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Drinking water and sewer networks in Spanish medium-sized cities: an environmental assessment from an industrial ecology perspective

(2014 SGR 1412)

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EXCELENCIA MARÍA DE MAEZTU

STATE OF THE ART

Important contribution of the DWTDN to the global environmental impact

Previous studies have not compared diferent constructive solutions

Author	System analysed	Phases included					Main Findings
		Production	Installation	Transport	Operation	Maintenance	
Amores et al, 2013	UWC	X			X		**DWTDN = 20 to 40%** of the global impact of the UWC
Lemos et al., 2013	UWC	X			X		**DWTDN and sewerage = 20 to 25%** of the impact of the UWC
Dennison et al., 1999	DWTDN	X					**Manufacturing** main contributor.
Venkatesh & Brattebø, 2012	DWTDN	X	X			X	Maintenance becomes a grater contributor in **stagnant grids**
Piratla et al., 2012	DWTDN	X	X		X		**Operation phase = 99%** of the global environmental impact.

UWC= Urban Water Cycle
DWTDN= Drinking Water Transport and Distribution Network

Supply and **sewer networks** need further assessment.

STATE OF THE ART

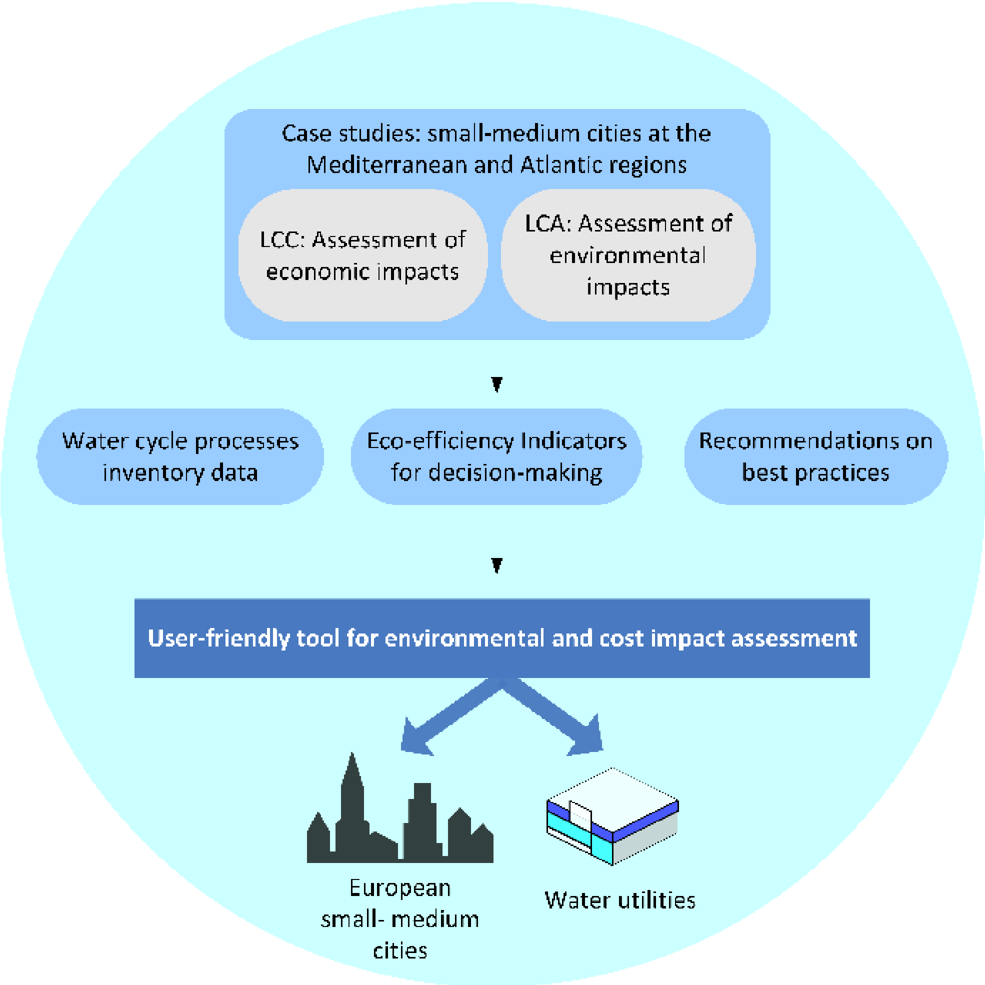
Variability of the environmental impacts of the use phase.
Dependence on the specific case.

Author	System analysed	Phases included: Construction	Phases included: Transport	Phases included: Operation	Phases included: Maintenance	Main Findings
Sharma et al., 2009	UWC	X		X		GHG emissions of water services for 86,000 resident → **16 to 25 t of CO_2 eq./year.**
Friedrich et al., 2009	UWC	X		X		GHG emissions of water services for 200,000 resident → **5.8 to 10 t of CO_2 eq./year.**
Muñoz et al., 2010	UWC	X		X		GHG emissions of water services → **1.5 to 2.5 tons of CO_2 eq./m3 supplied.**
Stokes & Horvath, 2006	UWC	X		X	X	**Operation (60 to 91%** of the impact), maintenance (5 to 26%).
Venkatesh & Brattebø, 2011	UWC				X	**Pumping energy: 17%** of the environmental impact.
Racoviceanu et al., 2007	DWTP		X	X		**Pumping energy: 73%** of the global environmental impact.
Vince et al., 2008	DWTP	X	X			**Pumping energy: 5%** of the global environmental impact.

UWC= Urban Water Cycle
DWTP= Drinking Water Treatment Plant

The use phase of networks must be assessed from a **top-down perspective**, provided the variability observed in previous studies.

AQUAENVEC LIFE+ PROJECT



This study has been conducted within the AQUAENVEC LIFE+ project

PROJECT WEBPAGE

http://www.life-aquaenvec.eu/

TOOL WEBPAGE (ALREADY AVAILABLE)

http://tool.life-aquaenvec.eu/en

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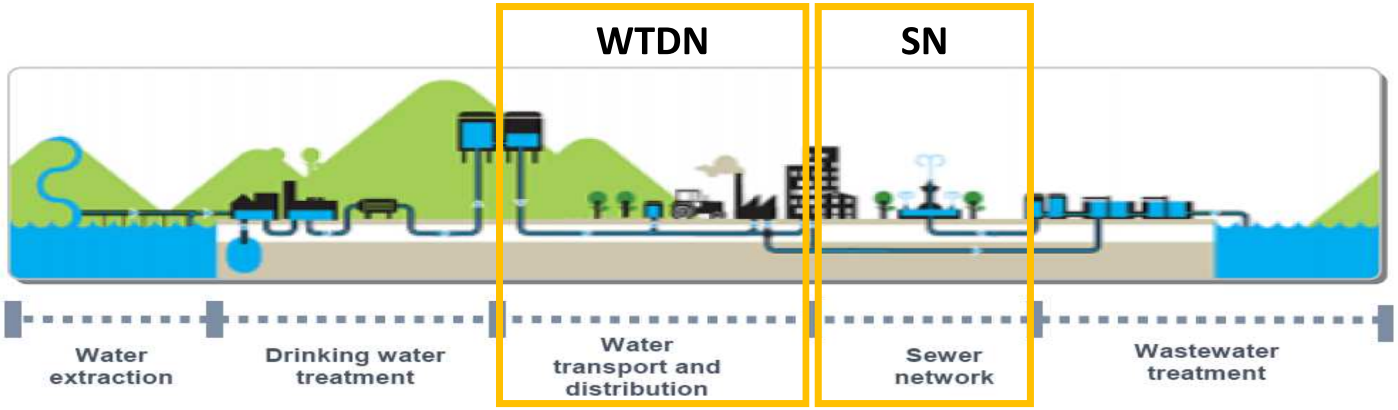
ASSESSMENT AND IMPROVEMENT OF THE URBAN WATER CYCLE ECO-EFFICIENCY USING LCA AND LCC

OBJECTIVES



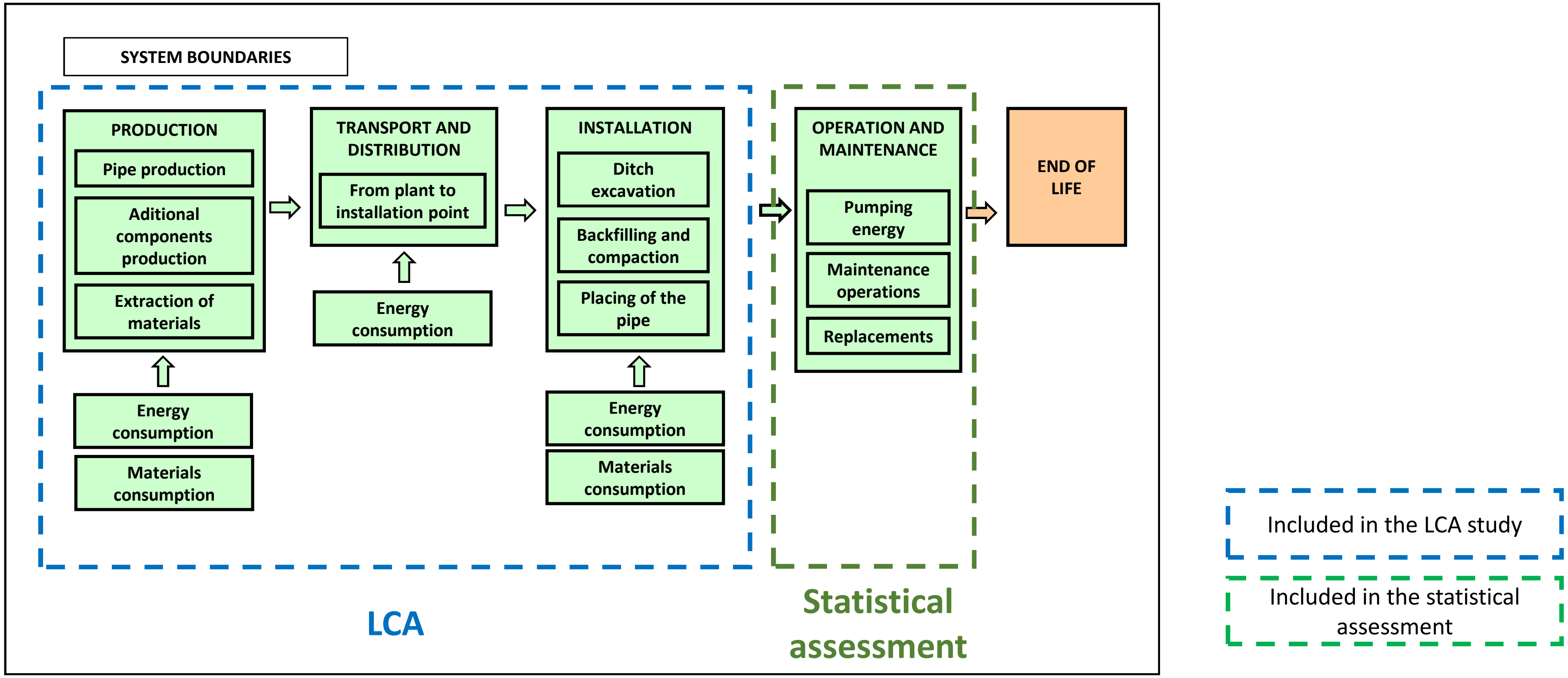
To assess the **environmental impacts** and the main influencing variables of **drinking water supply** and **sewer networks**.

Specific objectives were defined

1. To assess the environmental impacts of the construction of networks using **life cycle assessment (LCA)**.
2. To determine the **impacts of the pipes** used in the construction of networks.
3. To characterize the operation phase of the networks and define the main variables affecting it through a **statistical assessment** of a sample of small and medium cities.

WATER SUPPLY NETWORK

System boundaries



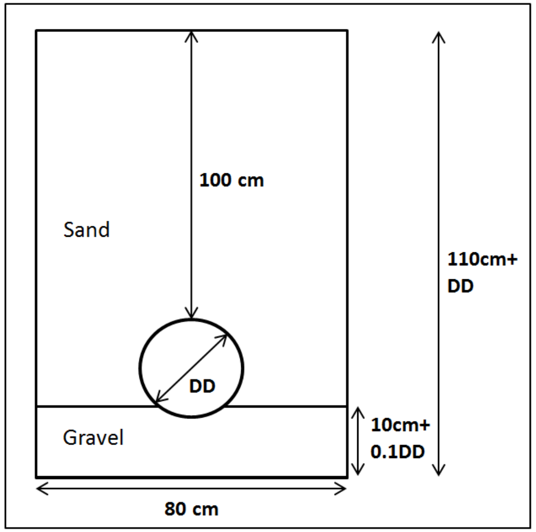
Comparison of pipe materials for drinking water supply network construction

❖ **Functional unit**: Production, transport and installation of a **linear meter of network with a pipe of 90 mm in diameter** and a maximum pressure of 6 bar or a **pipe 200 mm in diameter** and a maximum pressure of 10 bar, including the accessories of the pipe and the backfilling and bedding materials, required to transport drinking water over the course of **50 years.**

Comparisons:

90 mm in diameter and 6 bar of maximum pressure: **high density polyethylene (HDPE), low density polyethylene (LDPE), poly vinyl chloride (PVC)**

200 mm in diameter and 10 bar of maximum pressure: **HDPE, PVC, ductile iron (DI), glass fibre reinforced polyester (GFRP)**

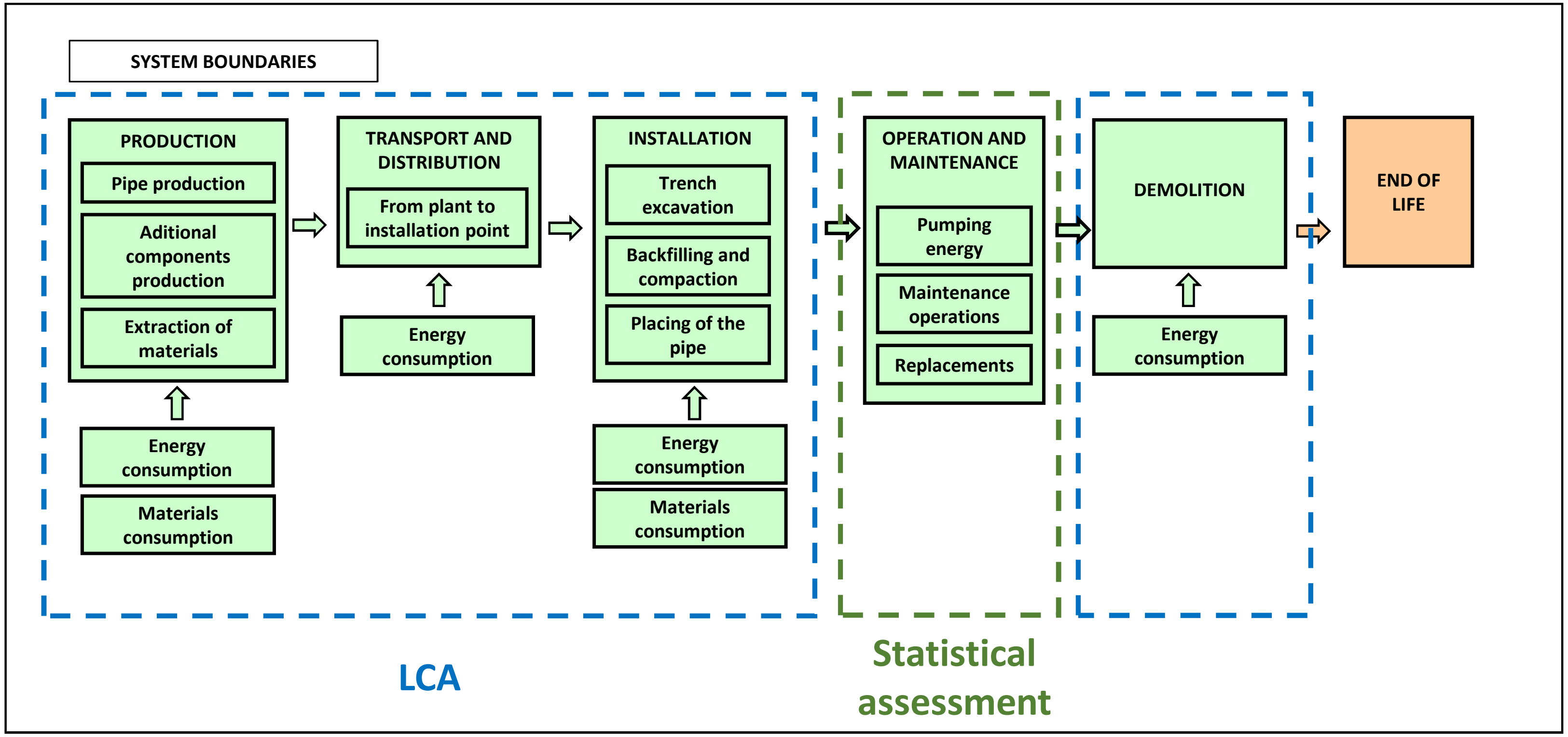


DD= Ditch Diameter

All the selected materials are commonly used for supply network pipes.

SEWER NETWORK

System boundaries



Included in the LCA study

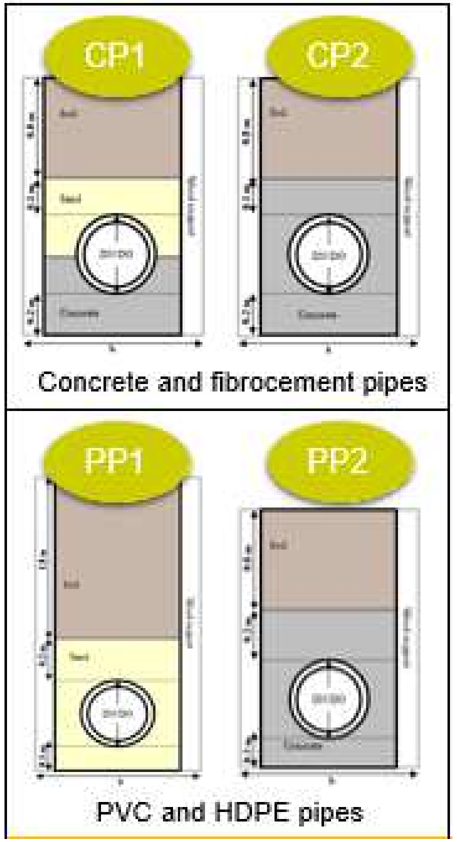
Included in the statistical assessment

Comparison of pipe materials for sewer construction

❖ **Functional unit**: **Production, transport and installation of a linear meter of network with a pipe of 300 mm in diameter made of plastic or concrete.**

Materials	Lifespan
Concrete Fibrocement	100 years
PVC HDPE	50 years

Constructive solutions



Concrete and fibrocement pipes

PVC and HDPE pipes

WATER SUPPLY NETWORK – statistical assessment

A statistical assessment of a sample of **50 networks from Spanish municipalities** has been assessed.

The following factors related with the environmental impacts of the networks have been analysed:

- **Size** (inhabitants)
- **Length of the distribution network** (km)
- **Population density** (inhabitants per km^2)
- **Seasonality** (maximum population that can be supplied/supplied population)
- **Electricity consumption** (kWh)
- **Water consumption** (m^3)
- **Gross income per capita** (€/inhabitant)

Software used: **IBM SPSS v18** for Windows

SEWER NETWORK – statistical assessment

A statistical assessment of a sample of **48 networks from Spanish municipalities** has been assessed.

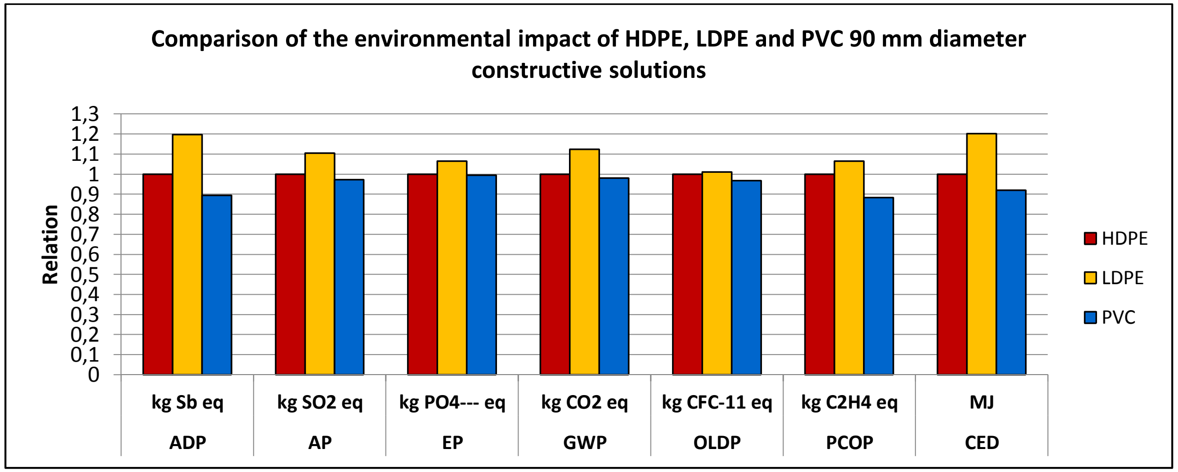
The following factors have been analysed:

- **Size** (number of inhabitants)
- **Length of the sewer** (km)
- **Waste- and stormwater flow** (m^3)
- **Height** (m)
- **Seasonality** (maximum population that can be supplied/supplied population)
- **Population density** (inhabitants per m^2)
- **Climate** (Mediterranean, Atlantic)
- **Location** (coast or inland)
- **Gross income per capita** (€/inhabitant)

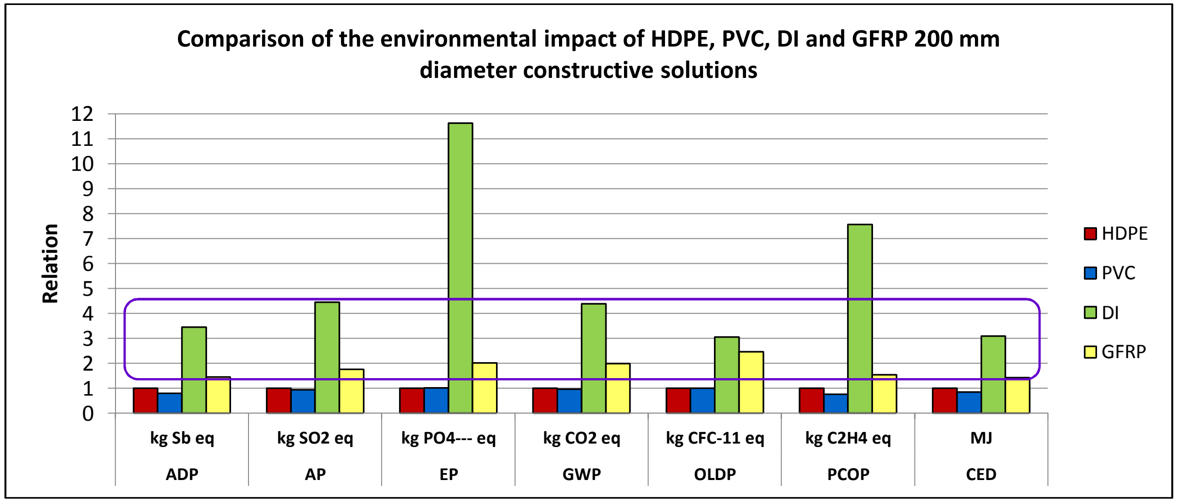
Software used: **IBM SPSS v18** for Windows

WATER SUPPLY NETWORK

- For 90 mm-diameter pipes, all materials have similar impacts
- In both comparisons, PVC was the less impactin option (90% less impact than ductile iron for 200 mm)
- DI and GFRP present clearly a higher environmental impact (more quantity of material for the pipe)



90 mm pipe diameter



200 mm pipe diameter

HDPE – High density polyethylene
LDPE – Low density polyethylene
PVC – Polyvinyl chloride
DI – Ductile iron
GFRP – Glass fibre reinforced polyester

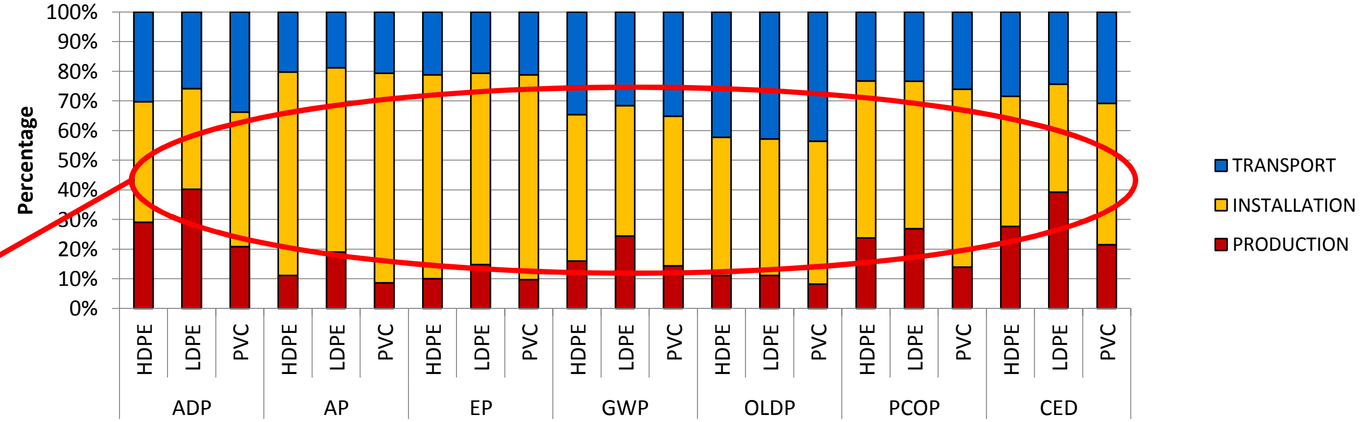
WATER SUPPLY NETWORK

Larger pipe diameters imply:
- Higher impact of the pipe production
- Lower importance of the installation

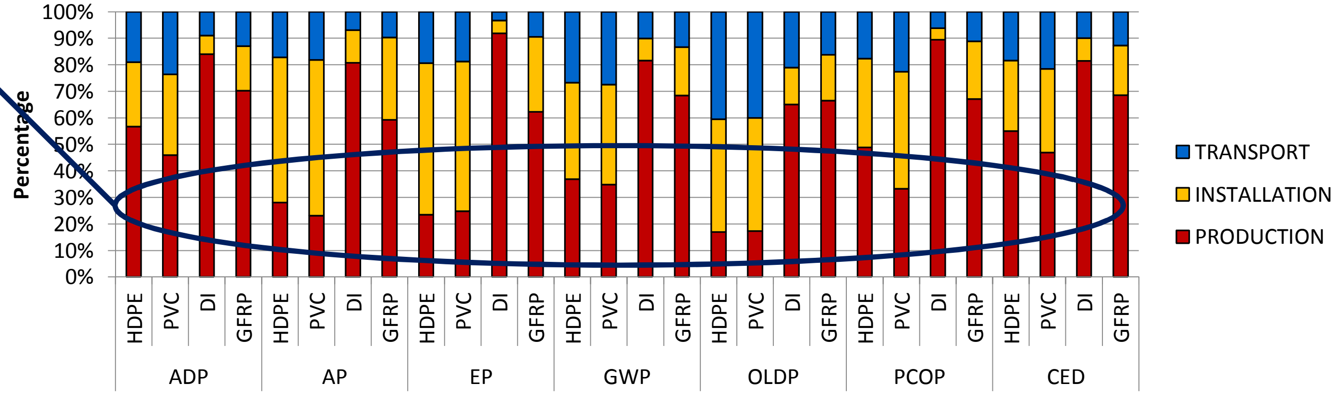
90 mm pipe diameter
INSTALLATION is the most impacting phase (more than 40% in 5 impact categories)

200 mm pipe diameter
PRODUCTION is the main contributor (up to 90%)

Contribution of each life cycle phase to the global environmental impact (HDPE, LDPE, PVC; 90 mm diameter)

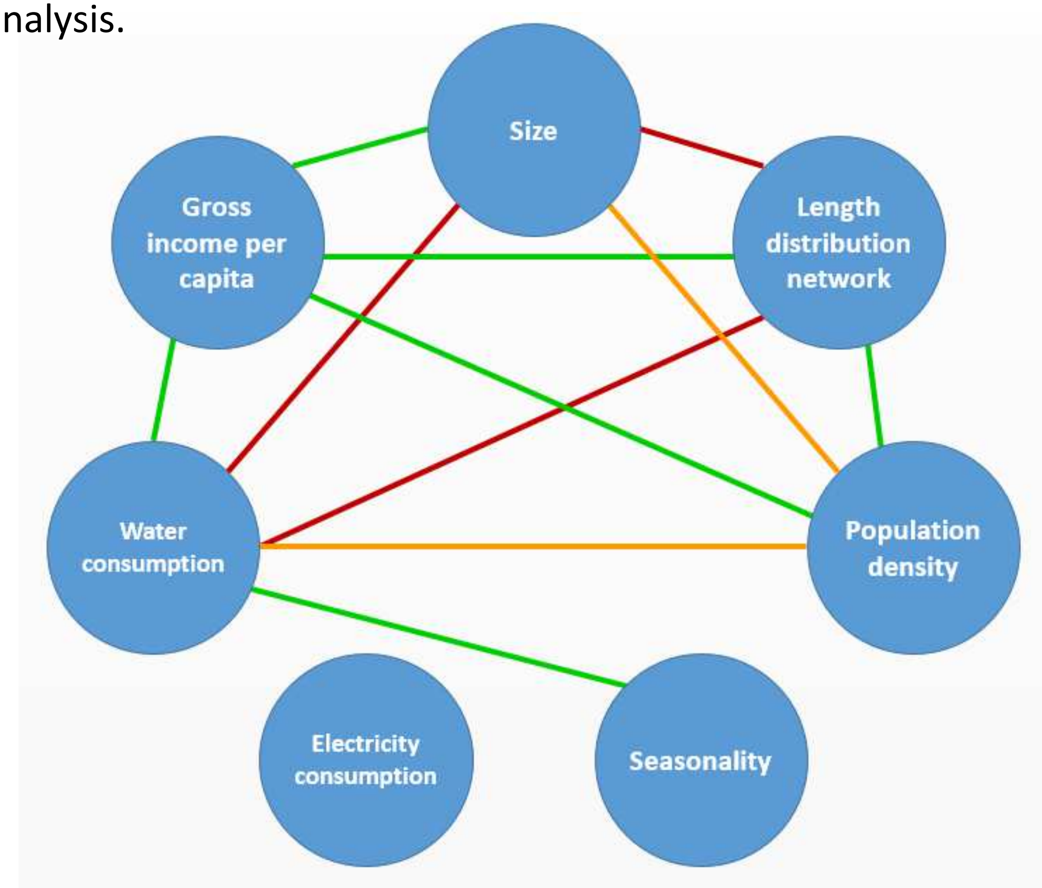


Contribution of each life cycle phase to the global environmental impact (HDPE, PVC, DI, GFRP; 200mm-diameter)



WATER SUPPLY NETWORK

Correlation between the different factors of the water supply networks included in the analysis.



30 to 50% correlated

50 to 65% correlated

More than 65% correlated

Correlations were observed between some variables. However, **no correlation was found with electricity** consumption due to the variability among cities.

SEWER NETWORK

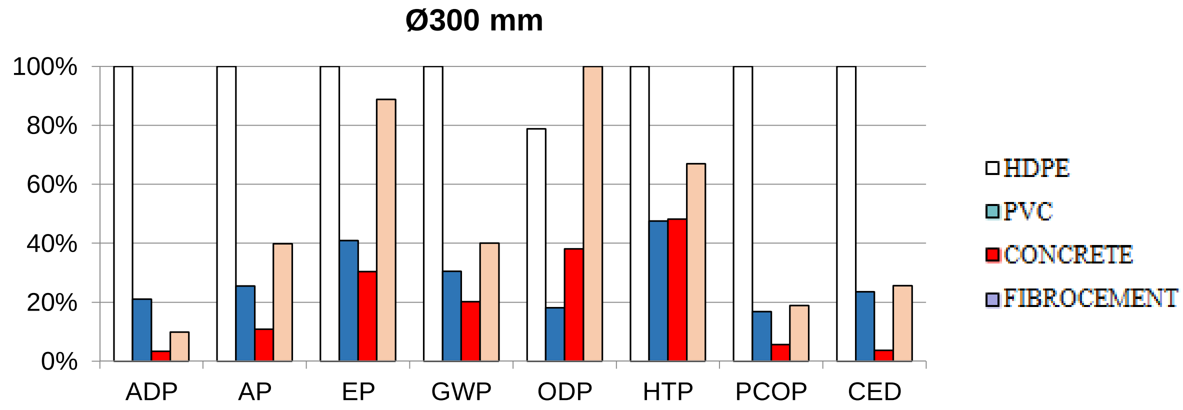
HDPE results in greater environmental impacts because:

- It is made of oil derivatives
- It has a shorter lifespan and needs reposition

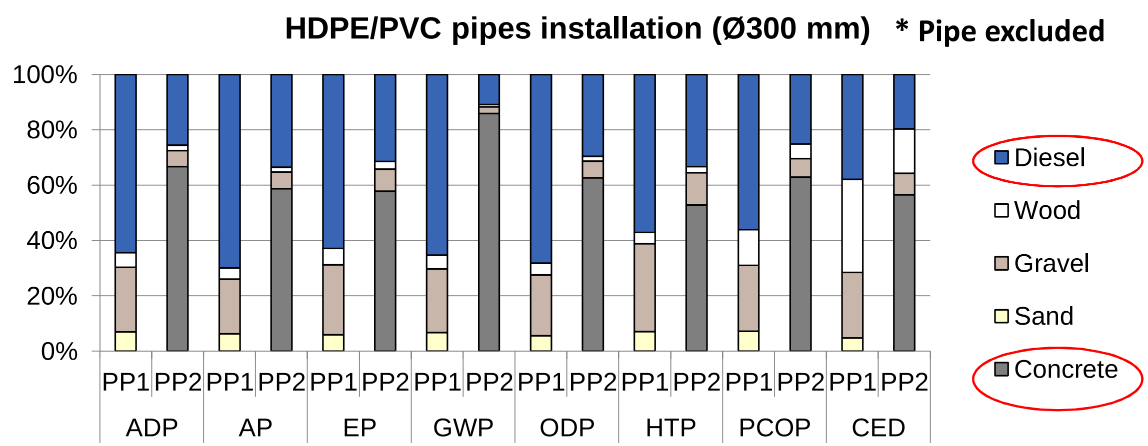
In general, **concrete is the best option**

Concrete beddings result in up to 80% greater environmental impacts than sand-bedded trenches

Pipe production



Installation



HDPE – High density polyethylene
PVC – Polyvinyl chloride

SEWER NETWORK

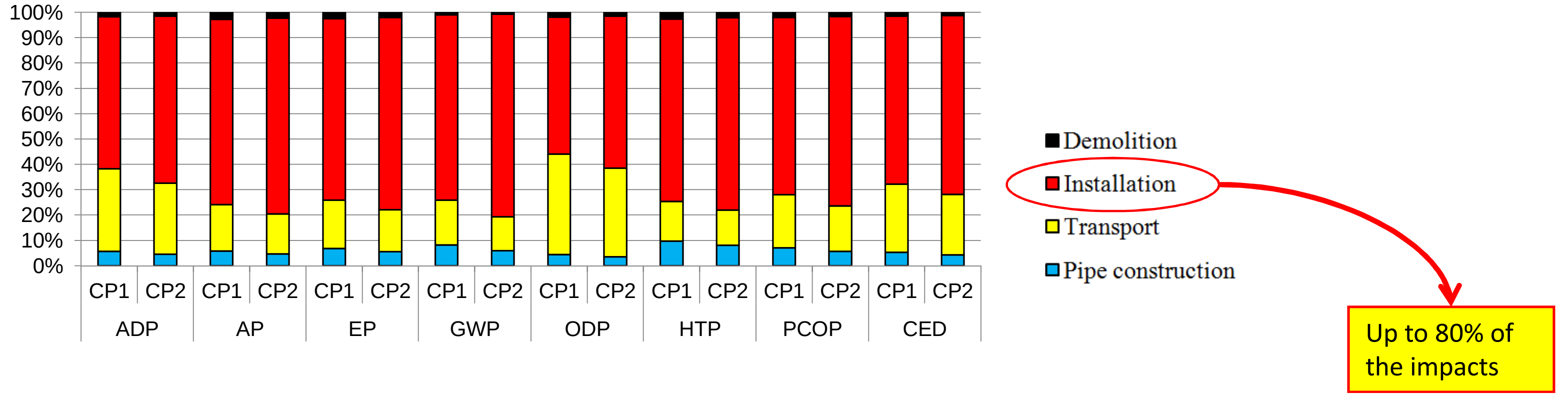
Best design: Concrete with trench design CP1 (20-30% of the impact of HDPE)

In 100 years:

1.2E+02 kg CO_2 eq.

1.3E+03 MJ

Life cycle stages concrete pipes (Ø300 mm)



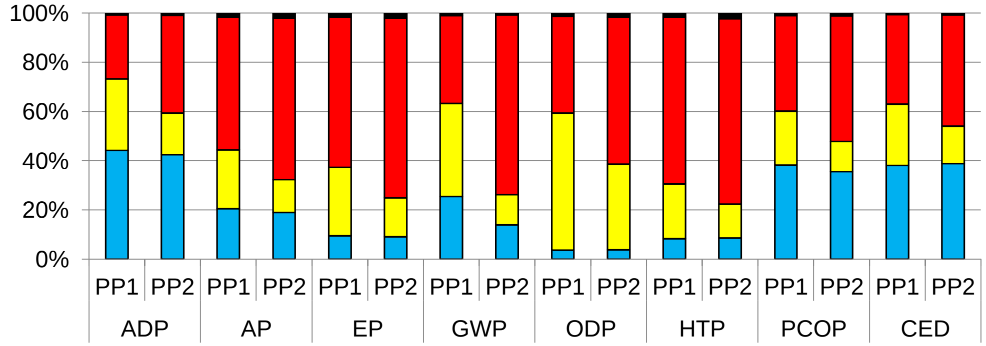
Worst design: HDPE pipes with trench design PP2

In 100 years:

3.4E+02 kg CO_2 eq.

4.6E+03 MJ

Life cycle stages HDPE pipes (Ø300 mm)

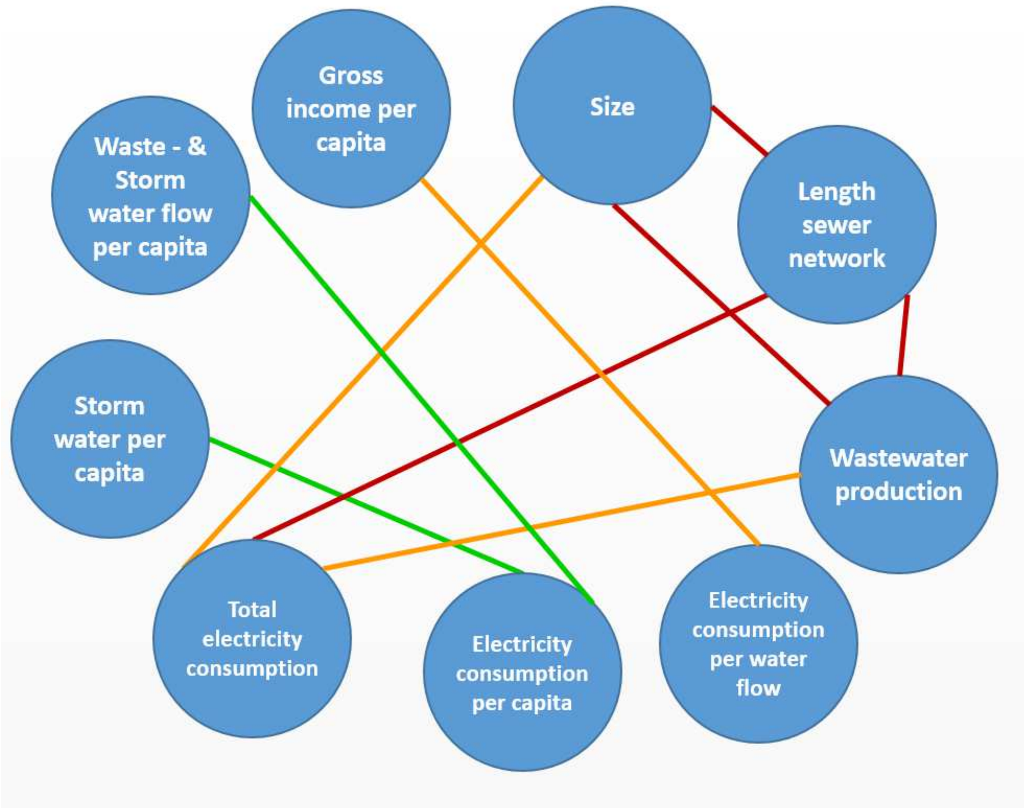


Concrete and fibrocement
CP1- mixed bedding
CP2- concrete bedding

Plastic
PP1- sand bedding
PP2- concrete bedding

SEWER NETWORK

Correlation between the different factors of the sewer networks included in the analysis.



30 to 50% correlated

50 to 65% correlated

More than 65% correlated

The total electricity consumption is mainly related to

length of sewer
&
wastewater production

CONCLUSIONS

LCA OF CONSTRUCTIVE SOLUTIONS

SUPPLY NETWORK

- **Installation** is the most impacting phase for smaller pipes (90 mm); **production** is the main contributor for larger diameters (200 mm).
- **Plastic pipes (PVC, HDPE and LDPE)** are recommended over glass fiber reinforced polyester and ductile iron.

SEWER NETWORK

- P**roduction and installation are the most impacting phases** and depend on the **diameter** of the pipe, the **pipe material** and the **ditch used**.
- **Concrete pipes with half-sand/half-concrete bedding** are recommended when installing new network or replacing obsolete sections.

USE PHASE - STATISTICAL ASSESSMENT

- Supply networks must be **assessed individually** due to the high variability among the cases.
- **Length of sewer and wastewater generation** are key factors when reducing electricity consumption of sewer networks.

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European Commission

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Generalitat de Catalunya

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MINISTERIO DE EDUCACIÓN, CULTURA Y DEPORTE

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