PVC-U Pipe Competitiveness:
A Total Cost of Ownership Approach

Introduction

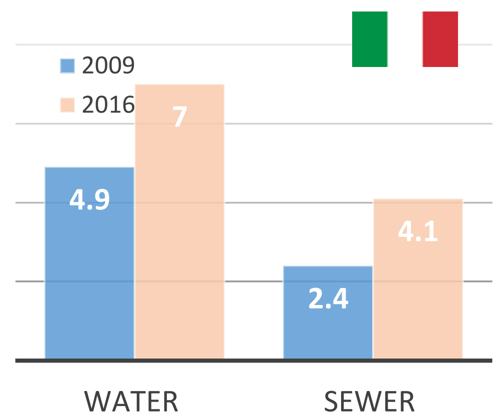
Pipes are key elements in the development of water and sewer networks. Due to fierce competition between pipe materials, price/ performance ratios are under pressure to reach increasingly optimised levels. Up to date cost calculations are critical to help the owners of water and sewer networks to make informed decisions on material selection.

A first study by Althesys, including Total Cost of Ownership (TCO) calculations, was commissioned by the European Council of Vinyl Manufacturers in 2010[1]. It demonstrated the significant cost savings that network owners could make over the entire lifespan of water/sewer network by choosing unplasticised PVC (PVC-U) pipes instead of the main functional alternatives. The cost advantages of using PVC-U pipes was illustrated using two European countries whose water infrastructures are developed to very different levels: Italy and Germany. The European water industry has been investing in its networks for many years, but the need for expansion and renovation is still very prevalent. An update to the study was completed by Althesys in 2018, taking into account new developments in regulatory policies, technologies and market trends.

The Italian and German Networks

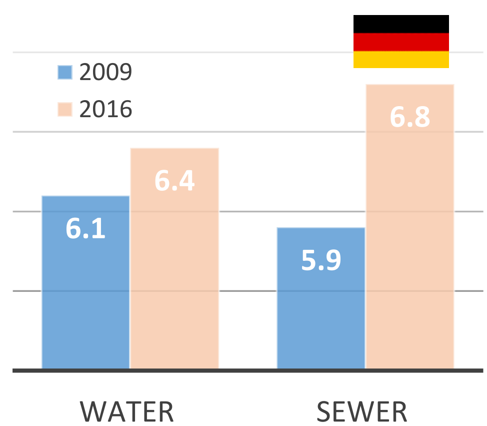
Thanks to the approval of Law Decree 214/ 2011, setting up a new regulatory design for the Italian water sector[2], significant infrastructure expansion was recorded in Italy between 2009 and 2016[3]. This improvement can be seen through dramatic increases in the infrastructure index; 44% for water networks and 70% for sewer networks. The gap observed in the late 2000's between Italy and Germany's water networks has now completely disappeared.

Infrastructure index in Italy
(m/capita)



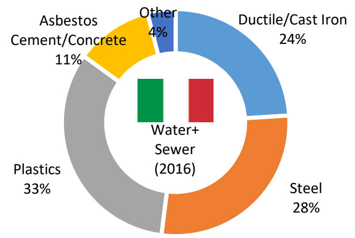
For sewer networks, despite a dramatic 70% index increase, Italy still lagged behind Germany in 2016.

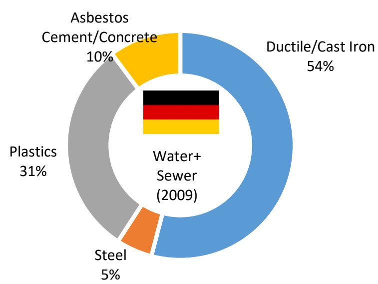
Infrastructure index in Germany
(m/capita)



In terms of materials used in the Italian water and sewer networks, the share of plastics was very small until a few years ago. However, due to a law mandating the replacement of asbestos cement in the sewer networks, the share of plastics has risen. The replacement of old sections of the water network made of cast iron and steel has also been recorded in recent years.

Material break-down in Italy and Germany





The 33% share of plastics in Italy's water and sewer infrastructure is now comparable to that in Germany. A big share of Germany's water network is still made of old cast iron pipes. Replacing this cast iron represents another great opportunity for plastics. In sewer networks, a larger share for plastics could be gained quickly by replacing the old sewer pipes made of asbestos cement.

Significant investments were made in Italy until 2017 with an investment intensity increasing from 24 to 34 €/capita[4]. As a result, Italy caught up with the European average in terms of infrastructure index for its water and sewer networks. The water networks are however still very old in Italy; 25% of the network is over 50 years old. To ensure the infrastructure index level for sewers met the European average and to renew the oldest sections of the network, even more investments were made over the last three years; increasing the investment intensity to 54.4 €/capita.

In Europe, Germany is the country that invests the most in its water network (0.54 €/m^3)[5]. In order to maintain its leadership position, new investment will be required.

The TCO Methodology

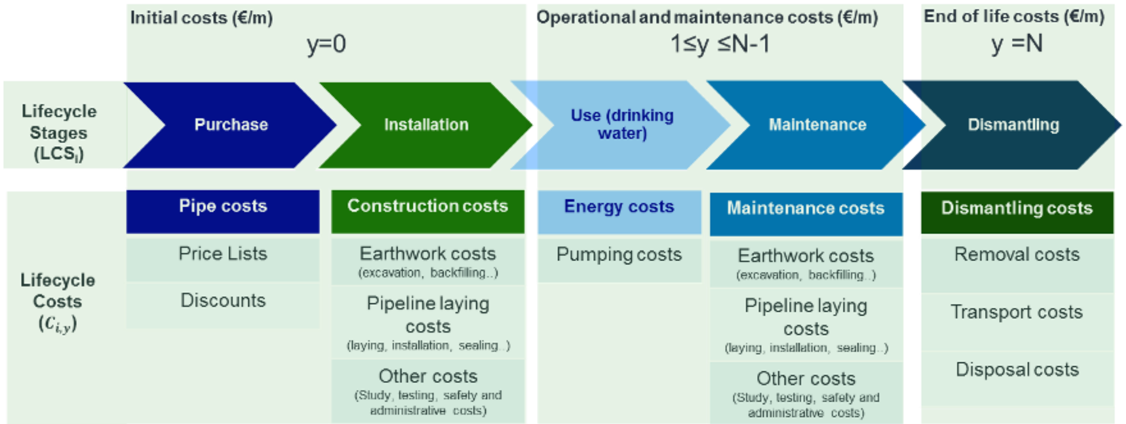
The TCO of an infrastructure asset, like a pipe network, is calculated by collecting all the direct and indirect costs incurred by an owner over the entire life cycle of the asset.

A quantitative cost model has been developed with 5 life cycle stages (LCS_i). The Purchase and Installation stages cover the first year of the asset (year 0). The Use and Maintenance stages cover the service life of the network from year 1 to year N-1. As this model assumes that the pipe network will have to be substituted at the end of its service life, a dismantling stage covering the end of life has also been defined (year N). For each of these stages, a set of direct and indirect costs ($C_{i,y}$) in €/meter of network (€/m) have been defined. A present value (PV) of the costs for each life cycle stage i ($PV(LCS_i)$), is computed by summing the future costs, adjusted for inflation and discounted at an annual rate with a nominal discount rate taken as the Weighted Average Cost of Capital (WACC) of the network owner (1% in Germany, 3% in Italy). The TCO of the network is then obtained by summing the present value of the costs for each lifecycle stage.

Pipe costs have been determined by consulting price lists obtained from pipe manufacturers and engineering consultancies. The typical discount rates applied for pipes in Italy and Germany have been accounted for.

For construction costs incurred during the installation stage, average cost rates were rigorously determined for each of the earth-work, pipeline laying and overhead operations. Field cost studies based on tender specifications and interviews with installers were carried out for each of these operations. Significant discrepancies were observed for these averages depending on the site location (urban vs. rural), type of paving or local regulation. Construction costs were generally higher in Germany due to higher labour costs.

Total Cost of Ownership methodology applied to pipes



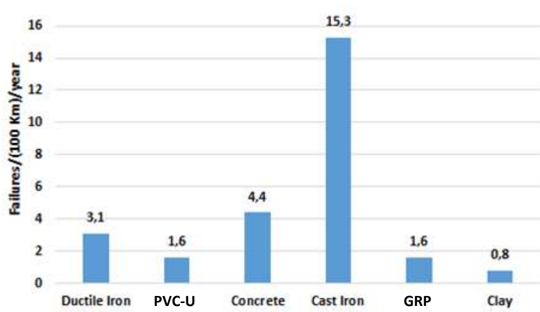
$$\mathrm{PV(LCS_i)} = \sum_{y=0}^{N} \frac{C_{i,y}(1+IR)^y}{(1+DR)^y}$$

$C_{i,y}$= sum of all *real* costs incurred during year #y for LCS #i
IR= inflation rate
DR= *nominal* discount rate

$$\mathrm{TCO} = \sum_{i=1}^{5} \mathrm{PV(LCS_i)}$$

Energy costs of the operational stage of the water networks were determined using the hydraulic analysis published in 2017 by the PVC Pipe Association[6]. Average annual energy consumptions were determined and converted into energy costs by using national energy prices. The energy costs for sewer networks are negligible.

Material failure rates for pipes



The maintenance costs that were taken into consideration for the water and sewer networks exclusively refer to the repairs needed after failure. Annual maintenance costs were estimated by multiplying the estimated cost for one repair by an annual failure rate. Average annual failure rates were estimated for each material covered in this study based on available data from the Utah State survey[7], as well as data for water and sewer networks available in Italy[8] and Germany[9]. Due to a lack of data, the failure rate for GRP was assumed to be the same as for PVC-U.

The repair costs in Italy and Germany were estimated using the same methodology as for the installation. Some costs rates, like those related to the earthworks, are typically higher because of the shorter sections processed.

Study Scope

TCOs were calculated in both countries for a range of pipe diameters (63 to 315 mm for the water networks, 250 to 630 mm for the sewer networks) and pipe materials typically used in the existing networks of these countries.

For the water networks, PVC-U was compared to Ductile Iron (DI) in both countries and, in Italy, to Glass-fiber Reinforced Plastic (GRP) as this material is increasingly used there for larger diameter pipes. For the sewer networks, PVC-U was compared to concrete and clay in both countries and to 3-layer PVC--U in Germany. 3-layer pipes with an inner solid layer of recycled PVC-U are increasingly used in Germany.

A wide range of dig-up reports prove that a service life of over 100 years is feasible for PVC-U pipes[10], therefore a service life of 100 years was adopted as a baseline scenario for the water networks. A service life of 50 years was selected for the sewer networks.

Key Results

The TCOs of the water networks in Italy made of PVC-U, DI and GRP pipes are compared in the first table herebelow. The second table compares the TCOs of the water networks in Germany made of PVC-U and DI.

In Italy, the construction costs for installation are the highest contributors to the TCOs. For all diameters, the costs for each life cycle stage are systematically lower for PVC-U compared to DI. The TCO for the network owner can be reduced between 27% and 30% depending on the diameter, if PVC-U is chosen instead of DI as the material. A significant TCO saving (9.3%) is also possible for the owner if pipes of 315 mm of PVC-U are selected instead of GRP, because of the lower pipe costs.

In Germany, a slightly lower average but again very significant TCO saving (26.5%), can be realized made for the network owner by selecting PVC-U instead of DI. As for Italy, the savings are realised at every stage of the life cycle of the network.

Total Cost of Ownership for water pipes in Italy (€/m)

	PVC-U					GRP	DI				
$PV(LCS_i)$ D (mm)	63	110	160	200	315	315	63	110	160	200	315
Purchase	1.6	3.7	7.9	12.3	30.5	46.0	10.7	14.5	23.9	31.2	56.1
Installation	59.5	62.4	73.7	78.0	92.1	92.1	68.1	73.4	82.4	85.4	100.1
Use	26.6	25.3	24.8	24.3	23.8	23.8	32.5	30.9	30.3	29.7	29.1
Maintenance	0.2	0.3	0.4	0.5	0.6	0.6	0.5	0.7	0.7	0.9	1.1
Dismantling	6.8	11.1	13.7	16.7	18.7	18.7	8.8	14.5	17.8	21.7	24.3
TCO	**94.8**	**102.9**	**120.5**	**131.7**	**165.7**	**181.2**	**120.6**	**133.9**	**155.1**	**168.8**	**210.6**
Increase vs. Minimum TCO (%)						9.3%	27.1%	30.1%	28.7%	28.2%	27.1%
Average Increase vs. Minimum TCO (%)	**minimum TCO**					**9.3%**	**28.2%**				

Total Cost of Ownership for water pipes in Germany (€/m)

	PVC-U					DI				
$PV(LCS_i)$ D (mm)	63	110	160	200	315	63	110	160	200	315
Purchase	1.6	3.7	7.8	12.0	29.9	10.5	14.3	23.4	30.6	55.0
Installation	71.7	75.1	88.7	93.9	110.9	82.0	88.4	99.3	102.8	120.5
Use	25.3	24.0	23.6	23.1	22.6	30.9	29.3	28.7	28.2	27.6
Maintenance	0.3	0.4	0.4	0.5	0.6	0.5	0.7	0.8	1.0	1.2
Dismantling	8.1	13.4	16.5	20.1	22.5	10.6	17.4	21.4	26.1	29.3
TCO	**107.0**	**116.6**	**137.0**	**149.6**	**186.6**	**134.5**	**150.1**	**173.6**	**188.7**	**233.6**
Increase vs. Minimum TCO (%)						25.6%	28.7%	26.8%	26.1%	25.2%
Average Increase vs. Minimum TCO (%)	**minimum TCO**					**26.5%**				

The hydraulic study of the PVC Pipe Association has demonstrated that significant energy savings could be made using PVC-U in the water networks thanks to lower friction losses. As a worst-case scenario, TCO calculations were made assuming the same energy consumption for PVC-U as for DI over the service life. The results show a slight decrease in the average TCO saving (22.5% vs. 28.2% in Italy, 21.7% vs. 26.5% in Germany), however the savings from PVC-U remain significant. Other worst-case calculations were carried out by considering a shorter 70-year service life for the water network. Again, the TCO saving for PVC-U is slightly reduced compared to the baseline case (22.6% vs. 28.2% in Italy, 21.5% vs. 26.5% in Germany), but the TCO saving remains significant compared to DI.

For the sewer networks in Italy, PVC-U remains the best choice. Savings can be made at all life cycle stages as opposed to concrete or clay. On average, selecting PVC-U instead of concrete or clay allows a TCO saving of 15.7% and 28.9% respectively.

As in Italy, PVC-U is the best choice for the owners of sewer networks in Germany. TCO savings of 16.2% and 27.9% can be made compared to concrete or clay respectively. A slightly higher TCO is obtained with the 3-layer PVC-U system due to a higher purchase cost. This cost difference is expected to be reduced in the future with the installation of more 3-layer systems.

Total Cost of Ownership for sewer pipes in Italy (€/m)

	PVC-U					Concrete			Clay				
PV(LCS_i) D (mm)	250	315	400	500	630	400	500	630	250	315	400	500	630
Purchase	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	207.6	257.8	320.4	100.7	147.8	207.6	257.8	320.4
Maintenance	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
Dismantling	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
TCO	**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**
Increase vs. Minimum TCO (%)						24.5%	14.1%	8.3%	38.0%	28.5%	34.4%	23.4%	20.1%
Average Increase vs. Minimum TCO (%)	**minimum TCO**					**15.7%**			**28.9%**				

Total Cost of Ownership for sewer pipes in Germany (€/m)

	PVC-U					3 Layer PVC-U			Concrete			Clay				
PV(LCS_i) D (mm)	250	315	400	500	630	250	315	400	400	500	630	250	315	400	500	630
Purchase	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	241.8	299.5	371.5	118.5	172.5	241.8	299.5	371.5
Maintenance	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
Dismantling	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
TCO	**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**
Increase vs. Minimum TCO (%)						5.8%	6.0%	6.8%	24.7%	14.5%	9.4%	36.5%	27.6%	33.2%	22.6%	19.7%
Average Increase vs. Minimum TCO (%)	**minimum TCO**					**6.2%**			**16.2%**			**27.9%**				

Takeaways

The superior cost competitiveness of PVC-U pipes in the Italian and German water and sewer networks was confirmed with this study update. PVC-U is the best TCO performer compared to all other non-plastic pipe materials, whatever the type of network or pipe diameter. Selecting PVC-U instead of other materials allows significant cost savings at all stages of the infrastructure life cycle. These savings are most significant for the construction costs incurred during the installation stage.

About the Author

Alessandro Marangoni is an economist specialised in the energy industry, utilities, waste management and recycling. He graduated with honours from Bocconi University (Milan, Italy), and started his career as a researcher at Space Bocconi, a joint venture with Northeastern University (Boston, USA). He is currently CEO of the consultancy Althesys and a Professor in Economy and Management of the Public Utility Services at Bocconi University. He also teaches in various academic and master classes. With broad experience in strategic management, Prof. Marangoni was one of the first in Italy to deal with accountancy and environmental reports, sustainability and cost-benefit analysis, becoming one of the main experts in business and financial issues on the environment. He is the author of several publications on the environment, energy, public utilities and infrastructures.

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