Effect of Water Costs on the Optimal Renovation Period of Pipes

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The problem: repair vs. replace

- Easy to explain in LESAM. Balance is the key:
- The longer a pipe stays in place, the higher the associated variable costs
- The longer a pipe stays in place, the "cheaper" the initial fixed costs become

Solutions (models)

- Shamir and Howard (1979) present a model with investment and repair costs, modelling pipe failure rates with time
- Since then, models have grown more complex and detailed
- However, the required data are not always available
- This paper uses this simplified model, includes other costs and studies the influence of the price of water

New costs come into play

Investment (fixed) costs

- Pipe costs
- Installation costs


An Analytic Approach to Scheduling Pipe Replacement

Maintenance (variable) costs

- Maintenance and repair costs

OTHER RENOVATION COSTS

- Opportunity costs (negative cost or benefit)
- Disruption social costs

ENVIRONMENTAL COSTS

- Water loss
- Energy

SOCIAL COSTS

- Lower standards of service

The analysis

- Costs are separated into fixed and variable

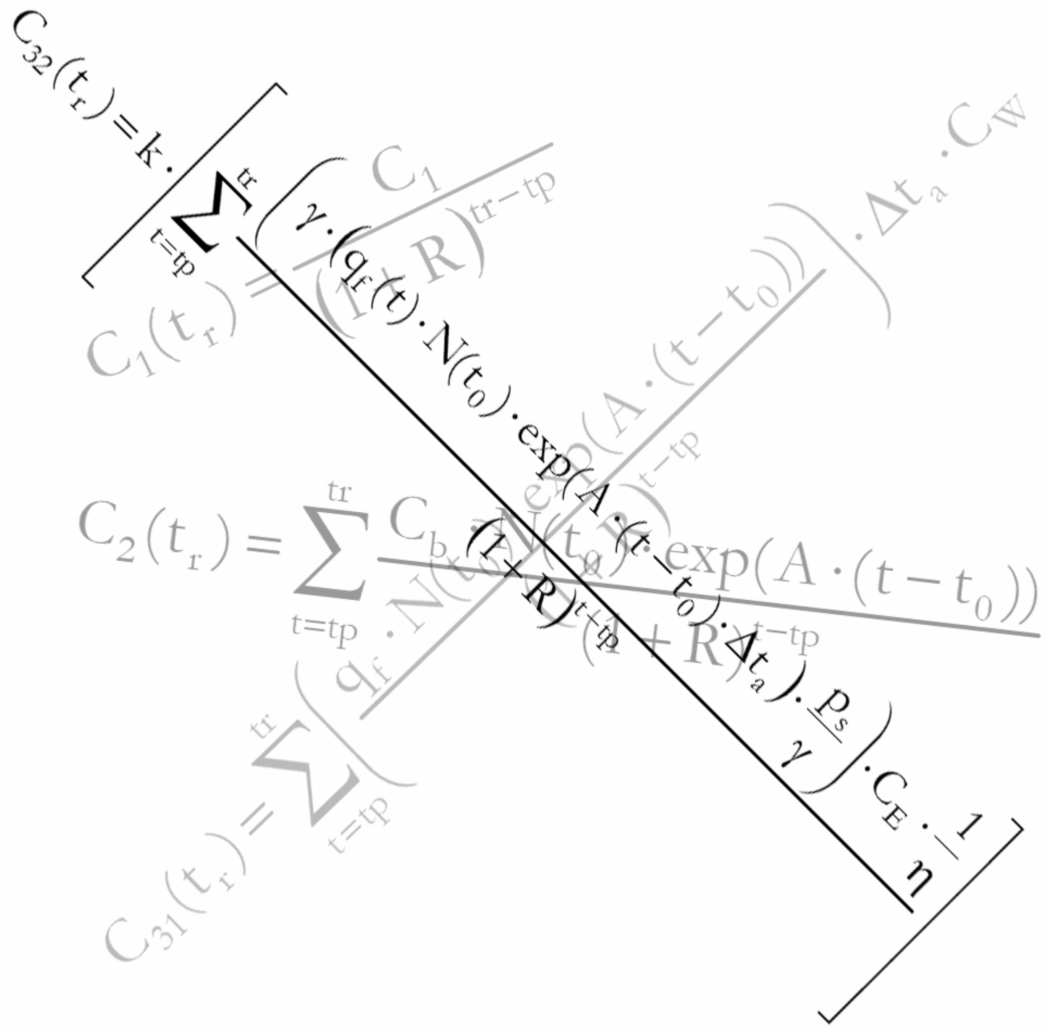
- All costs considered for a reference period (current year t_p)

- Calculations are carried out from initial year t_0, the first in which failure data is available. Results are independent of t_0

- Optimum renovation period assumes that all costs (social, environmental, etc.) are real and affect the utility

The analysis

Full mathematical analysis
in the paper



The analysis

$$t_r^* = t_0 + \frac{1}{A} \ln\left(\frac{I \cdot (\ln(1+R))}{M \cdot N(t_0)} \right)$$

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$$M = C_b + \left(q_f \cdot \Delta t_a \cdot \left(C_W + \frac{k \cdot p_s}{\eta} \cdot C_E \right) \right) \text{ and } I = C_1 + C_S$$

Pipe failures related costs

Water costs
- Production
- Environmental

Energy costs

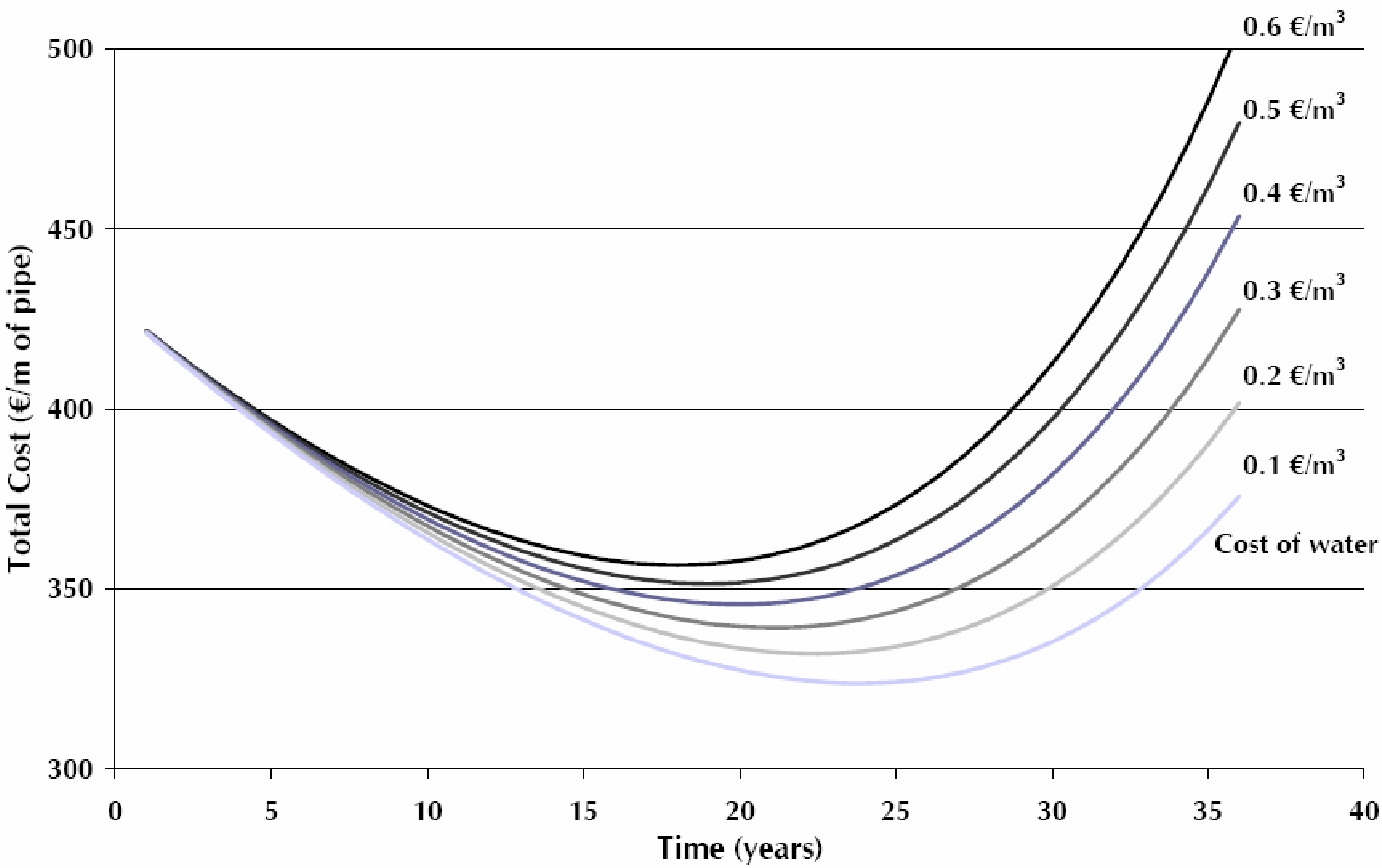
Pipe renovation costs

Social costs

The example

- Sample case with economic data from a mid size Spanish utility (repair costs, failure rates, etc.)
- Social and environmental costs calculated according to the literature
  - **miparpi@ita.upv.es for more information**
- Several scenarios studied. Sensitivity analysis of several variables performed
  - **See the paper for the complete analysis**
- Total costs graphs display YEARLY total costs (minimizing the function delivers the optimum renovation period)

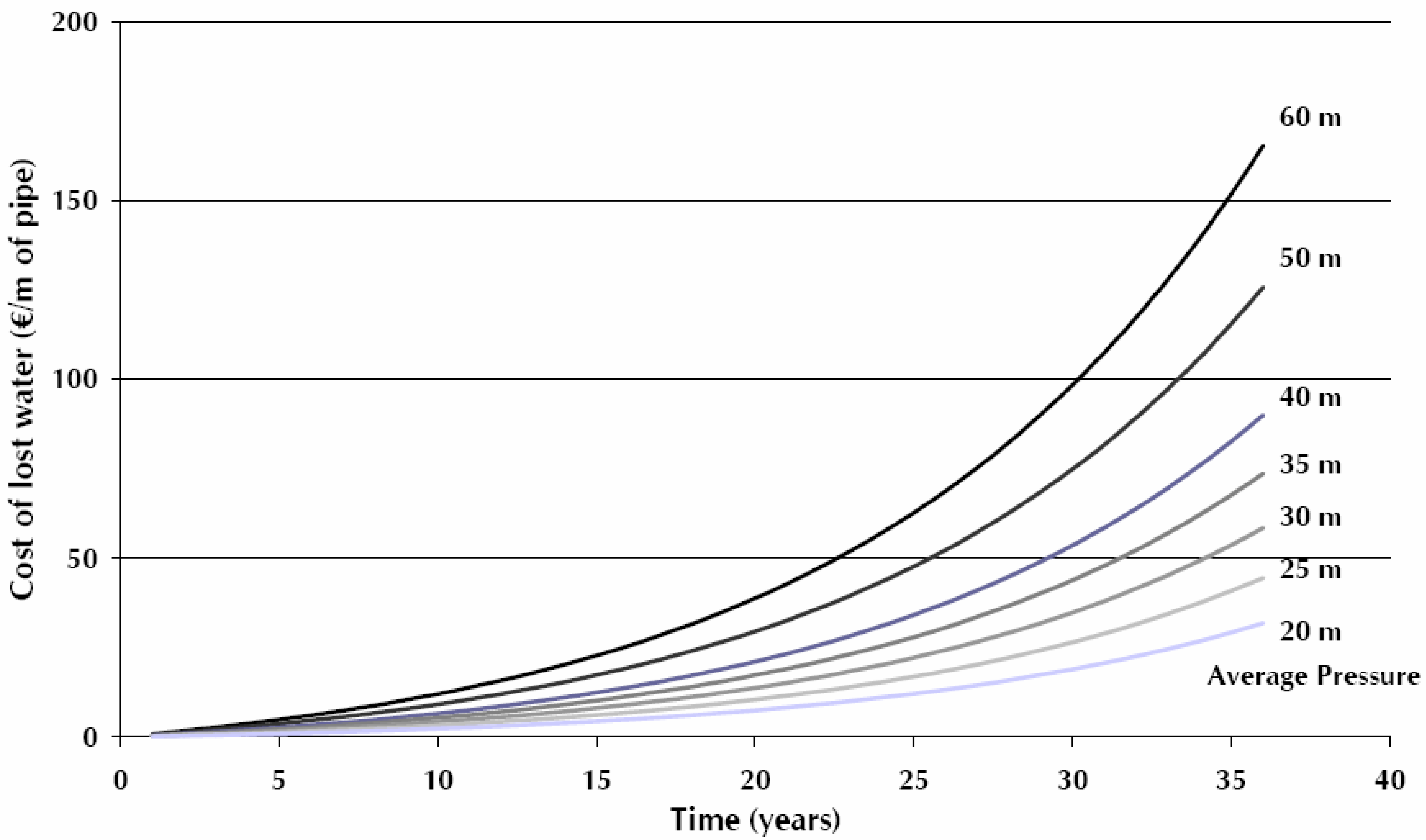
Renovation period depends on cost of water



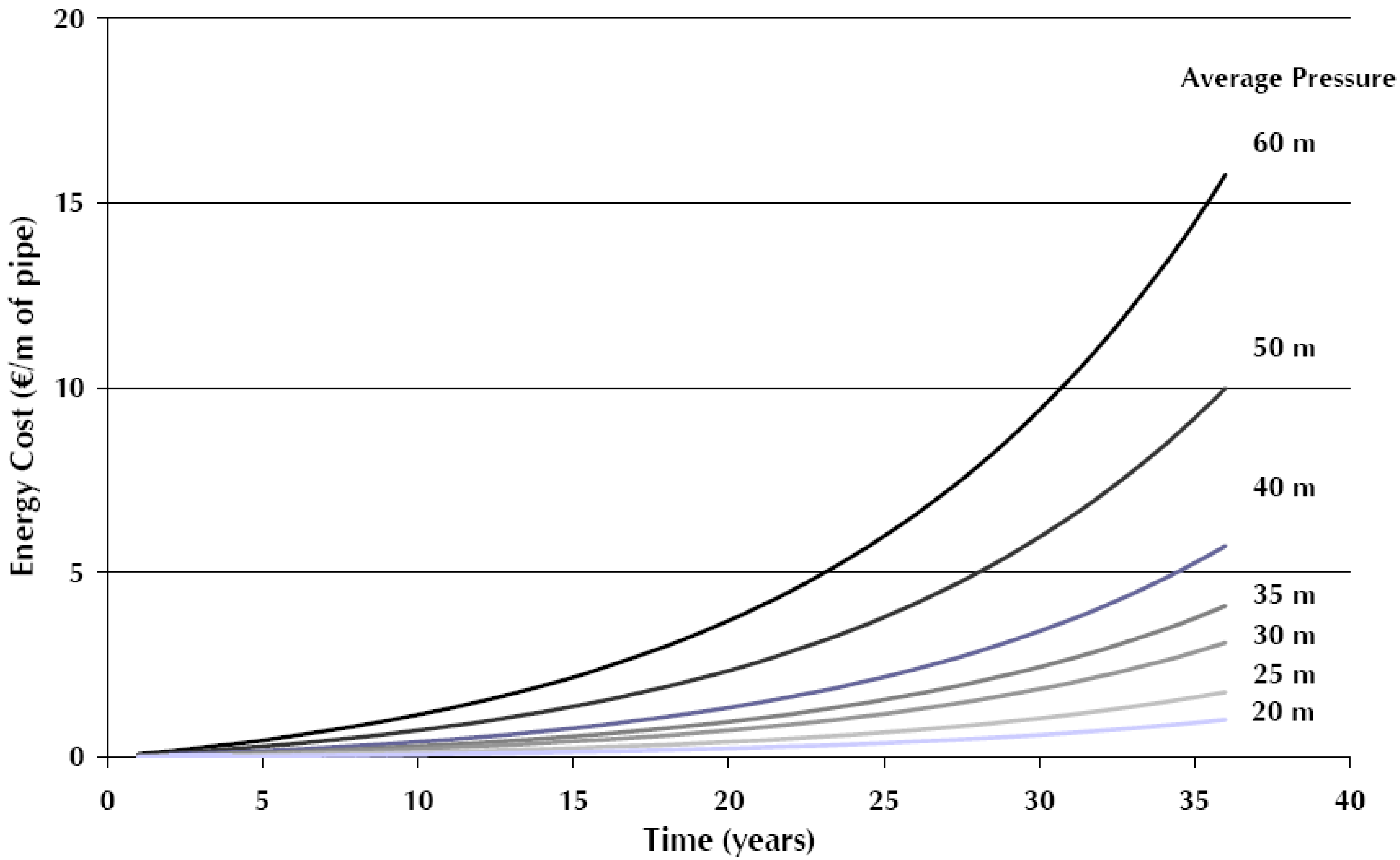
Renovation period depends on cost of water

Cost of water C_w (€/m^3)	Optimum renovation period (years)
0.1	23.7
0.2	22.3
0.3	21
0.4	20
0.5	19
0.6	18

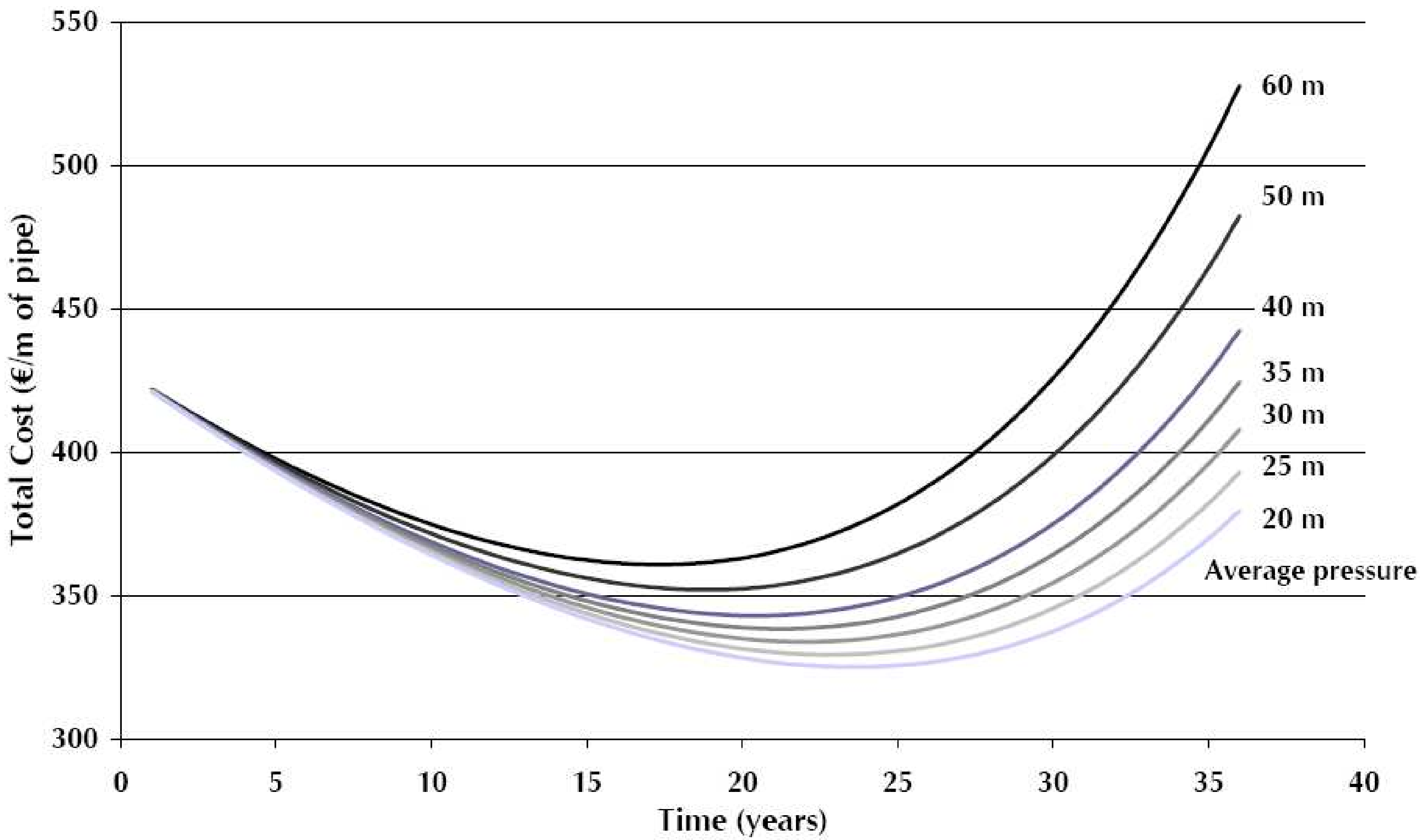
The effects of pressure – leakage (€)



The effects of pressure – energy (€)



The effects of pressure – renovation



The effects of pressure – renovation

Avg. pressure (mcw)	Unit leakage flow rate q_f (m^3/day)	Optimum renovation period (years)
20	16	21.84
25	20	21.04
30	24	20.29
35	28	19.59
40	32	18.92
45	40	19.67

How much water can we allow to leak?

- The concept of the economic level of leakage (ELL) becomes an interval. The Maximum Acceptable Leakage Volume

[0, MALV]

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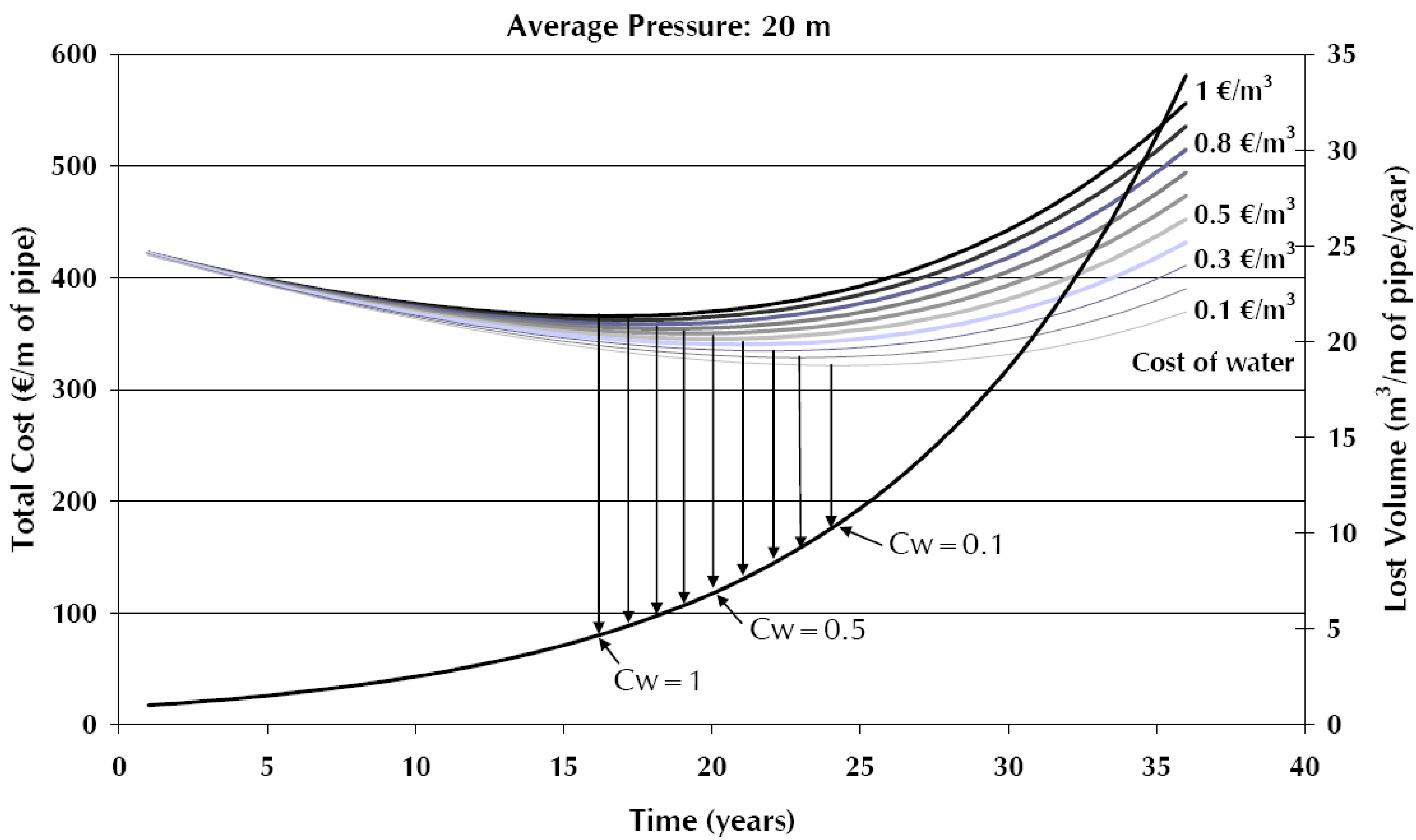
- The concept of the economic level of leakage (ELL) becomes an interval. The Maximum Acceptable Leakage Volume

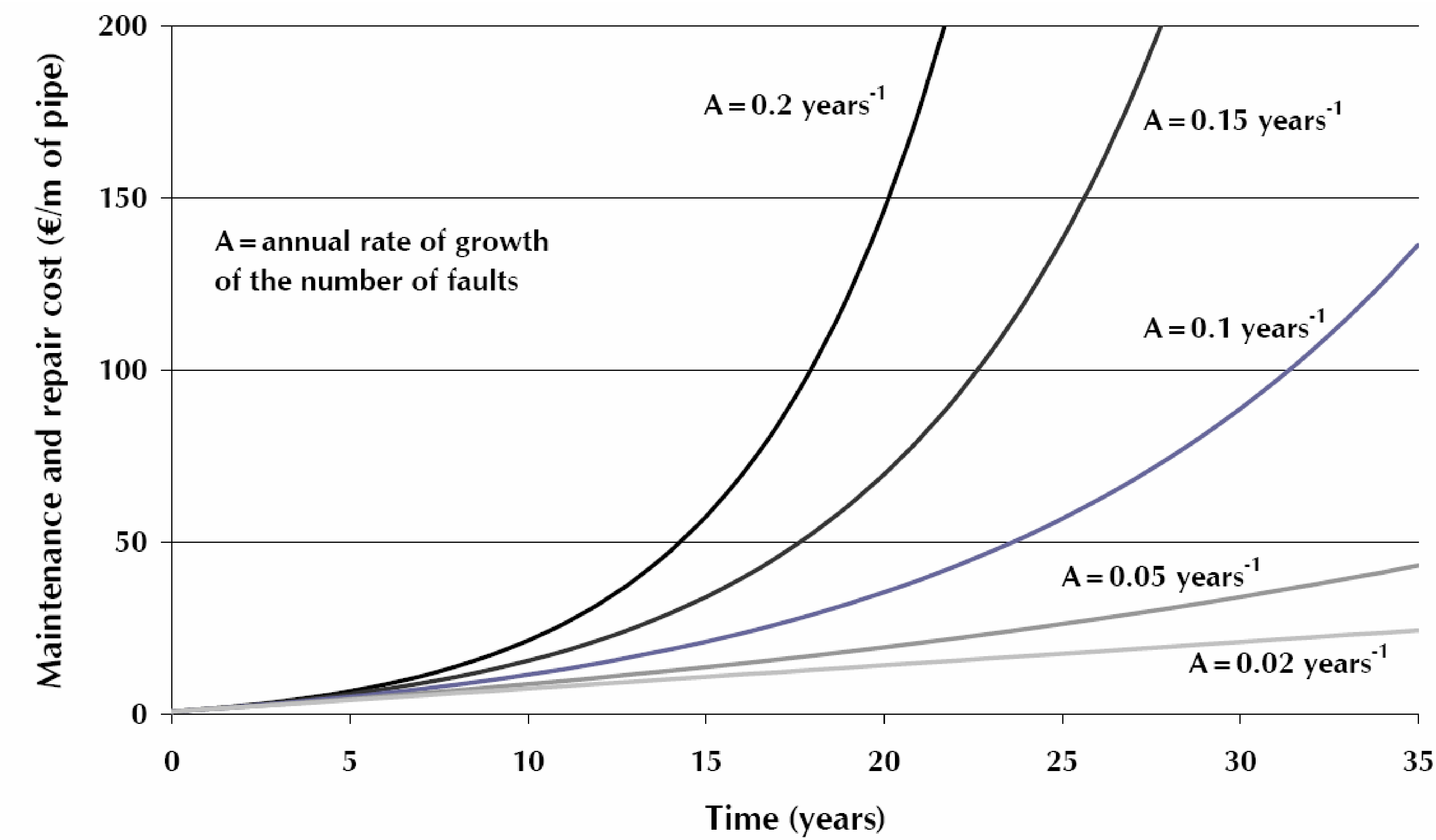
[0, MALV]

- MALV
  - **Leakage increases with time**
  - **Depending on the price of water, at one stage renovation will be cheaper**
  - **Therefore the economic level of leakage is a dynamic concept**

How does MALV change with price of water?



What if pipes break faster than expected?



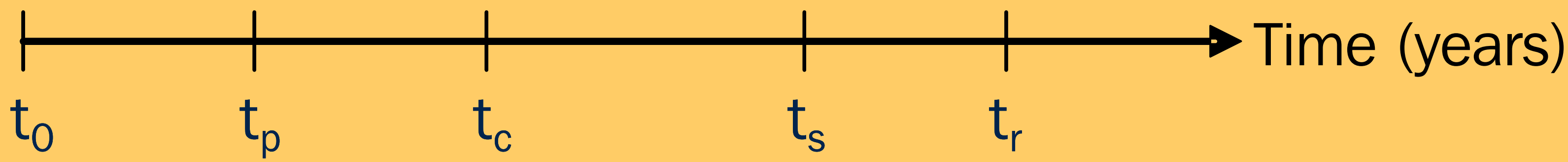
Summary

- As more constraints and stakeholders become relevant in water services, the problem of repair vs. replace needs to take into account more factors
- This model allows to take into account the production and environmental costs of water in a simple way
- All these factors can affect the optimum renovation period if they are translated into costs for the utility
- The economic level of leakage is as a matter of fact a dynamic figure which increases every year until reaching the MALV in the optimum renovation year

Costs

Cost	***Year of estimation of the cost***	***Sub-cost***	***Does technology have an influence?***	***Cost nature***
C_1 Renovation	t_p t_p	C_{11} Pipe cost C_{12} Pipe installation	No Yes	Investment Investment
C_2 Repairs and maintenance	t_p	C_2	No	Maintenance
C_3 Variable costs related to water	t_p t_p	C_{31} Leakage C_{32} Energy losses	No No	Maintenance Maintenance
C_4 Social	t_p t_s	C_{41} Disruptions caused by the works C_{42} Costs related to lower standards of service	Yes No	Occasional Maintenance
C_5 Opportunity	t_c	C_5	Yes	Savings in the investment

Time frame



- to, tp and tr are the same than those in the Shamir & Howard's paper.
- tc is the year when the installation costs may be lower (due to other utility works)
- ts is the year in which the service does not fulfil standard's requirements (i.e. pressure level)