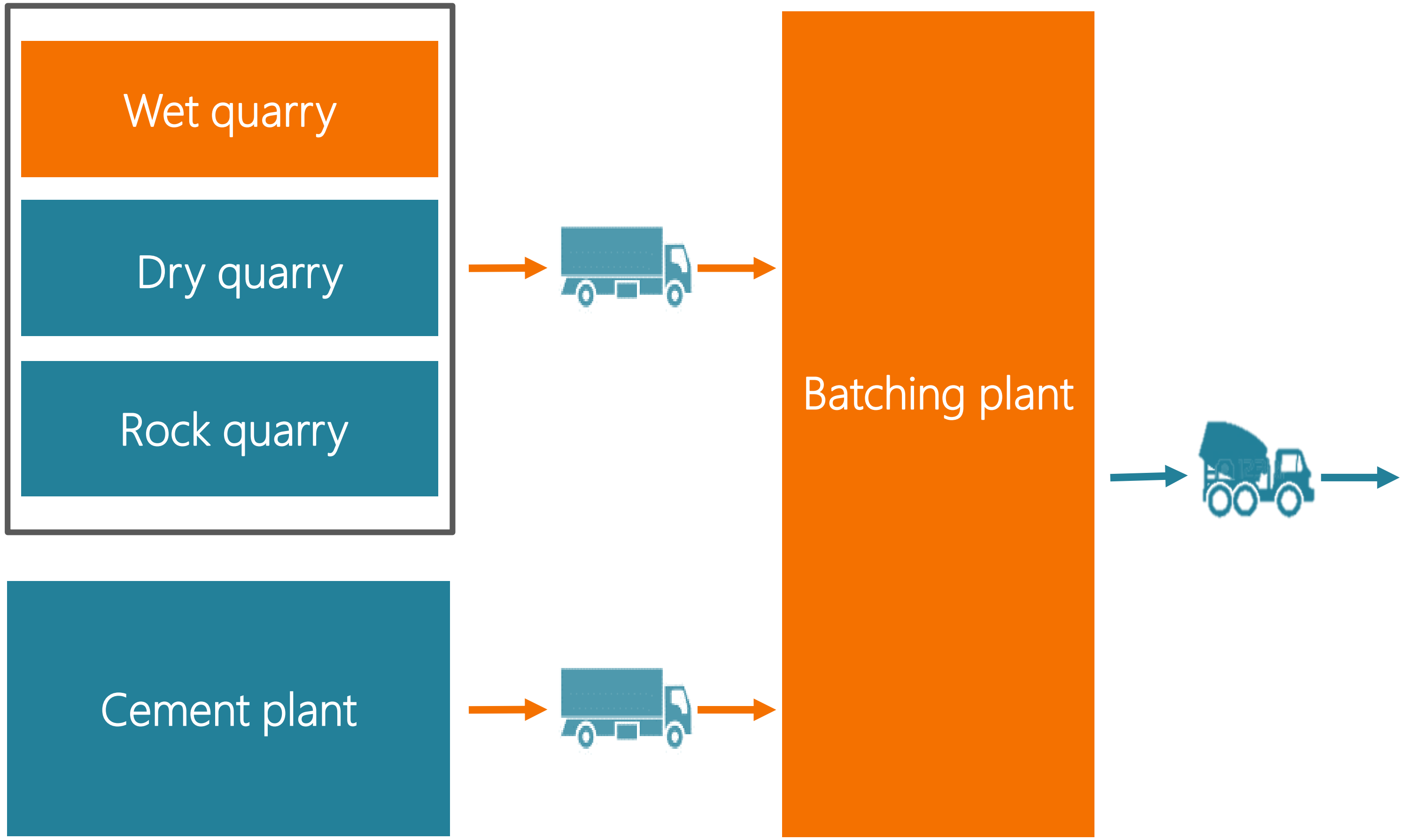


Scope
Geography

Life Cycle Inventory

1. Inventory of materials, energy and water flows
2. Geolocation of quarries, cement plants and batching plants
3. Geolocation of water intake and marine aggregates discharge facilities
4. Distance calculation

Life Cycle Inventory
Sources of data

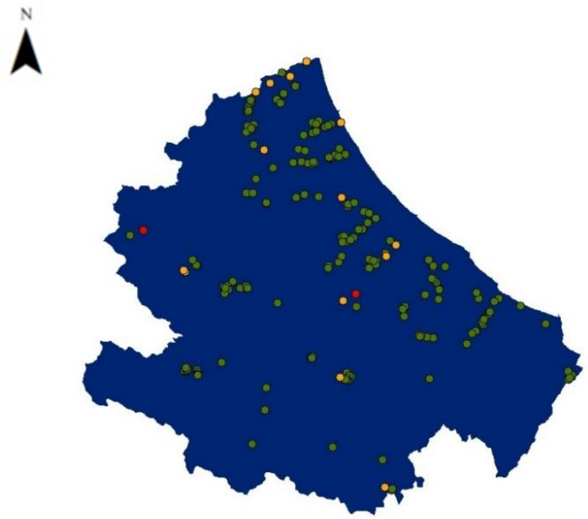


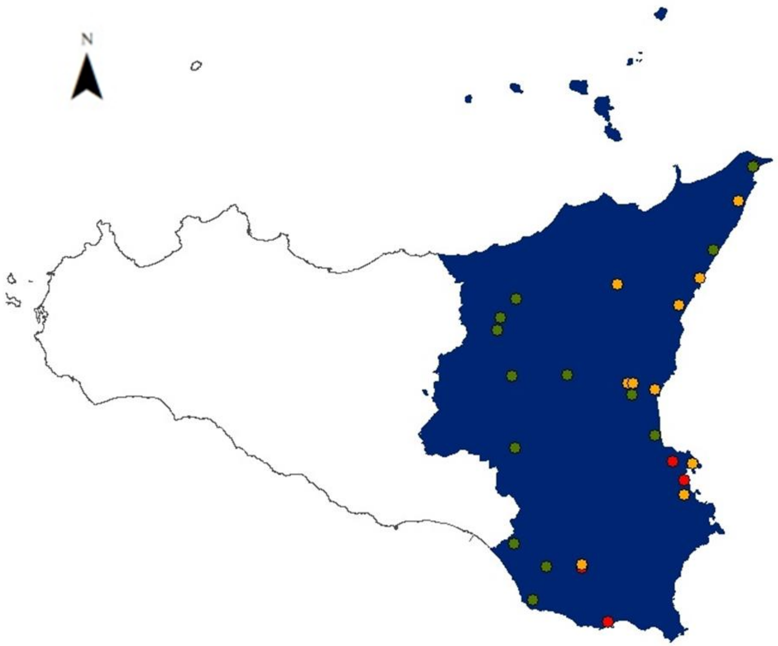
- Primary data (Producers)
- Primary data (API Google Distance matrix)
- Secondary data (Ecoinvent, scientific literature)

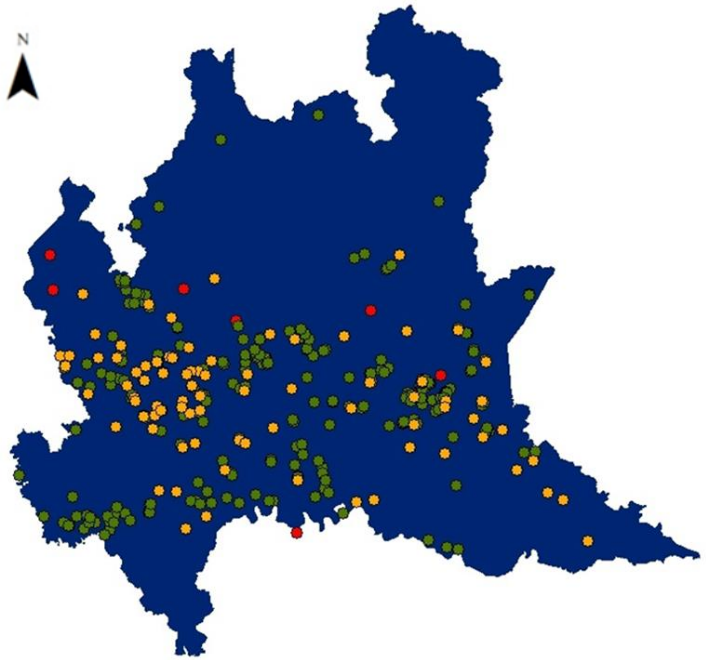
Life Cycle Inventory

Geolocation of quarries, cement plants and batching plants

Abruzzo	Eastern Sicily	Lombardy







Legend
- Quarries
- Cement plants
- Batching plants

Sources of data:
- ❑ Official regional websites
- ❑ Italian Association of Cement manufactures
- ❑ Italian Technical Economic Association for Ready-Mixed Concrete

ArcGIS® ESRI

Life Cycle Inventory

Geolocation of seawater intake facilities and marine aggregates processing plants

Point along coast at the minimal linear distance from each batching plant

=

- ❑ Seawater intake facility
- ❑ Marine aggregates processing plants

Legend
- Intake facilities
- Batching plants

ArcGIS

Indirect water use

Water used in preceding processes, embedded in materials and energy flows entering the process unit.

Direct water use

Water used directly in the process analyzed.

Life Cycle Inventory

Direct freshwater use

Aggregates production

Dry quarry

- ❑ Wash the machinary
- ❑ Wash the aggregates

Wet quarry

- ❑ Wash the machinary
- ❑ Wash the aggregates
- ❑ Evaporation from quarry lake

Rock quarry

- ❑ Wash the machinary
- ❑ Dust control

Aggregates production

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Rock quarry

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- ❑ Dust control

Water consumption:

- ❑ Evaporated water
- ❑ Water incorporated in the final product

Life Cycle Inventory

Direct freshwater use

Cement plant

- ❑ Wash the machinary and the yards
- ❑ Cooling activities
- ❑ Gas conditioning

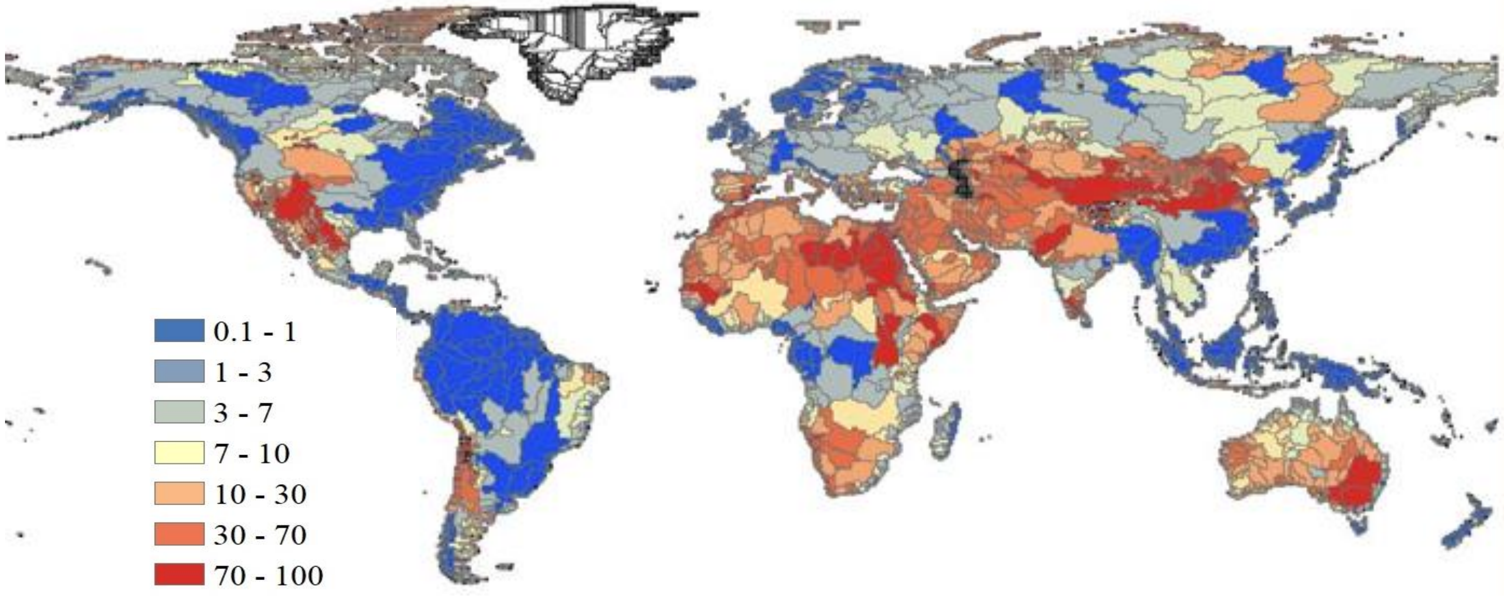
Batching plant

- ❑ Mixing the concrete
- ❑ Wash the trucks
- ❑ Wash the yards

Water consumption:
- ❑ Evaporated water
- ❑ Water incorporated in the final product

Life Cycle Impact Assessment
AWARE

Water Footprint = water consumption x characterization factor



AWARE characterization factors

- Account for the Available WAter Remaining in a watershed after the demand of humans and aquatic ecosystems is met.
- Unit of measure: $\frac{m^3_{water\,world-eq}}{m^3_{consumed\,water}}$

Direct water consumption	Basin scale factors
Indirect water consumption	National scale factors

Freshwater consumption in the base case scenario

Water footprint - base case scenario

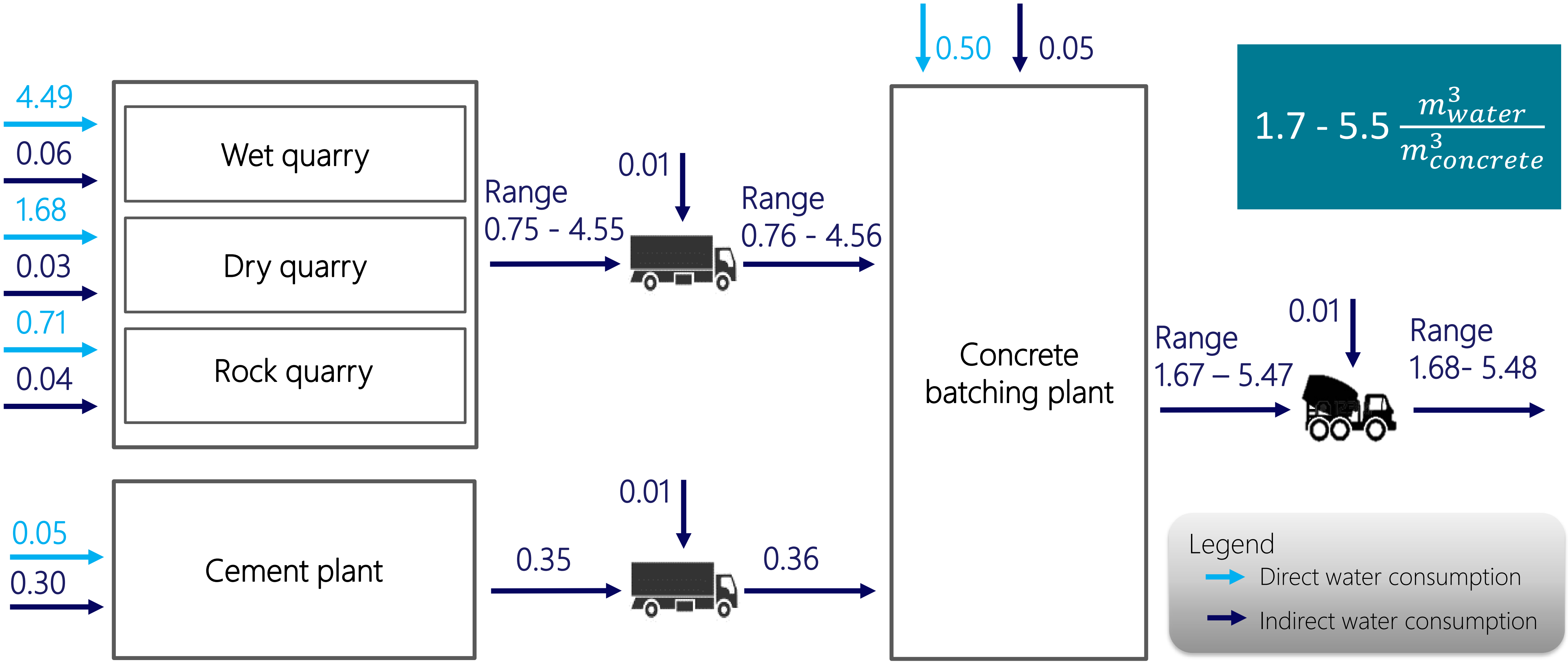
- ❑ Abruzzo
- ❑ Eastern Sicily
- ❑ Lombardy
- ❑ Contribution of each unit process

Water footprint – Alternatives comparison

- ❑ LAFW → LASW
- ❑ LAFW → MASW

Results

Freshwater consumption (base case scenario)



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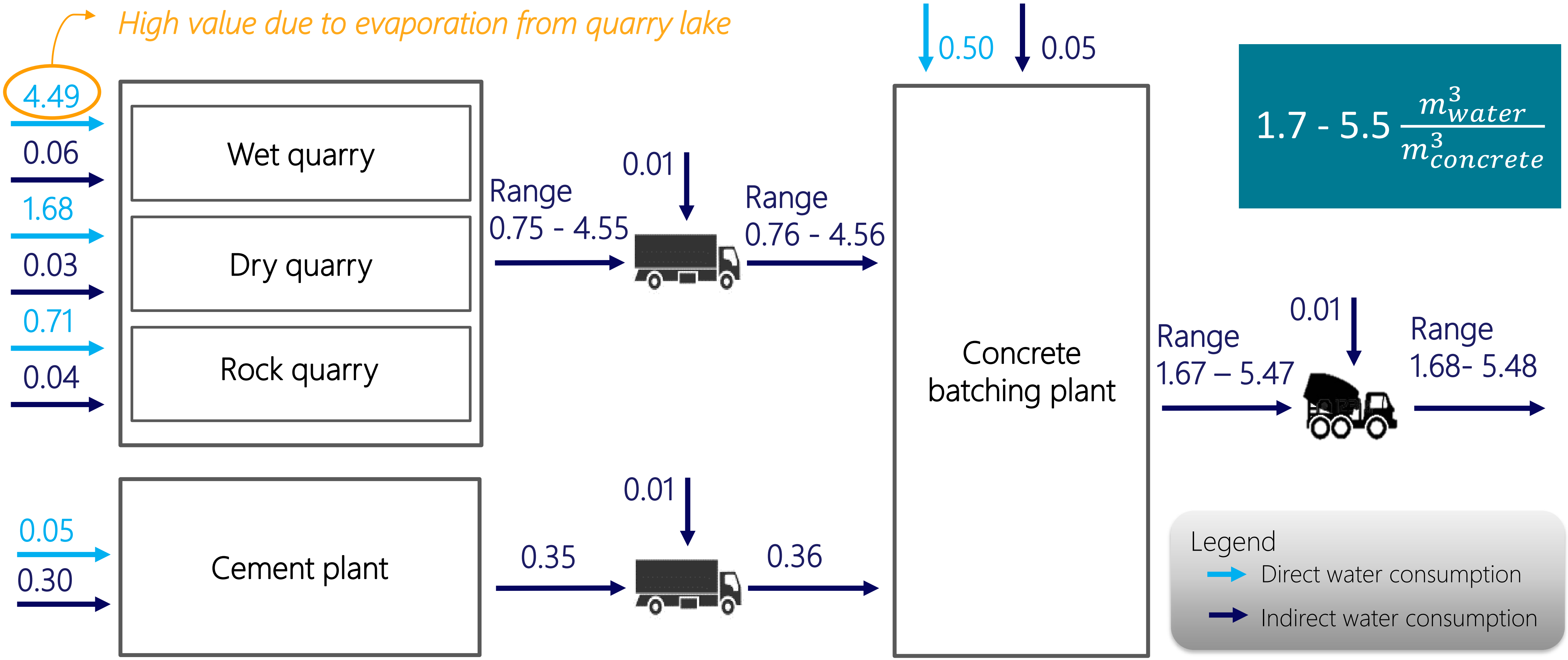
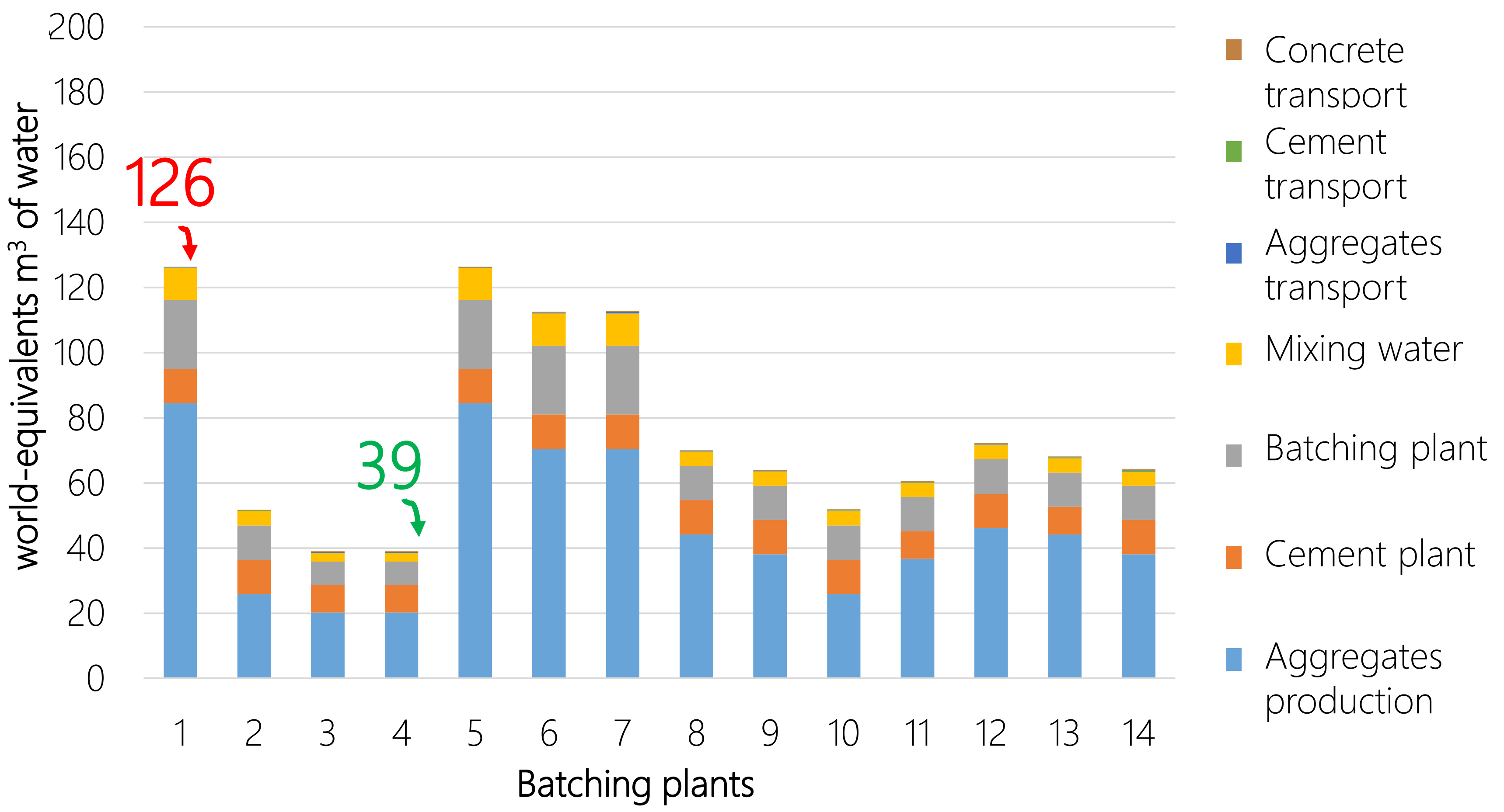
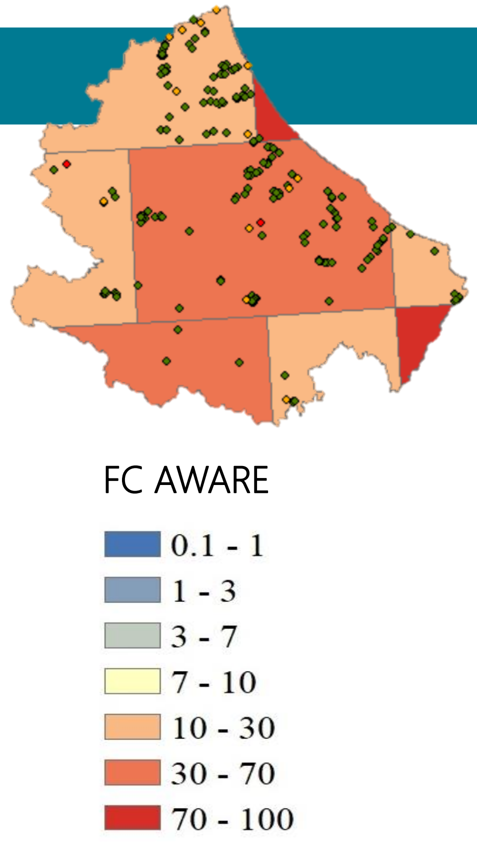


Results

Water Footprint base case scenario (LAFW)

WF of 1 m³ of concrete (D.U.) in Abruzzo





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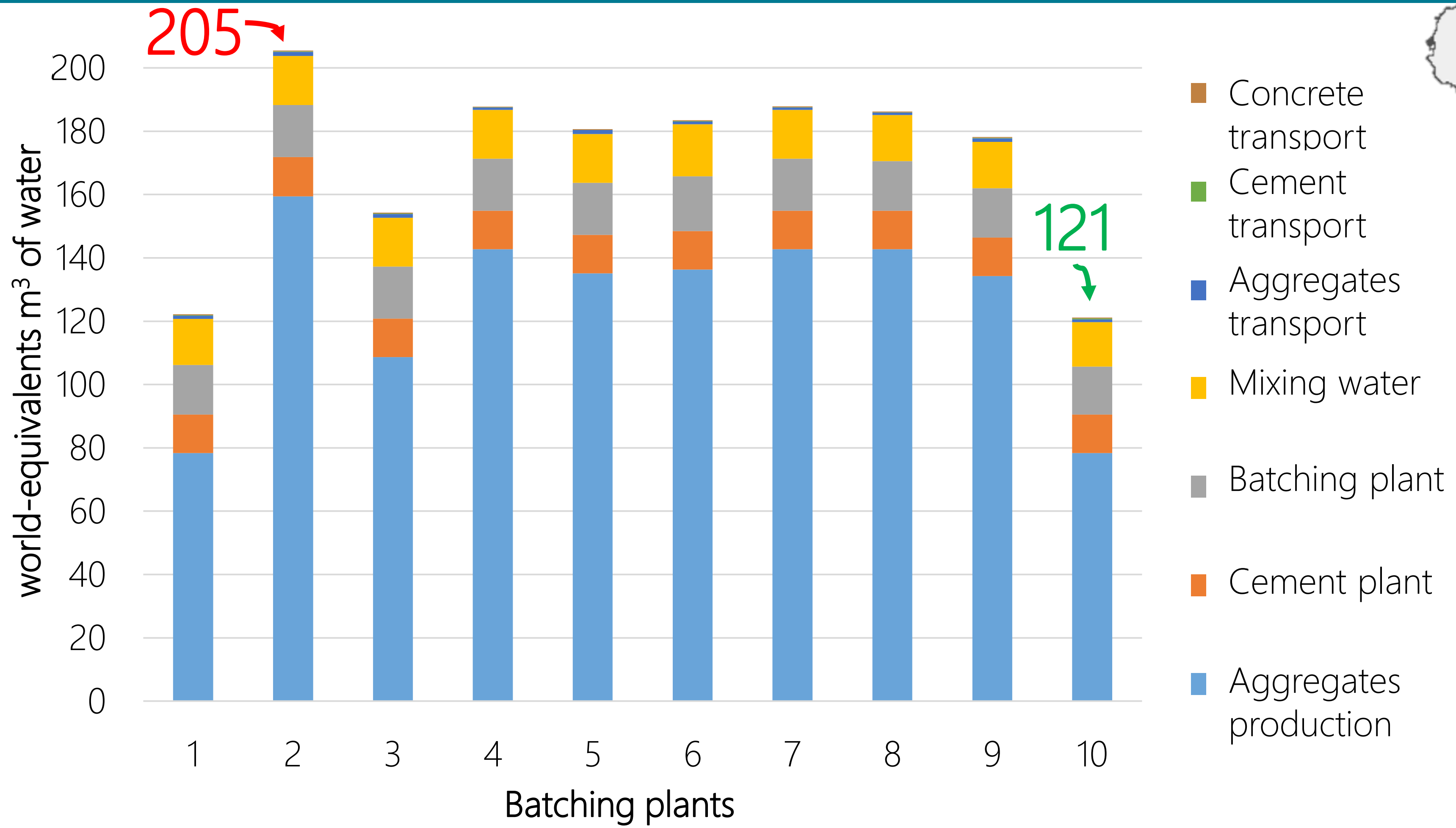
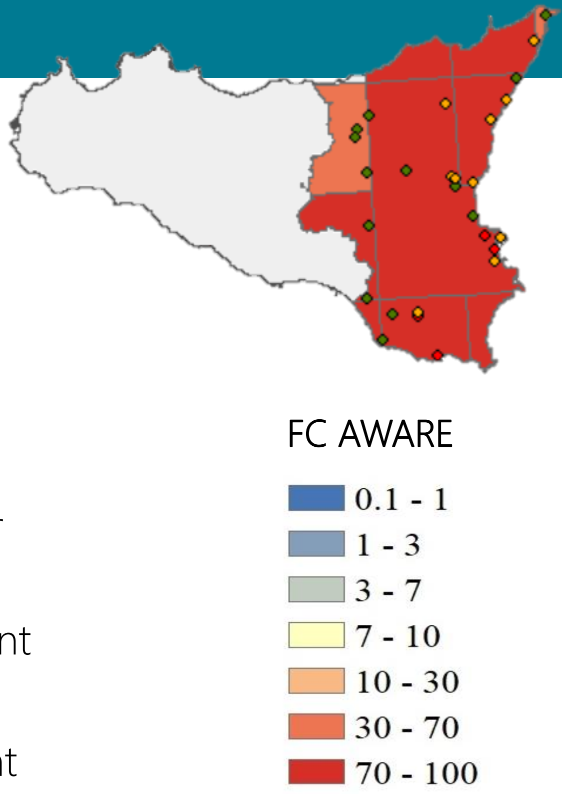
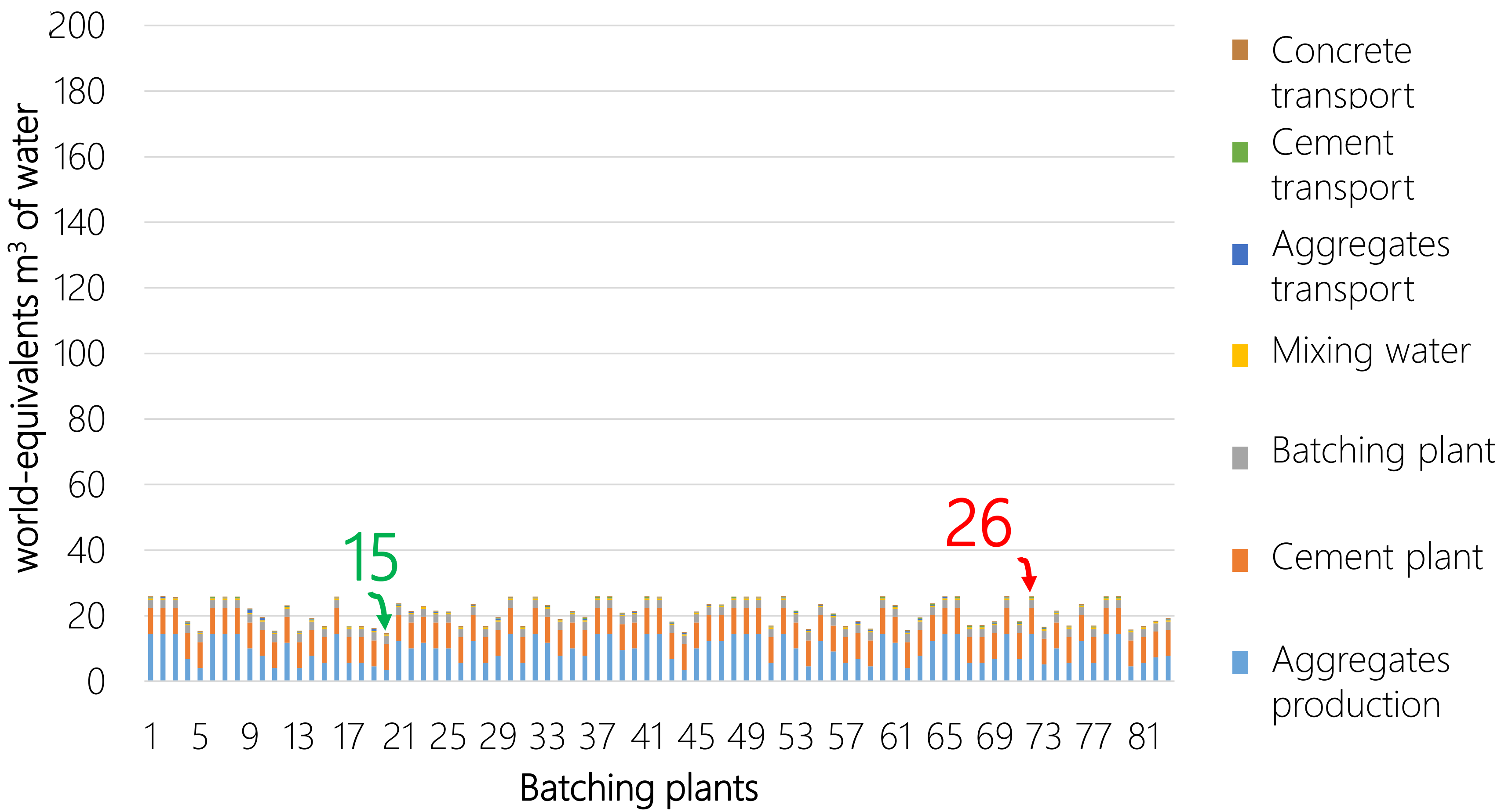


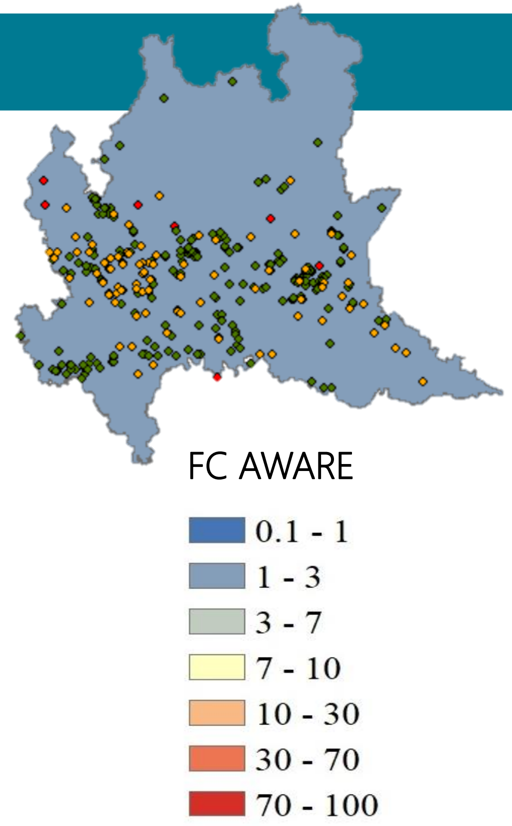


Results

Water Footprint base case scenario (LAFW)

WF of 1 m^3 of concrete (D.U.) in Lombardy

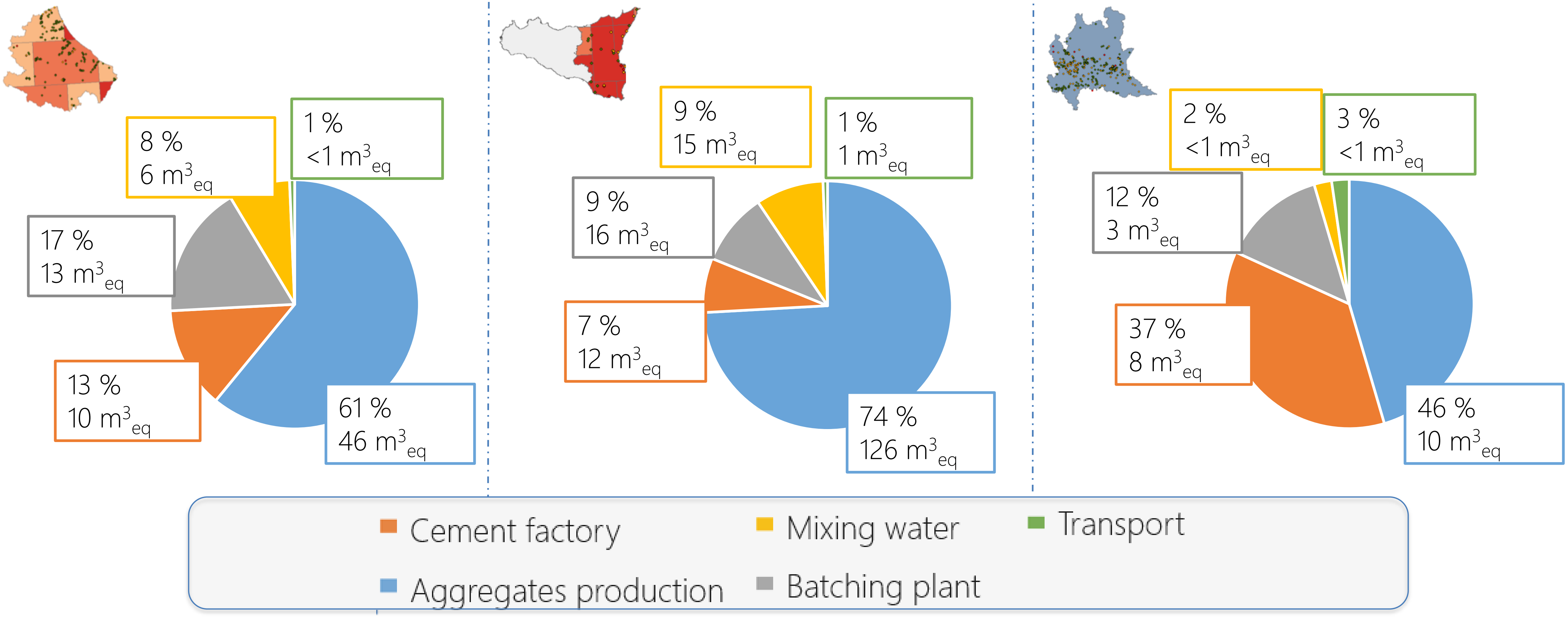




Results

Water Footprint base case scenario (LAFW)

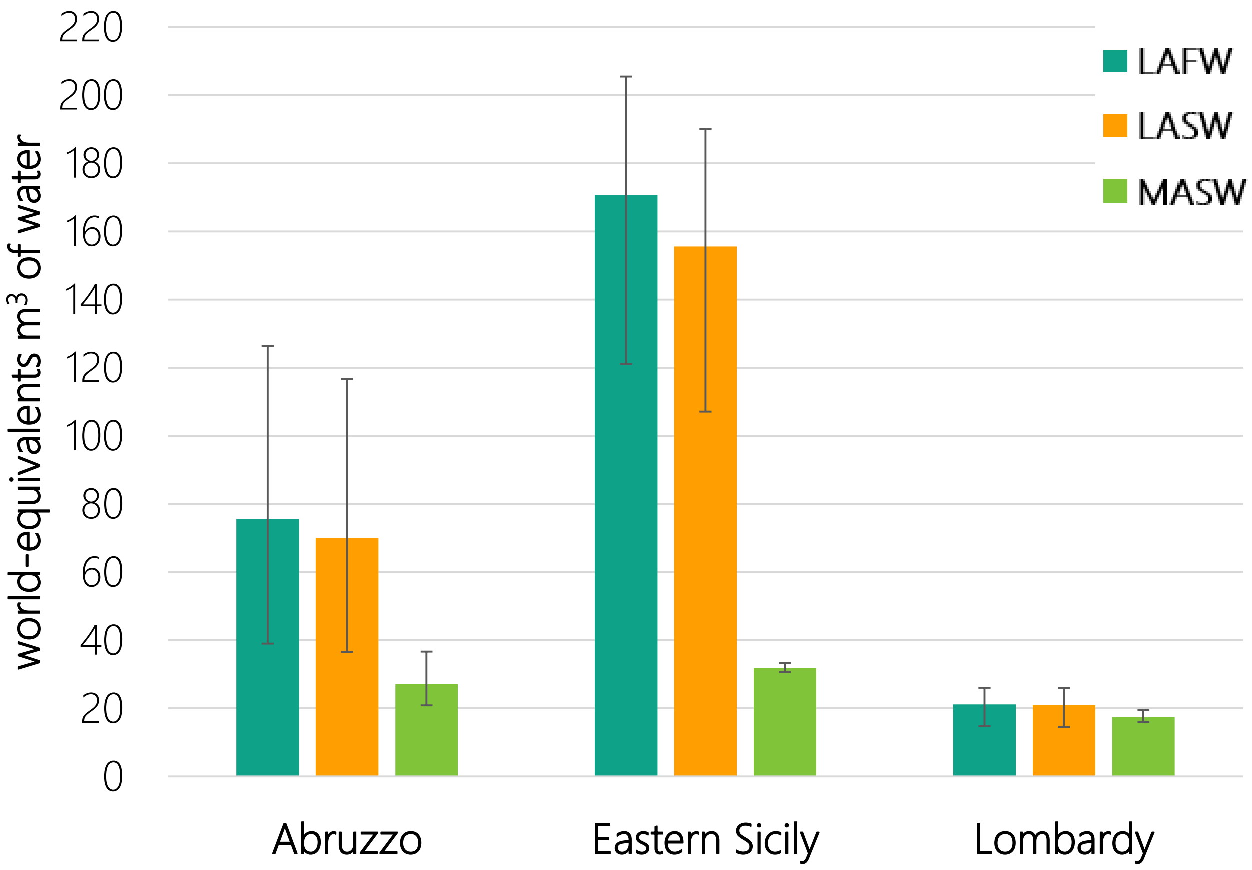
Mean WF and share of each unit process in the regions investigated



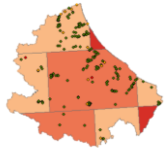
Results

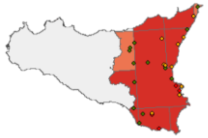
Alternatives comparison

Mean, minimum and maximum WF in the different alternatives in the regions investigated



WF variation from basecase scenario (LAFW) to alternative mixes (LASW and MASW)





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		Max ↓ (Min ↑)	Max ↑ (Min ↓)	Max ↓ (Min ↑)	Max ↑ (Min ↓)	Max ↓ (Min ↑)	Max ↑ (Min ↓)
LAFW ⇨ LASW	%	-10%	-7%	-12%	-8%	-2%	0%
LAFW ⇨ MASW	%	-78%	-50%	-84%	-75%	-44%	20%

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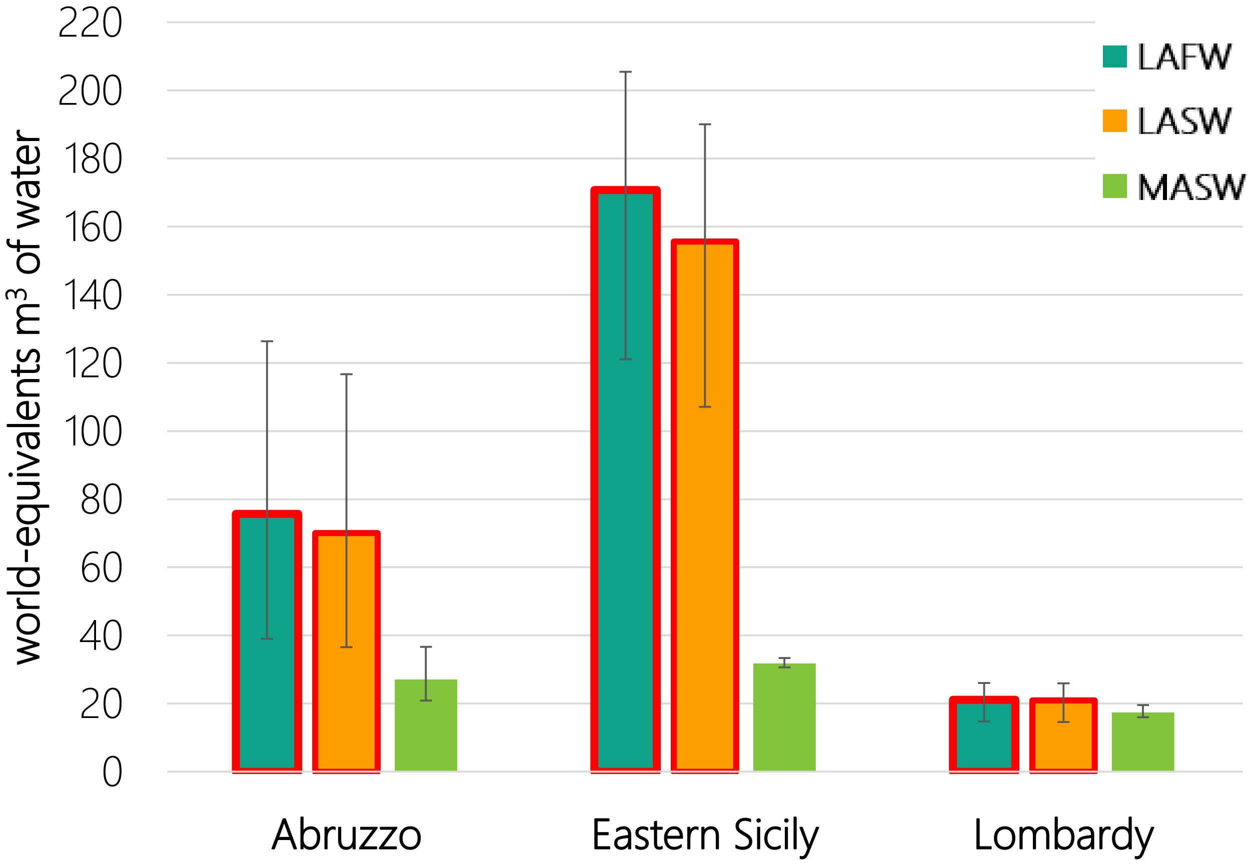

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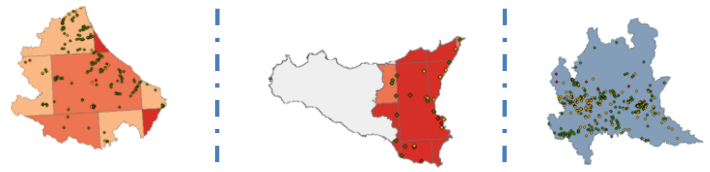

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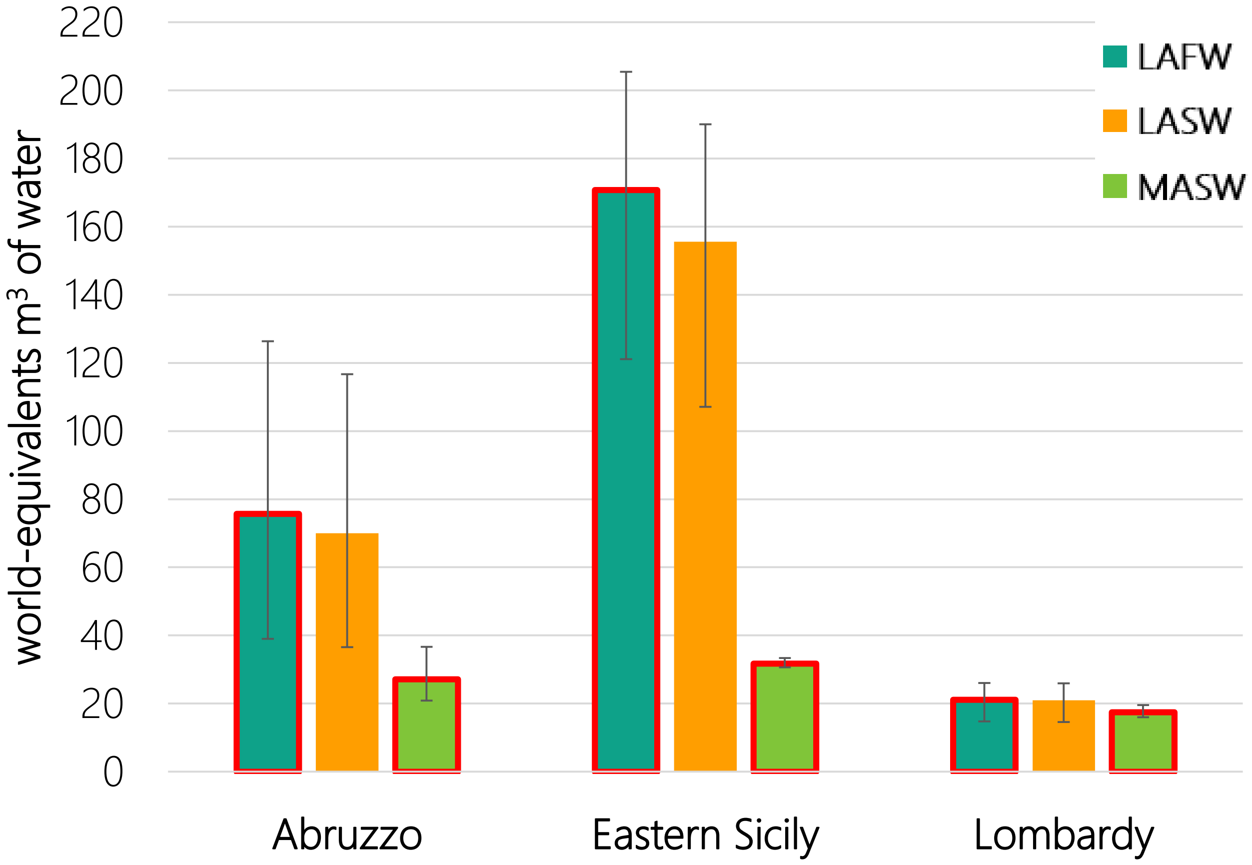

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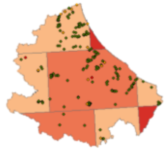
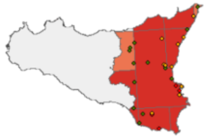


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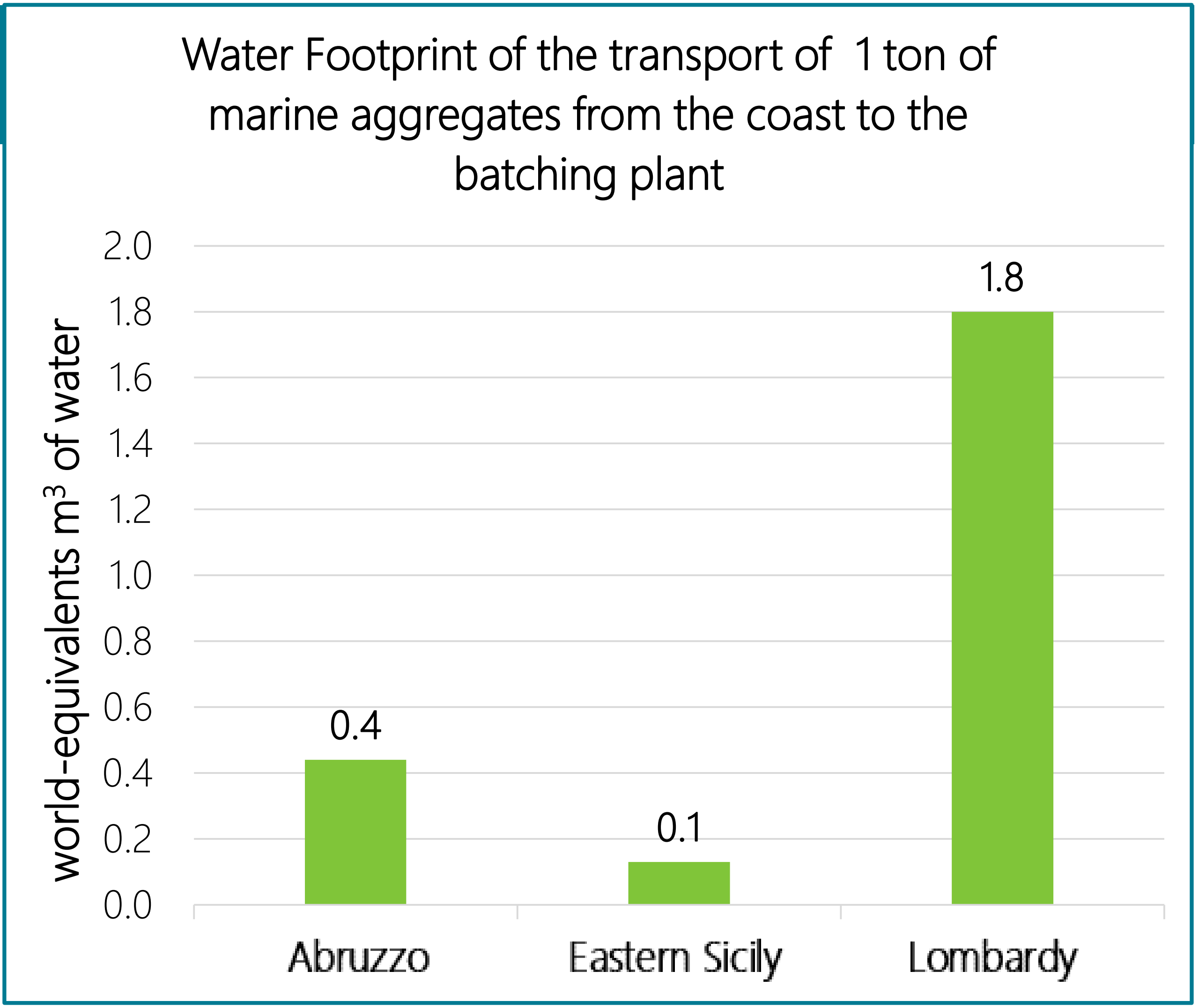

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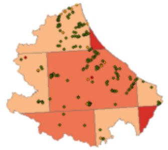
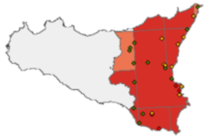


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- Seawater as mixing water → reduction of the WF of concrete up to 12% in Eastern Sicily, negligible effect on the WF in Lombardy
- Marine aggregates instead of land-won aggregates
  - → in areas affected by water stress → considerable reduction of WF (i.e. in up to 80% in Eastern Sicily);
  - → if aggregates need to be transported for a long distance → possible increase of WF

Further investigations

Burden shiftings

Global warming potential

Impacts on aquatic ecosystems

Reinforcement elements

Carbon steel

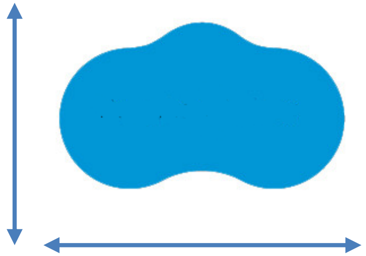
GFRP

Stainless steel

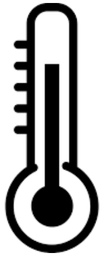
- ❑ Durability
- ❑ Whole life cycle
- ❑ LCC

Further investigations

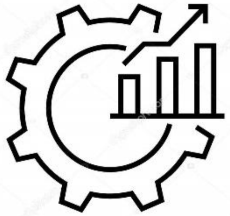
Water evaporating from the quarry lake



Area



Temperature



Productivity

Different provenience of freshwater for mixing

- ❑ Desalinated water
- ❑ Municipal water network

Sensitivity analysis

- ❑ Different strenghts and water-to-binder ratios for concrete

THANK YOU FOR THE ATTENTION!