MRPS TREND ANALYSIS 2023

Trend Analysis for Leaks and Incidents in the UK Gas Distribution System – 2023 Update

National Replacement Forum

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Applicable contract(s) governing the provision of this Report:

Objective: To provide insights into the failures, Gas in Buildings and explosions occurring on ferrous mains in the GB distribution networks.

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1	22/05/2024	Updated seasonal analysis and addition of GiB rates section	Jonathan Hague	Claire Ashton	Suzanne Bradbury

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1 EXECUTIVE SUMMARY

The Mains Risk Prioritisation Scheme (MRPS) was developed in 1999 to enable the UK gas distribution network owners to prioritise their 30-year iron distribution main replacement programme. The aim of the replacement programme is ultimately to reduce the occurrence of building explosions due to failed distribution mains. Explosions are caused by gas tracking into properties, which then builds up and ignites. Gas in building (GiB) occurrences may result from any type of distribution main failure but have historically been considered to be more likely when a cast or spun iron main fractures, or a ductile iron main has a corrosion hole or joint leak, or a steel main has a corrosion hole. It should be noted that building explosions may also be caused by leakage of gas from service pipes, meter installations and internal gas pipework, but this report is only concerned with leaks from distribution mains.

Periodically, the distribution networks provide DNV with several data extracts from their respective asset repositories. This data is used to carry out a trend analysis to determine if there has been a significant deterioration in the condition and performance of the gas distribution system, which then determines whether the coefficients and models used within MRPS require updating. The following conclusions and recommendations can be drawn from this analysis:

Total failures

- The decreasing trend in number of failures per year on ferrous distribution pipes has continued for Cadent and NGN. The number of failures per year appears to be levelling off for WWU and has increased for SGN.
- The failure rates for SGN and WWU have both increased in 2022, with SGN having their highest failure rate recorded as part of this analysis (since 2013). Meanwhile the failure rates for Cadent and NGN have decreased, with both having their lowest failure rate recorded as part of this analysis.
- The average total failure rate was 0.596 failures/km/year in 2022 (the range by network is 0.425 – 0.906 failures/km/year).
- The GiBs/leak rate has increased across all GDNs. In 2022, Cadent and WWU had their highest GiBs per leak since 2018, whilst SGN has their highest GiBs per leak recorded as part of this analysis (since 2013).
- The average total GiB rate was 0.056 GiBs/leak in 2022 (the range by network is 0.025 – 0.094 GiBs/leak).
- In terms of specific networks, WWU continues to have the highest overall failure/km rates, though both SGN networks have a major uptick, with the rate of failure in the SGN Scotland network rising to meet the rate of failure in the Cadent North London network.
- Cadent North London has the highest GiB per leak rate, whilst SGN Scotland and NGN have the lowest.

Failures and GiBs by material

- In 2022, there has been an increase in GiBs/leak rates for all materials, though this is still in line with historic levels.
- WWU failure rates for cast/spun iron and ductile iron mains remain high; Cadent have high GiB rates for cast/spun iron and ductile iron mains.
- Cast/spun iron failures remain over 1.5 times as frequent as ductile iron failures.
- The GiBs/leak rate is greatest for cast/spun iron (0.060 GiB/failure), with ductile iron slightly lower (0.053 GiB/failure) and steel the lowest (0.035 GiB/failure).

Failures and GiBs by type (fractures, corrosions and joints)

- Cast/spun iron fractures are becoming less frequent and represent a small proportion of overall failures, however they have the highest GiB rate (0.115 GiB/failure) for specific failure types.

- Joint failures are now the predominant failure mode for cast/spun iron.
- Fractures comprise 13.4% of ductile iron GiBs but are currently collated with corrosion failures in MRPS, even though these have a much lower GiB rate.
- Joint failures comprise 26.5% of steel pipe failures but are not currently included in MRPS.

Qualifying Failures

- Following a slight dip in 2021, it appears the number of MRPS qualifying failures is remaining between 0.1 and 0.2 failures per km per year for all GDNs.
- This trend is also consistent for non-MRPS failures indicating that basing replacement on the failures covered by MRPS is also successful in reducing the rate of failures that are not included.
- Overall, only 28.3% of ferrous mains failures qualify under MRPS.

Seasonal Trends

- The seasonal trends show a large variance between the number of failures and GiBs seen during winter months and summer months.
- This trend is consistent across failure rate, GiBs per failure and GiBs per km, indicating that cold weather increases both the likelihood of a failure occurring and the probability that the escaped gas will track into a building.
- Failure type analysis shows that the cast/spun iron fracture rate remains fairly consistent for temperatures greater than 7°C, but slightly increases when the temperature drops to 7°C, then increases further when the temperature decreases to 4°C. Meanwhile, the ductile iron corrosion rate decreases gradually with increasing temperature, and the steel corrosions rate remains consistent at temperatures greater than 10°C, but has a slight increasing trend as the temperature decreases below 10°.

GiB Predictions

- The MRPS risk model is currently underpredicting GiB levels from cast iron fractures, and overpredicting GiB levels from steel corrosions. It is recommended that, to bring the prediction in line with actual levels, a coefficient update should be undertaken to update the current factors.
- In addition, when considering all failure types (except interference damage), MPRS underpredicts GiBs for all three materials. This is a particular issue for the cast/spun iron model, which is currently based only on fractures which only comprise 27.6% of cast iron GiBs. It is recommended that corrosions and joint failures are introduced into the cast/spun iron risk model and joint failures into the steel model to allow more accurate risk predictions.

[redacted]

Recommendations

1. The cast/spun iron model should be updated to include corrosion and joint failures.
2. The ductile iron model should be updated to separate fractures from corrosions.
3. The steel model should be updated to include joint failures.
4. A coefficient update should be undertaken to ensure that predicted GiBs closely align to recent GiB rates.

2 INTRODUCTION

The Mains Risk Prioritisation Scheme (MRPS) was developed in 1999 to enable the UK gas distribution network owners to prioritise their 30-year iron distribution main replacement programme. The aim of the replacement programme is ultimately to reduce the occurrence of building explosions due to failed distribution mains. Explosions are caused by gas tracking into properties, which then builds up and ignites. Gas in building (GiB) occurrences may result from any type of distribution main failure but have historically been considered to be more likely when a cast or spun iron main fractures, or a ductile iron main has a corrosion hole or joint leak, or a steel main has a corrosion hole. It should be noted that building explosions may also be caused by leakage of gas from service pipes, meter installations and internal gas pipework, but this report is only concerned with leaks from distribution mains.

Periodically, the distribution networks provide DNV with several data extracts from their respective asset repositories. This data is used to carry out a trend analysis to determine if there has been a significant deterioration in the condition and performance of the gas distribution system, which then determines whether the coefficients and models used within MRPS require updating.

Analyses of pipe length, failure and GiB rates, failure types, seasonal trends, predicted GiBs, and explosion incidents between April 2021 and March 2023 are contained in the following six sections, respectively. Conclusions and recommendations are found in Sections 9 and 10 respectively.

3 PIPE LENGTH

The length of ferrous pipe in the distribution network (particularly cast, spun and ductile iron) should be reducing year on year, as the GDNs continue with the 30-year replacement programme.

For this section, asset data received from the GDNs has been filtered to remove any steel services, intermediate pressure mains and steel mains with diameter less than 3 inches. The data has then been analysed to obtain lengths of mains materials for each of the GDNs, using only those mains classified as 'live' or 'planned abandonned'.

3.1 Length in Use

Figure 1 shows the length of pipe by material for all four GDNs over the past five years. The length data is a summary of the asset data extracted on 31st March for each financial year, so the data for '2022' was extracted on 31st March 2023. Pipe length by material for each GDN is shown in Figure 2 to Figure 5.

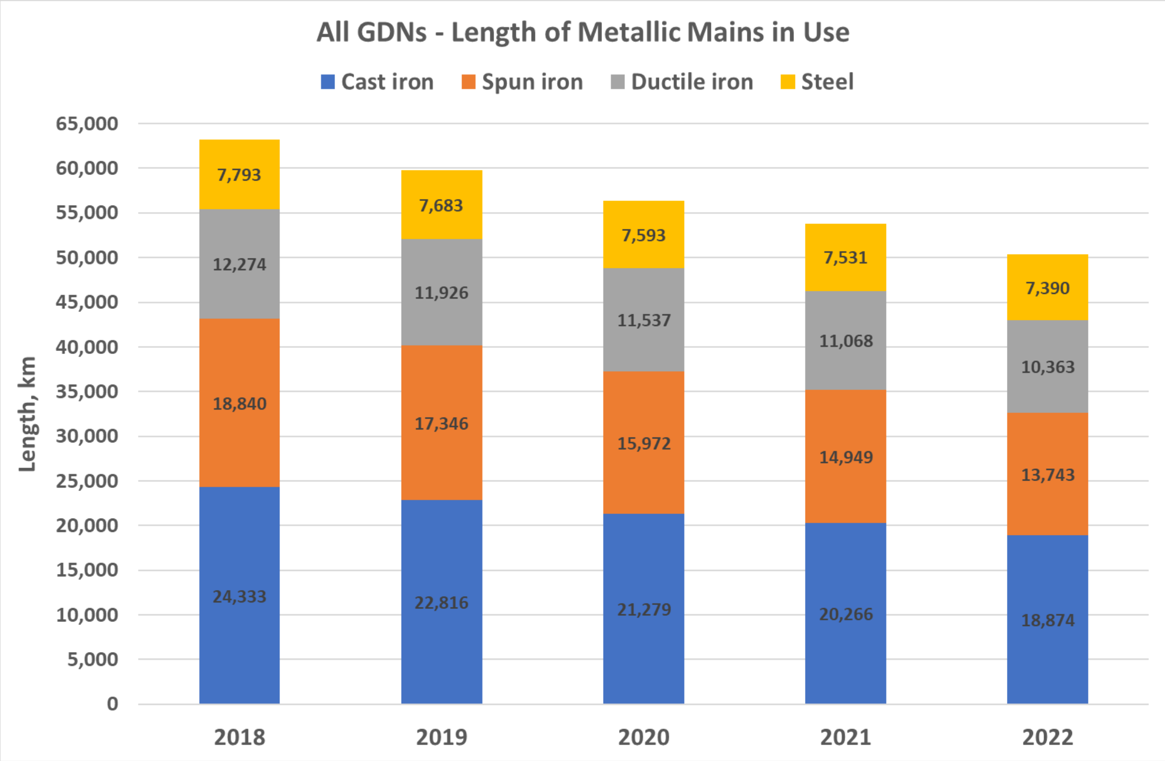

Figure 1 – Length of metallic mains in use, all GDNs

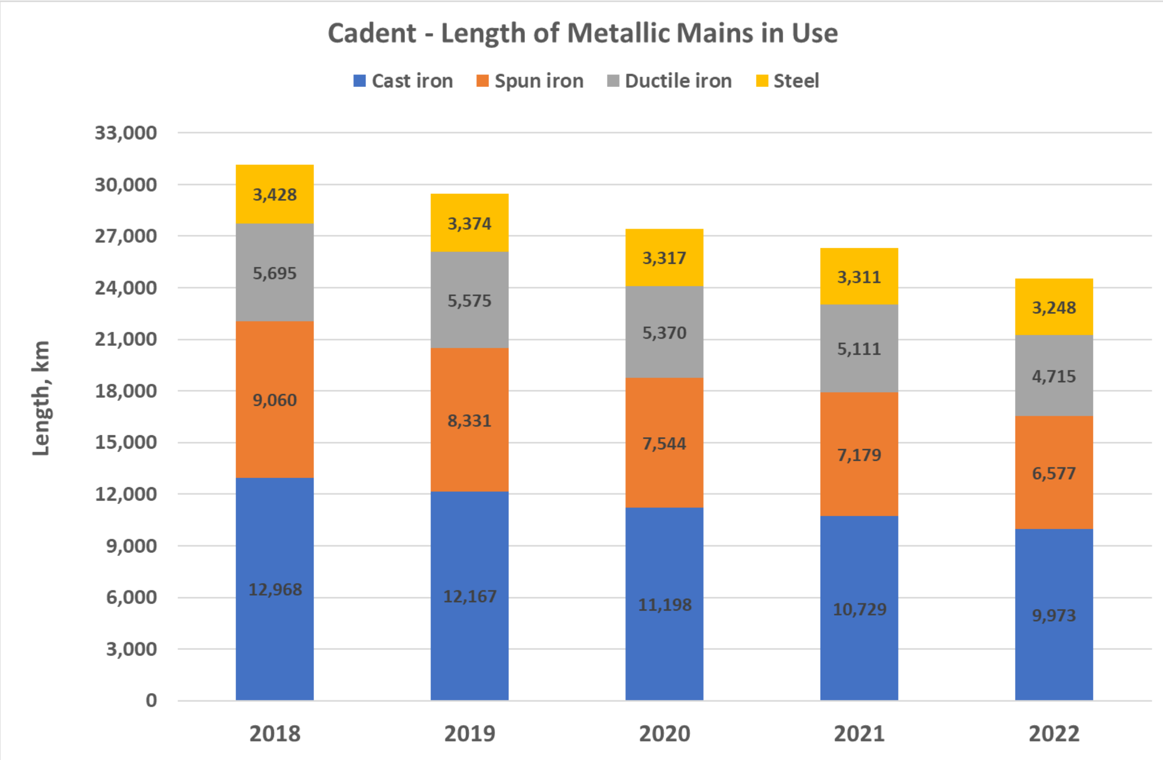

Figure 2 – Length of metallic mains in use, Cadent

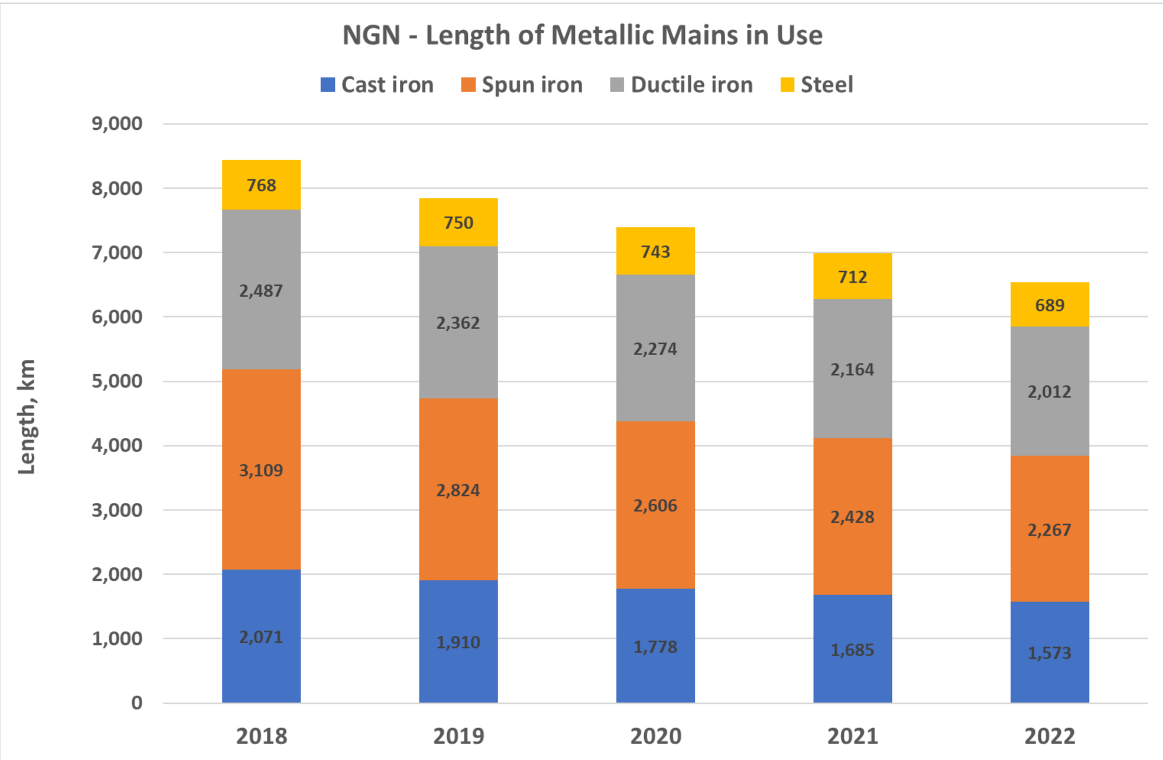

Figure 3 – Length of metallic mains in use, NGN

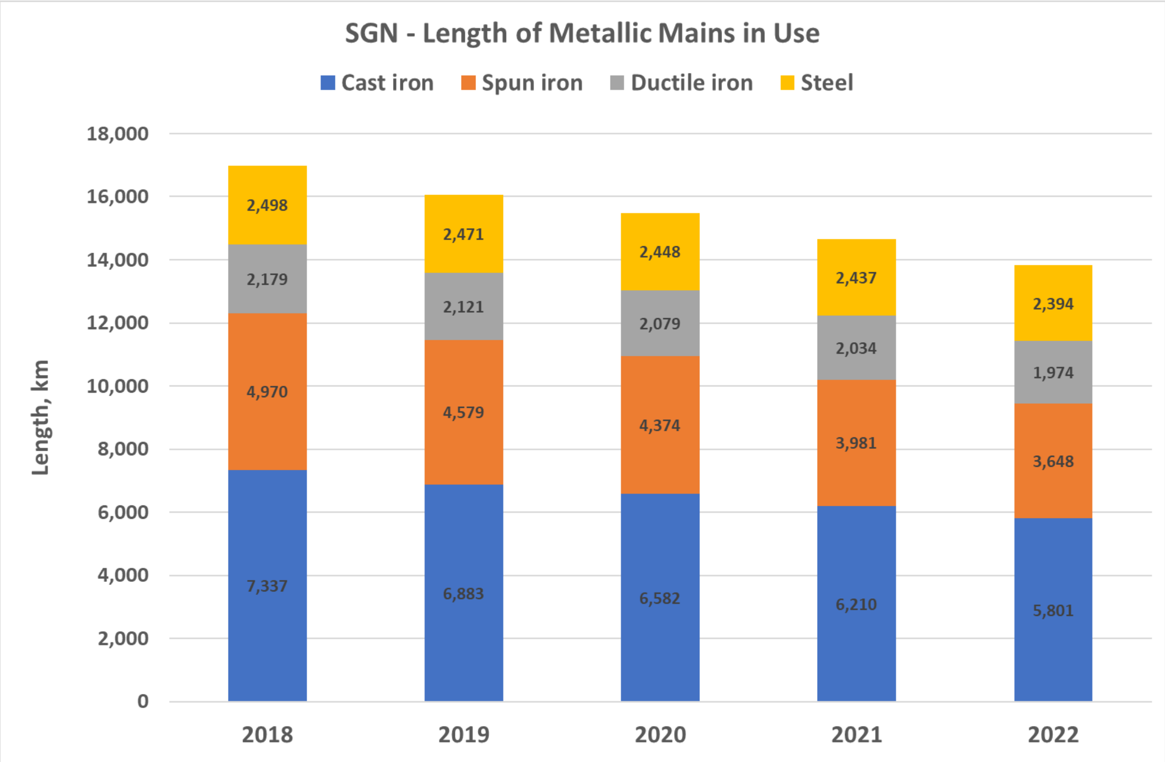

Figure 4 - Length of metallic mains in use, SGN

* SGN 2018 annual length number was estimated from the 2017 and 2019 numbers

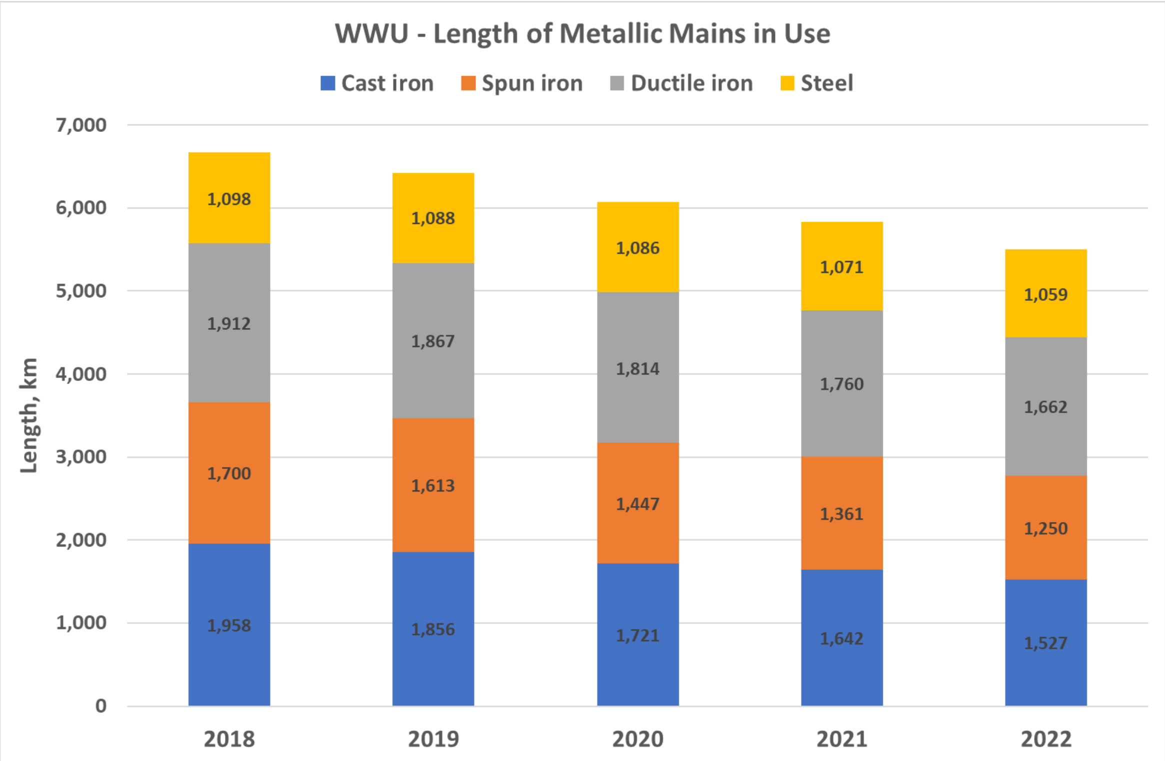

Figure 5 - Length of metallic mains in use, WWU

3.2 Change in Length in Use

The annual change in length in use by GDN and material, averaged over the past 5 years, is shown in Table 1, with the respective graphs for each GDN shown in Figure 6 to Figure 10. The change in length accounts for the net reduction in length from mains replaced under the Iron Mains Risk Reduction Programme (IMRRP).

Table 1 – Average annual replacement length by GDN and material, 2018-2022

Average annual replacement length, km					
	Cadent	**NGN**	**SGN**	**WWU**	**All GDNs**
Cast iron	678	123	401	123	**1,325**
Spun iron	566	213	349	129	**1,258**
Ductile iron	209	118	53	65	**445**
Steel	50	19	25	8	**101**
All ferrous	**1,503**	**473**	**829**	**325**	**3,129**

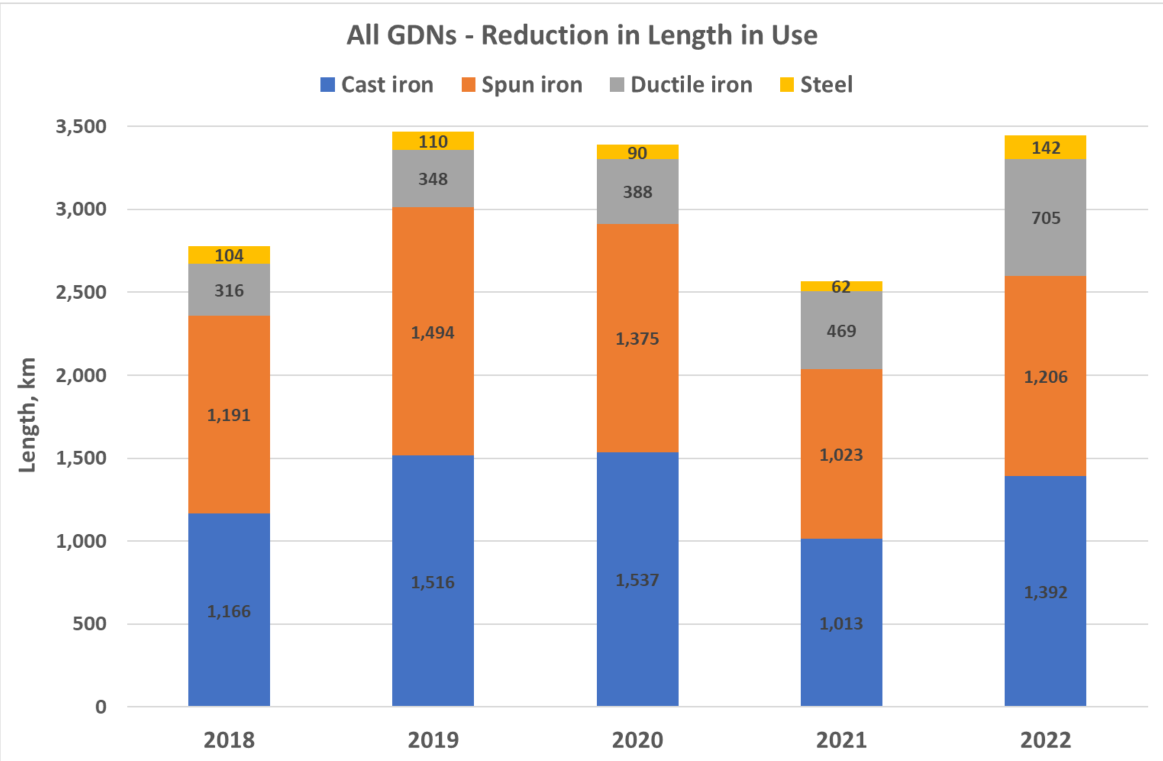

Figure 6 – Reduction in Length in Use, All GDNs

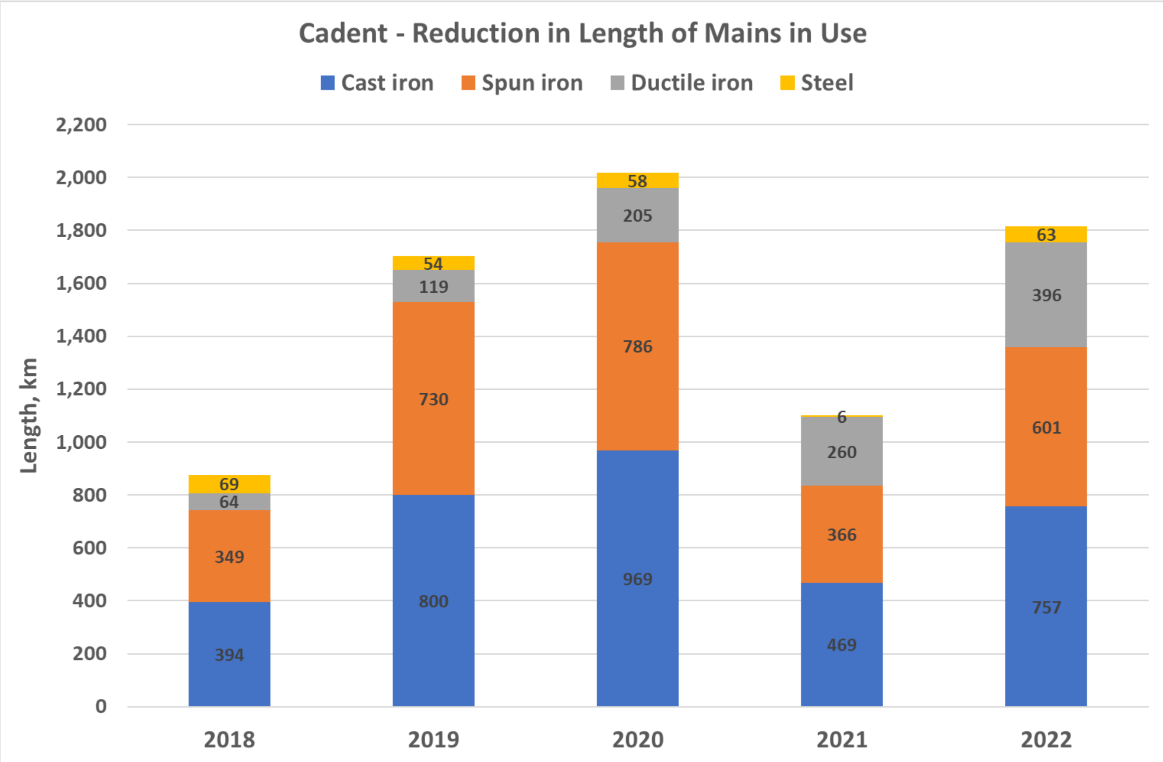

Figure 7 - Reduction in Length in Use, Cadent

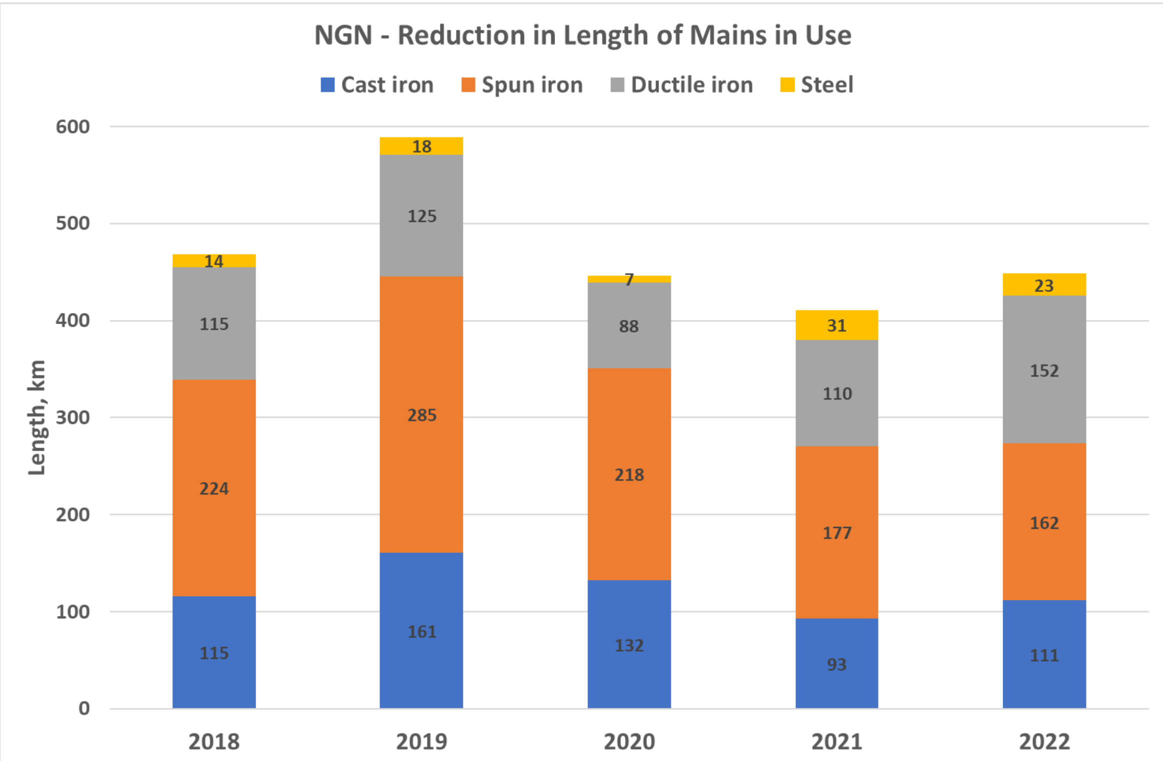

Figure 8 - Reduction in Length in Use, NGN

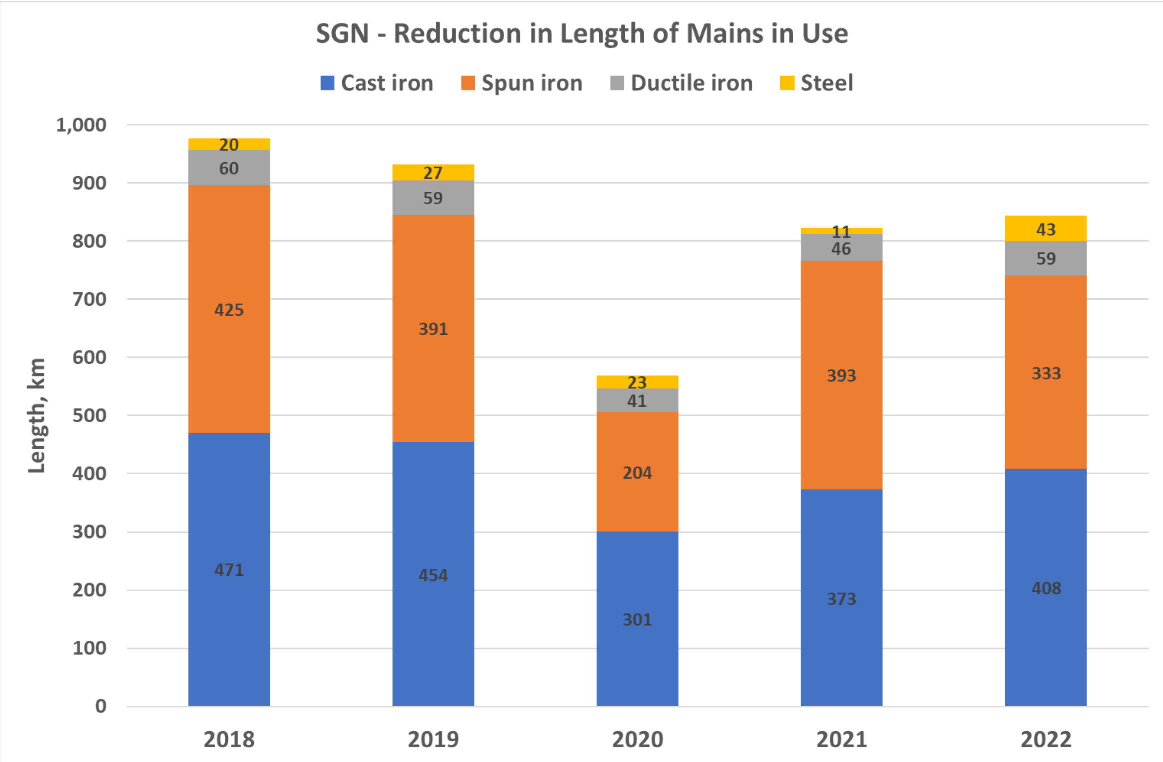

Figure 9 - Reduction in Length in Use, SGN

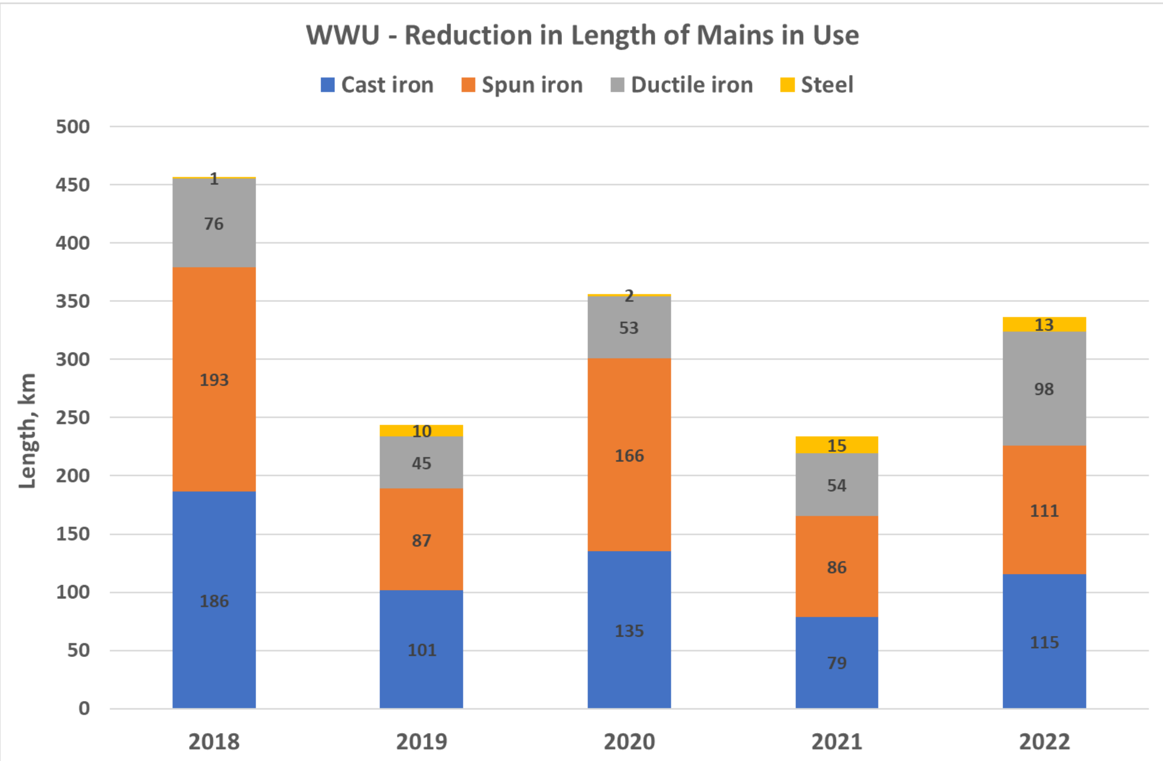

Figure 10 - Reduction in Length in Use, WWU

4 FAILURE AND GIB TRENDS

Three levels of failures and gas in building events (GiBs) are examined in the sections below. Firstly, in Section 4.1, total failures and GiBs for all ferrous distribution mains are reviewed. Section 4.2 considers failures and GiBs by material, and specific failure types and associated GiBs (fractures, corrosions) are reviewed in Section 4.3. Finally, in Section 4.4 the differences between trends in failures that are included in MRPS and those that are omitted is investigated. In all of the analyses, the data prior to 2018 is for the calendar year and for 2019 onwards is for the financial year (April to March). For 2018 there is essentially 15 months of data to analyse, including two winter periods; as such, the data for each of the winter months (January, February and March) has been averaged, so the data for January 2018 is actually the average of the data for January 2018 and January 2019.

4.1 Total failure and GiBs

Total failure and GiB rates for all cast, spun, ductile iron and steel distribution mains, by GDN, for 2022 are given in Table 2; total failures and GiB rates by network for 2022 are given in Table **3**. Total failures by GDN are shown in Figure 11 below and these are normalised by length of main (calculated each year) in Figure 12. Similar graphs are presented in Figure 13 and Figure 14 but with each network shown separately for the larger GDNs. Total failures by tier are presented in Figure 15 to Figure 17.

The failure rates for SGN and WWU have both increased in 2022, with SGN having their highest failure rate recorded as part of this analysis (since 2013). Meanwhile the failure rates for Cadent and NGN have decreased, with both having their lowest failure rate since the start of this analysis in 2013. WWU continues to have the highest failure rate of the GDNs, with SGN having a rate of failure around 81% that of WWU, whilst NGN and Cadent have a rate of failure around 54% that of WWU. The Cadent North London network is the only Cadent network to see an uptick in failure rate, however it is still significantly lower than the peak in 2018. Both SGN networks have a major uptick, with the rate of failure in the SGN Scotland network rising to meet the rate of failure in the Cadent North London network. When considered by pipe diameter tier, the number of failures from tier 1 mains (<9") has decreased for Cadent and NGN in 2022, whilst WWU numbers have remained level and SGN have increased to match the number of failures seen in 2018. This trend continues for tier 2 (9-17") and tier 3 (>=18") pipes.

Total GiBs are presented in Figure 18, with the data normalised by length and by leak in Figure 19 and Figure 20, respectively. All failures and GiBs are included, except those caused by interference damage and any duplicate entries.

There has been an increase in GiB rates for all GDNs in 2022. Cadent and WWU have their highest GiBs per leak since 2018, whilst SGN has their highest GiBs per leak recorded as part of this analysis (since 2013). NGN saw a dip in GiB rate in 2021, and despite the increase in 2022, their rates of GiB events remain below 2020 levels. Cadent continues to have the highest GiB per leak rate, however SGN now has the highest GiBs per km. When considered by pipe diameter tier, the number of GiBs for tier 1 mains has a slight uptick for Cadent, SGN and WWU, with the number of GiBs for NGN remaining level. For tier 2 mains, the number of GiBs for SGN is the highest since 2013, whilst both Cadent and NGN saw a dip in 2021 but have now increased to the level recorded in 2020. WWU GiB numbers remain level. For tier 3 mains, SGN, WWU and Cadent continued their respective trends from the tier 2 numbers, whilst NGN has recorded no tier 3 GiBs for 2021 and 2022.

Table 2 – Total failure rate and GiB rate, by GDN (all ferrous mains)

Network	Failures/km/year	GiBs/km/year	GiBs/leak/year
Cadent	0.473	0.036	0.076
NGN	0.501	0.014	0.027
SGN	0.736	0.038	0.052
WWU	0.906	0.034	0.037

Table 3 – Total failure rate, by network (all ferrous mains)

Network	Failures/km/year	GiBs/km/year	GiBs/leak/year
Cadent East of England (EE)	0.437	0.032	0.073
Cadent North London (NL)	0.628	0.059	0.094
Cadent North West (NW)	0.433	0.028	0.064
Cadent West Midlands (WM)	0.425	0.030	0.070
NGN	0.501	0.014	0.027
SGN Scotland	0.629	0.016	0.025
SGN Southern	0.772	0.046	0.059
WWU	0.906	0.034	0.037

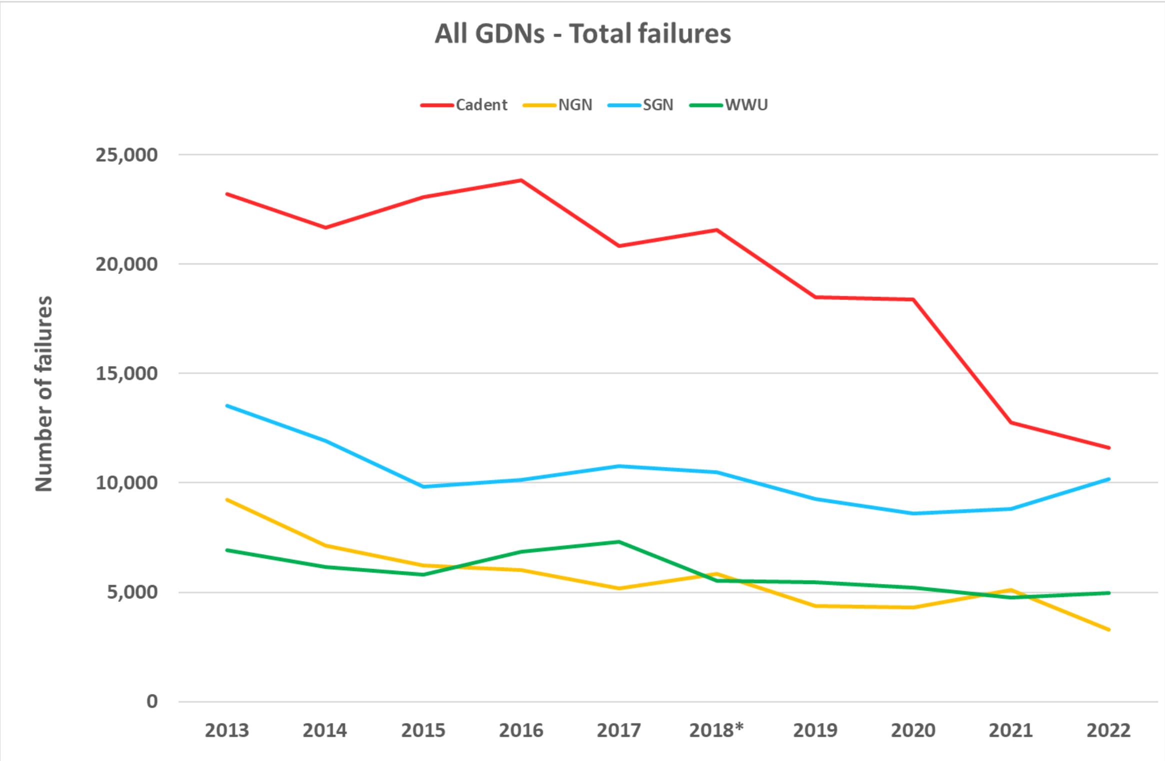

Figure 11 – Total failures, all GDNs

* Data for 2018 includes an average of the two winter periods as the analysis transitioned from calendar year to financial year

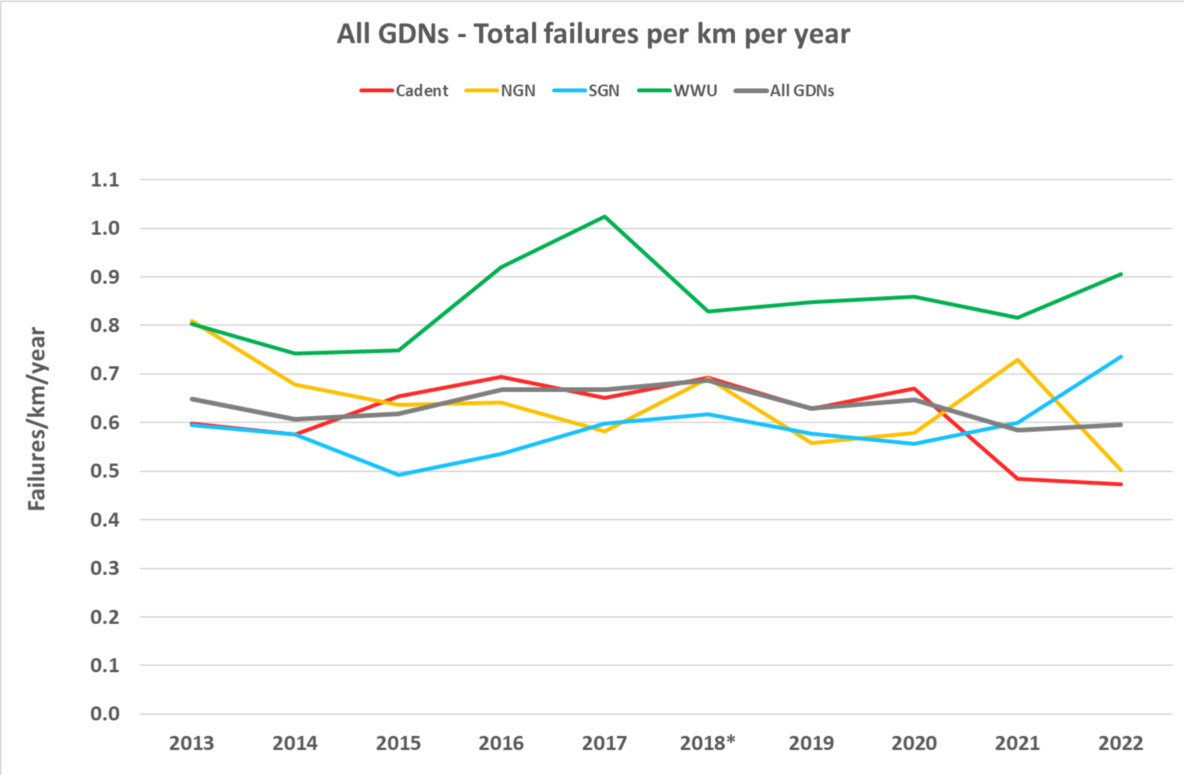

Figure 12 – Total failures per km per year, all GDNs

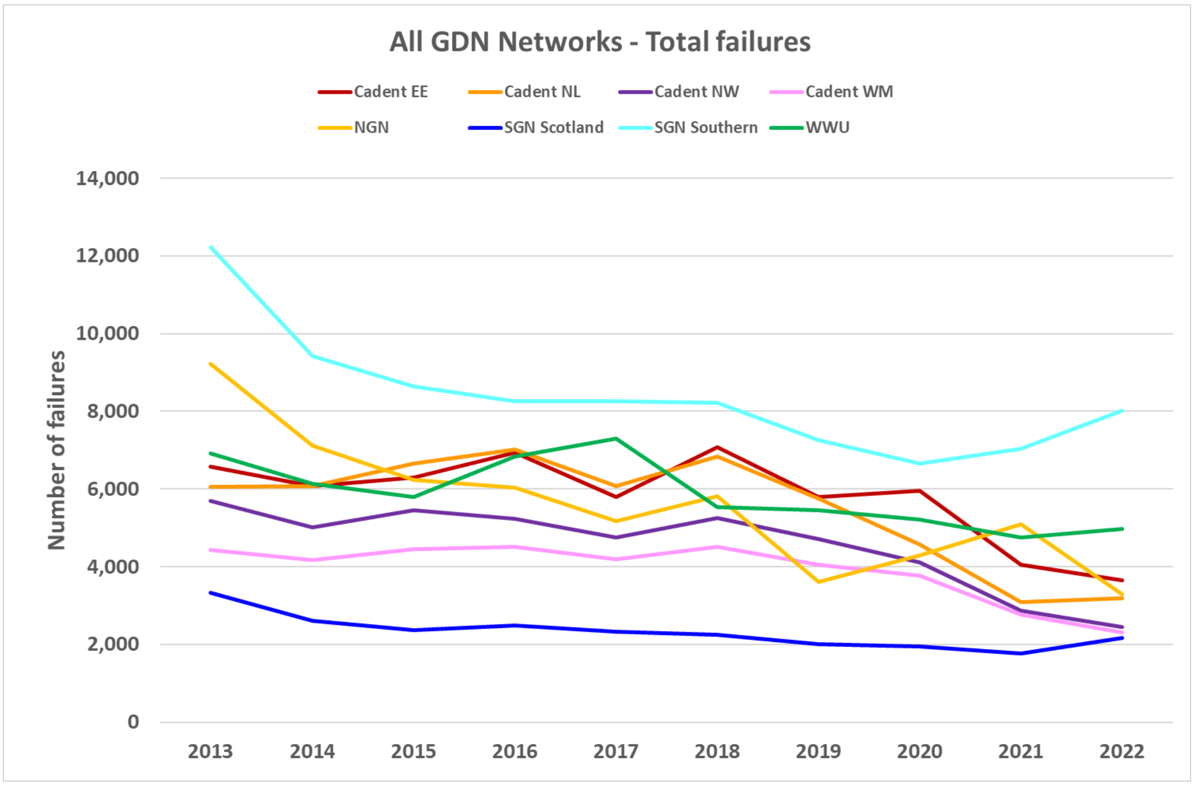

Figure 13 – Total failures, all GDN networks

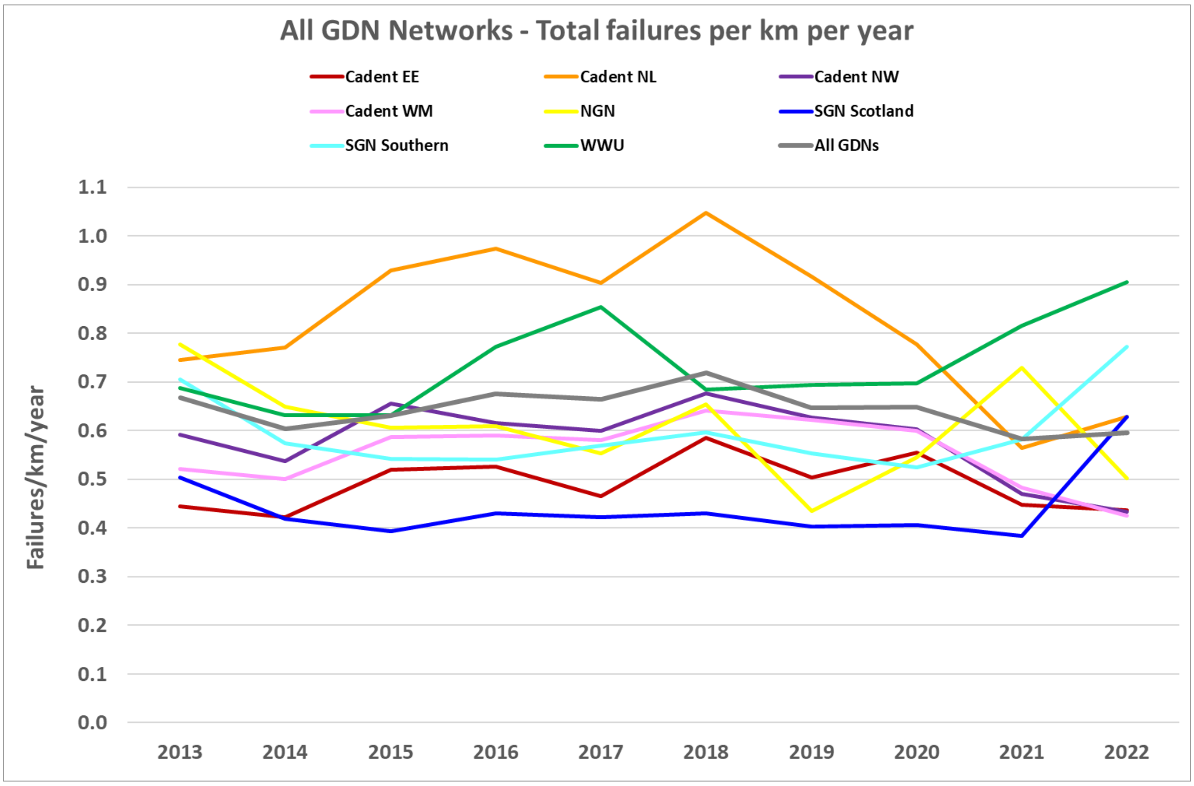

Figure 14 – Total failures per km per year, all GDN networks

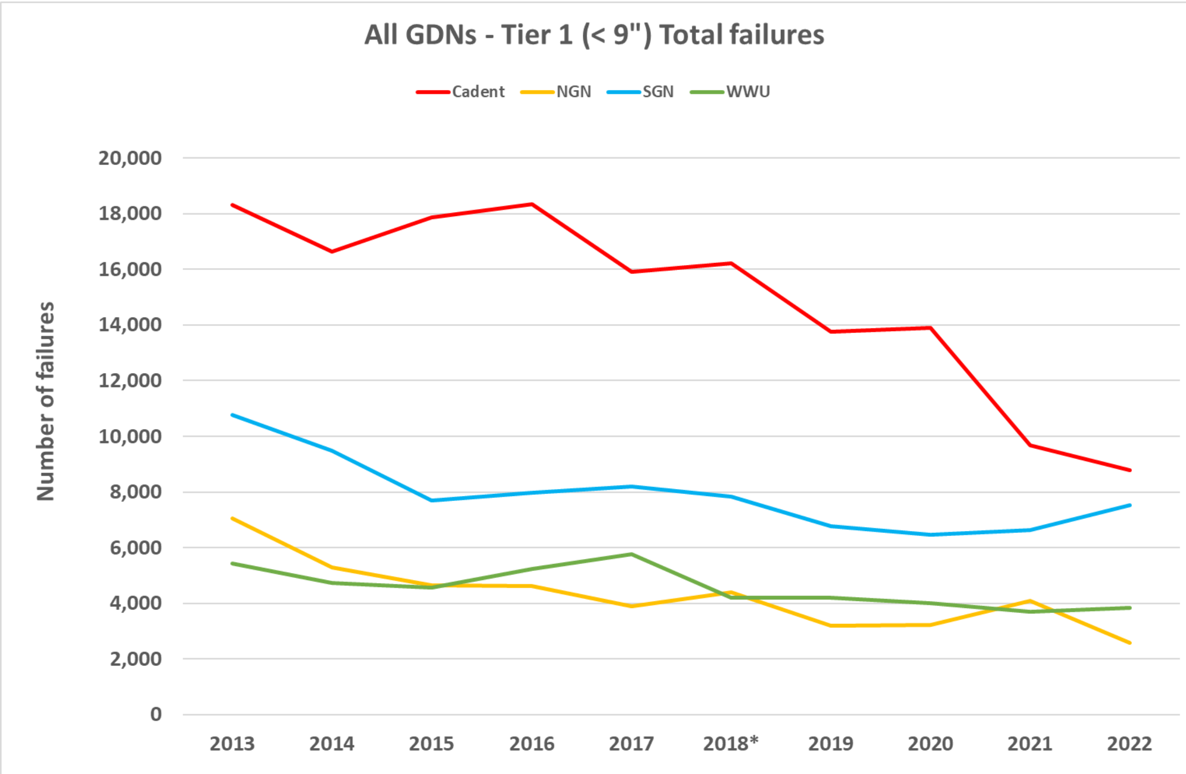

Figure 15 – Total failures, diameter tier 1

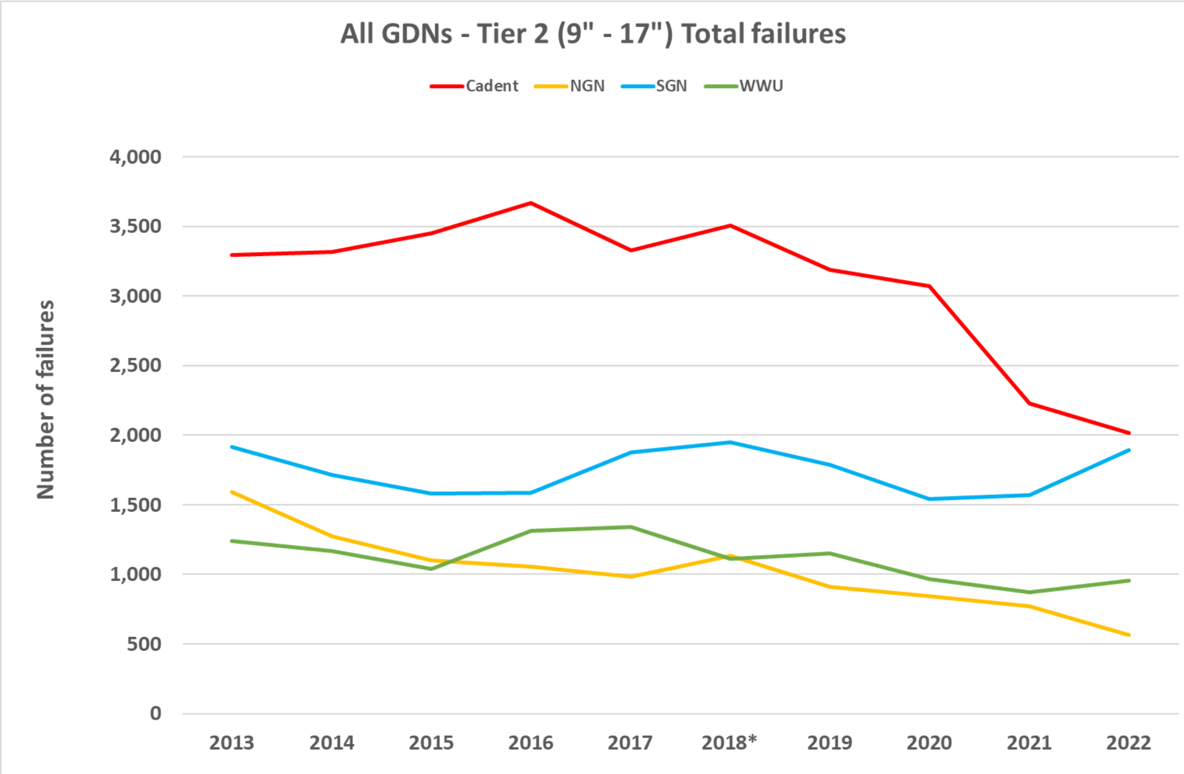

Figure 16 – Total failures, diameter tier 2

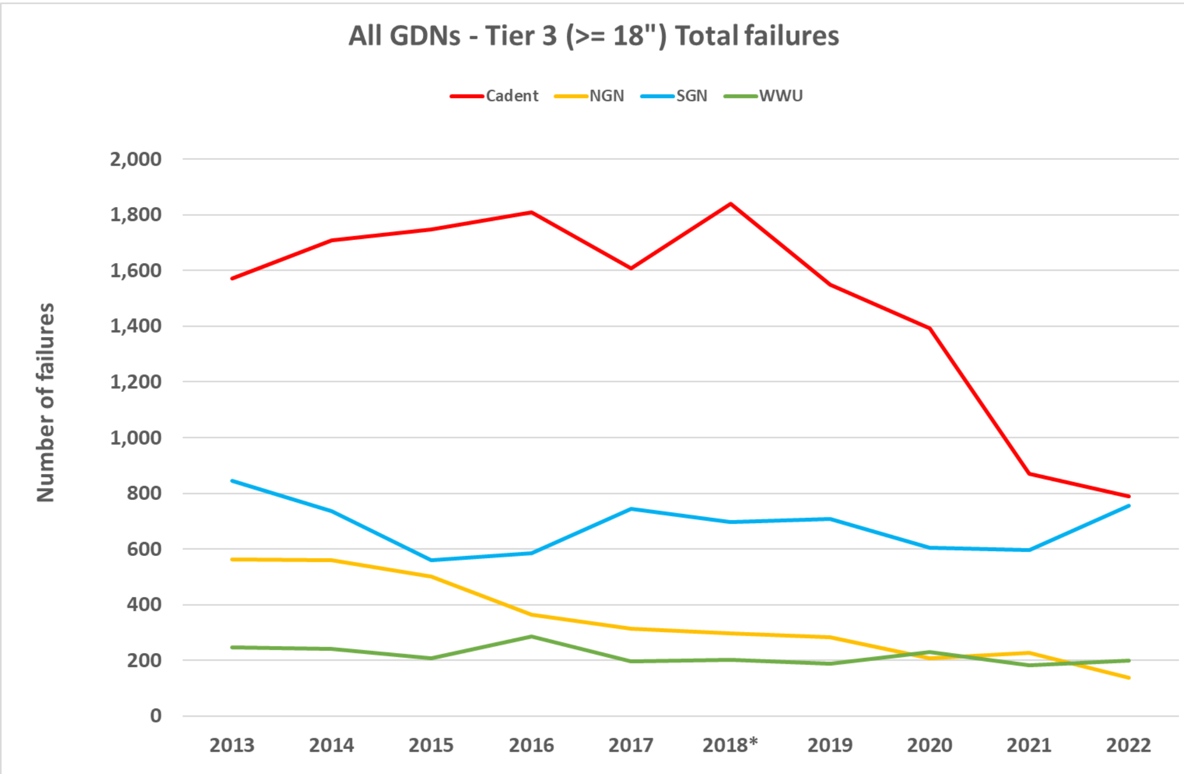

Figure 17 – Total failures, diameter tier 3

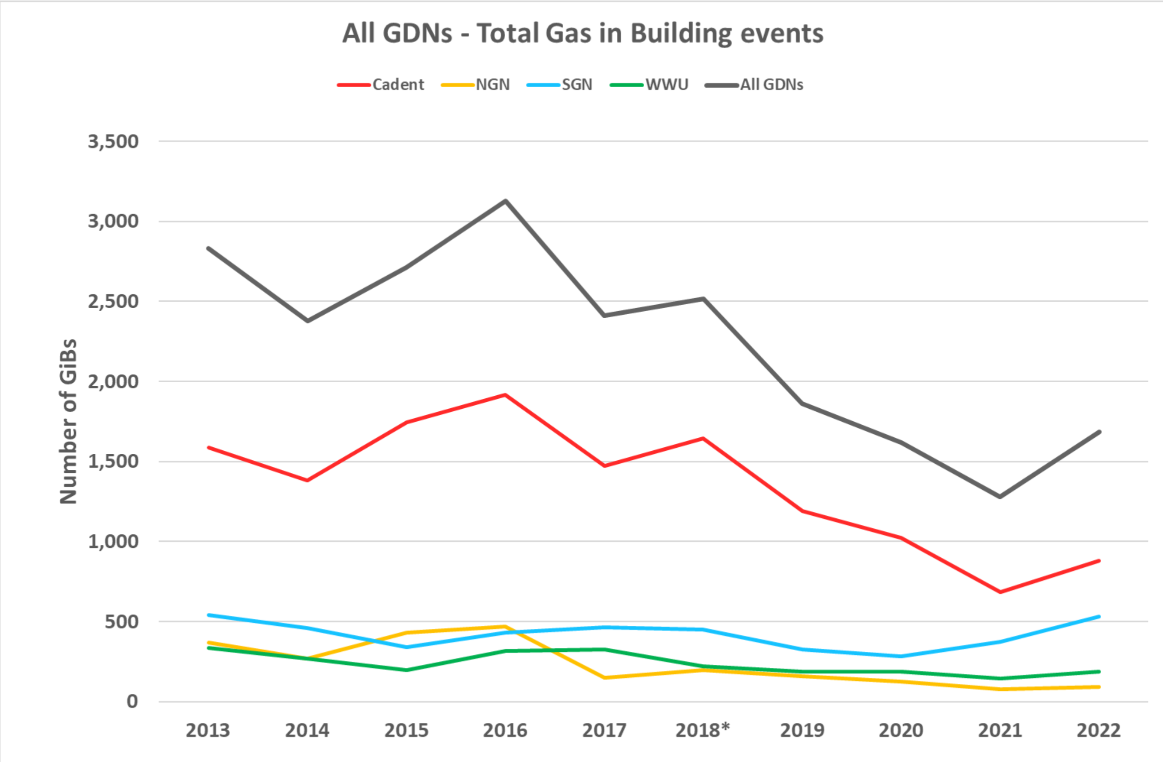

Figure 18 – Total gas in buildings, all GDNs

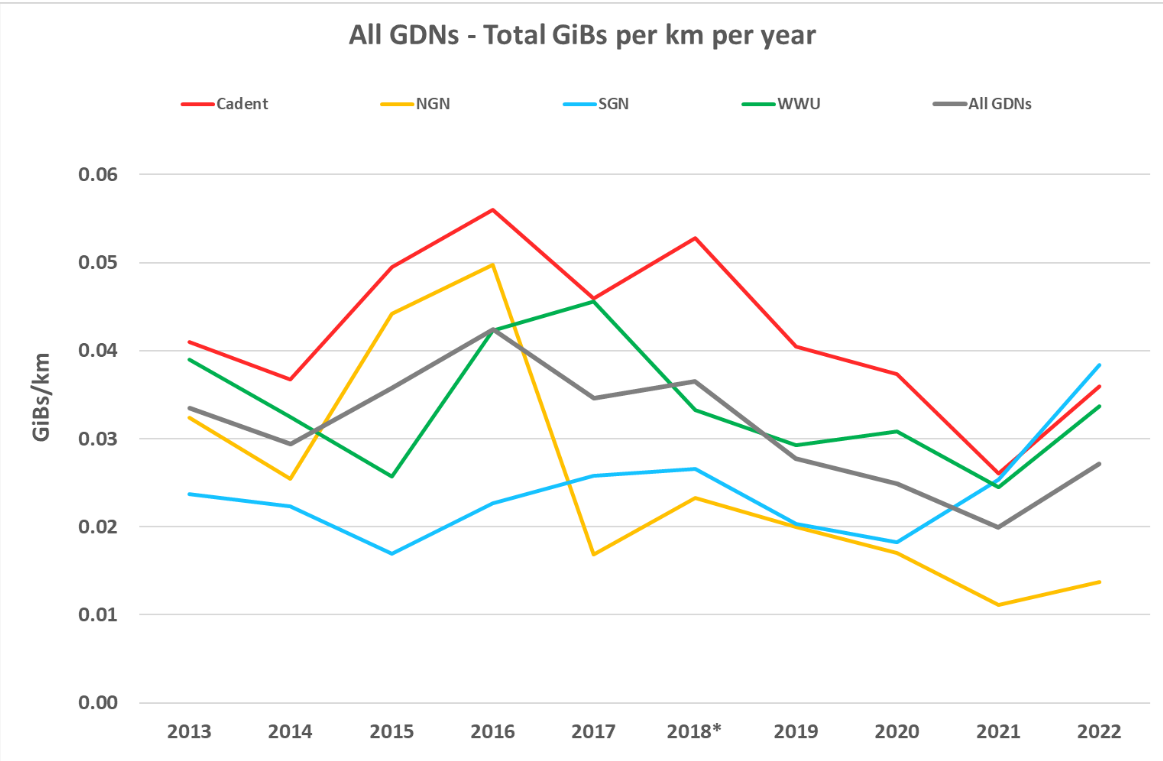

Figure 19 – Total gas in buildings per km per year, all GDNs

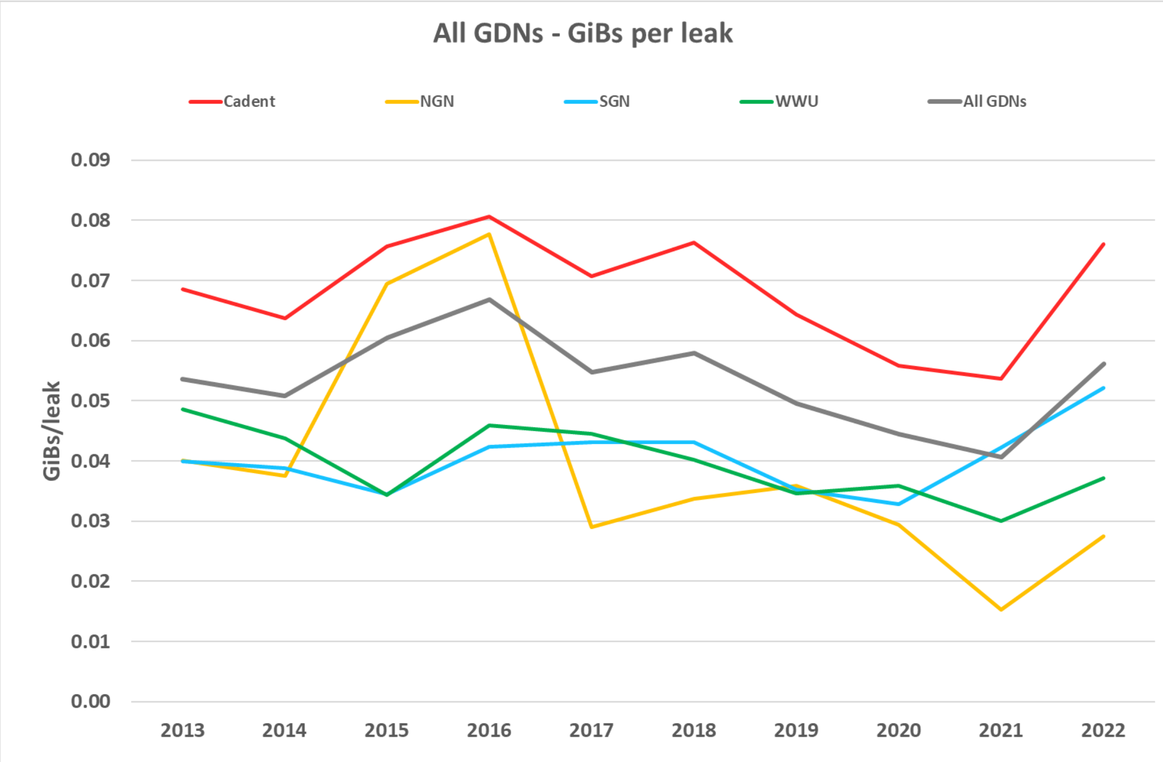

Figure 20 - Gas in buildings per leak, all GDNs

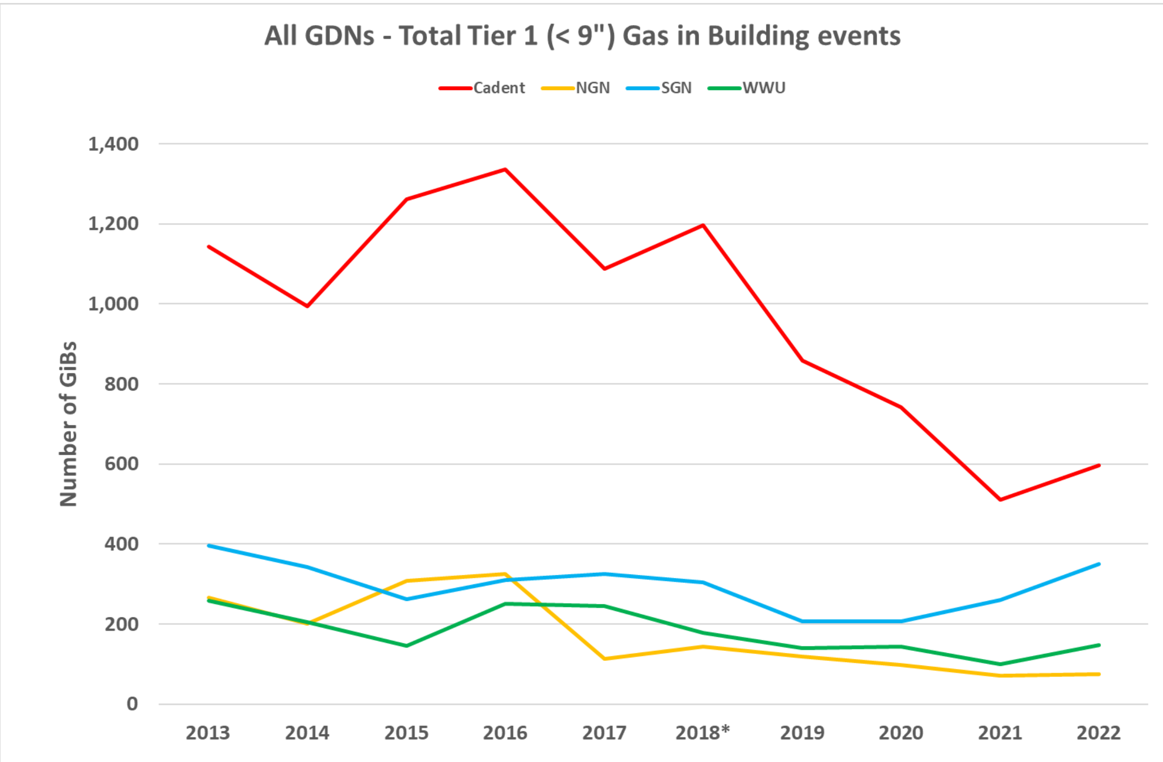

Figure 21 – Total gas in buildings, diameter tier 1

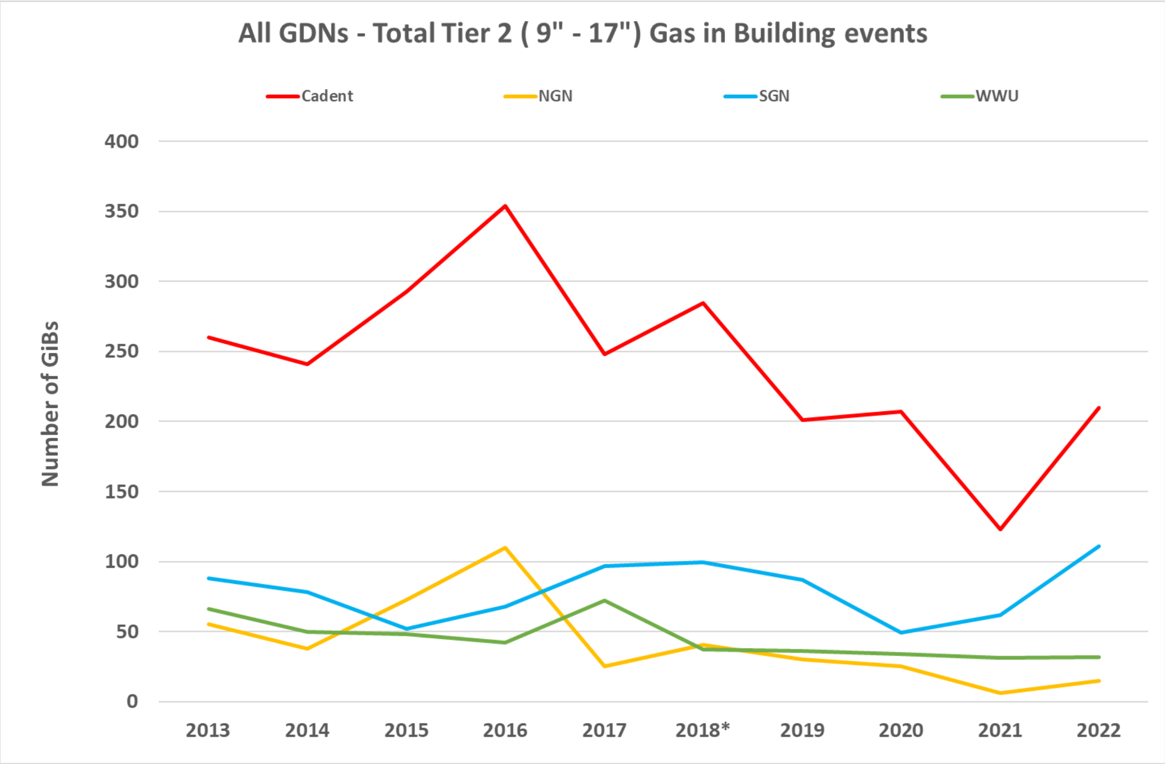

Figure 22 – Total gas in buildings, diameter tier 2

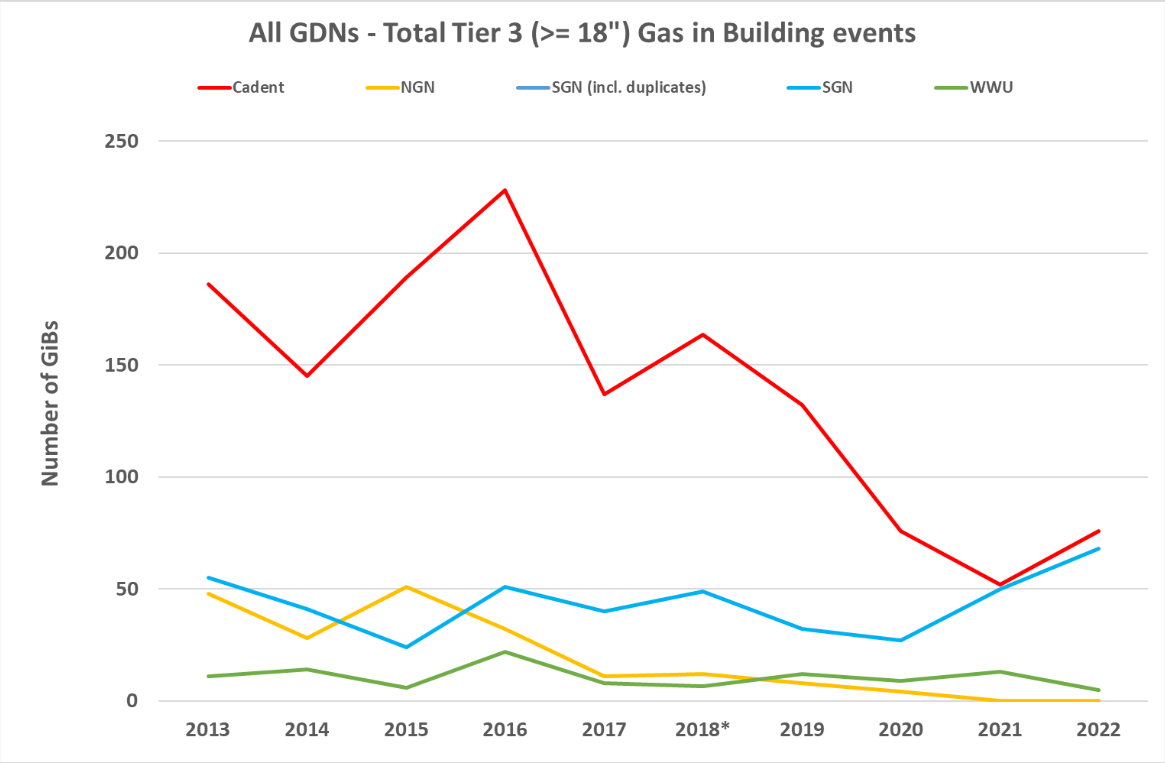

Figure 23 - Gas in buildings per leak per year, diameter tier 3

4.2 Failures and GiBs by material

In this section, total failures and gas in building events by each material are reviewed. Cast and spun iron are combined due to the similarity of the metallurgy and failure modes, and the difficulty in determining the difference in the field. All failures, except interference damage, are included. A summary of fracture and GiB rates is given in Table 5 (Section 6 below).

4.2.1 Cast and spun iron failures and GiBs

Cast and spun iron failures per km are shown in Figure 24, and the number of failures by diameter tier are shown in Figure 25 to Figure 27. The failure rate for cast and spun iron pipes has seen an increase for SGN and WWU, whilst for NGN there has been a decrease to match Cadent's failure rate. WWU's failure rate remains very high when compared to the other GDNs. When considered by diameter tier, the rate of decrease of cast and spun iron tier 1 failures appears consistent for Cadent and NGN, whilst WWU numbers of failures remain consistent with recent years. For tier 2 failures, Cadent and NGN remain consistent with trends observed for tier 1 failures, and WWU has a slight increase to levels seen in 2020. SGN has seen an increase in cast and spun iron failures across all diameter tiers.

Cast and spun iron GiBs are shown in Figure 28. The GiB rate from cast and spun iron failures has increased for Cadent, NGN and SGN, while it has remained relatively constant for the past four years for WWU. Cadent's GiB per leak rate has increased to match the peak in 2016, whilst the GiB rate for SGN has increased to the highest level since the start of this analysis in 2013. For NGN, the increase in GiB rate follows a dip in 2021. These trends are seen across all diameter tiers, however the largest rate of increase in cast and spun iron GiBs for Cadent and SGN is seen in tier 2 pipes.

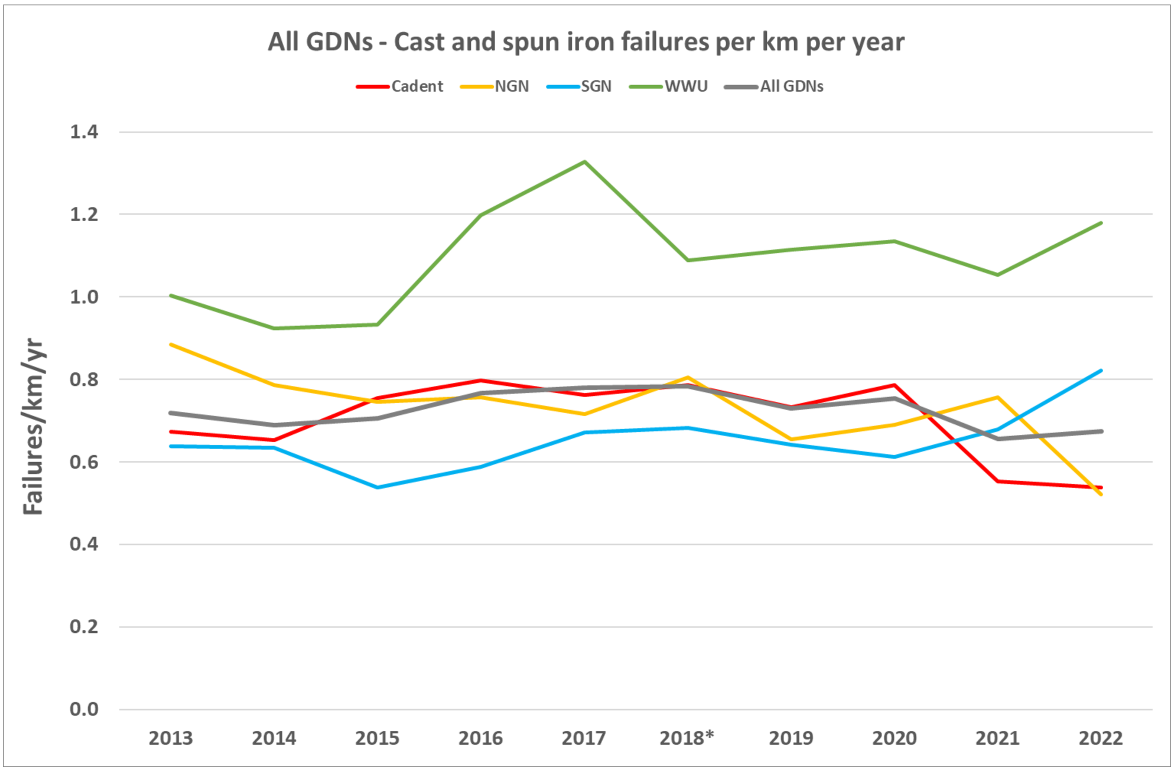

Figure 24 – Cast and spun iron failures per km per year, all GDNs

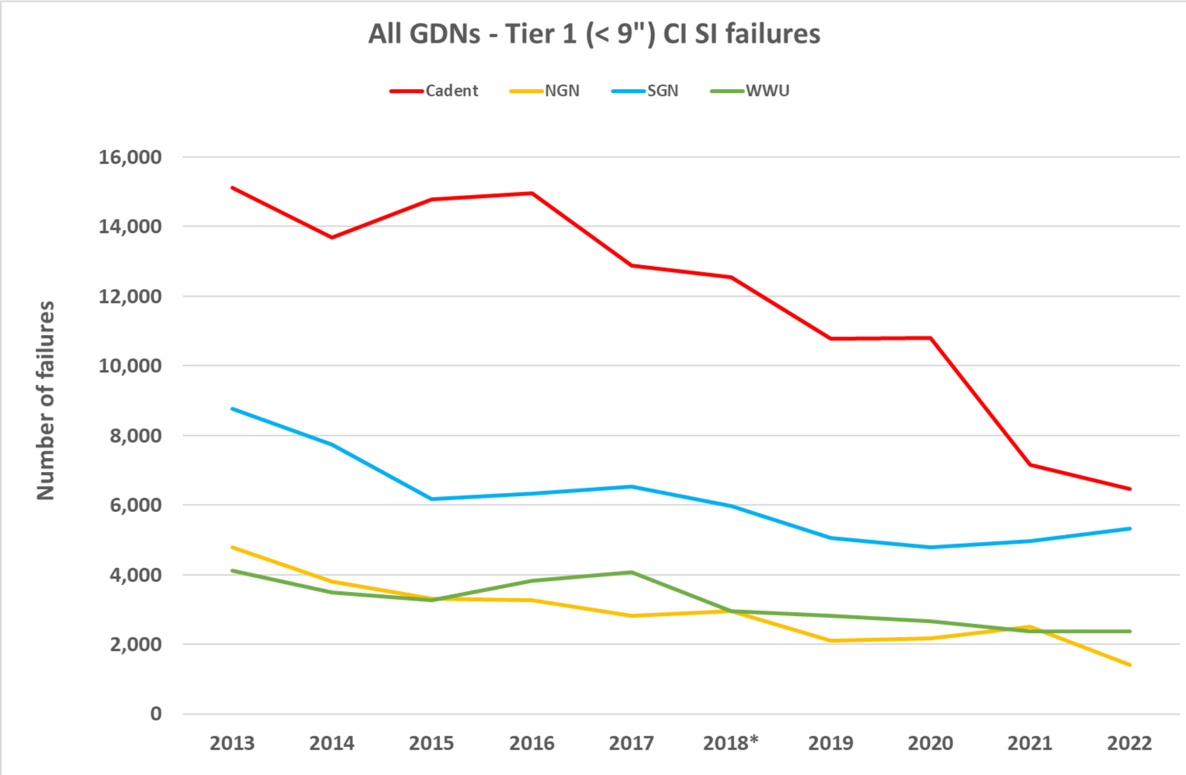

Figure 25 – Cast and spun iron failures, diameter tier 1

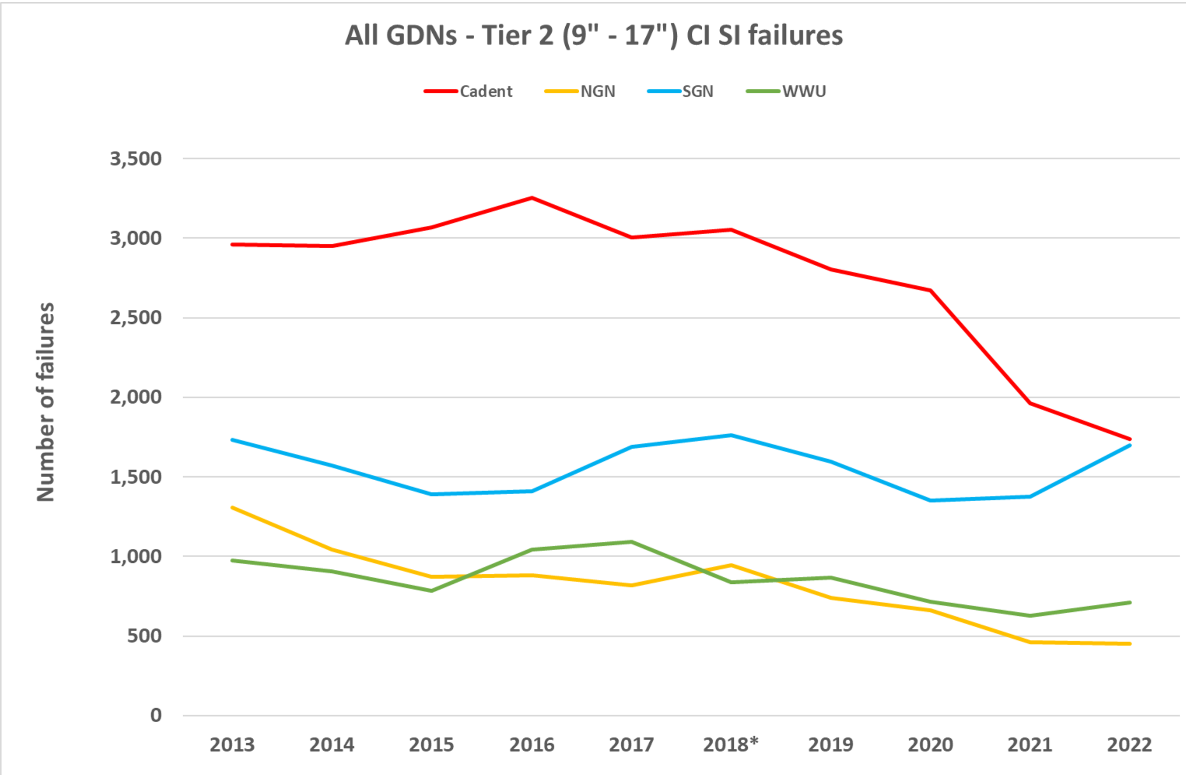

Figure 26 – Cast and spun iron failures, diameter tier 2

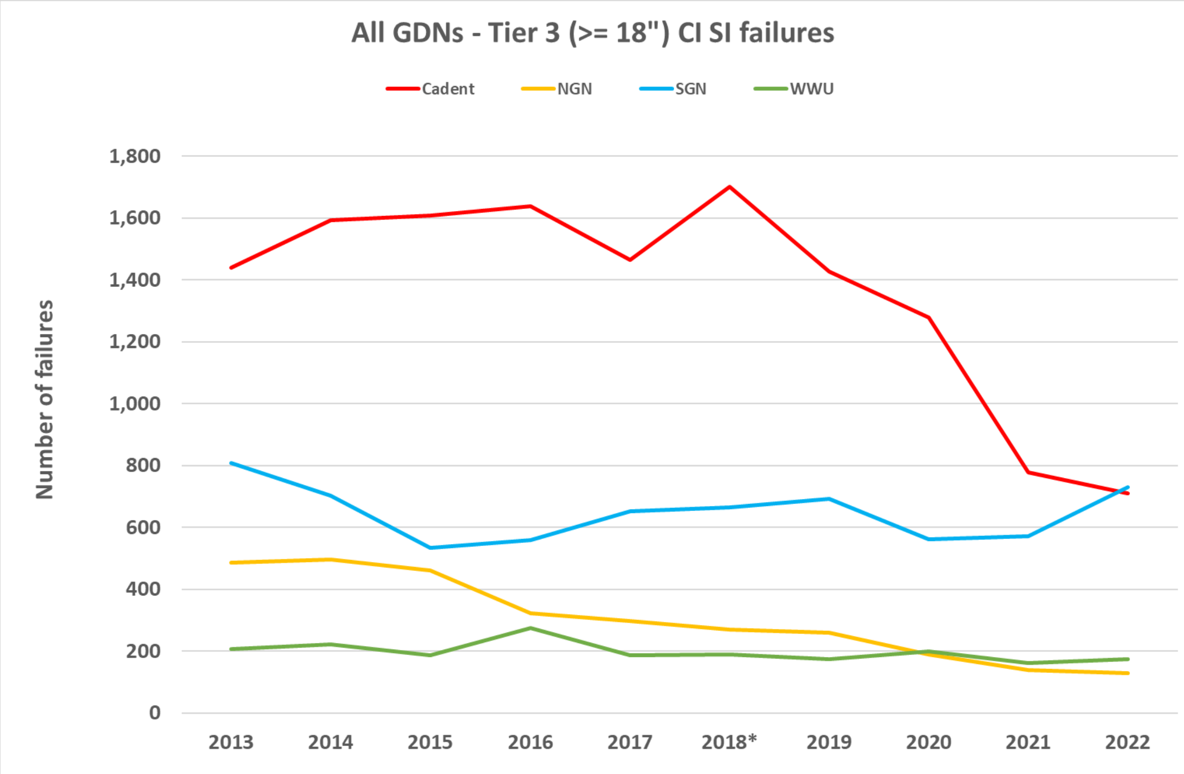

Figure 27 – Cast and spun iron failures, diameter tier 3

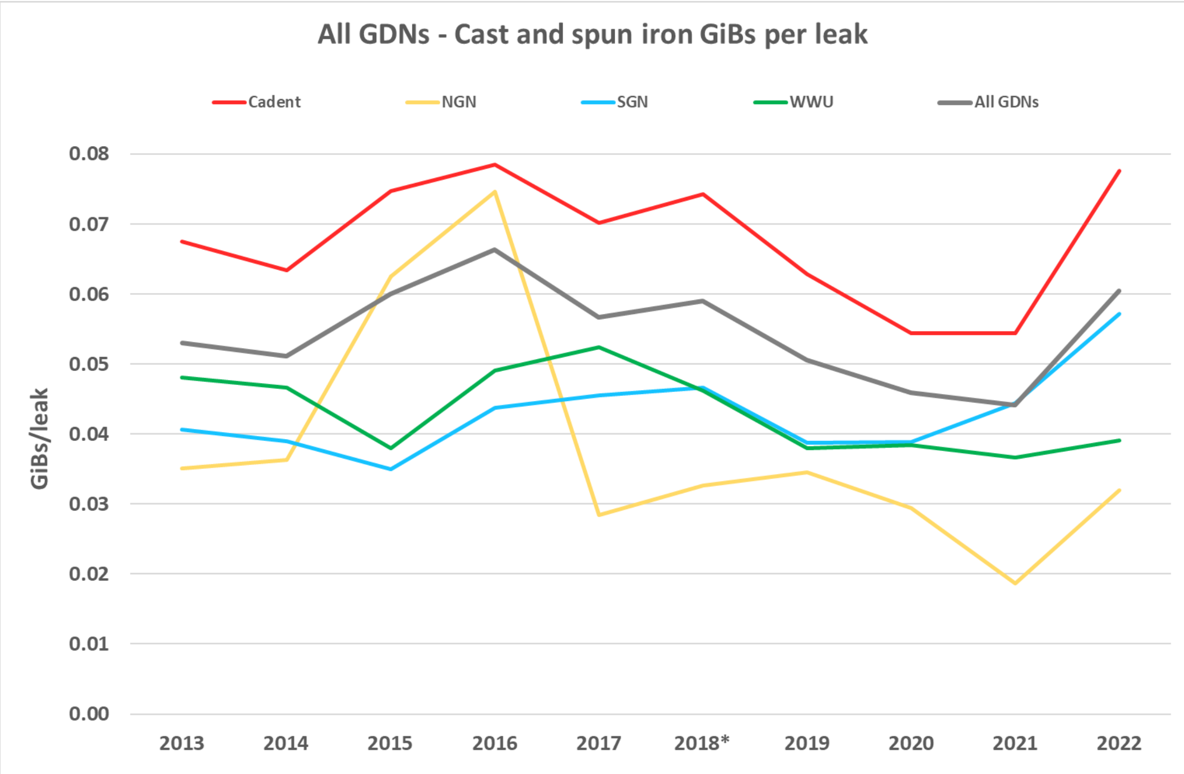

Figure 28 – Cast and spun iron gas in buildings per leak, all GDNs

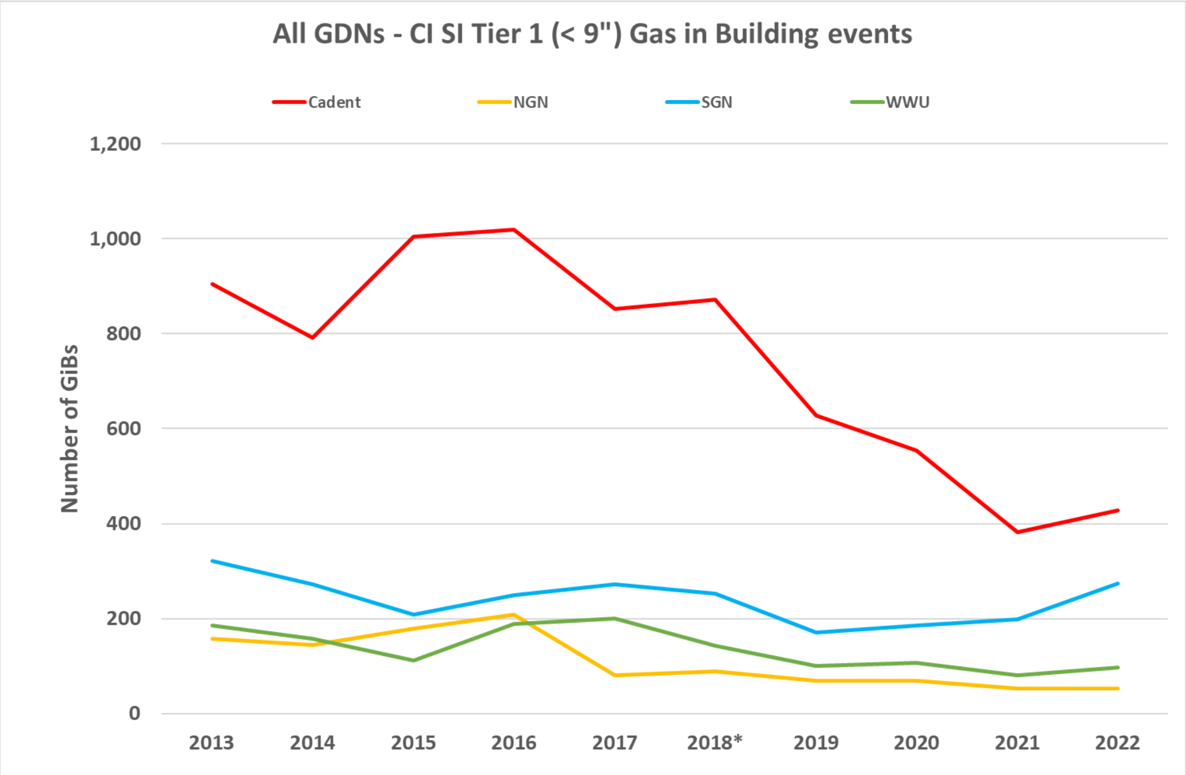

Figure 29 – Cast and spun iron gas in buildings, diameter tier 1

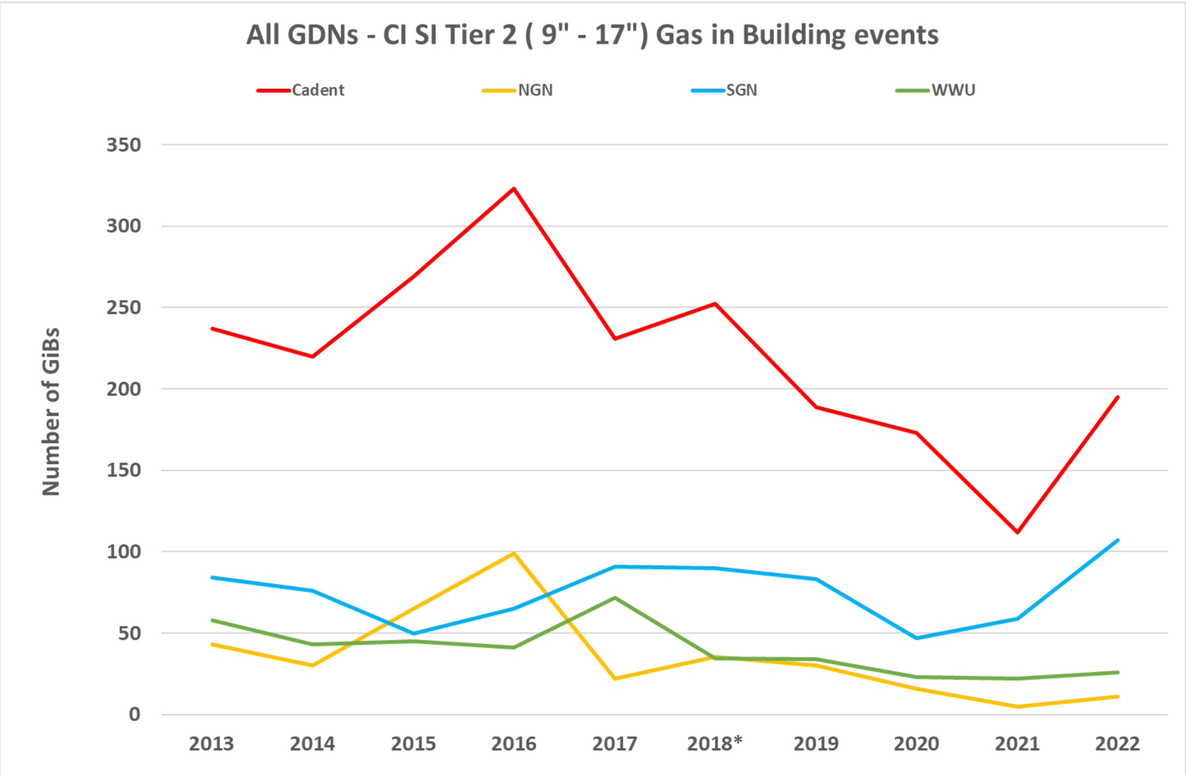

Figure 30 – Cast and spun iron gas in buildings, diameter tier 2

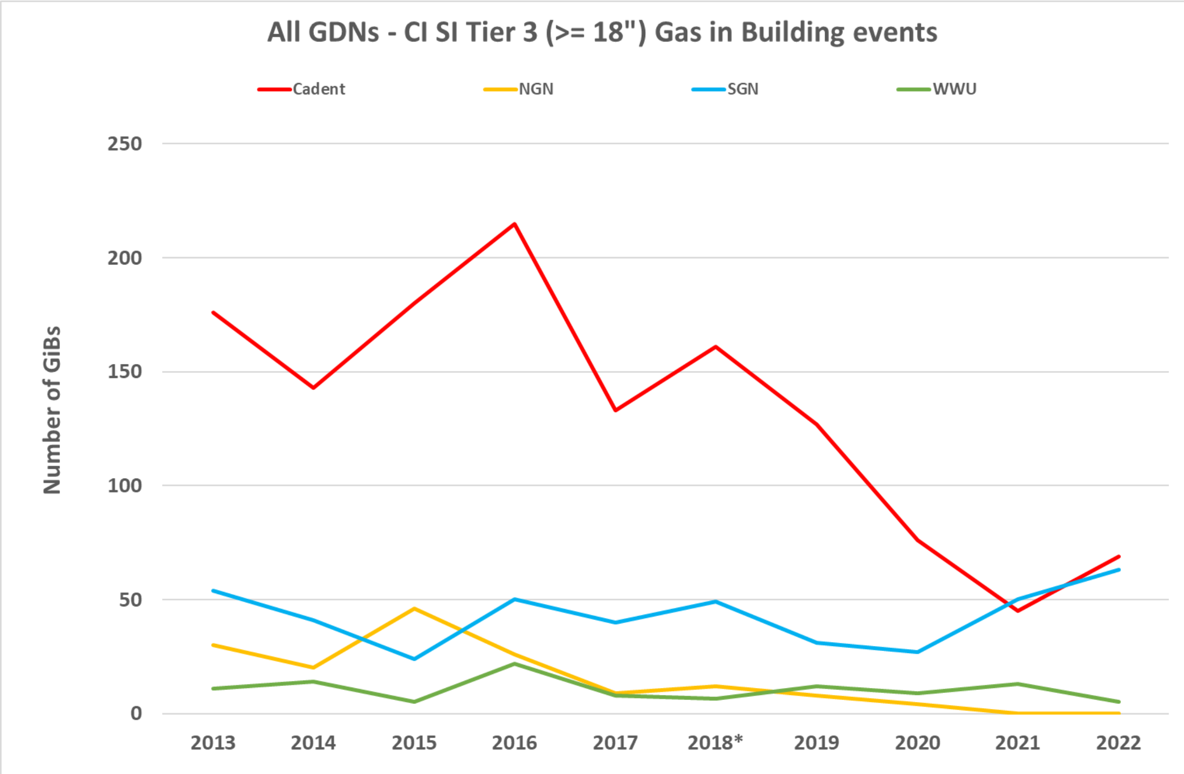

Figure 31 – Cast and spun iron gas in buildings, diameter tier 3

4.2.2 Ductile iron failures and GiBs

Ductile iron failures per km are shown in Figure 32, with the number of failures by tier presented in Figure 33 to Figure 35. In 2022, failure rates have shown an increase for WWU and SGN, and a decrease for NGN, with Cadent remaining consistent with recent years. For WWU and SGN, this increase appears to be driven by an increase in tier 1 ductile iron mains failures. NGN saw a peak in failures in 2021, particularly for larger diameter pipes; it is believed that this is due to proactive internal joint sealing being undertaken and recorded in the failure data so may not be a true indication of pipe deterioration. The rate of failure for ductile iron mains for NGN is higher in 2022 than in 2020 which suggests the continuation of an increasing trend. For Cadent, the number of tier 1 failures has decreased, the number of tier 2 failures has increased, and tier 3 failures have remained consistent. The failure rate for WWU remains significantly higher than the other GDNs. Overall, the ductile iron failure rate is approximately 60% that of the cast and spun iron failure rate.

Ductile iron GiBs per leak are shown in Figure 36, with the number of GiBs by diameter tier presented in Figure 37 to Figure 39. The ductile iron GiB rate has risen for all GDNs, however they are all within historic levels with SGN equalling their 2017 peak. Cadent has the highest rate of GiBs per ductile iron failure, whilst NGN has the lowest at around 30% that of Cadent. NGN and WWU continued the trend of not reporting a GiB from a failure of a tier 3 ductile iron main since 2014 and 2015 respectively, whilst SGN recorded an increase and Cadent reported a decrease. SGN recorded their highest number of GiBs from tier 3 ductile iron failures in 2022, however this is comparable to some historic levels from other GDNs. Numbers of GiBs from tier 2 ductile iron failures see an increase for WWU, NGN and SGN, whilst Cadent remain consistent. The increase from NGN remains comparable to historic levels and the high variance is due to the low number of tier 2 / tier 3 ductile iron GiBs observed.

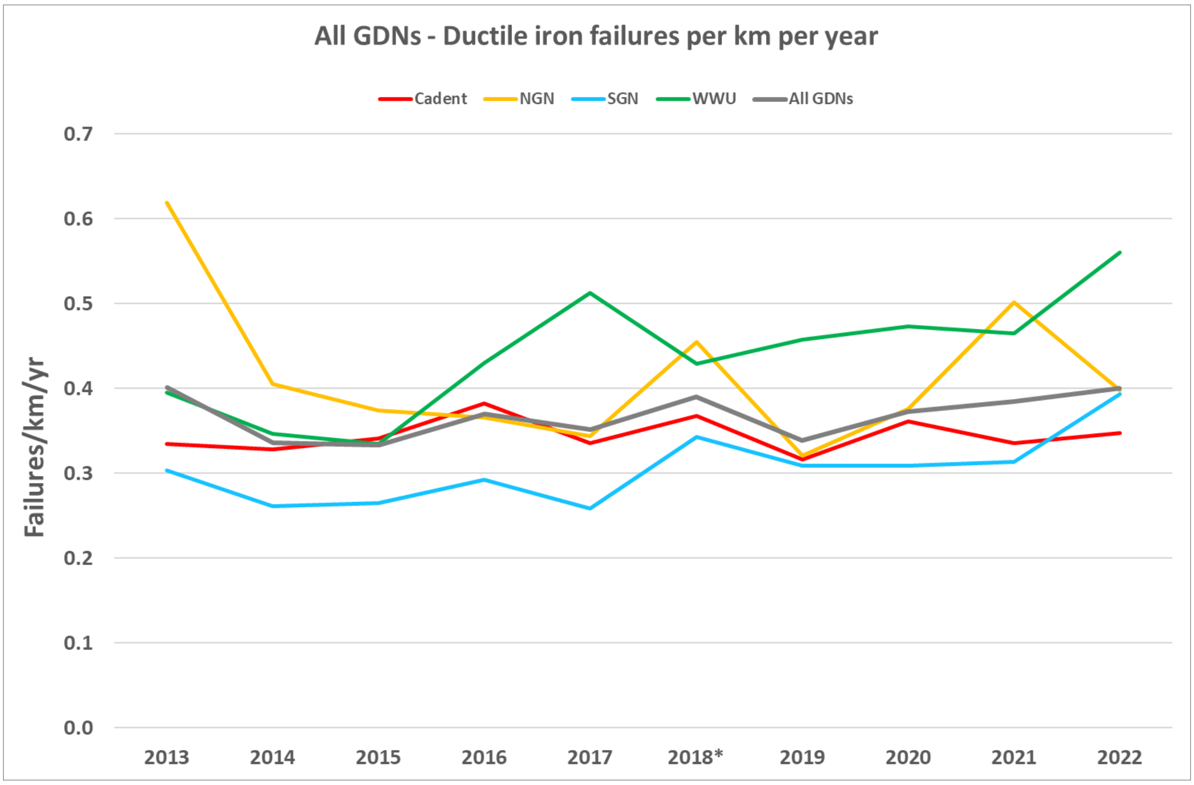

Figure 32 – Ductile iron failures per km per year, all GDNs

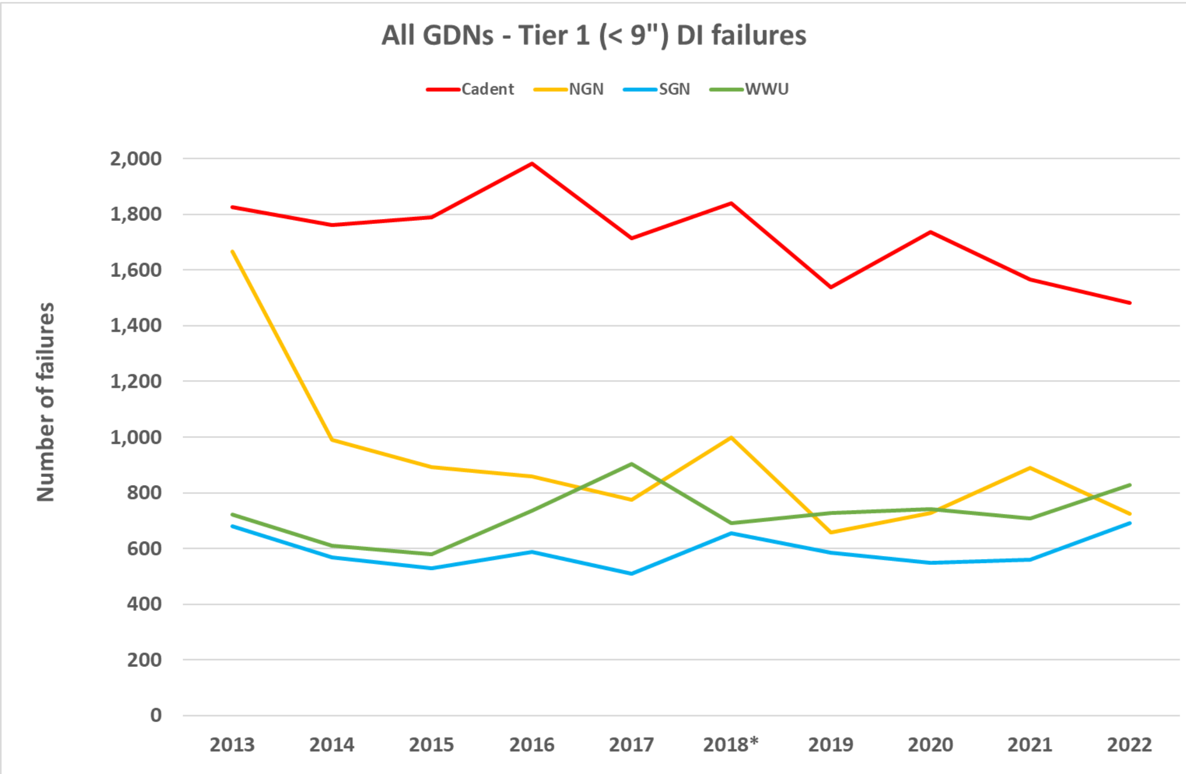

Figure 33 – Ductile iron failures, diameter tier 1

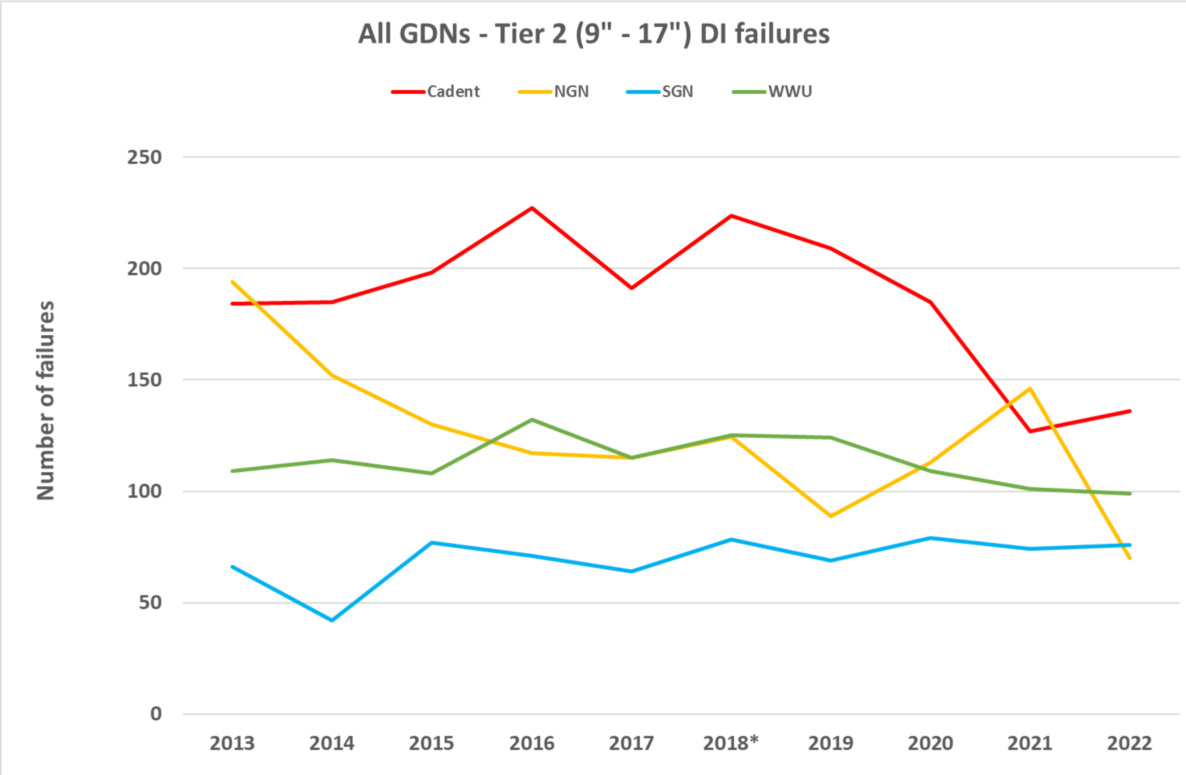

Figure 34 – Ductile iron failures, diameter tier 2

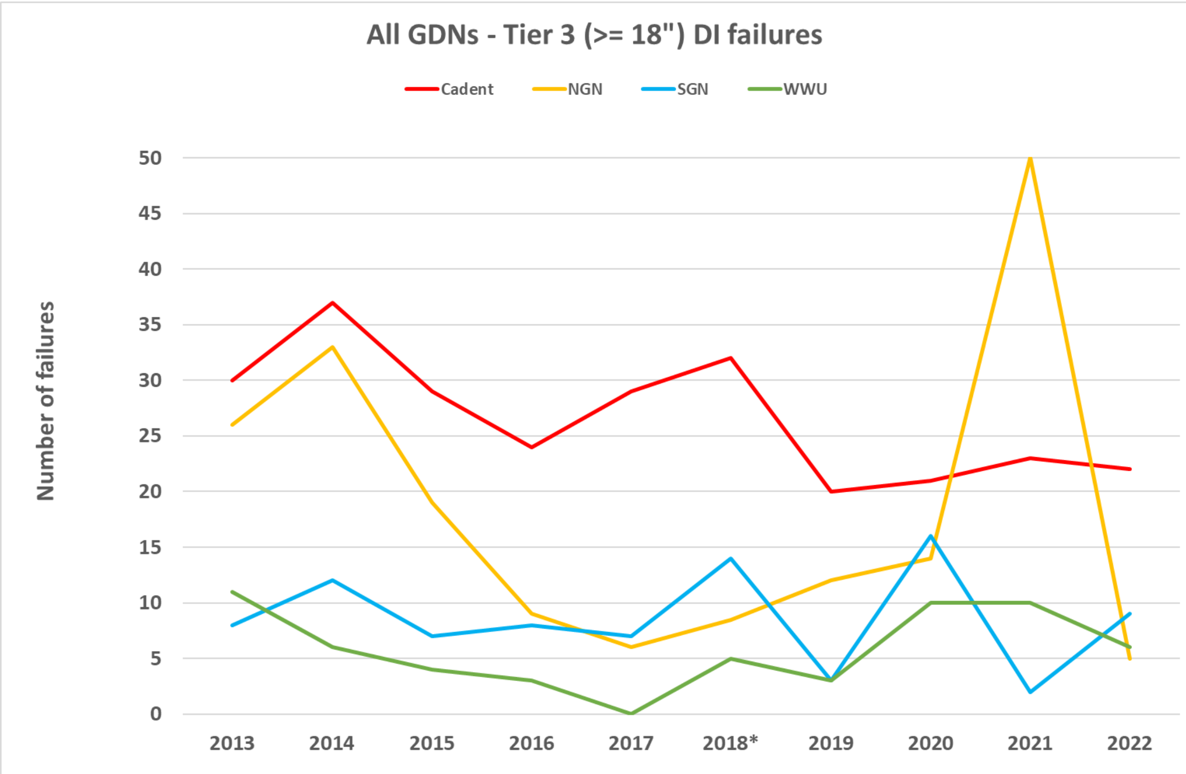

Figure 35 – Ductile iron failures, diameter tier 3

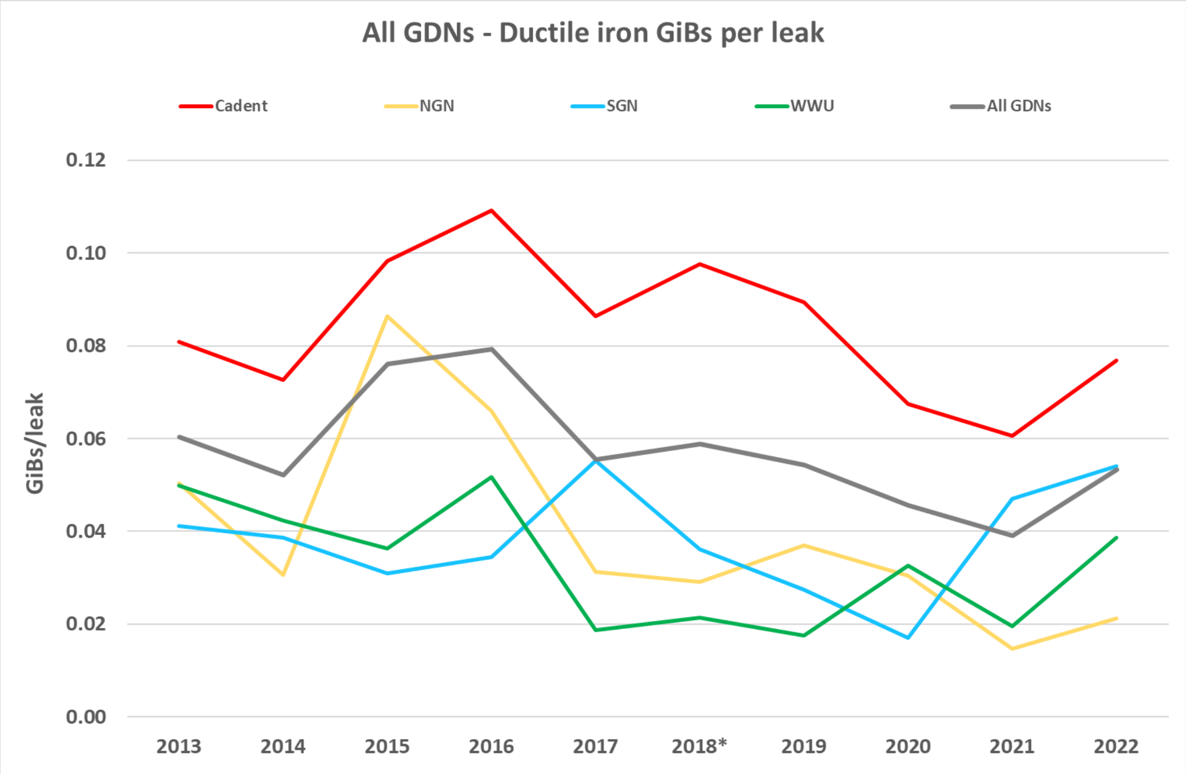

Figure 36 – Ductile iron gas in buildings per leak, all GDNs

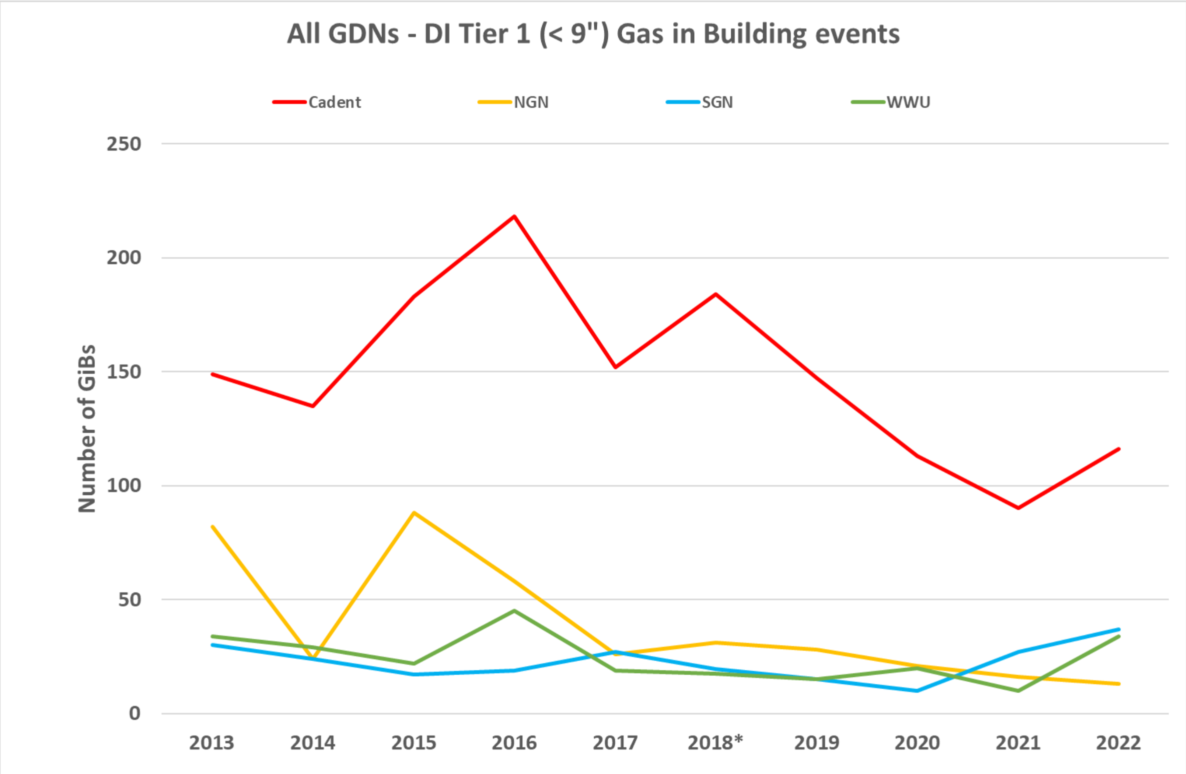

Figure 37 – Ductile iron gas in buildings, diameter tier 1

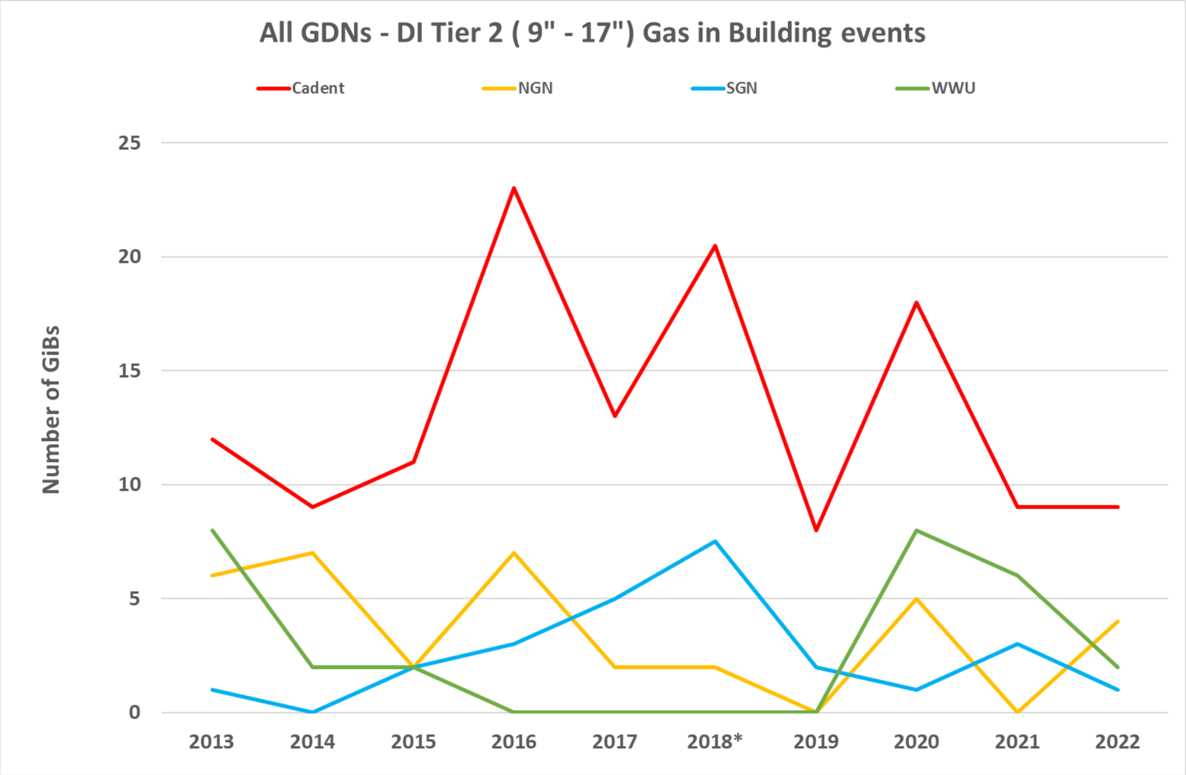

Figure 38 – Ductile iron gas in buildings, diameter tier 2

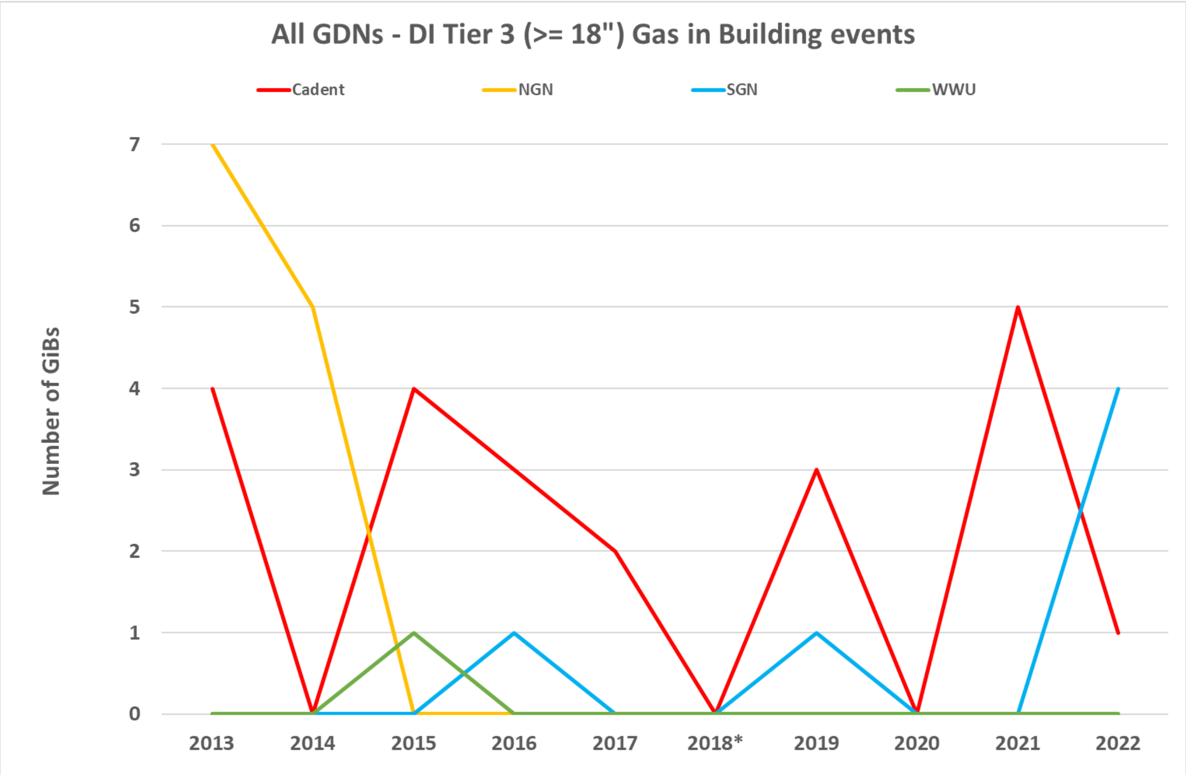

Figure 39 – Ductile iron gas in buildings, diameter tier 3

4.2.3 Steel failures and GiBs

Steel failures per km are shown in Figure 40, and the number of steel failures by diameter tier are presented in Figure 41 to Figure 43. The failure rate for steel mains has slightly decreased for Cadent and NGN, increased for SGN and remains consistent for WWU across all diameter tiers. It appears that the overall increase in steel failure rate for SGN is due to a 36% increase in tier 1 failures, whilst Cadent's decreasing trend is observed for tier 1 and tier 3 steel mains. It should be noted that NGN saw a peak in steel mains failures in 2021 across all tiers, some of which may be attributed to proactive joint sealing. The 2022 steel failure rate for Cadent less than half that of the other three GDNs. Overall, the steel failure rate is approximately 80% that of the cast and spun iron failure rate.

Steel GiBs per leak are shown in Figure 44, and the number of steel GiBs by diameter tier are presented in Figure 45 to Figure 47. The GiB rate has increased for Cadent, WWU and NGN, and has remained level for SGN. All GDNs recorded an increase in the number of GiBs from tier 1 steel failures, whilst only NGN saw a decrease in GiBs for tier 2 mains. Despite numbers of GiBs increasing across all diameter tiers for SGN, the consistent GiBs per leak rate shows that it is the increase in failures that is driving this. The GiB per leak rate for steel is approximately 60% that of the other ferrous mains.

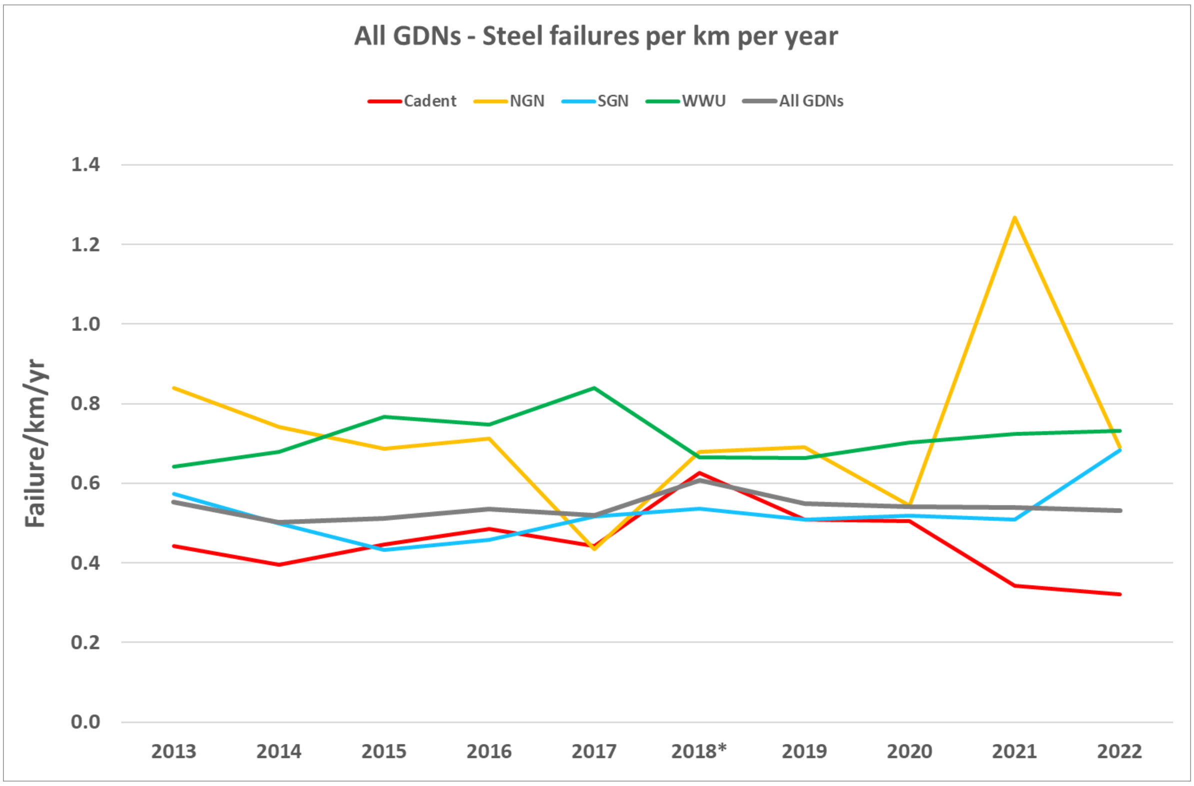

Figure 40 – Steel failures per km per year, all GDNs

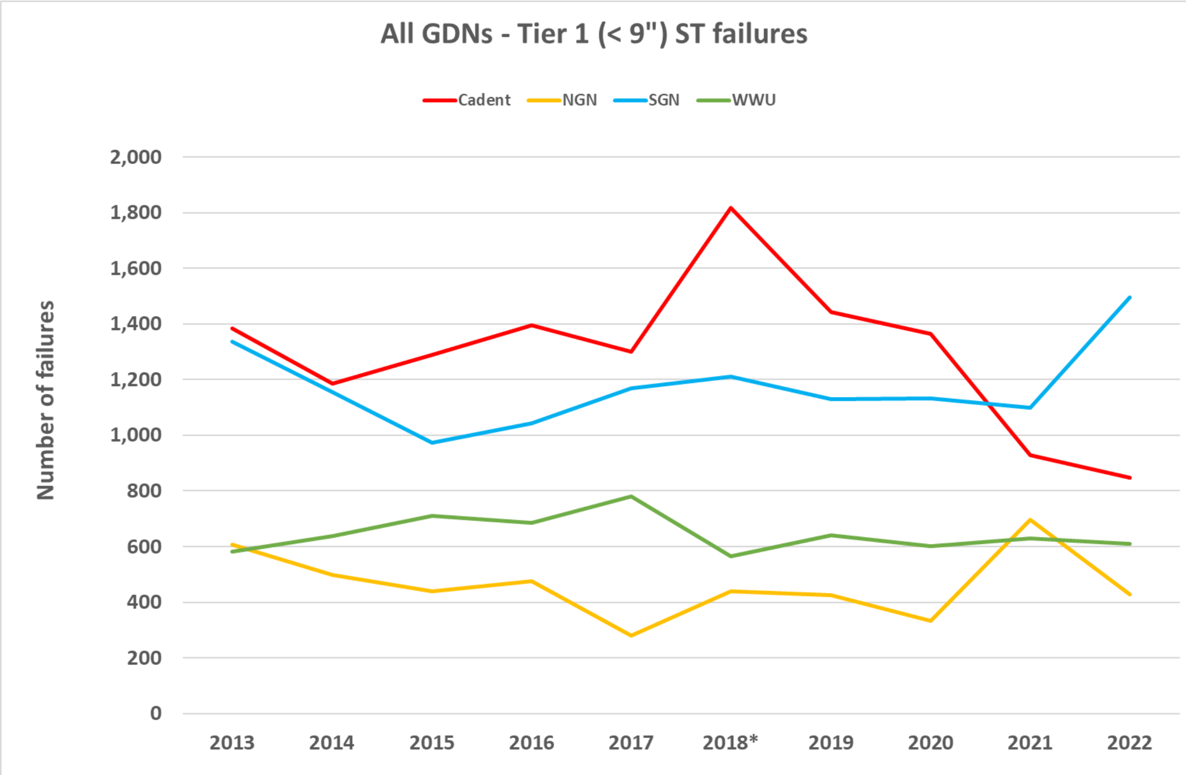

Figure 41 – Steel failures, diameter tier 1

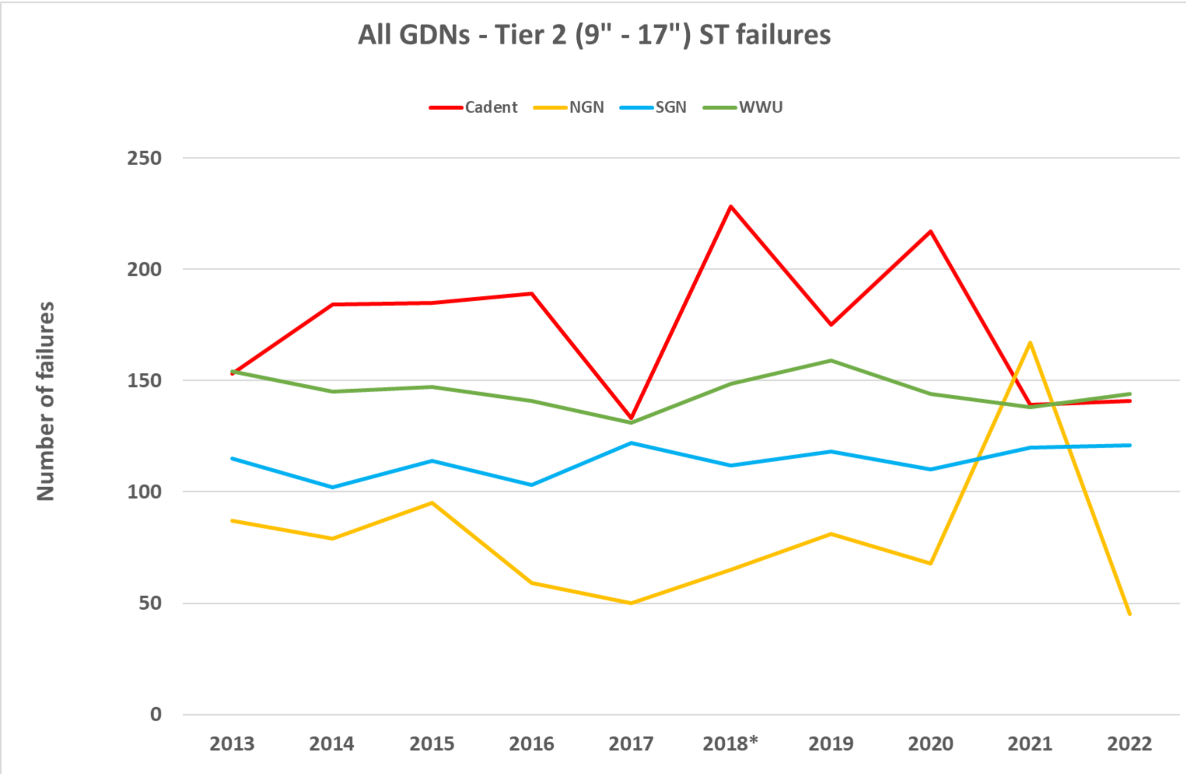

Figure 42 – Steel failures, diameter tier 2

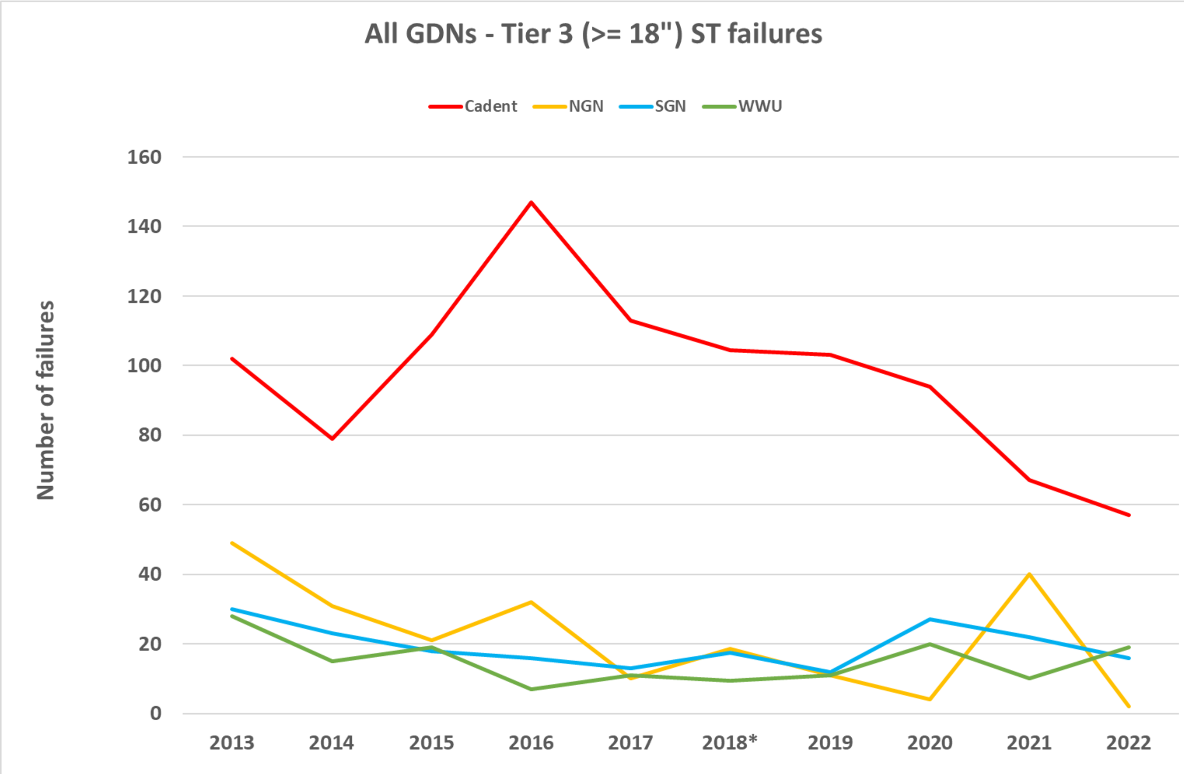

Figure 43 – Steel failures, diameter tier 3

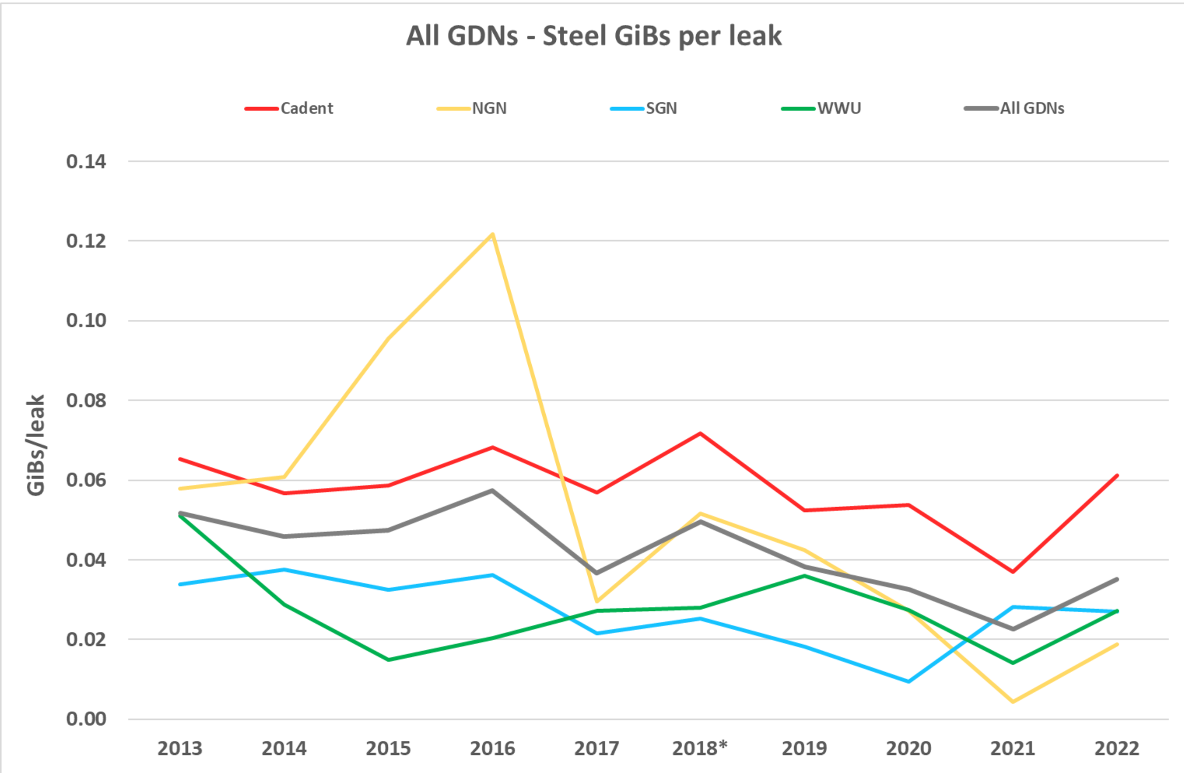

Figure 44 – Steel gas in buildings per leak, all GDNs

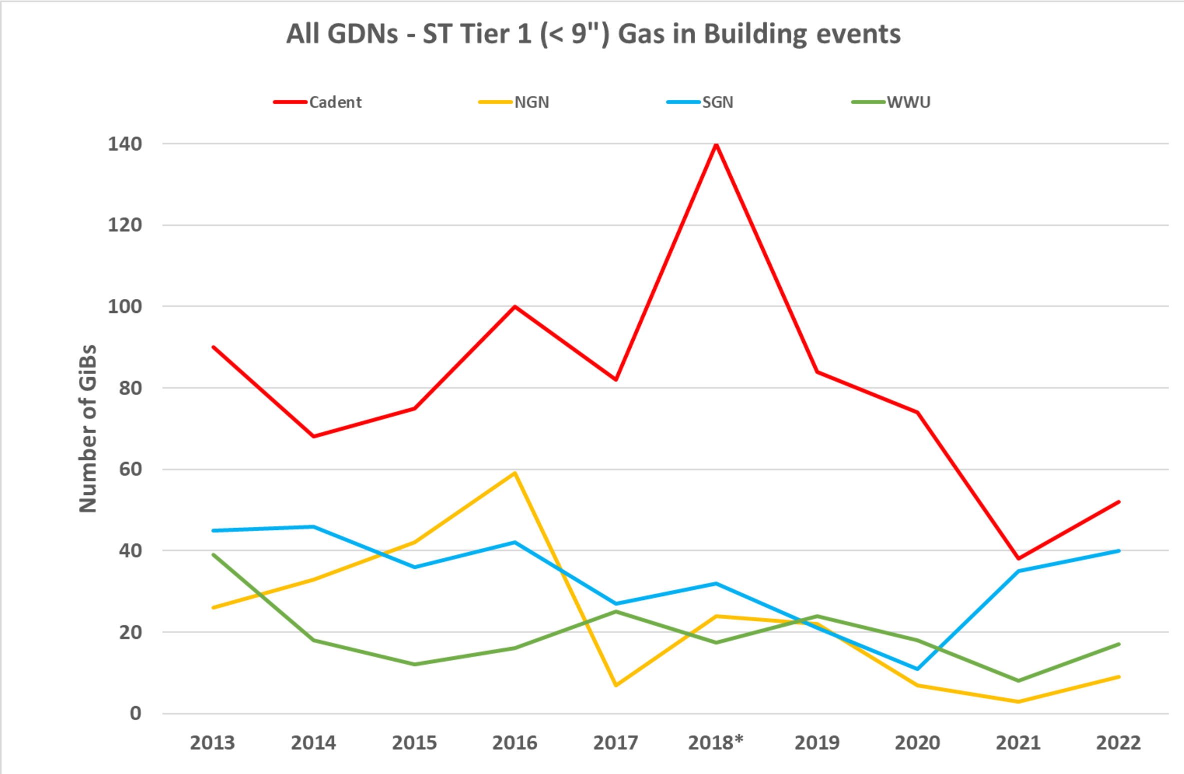

Figure 45 – Steel gas in buildings, diameter tier 1

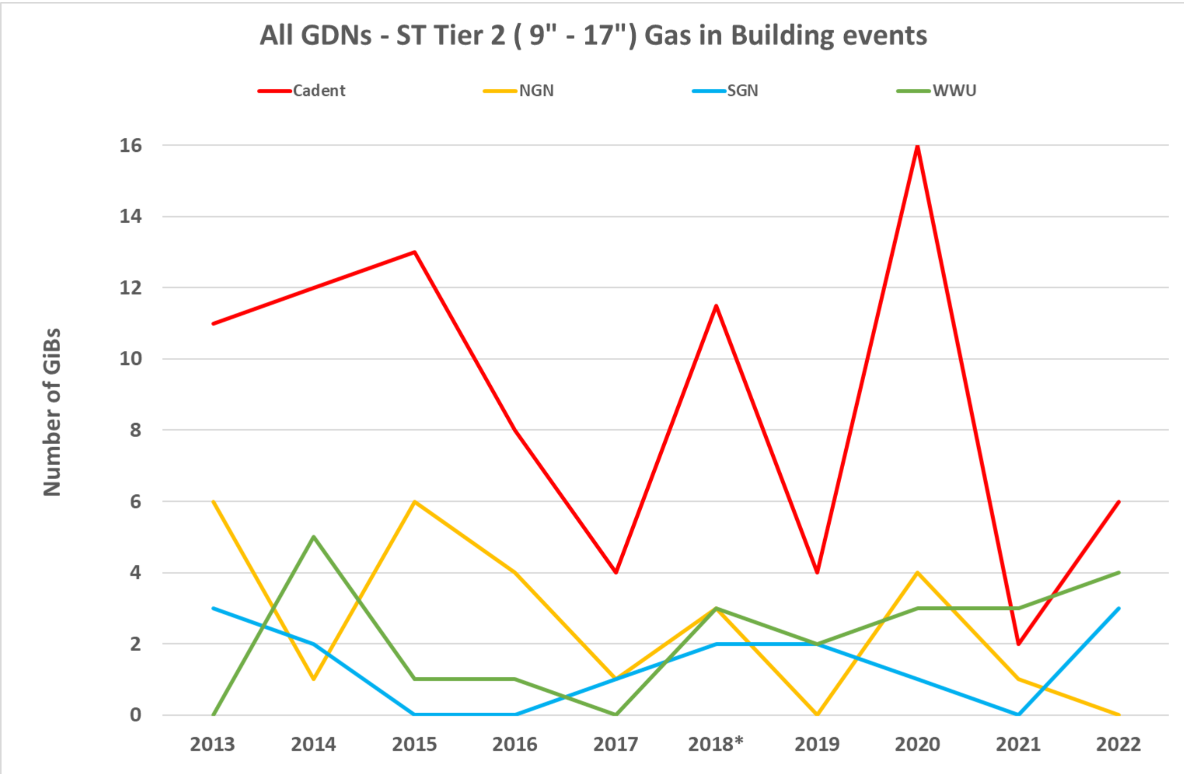

Figure 46 – Steel gas in buildings, diameter tier 2

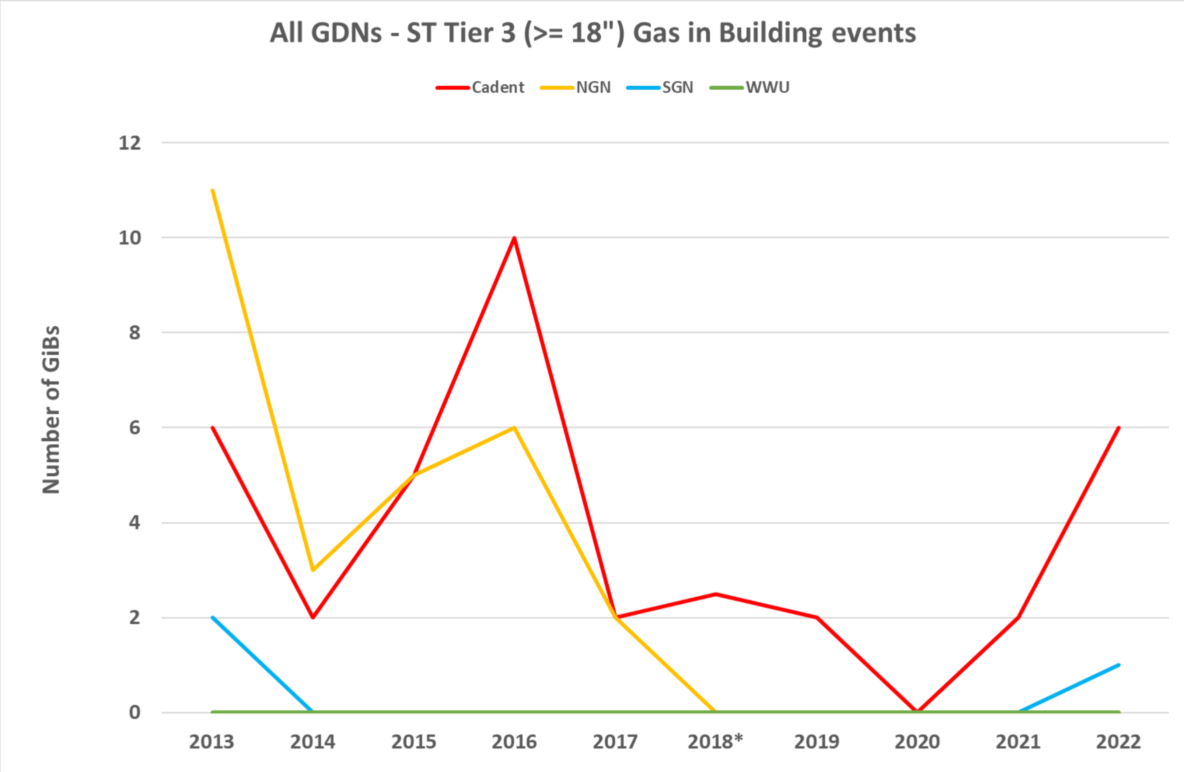

Figure 47 – Steel gas in buildings, diameter tier 3

4.3 Specific failures and GiBs

The risk scores in MRPS are based on specific failure types for each pipe material: fractures for cast and spun iron, and corrosion failures for ductile iron and steel. These are reviewed in turn below. The specific leakage codes (cause and component) used in the analysis for each GDN are given in Appendix A.

4.3.1 Cast and spun iron fractures

Figure 48 to Figure 51 show cast and spun iron fractures, by number and normalised by length, and GiB events from cast and spun iron fractures, again by number and normalised by number of leaks.

There has been an increase in the fracture rate for cast and spun iron mains for all GDNs in 2022, continuing the high variance in cast and spun iron fracture rate observed since 2018. The fracture rate for SGN is the highest since the start of the data analysis in 2013, whilst the current rates for the other GDNs are within historic levels.

Gas in building events due to cast and spun iron fractures vary across the GDNs. Cadent and SGN have seen the GiB rate from fractures increase in 2022, while the rate for WWU has reduced to continue a decreasing trend since the peak in 2017. The GiB rate from fractures for NGN saw a dip in 2021 but has now increased to meet GiB rates from previous years.

Fracture and GiB rates for 2022 are given in Table 5 below.

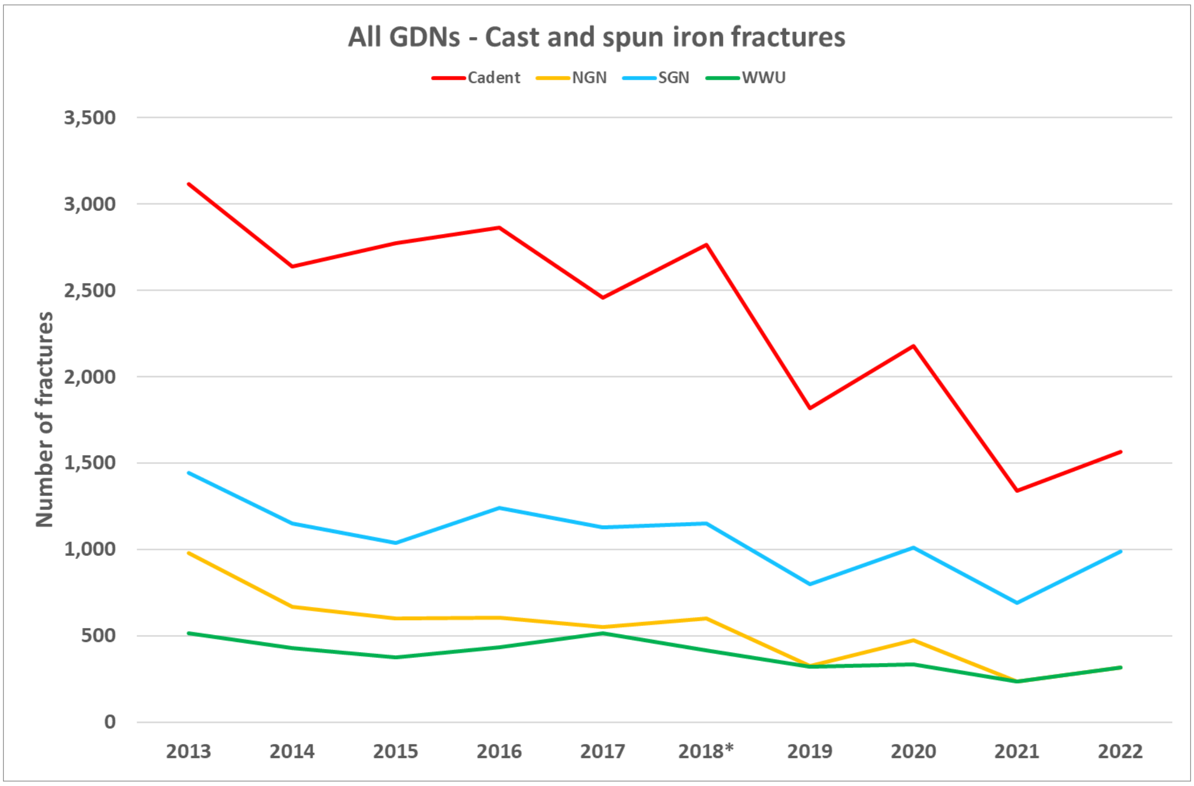

Figure 48 – Cast and spun iron fractures, all GDNs

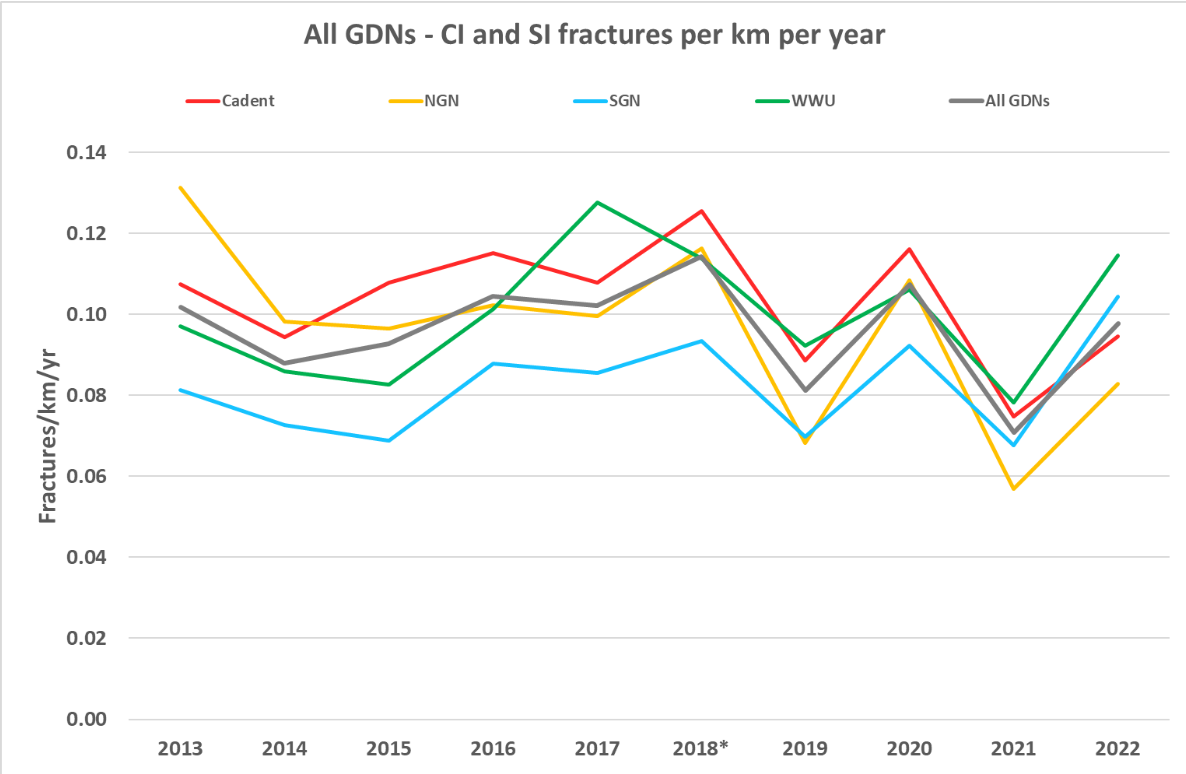

Figure 49 – Cast and spun iron fractures per km per year, all GDNs

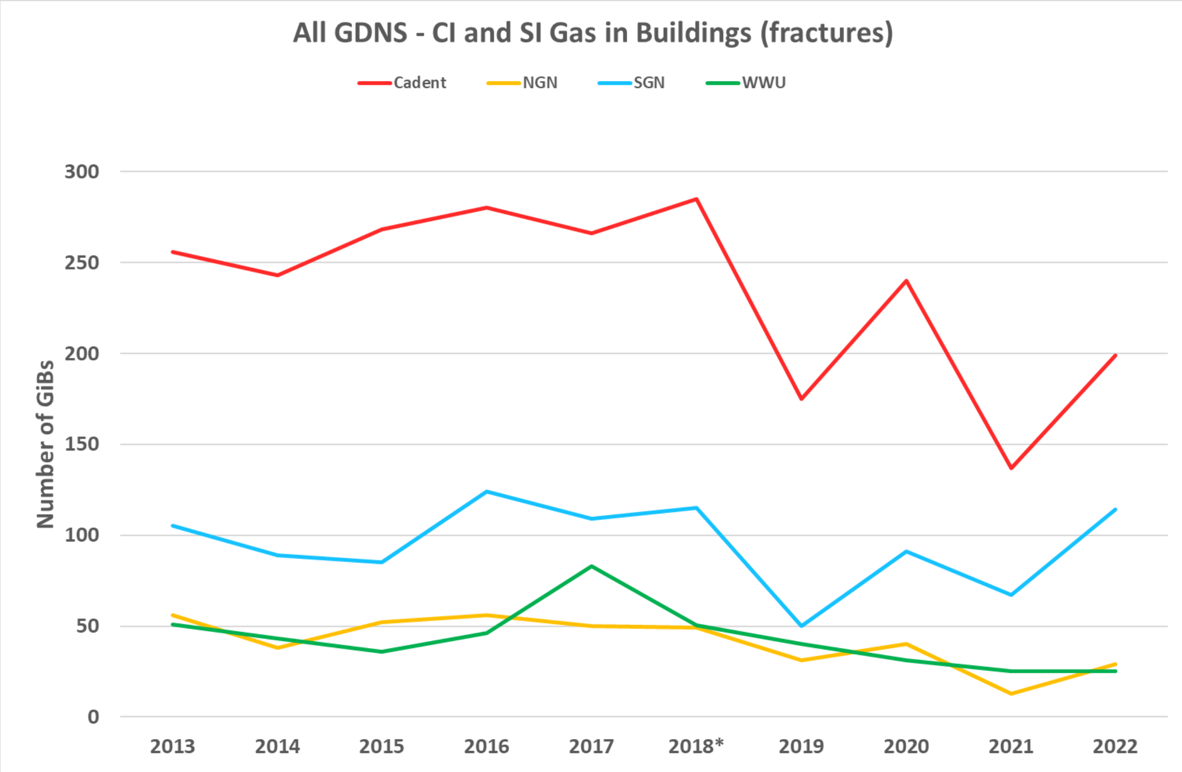

Figure 50 – Cast and spun iron GiBs from fractures, all GDNs

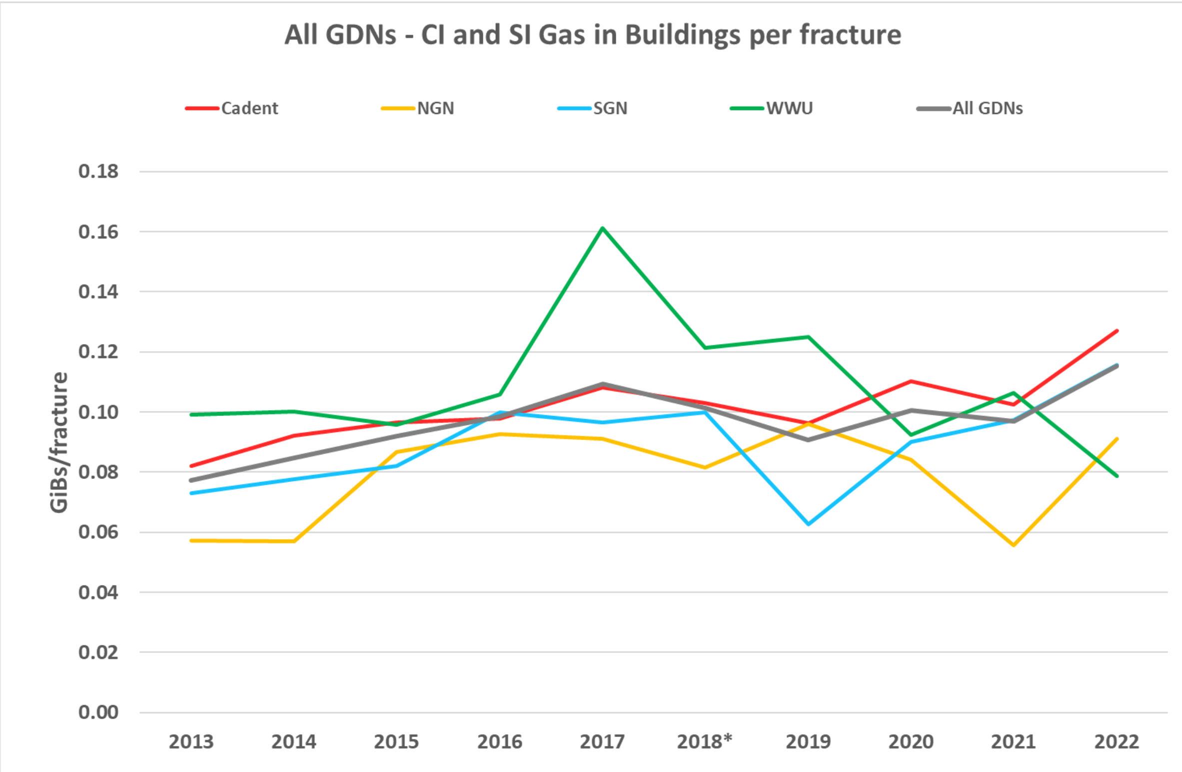

Figure 51 – Cast and spun iron GiBs per fracture, all GDNs

4.3.2 Ductile iron corrosions and joint failures

The corrosion and GiB rates for ductile iron include corrosions on the pipe barrel and on bolts (comprising joints and fittings) and these have been examined separately. Graphs showing all corrosion failures (barrel and bolt combined) for the past ten years have also been included. All the leakage codes used are detailed in Appendix A.

Figure 52 to Figure 55 show ductile iron barrel corrosions and GiBs. Figure 56 to Figure 59 show ductile iron bolt corrosions and GiBs. Figure 60 to Figure 63 show all ductile iron corrosions (barrel and bolt combined) and GiBs.

Barrel corrosions appear to be increasing over time for all GDNs, despite dips in ductile iron barrel corrosion rates for WWU and SGN in 2021. All GDNs have seen an increase in the rate of barrel corrosions in 2022, alongside an increase in the GiBs per barrel corrosion rate, although this remains within historic levels for Cadent, NGN and WWU. NGN and WWU have the lowest GiB per barrel corrosion rates, whilst the rates for SGN and Cadent are significantly higher, at approximately 4.7 and 5.5 times, respectively, that of NGN and WWU.

Bolt corrosion rates appear to be slightly increasing over time for all GDNs, though the failure rate for NGN has decreased to levels similar to WWU and Cadent. SGN have the smallest bolt corrosion rate, and WWU have the highest, however all GDNs have similar rates within the range of 0.15 – 0.20 corrosions per km per year. The GiB per bolt corrosion rate has increased for all GDNs, with WWU having the greatest rate of increase and NGN having the lowest. Despite the increase, all current GiB per bolt corrosion rates are within historic levels.

For all ductile iron corrosions (barrel and bolt combined), NGN still has the highest rate of corrosions per km despite the decrease in bolt corrosions. However, the higher failure rate does not directly translate to more GiBs since NGN have the lowest GiBs per ductile iron corrosion rate of all the GDNs. Cadent still have the highest GiBs per corrosion rate, though there have been notable increases for SGN and WWU.

Corrosion and GiB rates for 2022 are given in Table 5 (Section 6 below).

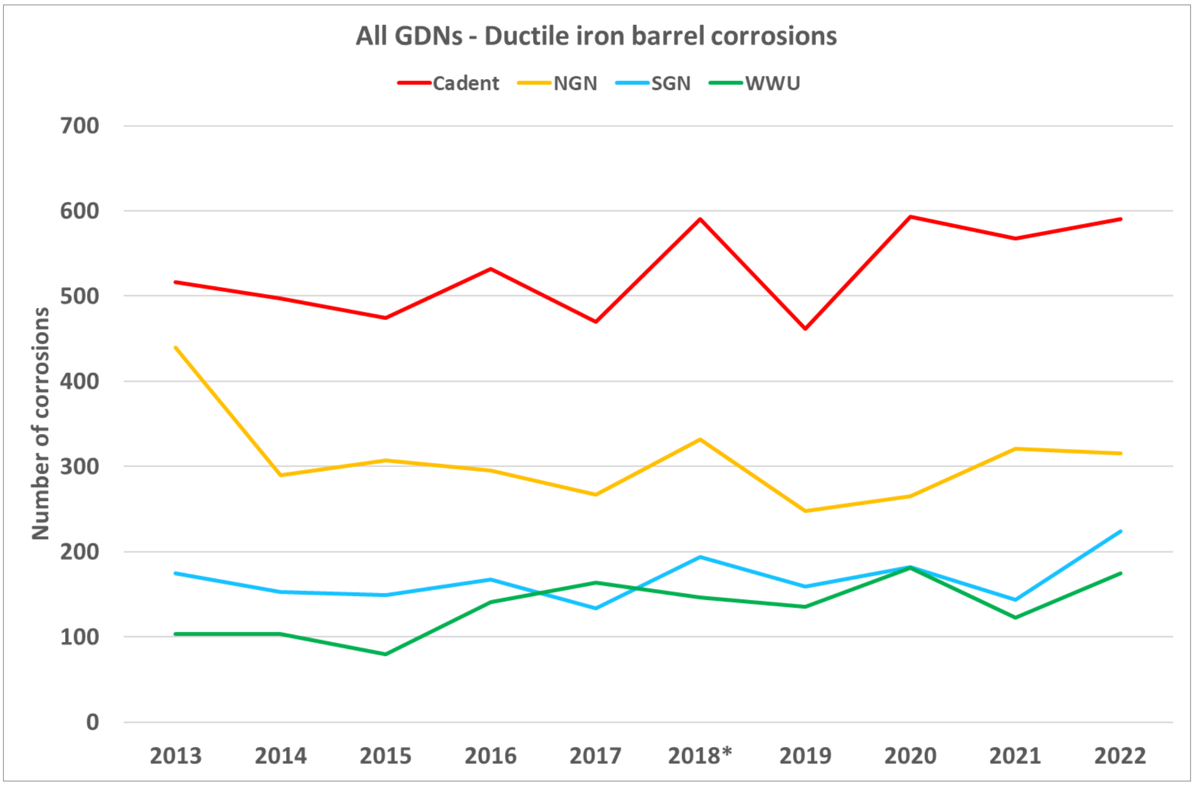

Figure 52 – Ductile iron barrel corrosions, all GDNs

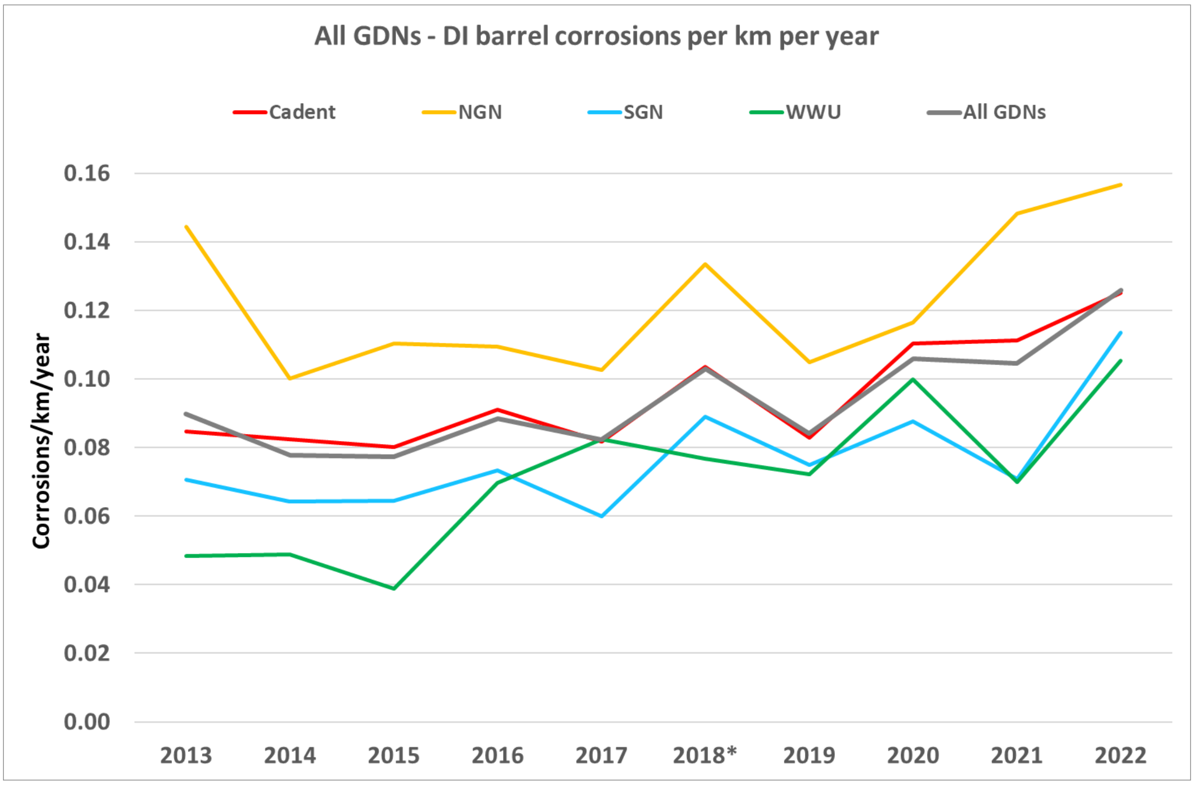

Figure 53 – Ductile iron barrel corrosions per km per year, all GDNs

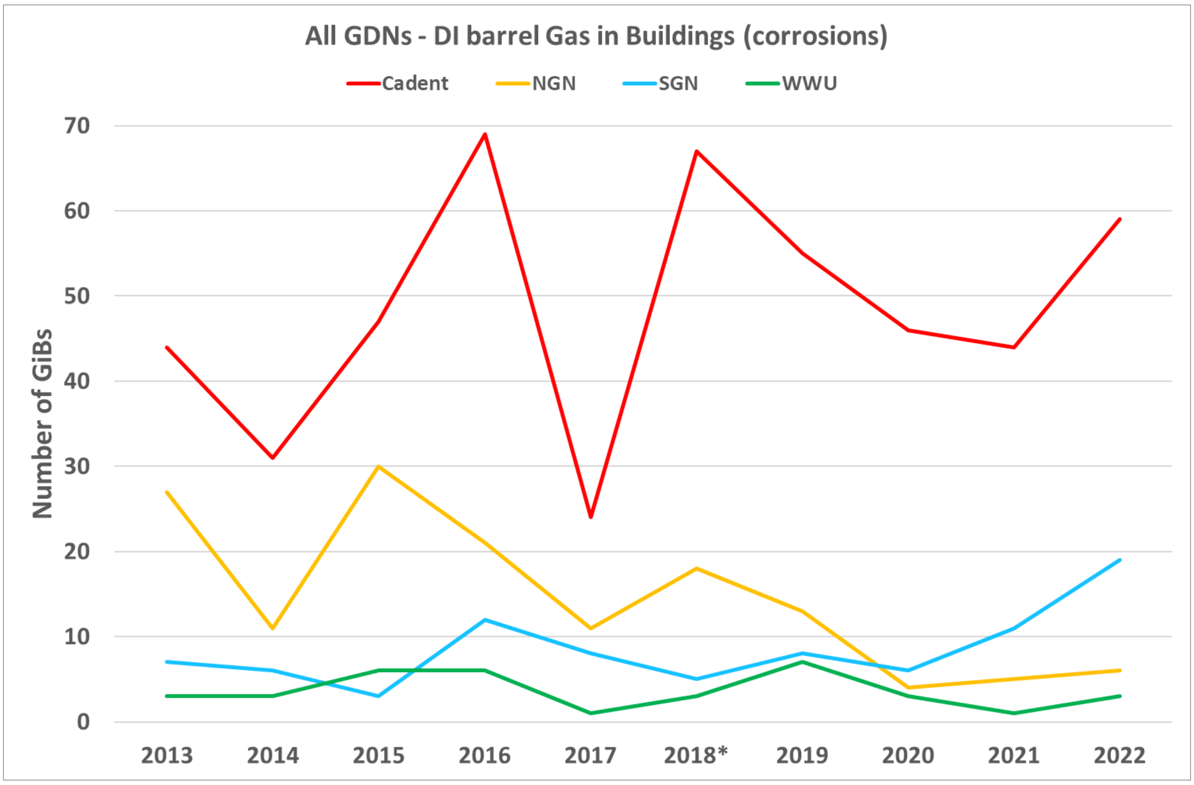

Figure 54 – Ductile iron GiBs from barrel corrosions, all GDNs

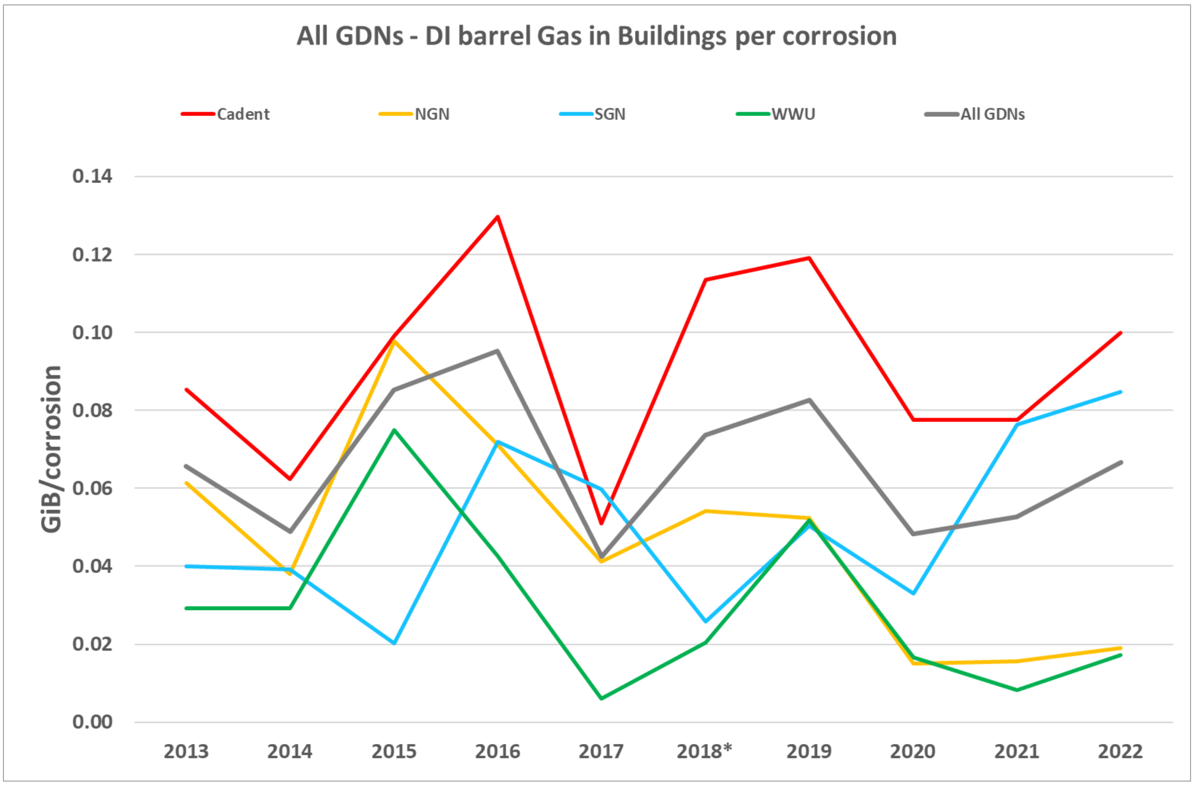

Figure 55 – Ductile iron GiBs per barrel corrosion, all GDNs

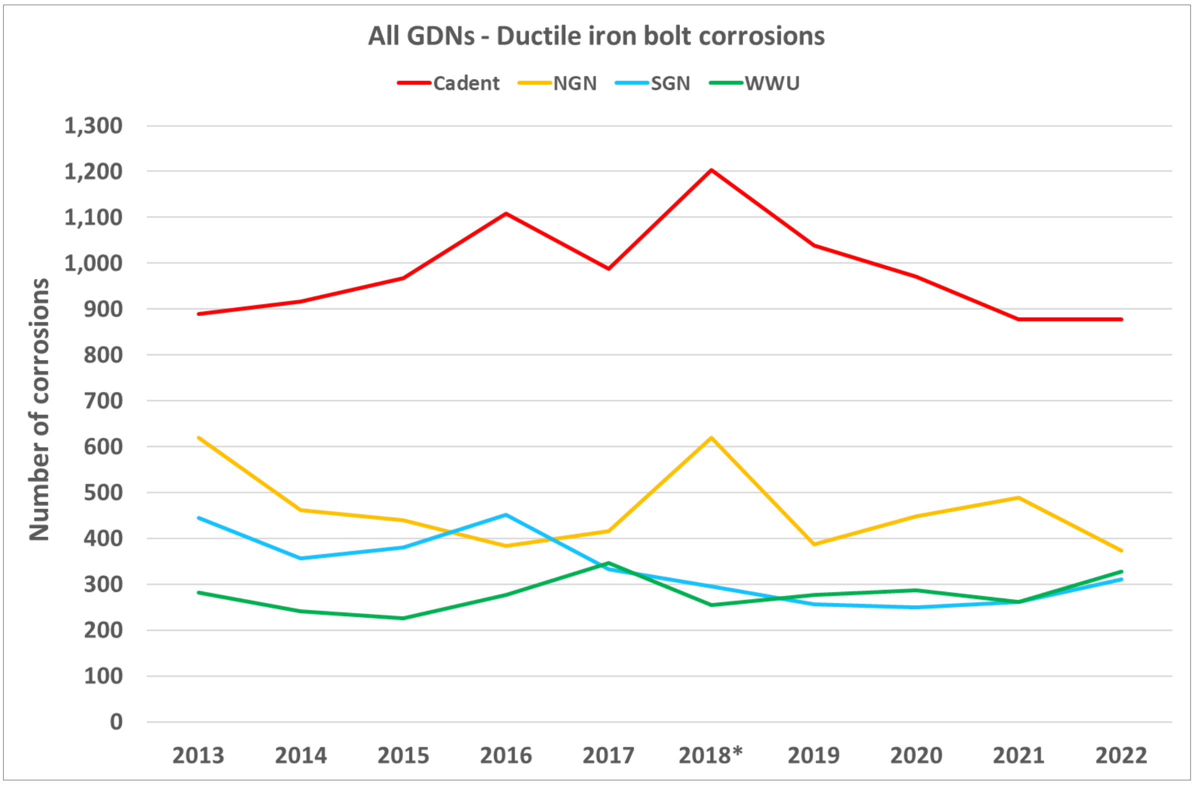

Figure 56 – Ductile iron bolt corrosions, all GDNs

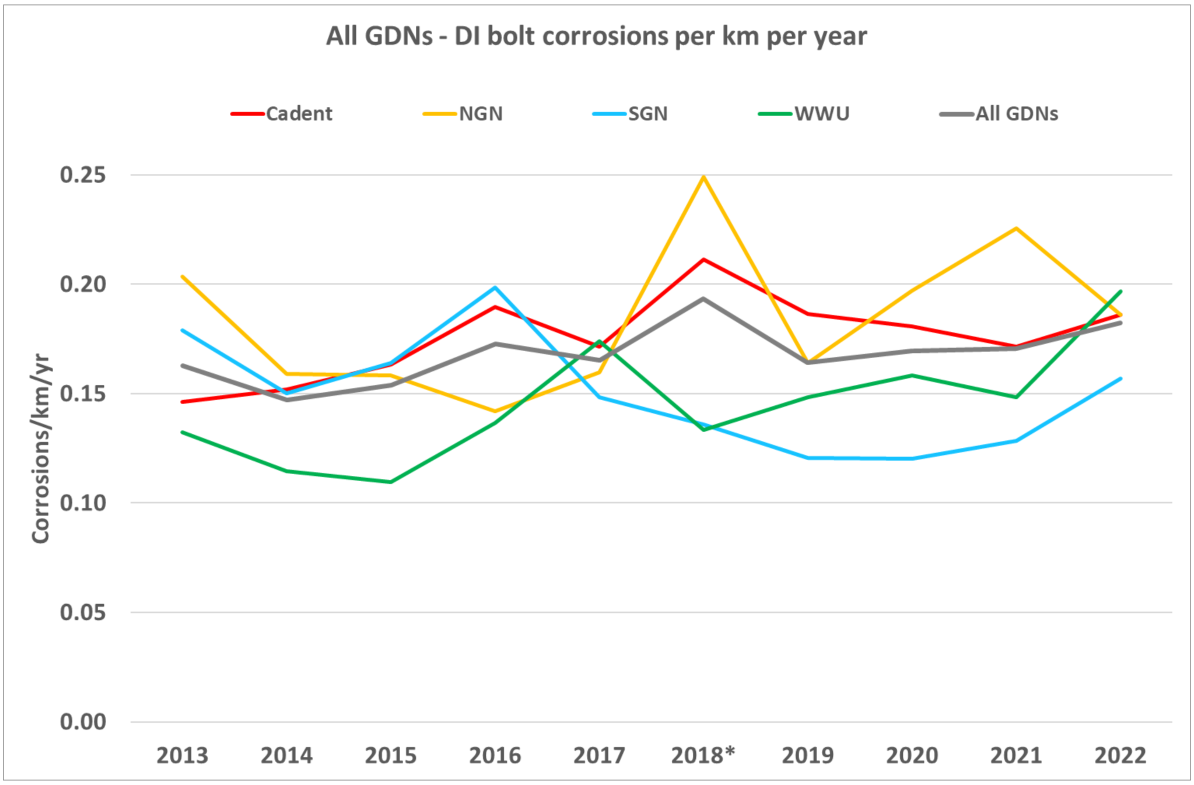

Figure 57 – Ductile iron bolt corrosions per km per year, all GDNs

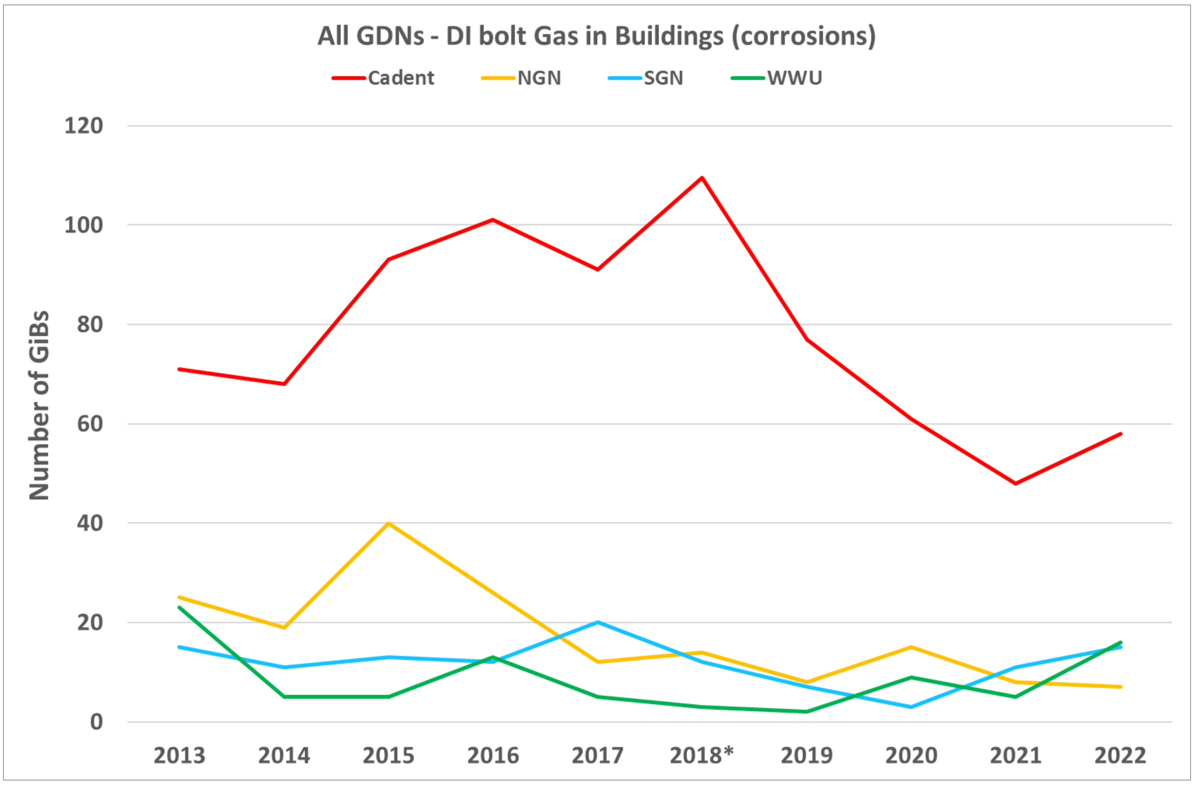

Figure 58 – Ductile iron GiBs from bolt corrosions, all GDNs

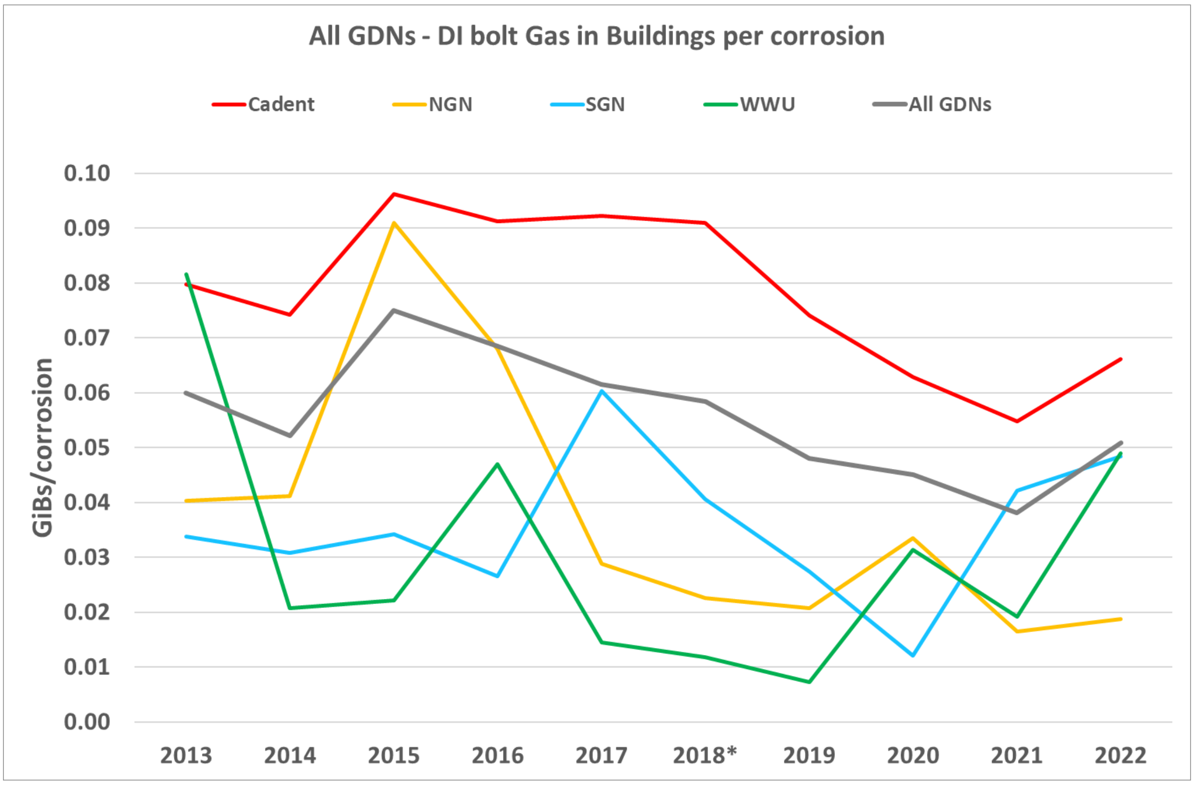

Figure 59 – Ductile iron GiBs per bolt corrosion per year, all GDNs

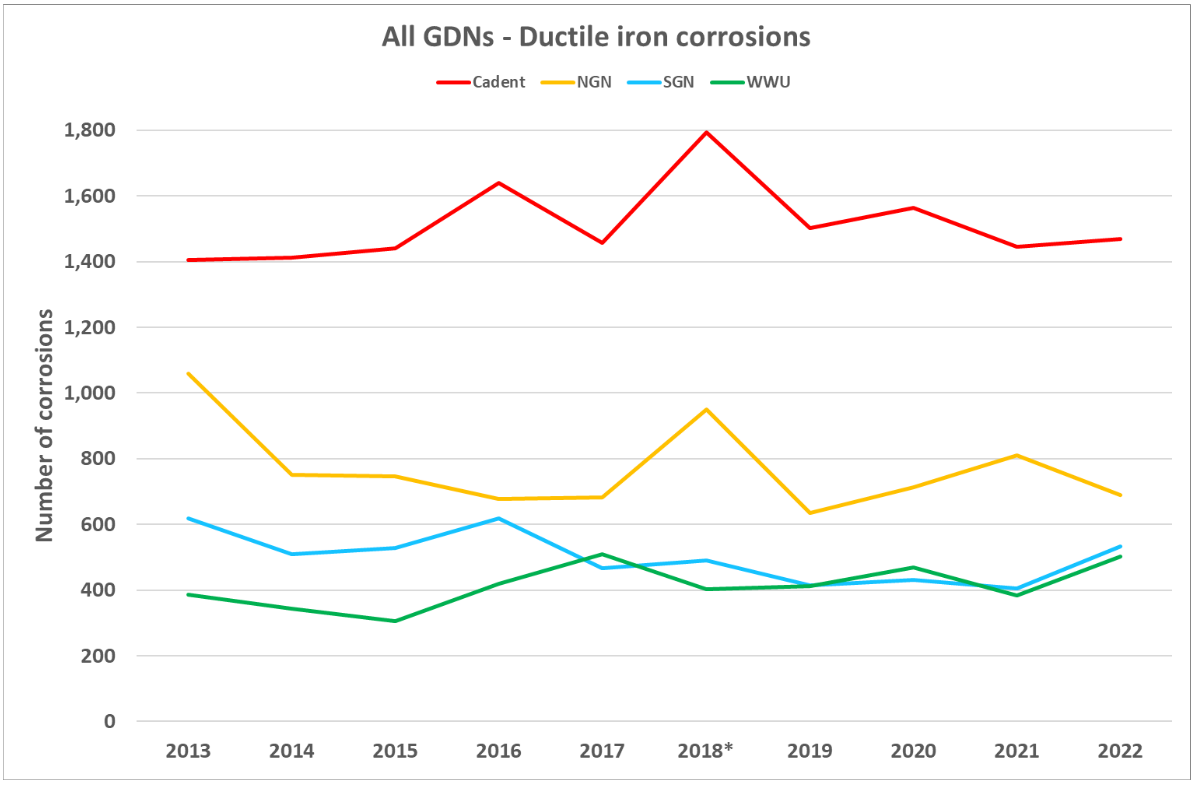

Figure 60 – Ductile iron corrosions, all GDNs

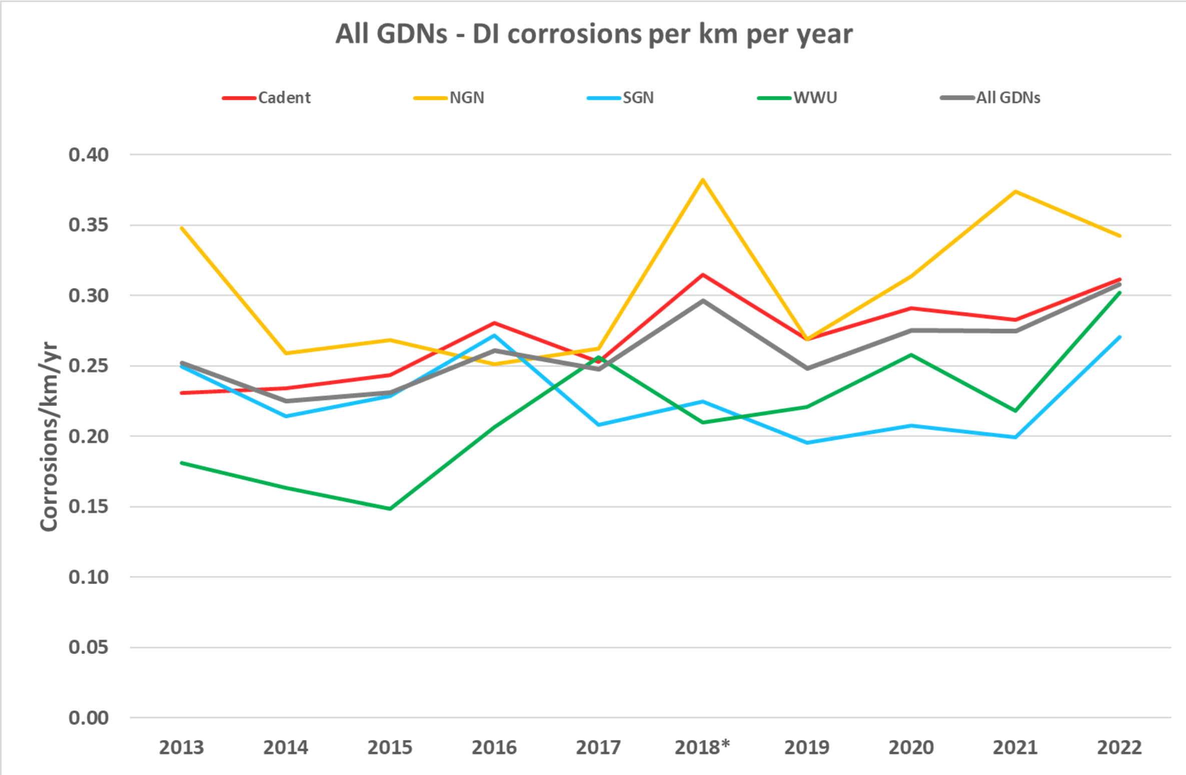

Figure 61 – Ductile iron corrosions per km per year, all GDNs

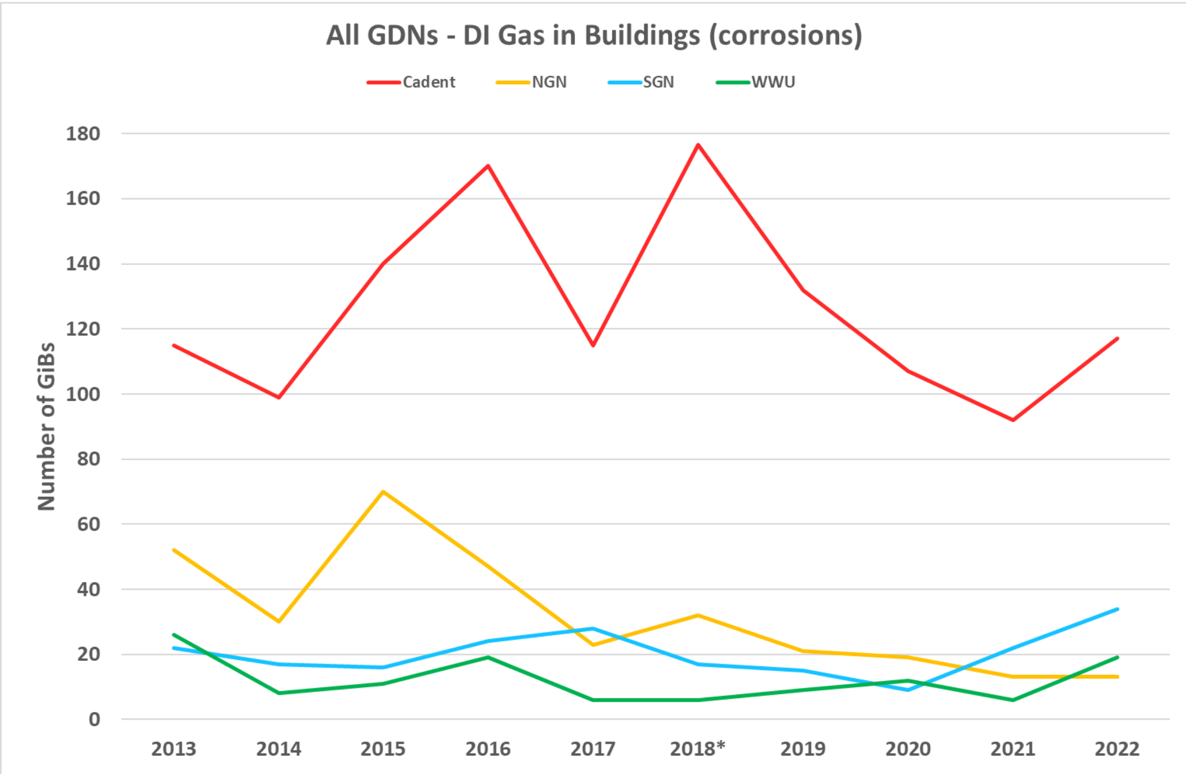

Figure 62 – Ductile iron gas in buildings corrosions, all GDNs

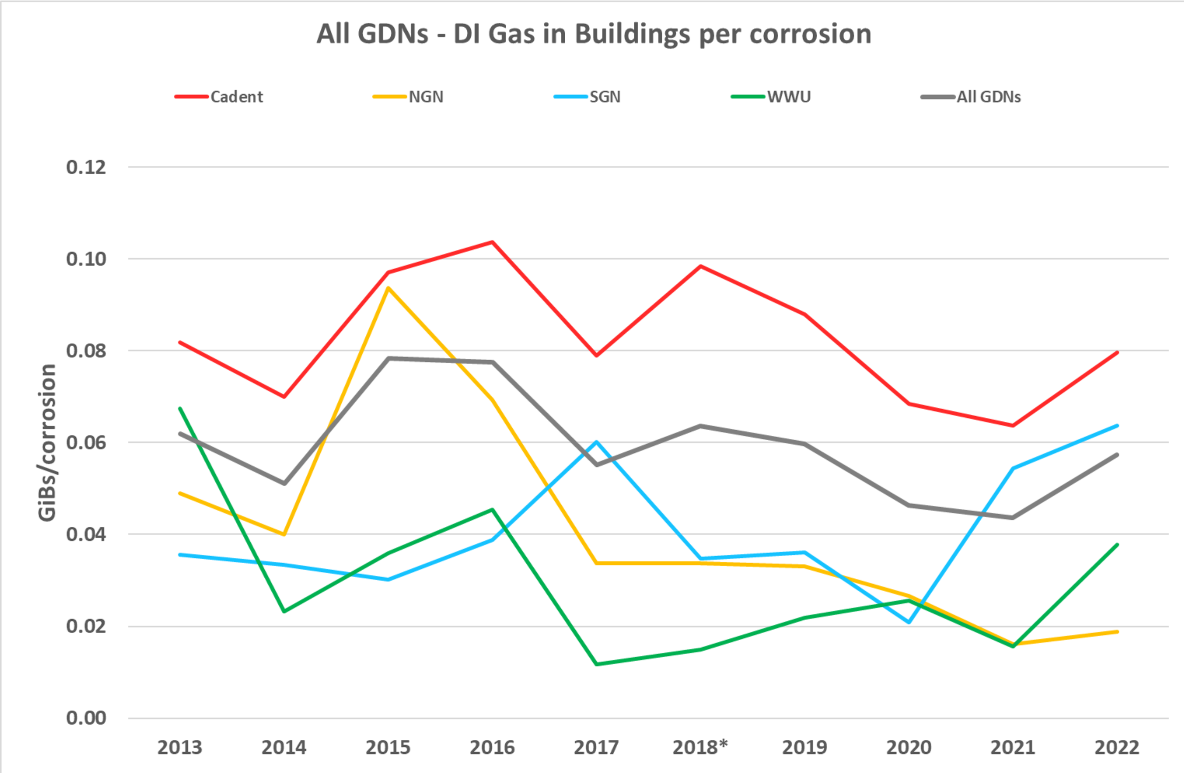

Figure 63 – Ductile iron gas in buildings per corrosion per year, all GDNs

4.3.3 Steel corrosions

Corrosions on steel pipes include any failure of the pipe barrel excluding fractures (which are assumed to occur due to loading rather than deterioration), plus corrosion of standpipes and tees. Failures of joints and clamps are not included.

Figure 64 to Figure 67 show steel corrosions, by number and normalised by length, and GiB events from steel corrosions, again by number and normalised by number of leaks. This year, the rate of steel corrosions has increased since 2021 for NGN and SGN, and remained consistent for Cadent and WWU. Historically, steel corrosion rates for SGN have remained consistent, however in 2022 SGN's steel corrosion rate increased by approximately 67%. Conversely, Cadent historically had the highest steel corrosion rate (peaking in 2018), but this is now the lowest. The GiB rate from steel corrosions has remained largely level since 2013 for all GDNs except NGN, whose rate has returned to historical levels following a peak in 2016. Cadent have the highest GiB per steel corrosion rate, with an increase in 2022 to approximately 2.7 times the other GDNs who all have similar rates.

Corrosion and GiB rates for 2022 are given in Table 5 (Section 6).

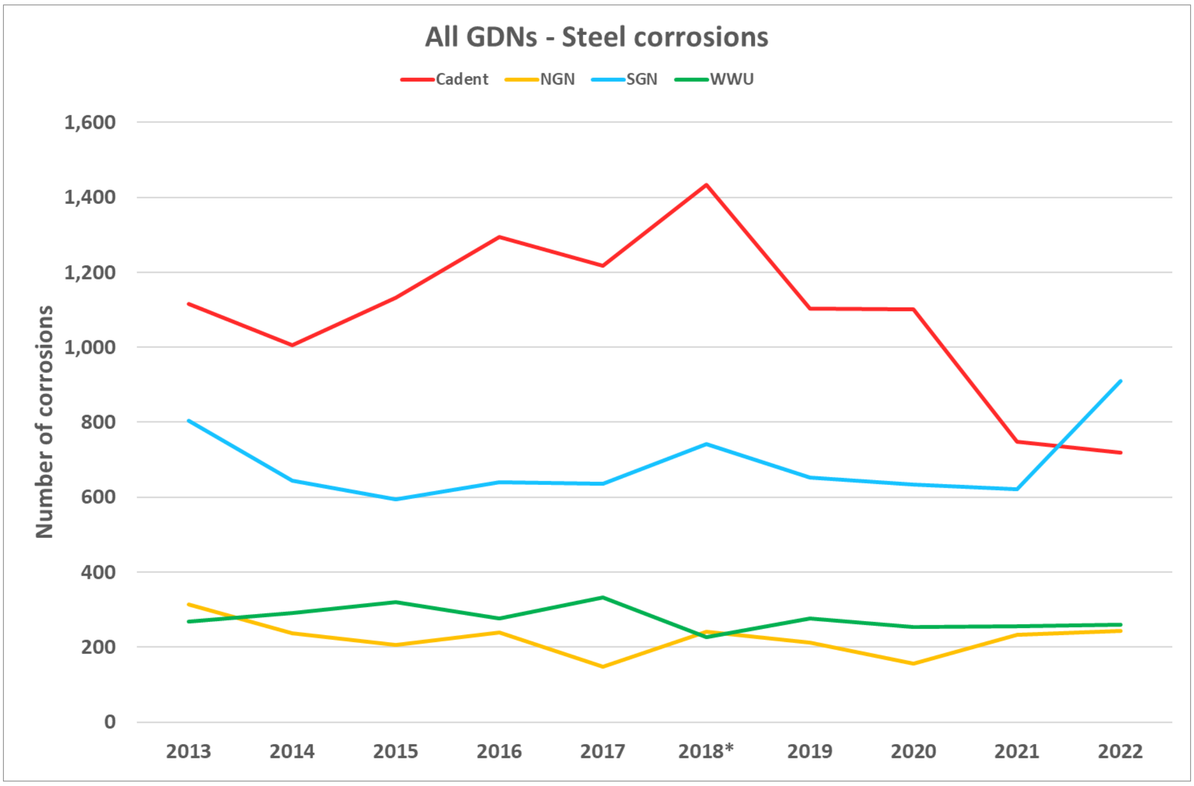

Figure 64 – Steel corrosions, all GDNs

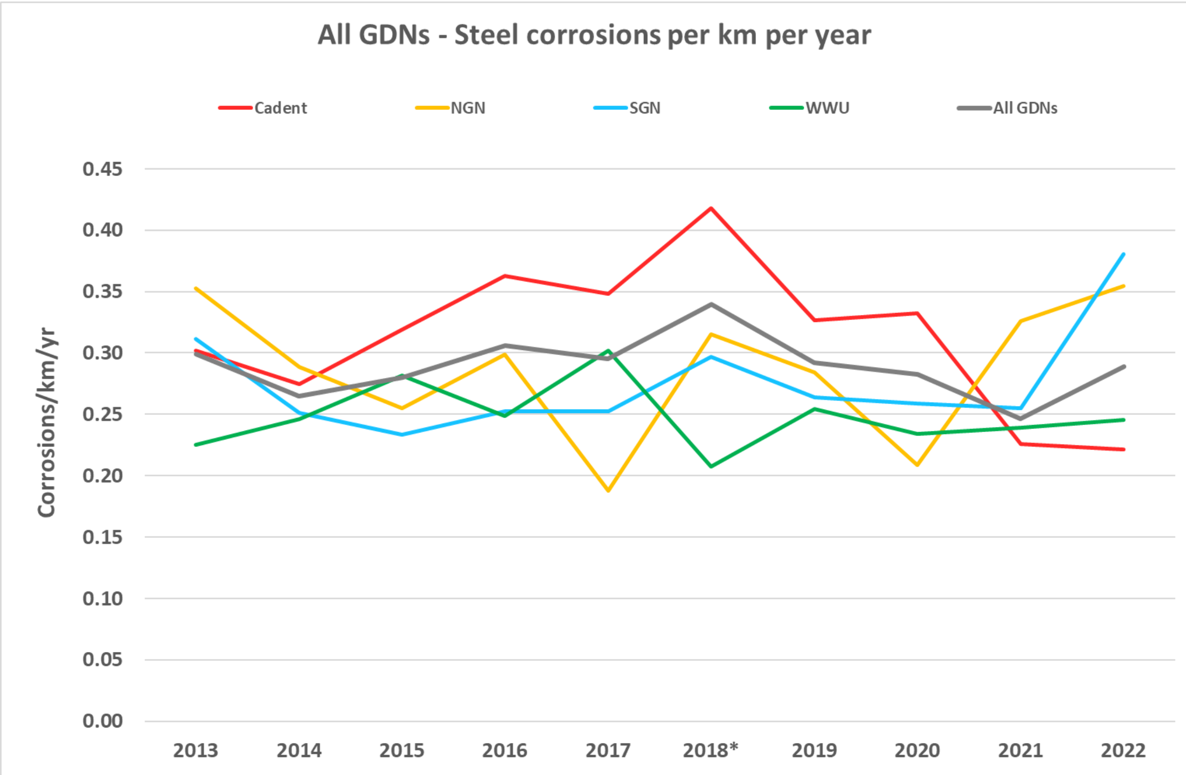

Figure 65 – Steel corrosions per km per year, all GDNs

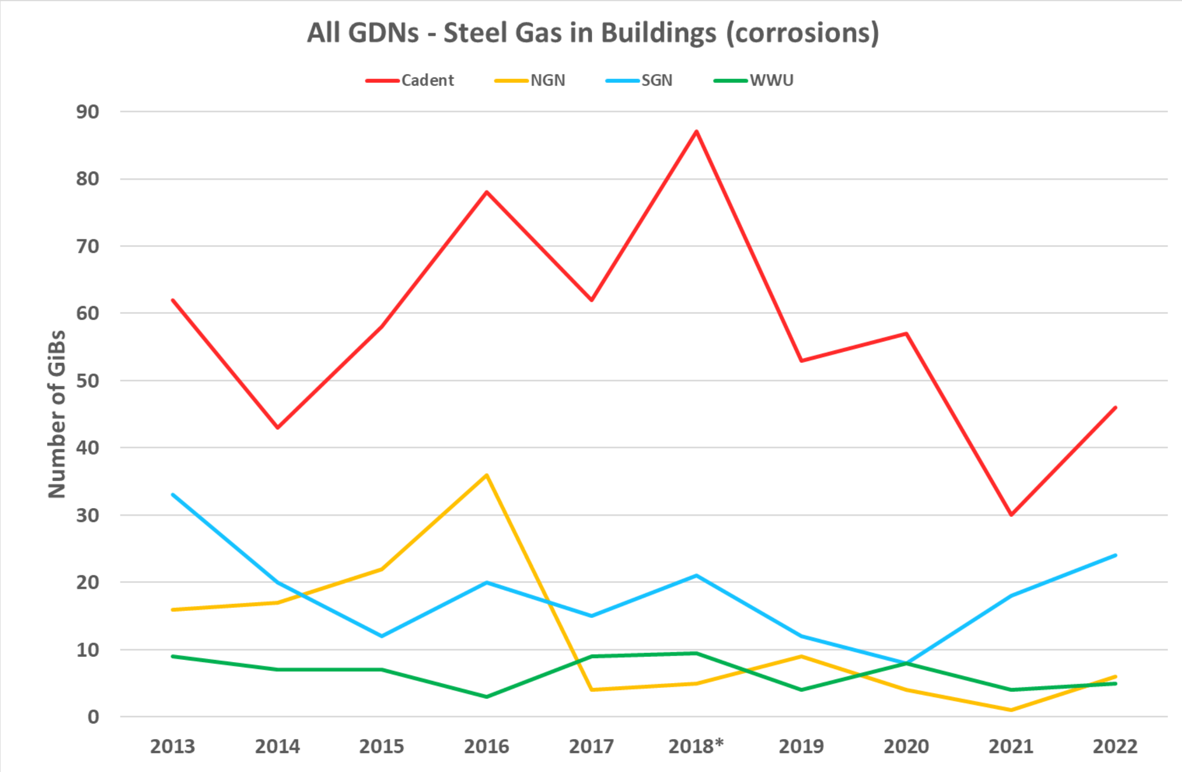

Figure 66 – Steel gas in building corrosions, all GDNs

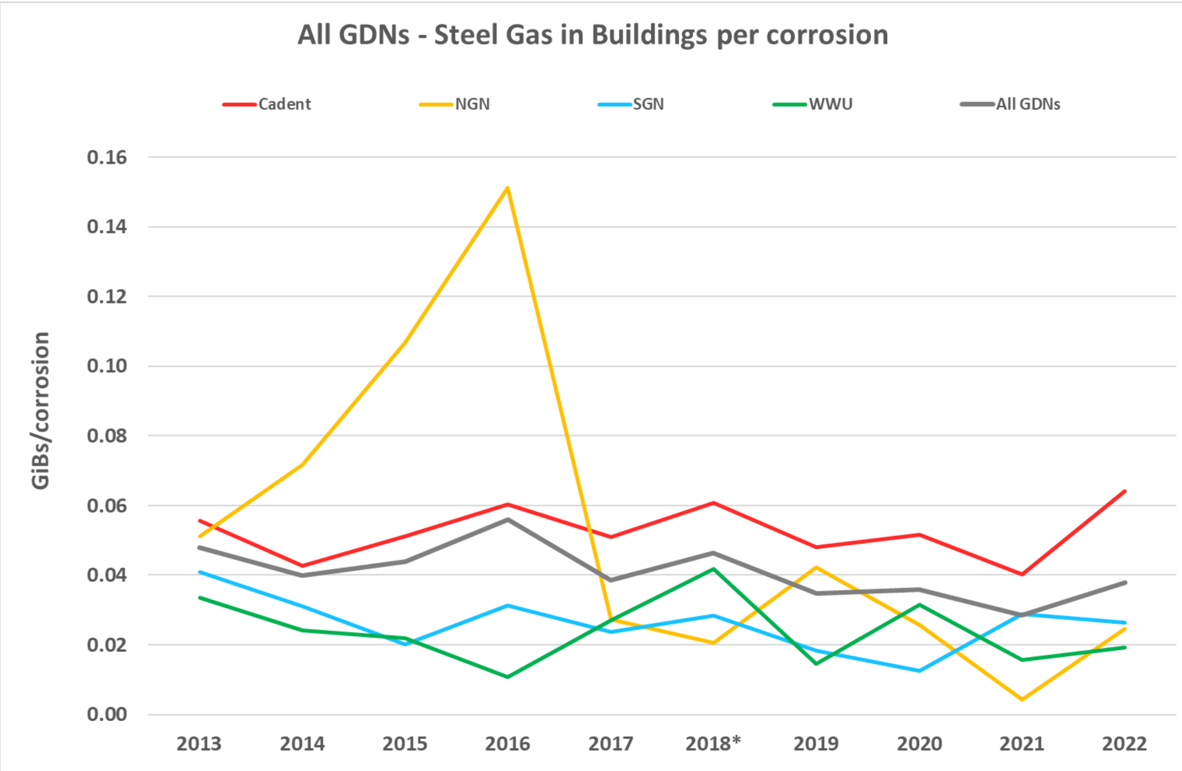

Figure 67 – Steel gas in buildings per corrosion per year, all GDNs

4.4 MRPS Qualifying Failures

4.4.1 MRPS Failures

Figure 68 and Figure 69 show the number of MRPS qualifying failures, for all materials for each GDN. Absolute numbers show a slight decrease in the number of MRPS qualifying failures over time, however when normalised by length it appears that the number of MRPS qualifying failures remains consistent, with some small fluctuation in recent years, across all GDNs.

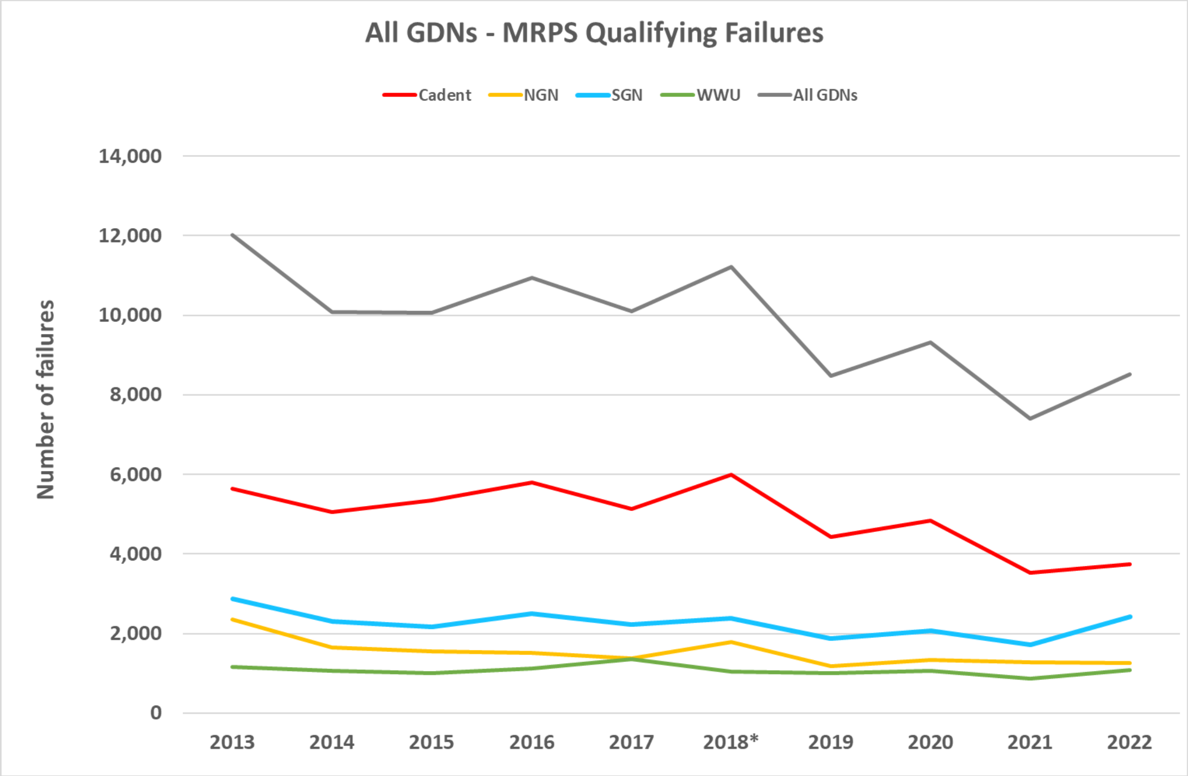

Figure 68 – MRPS Qualifying Failures, all GDNs

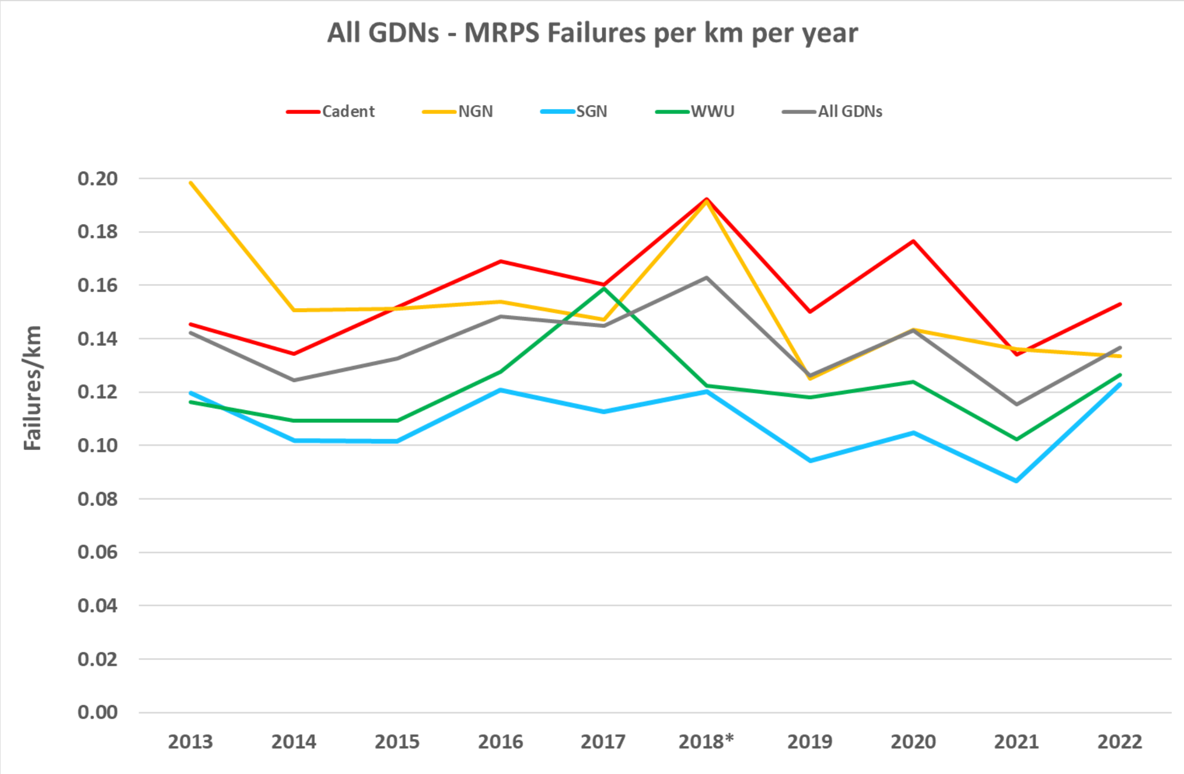

Figure 69 – MRPS Failures per km per year, all GDNs

4.4.2 Non-MRPS Failures

Figure 70 and Figure 71 show the number of failures for each GDN that do not qualify under MRPS, excluding interference damage. These failures include joint failures for cast and spun iron and steel, and failures of fittings and previous repairs. These failures largely follow the trend for MRPS qualifying failures shown in Section 4.4.1, indicating that basing replacement on the failures covered by MRPS is also successful in reducing the rate of failures that are not included.

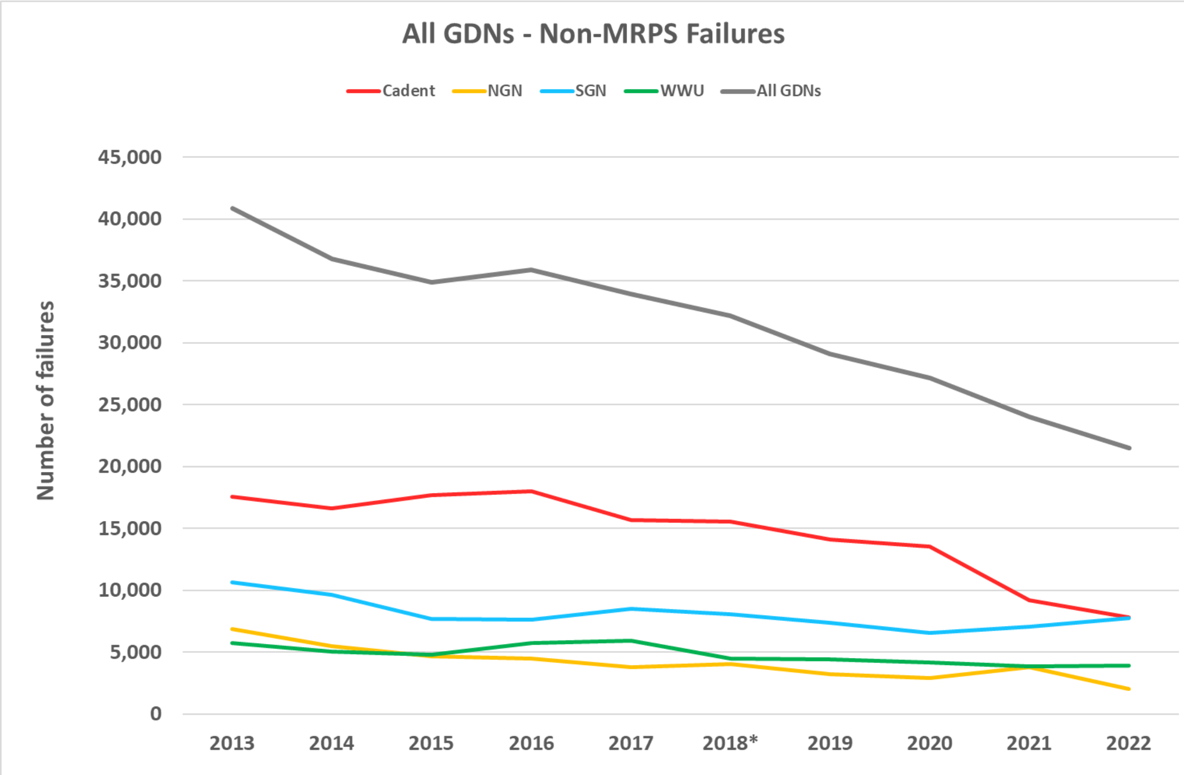

Figure 70 – Non-MRPS Failures, all GDNs

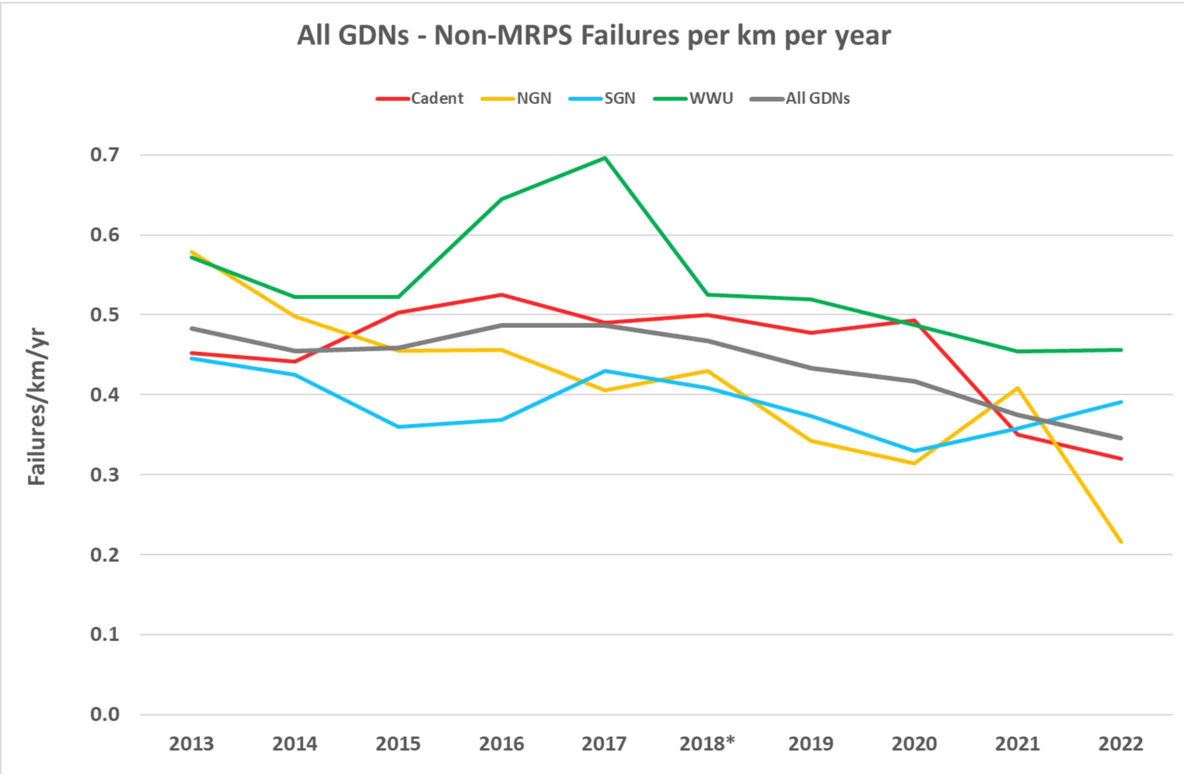

Figure 71 – Non-MRPS Failures per km per year, all GDNs

4.4.3 Ratio of Failures

To investigate whether there is an increasing trend in the failures which are not being recognised by MRPS, the percentage of total failures that qualify as MRPS failures has been plotted for each of the GDNs. Figure 72 shows that the percentage of failures that qualify under MRPS is largely level for SGN, and is increasing for NGN, Cadent and WWU, particularly in the past year. Overall, only 28.3% of failures are accounted for within MRPS.

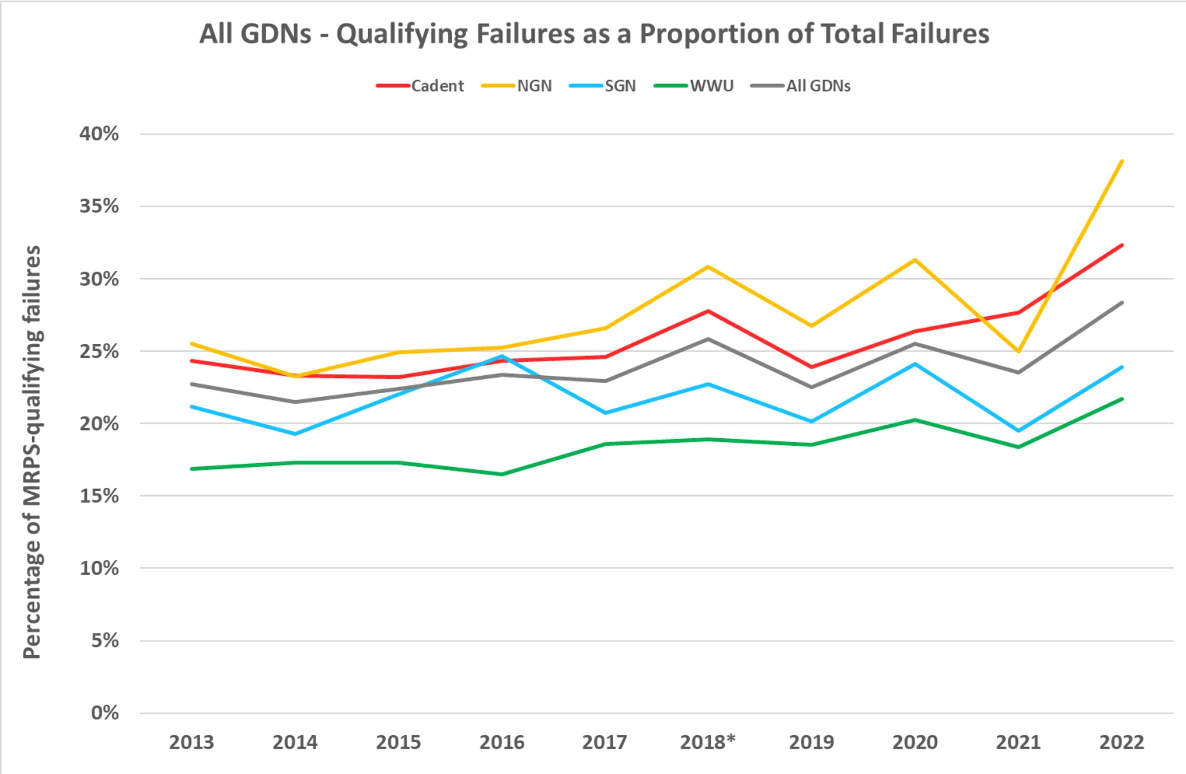

Figure 72 – MRPS Qualifying Failures as a Proportion of Total Failures, all GDNs

5 FAILURE TYPE ANALYSIS

The 2022 failures and GiBs have been analysed by material to determine the proportions attributed to each failure type. Failures have been grouped as follows:

- Pipe corrosion
- Pipe fracture
- Pipe failure
- Joint corrosion
- Joint deterioration (including failure of seal)
- Joint fracture
- Joint failure
- Fitting deterioration (including plugs, valves, standpipes and tees)
- Fitting Failure (including plugs, valves, standpipes and tees)
- Previous repair failure (including joint clamps, pipe clamps, polyform and encapsulation)

A summary of the causes of failures and GiBs by percentage are shown graphically in Figure 73 to Figure 78 and also in Table 4. This includes all ferrous failures (excluding interference damage), failures by material, and specific failure types.

In Table 5, the failure and GiB rates for specific failures currently used to generate MRPS risk scores are provided. Note that these are slightly different to the specific failure types in Table 4. The differences are:

- The current MRPS qualifying ductile iron barrel corrosions include both ductile iron fractures and corrosions
- The current MRPS qualifying steel corrosions includes fitting deterioration

For cast and spun iron mains, the predominant failure type is failure of the joint, with 55.5% of failures being recorded as either joint failure, joint fracture, joint deterioration, or joint corrosion. Alongside this, the same selection accounts for 51.1% of GiBs. Currently, the cast iron risk model considers only fractures of the pipe to determine risk scores for mains; these only account for 14.5% of cast iron failures. It is recommended that the cast iron model is updated to include joint failure and corrosion to improve the accuracy.

For ductile iron mains, the predominant failure modes are joint failures and pipe corrosion, which are both included in the current risk model. Pipe fractures comprise 6.2% of ductile iron failures but represent 13.4% of GiBs, which is more than twice the GiB rate for corrosions. These failures are currently collated with corrosions to give MRPS-qualifying ‘ductile iron pipe barrel corrosions’; as such it is recommended that the ductile iron risk model is updated to include fractures as a separate failure mode to improve the accuracy.

For steel mains, the predominant failure mode is pipe corrosion, which accounts for 44.8% of failures. Another significant failure mode is the failure of the joint, with 26.5% of failures being recorded as either joint failure, joint deterioration or joint corrosion and a similar proportion of GiBs resulting from this. Therefore, it is recommended that the steel risk model is updated to include joint failures to improve the accuracy.

When comparing failures across materials it can be seen that, despite cast/spun iron fractures becoming less frequent, overall cast/spun iron failures remain over 1.5 times as frequent as ductile iron failures. In terms of GiBs, the GiB rate per failure is greatest for cast/spun iron, with ductile iron slightly lower and steel the lowest.

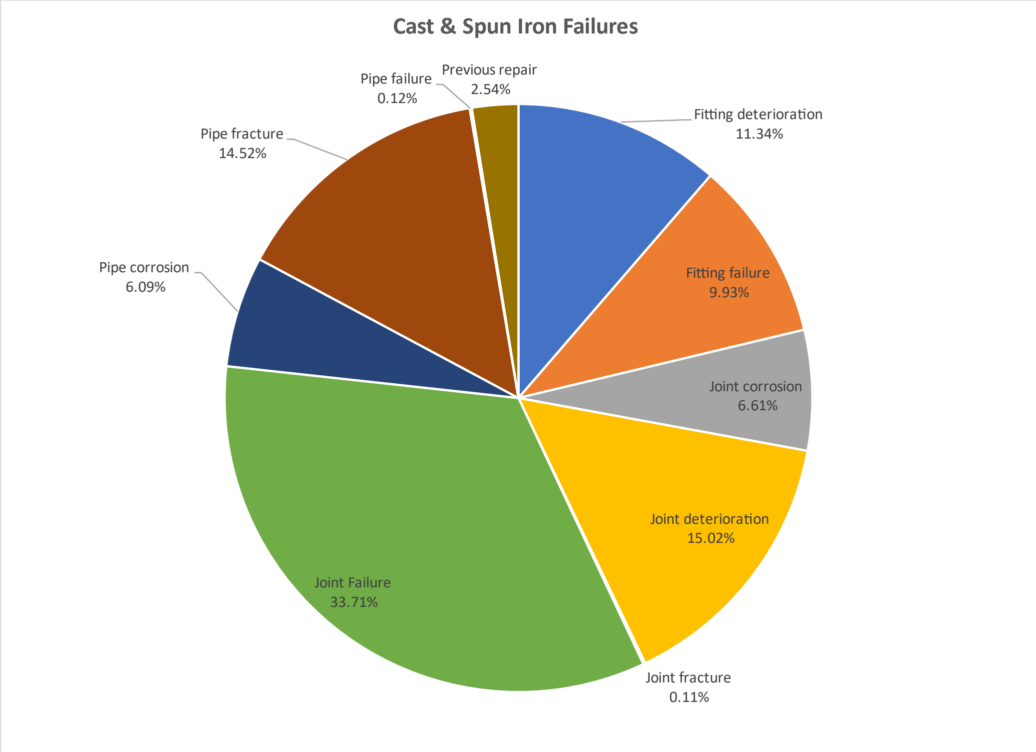

Figure 73 - Proportion of cast and spun iron failures by cause, All GDNs

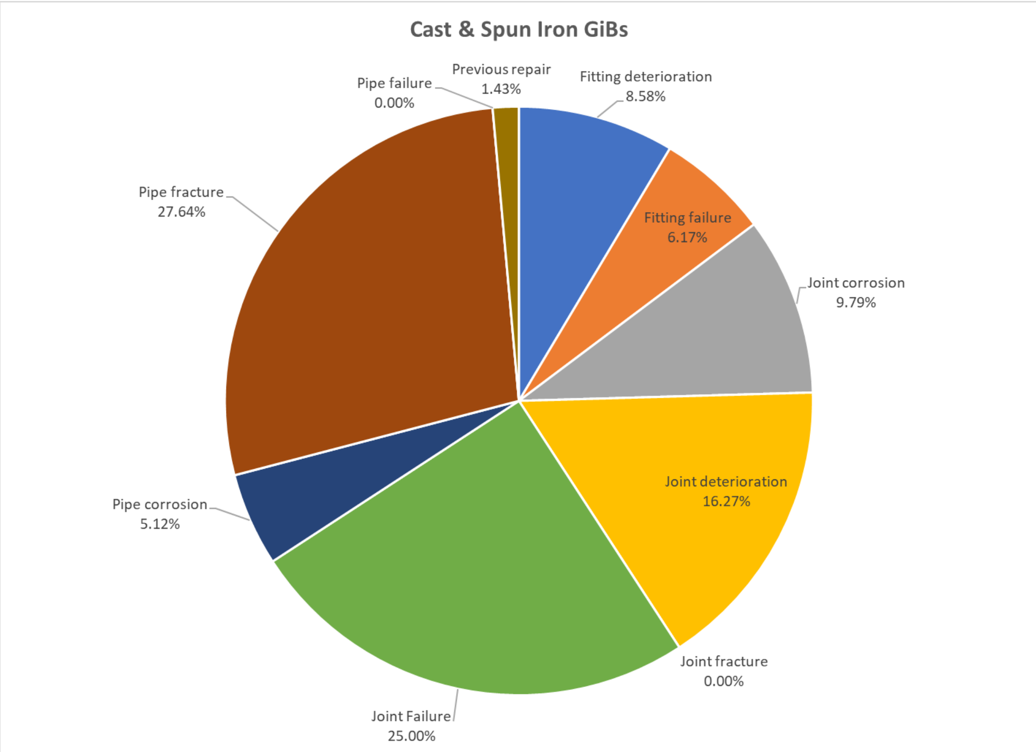

Figure 74 - Proportion of cast and spun iron GiBs by cause, all GDNs

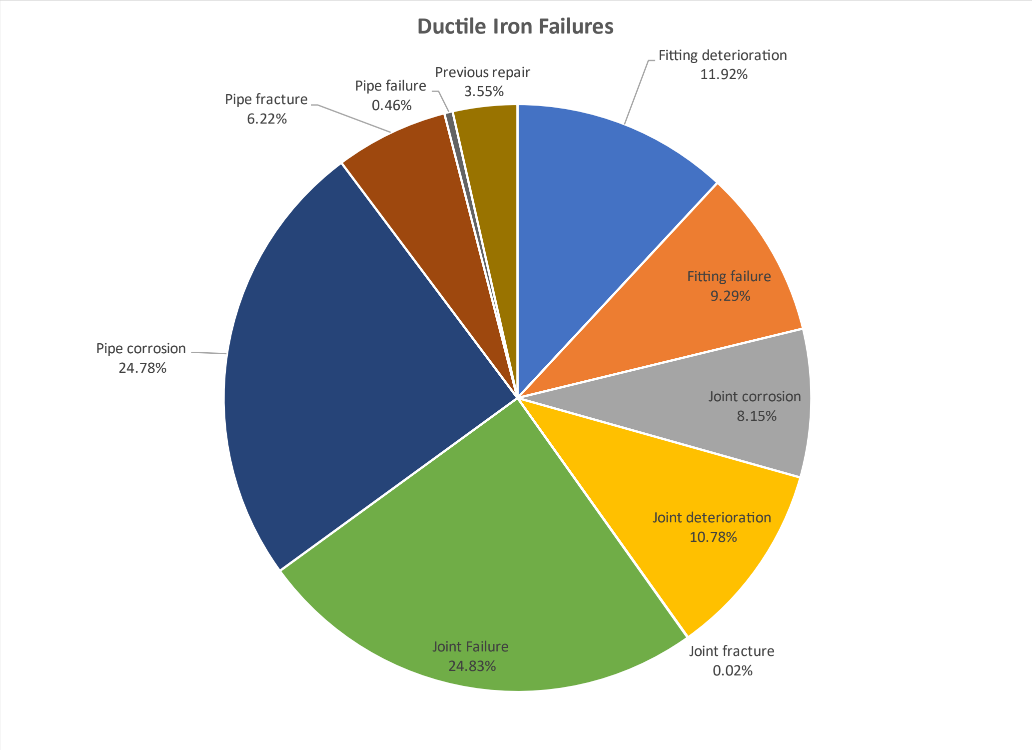

Figure 75 - Proportion of ductile iron failures by cause, all GDNs

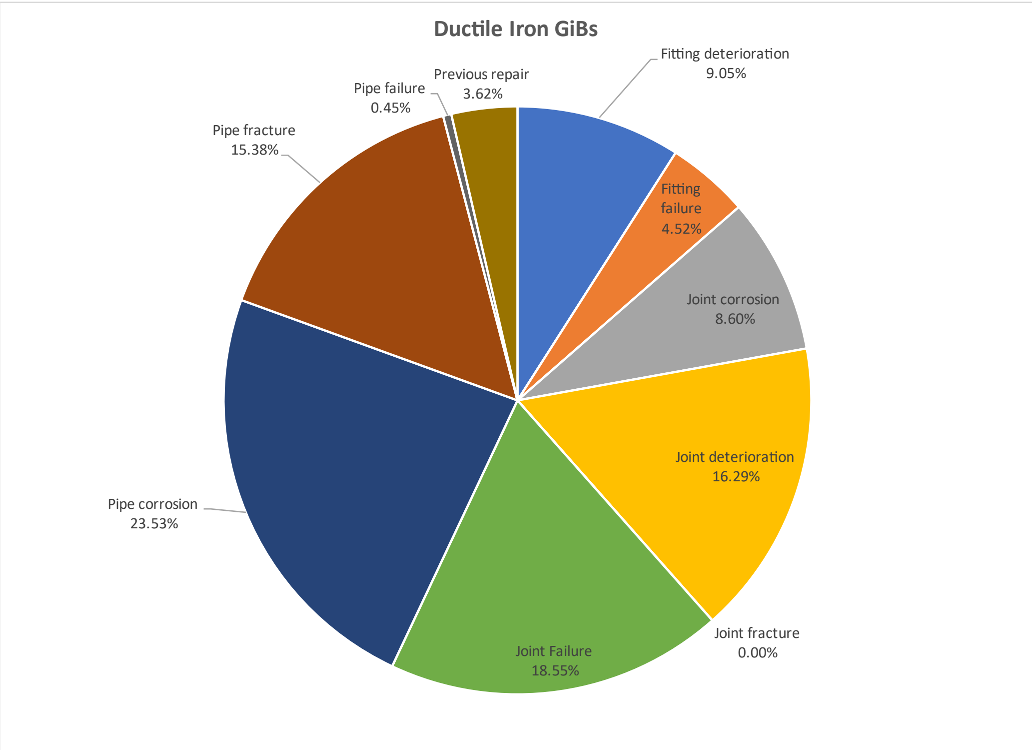

Figure 76 - Proportion of ductile iron GiBs by cause, all GDNs

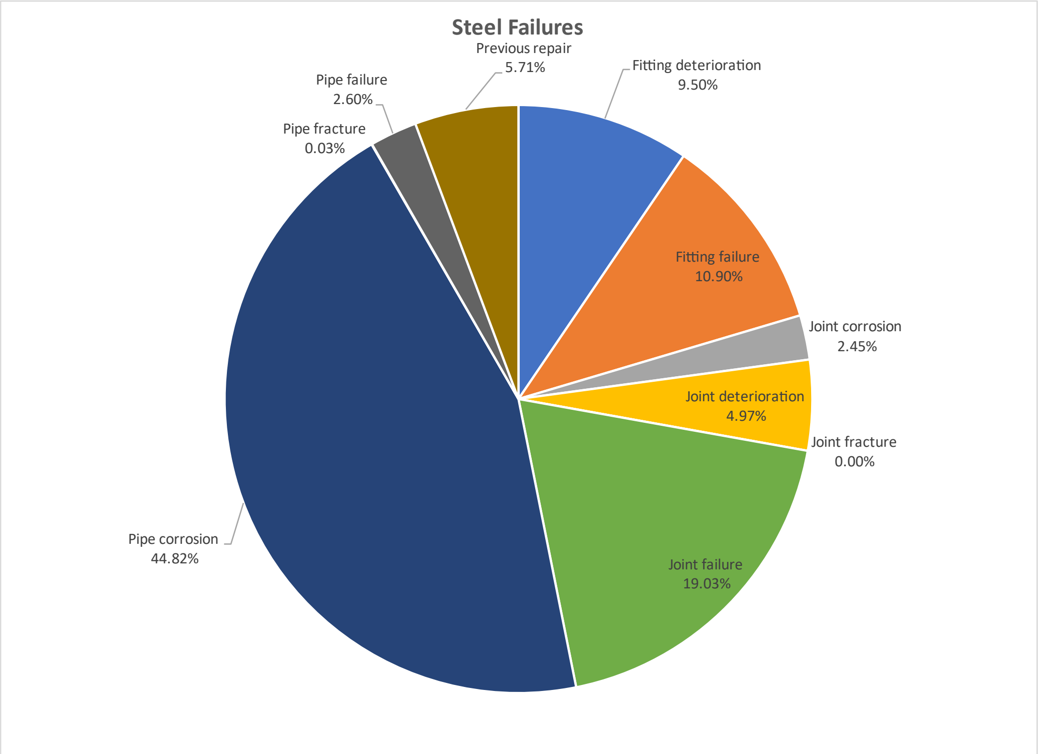

Figure 77 - Proportion of steel failures by cause, all GDNs

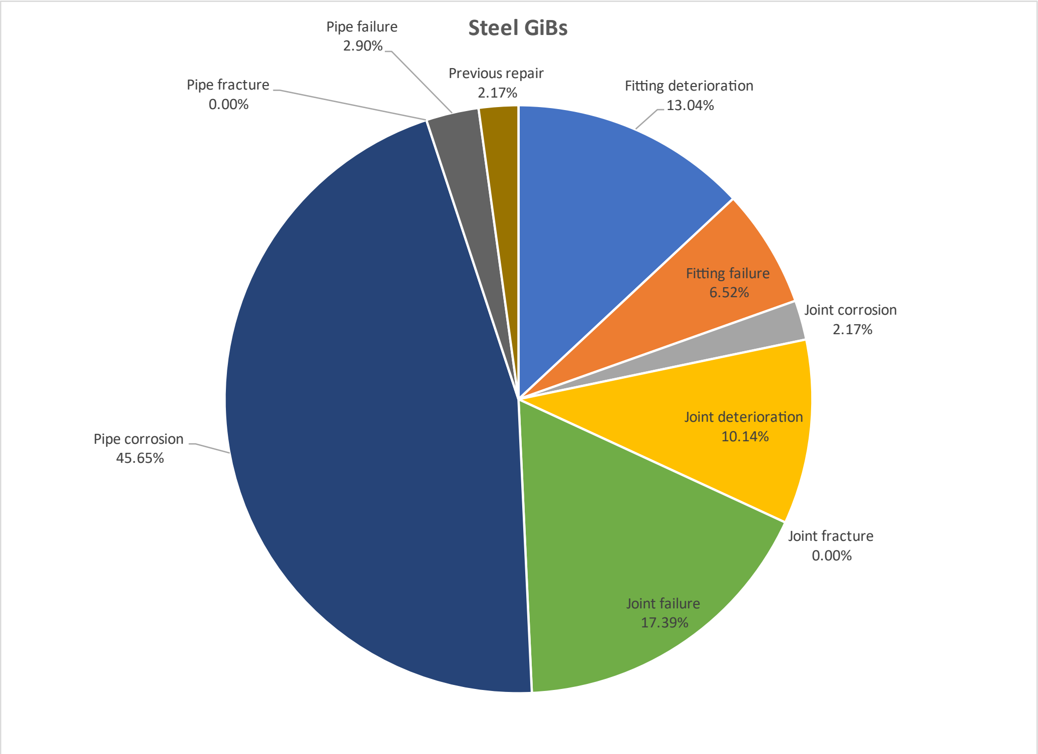

Figure 78 - Proportion of steel GiBs by cause, all GDNs

Table 4 – Summary of failure and GiB rates by type

Material	Failures/km/year	GiBs/failure
Total failures	0.596	0.056
All cast/spun iron	0.673	0.060
Cast/spun iron fractures	0.098	0.115
Cast/spun iron joints	0.373	0.056
Cast/spun iron corrosions	0.042	0.050
Cast/spun iron fittings	0.143	0.042
All ductile iron	0.400	0.053
Ductile iron fractures	0.025	0.132
Ductile iron joints	0.175	0.053
Ductile iron corrosions	0.101	0.051
Ductile iron fittings	0.085	0.034
All steel	0.532	0.035
Steel fractures	0.000	-
Steel joints	0.140	0.039
Steel corrosions	0.252	0.036
Steel fittings	0.108	0.034

Table 5 – Summary of current MRPS Qualifying failure and GiB rates

Material	Failures/km/year	GiBs/failure
Total failures	0.596	0.056
All cast/spun iron	0.673	0.060
Cast/spun iron fractures	0.098	0.115
All ductile iron	0.400	0.053
Ductile iron corrosions	0.308	0.057
Ductile iron barrel corrosions	0.126	0.067
Ductile iron bolt corrosions	0.182	0.051
All steel	0.532	0.035
Steel corrosions (incl. fitting deterioration)	0.289	0.038

6 SEASONAL TRENDS

To investigate the seasonal trends and effect of temperature on the number of failures and GiBs from ferrous mains, the number of failures and GiBs in each month have been plotted against the mean temperature across that month. The temperature data used for this analysis is the monthly mean air temperature across the UK extracted from the Met Office National Climate Information Centre. In Section 5.1 the charts for failures are presented, whilst in Section 5.2 the relationship between GiBs and temperature is explored.

6.1 Failures

6.1.1 Failure summaries

Figure 79 to Figure 83 show the seasonal trend in failures over the last five years; Cadent data has been plotted separately to the other three GDNs due to scaling. Across all GDNs and diameter tiers, failures occur at the highest rate in the months when the temperature is lowest. The trend also indicates that the correlation applies such that a colder winter will produce more failures than a warmer winter. The width of the failures peaks each year indicate how long the cold weather during winter continued.

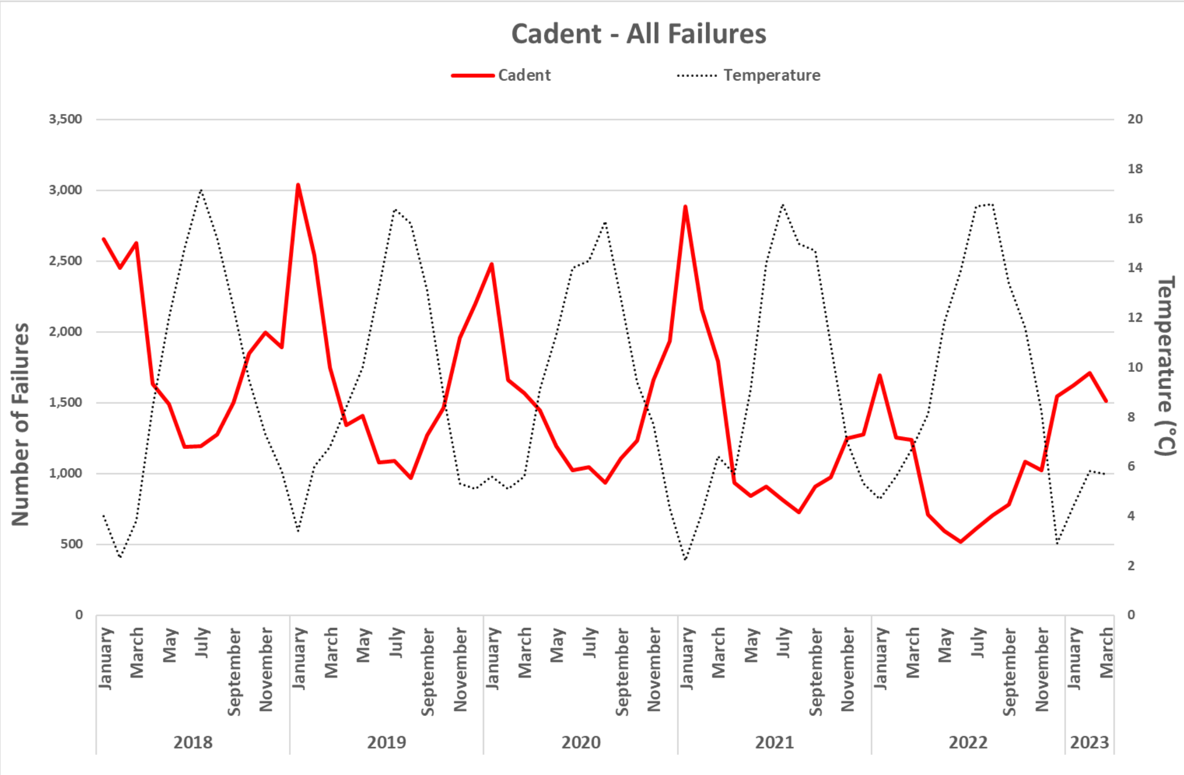

Figure 79 – Failures by Month, Cadent

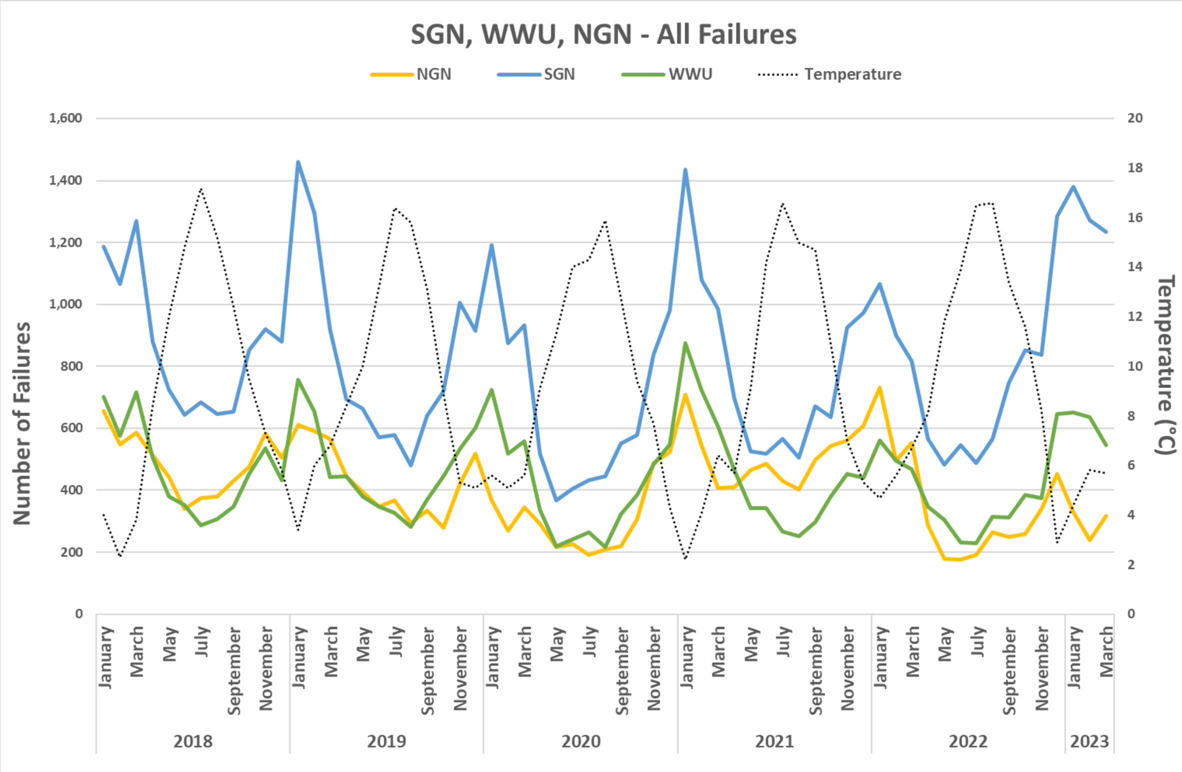

Figure 80 – Failures by month, SGN, NGN, WWU

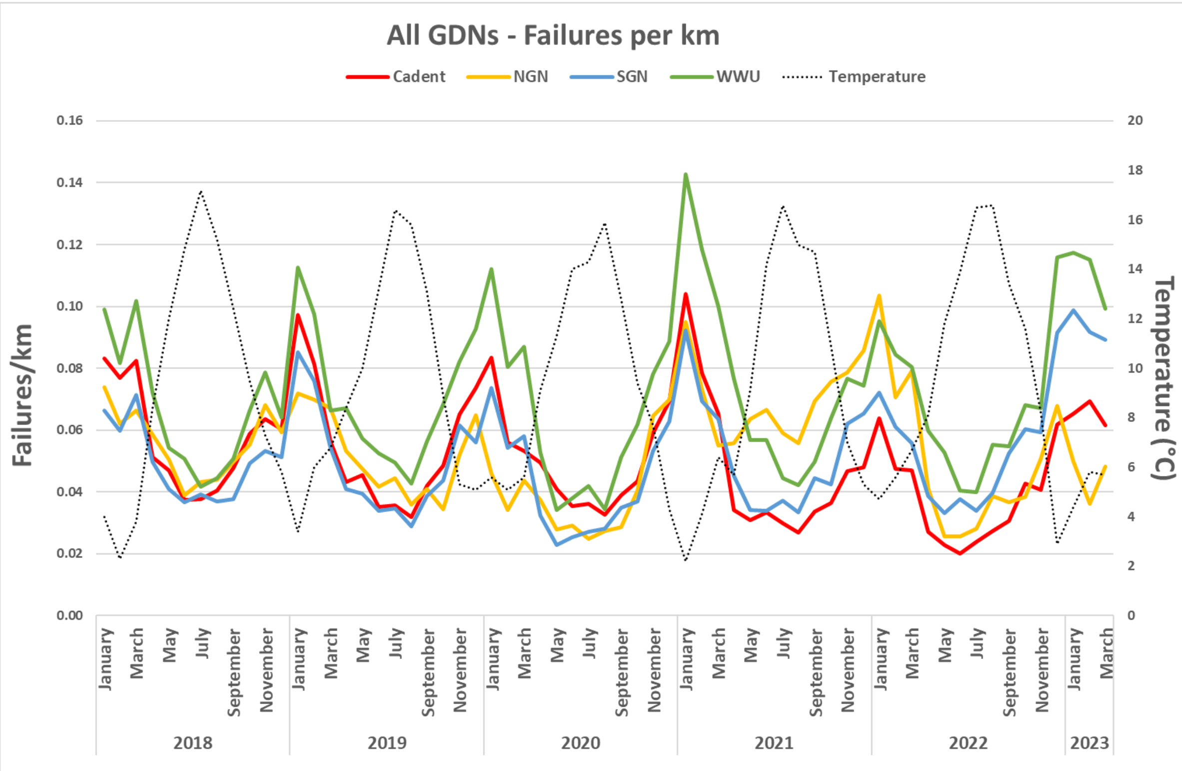

Figure 81 – Failures per km by month, all GDNs

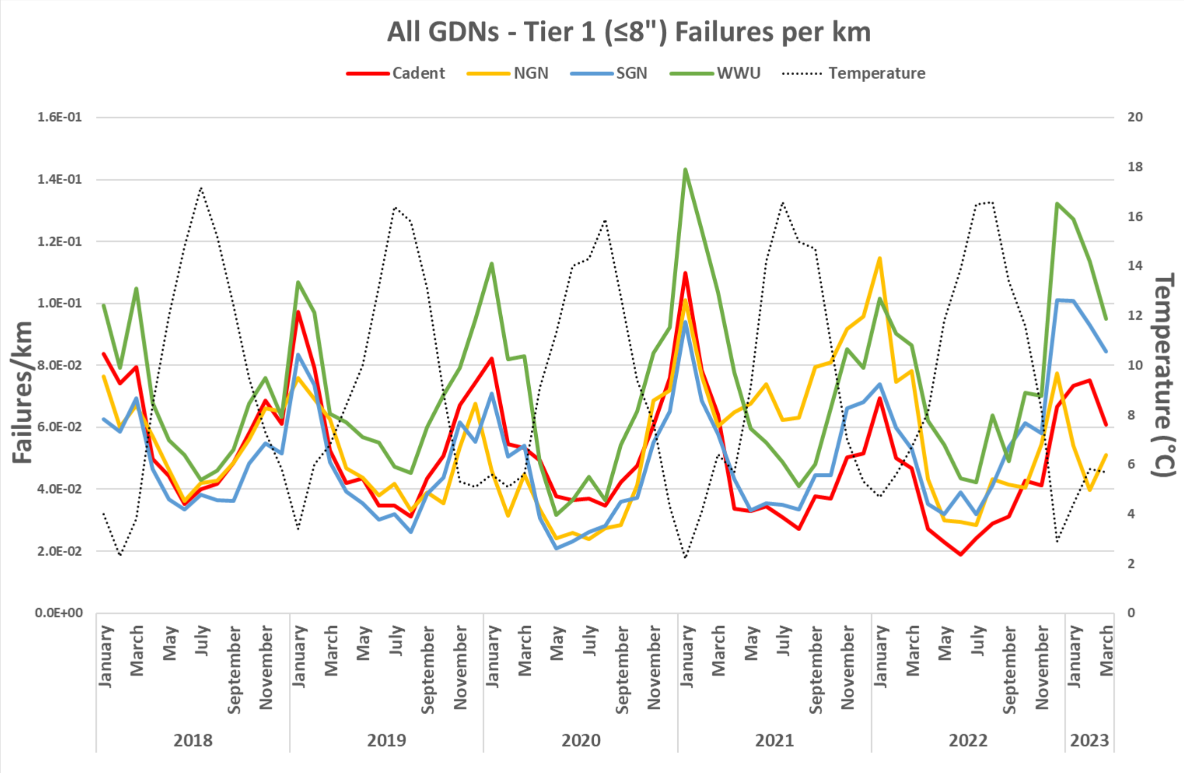

Figure 82 – T1 Failures per km by month, all GDNs

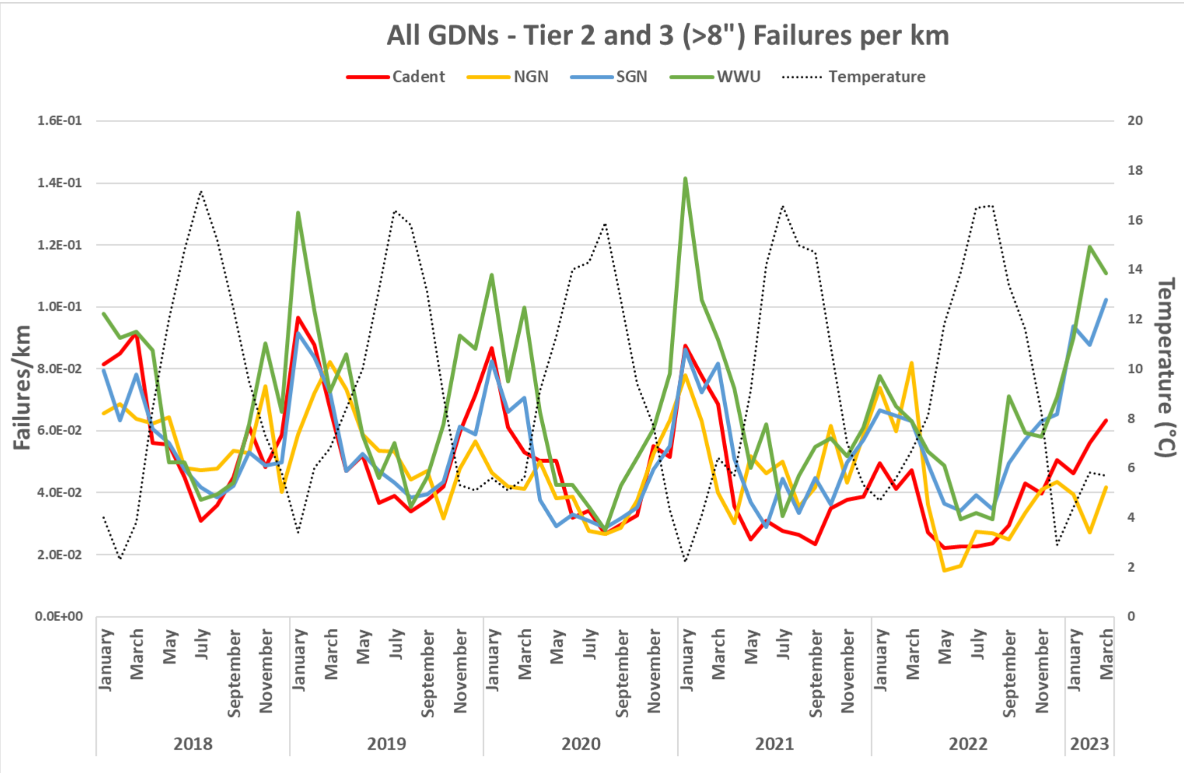

Figure 83 – T2/3 Failures per km by month, all GDNs

6.1.2 Failure type analysis

To investigate which failure types are affected most by temperature, monthly failure rates were plotted against the average temperature in that month for different failure modes. Failure data dating back to 2013 across all GDNs was collated to calculate failure rates for each month which have been plotted against the mean air temperature across the UK in that month. The results for cast/spun iron fractures, ductile iron corrosions and steel corrosions are shown in Figure 84 to Figure 87, noting that the temperature has been rounded down to the nearest whole number to allow for a discrete view of the data.

Figure 84 shows that the cast/spun iron fracture rate remains fairly consistent for temperatures greater than 7°C, however there is a slight increase in fracture rate when the temperature drops to 7°C, then a further increase when the temperature decreases to 4°C. Figure 85 and Figure 86 show that the ductile iron corrosion rate increases gradually with decreasing temperature. Figure 87 shows that the steel corrosion rate remains consistent for temperatures greater than 10°C, but has a slight increasing trend as the temperature decreases below 10°. The peak at 10°C is believed to be due to limited data since there are fewer months with an average monthly temperature of 10°C.

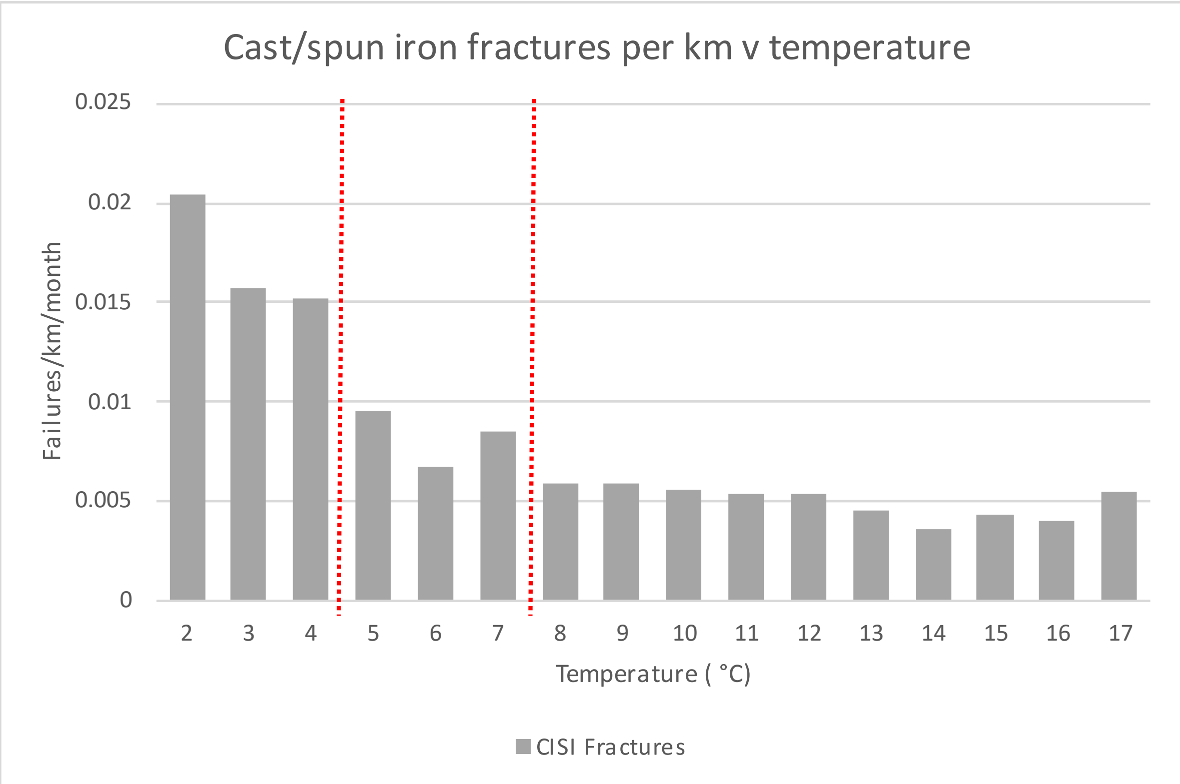

Figure 84 - Monthly cast/spun iron fractures per km against temperature, all GDNs

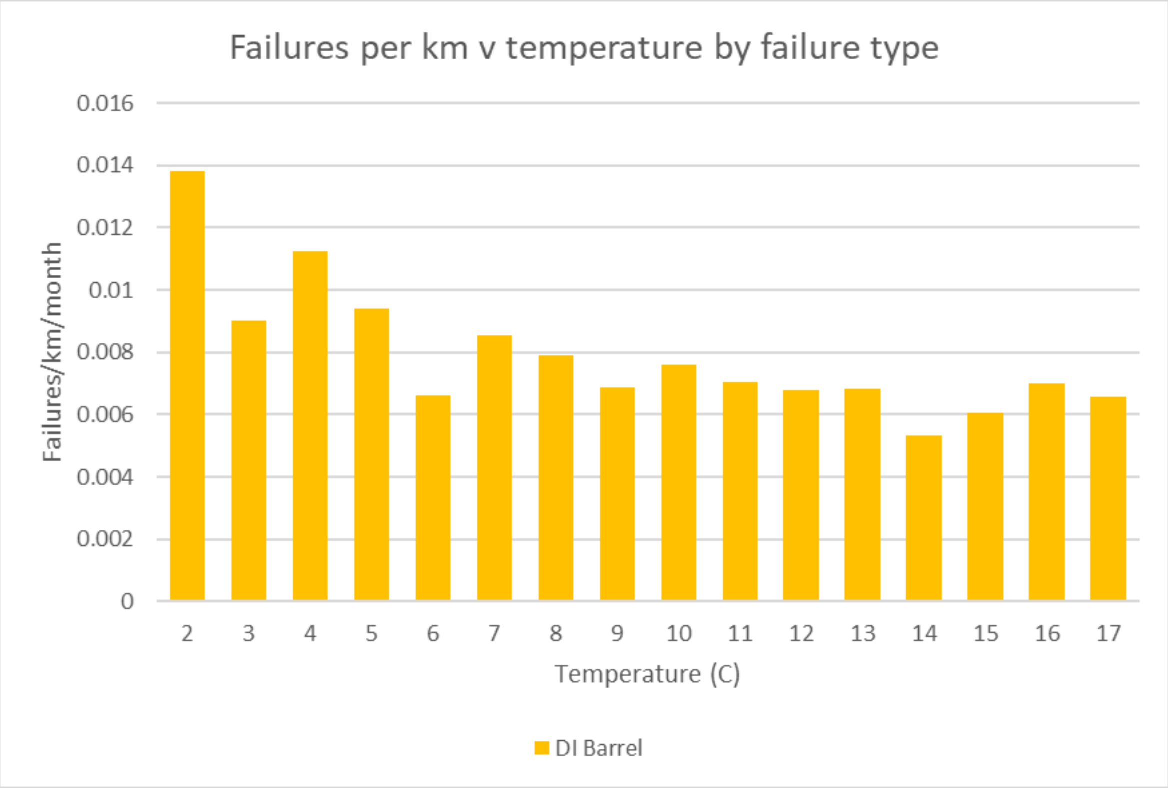

Figure 85 - Monthly ductile iron barrel corrosions per km against temperature, all GDNs

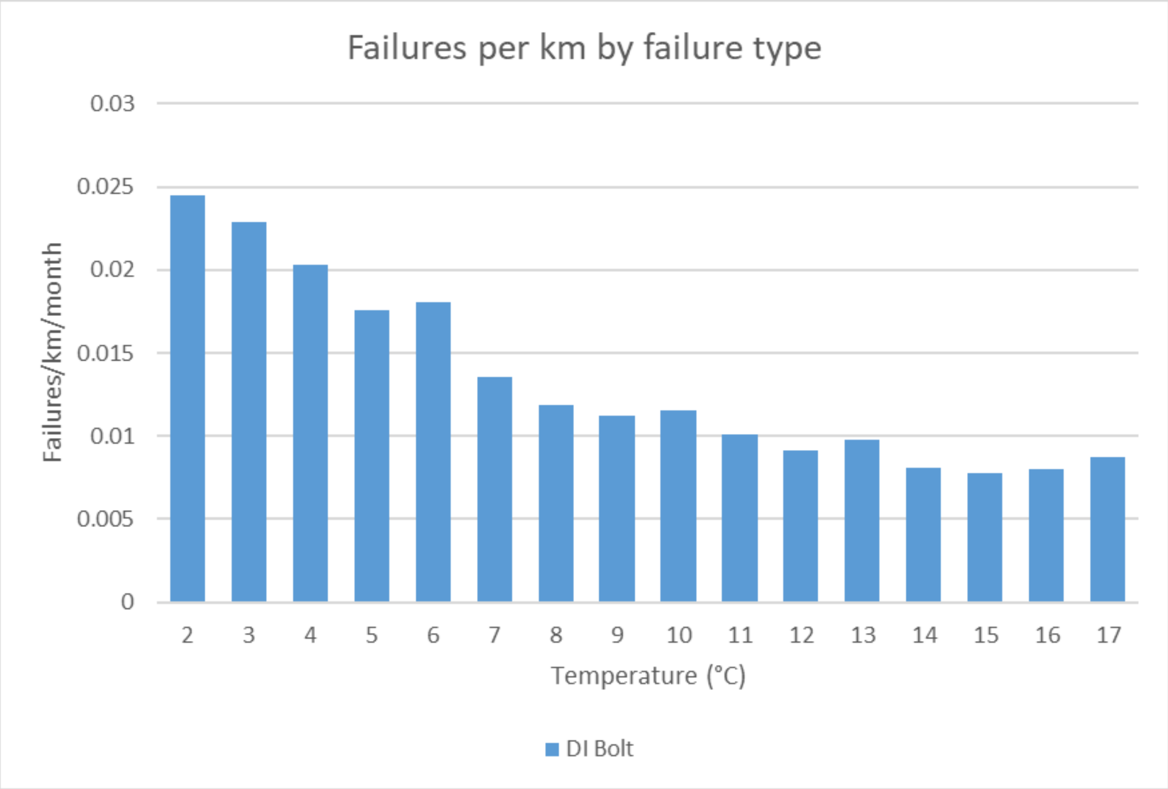

Figure 86 - Monthly ductile iron bolt corrosions per km against temperature, all GDNs

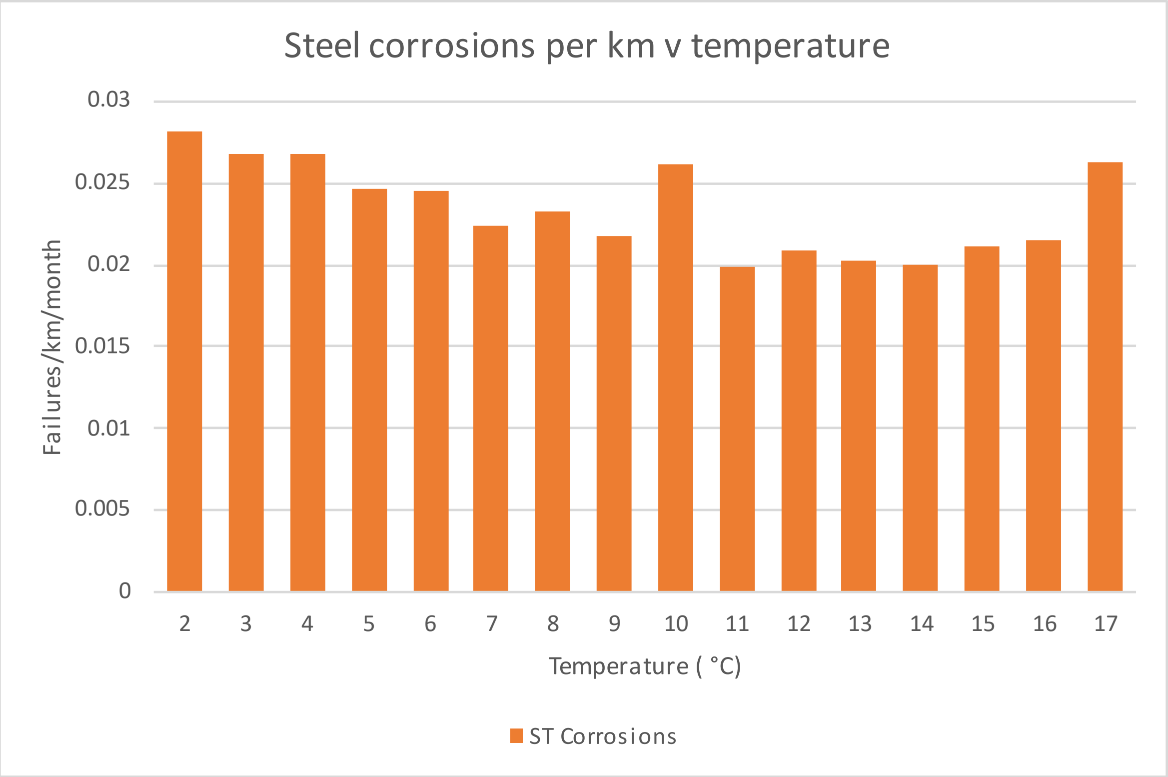

Figure 87 - Monthly steel corrosions per km against temperature, all GDNs

6.2 GiBs

Figure 88 to Figure 92 show the seasonal trend in GiBs over the last five years. The GiB trends follow the failure trends directly, with more GiBs occurring when the weather is colder. Figure 90 shows that it is more likely that a failure causes a GiB during the colder months, indicating that temperature affects not only the likelihood of a failure occurring, but also the likelihood of gas ingress when the failure event occurs. The winter of 2022/23 shows a higher rate of GiBs per failure than previous comparable winters (Figure 90), which is of concern.

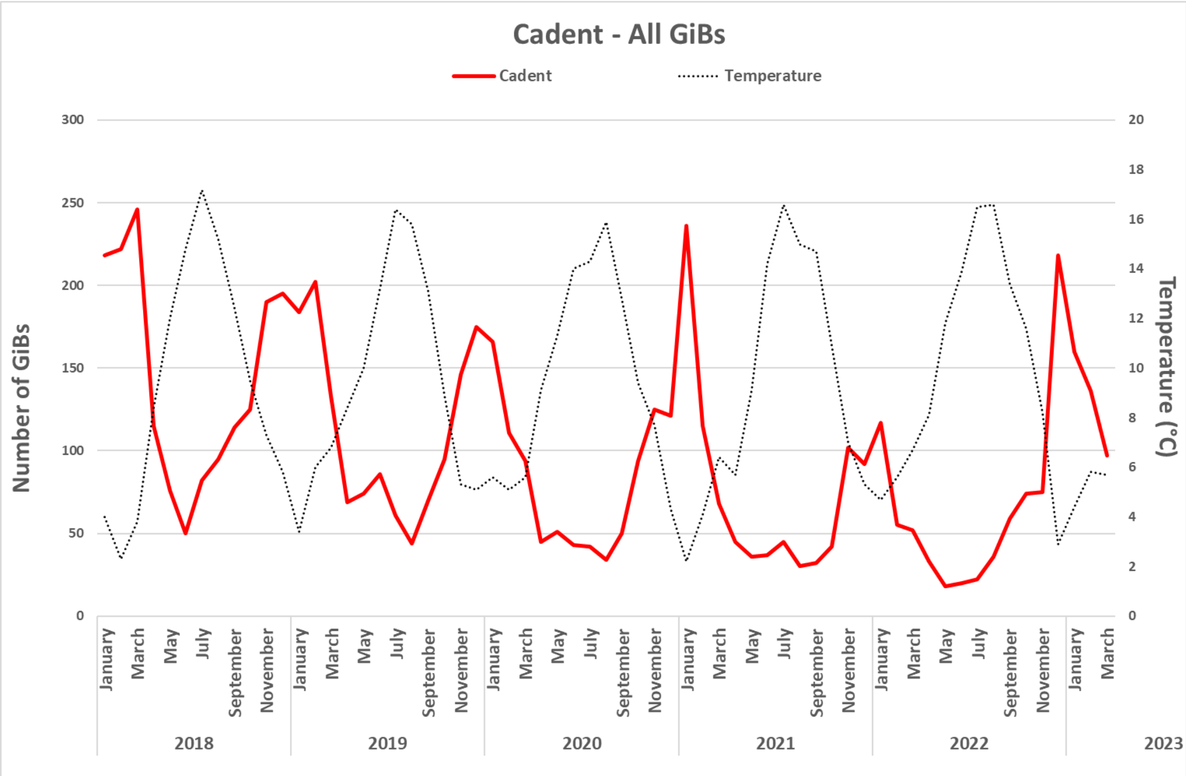

Figure 88 – GiBs by Month, Cadent

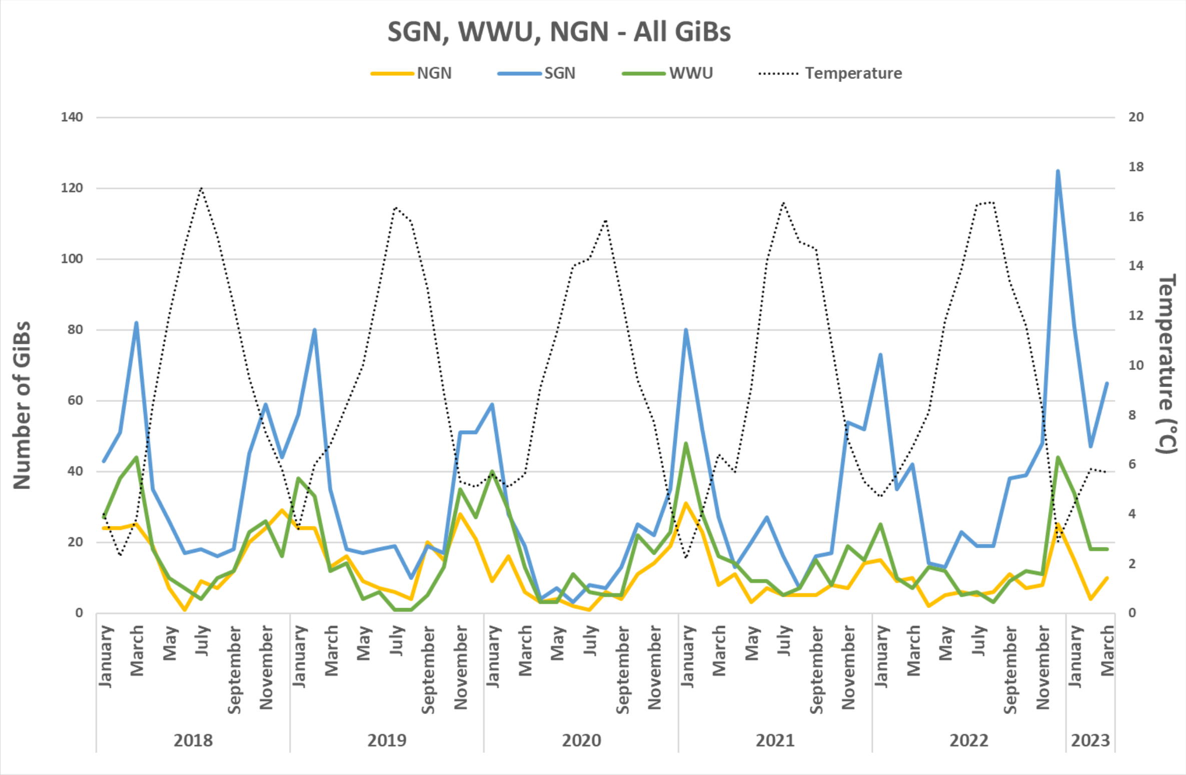

Figure 89 – GiBs by month, SGN, NGN, WWU

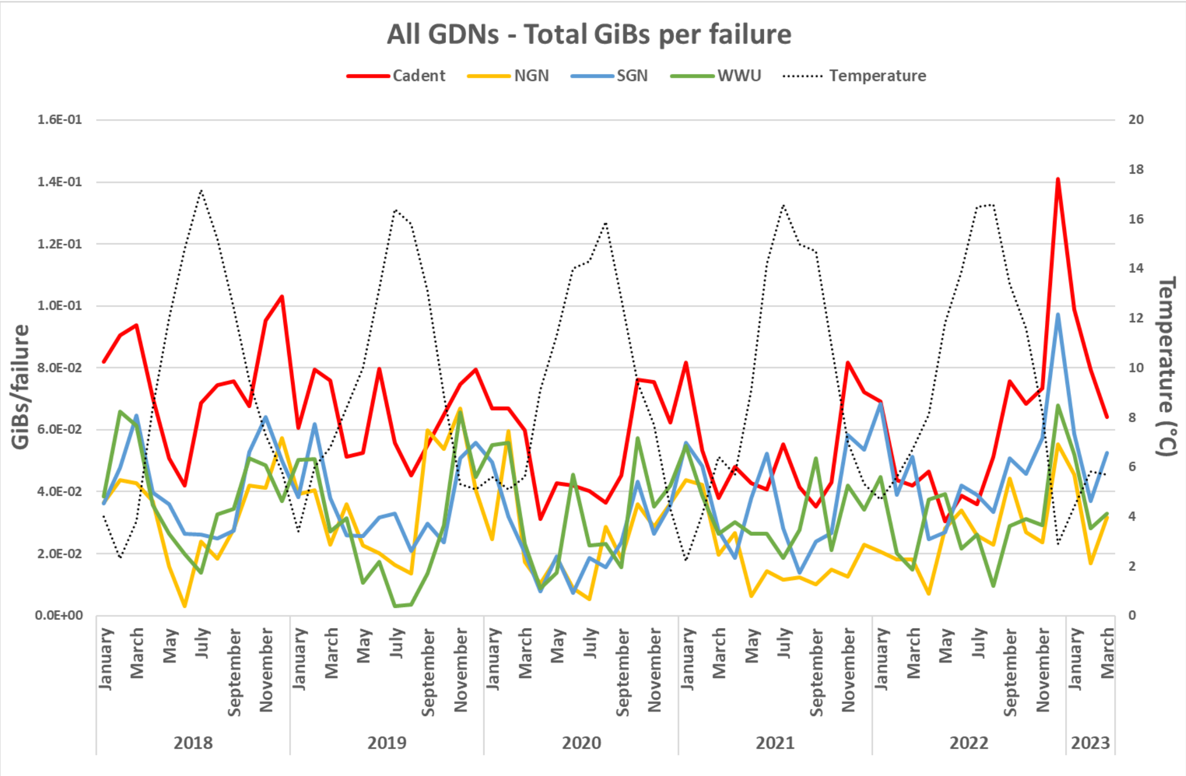

Figure 90 – GiBs per failure by month, all GDNs

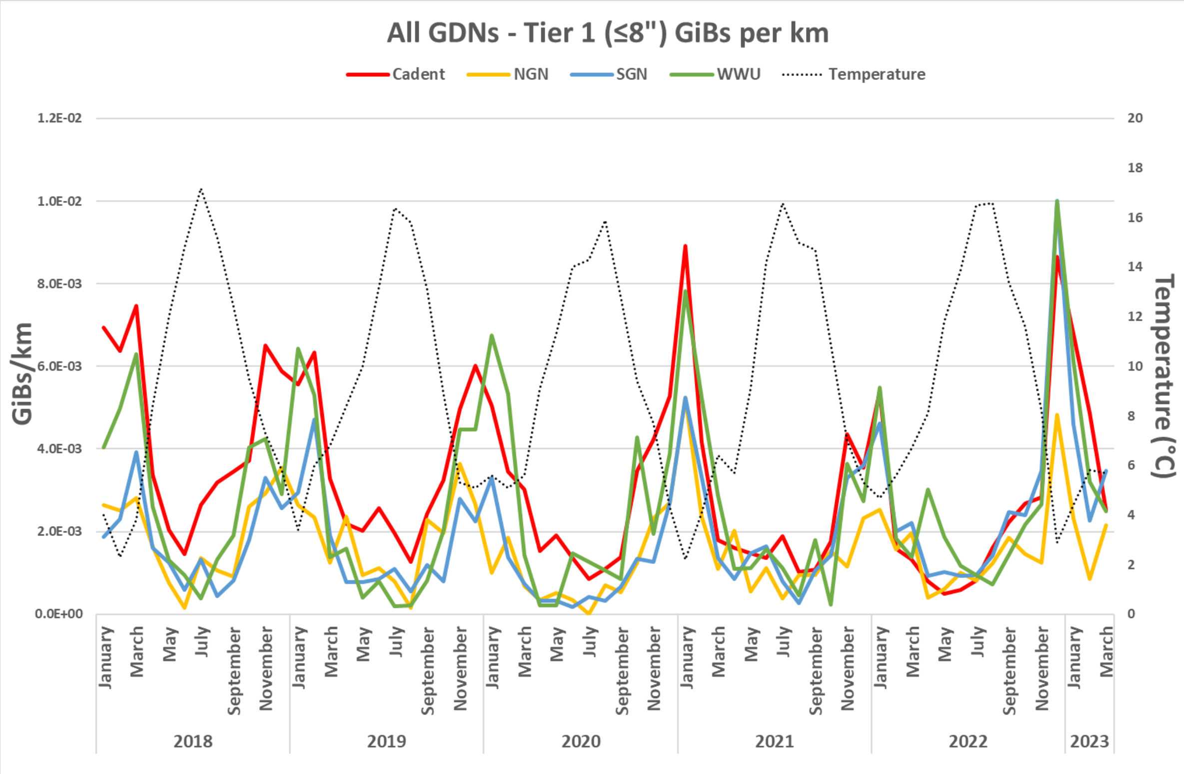

Figure 91 – T1 GiBs per km by month, all GDNs

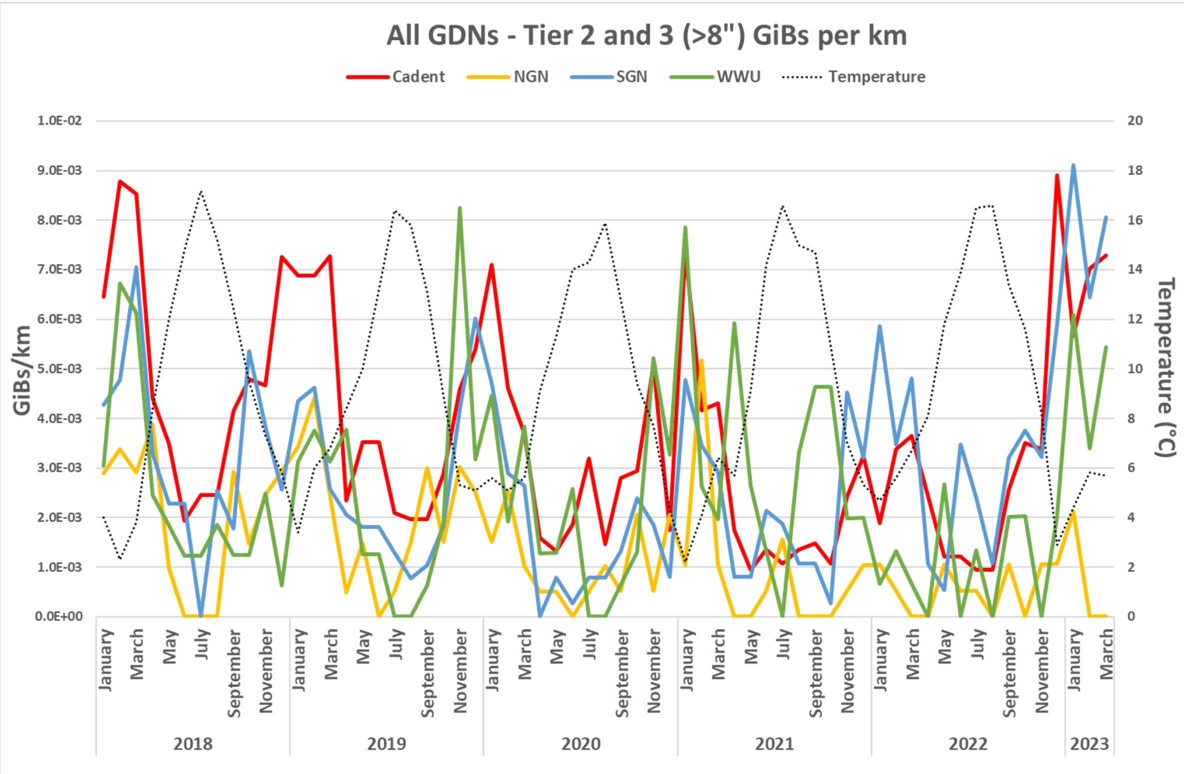

Figure 92 – T2/3 GiBs per km by month, all GDNS

7 GIB PREDICTIONS

As part of the trend analysis report for 2023, the GDNs have requested the calculation of predicted GiB numbers using MRPS risk scores. These scores have been calculated and compared to actual annual GiB numbers to investigate the accuracy of the GiB predictions from MRPS.

7.1 Approach

The equation for calculating the number of predicted GiBs per year for one pipe is:

$$Predicted\ GiBs = \frac{Risk\ Score}{Consequence\ Factor} \times Pipe\ length$$

The consequence factor is dependent on cellar information and operating pressure, however since the asset data supplied for the trend analysis does not contain cellar information, consequence factors corresponding to 0% cellars and 100% cellars have been used to represent ‘worst case’ and ‘best case’ GiB levels. Ideally, the actual GiB values would lie in between the best and worse thresholds.

Due to the variance in annual GiB numbers, this calculation has been performed for 2021 and 2022 and a 2-year average has been used.

7.2 Results

In this section, the predicted GiBs are compared to both GiBs due to MRPS qualifying failures and total GiBs (excluding interference). The results are presented by material and tier.

7.2.1 MRPS Qualifying GiBs

The predicted GiBs compared to actual MRPS qualifying GiBs for each material are presented in Figure 93 to Figure 95. Note that the values for actual GiBs should sit between the two predicted values (with and without cellars) to indicate that MRPS is predicting the GiB numbers correctly.

Figure 93 shows that MRPS is currently underpredicting the number of MRPS qualifying GiBs from cast iron mains. This is because the GiB per cast iron fracture rate, shown in Figure 51, has increased since the last coefficient update, which used data from 2014 to 2018. Figure 94 shows that, for ductile iron mains, MRPS is currently predicting tier 1 GiBs correctly, slightly overpredicting tier 2 GiBs, and slightly underpredicting tier 3 GiBs. There are only a small number of large diameter ductile iron mains, and hence a low absolute number of GiBs, which may not be statistically significant. The predictions for these pipes may improve with a coefficient update however, due to low GiB levels, these pipes are not a major concern. Figure 95 shows that MRPS is currently overpredicting the number of MRPS qualifying GiBs from steel mains across all tiers. This is because the average GiB per steel corrosion rate, shown in Figure 67, has decreased since the last coefficient update.

It is recommended that a coefficient update should be undertaken to bring the cast iron and steel predictions in line with actual levels.

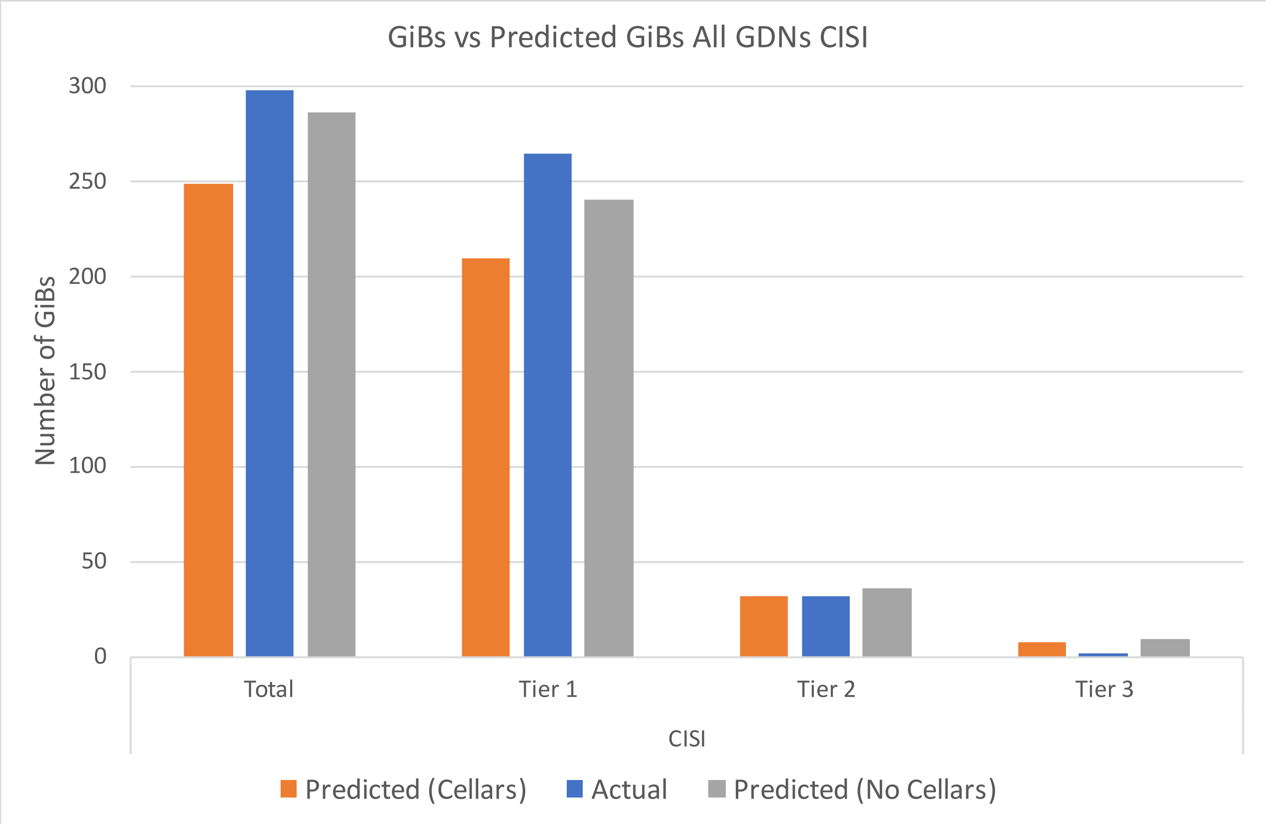

Figure 93 - Predicted GiBs vs actual MRPS qualifying GiBs for cast and spun iron

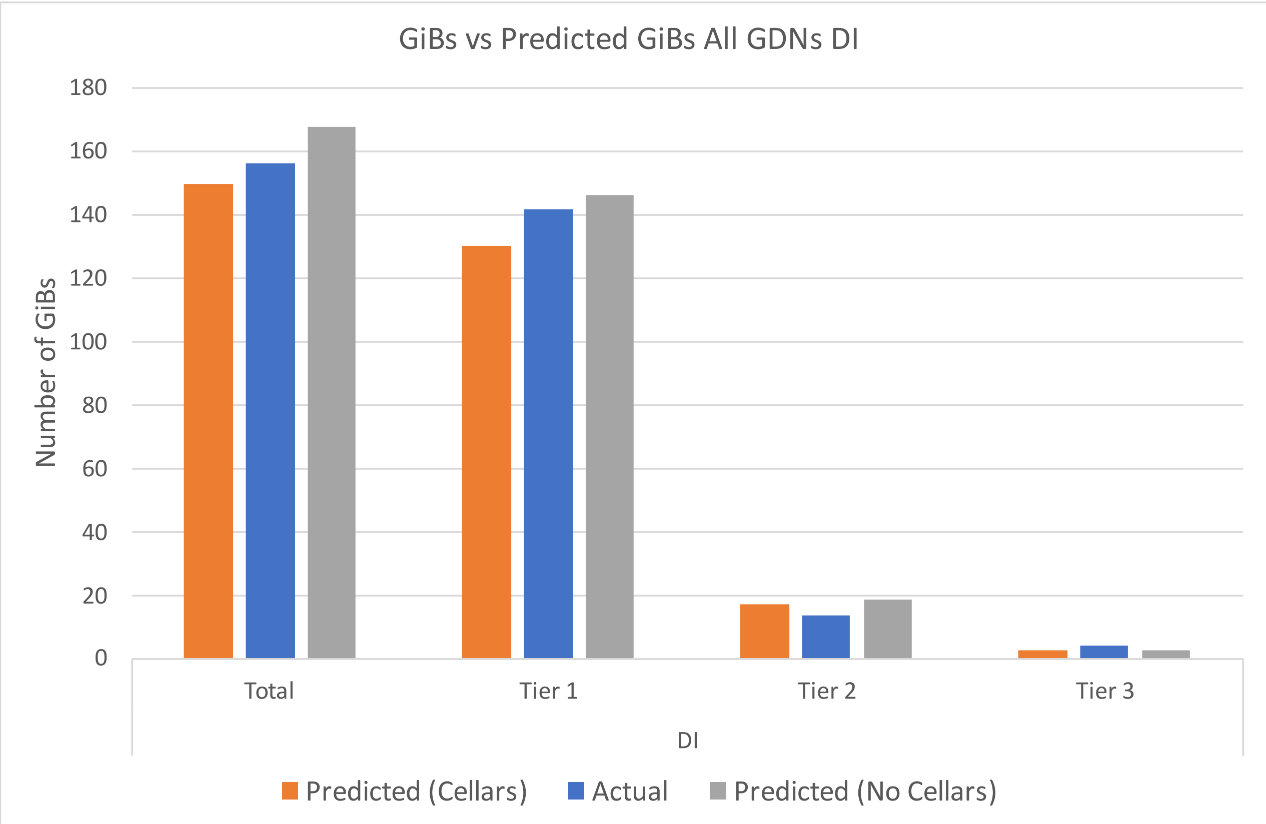

Figure 94 - Predicted GiBs vs actual MRPS qualifying GiBs ductile iron

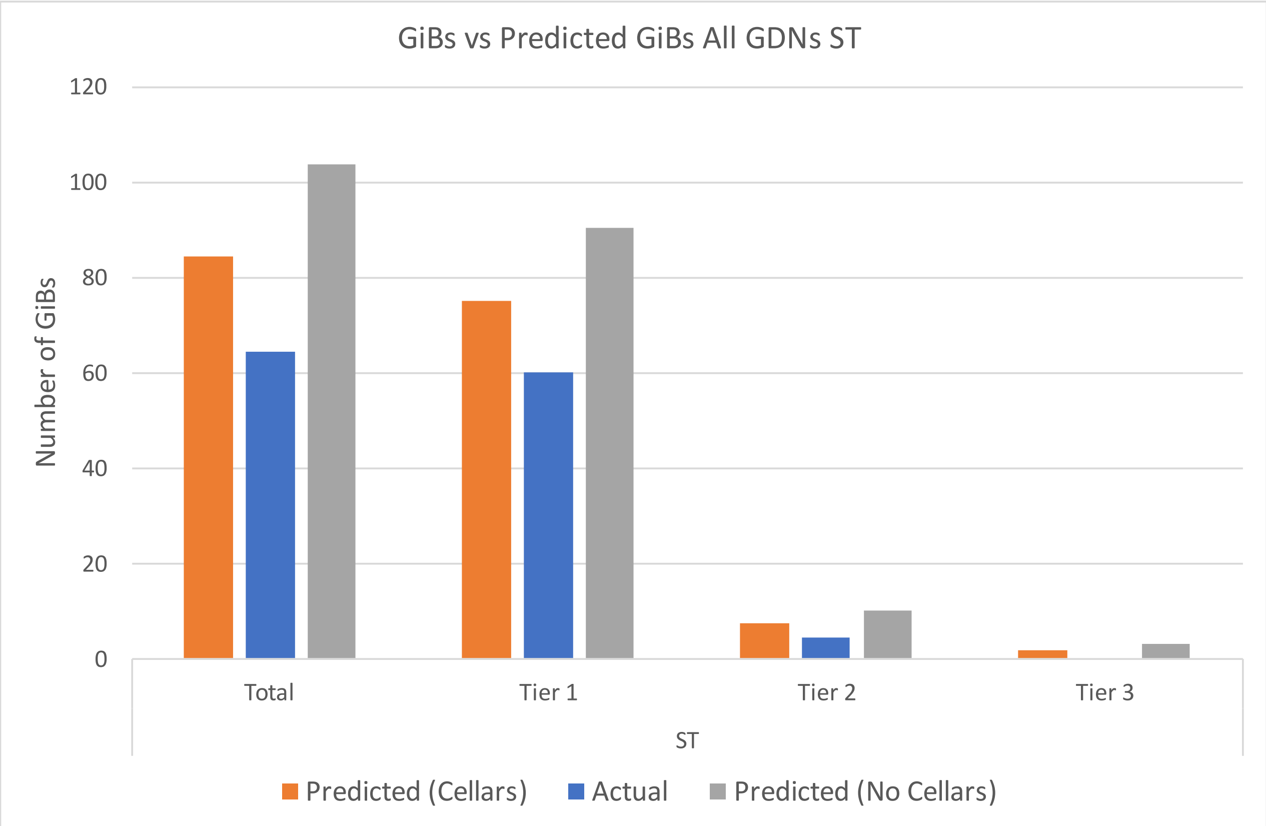

Figure 95 - Predicted GiBs vs actual MRPS qualifying GiBs steel

7.2.2 Total GiBs

MRPS predicted GiBs compared to actual total GiBs for each material are presented in Figure 96 to Figure 98. MRPS does not include all failure modes, so it is anticipated that this comparison will demonstrate that MRPS underpredicts the number of GiBs; these graphs are presented to demonstrate the scale of the underprediction.

When comparing cast iron MRPS GiB predictions to actual total cast iron GiB levels, Figure 96 shows that MRPS is severely underpredicting. This is because the current model is based on cast iron fractures, which only comprise 28% of GiBs. To improve this prediction, it is recommended that the cast iron risk model is updated to include corrosions and joint failures.

In terms of ductile iron GiB levels, Figure 97 shows that MRPS is slightly underpredicting. An update to the structure of the ductile iron risk model to introduce a separate Gas Ingress Factor (GIF) for each failure mode could improve these predictions.

Figure 98 shows that, for steel mains, MRPS is underpredicting total GiB levels. However, this should be balanced against the conclusion from the previous section that MRPS-qualifying steel failures are being overpredicted, meaning that a greater proportion of non-MRPS failures are being underpredicted than Figure 98 shows. To improve this prediction, it is recommended that the steel risk model is updated to include joint failures.

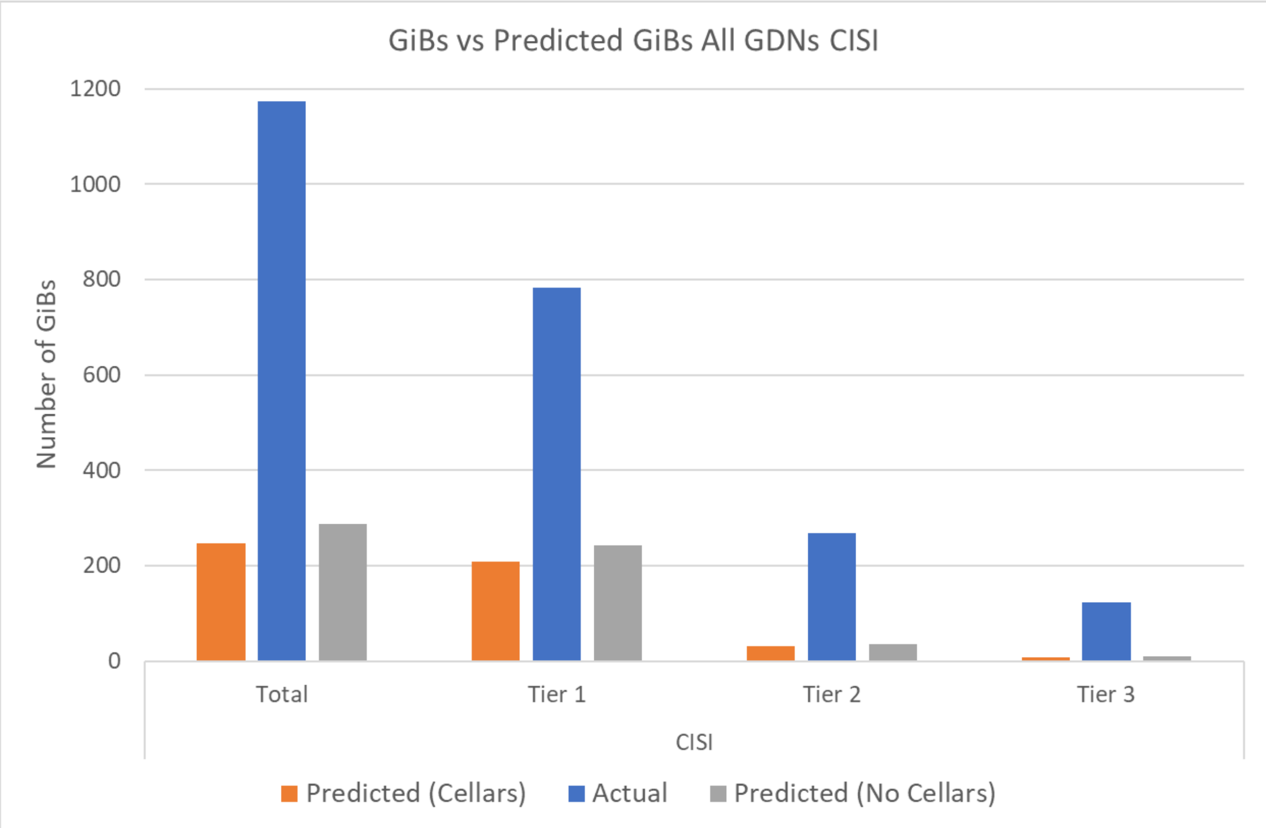

Figure 96 - Predicted GiBs vs actual total GiBs cast and spun iron

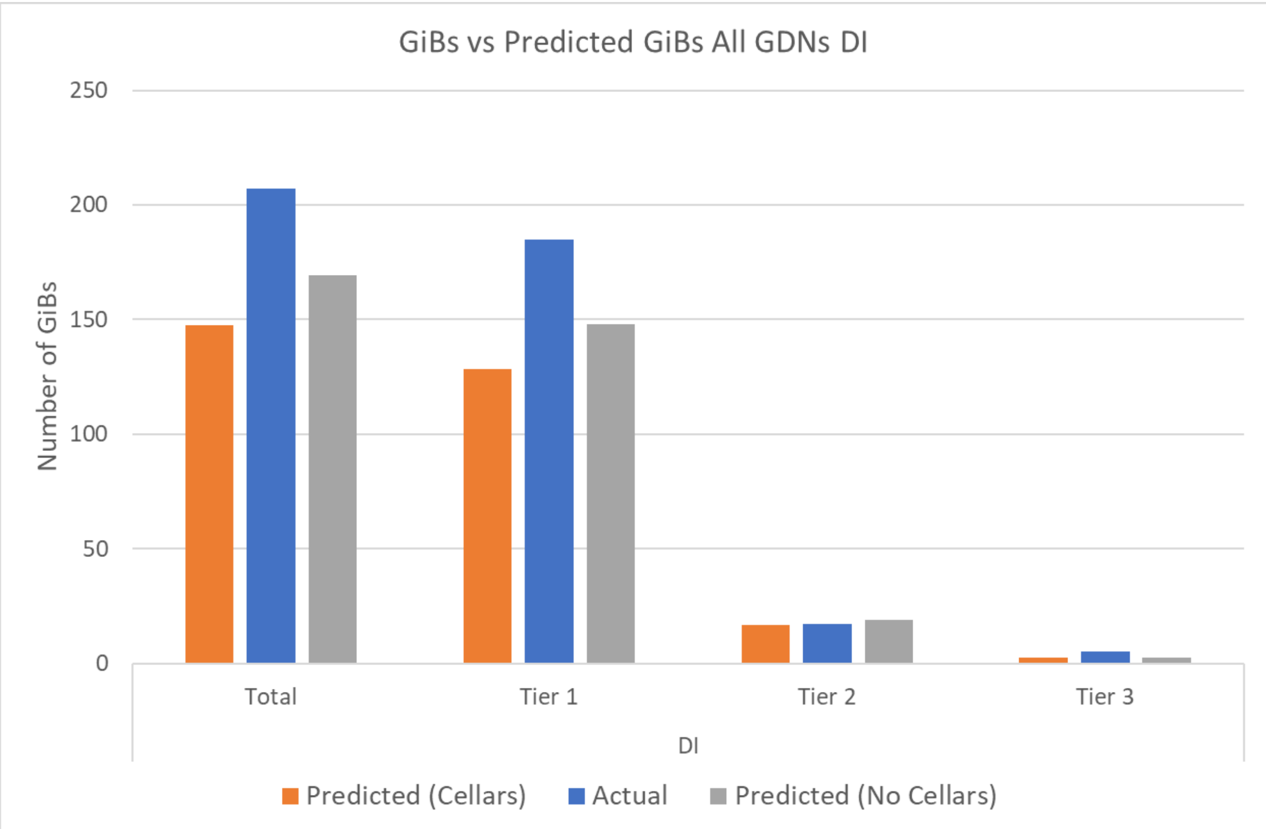

Figure 97 - Predicted GiBs vs actual total GiBs ductile iron

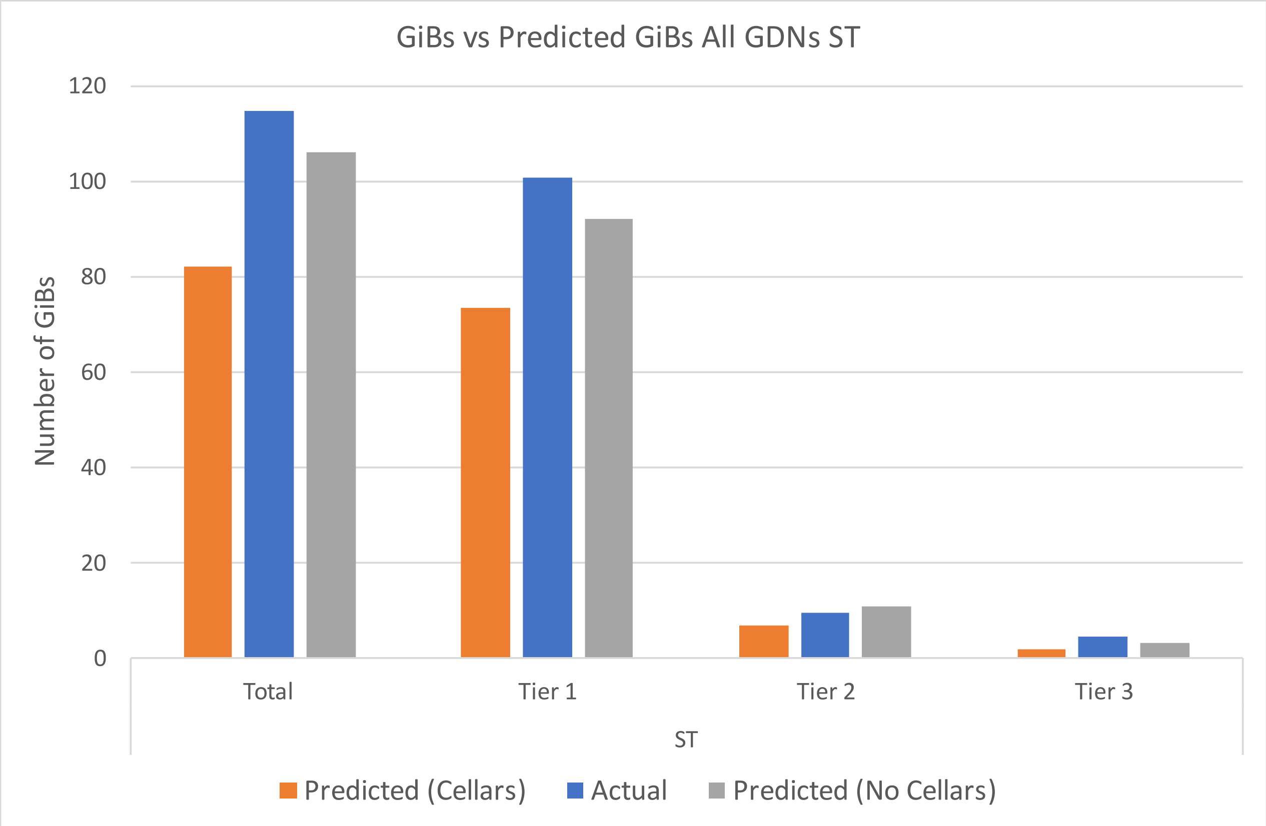

Figure 98 - Predicted GiBs vs actual total GiBs steel

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[redacted]

[redacted]

[redacted]

Figure 99 – [redacted]

9 CONCLUSIONS

The following conclusions can be drawn from this analysis:

Total failures

- The decreasing trend in number of failures per year on ferrous distribution pipes has continued for Cadent and NGN. The number of failures per year appears to be levelling off for WWU and has increased for SGN.
- The failure rates for SGN and WWU have both increased in 2022, with SGN having their highest failure rate recorded as part of this analysis (since 2013). Meanwhile the failure rates for Cadent and NGN have decreased, with both having their lowest failure rate recorded as part of this analysis.
- The average total failure rate was 0.596 failures/km/year in 2022 (the range by network is 0.425 – 0.906 failures/km/year).
- The GiBs/leak rate has increased across all GDNs. In 2022, Cadent and WWU had their highest GiBs per leak since 2018, whilst SGN has their highest GiBs per leak recorded as part of this analysis (since 2013).
- The average total GiB rate was 0.056 GiBs/leak in 2022 (the range by network is 0.025 – 0.094 GiBs/leak).
- In terms of specific networks, WWU continues to have the highest overall failure/km rates, though both SGN networks have a major uptick, with the rate of failure in the SGN Scotland network rising to meet the rate of failure in the Cadent North London network.
- Cadent North London has the highest GiB per leak rate, whilst SGN Scotland and NGN have the lowest.

Failures and GiBs by material

- In 2022, there has been an increase in GiBs/leak rates for all materials, though this is still in line with historic levels.
- WWU failure rates for cast/spun iron and ductile iron mains remain high; Cadent have high GiB rates for cast/spun iron and ductile iron mains.
- Cast/spun iron failures remain over 1.5 times as frequent as ductile iron failures.
- The GiBs/leak rate is greatest for cast/spun iron (0.060 GiB/failure), with ductile iron slightly lower (0.053 GiB/failure) and steel the lowest (0.035 GiB/failure).

Failures and GiBs by type (fractures, corrosions and joints)

- Cast/spun iron fractures are becoming less frequent and represent a small proportion of overall failures, however they have the highest GiB rate (0.115 GiB/failure) for specific failure types.
- Joint failures are now the predominant failure mode for cast/spun iron.
- Fractures comprise 13.4% of ductile iron GiBs but are currently collated with corrosion failures in MRPS, even though these have a much lower GiB rate.
- Joint failures comprise 26.5% of steel pipe failures but are not currently included in MRPS.

Qualifying Failures

- Following a slight dip in 2021, it appears the number of MRPS qualifying failures is remaining between 0.1 and 0.2 failures per km per year for all GDNs.
- This trend is also consistent for non-MRPS failures indicating that basing replacement on the failures covered by MRPS is also successful in reducing the rate of failures that are not included.

- Overall, only 28.3% of ferrous mains failures qualify under MRPS.

Seasonal Trends

- The seasonal trends show a large variance between the number of failures and GiBs seen during winter months and summer months.
- This trend is consistent across failure rate, GiBs per failure and GiBs per km, indicating that cold weather increases both the likelihood of a failure occurring and the probability that the escaped gas will track into a building.
- Failure type analysis shows that the cast/spun iron fracture rate remains fairly consistent for temperatures greater than 7°C, but slightly increases when the temperature drops to 7°C, then increases further when the temperature decreases to 4°C. Meanwhile, the ductile iron corrosion rate decreases gradually with increasing temperature, and the steel corrosions rate remains consistent at temperatures greater than 10°C, but has a slight increasing trend as the temperature decreases below 10°.

GiB Predictions

- The MRPS risk model is currently underpredicting GiB levels from cast iron fractures, and overpredicting GiB levels from steel corrosions. It is recommended that, to bring the prediction in line with actual levels, a coefficient update should be undertaken to update the current factors.
- In addition, when considering all failure types (except interference damage), MPRS underpredicts GiBs for all three materials. This is a particular issue for the cast/spun iron model, which is currently based only on fractures which only comprise 27.6% of cast iron GiBs. It is recommended that corrosions and joint failures are introduced into the cast/spun iron risk model and joint failures into the steel model to allow more accurate risk predictions.

[redacted]

- [redacted]

10 RECOMMENDATIONS

The above analysis of failure types and GiB rates has identified the need for some updates to the MRPS models, specifically:

1. The cast/spun iron model should be updated to include corrosion and joint failures.
2. The ductile iron model should be updated to separate fractures from corrosions.
3. The steel model should be updated to include joint failures.
4. A coefficient update should be undertaken to ensure that predicted GiBs closely align to recent GiB rates.

11 APPENDIX A – LEAKAGE CODES

Leakage codes are used to determine the appropriate failures to include in the above analysis. They are detailed below by GDN, as each company uses variations on the original codes.

11.1 Cadent

Cast iron fractures (CI and SI)

Leakage Cause	Leakage Component
ST (Fracture)	PI (Pipe)

Ductile iron barrel corrosions (DI)

Leakage Cause	Leakage Component
CO	PI
ST	PI

Ductile iron bolt corrosions (DI)

Leakage Cause	Leakage Component
CO (Corrosion)	BO (Bolts)
CO	JM (Joint mechanical)
CO	PR (Previous External Repair)
CO	PG (Plug)
CO	SN (Syphon)
CO	FI (Fitting)
CO	VA (Valve)
DT (Deterioration)	PG (Plug)
DT (Deterioration)	FI (Fitting)
DT (Deterioration)	SN (Syphon)
DT (Deterioration)	JM (Joint mechanical)
ST	JM (Joint mechanical)
FA	JO (Joint)

Steel corrosions (ST)

Leakage Cause	Leakage Component
CO (Corrosion)	PI (Pipe)
CO	SN (Syphon)
CO	FI (Fitting)
DT	FI (Fitting)
DT	SN (Syphon

11.2 NGN

Cast iron fractures (CI and SI)

Leakage Cause	Leakage Component
ST	PI

Ductile iron barrel corrosions (DI)

Leakage Cause	Leakage Component
CO	PI
FA	PI
ST	PI

Ductile iron bolt corrosions (DI)

Leakage Cause	Leakage Component
CO	BO
CO	CL
CO	PG
CO	SP
CO	TE
CO	VA
FA	BO
FA	JO
FA	PG
FA	TE

Steel corrosions (ST)

Leakage Cause	Leakage Component
CO	SP
CO	PI
FA	TE
CO	TE
FA	PI
ST	PI

11.3 SGN

Cast iron fractures (CI and SI)

Leakage Cause	Leakage Component
ST	PI
CR	PI
LG	PI

Ductile iron barrel corrosions (DI)

Leakage Cause	Leakage Component
CO	PI
FA	PI
EB	PI
CR	PI
LG	PI
PH	PI
SC	PI
ST	PI

Ductile iron bolt corrosions (DI)

Leakage Cause	Leakage Component
CO	BO
CO	JC
CO	JO
CO	PC
CO	PG
CO	SP
CO	TE
CO	VA
FA	BO
FA	JO
FA	PG
FA	TE

Steel corrosions (ST)

Leakage Cause	Leakage Component
CO	SP
CO	PI
CO	TE
FA	TE
FA	PI
EB	PI
PH	PI
ST	PI
SC	PI

11.4 WWU

Cast iron fractures (CI and SI)

Leakage Cause	Leakage Component
ST	PI
FR	PI

Ductile iron barrel corrosions (DI)

Leakage Cause	Leakage Component
CO	PI
FA	PI
FR	PI
ST	PI

Ductile iron bolt corrosions (DI)

Leakage Cause	Leakage Component
CO	BO
CO	CL
CO	PG
CO	SP
CO	TE
CO	VA
FA	BO
FA	JO
FA	PG
FA	TE

Steel corrosions (ST)

Leakage Cause	Leakage Component
CO	SP
CO	PI
FA	TE
CO	TE
FA	PI
FR	PI
ST	PI

DNV

About DNV

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Whether assessing a new ship design, optimizing the performance of a wind farm, analyzing sensor data from a gas pipeline or certifying a food company's supply chain, DNV enables its customers and their stakeholders to make critical decisions with confidence.

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