PVC PIPES COMPETITIVENESS

Total Cost of Ownership of PVC pipes and Cost Benefit of its recycling

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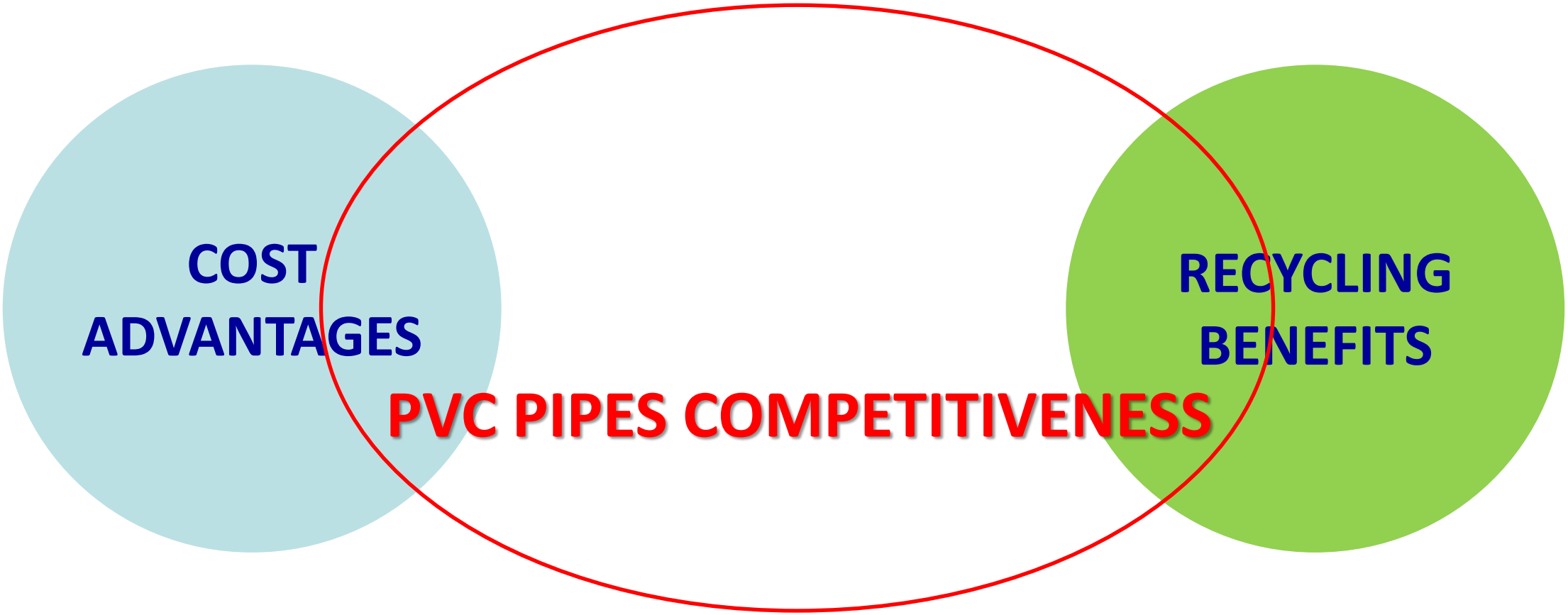
PVC pipes bring value to the utility industry …

- Plastics pipes are a key element in infrastructures development and competition with other materials is pushing the price/performance ratio
- In this context, the PVC pipes competitiveness brings benefits both to the plastics industry and to the utility sector, end user of pipes in its network
- PVC4pipes and ECVM carried out in 2010 and 2018 a study about the PVC pipes competitiveness showing the advantages of these products
- Sustainability has become more and more a key issue and a study about the cost-benefit of PVC pipes recycling has been carried out

… merging financial and sustainability advantages



Total Cost of Ownership of PVC pipes

SUMMARY

1. Objectives

Mission: **to analyse the competitiveness of PVC pipes, through assessing the costs saving resulting from the use of PVC instead of the main functional alternatives along its entire lifetime**

Scope: a) the most alternative materials for:

- Pipes for drinking water mains
- Pipes for wastewater - sewerage

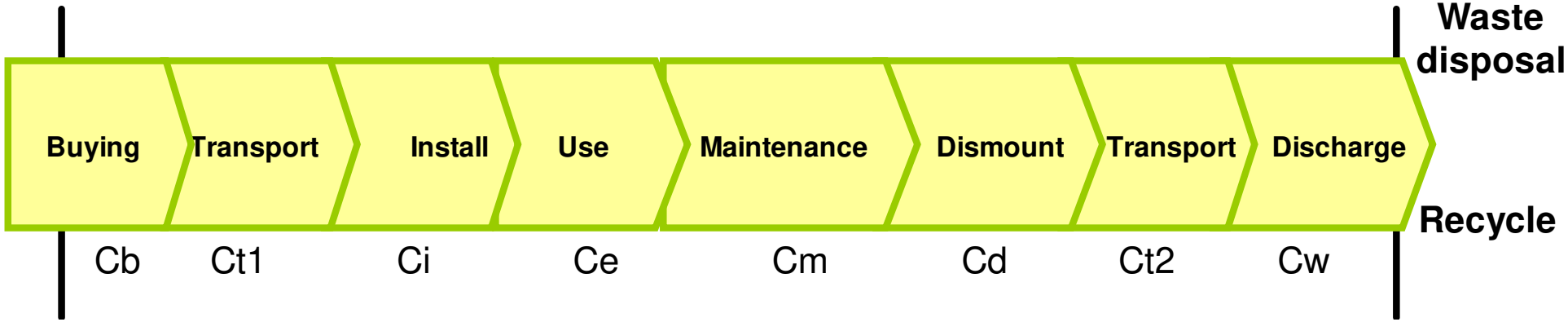
Geographical scope of the study:

- Italy
- Germany

2. Methodology

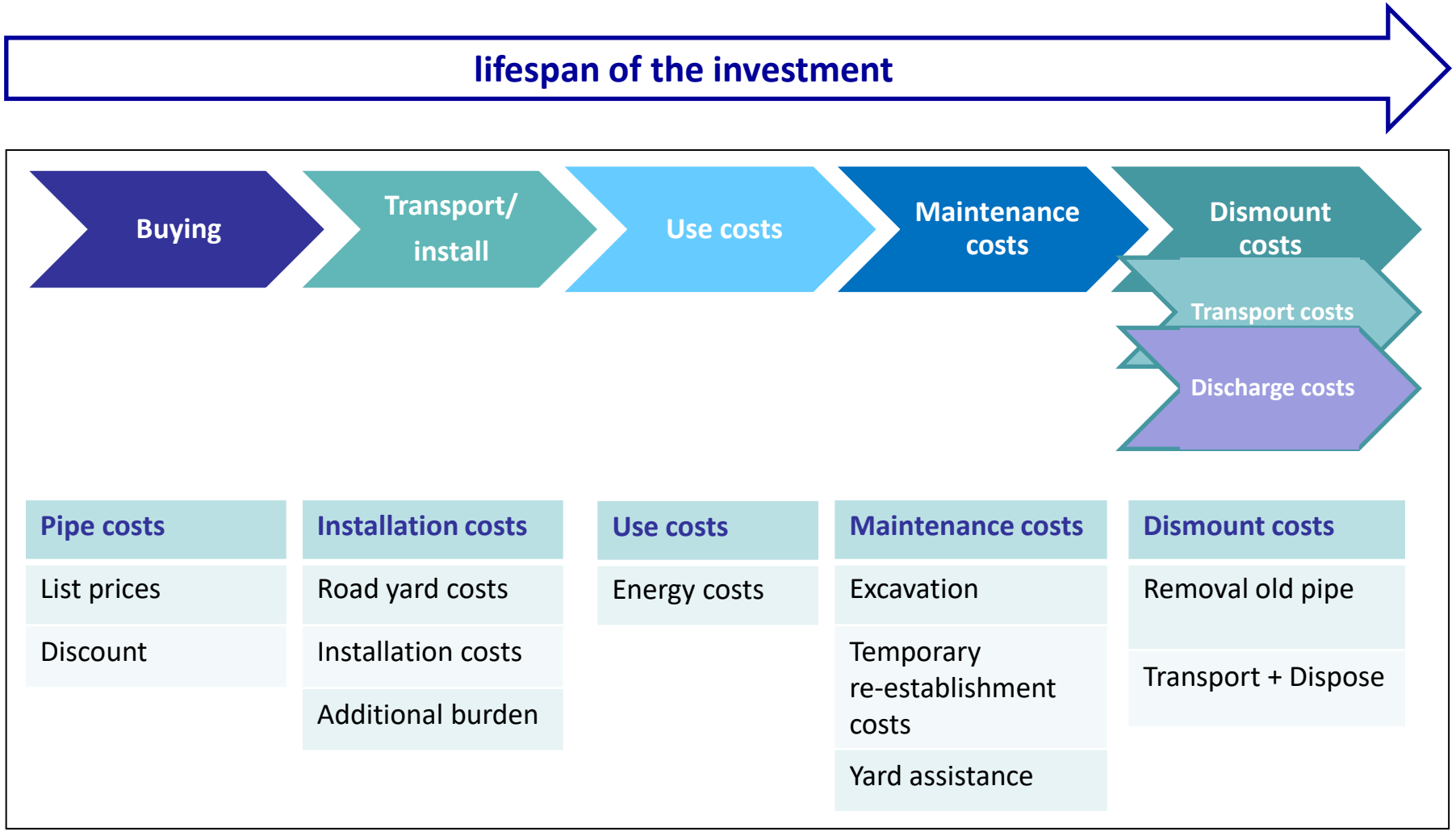
Since the aim of the study (a) is to provide an analysis of the **users' monetary costs** throughout the pipes lifetime", **Total Cost of Ownership (TCO)** is the best method

- A Cost of Ownership assessment is a methodology designed to find the lifetime costs of acquiring, operating and changing something
- TCO is a "customer centric" analysis aimed to account for the difference between the purchase price of something and its long term cost



$$TCO = \sum Cx$$

Applying the TCO methodology to pipes



Pipe costs	Installation costs	Use costs	Maintenance costs	Dismount costs
List prices	Road yard costs	Energy costs	Excavation	Removal old pipe
Discount	Installation costs		Temporary re-establishment costs	Transport + Dispose
	Additional burden		Yard assistance	

Applying the TCO methodology to pipes

- For each family of materials the study compared the costs for the entire life cycle of the pipes. All the cost items related to pipes of various materials and diameters are considered over the selected planning periods
- The total cost of ownership is based on the following formula:

$$C_{Tot} = C_{Materials} + C_{Installation} + C_{O\&M} + C_{dismantling}$$

Where:

- $C_{Materials}$ is the cost of pipes (ex-work);
- $C_{Installation}$ sums up all the industrial costs related to building the networks
- $C_{O\&M}$ considers the Operation & Maintenance costs necessary to allow the network functionality
- $C_{Dismantling}$ estimates the costs for dismantling old substituted pipes

Scope of the analysis

The analysis considers **the most adopted materials and sizes**

Drinking water pipes
Ductile Iron (DI)
Polyethylene (PE – HDPE)
PVC
Fiberglass (for larger diameters* - only for Italy)
**The use of fiberglass is limited to diameters over 315 mm*

Sewage pipes**
Concrete
Polyethylene (Corrugated PE)
PVC
Clay (gres)
PVC 3 layer (only for Germany)
***Cast iron is not considered because no longer used in new*

Diameters (mm)		
Size	**Water Mains**	**Sewerage**
S	63	250
M	110	315
L	160	400
XL	200	500
XXL	315	630

The final users are the utilities which, according to the TCO approach, buy, install, operate, repair, replace, dismount water networks over their technical service lives

$$C_{Tot} = C_{Materials} + C_{Installation} + C_{O\&M} + C_{dismantling}$$

Costs of materials

- **Costs of materials relate to the costs of the pipes** in different materials and diameters.
- Lists of pipes manufacturers, as well as engineering consulting firms and utilities public tenders have been reviewed. Significant discounts according to market practice have been applied.

Costs of Installation

- Installation costs are the result of the following formula:

$$C_{Construction} = C_{road\ yard} + C_{installation} + C_{additional\ burdens}$$

- Each entry then depends on multiple factors, the main ones are:
  - ✓ The material installed
  - ✓ The steps involved and the location of the site (urban, suburban, rural)
- Installation costs include dismantling and disposing of old pipes

Cost items of construction

Traditional technologies		
Class	**Cost Items**	**€/km**
Road yard costs	*Asphalt cutting*	Depends on different aspects of underground
	Excavation	
	Refilling	
	Provisional and final paving	
	Trasportation	
	Waste management	
Installation costs	*Laying*	
	Installation of pipe	
	Sealing costs	
	Technical costs	
Additional burden	*Investigation*	
	Planimetry update	
	Safety costs	
	Admistrative costs	
	Test	
	Cathodic protection	

$$C_{Tot} = C_{Materials} + C_{Installation} + C_{O\&M} + C_{dismantling}$$

O&M - Operational and maintenance costs

1. Network maintenance

Networks maintenance is mainly referred to pipe repairs when failures occur. Therefore these costs depend on the number of failures of different materials and on the repair costs.

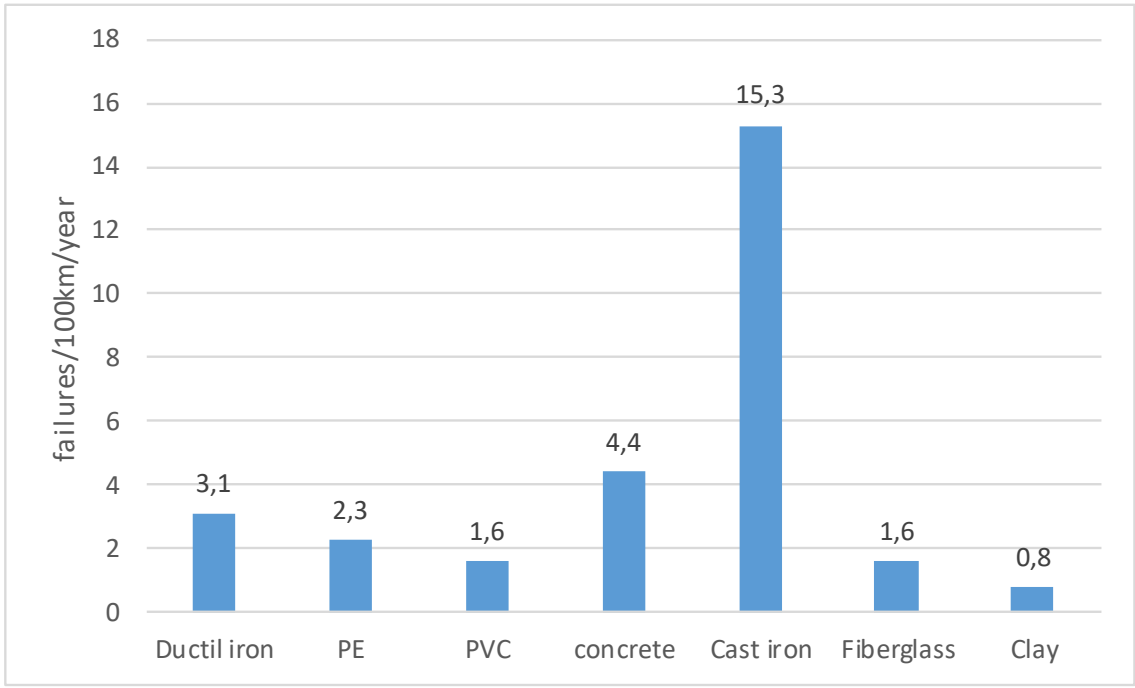
$$C_{Maintenance} = (\text{N° failures} \times C_{Maintenance})$$

for each material

The number of failures has been estimated on the basis of national data provided by Utilitalia for Italy and DVGW for Germany. Other relevant sources have been reviewed.

"Old" materials like cast iron suffer higher rates

N° of Failures /100 km



Source: Althesys elaboration on data "AWWA, Utah University, Utilitalia and and DVGW

O&M - Operational and maintenance costs

$$C_{Tot} = C_{Materials} + C_{Installation} + C_{O\&M} + C_{dismantling}$$

2. Energy consumption (drinking water pipes)

- **In drinking water network energy consumption is related to friction loss**. Different materials roughness and internal diameters result in different energy costs
- According to a caution principle, we set a sensitivity on energy consumption**: a scenario with energy consumption of PVC lower than Ductile Iron and another with similar energy consumption**.
  This second scenario is also considered in case water is pushed by gravity rather than by pumping systems.

Service life and planning period

Drinking water pipes

The analysis for all materials is set on **two scenarios**:

- **100 years lifetime**
- **70 years lifetime**

Sewerage pipes

50 years planning period is considered, due to the applications of these pipes, exposed to extremely corrosive agents

3. The key findings

3.1 Drinking water pipes

Total Cost of Ownership drinking water pipes (€/m) - DCF 100 years

	PVC					PE (HDPE)					Fiberglass	Ductile Iron				
diameters (mm)	63	110	160	200	315	63	110	160	200	315	315	63	110	160	200	315
Buying	1.6	3.7	7.9	12.3	30.5	2.5	8.4	12.7	19.9	49.1	46.0	10.7	14.5	23.9	31.2	56.1
Installation	59.5	62.4	73.7	78.0	92.1	59.5	62.4	73.7	78.0	92.1	92.1	68.1	73.4	82.4	85.4	100.1
Old pipe dismantling	6.8	11.1	13.7	16.7	18.7	6.8	11.1	13.7	16.7	18.7	18.7	8.8	14.5	17.8	21.7	24.3
Use	26.6	25.3	24.8	24.3	23.8	24.0	22.8	22.3	21.9	21.4	23.8	32.5	30.9	30.3	29.7	29.1
Maintenance	0.2	0.3	0.4	0.5	0.6	0.2	0.3	0.4	0.4	0.5	0.5	0.5	0.7	0.7	0.9	1.1
Total cost of ownership	**94.8**	**102.9**	**120.5**	**131.7**	**165.7**	**93.0**	**105.0**	**122.8**	**136.8**	**181.9**	**181.2**	**120.6**	**133.9**	**155.1**	**168.8**	**210.6**
%						-1.9%	2.1%	1.9%	3.9%	9.7%	9.3%	27.1%	30.1%	28.7%	28.2%	27.1%
Avg. Increase compared to the minimum	**minimum TCO**					**3.1%**					**9.3%**	**28.2%**				

Discount rate = 3.0%
Inflation rate = 1.5%

Total Cost of Ownership drinking water pipes (€/m) – DCF 100 years

	PVC					PE (HDPE)					Ductile Iron				
diameters (mm)	**63**	**110**	**160**	**200**	**315**	**63**	**110**	**160**	**200**	**315**	**63**	**110**	**160**	**200**	**315**
Buying	1.6	3.7	7.8	12.0	29.9	2.5	8.2	12.5	19.5	48.1	10.5	14.3	23.4	30.6	55.0
Installation	71.7	75.1	88.7	93.9	110.9	71.7	75.1	88.7	93.9	110.9	82.0	88.4	99.3	102.8	120.5
Old pipe dismantling	8.1	13.4	16.5	20.1	22.5	8.1	13.4	16.5	20.1	22.5	10.6	17.4	21.4	26.1	29.3
Use	25.3	24.0	23.6	23.1	22.6	22.8	21.6	21.2	20.8	20.4	30.9	29.3	28.7	28.2	27.6
Maintenance	0.3	0.4	0.4	0.5	0.6	0.3	0.4	0.4	0.5	0.6	0.5	0.7	0.8	1.0	1.2
Total cost of ownership	**107.0**	**116.6**	**137.0**	**149.6**	**186.6**	**105.3**	**118.8**	**139.3**	**154.7**	**202.5**	**134.5**	**150.1**	**173.6**	**188.7**	**233.6**
%						-1.6%	1.8%	1.7%	3.4%	8.5%	25.6%	28.7%	26.8%	26.1%	25.2%
Avg. Increase compared to the minimum	**minimum TCO**					**2.8%**					**26.5%**				

Discount rate = 1.0%
Inflation rate = 1.5%

Values change in different countries, but PVC remains the best TCO performer

3.2 Sewerages pipes

Total Cost of Ownership sewage pipes (€/m) - DCF 50 years

	PE (CORRUGATED)					PVC					CONCRETE			Clay				
diameters (mm)	**250**	**315**	**400**	**500**	**630**	**250**	**315**	**400**	**500**	**630**	**400**	**500**	**630**	**250**	**315**	**400**	**500**	**630**
Buying	12.0	17.1	26.9	44.7	68.6	13.5	21.4	34.7	59.5	98.1	45.4	56.9	68.5	30.0	39.6	71.2	89.6	125.0
Installation	85.6	131.4	180.8	236.8	300.2	85.6	131.4	180.8	236.8	300.2	207.6	257.8	320.4	100.7	147.8	207.6	257.8	320.4
Old pipe dismantling	19.6	22.5	32.0	39.0	67.0	19.6	22.5	32.0	39.0	67.0	54.3	66.3	113.8	33.3	38.3	54.3	66.3	113.8
Maintenance	0.4	0.5	0.5	0.6	0.8	0.2	0.5	0.6	0.4	0.9	1.6	1.9	2.3	0.2	0.3	0.3	0.3	0.4
Total cost of ownership	**117.6**	**171.6**	**240.2**	**321.1**	**436.5**	**118.9**	**175.9**	**248.1**	**335.6**	**466.1**	**308.9**	**382.9**	**505.0**	**164.1**	**225.9**	**333.4**	**414.0**	**559.7**
%						1.1%	2.5%	3.3%	4.5%	6.8%	28.6%	19.3%	15.7%	39.6%	31.6%	38.8%	29.0%	28.2%
Avg. Increase compared to the minimum	**minimum TCO**					**3.6%**					**21.2%**			**33.4%**				

Discount rate = 3.0%
Inflation rate = 1.5%

Total Cost of Ownership sewage pipes (€/m) - DCF 50 years

	PE (CORRUGATED)					PVC					PVC 3 LAYER			CONCRETE			Clay				
diameters (mm)	**250**	**315**	**400**	**500**	**630**	**250**	**315**	**400**	**500**	**630**	**250**	**315**	**400**	**400**	**500**	**630**	**250**	**315**	**400**	**500**	**630**
Buying	11,8	16,8	26,4	43,8	67,2	13,2	21,0	34,0	58,3	96,2	21,3	33,3	53,5	44,5	55,8	67,1	29,4	38,8	69,8	87,8	122,6
Installation	100,4	152,8	209,6	274,2	347,1	100,4	152,8	209,6	274,2	347,1	100,4	152,8	209,6	241,8	299,5	371,5	118,5	172,5	241,8	299,5	371,5
Old pipe dismantling	22,3	25,6	36,3	43,2	74,1	22,3	25,6	36,3	43,2	74,1	22,3	25,6	36,3	61,7	73,4	126,0	37,9	43,5	61,7	73,4	126,0
Maintenance	0,4	0,6	0,6	0,7	0,9	0,3	0,6	0,7	0,4	1,0	0,2	0,3	0,3	1,8	2,1	2,6	0,2	0,3	0,3	0,4	0,5
Total cost of ownership	**134,8**	**195,8**	**272,9**	**361,9**	**489,4**	**136,2**	**200,0**	**280,6**	**376,1**	**518,4**	**144,1**	**212,0**	**299,7**	**349,8**	**430,8**	**567,2**	**186,0**	**255,1**	**373,6**	**461,1**	**620,5**
%						1,0%	2,1%	2,8%	3,9%	5,9%	6,9%	8,3%	9,8%	28,2%	19,0%	15,9%	37,9%	30,3%	36,9%	27,4%	26,8%
Avg. Increase compared to the minimum	**minimum TCO**					**3,2%**					**8,3%**			**21,0%**			**31,9%**				

Discount rate = 1.0%
Inflation rate = 1.5%

Plastics are the winners, spread in the family is small

4. Take-aways

Total Cost of Ownership of plastics is the lowest among materials

Drinking water networks:

- **Italy**: PVC pipes are the best TCO performer. Fiberglass is on average 9,3% more expensive. Ductile Iron is the more epensive: 28.2% more than PVC
- **Germany**: PVC pipes are the best TCO performer. Ductile Iron is 26.5% more costly.

Sewerage networks:

- **Italy**: Concrete is on average 15,7% more expensive than PVC; clay +28,9%;
- **Germany**: Cement is on average 16,2% more expensive than PVC, whereas clay +27.9%

In **all criteria** of calculation (yearly total costs, or DCF, assuming different planning period 70-100 years), the results are very similar, and the ranking doesn't change

The main cost is installation:

- In Italy this cost is on average 57% in water networks and 68% in sewerage;
- In Germany it is on average 56% in water networks and 68% in sewerage.

Materials are a small share of TCO

- In **drinking water pipes** they range from:
  - In Italy: 2-3% of TCO up to 27% depending on material. For PVC small diameters this item is negligible (less than 2%).
  - In Germany: some 1.5% of TCO up to 24%, as diameter grows.
- For **sewerage** the weight of material cost is higher than drinking water (10%-20%) due to bigger diameters and better technical features (e.g. resistance to corrosion).

Cost benefit Analysis of PVC pipes recycling

SUMMARY

1. The PVC recycling benefits
2. Cost-Benefit Analysis methodology
3. The scope of the study
4. The main results
5. Conclusions

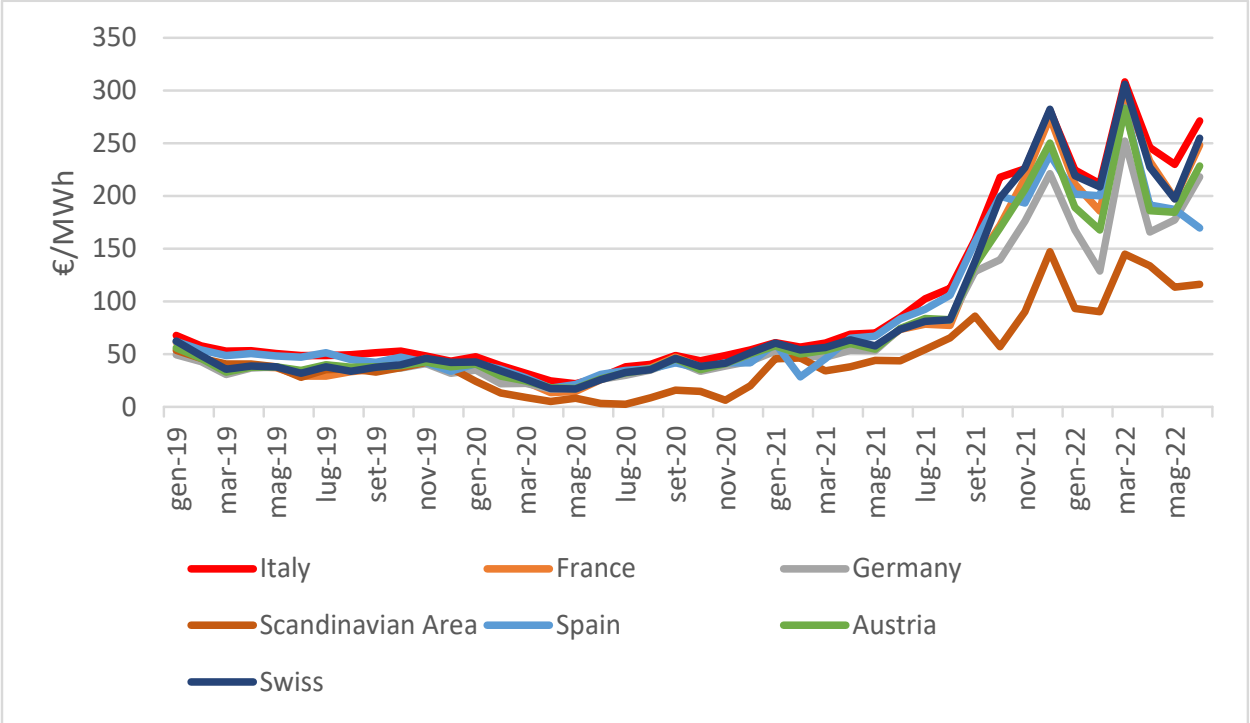
1. The PVC recycling benefits

- The European PVC industry has been working hard since the late 90's to address the challenges of sustainable development. Significant progress has been achieved in waste management, innovative recycling technologies and responsible use of additives.
- Recycling is a key challenge for the PVC industry, given the increasing importance of the Circular Economy Package adopted by the European Commission and its Plastics Strategy.
- The VinylPlus® sustainability program has put the European PVC industry on track toward a model of circular economy and demonstrated that PVC pipes are recyclable.

The objective of the study is to provide a Cost-Benefit Analysis of recycling PVC pipes

- A first study was done in 2019 showing the net benefits of PVC pipes recycling
- The dramatics changes in the financial and geopolitical scenario make necessary checking the results of the analysis in the new market framework.
- The price increases of raw materials, components and manufacturing processes which occurred between the second half of 2021 and 2022, affect the all manufacturing industries in Europe
- The sharp price growth has been triggered mainly by the amazing rise in energy prices

Power prices in Europe



Source: elaboration on various sources

2. Cost-Benefit Analysis methodology

- The methodology used for the study is the Cost-Benefit Analysis (CBA).
- This approach allows to examine the direct and indirect impacts of a project (investment, technology, plant, etc.) for the community (or a country) as a whole.
- The CBA aims to verify that costs incurred by a project are lower than its benefits.
- The analysis compares of different scenarios of carrying on (or not) a project.
- CBA has been developed according to the best practices described in the literature and OECD guidelines.

Cost-Benefit Analysis methodology

- For the purpose of this study, the CBA considers the direct and indirect impacts of PVC pipes recycling.
- Both economic as well as environmental aspects are considered.

Economic aspects

- Costs (or missed benefits)
- Benefits (or avoided costs)

of the PVC pipes recycling

Environmental aspects

- Monetary evaluation of environmental costs (or missed benefits)
- Benefits (or avoided costs)

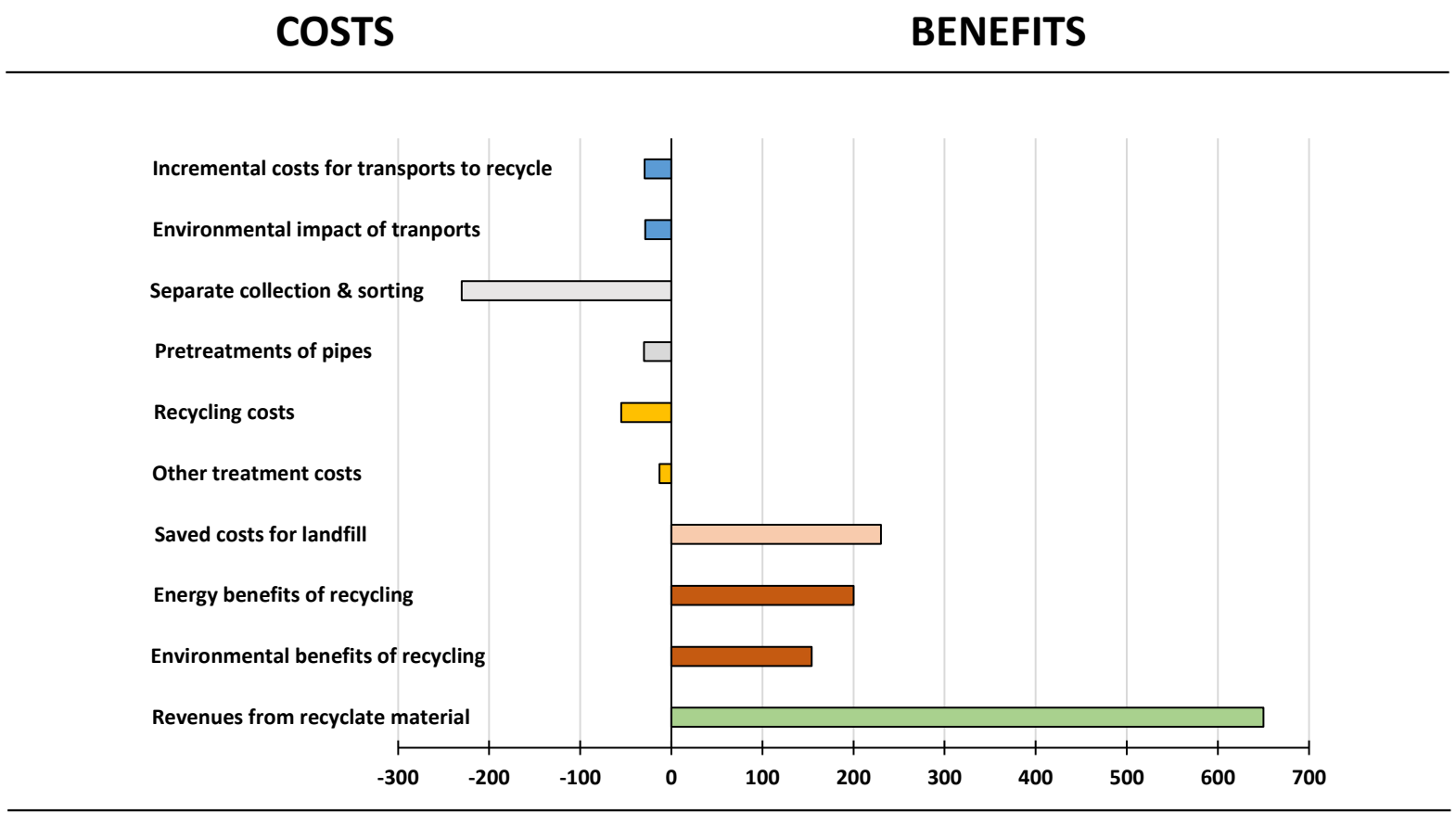
of the PVC pipes recycling

3. The study scope

- Geographical scope: Germany and Italy.
- Products: solid wall pipes (Germany and Italy); 3-layer pipes, with inner layer made of recycled PVC (Germany).
- Functional unit: 1 ton of PVC pipe, in order to conduct a diameter-independent CBA analysis. Items expressed in different units of measure have been parametrised according to the functional unit.
- Two different scenarios are considered:
- a) recycling vs. incineration (Germany and Italy)
- b) recycling vs. landfill (Italy)

The main results

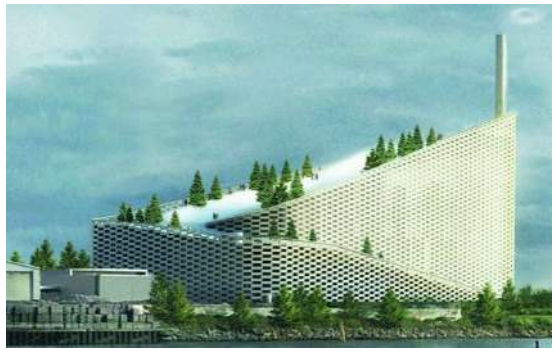
Solid wall pipe
-
Recycling vs. Landfill

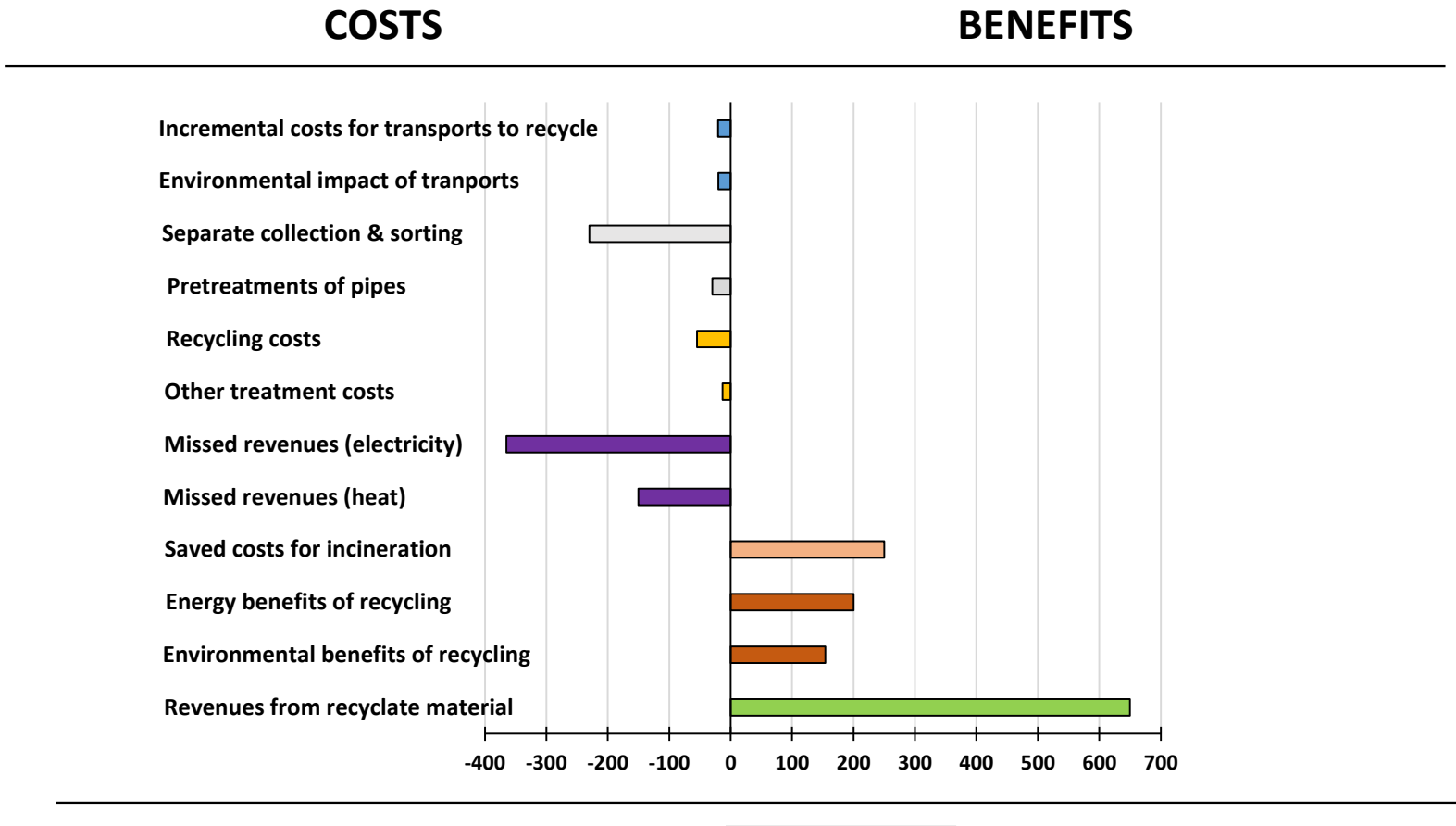


€/ton PVC pipe

The main results

Solid wall pipe
-
Recycling
vs. Incineration





4. The main results

Solid wall pipe

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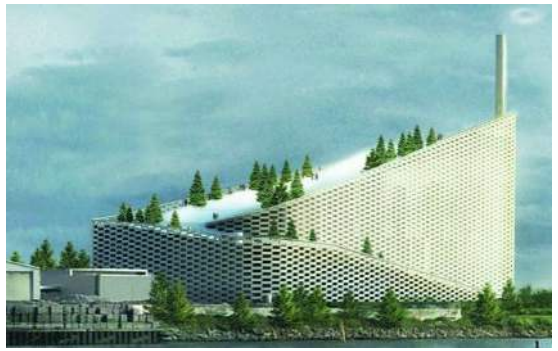
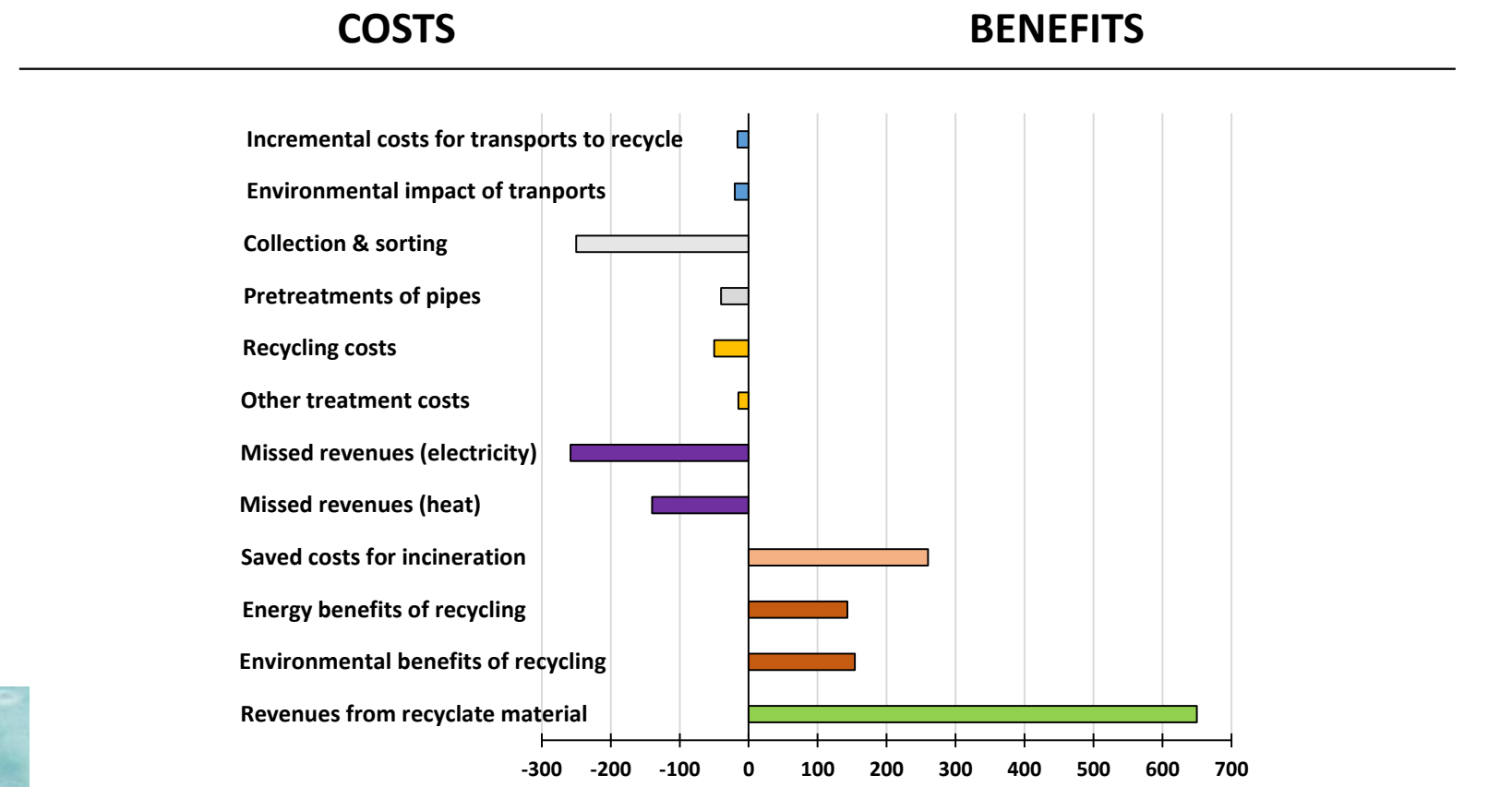
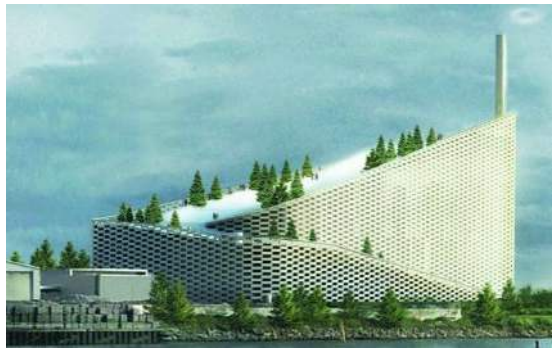
Recycling vs. Incineration

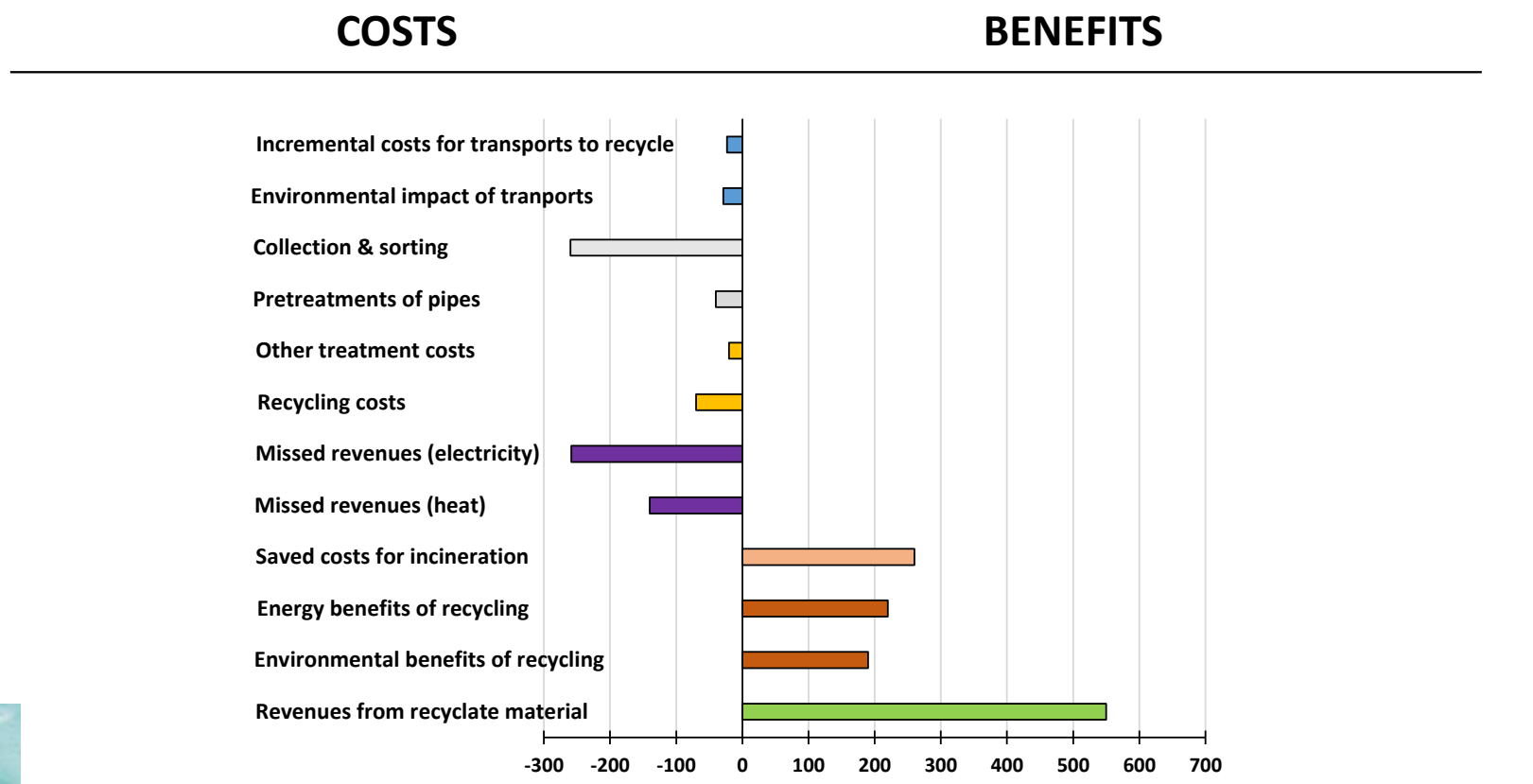


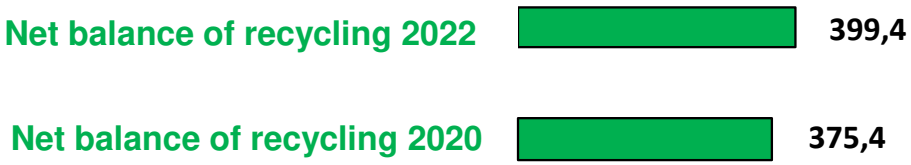


The main results

3-layers pipe - Recycling vs. Incineration







€/ton PVC pipe

4. Conclusions

- The 2022 CBA results confirm a net benefits balance for recycling in all cases considered.
- In Italy, the net benefits of recycling vs. landfill are greater than recycling vs. incineration due to energy recovery (electricity and heat) during incineration.
- In Germany, the net benefits for 3 layers PVC pipes is lower than for solid wall PVC pipes
- For **Italy** the comparison between 2022 and 2020 shows:
  - the net benefits of recycling vs. landfill increase of 56%: the reason is the growth of revenues for recycled PVC and energy savings exceeding the higher costs of separate collection and sorting;
  - Instead, the net benefits of recycling vs. incineration, while remaining largely positive, decrease of 28% due to the higher energy prices increasing the incineration revenues.
- **Germany** (only incineration as destination): the net benefit of recycling (2022 vs. 2020) is similar for both kind of pipes, due to a lower than in Italy increase of electricity price.
- The current discussion about the inclusion of incineration under the ETS system could modify the results of this CBA, improving the net benefit of recycling vs. incineration.

Backup – CBA: assumptions and input data

COMPARISON 2022 vs. 2020 analysis (2019 data)

ITALY	2022	2020
Landfill disposal (€/ton)	230	200
Separate collection and sorting (€/ton)	260	210
Recycling (€/ton)	55	40
Other treatments (€/ton)	13	10
Incineration (€/ton)	250	220
Recovered PVC (€/ton)	650	500
EUAs (€/tonCO2)	77	30
Electricity price (€/MWh)	450	50
Gas price (€/MWh)	170	20

Backup – CBA: assumptions and input data

COMPARISON 2022 vs. 2020 analysis (2019 data)

GERMANY	2022	2020
Separate collection and sorting standard PVC pipe (€/ton)	290	250
Separate collection and sorting 3-layer pipe (€/ton)	300	260
Recycling (€/ton)	60	43
Other treatments (€/ton)	15	12
Incineration (€/ton)	230	200
Recovered PVC (€/ton)	650	500
EUAs (€/tonCO2)	77	30
Electricity price (€/MWh)	315	35
Gas price (€/MWh)	160	18

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