Investing in the Future

Long-Term Optimization of Asset Replacement in the Collective Regional Gas Grids of The Netherlands

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September 18, 2014
IGRC 2014, Copenhagen

Enexis

Key figures

- 4,300 employees
- Turnover € 1.4 billion
- 34.9 TWh
- 6.5 billion m^3

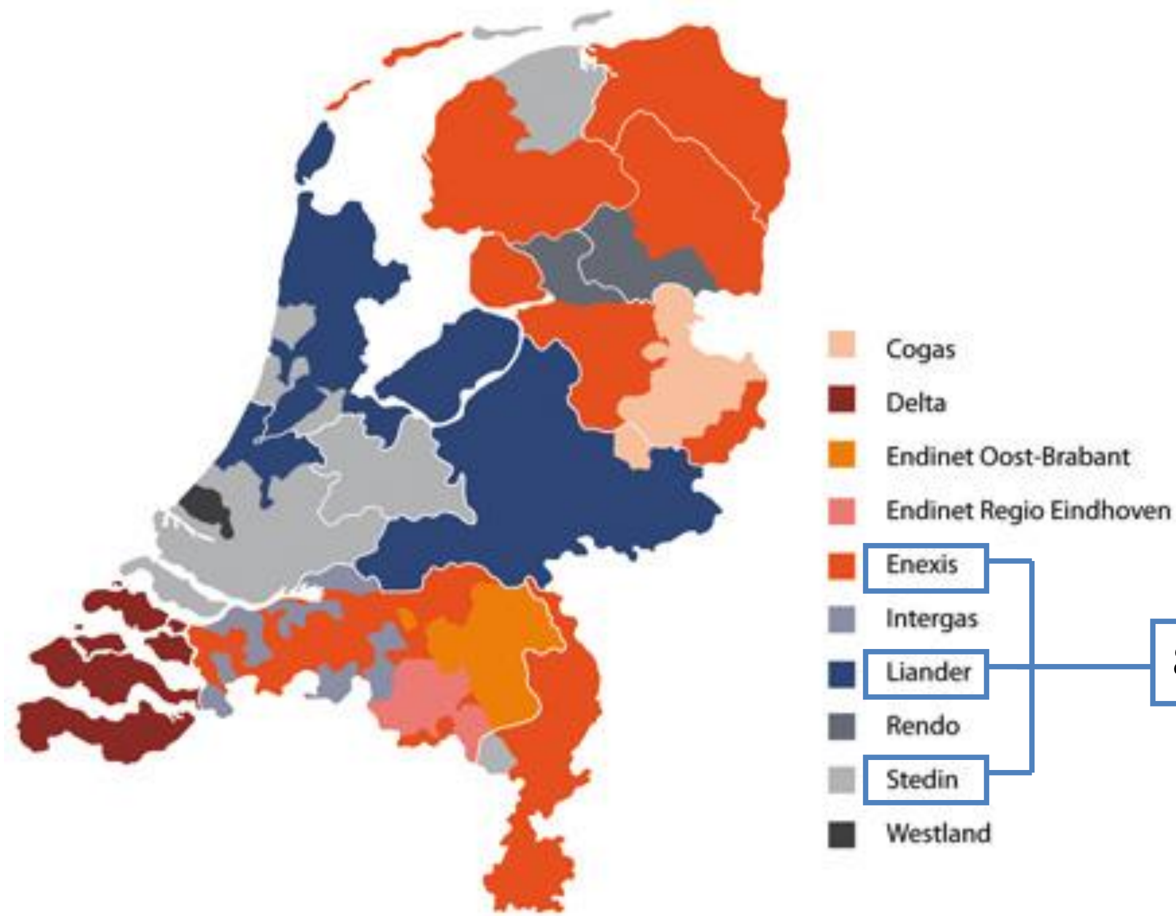
Electricity network

- 2.7 million connections
- 45,000 km MV cable
- 100,000 km LV cable
- 50,000 stations
- 22 min/customer SAIDI

Gas network

- 2.1 million connections
- 45,000 km mains
  - 20% high pressure 1-8 bar
  - 80% low pressure 30/100 mbar
- 25,000 stations
- < 1 min/customer SAIDI

Distribution of regional gas grids



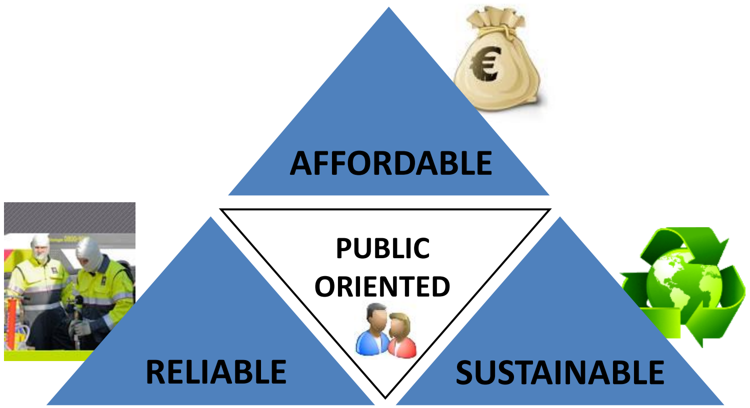
85% of asset base

Collective figures

- 6.7 million connections
- 120,000 km mains
- 60,000 stations

Problem setting

- Mission: Maintain a safe, reliable, affordable and sustainable energy supply
- Challenge: Realize a long-term, socially optimal trade-off between these elements



- Complication:
  - Ageing of the grid infrastructure
  - No direct stimulus in regulatory regime to increase replacement investments
- Aim of study:
  - A collective view on the effects of asset ageing on relevant company values, based on common scenarios
  - Insight into common strategies to anticipate these effects

Model development

- Simulate the effects of asset ageing on company values
- Contain collective knowledge of and accepted by all DNOs
- Give answers to strategic questions:
  - What asset replacement investments are necessary to fulfil preset company targets?
  - How can an optimal balance between company values be obtained?

    → Show the supervisory authorities that the right measures are taken to achieve targets

- Umbrella approach:
  - Combination of different types of network components in one model
  - Outline representation of the network
- Out of scope:
  - Innovations in materials
  - Changes in net concepts

Problem statement

- What is the optimal replacement strategy for the next 10 to 50 years?

- Objective function:

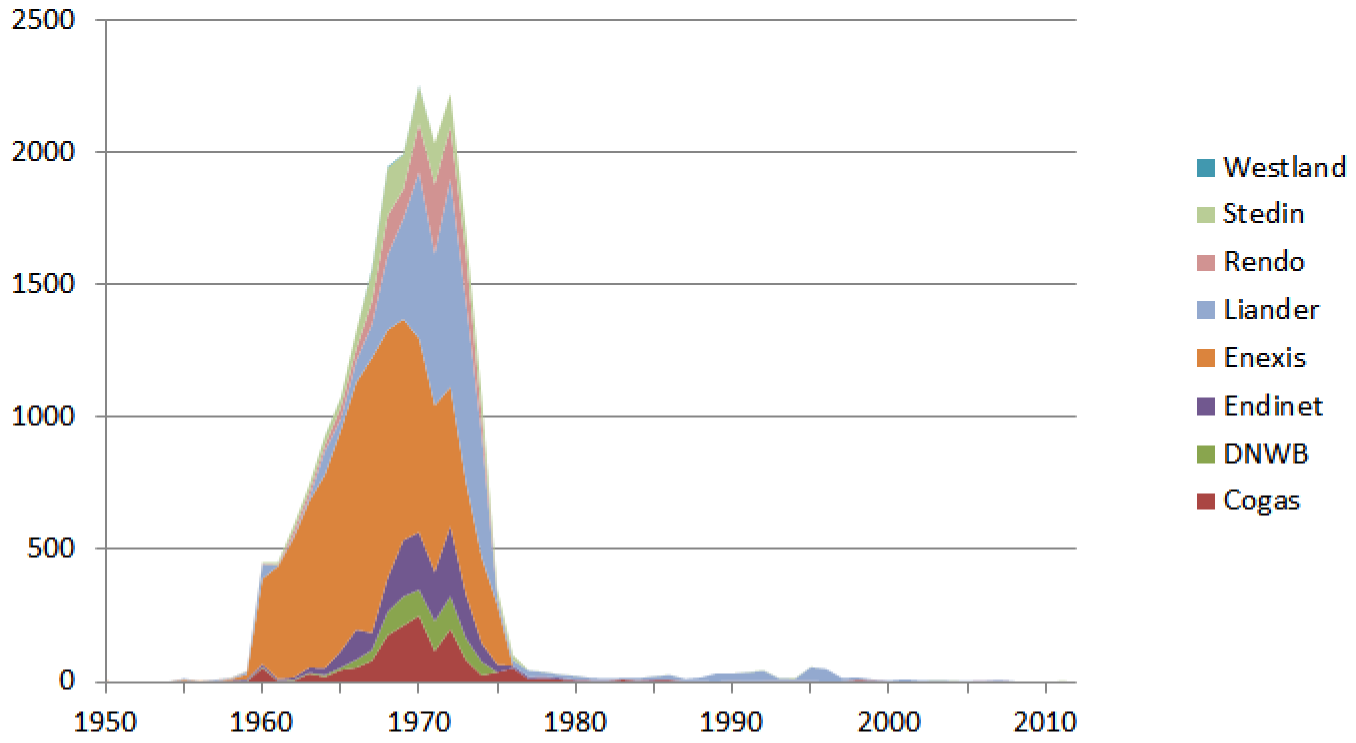
  Net present value of weighted sum of expected risk costs and preventive replacement costs over a period of 50 years

- Key ingredients:
  - Grid structure
  - Company values:
    - Financial
    - Safety
    - Quality of Supply
    - Sustainability
  - Asset failure behaviour
  - Policy constraints

Asset types

number	asset type	unit	population	average age
	Stations			
1	Transit	#	719	22
2	Distribution	#	10,814	22
3	Delivery (metered)	#	11,586	20
4	Delivery (unmetered)	#	34,264	25
	Transmission mains (1-8 bar)			
5	PE 3rd generation 8 bar	km	909	8
6	PE 1st generation 1-4 bar	km	2,870	43
7	PE 2nd generation 1-4 bar	km	3,568	24
8	PE 3rd generation 1-4 bar	km	742	14
9	Ductile Cast Iron	km	761	31
10	Grey Cast Iron or Asbestos Cement	km	113	47
11	Steel Bitumen coated (-1972)	km	4,973	48
12	Steel PE coated (1972-)	km	8,871	28
	Distribution mains (<1 bar)			
13	PE 1st generation	km	2,705	43
14	PE 2nd generation	km	6,654	24
15	PE 3rd generation	km	2,140	12
16	Asbestos Cement	km	1,490	47
17	Ductile Cast Iron	km	1,081	34
18	Grey Cast Iron	km	5,120	51
19	Steel	km	5,003	42
20	PVC	km	21,527	45
21	PVC HI	km	55,258	24
	Service lines			
22	Susceptible to corrosion	#	386,403	45
23	Susceptible to subsidence	#	417,766	22
24	Other	#	5,917,930	24

Example of age distribution



Age distribution of PVC distribution mains

Valuation of safety

Safety:

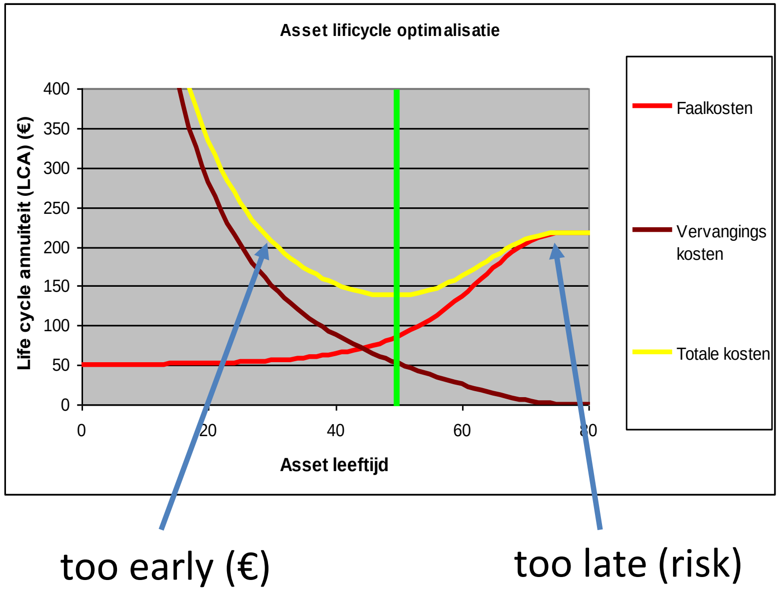
- Classification according to the “Safety Indicator Gas”

Classification	Safety accidents with bodily harm	Financial accidents with collateral damage	Social unrest evacuation duration in customer hours
Negligible	dangerous situation only	< 1k€	< 10
Small	near-accident or first-aid	1k€ - 10k€	10 - 100
Moderate	injury with absence	10k€ - 100k€	100 - 1,000
Considerable	serious injury with absence	100k€ - 1M€	1,000 - 10,000
Serious	one fatality	1M€ - 10M€	10,000 - 100,000
Catastrophic	multiple fatalities	> 10M€	> 100,000

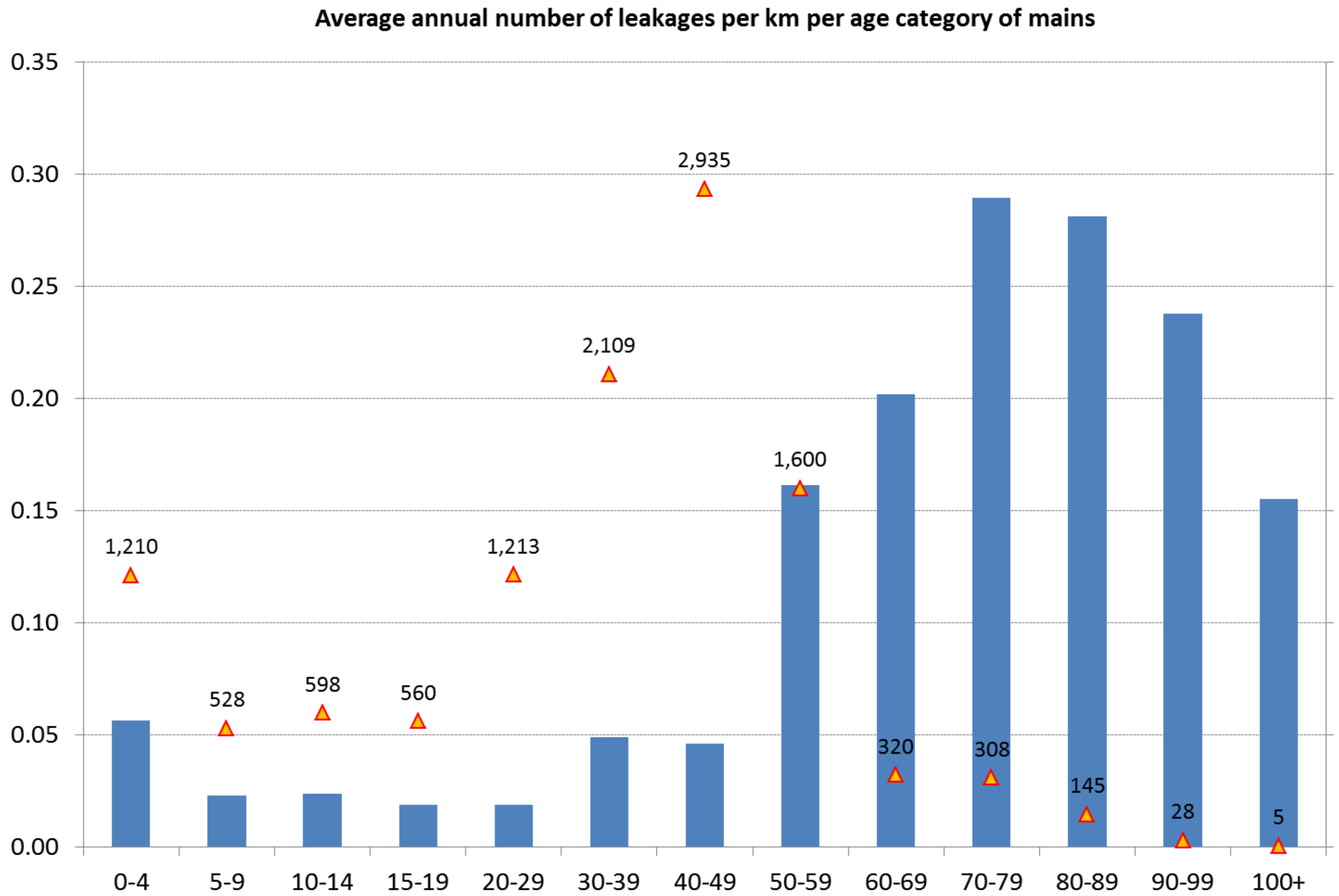
- Reference event:
  - accident with injuries with absence
  - collateral damage in the order of 100 k€
  - evacuation in the order of 1,000 hrs

Optimal replacement

- The asset failure probability increases over time
- Preventive replacement is more favourable than corrective replacement: no emergency measures, no outage, no safety incident
- The asset should be replaced when the sum of failure risk and net present replacement cost is minimal



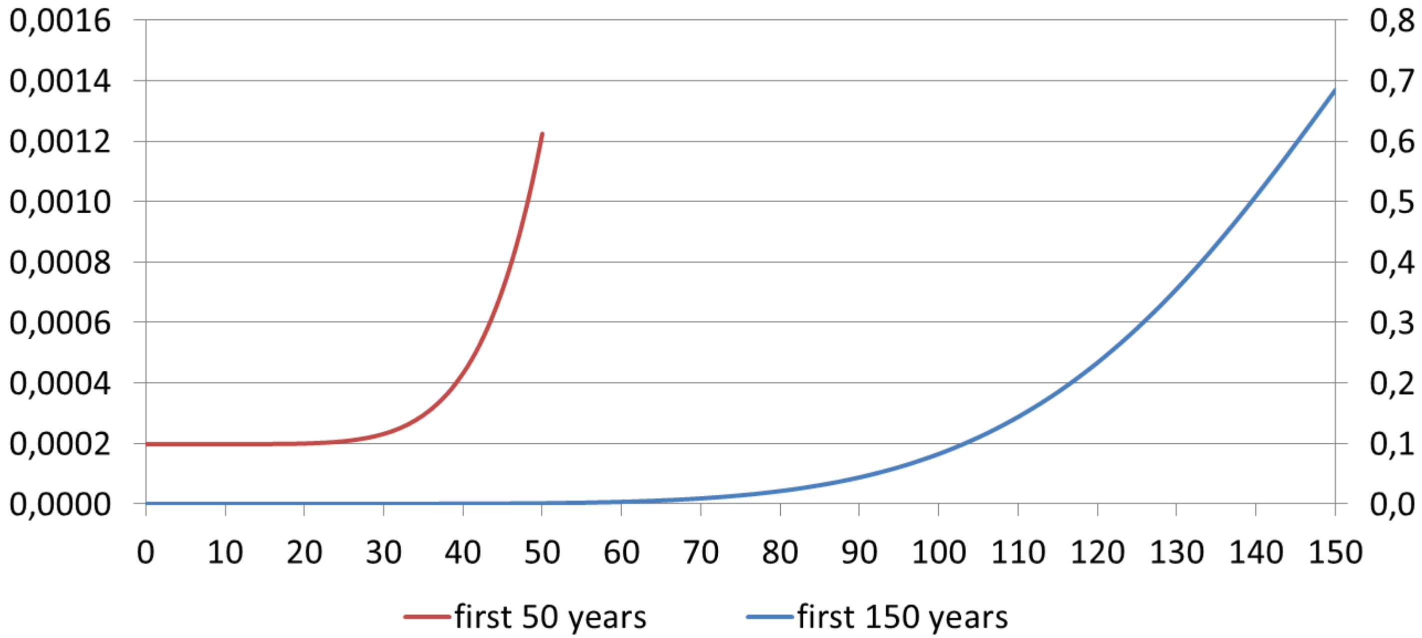
Failure probabilities



Age-dependent failure curves

- Constructed such that modelled failure behaviour is in exact correspondence with the current yearly number of failures

- Beta distribution



Yearly failure probability of 10 m section of steel distribution mains

Risk per failure

<table>
<tr><th>expected number of reference events per 1,000 failures</th><th>risk per failure (age independent)</th><th>risk per failure (age dependent)</th></tr>
<tr><td>1 Transit</td><td rowspan="4">8.27</td><td rowspan="4">0.11</td></tr>
<tr><td>2 Distribution</td></tr>
<tr><td>3 Delivery (metered)</td></tr>
<tr><td>4 Delivery (unmetered)</td></tr>
<tr><td>5 PE 3rd generation 8 bar</td><td rowspan="8">95.34</td><td rowspan="4">3.20</td></tr>
<tr><td>6 PE 1st generation 1-4 bar</td></tr>
<tr><td>7 PE 2nd generation 1-4 bar</td></tr>
<tr><td>8 PE 3rd generation 1-4 bar</td></tr>
<tr><td>9 Ductile Cast Iron</td><td>1.89</td></tr>
<tr><td>10 Grey Cast Iron or Asbestos Cement</td><td>10.86</td></tr>
<tr><td>11 Steel Bitumen coated (-1972)</td><td rowspan="2">1.28</td></tr>
<tr><td>12 Steel PE coated (1972-)</td></tr>
<tr><td>13 PE 1st generation</td><td rowspan="9">15.93</td><td rowspan="3">0.89</td></tr>
<tr><td>14 PE 2nd generation</td></tr>
<tr><td>15 PE 3rd generation</td></tr>
<tr><td>16 Asbestos Cement</td><td>3.23</td></tr>
<tr><td>17 Ductile Cast Iron</td><td>0.85</td></tr>
<tr><td>18 Grey Cast Iron</td><td>9.08</td></tr>
<tr><td>19 Steel</td><td>0.15</td></tr>
<tr><td>20 PVC</td><td>3.36</td></tr>
<tr><td>21 PVC HI</td><td>2.82</td></tr>
<tr><td>22 Susceptible to corrosion</td><td rowspan="3">5.60</td><td rowspan="3">1.69</td></tr>
<tr><td>23 Susceptible to subsidence</td></tr>
<tr><td>24 Other</td></tr>
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Scenarios

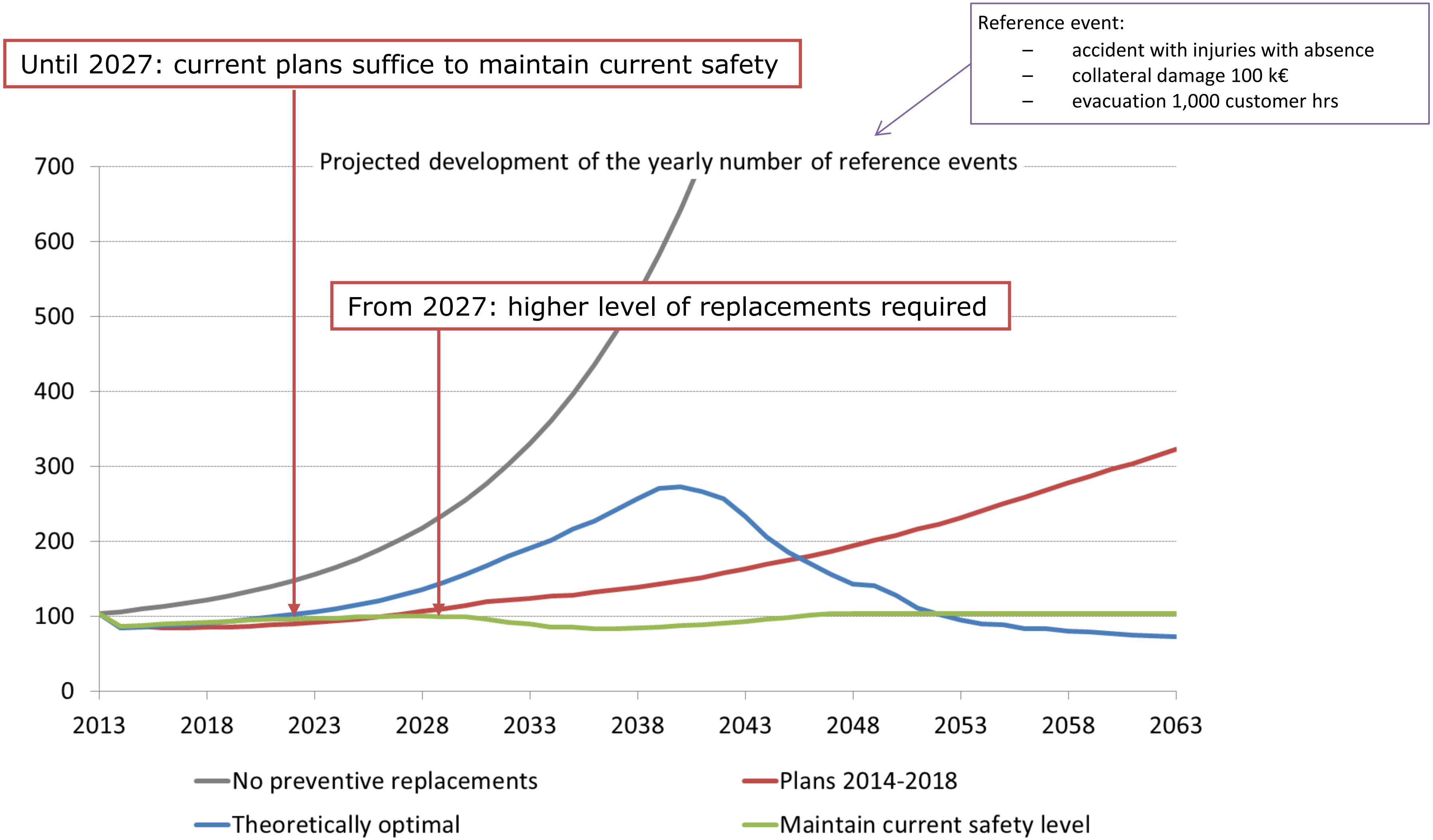
- Common scenarios:

scenario	strategy
0	No preventive replacements
1	Plans issued in 2013
2	Theoretically optimal
3	≤ 103 reference events / year

- Replacement plans 2014-2018:

	Plans 2010-2014	Plans 2014-2018
Stations	1.24%	1.57%
Transmission mains	0.38%	0.66%
Distribution mains	0.70%	0.92%
Service lines	2.32%	1.33%

Comparison Safety



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Comparison Financial

- Projected replacement investments

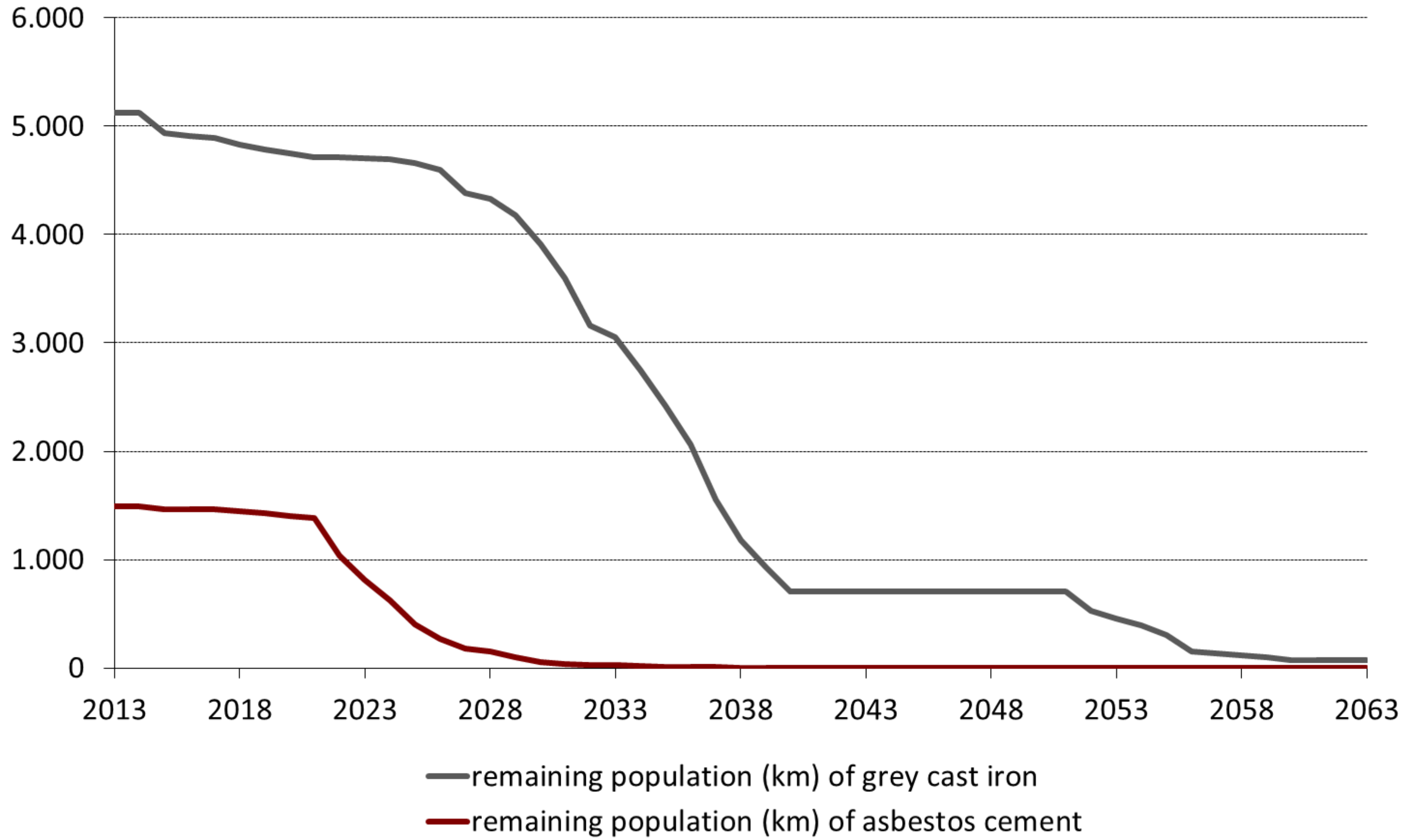
	scenario	
next 50 years	Prolongation of current plans	Maintain current safety
Average preventive replacement costs (M€/yr)	262	436
Average per customer (€/yr)	*39*	*65*
Net Present Value (M€)	6,182	9,257

- Average yearly replacements to maintain current safety

	10 years		20 years		50 years	
Stations	0	0.00%	0	0.00%	908	1.58%
Mains (km)	346	0.28%	1,717	1.39%	2,106	1.70%
Service lines	42,921	0.64%	136,648	2.03%	106,488	1.58%

IGU: "*The estimated annual replacement level of networks will settle at around 1.6 percent of their total length*"

Replacement of mains of brittle material



Conclusions

In our study we have:

- Created a common view on the effects of asset ageing
- Developed a numerical model which predicts future asset failures and calculates the theoretically optimal replacement policy, either with or without safety target
- Provided insight into what plans are required to realize an optimal trade-off between company values, based on the current state of knowledge of asset ageing

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