25th world gas conference
"Gas: Sustaining Future Global Growth"

Investing in the Future

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

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Key figures

- 4,000 employees
- Turnover € 1.2 billion
- 34.9 TWh
- 7.0 billion m^3

Electricity network

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

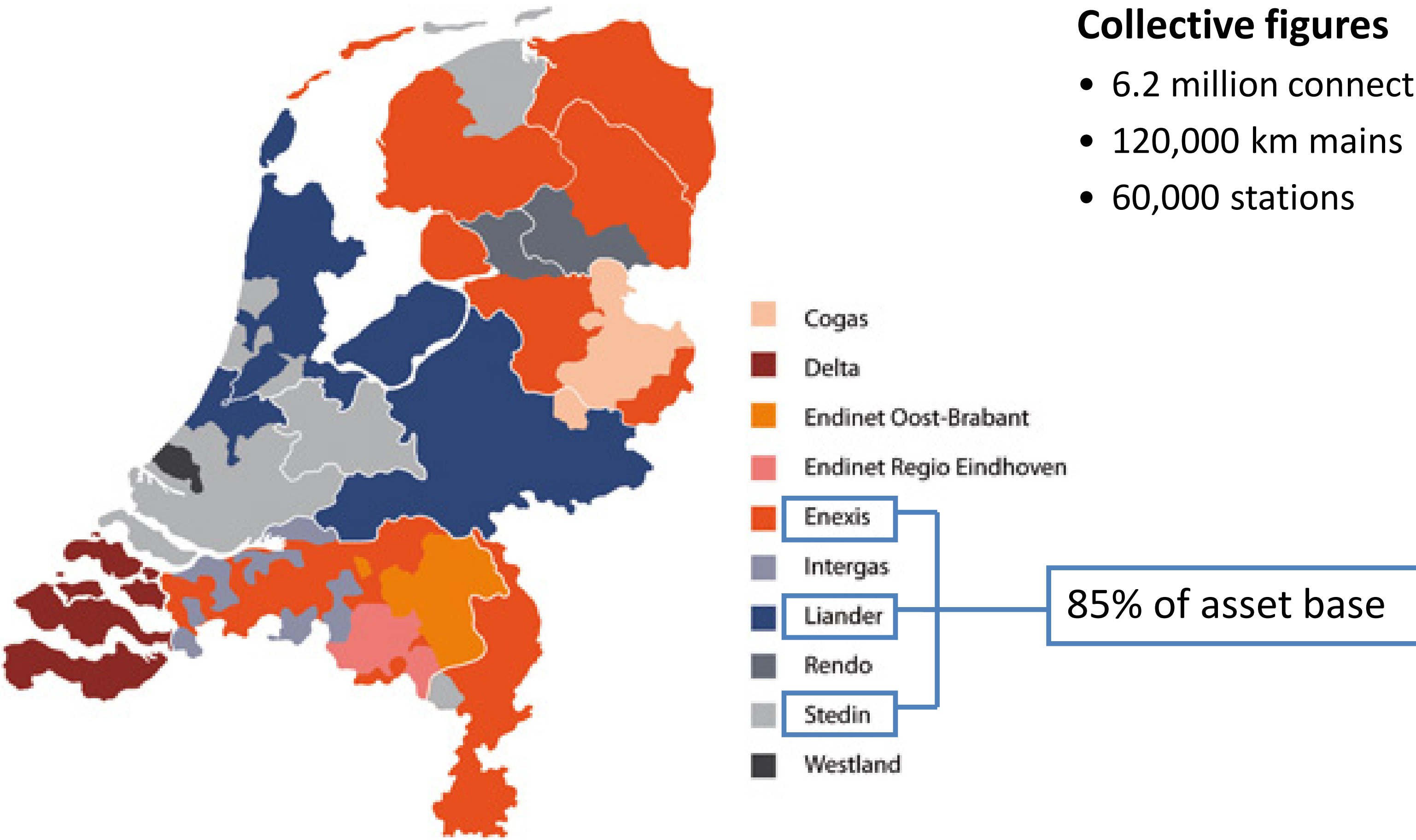
Gas network

- 2.0 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

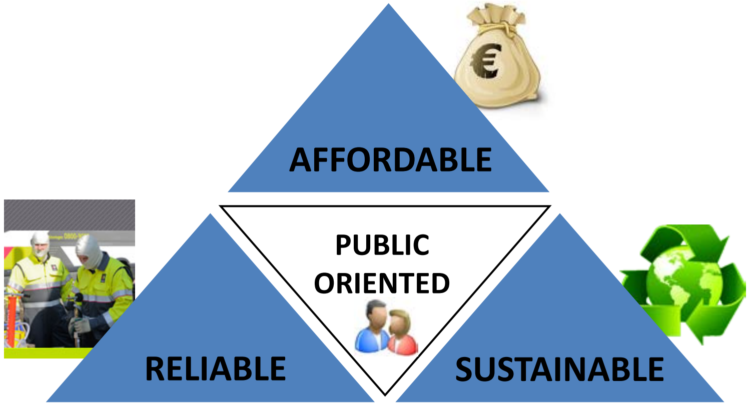
Distribution of regional gas grids

Collective figures

- 6.2 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:

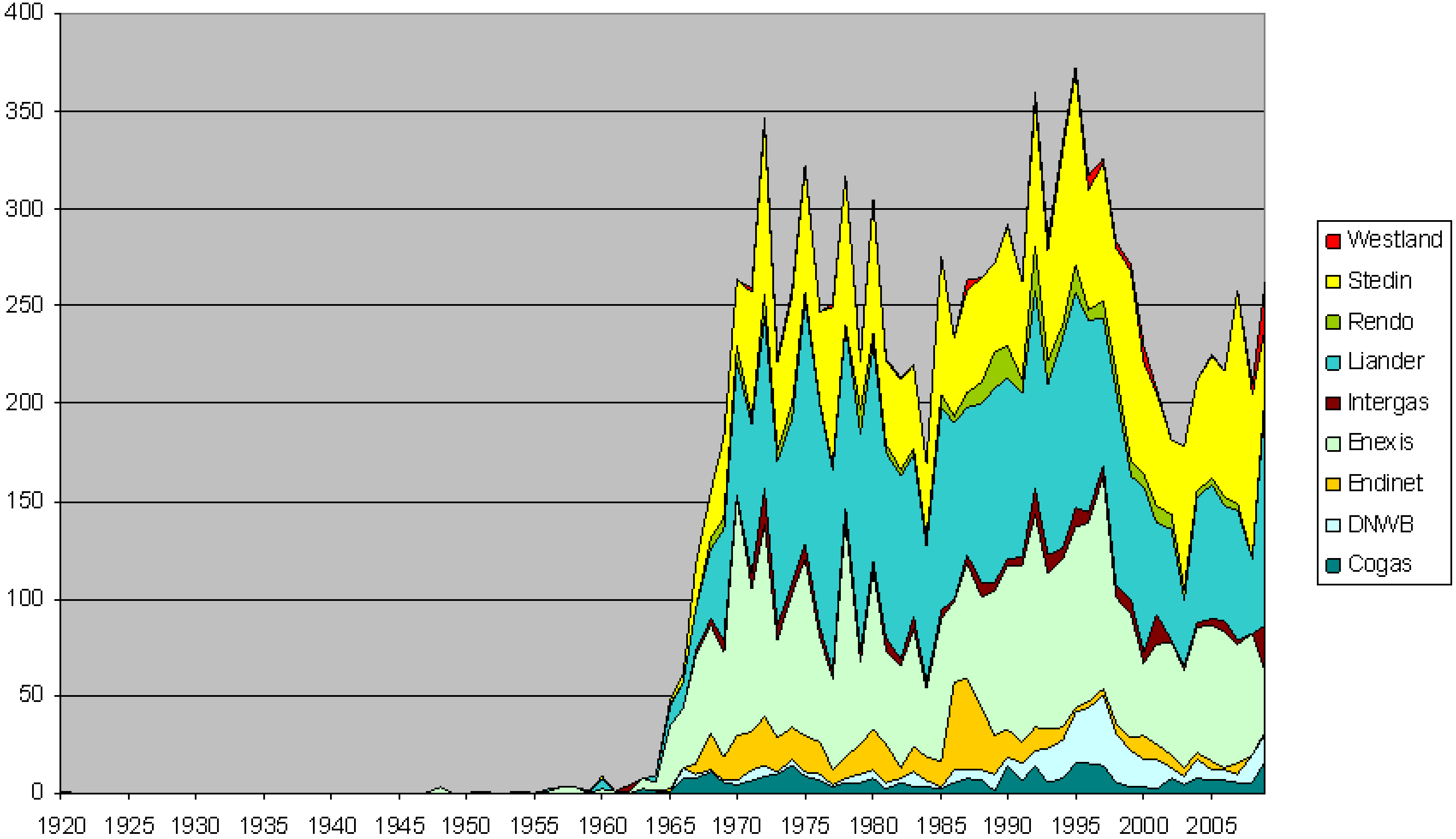
  Net present value of weighted sum of expected risk costs and preventive replacement costs over a period of 50 years

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

Asset types

number	asset type	replacement	unit	population	average age
	Stations				
1	Transit	1	#	739	22
2	Distribution	2	#	11,044	22
3	Delivery (metered)	3	#	11,469	20
4	Delivery (unmetered)	4	#	34,950	20
	Transmission mains (1-8 bar)				
5	PE 1st generation 8 bar	7	km	150	38
6	PE 2nd generation 8 bar	7	km	52	25
7	PE 3rd generation 8 bar	7	km	628	6
8	PE 1st generation 1-4 bar	10	km	2,776	40
9	PE 2nd generation 1-4 bar	10	km	2,878	24
10	PE 3rd generation 1-4 bar	10	km	1,380	10
11	Ductile Cast Iron	14	km	880	35
12	Grey Cast Iron or Asbestos Cement	14	km	170	48
13	Steel Bitumen coated (-1972)	14	km	5,695	43
14	Steel PE coated (1972-)	14	km	8,093	24
	Distribution mains (<1 bar)				
15	PE 1st generation	17	km	3,072	39
16	PE 2nd generation	17	km	6,039	22
17	PE 3rd generation	17	km	2,239	9
18	Asbestos Cement	23	km	1,742	42
19	Ductile Cast Iron	23	km	1,180	30
20	Grey Cast Iron	23	km	6,343	47
21	Steel	23	km	5,393	38
22	PVC	23	km	21,492	41
23	PVC HI	23	km	53,139	21
	Service lines				
24	Susceptible to corrosion	26	#	669,665	28
25	Susceptible to subsidence	26	#	77,277	32
26	Other	26	#	5,399,727	21

Example of age distribution



Age distribution of distribution stations

Valuation of safety and sustainability

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

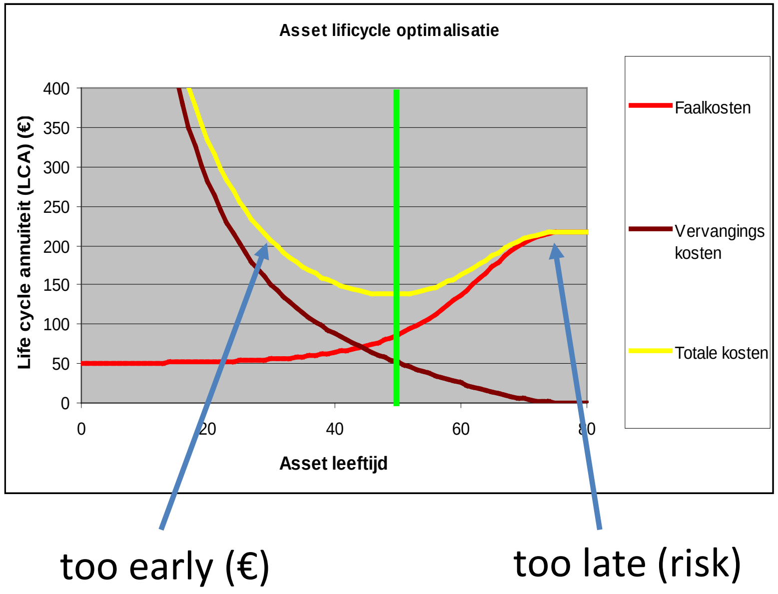
Sustainability

- Methane emission: 1 m^3 CH_4 corresponds to 0.017 tons CO_2
- Trade price CO_2: € 20/ton
- Valuation CH_4: € 0.35/m^3

- For comparison:
  - trade price natural gas: € 0.28/m^3
  - methane content 80%: € 0.35/m^3 CH_4

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

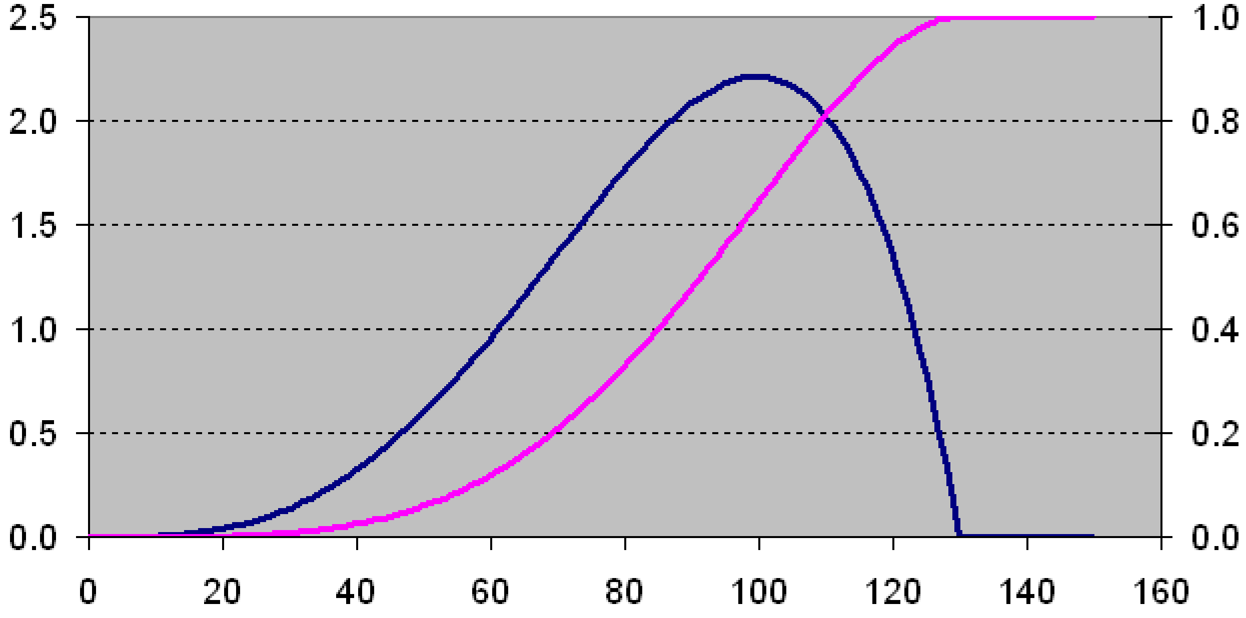


Age-dependent failure curves

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

- Beta distribution

pdf:	$\frac{x^{\alpha-1}(1-x)^{\beta-1}}{\mathrm{B}(\alpha,\beta)}$



Modelled failure probability distribution of ductile cast iron distribution mains

Scenarios

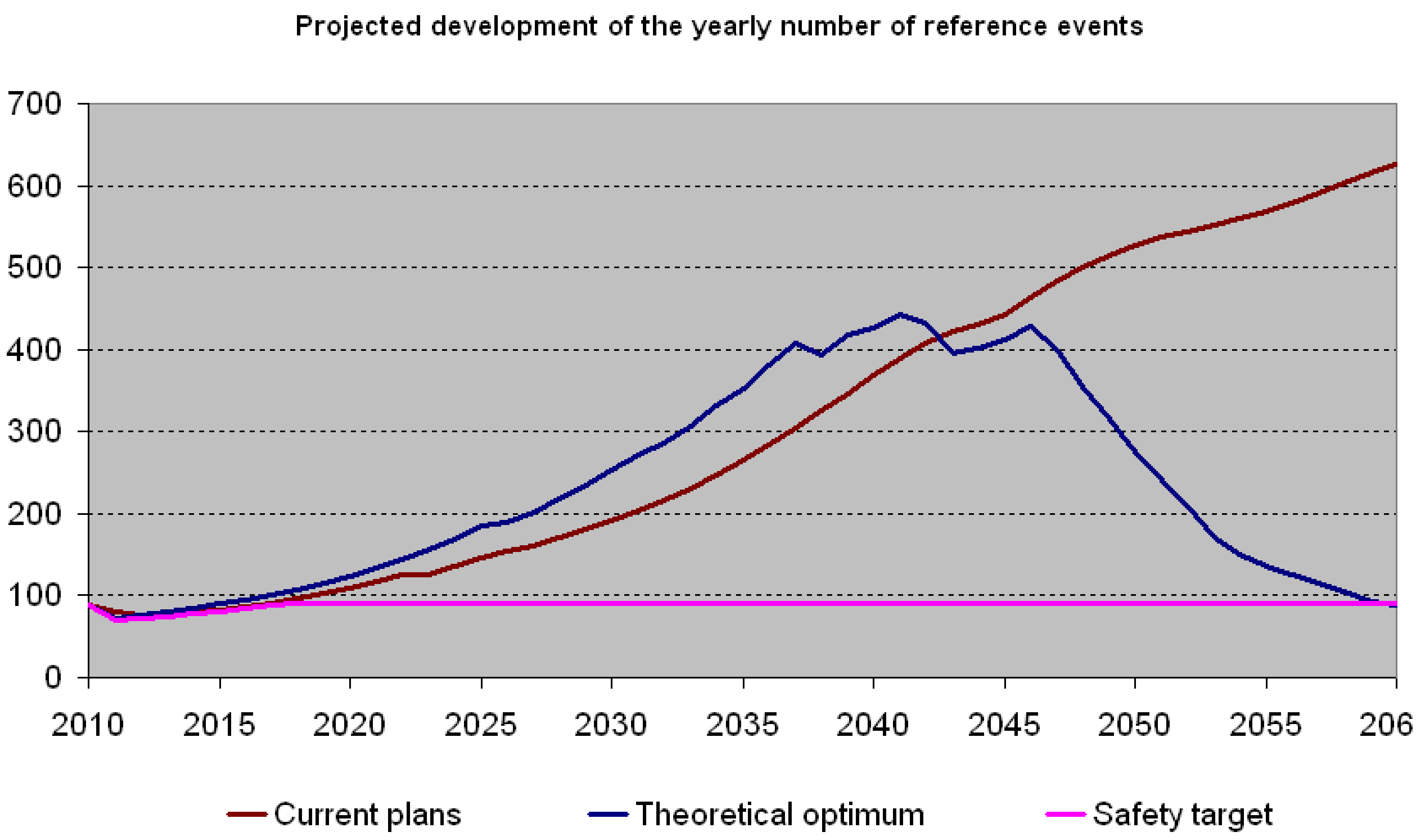
- Common scenarios:

scenario	strategy	safety target
1	Plans issued in 2009	
2	Theoretically optimal	
3	Theoretically optimal	≤ **90** reference events / year

- Replacement plans 2010-2014:

	2010	2011	2012	2013	2014
Stations	1.28%	1.27%	1.22%	1.22%	1.22%
Transmission mains	0.49%	0.41%	0.39%	0.31%	0.31%
Distribution mains	0.61%	0.66%	0.71%	0.74%	0.77%
Service lines	2.13%	2.33%	2.35%	2.34%	2.43%

Comparison Safety



Comparison Financial

- Projected replacement investments

	scenario		
50 years	Prolongation of current plans	Theoretical optimum	Safety target
Absolute value (M€)	11,075	17,258	19,803
Average per year (M€)	*222*	*345*	*396*
NPV (M€)	3,651	3,159	6,066

- Replacements Theoretical optimum

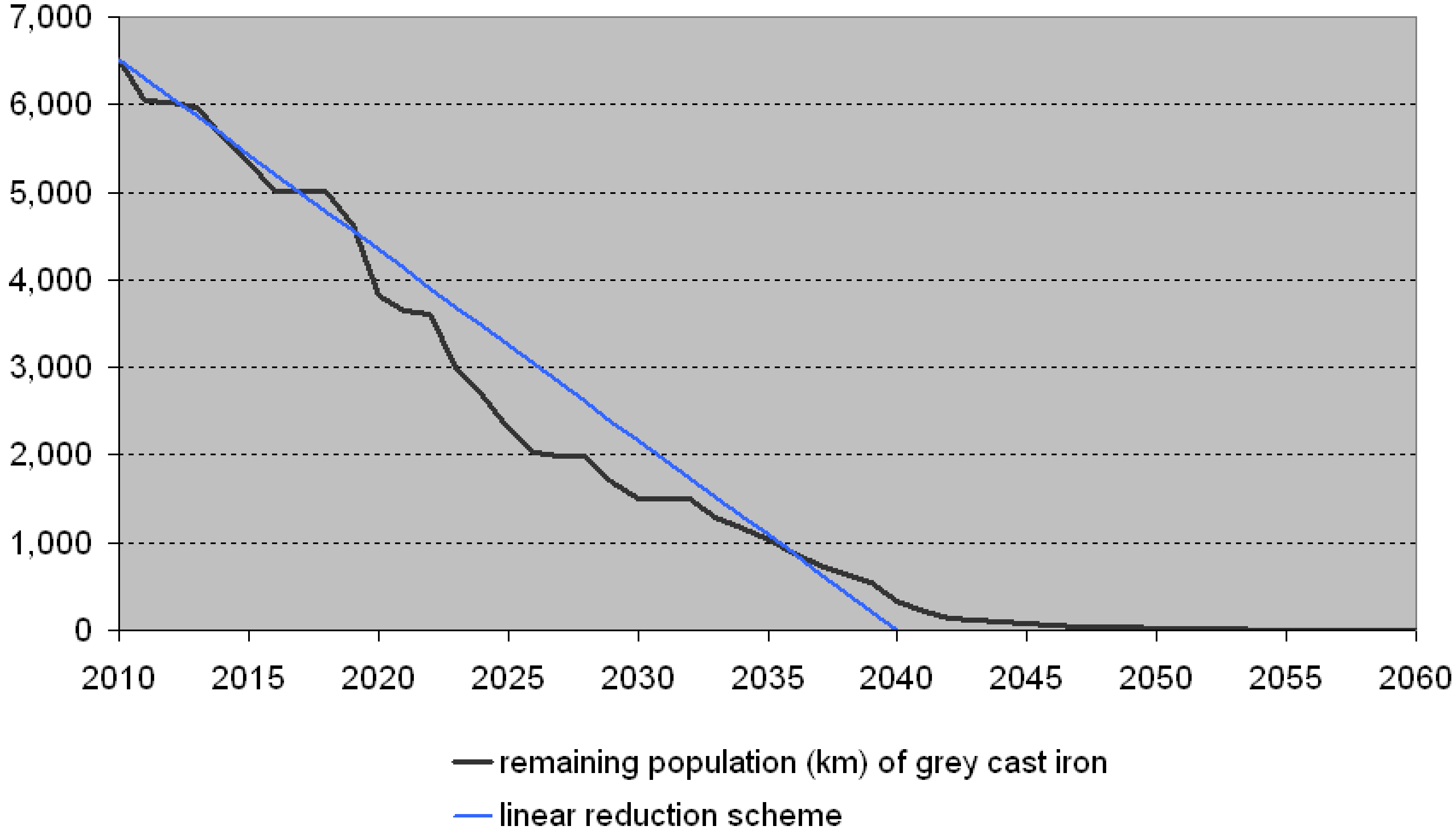
	10 years		50 years	
Stations	657	1.13%	1020	1.75%
Mains (km)	59	0.05%	2184	1.77%
Service lines	107594	1.75%	120305	1.96%

- Replacements Safety target

	10 years		50 years	
Stations	998	1.71%	1458	2.51%
Mains (km)	1227	1.00%	2326	1.89%
Service lines	132539	2.16%	149418	2.43%

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

Replacement of grey cast iron



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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