Final report for the Agency for Data Supply and Infrastructure

Analysis of the Danish spectrum fee model

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1 Executive summary

This document is the final report of a study carried out by Analysys Mason on behalf of the Agency for Data Supply and Infrastructure (ADSI) to review the existing model for spectrum licence fees imposed in Denmark.

As part of its spectrum management activities, the ADSI imposes annual fees on spectrum licence holders. The current model for determining these fees has been in place since 2010. The ADSI now wishes to re-evaluate this model, with a view to putting in place an updated model.

The current fee model applies generally higher fees to lower-frequency spectrum, owing to its more favourable propagation characteristics (which tend to result in increased demand for and greater scarcity of this spectrum). However, recent technological advances (such as in 5G mobile systems) are leading to increased demand in other, higher-frequency, bands, meaning the historical position could be changing.

Analysys Mason was appointed by the ADSI to assist in this re-evaluation, drawing on its expertise in the telecoms sector to understand relevant technology and demand trends, as well as international benchmarks of licence fee regulation. Where any changes are recommended, we understand that these must result in a revenue-neutral outcome for the ADSI.

1.1 Overview of approach

After first analysing the current fee model in Denmark, we have gathered evidence, of two main types, relevant to the consideration of any changes to the fee model:

- Recent and future demand and technology trends, which may suggest changes in the nature of the demand for spectrum
- international benchmarks, focusing on the way in which other countries define similar fee models.

We have then analysed the available evidence in order to identify potential issues with the current fee model, identify potential approaches to addressing these issues, and through consideration of the likely implications of such changes, make recommendations for an updated fee model.

1.2 Current spectrum fee model in Denmark

The existing licence fee model in Denmark consists of two parts: a variable component and a smaller fixed component. The fees imposed vary depending on the type of licence and are republished annually, although the fees imposed have not changed in recent years. There is currently no mechanism for automatic adjustment for inflation, resulting in an effective reduction in fees in real terms over time.

Licences are allocated to one of nine fee classes (or groups) for the purposes of calculating the variable fee component. Fees imposed on fee classes 2 and 3 are calculated on the basis of the number of base station positions ('positions') operated by the licensee, while fee classes 1 and 4–9 are calculated for the licence as a whole and do not depend on the number of positions. The allocated fee class depends both on the technology and the geographical scope of the licence, while variation in the frequency of assigned spectrum is accounted for within the fee classes. Each frequency band is assigned a 'band-value factor' that is used to weight the fee appropriately between frequency bands in light of variation in the usefulness of different frequencies.

As part of our work, we have examined the appropriateness of both the frequency band breaks, as well as the band-value factors within each fee class, in light of demand and technology trends, as well as international benchmarking. Other factors have also been investigated, such as the provisions for licensing at sea and the impact of replacing the fixed component of the fee.

1.3 Demand and technology trends

Consideration of both historical and future demand and technology trends are critical in developing an updated fee model. Our consideration of these trends is informed by consideration both of relevant market drivers within Denmark, and international developments that may affect spectrum use. Our research in this area also draws upon our 2020 report for the DEA (now ADSI) on this subject, entitled "*Spectrum needs for future radio services and the licensing of fixed links in Denmark*".

Our high-level findings of international developments likely to affect spectrum allocation in Denmark are summarised in Figure 1.1. Out of the sectors of interest for this study, a large number of bands were identified for both public mobile and fixed links, while no significant changes in frequency allocation are expected within PMR or broadcasting in the medium term (up to 2030).

Figure 1.1: Impact of recent and on-going international developments on frequency allocations by sector of interest [Source: Analysys Mason, 2022]

Sector of interest	Consideration of bands for future use
Public mobile	Future assignment of spectrum identified for public mobile use in Denmark/Europe at WRC-19: • 37–43.5GHz • 66–71GHz For study at WRC-23: • 470–960MHz[1] • 3300–3400MHz • 3600–3800MHz[2]

1 470–694MHz is the relevant part under consideration for further allocation to mobile services, with the 700MHz, 800MHz and 900MHz bands already assigned for mobile use in Denmark

2 Already being planned in Denmark and other European countries for 5G use (part of the European 5G pioneer band from 3.4–3.8GHz)

Sector of interest	Consideration of bands for future use
	• 4800–4990MHz • 6425–7025MHz • 7025–7125MHz 3.8–4.2GHz has also been considered at EU level for private mobile networks
Broadcasting	No change in future availability of spectrum expected in the medium term, but possible reduction in availability of spectrum within the 470–694MHz band post-2030 (noting the study of 470–960MHz at WRC-23, and possibilities for a mobile allocation in the 600MHz band, co-primary with broadcasting).
PMR	No change in future allocations expected in the medium term
Fixed links	Identification of bands for mobile use at WRC-19 may affect existing fixed links: • 24.25–27.5GHz • 37–43.5GHz • 66–71GHz Some bands under study for mobile use at WRC-23 may affect future assignments in these bands for fixed links: • 6425–7025MHz • 7025–7125MHz A number of high-frequency bands were identified at WRC-19 for future commercial use: • 275–296GHz • 306–313GHz • 318–333GHz • 356–450GHz

1.4 International benchmarking of spectrum licence fee models

Our recommendations for changes to the existing fee model are further informed by a benchmarking exercise to compare licence fee models internationally in other relevant markets. We have considered seven other markets as part of the benchmarking process, namely: Norway, the UK, Ireland, Finland, the Netherlands, Malta and Germany, with our benchmark of Germany only covering its approach to private 5G network licensing. These markets were selected as they either offer a comparable example to Denmark, or have features in their fee models that are of note.

We found that spectrum licence fees are set using a wide variety of methods across the benchmarked countries, as shown in Figure 1.2.

- The UK and Ireland both take an approach of setting licence fees individually depending on the nature of the use under consideration. In both cases, auctions are used to assign frequencies for public mobile use. In the UK, an auctioned licence has an initial licence term in which no annual

fees are imposed, and thereafter, annual licence fees are set based on the opportunity cost of assigning spectrum to the current licensee in a system known as Administrative Incentive Pricing (AIP). This system is also applied to some other licence categories (e.g. fixed links), where the regulator deems there to be excess demand for licences (i.e. scarcity) and is intended to ensure the spectrum is used efficiently. In cases where AIP is not applied, licence fees are imposed on the basis of administrative cost recovery. In Ireland, the approach is slightly different to the UK for auctioned spectrum, and public mobile operators pay an upfront fee (determined by the auction), and a spectrum usage fee (SUF), which is index-linked. For other categories of use in Ireland (e.g. fixed links), fees are determined based on the frequency band and bandwidth, taking account of factors such as congestion.

- Finland's approach to licence fees is particularly noteworthy, as the regulator sets licence fees according to a single unified formula with different weighting factors used to differentiate between spectrum frequencies, technology and geographical scope.

- Both Norway and the Netherlands use charges to recover administrative costs, but their treatment of various band values/breaks and technologies mean they are nonetheless informative examples.

A summary of the key results of the benchmarking exercise is provided in Figure 1.2.

Figure 1.2: Summary of licence fee approaches by country [Source: Analysys Mason, 2022]

	Primary purpose of fees[3]	Minimum fee/ fixed fee component	Unified fee model	Light licensing	Inflation adjustment	Geographical scaling
Norway	Administrative cost recovery	Yes Fixed component of 'direct price' licence charge	Partly Charges consist of a variable charge component which is unified across different types of use	Yes	Yes Cost-dependent	Yes Population scaling
UK	Efficient spectrum use	Yes A minimum fee applies to most uses	No Licence fees are set individually for each type of use (or licence in the case of public mobile)	Yes	Yes CPI	Yes For fixed links, depending on pop. density of area covered

3 It seems to be the case that even where it is not the primary objective, most regulators do include recovering their own administrative costs as one of the objectives in setting spectrum fees

	Primary purpose of fees[3]	Minimum fee/ fixed fee component	Unified fee model	Light licensing	Inflation adjustment	Geographical scaling
Ireland	Efficient spectrum use	Yes A fixed fee component applied to most uses	No Licence fees are set individually for each type of use (or licence in the case of public mobile)	No	Public mobile only (using CPI)	No
Finland	Efficient spectrum use	Yes A minimum fee applied to all uses	Yes All licence fees are determined according to a single unified formula	No	No	Yes Population scaling
Nether -lands	Administrative cost recovery	Yes Through a one-off charge for all licences	No Licence charges are set individually for each type of use (or licence in the case of public mobile)	No	Yes Cost-dependent	Yes By area
Malta	Efficient spectrum use	Yes A fixed fee component applies to most uses	No Licence fees are set individually for each type of use	No	No	No

1.5 Proposed changes to the Danish model and revenue modelling results

Taking into account the results of both the identification of demand and technology trends, as well as the international benchmarking exercise, we developed a set of recommendations for adjusting the Danish fee model. These recommendations are summarised in Figure 1.3.

Figure 1.3: Recommendations for changes to the spectrum fee model [Source: Analysys Mason, 2022]

Issue	Recommendation
Insufficient band breaks	Adopt a unified banding structure across classes 1–4. This approach allows for more granular setting of licence fees in line with updated groupings of spectrum of similar value, consistent with modern technology trends. In particular, this will allow for more targeted encouragement of efficient use of spectrum, for example for PMR uses.
Band-value factors	Adopt a new set of band-value factors. These band-value factors have been adapted for the proposed updated band structure and have been set based

Issue	Recommendation
	on expected technology and demand trends in Denmark, as well as both international regulatory and spectrum auction price benchmarking.
Replacement of fixed fee	Replace the fixed fee with an 'incremental minimum fee'[4] for fee classes 1–4 and a minimum fee for fee classes 5–9 to avoid unduly discriminating against licensees with smaller payable licence fees while maintaining disincentives for small licensees to use more spectrum than is required. We suggest adjusting the value of this minimum fee slightly from the current fixed fee level (DKK600) to account for the small revenue shortfall created by this change.
Replacement of geographical area factor	Do not replace the existing geographical area factor with a population-based factor due to the additional administrative effort required and the relatively small number of licensees affected.
Provisions for licensing at sea	Adopt a fixed area scaling factor of 20% for licensing at sea to encourage use of spectrum in these areas. The existing area-based fee model is likely to overprice these licences relative to their commercial value, discouraging licensing and use.
Introduction of light licensing	Consider adopting a light licensing approach for fixed links in the 70GHz band, although specific implementation will depend on ADSI's objectives as well as existing spectrum plans for this band.

A major component of these recommendations is the adjustment of the frequency band breaks, combined with an adjustment of the band-value factors. The proposed changes in frequency band breaks have been largely informed by the analysis of demand and technology trends, and align the proposed fee model with current and expected developments in spectrum use. The proposed band-value factors are then guided by consideration of a combination of demand and technology trends, international benchmarks and benchmarks of spectrum auction prices in Europe. These sources have been combined to align the proposed frequency band breaks with their relative spectrum value. The proposed frequency bands and band-value factors are intended to cover fee classes 1–4, while fee classes 5–9 remain unchanged. These proposed band breaks and band-value factors, along with the corresponding fees, are summarised in Figure 1.4.

Figure 1.4: Summary of updated licence fees for fee classes 1–4 [Source: Analysys Mason, 2022]

Frequency band (MHz)	Band-value factor	Class 1 fee (DKK per MHz)	Class 2 fee (DKK per MHz per position)	Class 3 fee (DKK per 25kHz)[5]	Class 4 fee (DKK per licence)
0–380	32	3301	39	22	232
380–470	64	6602	78	45	464
470–694	320	33 008	390	224	2320
694–960	960	99 024	1171	672	6960
960–4200	320	33 008	390	224	2320

4 i.e. a minimum fee but with incremental variable fees charged for additional spectrum blocks, or 'positions'.

5 Note: the fee shown is for ≤30 mobile units, the fee for >30 mobile units is four times larger, in line with the original fee model

Frequency band (MHz)	Band-value factor	Class 1 fee (DKK per MHz)	Class 2 fee (DKK per MHz per position)	Class 3 fee (DKK per 25kHz)[5]	Class 4 fee (DKK per licence)
4200–12000	64	6602	78	45	464
12000–24250	16	1650	20	11	116
24250–43500	16	1650	20	11	116
43500–90000	1	103	1	1	7
over 90000	0.5	52	1	1	4

The combined effect of these proposals has been modelled and they are expected to produce an overall revenue neutral outcome for the ADSI, ultimately increasing total revenue by 0.14% under an assumption of fixed demand (at 2022 year-to-date levels). Inevitably, the fees for individual licensees may increase or decrease depending on the licence held as well as the use case, however we believe that all of these changes are justifiable in light of the current technological landscape as well as the wider objectives of the ADSI.

The final proposed fee model takes into account changes in technology and demand that have occurred since the creation of the original fee model, as well as expected future developments. The spectrum band breaks have been carefully designed to categorise similar frequencies together, taking into account expected future demand and technology developments, thereby providing a framework for encouraging efficient use of spectrum. The proposed fee model is therefore expected to provide a level of future-proofing, allowing regulatory flexibility as the various spectrum use cases mature. A number of broad objectives are also achieved by updating the proposed frequency bands and band-value factors, including the encouragement of high-frequency fixed links, modernisation of public mobile licence fees to represent current technological trends and ensuring efficient use of PMR spectrum.

While the licence fees for fee classes 5–9 were not changed, the replacement of the fixed fee with a minimum fee, as noted in Figure 1.3, caused small changes in revenue in these fee classes. We recommended a minimum fee level of DKK690, replicating the fee revenue previously derived from the fixed fee component while discouraging inefficient use of spectrum for smaller, previously inexpensive licences.

2 Introduction

This document is the final report of a study carried out by Analysys Mason on behalf of the Agency for Data Supply and Infrastructure (ADSI) to review the existing model for spectrum licence fees imposed in Denmark.

Efficient use of frequencies is essential to ensure that spectrum is put to good use, and is managed for the good of Danish society, and the economy. The ADSI is responsible for administering national frequency resources in Denmark, with the objectives to meet demand for frequencies for new applications whilst maintaining the spectrum needed to deliver existing services, and to maintain alignment of the Danish national frequency plan with European and international frequency regulations and use.

As part of its spectrum management activities, the ADSI imposes annual fees on spectrum licence holders. The current model for determining these fees has been in place since 2010. The ADSI now wishes to re-evaluate this model, with a view to putting in place an updated model.

The current fee model applies generally higher fees to lower-frequency spectrum, owing to its more favourable propagation characteristics (which tend to result in increased demand for and greater scarcity of this spectrum). However, recent technological advances (such as in 5G mobile systems) are leading to increased demand in other, higher-frequency, bands, meaning the historical position could be changing.

Analysys Mason was appointed by the ADSI to assist in this re-evaluation, drawing on its expertise in the telecoms sector to understand relevant technology and demand trends, as well as international benchmarks of licence fee regulation. Where any changes are recommended, we understand that these must result in a revenue-neutral outcome for the ADSI.

2.1 Overview of Analysys Mason's approach to the study

After first analysing the current fee model in Denmark, we have gathered evidence, of two main types, relevant to the consideration of any changes to the fee model:

- **Recent and future demand and technology trends**, which may suggest changes in the nature of the demand for spectrum
- **international benchmarks**, focusing on the way in which other countries define similar fee models.

We have then analysed the available evidence in order to identify potential issues with the current fee model, identify potential approaches to addressing these issues, and through consideration of the likely implications of such changes, make recommendations for an updated fee model.

We provide some further detail on the types of evidence and our approach to analysing it within the sub-sections below.

2.1.1 Identification of demand and technology trends

One component of our analysis is the identification of historical and future demand and technology trends that may influence the fees that should be imposed for different frequency bands, as well as the categorisation of frequencies into frequency bands (i.e. the 'band breaks').

Our analysis in this area also draws in part from a 2020 study carried out by Analysys Mason on behalf of the DEA (now ADSI) entitled "Spectrum needs for future radio services and the licensing of fixed links in Denmark". This study examined the historical changes in spectrum use and market demand in Denmark, as well as known and expected future developments likely to affect future use.

Another key source for our analysis of trends is the known and expected agenda items for the next two World Radiocommunications Conferences (WRCs). We draw on the results of WRC-19 as well as the proposed agenda items for the next conference, WRC-23, and expectations for WRC-27, in identifying international developments in spectrum assignment.

2.1.2 International benchmarking exercise

Another major component of our analysis of the ADSI's current fee model is international benchmarking of approaches to setting spectrum licence fees in other markets that are either somewhat comparable to Denmark, or are otherwise interesting in relation to their approach to setting spectrum fees. We have benchmarked seven European countries, namely: Norway, the UK, Ireland, Finland, the Netherlands, Malta and Germany. Germany, which is not generally a good comparator for Denmark in this context, is considered only in part, with particular focus on its licensing of private, local 5G networks. The other six markets are considered in greater detail.

2.1.3 Analysis of evidence to propose changes to the spectrum fee model in Denmark

Based on the evidence gathered, we have analysed the appropriateness of the current Danish fee model and have developed a set of recommendations for changes. These recommendations take into account specific points identified by the ADSI in its scope of work:

- consideration of removing the fixed fee component
- considerations for licensing at sea for geographical areas within the Danish Exclusive Economic Zone (EEZ)
- means to encourage efficient use of PMR spectrum in light of technological developments.

To ensure our recommendations remain revenue-neutral, Analysys Mason has developed a simple model in Microsoft Excel, based on partial 2022 data provided by the ADSI, to calculate total spectrum licence fees that would be payable based on current-year demand under both the current

and proposed alternative fee models. Our recommendations are thus tested within this model to ensure neutrality of revenue is (roughly) achieved.[6]

2.2 Structure of the report

The remainder of this report is laid out as follows:

- Section 3 describes the current fee model in Denmark
- Section 4 sets out the demand and technology trends identified
- Section 5 details the results of the international benchmarking exercise
- Section 6 analyses the evidence gathered in Sections 4 and 5 to propose changes to the current fee model
- Section 7 describes the implications of the changes recommended in Section 6 in the context of revenue neutrality
- Section 8 provides our overall conclusions and recommendations, alongside further considerations for the ADSI.

The report includes two annexes containing supplementary material:

- Annex A includes details of the variable fee class structure in Denmark
- Annex B lists the foreign exchange rates used throughout this report.

6 Note that we do not seek to ensure revenue remains exactly neutral, since this may create a somewhat artificial constraint on the nature of any recommended changes (for example, band breaks or band weighting factors needing to be set at unrounded numbers, which could create artificial complexity).

3 Fee model in Denmark

The existing licence fee model in Denmark consists of two parts: a variable component and a smaller fixed component. The fees imposed vary depending on the type of licence and are republished annually, although the fees imposed have not changed in recent years. There is currently no mechanism for automatic adjustment for inflation, resulting in an effective reduction in fees in real terms over time.

Licences are allocated to one of nine fee classes (or groups) for the purposes of calculating the variable fee component. Fees imposed on fee classes 2 and 3 are calculated on the basis of the number of base station positions ('positions') operated by the licensee, while fee classes 1 and 4–9 are calculated for the licence as a whole and do not depend on the number of positions. The allocated fee class depends both on the technology and the geographical scope of the licence, while variation in the frequency of assigned spectrum is accounted for within the fee classes. In summary, each frequency band is assigned a 'band-value factor' that is used to weight the fee appropriately between frequency bands in light of variation in the usefulness of different frequencies.

The sectors within the scope of our study (public mobile, broadcasting, PMR and fixed links) can fall into a range of fee classes, as shown in Figure 3.1, although in practice each sector is largely contained within one or two fee classes. For PMR 99% of fees are collected from fee class 3, while for fixed links approximately 32% and 68% of variable fees are collected from classes 1 and 2 respectively.

The variable fee model for all nine classes is detailed in Annex A.

Figure 3.1: Matrix relating spectrum licence use and fee class [Source: ADSI[7], 2022]

	Public mobile	Broadcasting	PMR	Fixed links
Class 1:	Public mobile services	N/A	LMR (nationwide)	Fixed links (above 3GHz)
Class 2:	N/A	N/A	N/A	Fixed links (above 3GHz) that are licenced per position
Class 3:	N/A	N/A	PMR (fixed positions or geographical area)	N/A
Class 4:	N/A	N/A	Video links	N/A
Class 5:	N/A	Digital TV	N/A	N/A
Class 6:	N/A	DAB (VHF)	N/A	N/A
Class 7:	N/A	FM networks	N/A	N/A

7 'New fee structure.doc', provided by the ADSI

	Public mobile	Broadcasting	PMR	Fixed links
Class 8:	N/A	FM radio that are licenced per position	N/A	N/A
Class 9:	N/A	N/A	N/A	N/A

The total fee for a given licence is then calculated as the sum of the fixed and variable fee components:

$$Fee = Fee_{fixed} + Fee_{variable}$$

where Fee_{fixed} is fixed at DKK600 per licence. According to revenue data provided by the ADSI for 2021, fixed fees made up only around 4% of the total fee paid by licensees.

Analysys Mason has developed a simple model on the basis of information provided by the ADSI regarding the number of positions and licences to calculate the overall revenue expected from the existing licence structure in 2022. This model is used firstly to reconcile the expected fees for 2022 with actual fees imposed in 2021, and secondly to analyse the impact of any proposed changes to the fee model to ensure revenue neutrality. The results generated by this model for January–May 2022 are shown in Figure 3.2. Any delta between the model results and the full-year 2021 results provided by the ADSI are assumed to be as a result of the 2022 data only applying from January to May, as well as inherent year-to-year variations.

Figure 3.2: Total modelled value of fees per fee class and per ADSI categorisation [Source: Analysys Mason, 2022]

Class	Fixed links	PMR	Saerlige
1	2 601 159	42 483	67 407 042
2	5 627 570	-	1 534 076
3	-	2 885 744	530 768
4	22 689	2 193	51 243
5	-	-	15 799 025
6	-	-	138 233
7	-	-	352 199
8	-	-	261 764
9	-	-	4800
Total	**8 251 418**	**2 930 420**	**86 079 150**

4 Demand and technology trends of relevance

4.1 Current and future frequency use in Denmark

In this section we summarise the recent trends in each of the sectors of interest in Denmark since the fee model came into force in 2010. We focus particularly on historical changes in spectrum use and market demand, as well as known or expected future developments that are likely to affect use over the remainder of this decade.

This section is based in part on our previous report for the ADSI entitled: "*Spectrum needs for future radio services and the licensing of fixed links in Denmark*".

4.1.1 Public mobile networks

Out of the sectors of interest, public mobile telecoms has arguably undergone the most significant transformation over the last decade due to the development and adoption of 4G, and latterly 5G technology. 5G use is expected to continue to increase rapidly over the next five years as coverage grows and subscribers move from 4G to 5G. Additional demand is expected to be driven by a plethora of innovative use cases, enabled by high data speeds, low latency and reliable connections. Data usage in Denmark is well above the Western European average for data usage per connection suggesting that there could be high demand for faster data services and 5G. In the last five years, mobile data usage per connection tripled from 5.52GB per month in 2017 to an estimated 17.84GB per month in 2022, and is expected to grow further to 31.55GB per month by 2025.

5G is widely expected to be the main technological development in the medium term for the public mobile sector. Its increasing use by MNOs will have a significant impact on the demand for spectrum and requirements for access to new frequency bands.

Spectrum availability for public mobile telecoms in Denmark is currently good by international standards, with all mobile operators able to offer competitive services over a wide coverage area, using multiple licensed bands. All four main operators launched commercial 5G services in late 2020. The DEA (now ADSI) auctioned several new mobile bands in its 2021 multiband auction[8] with TDC, Hi3G and TT-Netavaerket[9] being awarded various spectrum blocks in the 1500MHz, 2.1GHz, 3.4–3.8GHz and 26GHz bands. The same three operators were also awarded spectrum in the February 2019 auction, namely blocks in the 700MHz, 900MHz and 2.3GHz bands.

As a result, many 5G bands have already been made available in Denmark through various auctions, including the 700MHz, 3.4–3.8GHz and 26GHz bands. The European 5G Action Plan (5GAP) identifies these as the 5G pioneer bands in Europe. In the near future additional mid-band spectrum

8 https://ens.dk/en/our-responsibilities/spectrum/auctions

9 TT-Netavaerket is a joint venture between Telia and Telenor to operate a shared network with spectrum pooling.

(1–24GHz) may be required to meet demand for additional capacity and provide new data intensive services.

Increasing demand for spectrum that supports the delivery of high-capacity 5G services is expected to require identification of further spectrum for mobile use over the next five to ten years. The full range of applications and services that are expected to be made available using 5G networks will require the use of bands in different frequency ranges in order to ensure a technically efficient deployment. For coverage purposes, 5G networks will use low-range frequency bands (such as existing mobile bands at 700MHz and 800MHz, but potentially also lower frequencies), but they will also need access to mid-range frequency bands (e.g. 3.4–3.8GHz) to provide sufficient wide-area capacity. In addition, high-frequency bands (mmWave bands such as 26GHz) will provide very large contiguous bandwidths to meet demand for high broadband speeds in localised areas.

Aside from the 26GHz band, a number of other mmWave bands were identified for 5G use at WRC-19, for which future uses should also be considered. In addition, further frequency bands are being considered for study at WRC-23. This will be discussed further in Section 4.2.1.

Private networks

As enterprises increasingly undergo process digitisation and digital transformation the demand for private (on-premise, or area-wide) wireless networks has increased. These private networks typically operate on a small scale: spectrum resources are managed directly by the enterprise, and can be designed and used to address specific enterprise or industrial needs. Several alternative technologies may be used by private networks, including LTE, and/or 5G, depending on spectrum availability. Some of the applications envisaged for these private wireless networks might require higher speed connectivity, and/or low latency, and hence private 5G networks are emerging to cater for applications such as remote control of machinery, automation and real-time video applications.

In Denmark, all MNOs already offer different narrowband IoT solutions to specific vertical sectors utilising technologies including narrowband IoT (NB-IoT) on 4G networks. NB-IoT is designed to cater for lower bit rate applications such as wireless sensors, energy meters, etc. Although no spectrum has been made available specifically for enterprises to operate their own private networks, there is a leasing obligation applied to spectrum in the 3740–3800 MHz range licensed to TT-Network. This requires the licence holder to make the spectrum available to parties wishing to operate private networks on regulated terms for the first four years of the licence period.

Where some European regulators have made specific spectrum assignments for private 5G networks, several band options have been considered for this, primarily:

- parts of the 3.4–3.8GHz band (e.g. 3.7–3.8GHz in Germany and Sweden)
- spectrum above 3.4–3.8GHz (e.g. 3.8–4.2GHz)
- spectrum in mmWave bands such as 26GHz and/or in licence-exempt bands including new bands such as 66GHz

- parts of lower-frequency bands if not used by public mobile networks, such as parts of the 1800MHz or 2.3GHz bands.

Guidance from the European Commission's Radio Spectrum Policy Group (RSPG) now recommends that administrations consider use of the 3.8-4.2GHz band for 'local vertical applications'[10].

4.1.2 Broadcasting

Both the 700MHz and 800MHz bands have been reallocated from broadcasting to public mobile use in Denmark, with the former band being auctioned in 2019, as noted in Section 4.1.1. A similar reallocation process has occurred (or is occurring) across Europe. The Lamy report recommends that the remainder of the 470–694MHz band continue to be used in Europe until at least 2030 for TV broadcasting.

In Denmark, the whole of the 470–694MHz range is currently used to deliver digital terrestrial television (DTT) using five multiplexes (MUXs), and the latest (DVB-T2) transmission technology, with MPEG-4 compression. Existing commercial DTT and public service broadcasting licences expire in 2030, requiring a decision to have been taken on the future of the 470–694MHz band. Reallocation before this date is unlikely, however.

Analogue and digital radio broadcasting are also important components of the broadcasting market in Denmark, with FM analogue radio being broadcast on frequencies between 87.5MHz and 108MHz and AM analogue radio being broadcast on longwave. Digital audio broadcast (DAB) is also present in Denmark, and since 2017 has been broadcast using VHF spectrum. There are currently no plans to discontinue FM broadcast, not least due to large amounts of investment by broadcasters following a re-tendering of all local radio in 2016.

4.1.3 PMR

Businesses globally have almost universally been increasing their use of data and digital applications to improve productivity, operational efficiency and communication. To a significant extent, the associated increase in data traffic has been met by commercial public mobile networks, and in future may potentially be serviced by private 5G networks.

Despite this, PMR (and LMR) can provide attractive options for businesses looking for tailored services or a greater degree of control over their network. Future transport systems could also use LMR spectrum, both for operational use and for delivering wireless voice and data connectivity for their users.

10 https://rspg-spectrum.eu/wp-content/uploads/2021/06/RSPG21-024final_RSPG_Opinion_Additional_Spectrum_Needs.pdf

In Denmark, most PMR licences are issued in the 435–472MHz band, followed by the 148.5–255MHz band[11]. We expect the overall demand for PMR spectrum to remain broadly stable.

Traditionally, the LMR sector was dominated by analogue systems (i.e. analogue LMR or MPT1327 trunked radio), with the use of digital solutions (such as digital mobile radio, or DMR and dPMR) becoming more widespread in recent years. Enhanced modulation techniques, increased spectral efficiency, interworking with legacy analogue and optimisation of the total cost of ownership have been key drivers of this migration.

Cellular technologies have also evolved to provide LMR functionality, and to provide M2M and IoT connections. One benefit of LMR technologies traditionally has been the wide-area coverage that can be provided via a single base station using VHF or UHF frequencies. However, cellular technology has also been standardised to use selected UHF bands. 3GPP at its meeting "RAN 84" has identified additional IMT bands below 500MHz, including 410–415/420–425MHz (Band 87) and 412–417MHz and 422–427MHz (Band 88) in addition to the 450–470MHz (Bands 31, 72, 73). Because of favourable propagation characteristics, new use cases for NB-IoT are to be expected in this frequency range.

4.1.4 Fixed links

Fixed links are primarily used by MNOs to provide backhaul and resilience in public mobile networks. As data traffic carried by public mobile networks increases, increasingly large fixed-link channel bandwidths are required to provide increased backhaul capacity.

Other potential users of fixed services are the energy and utilities sectors in Denmark, for activities such as carrying data to monitor water or energy distribution equipment, gas compressors, pumping stations and sewage treatment plants.

5G is expected to drive further demand from MNOs for fixed-link spectrum as the demand for data capacity increases. In parallel, as macro and small cells become more ubiquitous, the distance between sites requiring mobile backhaul diminishes, increasing the usefulness of high-frequency spectrum thanks to its potential for high-bandwidth but low-penetration applications. It should be noted that while, in general, MNOs prefer to use fibre connectivity for backhaul, fixed links will continue to play an important role in areas where fibre is not yet available or is prohibitively expensive to install, enabling more rapid 5G deployment.

In Denmark, we understand a large number of fixed links are currently issued in the 17GHz and 22GHz bands. However, we expect the demand for higher-frequency bands will increase in the medium term, as demand for data capacity increases.

Internationally, there have been various technological developments related to the use of the 60GHz and 70–80GHz bands. It is likely that in the future, high-frequency bands (>100GHz) will need to

11 Based on previous analysis in the "*Spectrum needs for future radio services and the licensing of fixed links in Denmark*" report

be considered for use to meet capacity requirements. Regulators and the fixed links industry are considering alternative bands for fixed services, such as the 92–95GHz, 95–114.5GHz and 130–174.8GHz bands. Additionally, a number of high-frequency bands were allocated at WRC-19 for the implementation of land mobile plus fixed services, including the 275–296GHz, 306–313GHz, 318–333GHz and 356–450GHz bands, as noted in Section 4.2.2.

4.2 International developments that may affect future spectrum use

WRC is held every 3–4 years, with the most recent one, WRC-19, taking place at the end of 2019. These conferences are used to decide on alignment and changes in spectrum use internationally and may have significant impact on European frequency assignments. The next WRC, WRC-23, will take place in late 2023. As a result of these timings, information presented in our previous report to ADSI, "*Spectrum needs for future radio services and the licensing of fixed links in Denmark*", is still up to date. We summarise the salient points below.

4.2.1 International developments affecting public mobile

A total of around 15GHz of globally harmonised mmWave spectrum was identified at WRC-19 for mobile use, intended for 5G, compared to around 1.9GHz of bandwidth before. Spectrum in the 26GHz, 40GHz and 66GHz ranges was identified for mobile services applicable in Europe:

- 24.25–27.5GHz (global)
- 37.0–43.5GHz (global)
- 45.5–47GHz (mainly outside Europe)
- 47.2–48.2GHz (mainly outside Europe)
- 66.0–71GHz (global).

At WRC-19, new agenda items for WRC-23 were determined and include a number of studies:

- To identify 3.3–3.4GHz (Regions 1 and 2), 3.6–3.8GHz (Regions 1 and 2), 4.8–4.99GHz (globally), 6.425–7.025GHz (Region 1), 7.025–7.125GHz (globally) and 10.0–10.5GHz (Region 2) for IMT, including possible additional allocations to the mobile service on a primary basis.

- For the use of HAPS as IMT base stations (HIBS) in the mobile service in selected frequency bands below 2.7GHz already identified for IMT, on a global or regional level.

- On the potential use of IMT technology for fixed wireless broadband in the frequency bands allocated to the fixed services on a primary basis, in accordance with Resolution COM6/18 (WRC 19).

- To review the spectrum use and spectrum needs of existing services in the 470–960MHz band in Region 1, including Europe.

We expect the outcome of WRC-23 to potentially play a key role in extending the 5G mid-band range (1–24GHz).

6G is expected to emerge as the successor to 5G in the late 2020s or early 2030s, following the typical ten-year release cycle of successive mobile generations. 6G is expected to provide data speeds over 1Tbit/s and latencies below 0.1ms, although research is still under way globally into precise characteristics and requirements. 6G is likely to require a broad range of spectrum, including existing low bands already supported by current generations of mobile technology specification (within the range from 380MHz–1GHz), mid-band (1–24GHz) and high band (24–275GHz). A number of candidate bands are under consideration by stakeholders, although given the uncertainty over what the final state 6G will look like we will not consider these further in this report, outside of bands discussed in past and upcoming WRCs.

4.2.2 International developments affecting fixed links

Some spectrum currently allocated to fixed links is increasingly being considered for other uses, including public mobile and HAPS systems. As a result, spectrum allocated to fixed links would become more limited, requiring fixed links to be migrated to other frequency bands.

Internationally, there have been various technological developments related to the use of the 60GHz and 70–80GHz bands. It is likely that in the further higher-frequency bands (>100GHz) will be considered into the longer term to meet capacity requirements for fixed services. Taking account of ITU-R studies, regulators are considering alternative bands for fixed services, such as the 92–95GHz, 95–114.5GHz and 130–174.8GHz bands.

WRC-19 introduced land mobile and fixed service allocations into a number of high- frequency bands for fixed links, namely the 275–296GHz, 306–313GHz, 318–333GHz and 356–450GHz bands. Although there is currently no commercially available equipment to use these bands commercially, allocations have been made to encourage experimentation, and potential commercial development. The potential applications of these so-called 'Terahertz' (THz) bands are broad, including real time sensing and imaging, as well as communications-type applications.

Given the loss of spectrum below 30GHz to mobile use (e.g. 26GHz), it is expected that the ADSI will see increased demand for existing fixed link bands between 30GHz and 80GHz.

4.3 Analysis of technology and demand trends

In this subsection we have analysed the technology and demand trends identified in Sections 4.1 and 4.2 in relation to the band breaks in the current fee model. A summary of the considerations to be taken into account as a result of existing and future frequency use in Denmark, as well as international developments, is presented in Figure 4.1.

Figure 4.1: Impact of recent international developments on future frequency allocations by sector of interest [Source: Analysys Mason, 2022]

Sector of interest	Consideration of bands for future use
Public mobile	Future assignment of spectrum identified for public mobile use in Denmark/Europe at WRC-19: • 24.25–27.5GHz • 37–43.5GHz • 66–71GHz Other bands considered in the EU: • 3.8–4.2GHz For study at WRC-23: • 470–960MHz[12] • 3300–3400MHz • 3600–3800MHz[13] • 4800–4990MHz • 6425–7025MHz • 7025–7125MHz
Broadcasting	No change in future allocations expected in the medium term, but possible reduction in allocation within the 470–694MHz band post-2030.
PMR	No change in future allocations expected in the medium term
Fixed links	Identification of public mobile bands at WRC-19 may affect existing fixed links: • 24.25–27.5GHz • 37–43.5GHz • 66–71GHz Some public mobile bands for study at WRC-23 may affect existing fixed links: • 6425–7025MHz • 7025–7125MHz A number of high-frequency bands were identified at WRC-19: • 275–296GHz • 306–313GHz • 318–333GHz • 356–450GHz

Detailed discussion of each sector as well as our resulting overall recommendations for appropriate band breaks are detailed in Section 6.2.1.

12 470–694MHz is the relevant part under consideration for further allocation to mobile services, with the 700MHz, 800MHz and 900MHz bands already assigned for mobile use in Denmark

13 Already assigned for mobile use in Denmark and many other European countries (part of the European 5G pioneer band from 3.4–3.8GHz)

5 International benchmarking of spectrum licence fee models

5.1 Summary of key findings

As part of our analysis of the spectrum fee model in Denmark, we have considered international benchmarks of approaches to setting spectrum fees in seven other markets: Norway, the UK, Ireland, Finland, the Netherlands, Malta and Germany. Germany is considered only in part, with a focus on the approach adopted in the 3.7–3.8GHz band for the licensing of private 5G networks, whilst the other benchmark countries are considered in more detail owing to interesting features of their spectrum fee models, and/or their similarity to the Danish market.

Spectrum licence fees are set using a wide variety of methods across the benchmarked countries, as shown in Figure 5.1.

The UK and Ireland both take an approach of setting licence fees individually depending on the nature of the use under consideration. In both cases, auctions are used to assign frequencies for public mobile use. In the UK, an auctioned licence has an initial licence term in which no annual fees are imposed, and thereafter, annual licence fees are set based on the opportunity cost of assigning spectrum to the current licensee in a system known as Administrative Incentive Pricing (AIP). This system is also applied to some other licence categories (e.g. fixed links), where the regulator deems there to be excess demand for licences (i.e. scarcity) and is intended to ensure the spectrum is used efficiently. In cases where AIP is not applied, charges are levied on the basis of administrative cost recovery. In Ireland, the approach is slightly different to the UK for auctioned spectrum, and public mobile operators pay an upfront fee (determined by the auction), and a spectrum usage fee (SUF), which is index-linked. For other categories of use in Ireland (e.g. fixed links), fees are determined based on the frequency band and bandwidth, taking account of factors such as congestion.

Finland's approach to licence fees is particularly noteworthy, as the regulator sets licence fees according to a single unified formula with different weighting factors used to differentiate between spectrum frequencies, technology and geographical scope.

Norway and the Netherlands use charges solely as a means of administrative cost recovery, but their treatment of various band values/breaks and technologies means they are informative examples. In Norway, the total amount of cost to be recovered is determined and, after subtraction of various technology-specific fixed charges, is then divided between licensees according to weights assigned on the basis of bandwidth and population coverage. In the Netherlands, charges are set annually by the regulator based on its costs and consist of a one-off fixed-charge component and an annual charge component.

Most benchmarked countries adopt an automatic inflationary adjustment mechanism, based on either actual incurred costs (in the case of administrative cost recovery) or the country's consumer

price index (CPI). The notable exceptions to this are Finland and Ireland (excluding public mobile fees).

Figure 5.1 provides a summary of the spectrum fee model used in each of our six main benchmark countries (excluding Germany).

Figure 5.1: Summary of licence fee/charge approaches by country [Source: Analysys Mason, 2022]

	Primary purpose of fees/charges [14]	Minimum fee or charge/fixed fee or charge component	Unified fee/charge model	Light licensing	Inflation adjustment	Geographical scaling
Norway	Administrative cost recovery	Yes Fixed component of 'direct price' licence charge	Partly, charges consist of a variable charge component which is unified across different types of use	Yes	Yes Cost-dependent	Yes Population scaling
UK	Efficient spectrum use	Yes A minimum fee applies to most uses	No Licence fees are set individually for each type of use (or licence in the case of public mobile)	Yes	Yes CPI	Yes For fixed links, depending on pop. density of area covered
Ireland	Efficient spectrum use	Yes A fixed fee component applied to most uses	No Licence fees are set individually for each type of use (or licence in the case of public mobile)	No	Public mobile only (using CPI)	No
Finland	Efficient spectrum use	Yes A minimum fee applied to all uses	Yes All licence fees are determined according to a single unified formula	No	No	Yes Population scaling

14 It seems to be the case that even where it is not the primary objective, most regulators do include recovering their own administrative costs as one of the objectives in setting spectrum fees

	Primary purpose of fees/charges [14]	Minimum fee or charge/fixed fee or charge component	Unified fee/charge model	Light licensing	Inflation adjustment	Geographical scaling
Nether-lands	Administrative cost recovery	Yes Through a one-off charge for all licences	No Licence charges are set individually for each type of use (or licence in the case of public mobile)	No	Yes Cost-dependent	Yes By area
Malta	Efficient spectrum use	Yes A fixed fee component applies to most uses	No Licence fees are set individually for each type of use	No	No	No

5.1.1 Spectrum band breaks

Of the benchmarked countries, all use spectrum band breaks analogous to those in Denmark for at least one of the sectors of interest (with the exception of Malta), although only Norway and Finland define these for types of use other than fixed links. In all of these countries the band breaks are generally spaced further apart at higher frequencies, reflecting the higher availability of spectrum at these frequencies.

In Norway, there are relatively few band breaks for the usage-specific charge component, covering a bandwidth of 1GHz, 4.15GHz, 3.35GHz and 11.5GHz in order of increasing frequency across five separate bands (the final band represents all frequencies greater than 57GHz so does not have a bandwidth). The technology-neutral charge component is only defined for frequencies under 2.2GHz, and is highly granular, covering 15 sub-bands within this frequency range with 12 different bands covered in the sub-1GHz range. In Denmark, only two sub-bands are defined in the sub-1GHz range.

In the UK, only fixed links are subject to specific band breaks, with 13 generally evenly spaced frequency bands covering frequencies from 1.35–57GHz. The same is true in Ireland, although here the regulator defines only five frequency bands covering the full spectrum. For PMR in the UK, bands are grouped according to 'popularity' rather than using band breaks (for example, highly popular, medium popular, least popular).

The Netherlands takes a similar approach to Ireland, with four frequency bands defined for fixed links.

In Finland, the regulator defines 17 band breaks covering all available technologies. The interval of these band breaks varies between 28MHz and 15.9GHz, increasing steadily as the frequencies increase. There are a total of nine bands defined in the sub-1GHz range, compared to Denmark's two.

These results suggest that Denmark's current system of defining frequency band breaks for each technology/sector of interest is broadly aligned with international standards. It should be noted however that Denmark defines comparatively few spectrum bands in comparison to benchmarked countries and in particular the fee model lacks granularity in the sub-1GHz and >33GHz segments of the spectrum. Compared to Norway and Finland, with 12 and 9 bands respectively defined in the sub-1GHz band, the fee model in Denmark may have scope to increase the granularity of its spectrum bands in this frequency range. The implications of this will be considered further in Section 6.

5.1.2 Spectrum band factors and values

In general, where benchmarked countries provide granularity in the 0–5GHz range, the spectrum band values first increase then decrease as the frequency of the band gets higher, in line with the existing band-value factors in Denmark where fees either increase or remain flat in the sub-1GHz region. The frequency of the 'peak' in spectrum band values can vary significantly between jurisdictions, however.

- In Norway, the frequency-dependent band value peaks in the 174–240MHz band (which we consider unlikely to be an optimal approach). This is slightly lower than Denmark's peak in the 300MHz–1GHz band, although accurate comparison is difficult due to the relatively large frequency bands defined in Denmark in the sub-1GHz range, as noted in Section 5.1.1.

- Direct comparison to the UK is challenging as frequency bands are not defined for sub-1GHz fixed links, although the general trend of decreasing band values still applies at higher frequencies. The application of AIP in bands where there is scarcity also means that fees in the UK are not just based on band factors but also on congestion within a band.

- The same is true of Ireland, where there is also no granularity for sub-1GHz fixed links. Again, the general trend of decreasing band values for higher-frequency bands holds true. It should be noted that in Ireland fees also depend on the congestion within a band, resulting in the peak spectrum band value lying in the most highly congested bands.

- In Finland, frequency band values peak in the range 174–862MHz, broadly in line with Denmark's peak, before decreasing at higher frequencies.

- In the Netherlands, frequency bands are only defined up to 150MHz making comparison difficult, although frequency band values do increase up to this maximum.

- In Malta, licence fees tend to be imposed irrespective of frequency band, with the exception of public mobile networks where frequency bands up to 1800MHz are imposed at a flat rate.

The general trend of Denmark's frequency bands therefore shows reasonable overall alignment with benchmarks, particularly the treatment of the sub-1GHz bands. However, there are some differences that are investigated further in Section 6.

To compare the relative magnitude of spectrum band values in Denmark and the benchmarked countries we have compiled a number of illustrative licence fees/charges in Figure 5.2. Where applicable, the licences have been assumed to be nationwide. In the case of Norway, the variable fee component cannot be calculated due to its dependence on all licences issued in a single year, which is not published by the regulator.

Figure 5.2: Example licence fees/charges by country (DKK) [Source: Analysys Mason, 2022]

Example licence	Denmark	Norway	UK	Ireland	Finland	Nether-lands	Malta
DTT *Assumes: one network, 100 transmitters, one channel, 1000W transmitters*	Fixed fee: 600 Variable fee: 631 913 (scaled assuming a multiplex of five channels)	584 659 + variable charge component[15]	326 927 (scaled assuming a multiplex of five channels)	N/A (based on licensee's annual revenue)	N/A (determined on a network-by-network basis)	One-off charge: 4976 Annual charge: 654 540	43 314
PMR *Assumes: one channel, national licence, UHF band I, 100 mobile radios and 10 base stations*	Fixed fee: 600 Variable fee: 2 820	25 744 + variable charge component	21 520	18 163	5 736	One-off charge: 1629 Annual charge: 32 154	21 630
PMR *Assumes: as above except for a local licence with five mobile radios and one base station*	Fixed fee: 600 Variable fee: 52	2736 + variable charge component (proportional to population covered)	217	1145	319	One-off charge: 1629 Annual charge: 3771	1298
Fixed link *Assumes: one point-to-point link, 20GHz band, 100MHz bandwidth, 20km distance*	Fixed fee: 600 Variable fee: 1100	1103	11 477	8368	6938	One-off charge: 3883 Annual charge: 915	6917
Fixed link *Assumes: as above except at a*	Fixed fee: 600 Variable fee:	1103	28 311	11 157	10 407	One-off charge: 3883	6917

15 This variable fee component varies by year and the amount is not published. However, as a whole, the variable fee component makes up about 65% of revenue under the Norwegian spectrum fee model.

Example licence	Denmark	Norway	UK	Ireland	Finland	Nether-lands	Malta
frequency of 6GHz	27 700					Annual charge: 2008	

5.1.3 Inflation adjustment mechanisms

In the UK, licence fees are generally updated automatically in line with inflation, measured using CPI. Ireland only adjusts public mobile licence fees using CPI, while other uses are not adjusted for inflation. In Finland, licence fees are instead updated annually by the regulator, although in practice remain the same across multiple years. In Norway and the Netherlands, where licence charges are used to recover administrative costs, charges are adjusted based on the actual costs incurred by the regulator. It can therefore be concluded that four out of the five benchmarked markets provide a mechanism to adjusted licence fees for inflation.

These results suggest that there may be scope to incorporate an inflation adjustment mechanism into the Danish licence fee model, given this is widely implemented in other markets. The simplest approach would be to use CPI, which is published on a monthly basis by Statistics Denmark[16]. The implications of this approach will be discussed further in Section 6.

5.1.4 Approach to geographical scaling

All benchmarked countries (except the Netherlands) that employ a geographical scaling component to licence fee calculations use population as a basis for doing so. The Netherlands, like Denmark, scales licences on the basis of geographical area covered, likely due to the comparatively high population density within certain urban centres making population scaling prohibitively expensive for some use cases.

Adapting the Danish fee model to use population scaling mechanisms in place of area scaling may provide a more equitable outcome for licensees. Spectrum is generally more valuable for commercial use when more people are covered, allowing access to a greater share of the country's market and resulting in area-limited spectrum being in greater demand over these high population areas. A population scaling fee model may therefore provide results that are more reflective of the relative value of the spectrum when compared to an area scaling model. This approach also has implications for licensing at sea, as a population coverage factor is potentially more reflective of the spectrum value than the area covered, which may be very large for areas at sea.

However, a change of approach in this area may add some complexity to the fee model. In particular, the effort involved in transitioning from an approach based on geographical area to one based on population coverage may be substantial. This may not be worthwhile if there is limited gain.

16 https://www.dst.dk/en/Statistik/emner/oekonomi/prisindeks/forbrugerprisindeks

In relation to licensing at sea, Norway sets a minimum population coverage factor of 20% for offshore uses, while Finland sets a minimum population coverage factor of just 5%. Similar minimum factors could however also be considered for a geographical area coverage approach, with the minimum automatically applied for licensing at sea. This concept is further explored in Section 6.

In the remainder of this section, we provide detailed benchmarking results for each of the benchmark countries studied.

5.2 Norway

Spectrum in Norway is managed by the National Communications Authority (Nkom). Nkom imposes spectrum licence charges exclusively as a means to fund its own operations, and as such these charges may be considered to be exclusively focused on administrative cost recovery. Nkom publishes an updated charge schedule each year to reflect increases in costs.

5.2.1 Spectrum licence charging model

Nkom's expenditure budget is determined by the state budget and dictates the maximum amount that Nkom can collect in charges across the sectors it administers. As of May 2022, 40.6% of Nkom's annual budget can be collected from spectrum licence holders, with the remainder being collected from electronic communication network providers, postal service providers and importers of radio equipment.

Nkom's charging model for spectrum licence holders consists of a set of charges that are priced directly by the regulator ('direct price charges') and a set that are calculated each year based on the regulator's actual costs ('variable charges'). Due to the way in which these charges are structured, the direct price charges generally incorporate a minimum fixed charge per licence, regardless of the amount of spectrum licensed, while the charges on individual decisions scales with the amount of spectrum used, and is not subject to a minimum charge. In practical terms however, it is very unlikely that charges for individual decisions would fall below a reasonable minimum charge threshold.

Broadcasting, PMR and fixed link licences all fall under the direct price charge component, while public mobile frequencies are governed by variable charges. In 2020 direct price charges made up around 35% of charges collected from spectrum licence holders, while variable charges made up the remaining 65%.

Direct price charge component

PMR systems are charged an annual charge of NOK800 [DKK588] per base station and NOK270 [DKK199] per mobile radio. Each additional frequency channel is charged at NOK420 [DKK309].

Holders of nationwide broadcasting network licences must pay an annual charge of NOK604 860 [DKK444 905] per network, in addition to the charges per transmitter detailed in Figure 5.3. Holders

of licences for non-nationwide broadcasting networks must pay an annual charge of NOK2420 [DKK1809] per network, in addition to the per transmitter charges detailed in Figure 5.3.

Figure 5.3: Broadcasting network charges per transmitter [Source: Nkom[17], 2022]

Frequency band	Transmitter power <50W (NOK [DKK])	Transmitter power 50–1000W (NOK [DKK])	Transmitter power >1000W (NOK [DKK])
Transmitter in frequency band <30MHz	28 530 [20 985]	47 550 [34 975]	95 100 [69 951]
Transmitter in frequency band ≥30MHz	570 [419]	950 [699]	1900 [1398]

Holders of licences for satellite earth stations pay a charge of NOK7260 [DKK5340] per transmitted frequency band per earth station. Equivalent licence holders operating in Svalbard and Antarctica must also pay this charge for receiving signals. Radio telemetry licence holders pay a charge of NOK260 [DKK191] for each transmitter with a power below 0.5W and NOK750 [DKK522] for each transmitter with a power above 0.5W.

Any other transmission licences that do not fall under the above categories (i.e. that are not satellite earth or radio telemetry systems) and do not pay the variable charge are charged a charge as illustrated in Figure 5.4, provided they do not already pay a charge for a given frequency, polarisation and bandwidth.

Figure 5.4: Charges for other licences [Source: Nkom[18], 2022]

Frequency bands the transmitters use	Bandwidth	Charge per transmitter (NOK [DKK])
<1GHz	<25kHz	740 [544]
<1GHz	25–150kHz	980 [721]
<1GHz	>150kHz	1640 [1206]
1–5.15GHz	≤2MHz	610 [449]
1–5.15GHz	>2MHz	720 [530]
5.15–8.5GHz	<25MHz	610 [449]
5.15–8.5GHz	25–55MHz	720 [530]
5.15–8.5GHz	≥55MHz	820 [603]
8.5–20GHz	<25MHz	410 [302]
8.5–20GHz	25–55MHz	610 [449]
8.5–20GHz	≥55MHz	720 [530]
20–57GHz	<25MHz	310 [228]
20–57GHz	25–55MHz	510 [375]
20–57GHz	≥55MHz	820 [603]

17 https://lovdata.no/dokument/SF/forskrift/2017-03-20-386/, Section 13; https://www.nkom.no/om-nkom/finansiering-av-nkom

18 https://lovdata.no/dokument/SF/forskrift/2017-03-20-386/, Section 14; https://www.nkom.no/om-nkom/finansiering-av-nkom

Frequency bands the transmitters use	Bandwidth	Charge per transmitter (NOK [DKK])
>57GHz	All	160 [118]

Variable charge component

The variable charge payable by each spectrum licence holder with frequency less than 2170MHz is calculated by means of a weighting system. The overall charge is calculated as a percentage of Nkom's annual budget, minus any charges collected from the direct price charge component. Despite the purpose of the spectrum licence charges charged by Nkom being to recover administrative costs, it is still informative to consider the way in which different spectrum bands are weighted, and therefore valued, by Nkom.

For each licence, a weighted bandwidth value is calculated as the product of both the licence bandwidth and a weighting factor. This weighting factor consists of a number of components:

$$Weighting\ factor = \frac{1}{f} \times band\ weight \times population\ coverage\ factor$$

where f is the centre frequency of the band in which the frequency band is located (see Figure 5.5 for frequency bands). The band weight is determined by Nkom, and is detailed in Figure 5.5 The population coverage factor is equal to the percentage of the population of Norway that live in the coverage area for the licence (and is therefore 100% for nationwide licences), with offshore areas carrying a factor of 20%.

Figure 5.5: Band weights [Source: Nkom[19], 2022]

Frequency band	Band weight
0–30MHz	0.025
47–68MHz	0.1
137–174MHz	4
174–240MHz	7
380–400MHz	3
400–470MHz	6
470–694MHz	3
738–758MHz	7
703–733 / 758–788MHz	7
791–821 / 832–862MHz	8
870–880 / 915–925MHz	4
880–915 / 925–960MHz	9
1427–1517MHz	14
1710–1785 / 1805–1880MHz	17

19 https://lovdata.no/dokument/SF/forskrift/2017-03-20-386/, Section 15

Frequency band	Band weight
1900–1980 / 2110–2170MHz	20

The first component of the variable licence charge payable by each licensee is calculated as

$$Variable\ charge\ (I) = \frac{Weighted\ bandwidth}{Total\ weighted\ bandwidth\ of\ all\ licensees} \times overall\ charge$$

where the overall charge refers to 80% of the amount that Nkom has determined it is able to collect from spectrum licence holders to cover its administrative costs, minus any charges collected as part of the direct price charge component. Licences above 2170MHz are exempt from this charge (Spectrum licence charge (I)). The remaining 20% of this value is collected from all licence holders proportionally to the number of continuous frequency blocks they hold:

$$Variable\ charge\ (II) = \frac{number\ of\ continuous\ frequency\ blocks\ held}{total\ number\ of\ contionous\ frequency\ blocks\ issued}$$

The overall variable spectrum licence charge payable by each licensee is then the sum of these two variable charge components.

5.2.2 Light licensing

Point-to-point fixed links in the 73.625–75.875GHz and 83.625–85.875GHz frequency bands are subject to a light licensing regime, subject to a number of conditions.[20] Operators of these fixed links are required to register the transmitter with Nkom and pay the associated licence charges (see Section 5.2.1). There are also a number of restrictions on the technical parameters of the transmission:

- FDD and TDD are not permitted in the same location.
- If using FDD, the use of both high (83.625–85.875GHz) and low (73.625–75.875GHz) transmission frequencies is not permitted at the same location.
- The maximum radiated power is 85dBm. The maximum permitted power supplied to the antenna is 30dBm. The maximum antenna gain is 38dBi.
- The power flux density at the border between Norway and neighbouring states should not exceed –122.5dBWm^{-2}, measured at a reference bandwidth of 1MHz.

Nkom also specifies that new use of the frequency band should not interfere with existing registered use. Nkom provides a pre-populated table of centre frequencies and channel bandwidths which are permitted for use in the light licensing regime.

20 https://lovdata.no/dokument/SF/forskrift/2012-01-19-77, Section 5

5.2.3 Spectrum licence charges for local 5G networks in the 3.8–4.2GHz band

Nkom has designated the 3.8–4.2GHz band for use by local and private 5G networks. Nkom plans to grant two different types of licence for these networks:

- **Low-power licence**: with flexibility for the licensee to place base stations freely within 50m from an approved central location. This type of licence would typically be used for indoor private mobile networks, with transmitters having a maximum radiated power of 24 dBm EIRP.
- **High-power licence**: with location-defined base stations. This type of licence is intended for outdoor use covering larger areas, with transmitters having a maximum radiated power of 42dBm EIRP.

These licence types may also be combined to cover a larger area.

Nkom will issue licences for up to five years to provide predictability for licensees, but requires that licences are in use within 12 months of being granted.

Nkom has set a relatively low-charge model for the 3.8–4.2GHz band, with annual licence charges varying depending on both the type of licence and the licenced bandwidth as illustrated in Figure 5.6. Holders of these licences are exempt from the variable charge component of the licence charge detailed in Section 5.2.1, reducing the cost burden significantly.[21]

Figure 5.6: Annual licence charges for the 3.8–4.2GHz band (per licence per annum) [Source: Nkom[22], 2022]

Bandwidth	Low-power licence (NOK [DKK])	High-power licence (NOK [DKK])
20MHz	100 [74]	200 [147]
40MHz	400 [294]	800 [588]
60MHz	900 [662]	1800 [1324]
80MHz	1600 [1177]	3200 [2354]

5.3 UK

The Office for Communications (Ofcom) is responsible for licensing and management of spectrum in the UK. Ofcom has adopted a split approach to licence fees, defining two pricing tiers depending on the anticipated demand for a given portion of spectrum. In cases where it anticipates that there are no competing demands that cannot be met for a block of spectrum (i.e. no scarcity) it will seek

21 If the 3.8–4.2GHz band had been otherwise allocated it is expected that Figure 5.5 would have been expanded to include this band

22 https://www.nkom.no/hoeringer/horing-av-lokale-5g-nett-i-3-8-4-2-ghz-bandet

to recover administrative costs only. On the other hand, when excess demand is anticipated, Ofcom will impose a higher AIP spectrum fee based on the opportunity cost of the spectrum used.

5.3.1 Administrative incentive pricing and cost-based fees

Administrative incentive pricing

AIP works on the principle of setting spectrum fees based on their opportunity cost. That is, the value of spectrum to the best alternative user that is denied access to it. It follows that users should continue to hold spectrum licences only if they value it more than the AIP fee, thus encouraging efficient use of spectrum and maximising its benefit to society. The objective of this fee model is to replicate pricing that would be set via a market mechanism (e.g. an auction) in a well-functioning market.

AIP is applied at the discretion of Ofcom to spectrum where there is expected to be excess demand from alternative users/uses. The alternative is that only cost-based charges are applied. Ofcom has therefore set the cost-based charges to act as a minimum AIP fee.

In general, when setting AIP spectrum fees Ofcom will first identify alternative uses for a given spectrum band as well as the value associated with each use. Ofcom then uses a 'least cost alternative' (LCA) method to estimate the value of the spectrum in terms of opportunity cost. This involves estimating the value of a small block of additional spectrum to the average user in terms of long-term avoided cost. Ofcom then considers a number of additional factors to convert the LCA value to fees including:

- the feasibility of alternative uses; and
- variations in demand by frequency and geography.

As a final check Ofcom will undertake an analysis of the impact of potential fee proposals to spectrum users and consumers in order to balance the opportunities and risks of implementing the proposed fees.

Cost-based charges

Ofcom charges cost-based charges to recover administrative costs where AIP spectrum fees are not applied. At a simplified level, Ofcom calculates the administrative costs associated with each spectrum licence class and uses this to determine an appropriate charge to recover its costs.

5.3.2 Spectrum licence fees

Public mobile networks

Licences for public mobile spectrum are generally awarded by means of an auction process. Licences remaining within the initial periods granted under the award process are not subject to

annual licence fees until those periods expire. Once the initial auctioned term is reached, Ofcom's policy is to make licences indefinite, and these become subject to annual licence fees imposed annually beyond the initial term.

A number of spectrum bands assigned to public mobile operators have now reached the end of their initial licence term, and hence are now subject to annual licence fees. The 900MHz and 1800MHz bands that were licenced before the use of spectrum auctions have always been subject to annual licence fees, which were most recently revised in 2018. Annual licence fees are also now payable in the 2.1GHz (FDD) spectrum and in some parts of the 3.4–3.8GHz bands[23] now that the initial 20-year licences have expired. A number of other auctioned licences, such as in the 40GHz band, will reach the end of their auctioned term soon.

In setting fees for the 900MHz and 1800MHz bands, Ofcom considered the market value of the spectrum based on both economic modelling and international benchmarks, resulting in a 'lump-sum value' for the spectrum blocks for a hypothetical 20-year licence. This lump-sum value is then annualised over a 20-year period, taking into account inflation in the form of CPI.[24] The payment is designed to be constant in real terms, so increases in nominal terms over time. The annual licence fees, expressed in 2018 terms, are:

- 900MHz: GBP1.093 [DKK9.504] million per MHz per annum
- 1800MHz: GBP0.805 [DKK6.999] million per MHz per annum.

Ofcom used a similar approach when setting licence fees for the 2.1GHz and 3.4–3.8GHz bands, ultimately setting prices at:

- 2.1GHz: GBP0.561 [DKK4.878] million per MHz per annum (in 2022 terms)
- 3.4–3.8GHz: GBP0.435 [DKK3.782] million per MHz per annum (in 2018 terms).

Ofcom has deliberately adopted a conservative approach to evaluating the licence fees, stating that the risks of setting the fees too high significantly outweigh the risks of setting the fees too low.

Broadcasting

Charges for the spectrum used by terrestrial television broadcasting (digital terrestrial television) are determined by Ofcom on a cost basis[25] and are summarised in Figure 5.7.

23 This refers to spectrum that was either auctioned for FWA use in 2003 (3.4GHz), or assigned administratively (3.6GHz), both parts now owned by Three UK after acquiring UK Broadband. But, Ofcom recently consulted on extending the Three licence durations to be the same as the 2018 auctioned licences, meaning Three has to pay a lump sum value rather than ALFs, Consultation: Aligning licence terms in the 3.4-3.8 GHz band (ofcom.org.uk)

24 https://www.ofcom.org.uk/__data/assets/pdf_file/0020/130547/Statement-Annual-licence-fees-900-MHz-and-1800-MHz.pdf

25 https://www.ofcom.org.uk/consultations-and-statements/category-1/cbfframework

Figure 5.7: TV broadcasting fees [Source: Ofcom[26], 2022]

Licence class	Annual charge (GBP [DKK] per MUX)
National DTT MUXs	188 000 [1 634 637]
Local TV DTT MUX	23 900 [207 808]
Northern Ireland DTT MUX	3360 [29 215]

National and local radio broadcasting licences are also charged annual cost-based charges which depend on the band used for transmission as well as the number of people covered. These charges are summarised in Figure 5.8.

Figure 5.8: National and local radio broadcasting fees [Source: Ofcom[27], 2022]

Licence class	Population covered	Annual charge (GBP [DKK])
Medium-wave band	<100 000 people	226 [1965]
	>100 000 people	339 [2948] per 100 000 people covered (rounded down)
VHF band	<100 000 people	339 [2948]
	>100 000 people	509 [4426] per 100 000 people covered (rounded down)

PMR

Ofcom broadly separates PMR licences into four categories[28]:

- **Simple UK light**: allows use of hand-held or mobile radio equipment anywhere within the UK. Charges for this licence are fixed at GBP75 [DKK652] for five years.
- **Simple site light**: allows use of a base station in addition to mobile radio stations within a small area. Charges for this licence are fixed at GBP75 [DKK652] for five years.
- **Technically assigned**: allows use of a wide variety of PMR equipment in specific frequencies across a large area. Charges depend on the size of the coverage area, the band used and the number of 6.25kHz channels used. Individual frequency assignments are coordinated by Ofcom
- **Area-defined**: allows exclusive use of a frequency across a 50km^2 grid square, a country or the whole of the UK. Charges for this licence depend on the size of the coverage area, the band used

26 https://www.ofcom.org.uk/__data/assets/pdf_file/0025/203929/wireless-telegraphy-regs-2020.pdf, page 25

27 https://www.ofcom.org.uk/__data/assets/pdf_file/0025/203929/wireless-telegraphy-regs-2020.pdf, page 24

28 https://www.ofcom.org.uk/manage-your-licence/radiocommunication-licences/business-radio/guidance-for-licensees/business-radio-faqs

and the number of 6.25kHz channels used, as summarised in Figure 5.9. Licences in this category are valid for 12 months and are coordinated by Ofcom.

A minimum charge of GBP75 [DKK652] per licence applies regardless of categorisation.

Figure 5.9: Licence charges for area-defined PMR (GBP [DKK] per 6.25kHz channel) [Source: Ofcom[29], 2022]

Area	High-usage band (UHF band I, II and VHF high band) [30]	Medium usage band (VHF band III and VHF mid band)	Low-usage band (26.225MHz band, 49.49375MHz band, VHF band I and VHF low band)	Band I
UK	2475.00 [21 520]	2062.50 [17 933]	825.00 [7173]	150.00 [1304]
England	2068.75 [17 988]	1723.75 [14 988]	689.50 [5995]	37.50 [326]
Wales	122.50 [1065]	102.50 [891]	40.75 [354]	37.50 [326]
Scotland	213.75 [1859]	177.50 [1 543]	71.25 [620]	37.50 [326]
Northern Ireland	70.00 [609]	58.75 [511]	23.25 [202]	37.50 [326]
High population density area[31]	296.25 [2576]	247.50 [2152]	98.75 [859]	37.50 [326]
Medium population area	37.50 [326]	31.25 [272]	12.50 [109]	12.50 [109]
Low population area	3.50 [30]	3.00 [26]	1.25 [11]	1.25 [11]

Figure 5.10: Licence charges for technically assigned PMR (GBP [DKK] per 6.25kHz channel) [Source: Ofcom[32], 2022]

		Small coverage area		Medium coverage area		Large coverage area	
		Exclusive	Shared	Exclusive	Shared	Exclusive	Shared
Hig h-	High pop. area	50.00 [435]	25.00 [217]	185.00 [1609]	92.50 [804]	370.00 [3217]	185.00 [1609]

29 https://www.ofcom.org.uk/__data/assets/pdf_file/0018/72144/feecalcdoc.pdf, page 2

30 UHF stands for Ultra high frequency and covers bands between 300MHz and 3GHz, VHF stands for very high frequency and covers bands between 30MHz and 300MHz

31 High, medium and low population areas are defined by Ofcom according to a 50km^2 grid reference system

32 https://www.ofcom.org.uk/__data/assets/pdf_file/0018/72144/feecalcdoc.pdf, page 3

		Small coverage area		Medium coverage area		Large coverage area	
		Exclusive	Shared	Exclusive	Shared	Exclusive	Shared
	Medium pop. area	25.00 [217]	18.75 [163]	50.00 [435]	25.00 [217]	75.00 [652]	37.50 [326]
	Low pop. area	18.75 [163]	18.75 [163]	23.75 [207]	18.75 [163]	27.50 [239]	18.75 [163]
High usage band	High pop. area	25.00 [217]	18.75 [163]	92.50 [804]	46.25 [402]	185.00 [1609]	92.50 [804]
	Medium pop. area	21.25 [185]	18.75 [163]	42.50 [370]	21.25 [185]	62.50 [543]	31.25 [272]
	Low pop. area	18.75 [163]	18.75 [163]	20.00 [174]	18.75 [163]	22.50 [196]	18.75 [163]
High-usage band	High pop. area	18.75 [163]	18.75 [163]	18.75 [163]	18.75 [163]	18.75 [163]	18.75 [163]
	Medium pop. area	18.75 [163]	18.75 [163]	18.75 [163]	18.75 [163]	18.75 [163]	18.75 [163]
	Low pop. area	50.00 [435]	25.00 [217]	185.00 [1609]	92.50 [804]	370.00 [3217]	185.00 [1609]

Fixed links

The annual spectrum licence fee for a two-way point-to-point fixed link is set by Ofcom according to the following formula:

$$Licence\ fee = Sp \times Bwf \times Bf \times Plf \times Avf$$

where –

- 'Sp' is the spectrum price, fixed at GBP88 [DKK765] per 2×1MHz bandwidth for each two-way fixed link
- 'Bwf' is the bandwidth factor and is equal to the bandwidth (in MHz) of the fixed link, subject to a minimum of 1MHz and a maximum of 135MHz[33]
- 'Bf' is the band factor and is determined by the frequency band (in GHz), as set out in Figure 5.13
- 'Plf' is the path length factor, and depends on the minimum path length (MPL) (see Figure 5.11) and the path length (PL) (distance in kilometres) between two fixed points of the link. The method for calculating the path length factor is detailed in Figure 5.12
- 'Avf' as the availability factor and is determined by the availability of the fixed link (in percentage terms), as set out in Figure 5.14.

The minimum fee for fixed links is set at GBP75 [DKK652] per annum, and the licence can be prorated down to the number of months it is valid for (if the period of validity is less than one year).

33 https://www.ofcom.org.uk/__data/assets/pdf_file/0018/72144/feecalcdoc.pdf, page 4

Each additional two-way point-to-point fixed link operating on the same channel is charged at 50% of the licence fee. Each one-way fixed link is charged at 75% of the licence fee.

The licence fees for fixed links have been set according to AIP principles.

Figure 5.11: Minimum path length (MPL) [Source: Ofcom[34], 2022]

Frequency band	MPL where the data rate is <2 Mbit/s (km)	MPL where the data rate is ≥2 Mbit/s (km)
1.35–2.69GHz	0	30
Frequency band	**MPL where the data rate is <140 Mbit/s (km)**	**MPL where the data rate is ≥140 Mbit/s (km)**
3.60–4.20GHz	24.5	16
5.92–7.13GHz	24.5	16
7.42–8.50GHz	15.5	9.5
10.70–11.70GHz	10	6
12.75–15.35GHz	9.5	5.5
17.30–19.70GHz	4	2.5
21.20–23.60GHz	4	2
24.50–29.06GHz	3	2
31.00–31.80GHz	0	0
31.80–33.40GHz	2	1.5
37.00–39.50GHz	0	0
49.20–57.00GHz	0	0

Figure 5.12: Path length factor (Plf) [Source: Ofcom[35], 2022]

Relationship between PL and MPL	Path length factor
MPL ≤ PL	1
MPL > PL	Smaller of $\sqrt{MPL/PL}$ and 4

Figure 5.13: Band factors (Bf) [Source: Ofcom[36], 2022]

Frequency band	Band factor
1.35–2.69GHz	1.00
3.60–4.20GHz	1.00
5.92–7.13GHz	0.74

34 https://www.ofcom.org.uk/__data/assets/pdf_file/0025/203929/wireless-telegraphy-regs-2020.pdf, page 46

35 https://www.ofcom.org.uk/__data/assets/pdf_file/0025/203929/wireless-telegraphy-regs-2020.pdf, page 46

36 https://www.ofcom.org.uk/__data/assets/pdf_file/0025/203929/wireless-telegraphy-regs-2020.pdf, page 45

Frequency band	Band factor
7.42–8.50GHz	0.74
10.70–11.70GHz	0.43
12.75–15.35GHz	0.43
17.30–19.70GHz	0.30
21.20–23.60GHz	0.30
24.50–29.06GHz	0.26
31.00–31.80GHz	0.26
31.80–33.40GHz	0.26
37.00–39.50GHz	0.26
49.20–57.00GHz	0.17

Figure 5.14: Availability factor (Avf) [Source: Ofcom[37], 2022]

Percentage availability	Availability factor
≤99.9%	0.7
99.9%–99.99%	0.7 + (Availability x 100 – 99.9) × (0.3 / 0.09)
≥99.99%	1.0 + (Availability x 100 – 99.99) × (0.4 /0.009)

5.3.3 Light licensing

Some PMR licences are subject to light licensing, specifically UK-wide handheld licences and local base station licences, as described in Section 5.3.3.

The 73.375–75.875GHz and 83.375–85.875 GHz band is also subject to light licensing for point-to-point fixed links. A link registration process applies, which is intended as an interim procedure until Ofcom announces a permanent process for managing the band through an on-line tool. Licences are granted on a non-exclusive basis and licensees are required to self-coordinate measures to limit interference. Licence applications incur a charge of GBP50 per link, which includes the licence charge for the first year if successful. Subsequent years are also charged at a rate of GBP50 per annum. The 60GHz, 65GHz and 66–71GHz bands are licence exempt for fixed link use.[38]

5.3.4 Spectrum licence charges for local 5G networks

Ofcom provides access to four frequency bands under its Shared Access Licence scheme, namely the 1800MHz, 2.3GHz, 3.8–4.2GHz and the 26GHz band. Under the Local Access licence scheme, Ofcom provides access to spectrum already licenced to MNOs in location where they are not using

37 https://www.ofcom.org.uk/__data/assets/pdf_file/0025/203929/wireless-telegraphy-regs-2020.pdf, page 46

38 https://www.ofcom.org.uk/__data/assets/pdf_file/0017/115631/statement-fixed-wireless-spectrum-strategy.pdf

the spectrum. The 1800MHz and 2.3GHz bands are already licensed by MNOs, but may be licensed locally in areas where the MNO is not using the spectrum. 390MHz of the 3.8–4.2GHz band has been reserved for local shared access while low-power indoor uses may be licenced in the 24.25–26.5GHz band. In the context of local 5G networks, the 3.8–4.2GHz and the 26GHz band are of most relevance.

Once an application for a local access licence has been submitted, Ofcom consults the MNO to determine if it has any objection to a shared access licence being granted in the specific location. Following approval, a fixed licence charge will be payable, depending on the frequency band and the bandwidth used but irrespective of use case. Licence charges are payable per low-power area and per medium-power base station. Licence charges for the 3.8–4.2GHz band are listed in Figure 5.15, while licence fees for the 26GHz band are set at a flat rate of GBP320 [DKK2782] per licence, regardless of the bandwidth used. Ofcom cites the purpose of these charges as being to cover its administrative costs.

Bandwidth	Licence charge per channel per low-power area/medium-power base station (GBP [DKK])
2×3.3MHz	80 [696]
10MHz	80 [696]
20MHz	160 [1391]
30MHz	240 [2087]
40MHz	320 [2782]
50MHz	400 [3478]
60MHz	480 [4174]
80MHz	640 [5565]
100MHz	800 [6956]

Figure 5.15: Local Access Licence charges for the 3.8–4.2GHz band [Source: Ofcom[39], 2022]

5.4 Ireland

Spectrum licensing in Ireland is the responsibility of the Commission for Communications Regulation (ComReg). Licence fees are generally fixed at the time of regulation and do not vary to account for inflation, with the notable exception of public mobile licences. ComReg charges licence charges to recover administrative costs as well as to encourage efficient use of spectrum.

39 https://www.ofcom.org.uk/__data/assets/pdf_file/0035/157886/shared-access-licence-guidance.pdf

5.4.1 Spectrum licence fees

Public mobile networks

ComReg employs a fee model that is unique to each band that is licensed. Annual spectrum licence fees are set out at the point of licensing and vary depending on the regulation governing the licence. If a licence has less than one year of validity remaining the licence fee will be prorated down relative to the number of days in the year it is valid for (or the nearest month in the case of 3G licences).

The licence fees imposed for each band are set out in table Figure 5.16:

Figure 5.16: Mobile spectrum licence fees [Source: ComReg[40] [41], 2022]

Frequency band	Technology	Inflation adjustment	Licence fee (EUR [DKK] per MHz)
1900–1980MHz	3G	No	63 487 [472 213]
2020–2025MHz	3G	No	63 487 [472 213]
2110–2170MHz	3G	No	63 487 [472 213]
791–821MHz/832–862MHz	Liberalised use	Yes, CPI[42]	108 000 [803 299]
880–915MHz/925–960MHz	Liberalised use	Yes, CPI	108 000 [803 299]
1710–1785MHz/1805–1880MHz	Liberalised use	Yes, CPI	54 000 [401 649]

Public mobile spectrum licences are generally auctioned, so these fees apply in addition to upfront auction payments.

Broadcast networks

As a result of the establishment of the Broadcasting Authority of Ireland (BAI), ComReg is not responsible for issuing broadcasting licences to entities other than the national broadcaster, RTÉ. The BAI is responsible for issuing all commercial broadcasting licences and charges a levy to licensees solely as a cost-recovery tool.[43] This levy is charged as a percentage of licensees' revenue on a progressive basis, meaning that licensees with higher incomes will pay a proportionally lower

40 https://www.comreg.ie/media/dlm_uploads/2015/12/SI340of2003.pdf

41 https://www.comreg.ie/media/dlm_uploads/2015/12/SI_251_of_2012.pdf

42 Spectrum fees change in line with the CPI published by the Central Statistics Office

43 https://www.bai.ie/en/about-us/levy/

percentage fee. A minimum charge of EUR750 [DKK5578] applies to all licensees, regardless of income.

PMR

Spectrum licence fees for PMR are imposed annually and are based on the number of radios in a network. The fee is set at EUR22 [DKK164] per radio plus a fixed charge of EUR22 [DKK164] for the duration of the licence. There are no specific mechanisms to account for inflation beyond ComReg updating the fee model.

Fixed links

Licence fees for fixed links are set differently depending on whether the connection is a 'high-usage path' (i.e. where the licensee has five or more radio links). For point-to-multi-point fixed links the annual fee is four times the equivalent point-to-point fee. All licence holders must pay the full annual fee, regardless of licence duration. The fee model is set out in Figure 5.17 and Figure 5.18.

Figure 5.17: Annual fee for point-to-point links not on a 'high-usage path' (EUR [DKK] per link) [Source: ComReg[44], 2022]

Frequency (F)	Bandwidth			
	< 3.5MHz	3.5–20MHz	20–40MHz	> 40MHz
<1GHz	750 [5 578]	N/A	N/A	N/A
1–17GHz	1000 [7 438]	1100 [8 182]	1200 [8 926]	1500 [11 157]
17–37GHz	750 [5 578]	825 [6 136]	900 [6 694]	1125 [8 368]
37–39.5GHz	550 [4 091]	605 [4 500]	660 [4 909]	825 [6 136]
>39 .5GHz	100 [744]	110 [818]	120 [893]	150 [1 116]

Figure 5.18: Annual fee for point-to-point links on a 'high-usage path' (EUR [DKK] per link) [Source: ComReg, 2022]

Frequency (F)	Bandwidth			
	< 3.5MHz	3.5–20MHz	20–40MHz	> 40MHz
<1GHz	900 [6694]	N/A	N/A	N/A
1–17GHz	1200 [8926]	1320 [9818]	1440 [10 711]	1800 [13 388]

44 https://www.comreg.ie/industry/radio-spectrum/licensing/search-licence-type/radio-links/

Frequency (F)	Bandwidth			
	< 3.5MHz	3.5–20MHz	20–40MHz	> 40MHz
17–37GHz	900 [6694]	990 [7364]	1080 [8033]	1350 [10 041]
37–39.5GHz	660 [4909]	726 [5400]	792 [5891]	990 [7364]
>39 .5GHz	120 [893]	132 [982]	144 [1071]	180 [1339]

5.5 Finland

Finland's telecommunications regulator, Traficom, is responsible for the licensing and management of spectrum. Traficom imposes an annual spectrum licence fee to licence holders based on both the economic value of the spectrum as well as the frequency management costs incurred. No automatic inflation adjustment mechanism is incorporated into the licence fee model.

5.5.1 Spectrum licence fees or charges

General frequency charge

Charges for most spectrum uses are calculated using a single, general formula, with coefficients set for specific uses and bands. This charge is referred to as the 'general frequency charge'. The updated fee model is published annually by Traficom.

The general frequency charge (in euro) is calculated as follows (the EUR1295.50 factor is equivalent to DKK9636):

$$General\ Frequency\ Charge = B_0 \times K_1 \times P \times S \times 1295.50$$

where B_0 is the relative bandwidth of frequencies, K_1 is the frequency band factor, P is the population coverage factor and S is the basic charge coefficient. The frequency band factor (K_1) and the basic fee coefficient (S) are factors set by Traficom and listed in Figure 5.19 and Figure 5.20 respectively. The population coverage factor (P) is determined by the proportion of the population of Finland covered by the licence, and has a minimum value of 0.05.

The relative bandwidth of frequencies (B_0) is the ratio of the bandwidth of the licence (B) to a reference bandwidth (B_{ref}), multiplied by a licence quality factor (K_j) which is determined by Traficom:

$$B_0 = \frac{B \times K_j}{B_{ref}}$$

where B_{ref} is 25kHz. The values of K_j are tabulated in Figure 5.21.

If licences are granted for a period of less than one year, the general frequency charge is scaled proportionally to the number of days the licence is valid for, down to a minimum of 25% of the annual charge. The overall minimum general frequency charge is set at EUR18 [DKK134] for all licences.

It should be noted that fees for broadcasting are imposed on a per-network basis.

Spectrum licence fees for television broadcasting networks are determined on a network-by-network basis.

Figure 5.19: Frequency band factors (K_1) [Source: Traficom[45], 2022]

Band	K_1
0–28MHz	0.2
28.0–87.5MHz	0.9
87.5–108MHz	1.5
108–146MHz	1.7
146–174MHz	1.9
174–380MHz	2
380–470MHz	2
470–862MHz	2
862–960MHz	1.4
960–2200MHz	1
2200–3100MHz	0.6
3100–5000MHz	0.4
5000–10700MHz	0.3
10700–19700MHz	0.25
19700–39500MHz	0.2
39500–55000MHz	0.1
>55000MHz	0.03

Figure 5.20: Basic fee coefficient (S) [Source: Traficom[46], 2022]

Licence use	S
1) radio transmitters in the mass communication network	0.018
2) mobile networks other than ultra-broadband mobile networks	0.018
2a) high-speed mobile networks	0.006
3) the 2GHz terrestrial network of the satellite system	0.018
4) authority network (VIRVE)	0.018

45 https://www.finlex.fi/fi/laki/kokoelma/2021/sk20211257.pdf, Annex 2

46 https://www.finlex.fi/fi/laki/kokoelma/2021/sk20211257.pdf, Annex 3

Licence use	S
5) fixed wireless access network radio systems	0.018
6) radio stations for ships and aircraft	0.001
7) portable aviation radio transmitters	0.001
8) personal emergency transmitter (PLB)	0.15
9) amateur radio stations with increased transmission power	0.004
10) monitoring systems intended for research use with a radiation power of up to 1mW	0.4
11) remote control, telemetry and data transmission systems	0.9
12) amateur radio transmitters	0.014
13) other amateur radio stations requiring a special permit	0.014
14) radio microphone transmitters	1
15) private radio networks (PMR)	2.1
16) radio control transmitters	2.1
17) paging networks	2.1
18) marine radio systems other than ship's radio stations	0.021
19) radio link transmitters below 960MHz and voice program link transmitters	3.1
20) fixed headset transmitters	3.8

Figure 5.21: Licence quality factors (K_j) [Source: Traficom[47], 2022]

Licence use group	Sub-categorisation[48]	K_j
1) mobile networks, authority network (VIRVE), fixed wireless access radio systems and mass communication networks	Nationwide exclusive channel	5
	Nationwide channel for a limited group of users	2
	Local exclusive channel	2
	Local common channel	1
2) radio link transmitters below 960MHz, voice link transmitters, private radio networks (PMR), paging networks, remote control, telemetry and data transmission systems and marine radio systems other than ship's radio stations	Nationwide exclusive channel	5
	Local exclusive channel	2
	Nationwide channel for a limited group of users	2
	Local common channel	1
	Nationwide common channel	0.4
3) radio control transmitters	Nationwide exclusive channel	5
	Local exclusive channel	2
	Nationwide channel for a limited group of users	2
	Local common channel	1
	Nationwide common channel	0.4

47 https://www.finlex.fi/fi/laki/kokoelma/2021/sk20211257.pdf, Annex 1

48 ‘ Exclusive’ refers to an exclusive right of use by the licensee in contrast to ‘common’ where other licensees may operate in the same frequency band. ‘Limited group of users’ generally refers to specific uses such as police radio

Licence use group	Sub-categorisation[48]	K_j
4) radio link transmitters above 960MHz	Local common channel	1
	Nationwide common channel	0.01
5) Radio transmitters and systems for military radiocommunications	Nationwide exclusive channel	5
	Local exclusive channel	2
	Local common channel	1
	Nationwide common channel	0.4
6) Other	All channels	1

Special licence fee for PMR

In the case of PMR an additional multiplicative factor is applied to the general frequency charge detailed in the previous subsection, and the ratio component (B/B_{ref}) of the relative bandwidth (B_0) is modified by a cubic root. The modified formula in this case is:

$$Modified\ Frequency\ Charge = \sqrt[3]{\frac{B}{B_{ref}}} \times K_j \times K_1 \times P \times S \times 1295.50 \times K_{6b}$$

where K_{6b} (the system factor) is determined by the number of transmitters in the network. The number of transmitters is allocated to a pre-determined stepped band then multiplied by 0.25, as illustrated in *Figure 5.22*.

Figure 5.22: System factors (K6b) [Source: Traficom[49], 2022]

Number of transmitters	Stepped value	K_{6b}
1	1	0.25
2–4	2	0.50
5–8	5	1.25
9–14	9	2.25
15–24	15	3.75
25–34	22	5.50
35–44	30	7.50
45–59	40	10.00
60–79	55	13.75
80–99	70	17.50
>100	95	23.75

49 https://www.finlex.fi/fi/laki/kokoelma/2021/sk20211257.pdf, Annex 4

5.5.2 Light licensing

Finland currently has no provision for light licensing of spectrum bands.

5.6 Netherlands

Spectrum licensing in the Netherlands is managed by the Ministry of Economic Affairs and Climate. The purpose of spectrum charges is cited as recovery of administration costs incurred in licensing and monitoring of spectrum, although there is no mechanism for returning overpaid charges to licence holders as there is in Norway for example. Licence charges are updated each year by the regulator, to reflect increases in costs. In 2022, charges were increased by 4.99%, primarily to account for increased cost of labour and materials, over and above the general wage and price increases calculated by the Ministry of Economic Affairs. We can therefore consider the annual increase to be partly an inflationary measure, with the regulator having scope to increase the charges beyond this if its costs have increased beyond standard inflationary measures.

5.6.1 Spectrum licence fee model

Spectrum licence charges set by the regulator consist of both a one-off charge and an annual 'supervision charge'. If a licence is specific to a limited geographical area the charge is scaled proportionally to the area covered. The regulator reserves the right to alter this for an individual licence if the costs are expected to exceed the charges chargeable on the smaller area.

Public mobile networks

The regulator charges broadly flat spectrum licence charges across all currently licensed spectrum bands, with specific charges in the 700MHz band to account for the additional monitoring required for spectrum sold with coverage and speed requirements. Spectrum charges are charged for each MHz, making higher-frequency spectrum bands (which tend to have a larger bandwidth) more expensive. However, as in most other European countries, the primary cost of mobile spectrum licences is determined by auction and is an upfront amount, separate from ongoing spectrum licence charges.

Figure 5.23: Public mobile spectrum licence charges [Source: [Source: Ministry of Economic Affairs and Climate[50], 2022]

Frequency	One-off licence charge (EUR [DKK] per licence)	Annual licence charge (EUR [DKK] per MHz)
700MHz	844 [6278]	Paired, with coverage/speed requirement: 9466 [70 408]
		Paired, without coverage/speed requirement: 8330 [61 958]

50 https://zoek.officielebekendmakingen.nl/stcrt-2021-45605.html, Appendix 1.A

Frequency	One-off licence charge (EUR [DKK] per licence)	Annual licence charge (EUR [DKK] per MHz)
		At sea[51]: 472 [3511]
800MHz–2.6GHz	844 [6278]	Paired: 8330 [61 958]
		Unpaired: 4166 [30 986]

Broadcasting

Spectrum licence charges for broadcasting licence holders are charged based on the number of installation locations as well as the transmission power (per kW) according to the following equation:

$$Fee = A \times nC \times nT + B \times P$$

where A is the charge charged per channel and per installation location, nC is the number of channels occupied by the licensee, nT is the number of transmission locations operated by the licensee, B is the charge charged per kW of transmission power and P is the transmission power in kW.

Figure 5.24: Broadcast spectrum licence charges [Source: Ministry of Economic Affairs and Climate[52], 2022]

Type	One-off licence charge (EUR [DKK] per licence)	Annual licence charge (EUR [DKK])
AM/shortwave and FM with frequency <104.9MHz	669 [4976]	Per channel and per transmission location: 368 [2737]
		Per kW of transmission power: 610 [4537]
FM with frequency ≥104.9MHz	164 [1220]	Per channel and per transmission location: 368 [2737]
		Per kW of transmission power: 610 [4537]
Digital broadcasting in bands III, IV and V (i.e. DAB and DTT)	669 [4976]	Per channel and per transmission location: 440 [3273]
		Per kW of transmission power: 440 [3273]
Low-power MW	164 [1220]	Per licence with power <1W: 175 [1302]
		Per permit with power 50–100W:

51 A separation between onshore and at-sea regions was made when licencing the 700MHz band to separately encourage the development of mobile communications services for companies with active operations in the North Sea

52 https://zoek.officielebekendmakingen.nl/stcrt-2021-45605.html, Appendix 1.D

Type	One-off licence charge (EUR [DKK] per licence)	Annual licence charge (EUR [DKK])
		462 [3436]

PMR

The regulator charges a fixed annual charge for PMR licences, which varies depending on the type of licence, as detailed in Figure 5.25.

Figure 5.25: PMR licence charges [Source: Ministry of Economic Affairs and Climate[53], 2022]

Type	One-off licence charge (EUR [DKK] per licence)	Annual licence charge (EUR [DKK])
VHF/UHF radio devices for (limited) land mobile use and local mobile broadband networks	219 [1,629]	83 [617] per licence and 424 [3154] per permanent position
HF calling device (OS-HF)	219 [1,629]	298 [2217] per radio device
Radio remote control	219 [1,629]	298 [2217] per radio device
Telemetry and DGPS overall planning	219 [1,629]	298 [2217] per radio device
Walkie-talkie for temporary use	219 [1,629]	332 [2469] per licence
Wireless audio connection	219 [1,629]	83 [617] per licence
Radio alarm	219 [1,629]	83 [617] per licence
Radio Security Installation	219 [1,629]	83 [617] per licence
HF radio devices (27MHz)	219 [1,629]	83 [617] per licence

Fixed links

Point-to-point fixed link licences are charged at a one-off charge of EUR522 [DKK3883]. Annual licence charge depend on both the bandwidth and frequency used, as detailed in Figure 5.26.

Figure 5.26: Point-to-point fixed link licence charges (EUR [DKK]) [Source: Ministry of Economic Affairs and Climate[54], 2022]

Bandwidth	<12GHz	12–24.5GHz	24.5–39.5GHz	>39.5GHz
<10MHz	154 [1145]	78 [580]	54 [402]	31 [231]
10–25MHz	193 [1436]	93 [692]	70 [521]	35 [260]
25–50MHz	231 [1718]	108 [803]	85 [632]	38 [283]
50–150MHz	270 [2008]	123 [915]	101 [751]	42 [312]
≥150MHz	N/A	138 [1026]	115 [855]	46 [342]

53 https://zoek.officielebekendmakingen.nl/stcrt-2021-45605.html, Appendix 1.b

54 https://www.agentschaptelecom.nl/onderwerpen/straalverbindingen

5.7 Malta

In Malta, spectrum allocations and licensing are managed by the Malta Communications Authority (MCA). The MCA charges licence fees both for the recovery of administrative costs as well as 'for the right to use scarce resources'. Even though there is an administrative cost recovery component, the overall motivation for imposing fees in Malta can be considered to be relatively closely aligned with the situation in Denmark.

There is currently no mechanism for automatic inflation adjustment within the fee schedules.

5.7.1 Spectrum licence charging model

Public mobile networks

Public mobile licence charges vary depending on both the frequency and the bandwidth used. Spectrum licence charges, or usage charges, are charged to public mobile licensees on an annual basis. The licence charges payable in 2022 are reproduced in Figure 5.27.

Figure 5.27: Public mobile spectrum licence charges [Source: MCA55, 2022]

Frequency	Annual licence charge (EUR [DKK] per MHz)
Paired	
700MHz	22 400 [166 610]
800MHz	22 400 [166 610]
900MHz	22 400 [166 610]
1800MHz	22 400 [166 610]
2.6GHz	2400 [17 851]
Unpaired	
1.5GHz	1600 [11 901]
2.6GHz	1100 [8182]
3.6GHz	1800 [13 338]

Broadcasting

As with public mobile licence holders, broadcasting licensees are charged a flat annual charge for each channel, or frequency block, held. The licence charges for DTT broadcasters are currently set at EUR5823.43 [DKK43 314] per channel per annum, while digital radio broadcasters pay EUR2329.37 [DKK17 326] per annum for each 1.536MHz frequency block held.

55 https://legislation.mt/eli/sl/399.48/eng, Twelfth Schedule

PMR

Licence charges for PMR are charged annually for each device irrespective of the frequency used. Licence charges payable for PMR are summarised in Figure 5.28.

Figure 5.28: PMR spectrum licence charges [Source: MCA[56], 2022]

Device	Charge (EUR [DKK] per annum)
Repeater station	116.40 [886]
Base station	58.20 [433]
Mobile station	23.20 [173]

Fixed links

Fixed links in frequency bands above 1GHz are charged on either a per-link basis, or on a nationwide coverage basis, allowing the use of any number of links. The MCA may license other users on the same frequency as an existing per-link fixed link licence, provided there is minimal potential for interference. The base charge payable for a single fixed link is set at EUR45 [DKK335] per MHz per annum, and does not depend on the frequency used.

For a per-link fixed-link licence, the first link is charged the base charge of EUR45 [DKK335] per MHz, while subsequent links using the same frequency are charged at 50% of this rate to encourage reutilisation of assigned frequencies.

The charge for nationwide licences is set at the equivalent of ten per-link licences on the same frequency, EUR247.5 [DKK1841] per MHz (i.e. 1 × EUR45 + 9 × EUR22.5). As previously stated, additional links using the same frequency on this licence are not charged for, so the 11th link onwards is effectively free of charge.

Fixed links in frequency bands below 1GHz are charged annual charges per transmitter/receiver depending on the bandwidth used, as summarised in Figure 5.29.

Figure 5.29: Charges for fixed links operating in bands below 1GHz [Source: MCA[57], 2022]

Bandwidth	Charge (EUR [DKK] per annum)
<100kHz	230 [1711]
100–1MHz	465 [3459]
1–10MHz	695 [5169]
10–100MHz	930 [6917]
>100MHz, per 100MHz bandwidth	930 [6917]

56 https://legislation.mt/eli/sl/35.1/eng/pdf, page 4

57 https://www.mca.org.mt/sites/default/files/pageattachments/Radio_Links_Guidelines_0.pdf

5.8 Germany

In Germany, the Bundesnetzagentur (BNetzA) is responsible for management of spectrum and the setting of licence charges. Of particular interest for this study is BNetzA's approach to licensing the 3.7–3.8GHz spectrum band for local use in private 5G networks.

5.8.1 Spectrum licence fees for local 5G networks in the 3.7–3.8GHz band

BNetzA is looking to encourage innovative use cases for local 5G networks and has set relatively low licence fees to avoid placing a significant cost burden on enterprises, while the fees can scale up significantly with increasing bandwidth and area coverage to encourage efficient use of spectrum. Annual licence fees (in euros) for the 3.7–3.8GHz band are calculated according to the following formula:

$$Fee = 1000 + B \times t \times 5(6a_1 + a_2)$$

where B is the assigned bandwidth, t is the fraction of the year the licence is valid for (in months), a_1 is the licence area in square kilometres covering settlements and transport infrastructure and a_2 is the licence area in square kilometres covering other types of land. The EUR1000 fixed component is equivalent to DKK7437.

The fees are higher for built-up areas (specifically settlements and transport networks) to account for the need for increased frequency coordination and to encourage licensing and use in less densely populated areas.

Assigned bandwidth can vary between 10MHz and 100MHz. There is no automatic mechanism to adjust the fee for inflation, meaning it has effectively decreased in real terms over time since it was set in October 2019.

BNetzA now also allows mobile operators to utilise the spectrum to offer local private 5G networks. This decision came following concerns that licensing the 3.7–3.8GHz band to industrial users only was an inefficient use of spectrum, and may indicate that there was insufficient demand for these local 5G networks. Operators and existing licensees are required to negotiate to ensure adjacent networks can coexist without significant interference and, if necessary, BNetzA can intervene to apply measures to ensure efficient use of spectrum in these cases.[58]

[58] https://www.policytracker.com/germany-allows-mobile-operators-to-use-3-7-3-8-ghz-campus-bands/

6 Proposed changes to the model

6.1 Identification of potential issues with current fee model

We have identified a range of potential issues with the existing spectrum fee model in Denmark in light of demand and technology trends identified in Section 4 as well as through comparison to the international benchmarks presented in Section 5. We have summarised these issues in Figure 6.1. We then examine possible approaches to addressing these issues in detail in Section 6.2, noting that changes to the current fee model are not necessarily required in all cases.

Figure 6.1: List of potential issues with the Danish spectrum fee model [Source: Analysys Mason, 2022]

Potential issue	Explanation	Affected usage
Insufficient band breaks	There are likely insufficient band breaks to fully capture current and expected future differences in spectrum value for already allocated bands across all uses.	All uses
Band-value factors	Band-value factors should be reconsidered in light of possible changes to the band breaks as well as to take into account past (since 2010) and expected future evolution of spectrum usage. Doing so can incentivise efficient use while countering that spectrum is subject to 'squatting', where licensees maintain licences for spectrum they are not using.	All uses
Replacement of fixed fee	A fixed fee affects smaller licensees disproportionately as it constitutes a larger proportion of their overall fee. It also has the potential to complicate the fee-setting process, as it creates a fixed additive factor where one may not always be desirable.	All uses
Replacement of geographical area factor	A geographical area factor is unlikely to correctly model the spectrum value of limited geographical licences for an unevenly distributed population as this is usually more closely tied to population coverage.	Licences with limited geographical scope (i.e. subnational licences)
Provisions for licensing at sea	Licensing at sea is currently treated in the same way as land-based licences, which has the potential to disincentivise use, even where there is limited or no scarcity.	Licensing at sea
Introduction of light licensing	Implementation of light licensing could be considered for a number of bands/technologies, including high-frequency fixed links, as is the case in the UK and Norway.	Fixed links

6.2 Potential approaches to addressing issues with current fee model

In this subsection we examine potential approaches to addressing each of the broad issues identified in Section 6.1. For each potential approach we consider its advantages and disadvantages, identifying impact on the various stakeholders as well as implications for efficient use of spectrum. Where necessary, identified issues have been broken down into their individual sectors of interest and treated separately. The impact of the proposed changes from a revenue-neutrality perspective is discussed in Section 7.2.

6.2.1 Spectrum band breaks

In this section we identify, for each sector of interest, possible adjustments to the existing band structure across fee classes 1–4, based on the review of relevant current and future demand and technology trends. We then summarise our resulting overall recommendations for appropriate band breaks and cross check with relevant benchmark countries.

Public mobile networks

As noted in Section 4.1.1, there is already a significant amount of spectrum available to mobile operators in Denmark, including large portions of 5G-suitable spectrum. Spectrum bands licenced to public mobile operators include the 450MHz, 700MHz, 800MHz, 900MHz, 1500MHz, 1800MHz, 2.1GHz, 2.3GHz, 2.6GHz, 3.4–3.8GHz and 26GHz bands.

The existing band breaks for public mobile licences (i.e. class 1), detailed in Figure A.1 (see Annex A), coarsely break the mobile spectrum into six bands: 0–300MHz, 300MHz–1GHz, 1–3GHz, 3–10GHz, 10–33GHz, and >33GHz. In our view, these breaks no longer provide sufficient granularity to represent the public mobile licence fees, given the significant variation in spectrum scarcity and value across the 450MHz–4.2GHz range.

For fee class 1, as with fee classes 2–4, we propose a more granular approach to the setting of bands that is closely aligned with historical and future expected use, outlined in Figure 6.2 below.

Figure 6.2: Possible updated fee class 1 structure [Source: Analysys Mason, 2022]

Proposed band	Reasoning
0–380MHz	Covers LMR primarily, no public mobile usage expected.
380–470MHz	Covers UHF LMR as well as the IoT/M2M-focussed 450MHz public mobile holding by Cibicom
470–694MHz	Used exclusively for DTT broadcasting and not expected to be reallocated prior to 2030. WRC-23 will examine the future of this band in its review of 470–960MHz.
694–960MHz	Encompasses public mobile spectrum in the 700MHz, 800MHz and 900MHz bands. These bands can be considered to have closely related data capacity and propagation properties, and can therefore be treated similarly when setting spectrum fees.

Proposed band	Reasoning
960MHz–4.2GHz	Covers existing 4G and 5G mid-band bands, as well as many other uses. Spectrum in this range is useful to MNOs to provide wide-area capacity and is generally highly attractive to many categories of use. The 3.8–4.2GHz band is potentially appropriate for the licensing of private 5G networks. In addition, a number of bands in this range are being considered for 6G in the longer term.
4.2–12GHz	Frequency in this range is generally not assigned for public mobile use at present, but the agenda for WRC-23 will consider parts of it as potentially useful spectrum to be considered for upper mid-band 5G use.
12–24.25GHz	Covers the upper range of mid-band that might be of interest for future mobile use. In practice these frequencies have less favourable characteristics than the 4.2–12GHz band for mobile use, so it is in our view appropriate to split them into a separate category.
24.25–43.5GHz	Covers two mobile bands identified for use in Europe at WRC-19, specifically the 24.25–27.5GHz and 37–43.5GHz bands.
43.5–90GHz	Covers one mobile band identified for use in Europe at WRC-19, namely the 66–71GHz band.
>90GHz	Not directly applicable to mobile use but provides flexibility to set licence fees for fixed service use using these frequencies once equipment is commercially available.

Broadcasting

Broadcasting is not expected to undergo significant change in the medium term (prior to 2030), largely due to the remaining validity of existing licences as well as broadly stable demand as, for example, OTT media services soak up excess demand for DTT and radio.

As a result, we do not recommend any changes to fee classes 5–8 on the basis of technology and demand trends. There are, however, other relevant approaches, one of which we discuss in section 8.2 which would require a considerable overhaul of broadcasting licences.

PMR

The overwhelming majority of spectrum fees (>99%) for PMR are collected from fee class 3, which varies depending on the number of mobile units being registered. The spectrum band breaks are structured similarly to fee class 1, with six bands defined as: 0–470MHz, 470MHz–1GHz, 1–3GHz, 3–9.5GHz, 9.5–33.4GHz, 33.4–57GHz and >57GHz.

Out of these bands, we understand that all PMR licences will be confined to the 0–470MHz band. In line with the unified band structure presented in Figure 6.2, we propose to break this band into two categories: the 0–380MHz and 380–470MHz bands. In doing so it will become possible to differentiate fees for the comparatively more valuable 380–470MHz from the less valuable 0–380MHz spectrum. This change will be discussed further in Section 6.3.

Fixed links

Fees for fixed-link spectrum are imposed either using fee class 1 (if they are not imposed per position) or fee class 2 (if they are imposed per position) in a roughly 30:70 split between the two in terms of total variable fee value collected. As a result of increasing data demands driven by 5G deployments, it is expected that demand for high-frequency spectrum for fixed links will increase in the short to medium term.

A number of high-frequency bands were identified at WRC-19, including the 275–296GHz, 306–313GHz, 318–333GHz and 356–450GHz bands, while regulators are widely considering the 92–95GHz, 95–114.5GHz and 130–174.8GHz for use by fixed links in the more immediate future.

Recent technological developments have also meant that use of the 60GHz and 70–80GHz bands for fixed links is becoming increasingly feasible, however there is currently no commercially available equipment available for frequencies greater than this (although bands above 90GHz are considered prime candidates for fixed services use, and standardisation activities have occurred)[59]. It is therefore important, in our view, to distinguish between the commercially exploitable above 90GHz frequencies (which include 92-114.5GHz, referred to as 'W' band, and 130-174.7GHz, referred to as 'D' band') and the other currently unusable frequencies above 90GHz. Adopting this approach will provide flexibility to set spectrum fees at appropriate levels to encourage use of nascent technologies in the frequencies above 90GHz.

We have also split frequencies in the 12–90GHz range, generally useful for high-capacity fixed links, into three bands: 12–24.25GHz, 24.25–43.5GHz and 43.5–90GHz, as presented in Figure 6.2. While these are broadly aligned with public mobile frequencies identified at WRC-19 and WRC-23, these also reflect blocks of spectrum with similar propagation and bandwidth properties and therefore commercial value. In our view these also therefore provide suitable band breaks for fixed links, supporting the unification of frequency bands across fee classes 1–4.

We note that for higher frequencies, the existing pricing framework may not provide a similar level of deterrence to spectrum hoarding/inefficient spectrum use. For example, given that absolute costs are relatively low, an MNO may choose to buy a nationwide block licence and use it to deploy a number of short-hop links in only a few dense urban locations across the country. Alternatively, an MNO may choose to buy a block licence of large channel size, but not make use of all of the bandwidth available in its deployments. Adjusting the pricing framework may not be the best tool to address this problem. Rather, only allowing block licensing at a regional level, or imposing some form of 'use-it-or-lose-it' condition to ensure full frequency use, may be more suitable.

59 For example, https://www.etsi.org/deliver/etsi_gr/mWT/001_099/018/01.01.01_60/gr_mWT018v010101p.pdf

Summary of recommendations for frequency band breaks

We recommend splitting many of the existing frequency bands into multiple sub-bands, ultimately moving from six or seven bands to ten bands.[60] We propose these adjustments are made across fee classes 1–4, standardising bands across frequency classes where previously fee class 1 was slightly different from the remaining three frequency-dependant, non-broadcasting fee classes. Our recommendations are summarised in Figure 6.3.

In the figure we have also included a column comparing the proposed bands with the international benchmarks presented in Section 5. In most cases, direct comparison of bands is difficult due to the variety of band breaks applied to different use cases in different jurisdictions. Because of this, Norway and Finland are the most relevant comparators due to their unified fee structure and form the primary basis for comparison to other European band breaks. Our proposed band breaks reveal general alignment with these European regulators.

60 Note that in the current fee model class 2 had seven bands while fee classes 1,3 and 4 had six

Figure 6.3: Proposed changes to existing band breaks [Source: Analysys Mason, 2022]

Current band(s)[61]	Proposed change	Comparison to benchmark countries	Affected public mobile bands
0–300MHz, 0–470MHz	Expand to cover 0–380MHz	Norway provides an equivalent 0–240MHz band, that is non-continuous with the next band. Finland provides six sub-bands in the same range, with an identical end-point of 380MHz.	Existing: • 450MHz Future: • No additional bands
0–470MHz, 300MHz–1GHz	Break into: • 380–470MHz • 470–694MHz • 694–960MHz	Norway defines an equivalent 470–694MHz band, while five bands span the range from 694–960MHz. Finland provides three bands in the same range: 380–470MHz, 470–862MHz and 862–960MHz.	Existing: • 700MHz • 800MHz • 900MHz Future: • 470–960MHz reassignment
1–3GHz	Expand to cover 960MHz–4.2GHz	Norway defines three frequency bands in the same range, although the variable fee does not extend beyond 2170MHz. Finland defines three bands: 960–2200MHz, 2200–3100MHz, 3100–5000MHz.	Existing: • 1500MHz • 1800MHz • 2.1GHz • 2.3GHz • 2.6GHz • 3.4–3.8GHz Future: • 3300–3400MHz • 3800–4200MHz
3–10GHz, 3–9.5GHz	Adjust to cover 4.2–12GHz	Finland defines three bands from 3100–5000MHz, 5000–10700MHz and 10700–19700MHz.	Existing: None Future: • 6425–7025MHz • 7025–7125MHz • 10.0–10.5GHz
10–33GHz, 9.5–21GHz, 21–33.4GHz	Break into: • 12–24.25GHz • 24.25–43.5GHz	Finland defined three bands in this range, with the upper band terminating at 55GHz.	Existing: • 26GHz Future: • 37–43.5GHz • 66–71GHz
>33.4GHz, 33.4–57GHz, >57GHz	Break into: • 43.5–90GHz • >90GHz	Finland defines two frequency bands: 39.5–55GHz and >55GHz while Norway defines 20–57GHz and >57GHz for fixed links.	Existing: None Future: Uncertain

The proposed band breaks, summarised in Figure 6.4 allow spectrum licence fees to be set at a more granular level, and blocks of spectrum with similar utility are grouped, reflecting recent and expected future technological developments. Increasing the top-end band break from 33GHz to 90GHz provides further regulatory flexibility to encourage use of near-future fixed-link uptake in these frequencies.

Breaking the sub-1GHz spectrum into four bands, instead of two in the original banding, reflects the actual use of this spectrum more accurately, and goes some way to providing the flexibility to regulate the more valuable PMR bands in the 380–470MHz range separately from the less valuable bands in the 0–380MHz range.

Bands
0–380MHz
380–470MHz
470–694MHz
694–960MHz
960MHz–4.2GHz
4.2–15GHz
15–24.25GHz
24.25–43.5GHz
43.5–90GHz
>90GHz

Figure 6.4: Proposed band break structure [Source: Analysys Mason, 2022]

From an administrative point of view, unifying the band structure across fee classes 1–4 also simplifies the fee schedules.

As with any change to the fee model, one disadvantage of the change is the added administrative complexity of implementing the change. On balance however, we believe that the added regulatory flexibility and the more accurate reflection of true frequency value groupings outweigh this additional administrative effort.

We are not recommending changes to fee classes 5–9 as there has not been significant development in the broadcasting sector and significant future development is not expected. In addition, Denmark's current licence fee model for broadcasting is generally aligned with international benchmarks.

61 Note that where multiple bands in the same frequency range are listed these refer to variations in band definitions in different fee classes under the current fee model

6.2.2 Band-value factors

Along with the spectrum band breaks, the corresponding band-value factors must be updated to reflect historical and future developments in technology and demand, as well as to encourage efficient use of spectrum. We have used results from the international benchmarking exercise (Section 5) as well as consideration of benchmarks of European spectrum auction prices to arrive at a suitable set of band-value factors. However, we note that this exercise nonetheless requires a significant degree of regulatory judgement: there is no unique and objectively justifiable 'right answer' in this case.

In the context of revenue neutrality, the numerical value of individual band-value factors is not relevant. Instead, revenue neutrality will be achieved within each fee class by setting an appropriate 'unit fee'. This will then be multiplied by the corresponding band-value factor to determine the corresponding fee for each band within each fee class.

Of the benchmarked countries, Norway and Finland provide relevant benchmarks of band-value factors as these are unified across use cases and span a wide range of frequencies. Due to differences between band breaks in each of the countries, it is impossible to precisely map band-value factors from benchmark countries onto our proposed bands. As a result, we have adopted a mapping that places the lowest frequency in each benchmark country's band into the corresponding band in our proposed spectrum banding and averaging across bands where multiple band weightings exist. Utilising this method, we were able to produce an approximate picture of international band weightings in each of the benchmarked countries, as presented in Figure 6.5. Each band weight has been normalised relative to the lowest band weight in the benchmark.

Figure 6.5: Normalised band-value factors in Norway and Finland [Source: Analysys Mason, 2022]

Frequency band	Norway band-value factor	Finland band-value factor
0–380MHz	3.1	45.6
380–470MHz	2.1	66.7
470–694MHz	1.0	66.7
694–960MHz	1.6	46.7
960MHz–4.2GHz	1.8	22.2
4.2–12GHz	-	9.2
12–24.25GHz	-	6.7
24.25–43.5GHz	-	3.3
43.5–90GHz	-	1.0
>90GHz	-	-

European spectrum auctions also provide another measure of band value, and are a useful indicator of spectrum scarcity when setting licence fees. We have benchmarked 54 European spectrum auctions in the last five years (since 2016) using Analysys Mason's in-house spectrum auction tracker to determine an average normalised auction value for each spectrum band where sufficient

auction data is available. The normalised value is calculated in terms of EUR per MHz of spectrum per head of population, in line with industry standards for comparing spectrum auction values. Our results are presented in Figure 6.6.

Frequency band	Spectrum value (EUR/MHz/pop)	Normalised spectrum value
0–380MHz	-	-
380–470MHz	0.03	13
470–694MHz	-	-
694–960MHz	0.43	219
960MHz–4.2GHz	0.15	74
4.2–12GHz	-	-
12–24.25GHz	-	-
24.25–43.5GHz	0.0020	1
43.5–90GHz	-	-
>90GHz	-	-

Figure 6.6: Comparison of international spectrum benchmarks[62] [Source: Analysys Mason, 2022]

On the basis of current and future demand and technology trends identified in Section 4, as well as the benchmarks presented above, we have determined a potential band-value factor structure, shown in Figure 6.7, to be applied to the band breaks proposed in Section 6.2.1. These band values are designed to apply to across fee classes 1–4. Fee classes 5–9 will not see updated band-value factors, in line with our view in Section 6.2.1 to keep these fees as they stand currently.

Frequency band	Proposed band-value factors
0–380MHz	32
380–470MHz	64
470–694MHz	320
694–960MHz	960
960MHz–4.2GHz	320
4.2–12GHz	64
12–24.25GHz	16
24.25–43.5GHz	16
43.5–90GHz	1
>90GHz	0.5

Figure 6.7: Proposed updated band-value factors [Source: Analysys Mason, 2022]

The 43.5–90GHz frequency band has been allocated the second-lowest band-value factor. This figure has been calibrated specifically to ensure revenue neutrality for >57GHz fixed links in the 43.5–90GHz band, avoiding punitive fees for operators and encouraging further use of this band. As

62 Note that in cases where the normalised spectrum value is not present there are insufficient auctions in this band to generate a representative benchmark value

only fixed links currently exist in the 43.5–90GHz band it is appropriate to apply this calibration across fee classes 1–4.

The band-value factor for the >90GHz band has been set at half that of the 43.5–90GHz band to provide incentives for use. This is intended to future-proof the fee model by encouraging future use in these high-frequency bands, such as fixed links.

The 12–24.25GHz and 24.25–43.5GHz have been given the same band-value factor to reflect the similarities in potential use-cases and spectrum value. Although frequencies up to the 24GHz band increasingly being referred to as possibilities for mobile deployment, it is acknowledged by industry sources that frequencies below 12GHz are significantly more suitable for mid-band (1–24GHz) mobile applications due to their advantageous propagation characteristics. These bands value factors are set at 16 times the 43.5–90GHz band, which, we believe, appropriately reflects the relative value of these frequencies in light of expected technological and demand trends.

The band-value factors of the 380–470MHz and 4.2–12GHz have been set four times higher than the 12–24.25GHz and 24.25–43.5GHz bands. In comparison, spectrum auction benchmarks indicate an equivalent factor of around 14 times (instead of four), while benchmarks in Finland place this figure across a broad range between 1.4 and 20. The spectrum auction benchmarking may be unreliable due to the relatively small sample size of auctions in this band, and the range in Finland provides little guidance due to its breadth. A mid-range factor of four represents the expected relative value to operators of the 4.2–12GHz band for mobile use relative to the 12–24.25GHz band.

The 0–380MHz and 380–470MHz bands, notably used in part by PMR, have a relative factor of two between them, with the lower-frequency band having half the band-value factor of the higher-frequency one. This reflects the relative usefulness of the spectrum for PMR, with the 380–470MHz band being generally more useful for digital PMR applications thanks to the greater availability of bandwidth and higher frequencies. It is therefore important to encourage use of the 0–380MHz band where possible to prevent overcrowding in the 380–470MHz band by setting a significantly lower band-value factor. While these band-value factors are likely to reduce the variable fee burden for PMR licensees, the introduction of a minimum fee, as discussed in the next section, is expected to rectify this effect.

The proposed band-value factor for the 960MHz–4.2GHz band is subject to a five-fold increase relative to the 380–470MHz and 4.2–12GHz bands, and sits just below the approximately six-fold increase suggested by spectrum auction benchmarks. Benchmarks in Finland suggest a 2.4-fold increase (from the 4.2–12GHz band to the 960MHz–4.2GHz) would be more appropriate. We have chosen to increase the band-value factor by a factor of five to more closely reflect the spectrum auction benchmark, as we believe this provides a more accurate measure of the economic value of the spectrum, therefore ensuring the relative licence fee burden is not excessive. The 470–694MHz band has also been set with an equivalent band-value factor to the 960MHz–4.2GHz band.

Finally, the 694–960MHz band has been given a band-value factor three times greater than the band-value factor for the 470–694MHz and 960MHz–4.2GHz bands. This band is key for public mobile

usage and has valuable coverage characteristics which have been essential for 2G/3G and 4G coverage and will continue to be essential for 5G networks. This closely aligns with the relative value of 2.7 times indicated by the spectrum auction benchmarks and has again been selected because we believe this provides a fair and objective measure of the relative economic band value.

6.2.3 Replacement of fixed fee

As mentioned previously, fixed fees disproportionately disadvantage smaller licensees. A solution to this issue would be the introduction of a minimum fee as a replacement. In this way, it could be possible to ensure that most smaller licensees are not unduly disadvantaged.

Of the countries benchmarked, the UK and Finland both utilise minimum fees in this way, providing precedent for adopting such an approach. It should also be noted that while Norway, Ireland and the Netherlands charge a fixed fee or charge in some way, it is not constant across different uses as is the case in the Danish fee model currently. In the case of Ireland, licence fees involving a fixed fee do not generally have an additional variable component. With this in mind, it is clear that the current approach in Denmark of imposing both a fixed and variable fee component annually does not have a direct parallel among the benchmarked countries.

We also note that in 2021 fixed fees made up only around 4% of the total revenue collected by the ADSI from licensees, as outlined in Section 3. Although replacing the fixed fee with a minimum fee could reduce the overall income collected by up to this amount, this can be remedied by marginally increasing the overall variable fee. This will be discussed fully in Section 7.

A significant risk of introducing a minimum fee is that smaller licensees, such as small PMR licence holders, would no longer be disincentivised from increasing the spectrum they licence beyond what they actually require. This is because under a 'pure' minimum fee model there is zero incremental cost while the overall variable licence fee remains below the minimum fee threshold. To address this risk, we are proposing an 'incremental minimum fee' model, such that minimum fees are applied to the entry in the licence database with the highest applicable fee and subsequent entries (i.e. additional spectrum blocks, or 'positions') under the same licence number are charged as incremental values on top of the minimum fee, calculated as variable fees in the same manner as if there was no minimum fee. This approach will have no effect on licensees exceeding the minimum fee, while introducing an incremental cost for additional spectrum for smaller licensees.

One solution could be to apply this incremental minimum fee model to fee classes 1-4 (which are charged on a per-position basis), while adopting a standard minimum fee approach for fee classes 5-9 as these fees are instead charged on a per-licence/per-network basis.

Following discussions with the ADSI, we understand that for licences valid for only a part of the year, the variable component of the licence fee is scaled proportionally. In moving from a fixed fee to a minimum fee the minimum fee could be similarly scaled, down to a minimum licence duration (which could be two weeks subject to case-by-case exceptions for large events). Adopting this

approach will discourage licensees from holding licences for longer than is necessary, while ensuring that the principle of a minimum fee remains applicable to all licence holders.

6.2.4 Replacement of geographical area factor

The spectrum value of sub-national licences is generally driven by population coverage, reflecting the expected demand for spectrum in a given area. Denmark's current approach of using a geographical area coverage factor is unlikely to be as reflective of spectrum value, given the variations in population density across the country, even if these variations are more limited in Denmark than in some other European markets. As a result, licensees with sub-national licences covering a lightly populated area may end up paying the same licence fees as a licensee with an equivalent licence covering a more densely populated area, despite the spectrum being more valuable in the latter case.

One solution to this problem would be to replace the geographical area factor with a population coverage factor, which expresses the percentage of the population of Denmark that is covered by a given licence. This approach is used in all benchmarked countries excluding Ireland and Malta, which do not have any form of geographical scaling factor, and the Netherlands, which uses an area scaling factor like Denmark.

The primary advantage of this change would be to make spectrum licence fees more closely reflective of spectrum value, reducing disparity between licensees under the current system. Use of a population coverage factor would also simplify adding provisions for licensing at sea, as discussed in Section 6.2.5, although this is a minor point as alternative remedies exist.

A major disadvantage of this adjustment, however, would be the increased administrative burden of assessing population coverage. Whilst a calculation of area coverage is relatively straightforward (and already setup), population coverage would require the ADSI to make assumptions on the population density of given areas within the country, and assess these against the geographical area covered by each licence. There are also currently very few licences subject to a geographical area factor (discussed further in Section 6.2.5), limiting the impact and need of replacing the geographical area factor.

As a result, we suggest that the limited benefits of transitioning to the population coverage factor are unlikely to justify the costs of doing so.

6.2.5 Provisions for licensing at sea

As noted previously in Section 6.2.4, a transition to a population coverage factor over a geographical area coverage factor would have the most significant implications for licensing at sea (in effect in the Danish Exclusive Economic Zone (EEZ)). While these licences would likely have very large geographical area coverage factors, their population coverage factor would be near zero, resulting in much lower licence fees.

It is important for prevention of spectrum hoarding that licences are not priced too low. Much like in Norway and Finland, the solution to this problem would be to set a minimum area scaling factor to ensure that an appropriate licence fee is still payable for licences at sea. Norway sets this minimum at 20% explicitly for these uses, while Finland uses a figure of 5% in general across all uses. We expect that a figure closer to 20% is likely to be most appropriate for licensing at sea in Denmark, as opting for the higher threshold will reduce the chance of 'spectrum squatting' by large maritime organisations, such as oil companies.

The effect of this approach on fees imposed on holders of licences for use at sea will be identical to using a population coverage factor. By setting a lower fee level for licences at sea compared to land-based licences, the ADSI can encourage efficient use of spectrum that would otherwise be unutilised by ensuring the fees are not excessive. In terms of disadvantages, there is some potential for lost revenue by effectively reducing the fees collected from holders of licences at sea, although this is expected to be negligible and will be discussed further in Section 7.

There is also the potential that licensees with low area coverage factors presently will be subject to higher fees as a result of this change. We note however that there are only 17 entries in the licence database that are subject to geographically scaled fees (class 1 licences) and have a coverage factor less than the proposed 20%, with all but one being below 5%. These licensees appear to be operating under 'nationwide' licences for fixed links and LMR, while simultaneously reporting low coverage areas. In all but two cases, this results in a lower overall variable licence fee than would be imposed if the licence was a class 2 licence instead, which would likely be more appropriate. The introduction of a minimum area scaling factor would encourage these licensees to transition to class 2 licences to avoid significantly higher fees. These licence database entries are listed in Figure 6.8.

Figure 6.8: Summary of class 1 licence database entries with area factors below 20% [Source: ADSI, 2022]

Licence number	Usage type	Area factor	Class 1 fee (DKK)	Class 2 fee (DKK)
H100593	Fixed links	0.35%	55	308
H100593	Fixed links	0.35%	55	308
H100593	Fixed links	0.70%	111	308
H100593	Fixed links	0.35%	55	308
H100593	Fixed links	0.35%	55	308
H100593	Fixed links	0.70%	111	308
H100593	Fixed links	0.35%	55	308
H100593	Fixed links	0.35%	55	308
H100593	Fixed links	0.35%	55	308
H100593	Fixed links	0.35%	55	308
H100818	Fixed links	4.17%	659	168
H100219	Saerlige	1.89%	213	1106
H100380	Saerlige	5.52%	15 571	13 850
H100425	Saerlige	2.15%	243	1106
H100524	Saerlige	1.12%	126	1106

Licence number	Usage type	Area factor	Class 1 fee (DKK)	Class 2 fee (DKK)
H101002	Saerlige	0.31%	350	5540
H101002	Saerlige	0.31%	350	5540

6.2.6 Introduction of light licensing

Light licensing has been introduced in some bands in a number of benchmarked countries, namely the UK and Norway, for high-frequency fixed links. Light licensing provides, among other things, a low barrier of entry for licensees and is generally used in cases where the administrative burden of directly managing the licensees would result in excessive fees or, as is the case in the UK, as an interim measure to encourage use of experimental frequencies (such as the THz bands above 100GHz and the upper 6GHz band) or use cases before a long-term regulatory approach is enacted once the spectrum is subject to sufficient demand[63].

Light licensing in Denmark could be used to offset the increase in class 1 fixed link licence fees under the newly proposed band structure, or to encourage these licensees to move into higher-frequency bands where a greater amount of spectrum is available. Denmark could adopt a similar approach to the UK and Norway in lightly licensing a portion of the 70GHz band for fixed link use. Interest in this lightly licensed band would likely be stimulated by the increase in class 1 fixed-link licence fees, and may provide an attractive alternative to fixed link licensees as the technology matures, future-proofing the fee model. In line with common light-licensing practices, this spectrum would not be actively managed by the ADSI, but it would instead be the responsibility of licensees to mitigate interference. The ADSI would instead define a set of operating parameters, such as transmission power and bandwidth, that all licensees must adhere to. It is noted that the argument against light licensing that has been made in some other countries is over unpredictable operating conditions in the band due to uncertainty over nearby uses, plus an overall lack of certainty of spectrum access.

6.3 Summary of recommendations for suitable changes

Following the discussion in Section 6.2 of potential approaches to addressing the issues identified in Section 6.1, we have collated a list of our recommendations for adjustment to the Danish fee model. Where applicable, the revenue implications of the proposed changes are be analysed in Section 7.2.

Figure 6.9: Recommendations for changes to the spectrum fee model [Source: Analysys Mason, 2022]

Issue	Recommendation
Insufficient band breaks	Adopt a unified banding structure across classes 1–4, as summarised in Figure 6.4 and discussed in detail in Section 6.2. This approach allows for more granular setting of licence fees in line with updated groupings of

63 The light licensing approach for the 70-80MHz bands is not interim, however the manual registration is and Ofcom intends to replace this with a database.

Issue	Recommendation
	spectrum of similar value, consistent with technology trends. In particular, this will allow for more targeted encouragement of efficient use of spectrum, for example for PMR use.
Band-value factors	Adopt the set of band-value factors indicated in Figure 6.7. These band-value factors have been adapted for the proposed updated band structure and have been proposed based on expected technology and demand trends in Denmark, as well as both international regulatory and spectrum auction price benchmarking.
Replacement of fixed fee	Replace the fixed fee with an incremental minimum fee for fee classes 1–4 and a minimum fee for fee classes 5–9 to avoid unduly discriminating against licensees with smaller payable licence fees while maintaining disincentives for small licensees to use more spectrum than is required. We suggest adjusting the value of this minimum fee slightly from the current fixed fee level (DKK600) to account for the small revenue shortfall created by this change. This is be discussed further in Section 7.2.
Replacement of geographical area factor	Do not replace the existing geographical area factor with a population-based factor due to the additional administrative effort required and the relatively small number of licensees affected.
Provisions for licensing at sea	Adopt a fixed area scaling factor of 20% for licensing at sea to encourage use of spectrum in these areas. The existing area-based fee model is likely to overprice these licences, discouraging use.
Introduction of light licensing	Consider adopting a light-licensing approach for fixed links in the 70-80GHz band, although specific implementation will depend on ADSI's objectives as well as existing spectrum plans for this band.

7 Implications of proposed changes

7.1 Revenue breakdown under current fee model

Analysys Mason has constructed a simple Microsoft Excel model of revenue from all spectrum licence fees in Denmark according to current 2022 data supplied by the ADSI. The objective of this model is to provide a means to test the revenue neutrality of any proposed changes to the Danish fee model.

The results from the model were compared to full-year 2021 figures supplied by the ADSI to confirm alignment. The results of this comparison are summarised in Figure 7.1. Following discussions with the ADSI, we understand that where misalignments exist between the model and the 2021 data, these can be discounted as they are due to year-to-year fluctuations (as we are comparing actual data from 2021 with results based on 2022 year-to-date data).

Figure 7.1: Comparison of model results to 2021 data supplied by the ADSI [Source: Analysys Mason, 2022]

Category	Model results (2022 year-to-date)			2021 full year data		
	Fixed fee (DKK)	Variable fee (DKK)	Total fee (DKK)	Fixed fee (DKK)	Variable fee (DKK)	Total fee (DKK)
Fixed links	166 800	8 084 618	8 251 418	155 400	7 848 461	8 003 861
PMR	2 344 800	585 620	2 930 420	2 400 600	843 605	3 244 205
Saerlige	619 800	85 459 298	86 079 098	636 600	75 592 888	76 229 488

Fee class 1 is the largest contributor to licence fees, accounting for around 72% of all fees collected. Fee class 5 is the second largest, accounting for just over 16% of fees collected, followed by fee class 2, accounting for just over 7% of fees. The remaining fee classes (3, 4 and 6–9) account for the final 4% of fees.

The data provided by the ADSI also separates fixed link, PMR and other ('saerlige') licences. In terms of these categories Saerlige makes up around 89% of fees collected, largely due to the public mobile and broadcasting licences captured within this category. A breakdown of licence fee revenue by both fee class and licence types is provided in Figure 7.2.

Figure 7.2: Breakdown of licence fee revenue by fee class and licence type [Source: Analysys Mason, 2022]

Class	Fixed links	PMR	Saerlige
1	2 601 159	42 483	67 407 642
2	5 627 570	-	1 534 076

Class	Fixed links	PMR	Saerlige
3	-	2 885 744	530 116
4	22 689	2 193	51 243
5	-	-	15 799 025
6	-	-	138 233
7	-	-	352 199
8	-	-	261 764
9	-	-	4 800
Total	**8 251 418**	**2 930 420**	**86 079 098**

7.2 Assessment of revenues under the proposed fee model

Adopting the changes proposed in Section 6.3 has significant implications for the fee model. Due to the revenue-neutrality requirements, the model must be carefully calibrated once it has been updated to incorporate the changes. The primary parameters involved in this calibration are the unit fees applied to each fee class to ensure revenue neutrality in that fee class, which will be discussed further in Section 7.2.3. In the remainder of this section the impact of each proposed change is discussed, and our final modelled results are presented.

7.2.1 Setting of the minimum fee level

Given the overall requirement for revenue neutrality, we propose setting the minimum fee at a level such that the effective income from the minimum fee is roughly equal to the income from the fixed fee under the original fee model. This approach will inevitably mean the minimum fee lies above the previous fixed fee: licensees paying more than the new minimum will effectively have a small reduction in licence fees; licensees paying less than the minimum fee will see their total licence fee increase as a result.

While this approach may seem to negatively affect smaller, more price-sensitive licensees, we expect the level of the minimum fee will not discourage any legitimate and efficient use of spectrum, while simultaneously (potentially) reducing the amount of 'spectrum squatting'. While larger licensees will see a small reduction in their overall licence fee relative to the original fee model, this change will be relatively small compared to the overall fee payable.

Licences with sub-annual durations will see a reduction of the applicable minimum fee, down to a minimum licence duration, which could be set at two weeks subject to case-by-case exceptions for large events. This change is expected to make a negligible difference to the overall revenue calculation as it is only applicable to nine entries in the 2022 licence database. This approach will ensure that individual licensees requiring short-term licences will not be subject to excessive fees while simultaneously being encouraged to return the licence to realise the fee reduction.

Under the original fee model, band breaks and band-value factors, fixed fees payable in 2022 amounted to DKK3 131 400, or 3.2% of the total fees. Under the proposed band breaks and band-value factors, the difference between the total variable fees before the minimum fee is applied, and the total fees after the minimum fee is applied can be considered to be the effective income from the minimum fee. Under the approach proposed in this section, the minimum fee should be set such that this figure is equal to the total fixed fees under the original fee model.

Setting a minimum fee of DKK690 results in an effective income from minimum fees of DKK3 111 115, within 0.7% of the original fixed fee income. We do not expect this minimum fee to impose a significant cost burden on licensees compared to the original DKK600 fixed fee.

We note that the ADSI may choose to impose a higher minimum fee if it wished to further dis-incentivise 'spectrum squatting'. However, in doing so there is also an increased risk of choking off efficient demand. Such a decision is a delicate balancing act, and an exercise in regulatory judgement for the ADSI. Our starting recommendation is therefore as above.

7.2.2 Impact of minimum area scaling factor

The introduction of a 20% minimum area factor increases the total fees collected from class 1 licences by approximately DKK500 000, although the precise figure will ultimately depend on the calibration chosen in Section 7.2.3. While this increase in fee revenue is relatively significant, it is expected that the bulk of these licensees will migrate to fee class 2 in response, reducing the real-world fee revenue increase. These licences were discussed in Section 6.2.5 and the effect is summarised in Figure 7.3.

Figure 7.3: Effect of minimum area factor on class 1 fee revenue for licence database entries with an area factor below 20% [Source: Analysys Mason, 2022]

Licence number	Current area factor	Current class 1 fee (DKK)	Proposed class 1 fee (DKK)[64]
H100593	0.35%	55	37 202
H100593	0.35%	55	37 202
H100593	0.70%	111	37 202
H100593	0.35%	55	37 202
H100593	0.35%	55	37 202
H100593	0.70%	111	37 202
H100593	0.35%	55	37 202
H100593	0.35%	55	37 202
H100593	0.35%	55	37 202
H100593	0.35%	55	37 202
H100818	4.17%	659	9300

64 Note that the updated class 1 fee also includes the effect of other proposed changes, including the updated band values and weightings

Licence number	Current area factor	Current class 1 fee (DKK)	Proposed class 1 fee (DKK)[64]
H100219	1.89%	213	266
H100380	5.52%	15 571	66 432
H100425	2.15%	243	266
H100524	1.12%	126	266
H101002	0.31%	350	26 573
H101002	0.31%	350	26 573

The introduction of a 20% minimum area scaling factor is also expected to stimulate growth with regard to licensing at sea, although the effect of this has not been modelled as the demand dynamics are uncertain (and not relevant to an assessment of revenue neutrality under fixed demand).

7.2.3 Impact of updated band-value factors and model calibration

Updating the spectrum band breaks and the corresponding band-value factors requires calibration of the unit fee (i.e. the fee corresponding to a band-value factor of one) for fee classes 1–4 to maintain revenue neutrality within each fee class. The fee for each band in a given fee class is then calculated by multiplying the band-value factor by the unit fee for that class, and then rounding to the nearest DKK. The licence fees for fee classes 5–9 have not been changed, although the overall revenue figures may move slightly due to the replacement of the fixed fee with a minimum fee.

The unit fees for fee classes 1–4 have been calibrated manually to achieve revenue neutrality and are summarised in Figure 7.4. It should be noted that the updated revenue also includes the minimum fee adjustment, explaining the small fee reductions in fee classes 5–9 as the fixed fee component has been removed. The overall revenue increases by 0.14%, which we consider to be within an acceptable margin, while ensuring that licence fees continue to be expressible as integer values of DKK.

The resulting fees for each band in fee classes 1–4 are summarised in Figure 7.5.

Figure 7.4: Summary of unit fees and revenues by fee class [Source: Analysys Mason, 2022]

Fee class	Unit fee (DKK)	Current revenue (DKK)	Proposed revenue (DKK)	Percentage change in total revenue
1	103.2	70 051 285	70 065 274	0.02%
2	1.2	7 161 646	7 346 504	2.58%
3	0.7	3 415 860	3 424 420	0.25%
4	7.3	76 125	76 380	0.33%
5	-	15 799 025	15 797 825	-0.01%
6	-	138 233	128 138	-7.30%
7	-	352 199	349 799	-0.68%
8	-	261 764	205 934	-21.33%

Fee class	Unit fee (DKK)	Current revenue (DKK)	Proposed revenue (DKK)	Percentage change in total revenue
9	-	4800	2760	-42.50%
Total	**-**	**97 260 937**	**97 397 034**	**0.14%**

Figure 7.5: Summary of updated licence fees for fee classes 1–4 [Source: Analysys Mason, 2022]

Frequency band (MHz)	Band-value factor	Class 1 fee (DKK per MHz)	Class 2 fee (DKK per MHz per position)	Class 3 fee (DKK per 25kHz)[65]	Class 4 fee (DKK per licence)
0–380	32	3301	39	22	232
380–470	64	6602	78	45	464
470–694	320	33 008	390	224	2320
694–960	960	99 024	1171	672	6960
960–4200	320	33 008	390	224	2320
4200–12000	64	6602	78	45	464
12000–24250	16	1650	20	11	116
24250–43500	16	1650	20	11	116
43500–90000	1	103	1	1	7
over 90000	0.5	52	1	1	4

We note that a possible modification to our proposal would be to round the fees per frequency band for each fee class (e.g. to the nearest DKK10, at least for fee class 1). This could offer 'rounder' numbers for the final fees, although the ratios between the different frequency bands would vary slightly. However, we use the calculated values for the purposes of our recommendation.

Following this approach, it is informative to compare the change in the nominal fee value for each frequency band between the current fee model and the proposed fee model. Given the different band structures in the two fee models it is helpful to define a set of frequency bands that conservatively capture frequency bands from both fee models. A summary for fee class 1 (the largest in terms of overall revenue) is provided in Figure 7.6. The ratio column identifies the extent to which licensees in different frequency bands will be impacted by the change.

65 Note: the fee shown is for ≤30 mobile units, the fee for >30 mobile units is four times larger, in line with the original fee model

Figure 7.6: Comparison of nominal fee values for fee class 1 between the current and proposed models. Significant deviations between fee models (>20%) have been highlighted in orange, while frequency bands with no affected licence database entries have been highlighted in grey [Source: Analysys Mason, 2022]

Frequency band (MHz)	Current model fee (DKK per MHz)	Proposed model fee (DKK per MHz)	Ratio	Affected licence database entries
0–380	56 405	3301	0.06	9
380–470	56 405	6602	0.12	55
470–694	112 811	33 008	0.29	-
694–960	112 811	99 024	0.88	12
960–1000	112 811	33 008	0.29	-
1000–3000	56 405	33 008	0.59	22
3000–4200	5640	33 008	5.85	3
4200–9500	5640	6602	1.17	3
9500–12700	564	6602	11.70	10
12700–24250	564	1650	2.93	43
24250–33400	564	1650	2.93	42
33400–43500	282	1650	5.85	29
43500–57000	282	103	0.37	-
57000–90000	94	103	1.10	6
over 90000	94	52	0.55	-

The 0–380MHz and 380–470MHz bands see the largest reduction in nominal variable spectrum licence fees. This reduction is offset by the minimum fee in a number of cases. However larger licensees will still see a significant reduction in the licence fee payable. As noted in Section 7.2.2, several of these licences will actually see an overall increase in fees due to the minimum area factor, encouraging them to migrate into fee class 2.

In terms of bands used for public mobile, the 694–960MHz band sees no significant change. The 1000–3000MHz band sees a fee reduction of around 40%, while the 3000–4200MHz band sees an increase of almost 500%, in line with the view that it has become significantly more useful for mobile use since the model's inception. The 24GHz band also sees a smaller increase of around 200%, again reflecting its increased value relative to the view of the original fee model. Operators holding licences in the 1500MHz, 1800MHz, 2.1GHz, 2.3GHz and 2.6GHz bands will therefore see a reduction in licence fees, while licensees in the 3.4–3.8GHz and 24GHz bands will see a significant increase. In practical terms, these are of course the same licensees.

Fixed links between 9500MHz and 43 500MHz will see significant increases in fees, in line with the ADSI's objective of encouraging fixed links to move above the 43 500MHz band. Fees for fixed links in the 57000–90000MHz bands remain broadly stable, continuing to encourage fixed-link licensees into this band.

A major impact of changes to the band-value factors is the transfer of fee burden across use cases within fee class 1, with around DKK6.0 million of fees 'transferred' from saerlige to fixed links (although overall revenue neutrality is achieved for fee class 1), as shown in Figure 7.7. We note however that these changes may not significantly affect individual licensees as fixed-link licensees are primarily MNOs, which would be the main beneficiaries of an equivalent fee reduction for the saerlige category. The relative increase in fixed-link fees could generate interest in alternative licensing approaches, and the fee impact could be partially offset through a (lower-cost) light-licensing approach in some high-frequency bands for fixed links.

Figure 7.7: Changes in fees between use cases in fee class 1 [Source: Analysys Mason, 2022]

	Fixed links	Saerlige
Current fee model	2 601 159	67 407 642
Proposed fee model	8 551 503	61 508 340
Delta between models	5 950 344	-5 899 302

8 Conclusions and further considerations

8.1 Overall conclusions

In light of analysis of both demand and technology trends, as well as international benchmarks of licence fee models in other European markets, we have proposed an updated set of frequency band breaks and band-value factors to be applied to fee classes 1–4. These proposed band breaks and band-value factors, along with the corresponding fees, are summarised in Figure 7.5.

Figure 8.1: Summary of updated licence fees for fee classes 1–4 [Source: Analysys Mason, 2022]

Frequency band (MHz)	Band-value factor	Class 1 fee (DKK per MHz)	Class 2 fee (DKK per MHz per position)	Class 3 fee (DKK per 25kHz)[66]	Class 4 fee (DKK per licence)
0–380	32	3301	39	22	232
380–470	64	6602	78	45	464
470–694	320	33 008	390	224	2320
694–960	960	99 024	1171	672	6960
960–4200	320	33 008	390	224	2320
4200–12000	64	6602	78	45	464
12000–24250	16	1650	20	11	116
24250–43500	16	1650	20	11	116
43500–90000	1	103	1	1	7
over 90000	0.5	52	1	1	4

We have further proposed a minimum fee of DKK690 is implemented to replace the existing DKK600 fixed fee. The level of this fee has been set to provide approximately equivalent fee income from the minimum fee as is currently provided by the fixed fee, while simultaneously discouraging inefficient use of spectrum by smaller licensees.

We also proposed the implementation of a minimum geographical area factor of 20%, in line with benchmarks of comparable markets. This serves the dual purpose of encouraging use of licences at sea while simultaneously discouraging the use of class 1 licences to reduce fees for low area coverage use cases, as is currently the case.

The combined effect of these proposals has been modelled and they are expected to produce an overall revenue-neutral outcome for the ADSI, ultimately increasing total revenue by 0.14% under an assumption of fixed demand (at 2022 year-to-date levels). Inevitably, the fees for individual licensees may increase or decrease depending on the licence held as well as the use case, however

66 Note: the fee shown is for ≤30 mobile units, the fee for >30 mobile units is four times larger, in line with the original fee model

we believe that all of these changes are justifiable in light of the current technological and demand landscape as well as the wider objectives of the ADSI.

The final proposed fee model takes into account changes in technology and demand that have occurred since the creation of the original fee model, as well as expected future developments. The spectrum band breaks have been carefully designed to categorise similar frequencies together, taking into account expected future demand and technology developments, thereby providing a framework for encouraging efficient use of spectrum. The proposed fee model is therefore expected to provide a strong level of future-proofing, allowing regulatory flexibility as the various spectrum use cases mature.

We also suggest that light licensing in Denmark could be used to partially offset the increase in class 1 fixed link licence fees under the newly proposed band structure, or to encourage these licensees to move into higher frequency bands where a greater amount of spectrum is available.

8.2 Further considerations for the ADSI

This report has identified potential issues with the current fee model and proposed possible approaches to addressing these issues, through proposed updates to the fee model. It is important to note that the recommendations contained in this report do not represent a unique solution: in many cases alternative solutions to those proposed in this report are available. We suggest that the ADSI can consider alternative solutions as it performs further analysis on the fee model to ensure that the updated fee model can be implemented in a straightforward manner and in line with the systems and capabilities of the ADSI. We provide a few examples of alternative approaches to key issues as follows.

Band breaks

Based on the review of relevant current and future demand and technology trends, we recommend splitting many of the existing frequency bands into multiple sub-bands, ultimately moving from six or seven bands to ten bands. Although generally aligned with other European regulators, there are slight differences in the choice of the band breaks between regulators. With some approaches choosing to split bands based on current or future usage and some based on technology.

For example, we recommended splitting the 470–694MHz and 694–960MHz bands due to differences in current usage (broadcasting and public mobile respectively). However, these bands can be considered as similar on a technological basis (i.e. the physical properties of the spectrum are very similar), and hence it could reasonably be argued that they could be included within a single category.

There are therefore a number of justifiable ways to define the band breaks for the Danish fee model, and similarly the band-value factors; these different approaches can be considered by the ADSI as it performs further analysis.

Broadcasting classes

Currently, broadcasting licences are issued under classes 5 to 8, based on historical market dynamics. In this report, we have not recommended changes to fee classes 5–9 as there has not been significant developments in the sector in recent years that would, in our view, warrant such changes. There are however other valid approaches to defining the fee model for the broadcasting classes, and updating the fee model to reflect these would also be a reasonable approach.

For example, an alternative approach would be to issue broadcasting licences under fee classes 1 to 4, in order to streamline the fee model and reflect changes in market dynamics and technologies – i.e. a 'generic classes' approach. Under this approach, current class 5 licences could be issued under class 1.

Implementing such a change would have an impact on the fees paid by users of class 5 to 8 licences as well as an impact on the overall revenue. The impact of the fee change on users would have to be reviewed and considerations would have to be made to maintain overall revenue neutrality (which would likely include raising the level of fees in some or all of classes 1-4).

Minimum fee vs fixed fee

In this report, we propose to apply an incremental minimum fee to fee classes 1-4, while adopting a standard minimum fee approach for fee classes 5-9. We noted that a significant risk of introducing a minimum fee is that smaller licensees may no longer be disincentivised from increasing their spectrum holdings beyond what they actually require due to the lack of an associated incremental cost while the overall variable licence fee remains below the minimum fee threshold. To address this issue, we have proposed an 'incremental minimum fee' approach.

Such an approach could however have some implementation challenges. For example, where individual positions are not held for an entire year, there is likely to be complexity concerning which position's variable fees should be covered by the minimum fee (and consequently what variable fees should be charged incrementally to this minimum fee).

The ADSI could consider alternative approaches, such as a fixed fee that scales depending on licence duration. This approach would disincentives licensees from holding onto licences for longer than they need them and benefit smaller users who only need licences for a short amount of time. This approach would however impact revenue neutrality and corresponding adjustments would have to be made across the fee model.

Annex A Variable fee class structure in Denmark

Figure A.1: Variable fee model for fee class 1 [Source: ADSI[67], 2022]

Frequency band	Variable unit fee (DKK/MHz)	Band-value factor	Total variable fee (DKK/MHz)
0–470MHz	282	600	56 405
470MHz–1GHz	282	1200	112 811
1–3GHz	282	600	56 405
3–9.5GHz	282	60	5 640
9.5–33.4GHz	282	6	564
33.4–57GHz	282	3	282
>57GHz	282	1	94

Figure A.2: Variable fee model for fee class 2 [Source: ADSI, 2022]

Frequency band	Variable unit fee (DKK/MHz)	Band-value factor	Total variable fee (DKK/MHz)
0–470MHz	1	5531	5531
470–1000MHz	1	5531	5531
1000–3000MHz	1	2766	2766
3000–9500MHz	1	277	277
9500–21 000MHz	1	11	11
21 000–33 400MHz	1	6	6
33 400–57 000MHz	1	3	3
over 57 000MHz	1	1	1

Figure A.3: Variable fee model for fee class 3 [Source: ADSI, 2022]

Frequency band	Total variable fee (≤30 mobile units) (DKK per 25kHz position)	Total variable fee (>30 mobile units) (DKK per 25kHz position)
0–470MHz	52	208
470–1000MHz	52	208
1000–3000MHz	26	104
3000–9500MHz	3	12
9500–33 400MHz	3	12
over 33 400MHz	3	12

67 https://ens.dk/sites/ens.dk/files/Tele/frekevensafgifter_2022_0_0.pdf

Figure A.4: Variable fee model for fee class 4 [Source: ADSI, 2022]

Frequency band	Variable unit fee (DKK)	Band-value factor	Total variable fee (DKK)
0–470MHz	1	1593	1593
470–1000MHz	1	3186	3186
1000–3000MHz	1	1593	1593
3000–9500MHz	1	159	159
9500–33 400MHz	1	16	16
over 33 400MHz	1	8	8

Figure A.5: Variable fee model for fee class 5 [Source: ADSI, 2022]

Frequency band	Variable unit fee (DKK per MUX)	Band-value factor	Total variable fee (DKK per MUX)
0–470MHz	1 579 782	1	1 579 782
470–1000MHz	1 579 782	2	3 159 565

Figure A.6: Variable fee model for fee class 6 [Source: ADSI, 2022]

Frequency band	Total variable fee (DKK per network)
0–470MHz	43 035

Figure A.7: Variable fee model for fee class 7 [Source: ADSI, 2022]

Frequency band	Total variable fee (DKK per network)
0–470MHz	72 064

Figure A.8: Variable fee model for fee class 8 [Source: ADSI, 2022]

Frequency band	Total variable fee (DKK per position)
0–470MHz	146

Figure A.9: Variable fee model for fee class 9 [Source: ADSI, 2022]

Frequency band	Total variable fee (DKK)
0–470MHz	600

Annex B Exchange rates

Figure B.1: Summary of exchange rates used throughout the report, rates correct as of 10 May 2022 [Source: Oanda, 2022]

Local currency (LCU)	Conversion rate (DKK/LCU)
EUR	7.43795
GBP	8.69488
NOK	0.73555
USD	7.05860