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Mathematical Model for electrical consumption in road tunnels in Norway and Spain

Forfatter
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Emneord
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Sammendrag
Denne rapporten er den andre av totalt seks rapporter fra et to-årige FoU-samarbeid Varige konstruksjoner har med det spanske engineering-selskapet Geocontrol. Samarbeidet er rettet mot utvikling av energieffektive tunneler gjennom prosjektet ENERTUN som Geocontrol leder. ENERTUN gjennomføres i regi av EEA GRANTS, en samarbeidsorganisasjon der EØS-landene Norge, Island og Lichtenstein gir midler og tilskudd (via Innovasjon Norge) til 16 EU-land i Sentral- og Sør-Europa.

Rapporten gir en oversikt over dagens totale strømforbruk i tunnelene med analyser av forbruksmønsteret og mulig optimalisering av fremtidig forbruk.

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Energy efficiency in tunnels - ENERTUN - D.2.1

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Harald Buvik

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Summary
This report is the second of a total of six reports from a two-year R&D collaboration Durable structures have with the Spanish engineering company Geocontrol. The partnership is aimed at developing energy efficient tunnels through the project ENERTUN as Geocontrol leads. ENERTUN is pursued by the EEA GRANTS, a cooperative organization where the EEA countries Norway, Iceland and Lichtenstein provides funds and grants (via Innovation Norway) for 16 EU countries in Central and Southern Europe.

The report provides an overview of the current total power consumption in the tunnels with analysis of consumption patterns and possible optimization of future consumption.

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Forord

Denne rapporten inngår i en serie rapporter fra **etatsprogrammet Varige konstruksjoner**. Programmet hører til under Trafikksikkerhet-, miljø- og teknologiavdelingen i Statens vegvesen, Vegdirektoratet, og foregår i perioden 2012-2015. Hensikten med programmet er å legge til rette for at riktige materialer og produkter brukes på riktig måte i Statens vegvesen sine konstruksjoner, med hovedvekt på bruer og tunneler.

Formålet med programmet er å bidra til mer forutsigbarhet i drift- og vedlikeholdsfasen for konstruksjonene. Dette vil igjen føre til lavere kostnader. Programmet vil også bidra til å øke bevisstheten og kunnskapen om materialer og løsninger, både i Statens vegvesen og i bransjen for øvrig.

For å realisere dette formålet skal programmet bidra til at aktuelle håndbøker i Statens vegvesen oppdateres med tanke på riktig bruk av materialer, sørge for økt kunnskap om miljøpåkjenninger og nedbrytningsmekanismer for bruer og tunneler, og gi konkrete forslag til valg av materialer og løsninger for bruer og tunneler.

Varige konstruksjoner består, i tillegg til et overordnet implementeringsprosjekt, av fire prosjekter:

Prosjekt 1: Tilstandsutvikling bruer
Prosjekt 2: Tilstandsutvikling tunneler
Prosjekt 3: Fremtidens bruer
Prosjekt 4: Fremtidens tunneler

Varige konstruksjoner ledes av Synnøve A. Myren. Mer informasjon om prosjektet finnes på vegvesen.no/varigekonstruksjoner

Denne rapporten tilhører **Prosjekt 4: Fremtidens tunneler** som ledes av Harald Buvik. Prosjektet skal bidra til at fremtidige tunneler bygges med materialer, utførelse og kontroll bedre tilpasset det miljøet konstruksjonene er utsatt for. Prosjektet skal bygge videre på arbeidet i Moderne Vegtunneler, samt innspill fra Prosjekt 2: Tilstandsutvikling tunneler, med hovedfokus på tunnelkonstruksjonen i et levetidsperspektiv. Prosjektet skal resultere i at installasjoner i fremtidige tunneler oppnår tiltenkt levetid med reduserte og mer forutsigbare drift- og vedlikeholdskostnader.

Rapporten er utarbeidet av *Daniel Octavio de Toledo, Geocontrol*.

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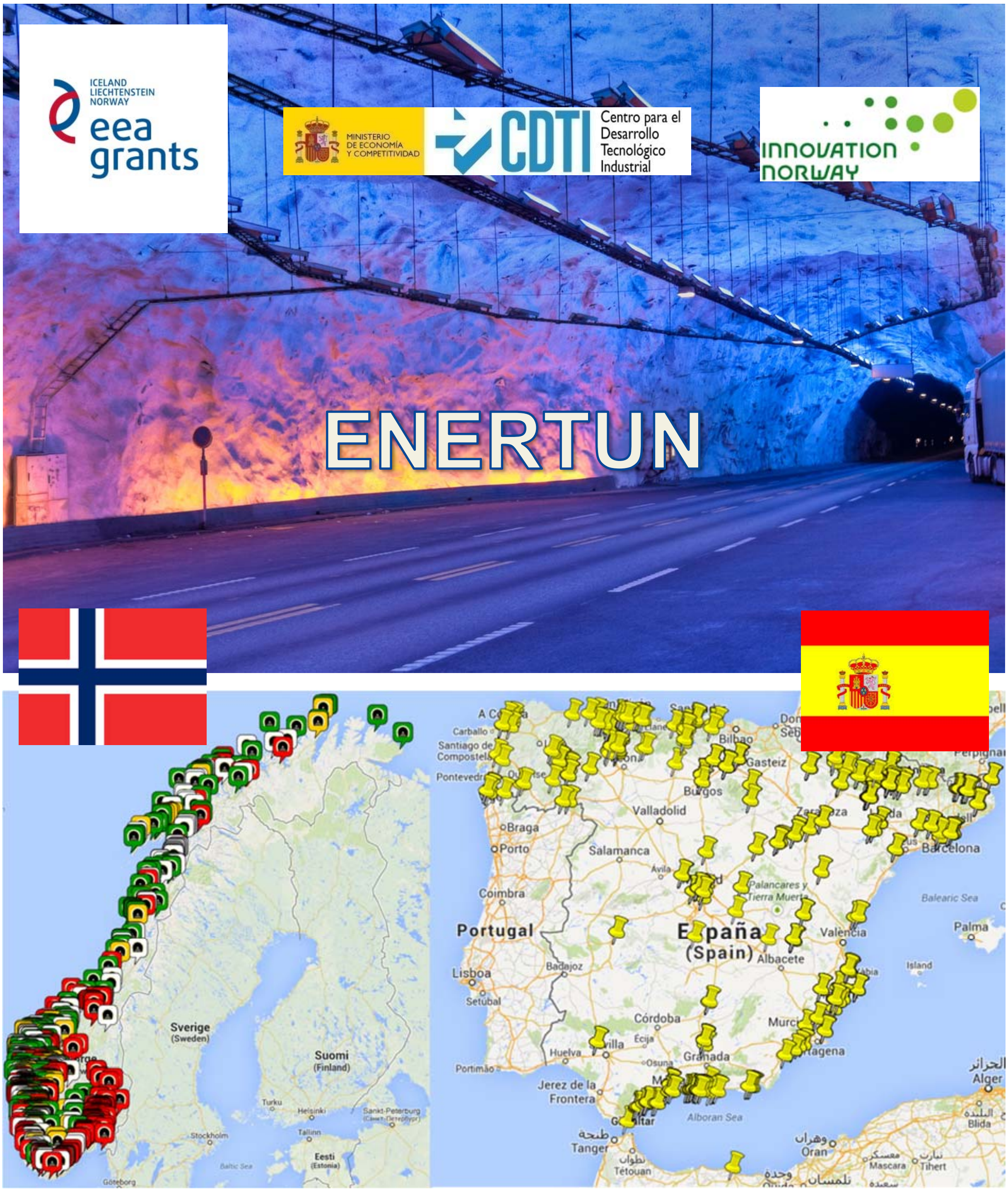

DELIVERABLE 2.1.- MATHEMATICAL MODEL FOR ELECTRICAL CONSUMPTION IN ROAD TUNNELS IN NORWAY AND SPAIN

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Date	18/09/2014	18/09/2014	18/09/2014
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ENERTUN

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INDEX

ENERTUN
DELIVERABLE 2.1.- MATHEMATICAL MODEL FOR ELECTRICAL CONSUMPTION IN ROAD TUNNELS IN NORWAY AND SPAIN

1. INTRODUCTION.

This report is written as the preliminary second document to deliver in the framework of the EnerTun project.

The deliveries in the framework of the Enertun project are divided into four phases or packages of work:

- Work Package 1:

This phase is oriented on investigating existing technologies for achieving energy efficiency in the industry sector and evaluating the possibility of integrating them in a tunnel.

- Work Package 2:

This phase consists on the study of the energy consumption in real cases of tunnels in Norway and Spain.

The electricity bills will be studied in order to set a pattern of consumption, which allows making proposals of improvements.

- Work Package 3:

This phase consists on the evaluation of measures to undertake in order to accomplish three objectives:

Reduction of the energy consumption.

Reduction of the time of consumption.

Increasing of the power generation.

This phase has to be done with the feedback of phase 2.

- Work Package 4:

The aim of this phase is a study of economic viability for the development of prototypes with the cutting-edge of technology.

The content of this second preliminary delivery is related to the study of energy consumption phase, which means an analysis of the electricity bills collected from Norwegian and Spanish tunnels. The interest of analysing the electricity bills is to verify whether there is a pattern for energy consumption that permits estimating and optimizing future consumptions.

In the current version of this document, the Norwegian road tunnels have been analysed, as the analysis of the Spanish road tunnels is not finished yet. In the next sections of the document, further information is given about all the collected information.

2. DATA TREATMENT.

The first step in order to carry out the study of the Energy Consumption of several Norwegian road tunnels has been the treatment of the available data provided by the NPRA (Norwegian Public Road Administration).

2.1. STORAGE OF DATA COLLECTED.

The website http://www.entro.no/nohovedside.aspx provides the available data of the Energy Consumption of 20 road tunnels, which are located in the western part of Norway.

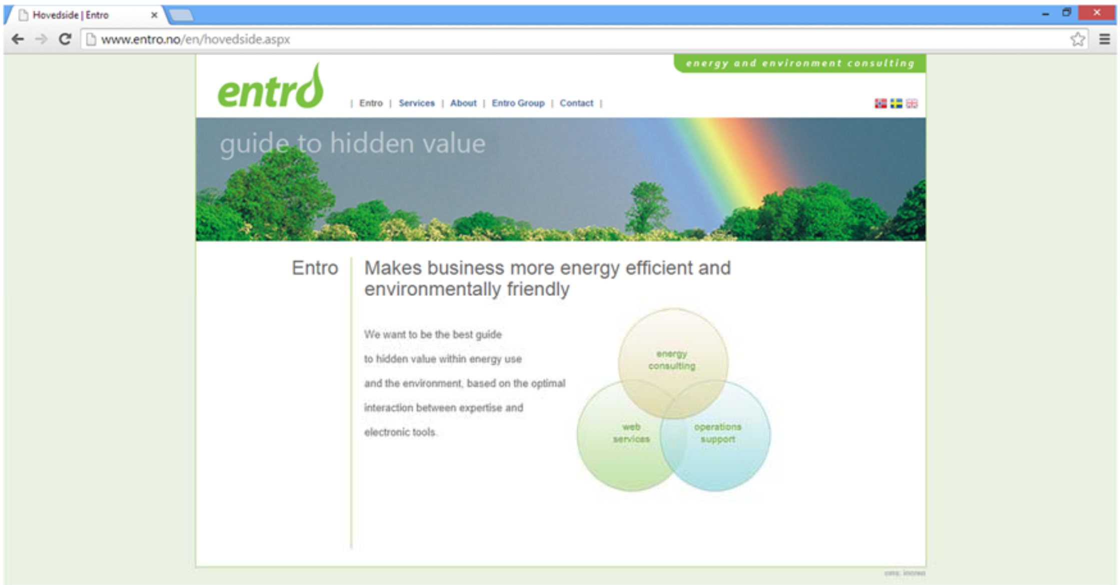


Figure 2.1.I. - Norwegian website with available data of Energy Consumption in road tunnels

This website permits downloading the available data of the following road tunnels:

- Arnanipa tunnel. (1)
- Byfjord tunnel. (2)
- Bømlafjord tunnel. (3)
- Damsgård tunnel. (4)
- Eikefet tunnel. (5)
- Flenja tunnel. (6)
- Fløyfjell tunnel. (7)
- Glasskar tunnel. (8)
- Gudvanga tunnel. (9)
- Lyderhorn tunnel. (10)
- Lærdal tunnel. (11)
- Løvstakk tunnel. (12)
- Masfjord tunnel. (13)
- Mastrafjord tunnel. (14)
- Nygård tunnel. (15)
- Risnes tunnel. (16)
- Røldal tunnel. (17)
- Stavenes tunnel. (18)
- Trengereid tunnel. (19)
- Åkrafjord tunnel. (20)

This website offers two possibilities for downloading the data stored:

- Download data in graphic format.
- Download data in table format (excel).

In the case of this study, the table format has been chosen, as it allows the treatment and subsequent creation of comparative graphics.

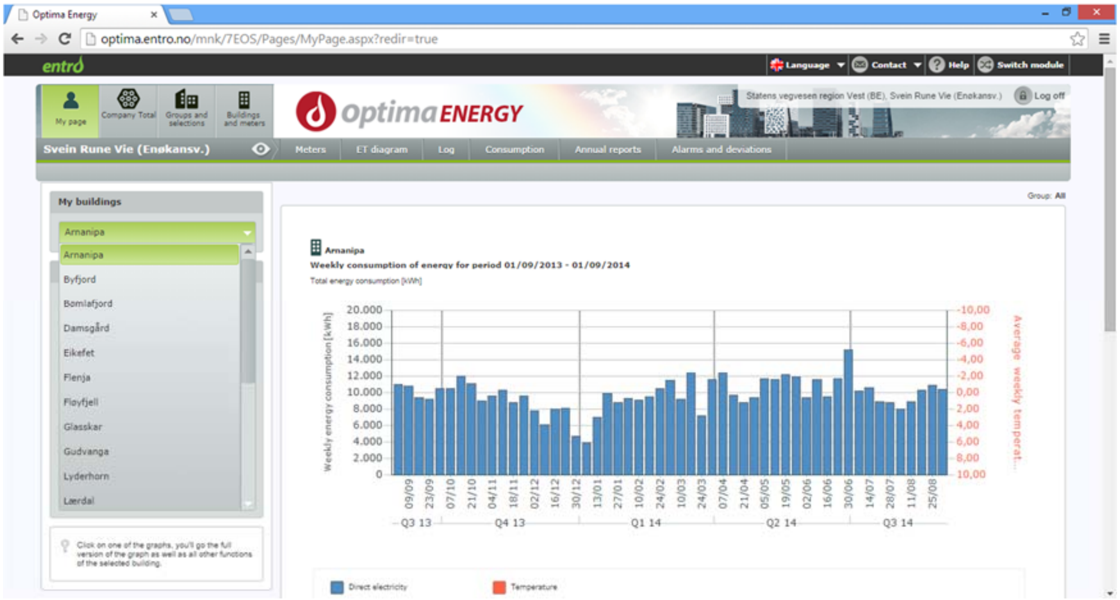


Figure 2.1.II. – Possibilities for downloading available data of the Norwegian tunnels.

2.2. SUMMARY OF THE ROAD TUNNELS AIMED TO BE STUDIED.

The **Table 2.2.I** summarises the main characteristics of the road tunnels aimed to be studied.

Name of tunnel	Type	Length [m]
Arnanipa	High traffic intensity	2.133
Byfjord	Subsea	5.875
Bømlafjord	Subsea	7.888
Damsgård	High traffic intensity	2.702
Eikefet	Low traffic intensity	4.910
Flenja	Low traffic intensity	5.053
Fløyfjell	High traffic intensity	7.020
Glasskar	High traffic intensity	1.172
Gudvanga	Low traffic intensity	11.425
Lyderhorn	High traffic intensity	2.202
Lærdal	Low traffic intensity	24.509
Løvstakk	High traffic intensity	2.045
Masfjord	Low traffic intensity	4.110
Mastrafjord	Subsea	4.424
Nygård	High traffic intensity	1.728
Risnes	High traffic intensity	1.718
Røldal	Low traffic intensity	4.657
Stavenes	High traffic intensity	2.771
Trengereid	High traffic intensity	1.770
Åkrafjord	Low traffic intensity	7.404
Total		**105.516**

Table 2.2.I. – Main characteristics of the Norwegian road tunnels aimed to be studied.

As it is shown in the previous table, there are significant differences among the tunnels. It's quite obvious that the Energy Consumption of the Lærdal tunnel, whose length is 24,509 km will not be the same as in the Risnes tunnel, whose length is 1,718 km.

The total length of the tunnels is 105,516 km altogether.

2.3. FILTERING OF THE DATA DOWNLOADED.

In this section it will be explained the treatment given to the available data in order to solve existing problems and to remove data considered as non-representative.

- First implemented filter for absence of values in data files:

First, it has been observed in the downloaded data files that some cells were empty, with no value. This generates a problem in the subsequent treatment of the values and needs to be solved.

In this case, the first filter has been carried out. The filter has consisted in detecting these situations and replacing the empty value in the hourly consumption cell C_h^d by the consumption at the same hour, but from the previous day C_h^{d-1}

The **Figure 2.3.I** shows this situation in the particular case of the Bømlafjord tunnel, with a missing value for the Energy Consumption de 30th of Mars of 2014 between 23:00h and 24:00h:

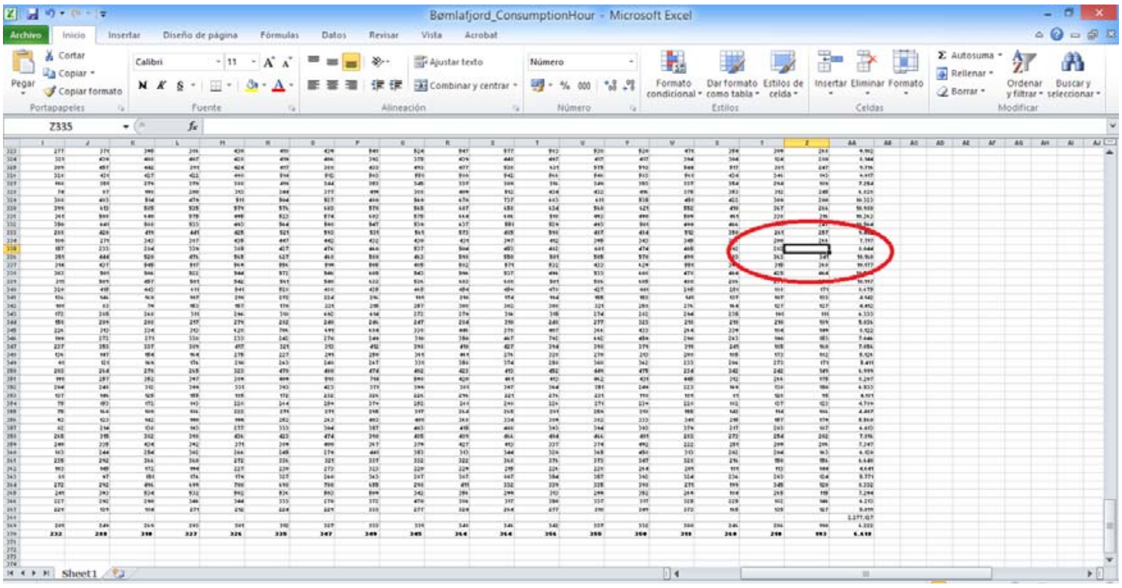


Figure 2.3.I. – Absence of value in the Bømlafjord tunnel data.

In the **Figure 2.3.II** it is shown the resolution for this situation:

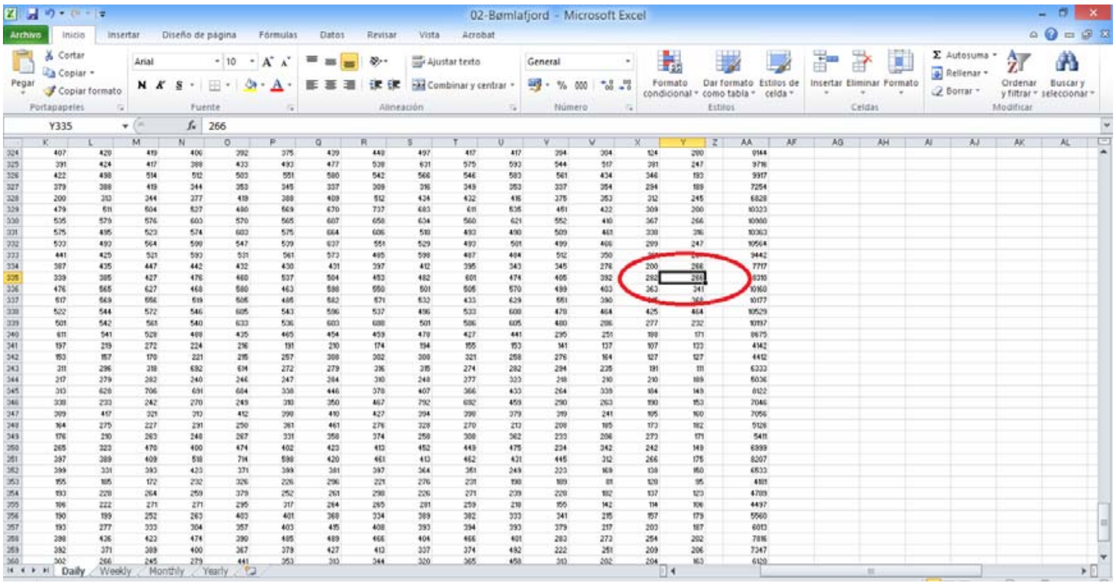


Figure 2.3.II. – Solution for absence of value in the Bømlafjord tunnel data.

The value filling the former empty cell corresponds to the value of the previous day (29th Mars 2014) in the same hourly period.

This problem is probably due to the measure equipment.

- <u>Second implemented filter to exclude non-representative values:</u>

After the first problem has been overcome, the next step forward deals with excluding from the analysis those values considered as non-representative or bizarre.

In order to remove these values, the following steps have been followed:

1) Calculation of the average value C_h^{av} of the hourly Energy Consumption data over a whole year.

$$C_h^{av} = \sum_{j=1}^{365} C_h^j \text{ (kW h)}$$

2) Calculation of the deviation of the hourly Energy Consumption data ε_h^d with respect to the average value (calculated in step 1).

$$\varepsilon_h^d = \left| C_h^d - C_h^{av} \right| \text{ (kW h)}$$

With:

h: the hour for which the deviation is calculated.

i: day of the year, from 1/5/2013 to 30/4/2014

Therefore, there will be 8760 (24h x 365days) values, one per each hour of a whole year.

3) Calculation of the average value for every hour within the day over a whole year, from 1/5/2013 to 30/4/2014:

$$\varepsilon_h^{av} = \sum_{j=1}^{365} \varepsilon_h^j \text{ (kW h)}$$

With:

av: average notation.

h: hour of the day for which the average is calculated.

Therefore, there will be 24 different average values, one per each hour of the day.

4) Calculation of the K Factor, defined as the ratio between ε_h^d and ε_h^{av}.

$$K = \varepsilon_h^d / \varepsilon_h^{av}$$

The K Factor gives us an idea of in which measure the data are far away from the hourly average value. This permits to establish criteria for acceptance of the values.

A 3-D surface graphical representation has been created in order to analyse the results directly at a glance. In all of the cases studied, it has been stated K=3 as maximum value for acceptance of the data.

If one of the data collected provides a higher value than 3 for the K Factor, then it has been replaced by the value of the same hour, but from the previous day.

The fact of putting K=3 as admissible margin suppose that a certain percentage of the data has been removed as non-representative, varying from a 1,36% for the Nygård tunnel to a 5,13% for the Løvstakk tunnel.

The **Figure 2.3.III** and **2.3.IV** shows an example, based on weekly average values, of the variation of the 3-D distribution for Energy Consumption after the implementation of the second filter, for the particular case of the Bømlafjord tunnel:

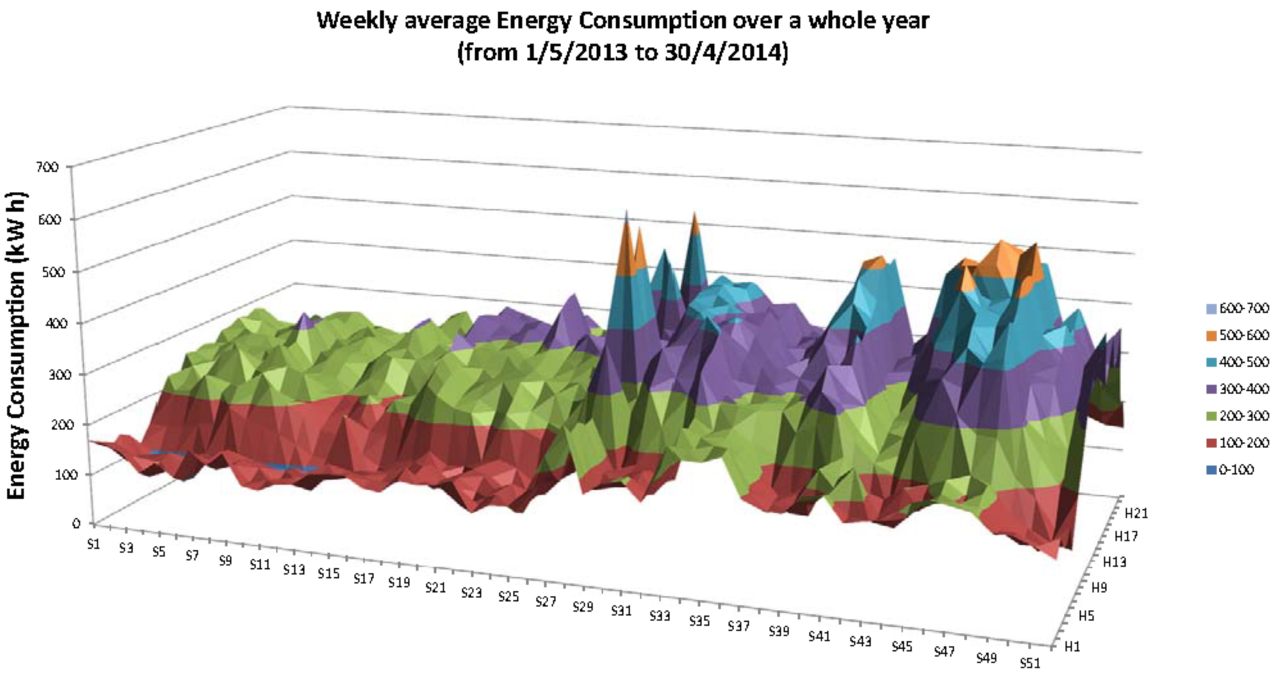


Figure 2.3.III. – Weekly average Energy Consumption before the second filter.

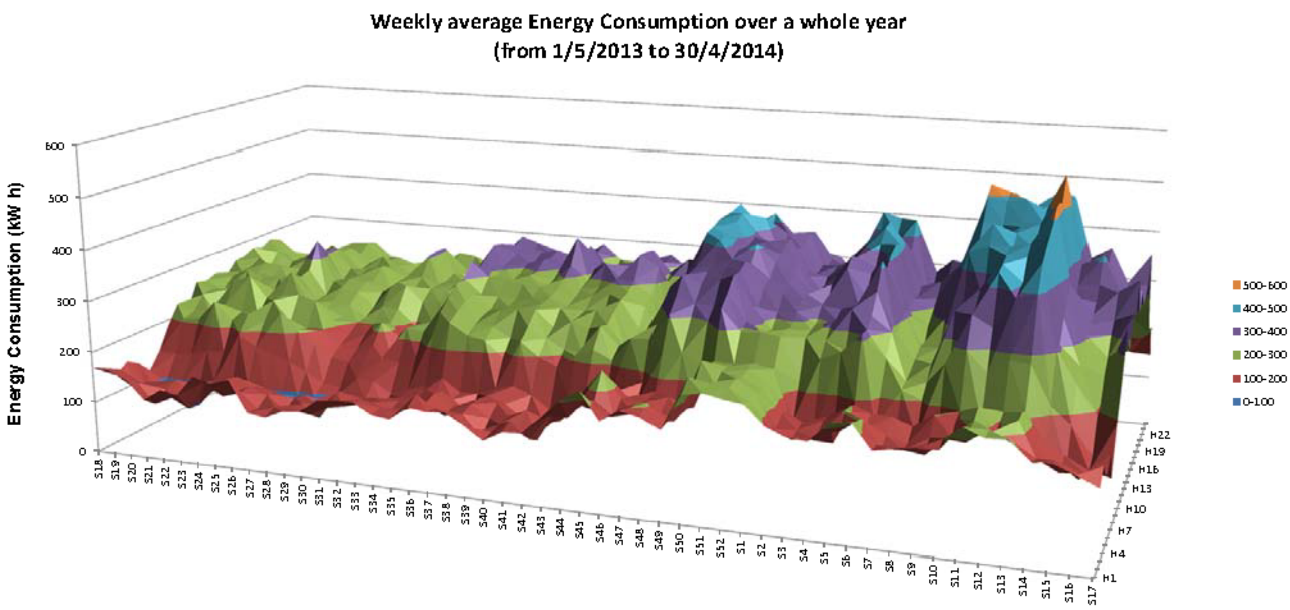


Figure 2.3.IV. – Weekly average Energy Consumption after the second filter.

2.4. RESULTS OBTAINED AFTER APPLYING THE SECOND FILTER.

The application of the second filter has permitted to remove those values considered as non-representative or bizarre among the whole data.

In some cases the application of the second filter has turned out in slight variations, while in other cases the changes have been more visible.

In this section, the cases with the most notorious variations will be outlined.

The **Table 2.4.I** shows those tunnels that present days with more than 12h with removed data, after evaluation of the K Factor.

For the tunnels outlined in this table, it would be necessary to be provided with further information about the consumptions of those special days. This way, it would be possible to clarify why those situation have taken place, which are out of the expected range of values.

The **Annexe 1** includes the graphical representations of the K Factor for each tunnel aimed to be studied.

Tunnel	Day	Period with >12h removed values
Arnanipa	-	0
Byfjord	-	0
Bømlafjord	05/11/2013	15
	08/11/2013	13
	09/11/2013	14
Damsgård	11/11/2013	15
	13/11/2013	13
Eikefet	04/08/2013	14
	03/09/2013	14
	15/04/2014	13
Flenja	24/01/2014	22
Fløyfjell	-	0
Glasskar	19/05/2013	14
	22/05/2013	14
Gudvanga	-	0
Lyderhorn	-	0
Lærdal	-	0
Løvstakk	18/06/2013	19
	19/06/2013	17
	20/06/2013	19
	21/06/2013	18
	22/06/2013	19
	23/06/2013	22
	24/10/2013	14
	25/10/2013	15
	05/02/2014	24
Masfjord	-	0
Mastrafjord	-	0
Nygård	-	0
Røldal	-	0
Stavenes	03/04/2014	13
Trengereid	-	0
Åkrafjord	17/02/2014	23
	18/02/2014	23
	03/04/2014	18
	04/04/2014	14

Table 2.4.I. –Tunnels with elevated removed data days

3. GRAPHICAL REPRESENTATION OF THE AVAILABLE DATA.

As stated previously, the first step has been downloading all the available data in an appropriate format, which allows the treatment to reach to results and subsequent conclusions.

3.1. HOURLY CONSUMPTION IN A WHOLE YEAR.

The first graphic obtained is the one that represents the Energy Consumption per hour in a whole year, after the filtering has been carried out.

In the particular case of the Fløyfjell tunnel, this graphic of the hourly consumption for 6 months would be:

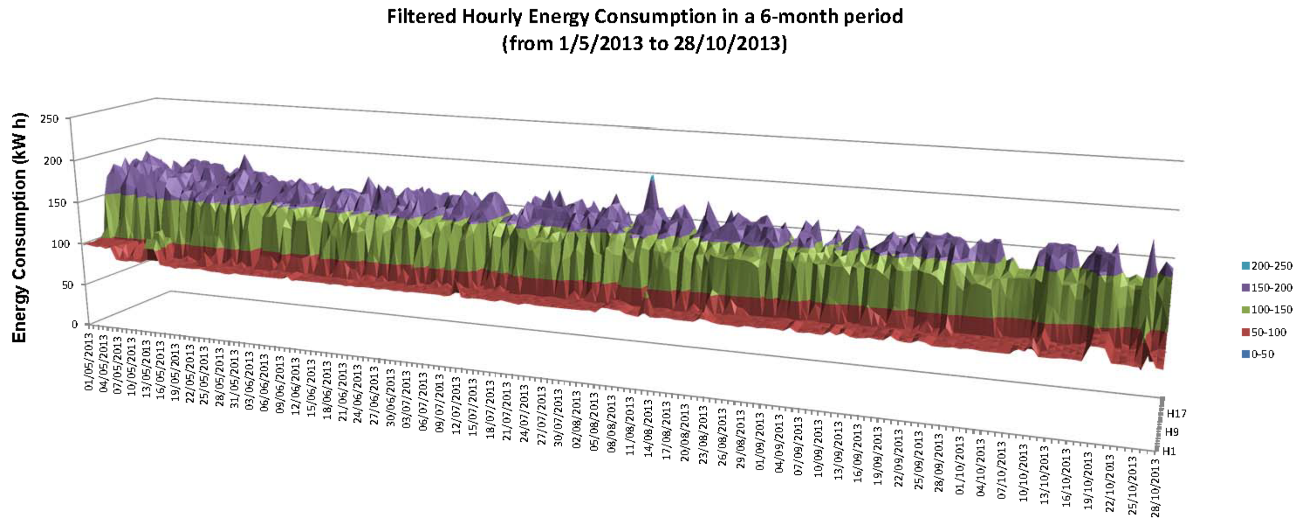


Figure 4.1.I. – Hourly Consumption in 6-month period in the Fløyfjell tunnel.

Due to the enormous volume of data, the representation is done for a 6-month period.

As it is shown, it is of great difficulty trying to establish a pattern for the consumption with this kind of graphic, what means that some approximations need to be adopted.

3.2. WEEKLY CONSUMPTION IN A WHOLE YEAR.

In order to analyse in a clearer way the data, an approximation has been implemented: for every hour of the day, it has been calculated the average value in a week.

This way, as we work with average values, in the X axis only 52 points are represented, which corresponds with the 52 weeks within a whole year, a considerable difference if we have to deal with 365 days, as in the previous graphics.

This sort of graphic will allow to analyse more easily the data and to verify whether they follow somehow a pattern.

Once again, if we consider the particular case of the Fløyfjell tunnel, this graphic would be:

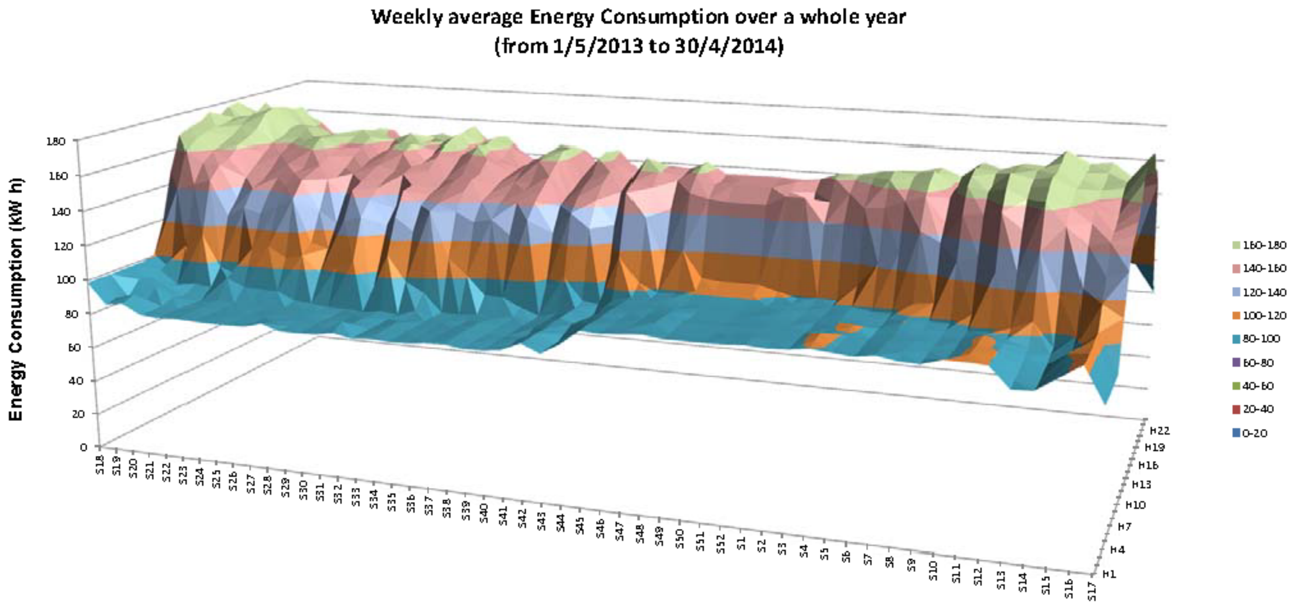


Figure 4.2.I. – Weekly average Consumption in a whole year in the Fløyfjell tunnel.

If we analyse the weekly average Consumption graphic for the Fløyfjell tunnel, we can extract several conclusions:

- For this particular case, there is a pattern of consumption that doesn't vary significantly throughout a whole year, with a peak near midday and a decreasing rate during night time.

- The Energy Consumption during night time varies throughout the year, with the lowest level between the 20th and 40th week.

The fact that the lowest rate of consumption is reached during night time may be explained especially because:

1) The lighting system is working only with the permanent luminaries, which means the lowest need of power supply for this system. It may also be studied if there is an energy flow reduction during certain time bands during the night.

2) The ventilation system is surely working less than during the day, since, unless in case of a fire appearance, it is due to work when the pollution level overpass a specific margin, which is closely related to the amount of vehicles in the tunnel.

The peak of Energy Consumption takes place the 18th week between 13:00h and 19:00h and, taken into account that this is a strange value over the rest of the data, it might be explained by the realisation of some installations tests, probably involving the ventilation system.

3.3. FIRST REPRESENTATIVE RESULTS.

In order to have a more global view of the Energy Consumption over a whole year, three new graphics have been obtained and are explained in the following sections of this report.

3.3.1. ENERGY CONSUMPTION DEPENDING ON THE DAY OF THE WEEK.

It is interesting to analyse whether the day of the week has some relevance or not as far as Energy Consumption is referred.

In this section, the Røldal tunnel has been taken as the reference tunnel to conduct the analysis. The graphic that shows the Energy Consumption accumulated every day of the week over a whole year (from the 1st of May 2013 to the 1st of May 2014) is presented in the following lines:

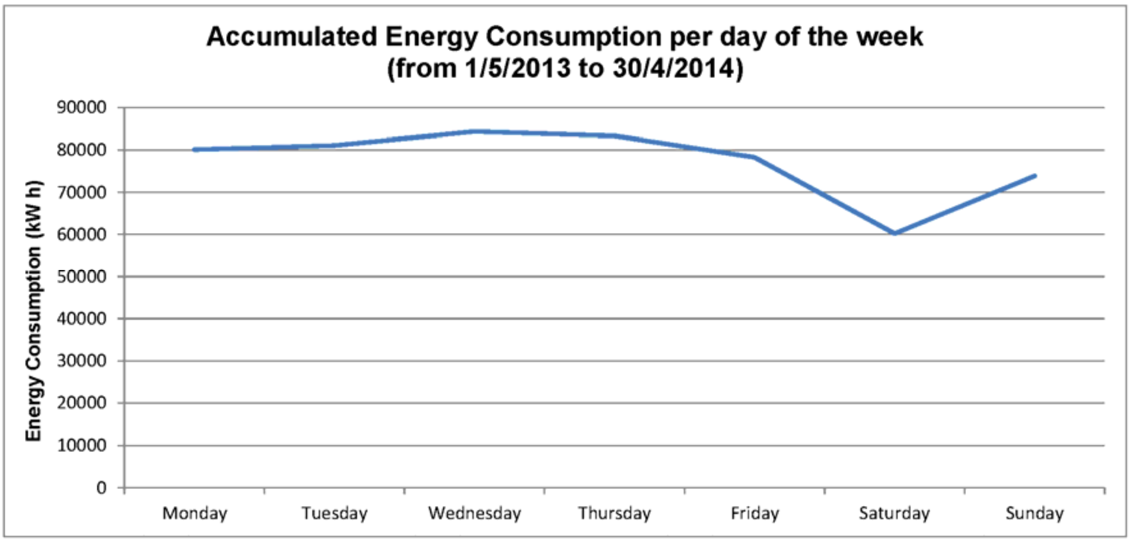


Figure 4.3.1.I. – Energy Consumption accumulated per day of the week over a whole year for the Røldal tunnel.

The **Figure 4.3.1.I** shows a clear distinction between the working days (from Monday to Friday) and the weekend as far as Energy Consumption is referred.

Under the assumption that the lighting system doesn't vary significantly depending on the day of the week, the existence of these two different regions may be explained by the traffic rate.

The ventilation system is activated, with the exception of the case of a fire appearance, only when the pollution level overpasses a certain admissible margin. The level of concentration of pollution gases is directly related with the traffic rate: the higher the traffic rate is, the higher value the pollution level reaches.

Therefore, the more vehicles there are in the tunnel, the longer time the ventilation system is working and, therefore, the higher the Energy Consumption is. Also, the rate of Heavy Goods Vehicles among the total traffic rate constitutes a key factor as far as pollution is concerned.

Unfortunately for this report, no available traffic rate or distribution data were available.

Nonetheless, the higher rate of traffic and maybe, a higher rate of Heavy Goods Vehicles during working days may explain the tendency between 8.000 – 9.000 kW h, which decreases during the weekend, when it is placed between 6.000 – 8.000 kW h.

3.3.2. ENERGY CONSUMPTION DEPENDING ON THE MONTH OF THE YEAR.

Another factor to analyse is the month of the year as far as Energy Consumption is referred.

For this analysis, the Røldal tunnel has been considered once more. The graphic which represents the Energy Consumption accumulated every month over a whole year (from the 1st of May 2013 to the 1st of May 2014) is the following one:

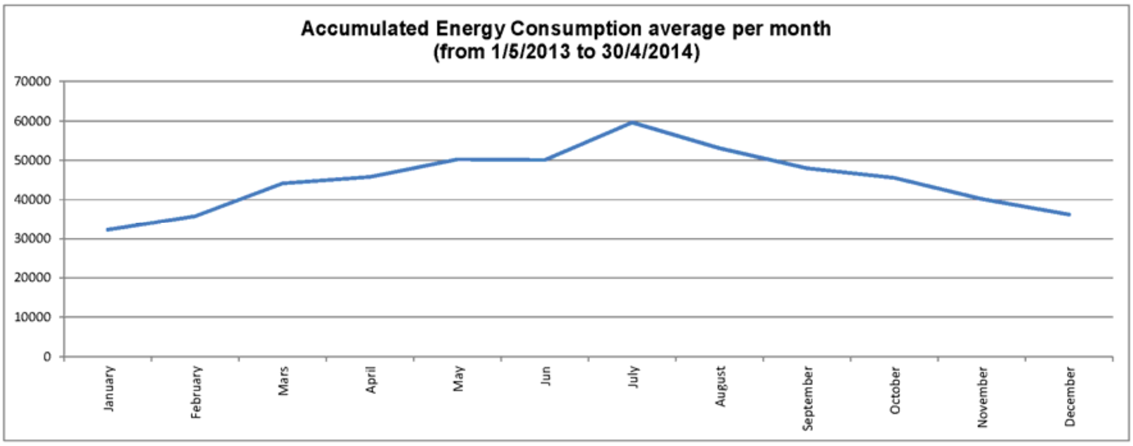


Figure 4.3.2.I. – Energy Consumption accumulated every month over a whole year for the Røldal tunnel.

In this case, we can state a tendency as well as in the previous section.

When analysing the **Figure 4.3.2.I**, we can differentiate 2 different regions:

- Region 1: from January to July. During this period, the Energy Consumption presents an increasing tendency and gets its highest level, reaching a peak of 59.665 kW h accumulated in the month of July. The registered Energy Consumption rate in January is 32.292 kW h.

- Region 2: from July to December. During this period the consumption presents a decreasing tendency, to reach its lowest value in the Region 2 in December, with a 36.188 kW h consumption rate.

It is remarkable that the maximum level of Energy Consumption in July (59.665 kW h) is almost the double of the minimum level, registered in January (32.292 kW h).

If we neglect the traffic rate, given that no data were available for this report, we can focus on the energy expenditure that involves the lighting system in order to explain this distribution of Energy Consumption.

The permanent lighting doesn't vary theoretically depending on the month of the year. Therefore, there is no choice but focusing on the daily lighting, located in the entrances of the tunnel, to analyse its influence over the global energy expenditure.

The daily lighting is aimed to aid to the tunnel users to adapt from external lighting conditions to internal lighting conditions, and so in the inverse case. In most of the cases of road tunnels, a great proportion of the global Energy Consumption is linked to this source.

Another evident conclusion is that, the longer the day is, the more elevated the Energy Consumption is. If we make a further analysis, we may try to establish a direct relation between these two factors: length of the day and Energy Consumption.

In order to carry out this study, some data about the length of the days have been downloaded from an online public website (http://www.noruega.viajerum.com/horas-de-luz-noruega), as it is shown in the following lines:

Duration of the day (h, min)			
Date	Oslo	Trondheim	Tromso
1st January	6h3min	4h44min	-
1st February	7h58min	7h13min	5h
1st Mars	10h30min	10h15min	9h36min
1st April	13h19min	13h32min	14h03min
1st May	16h	16h43min	18h48min
1st Jun	18h17min	19h44min	24h
1st July	18h41min	20h21min	24h
1st August	16h49min	17h43min	20h52min
1st September	14h08min	14h29min	15h23min
1st October	11h28min	11h22min	11h07min
1st November	8h42min	8h08min	6h32min
1st December	6h30min	5h20min	-

Table 4.3.2.I. – Duration of the day for 3 Norwegian cities.

According to the **Table 4.3.2.I**, there is a pattern as far as duration of the days depending on the month of the year: the longest days are located between the months of May and August. The length of the days fluctuates between 16h and 24h.

Also, a second period may be identified from August to October and from Mars to May, where the length of the days varies from 9h36min to 15h23min.

And in the end, the last region would be the rest of the months: from October to Mars, where the days last between 4h44min and 8h42min.

There is a strong correlation between the length of the days depending on the month and the Energy Consumption per month: the longer the day lasts, the higher the Energy Consumption is.

3.4. COMPARISON AMONG THE TUNNELS.

In this section it will be presented the results concerning all the tunnels aimed to be studied in graphical representations that permit to make a comparison among them.

3.4.1. ENERGY CONSUMPTION DEPENDING ON THE DAY OF THE WEEK.

In this section, it will be presented the graphical representation of the data that permits to make the comparison among the Norwegian tunnels aimed to be studied (there were no data available for the Risnes Tunnel).

The **Figure 4.4.1.I** shows the Accumulated Energy Consumption depending on the day of the week.

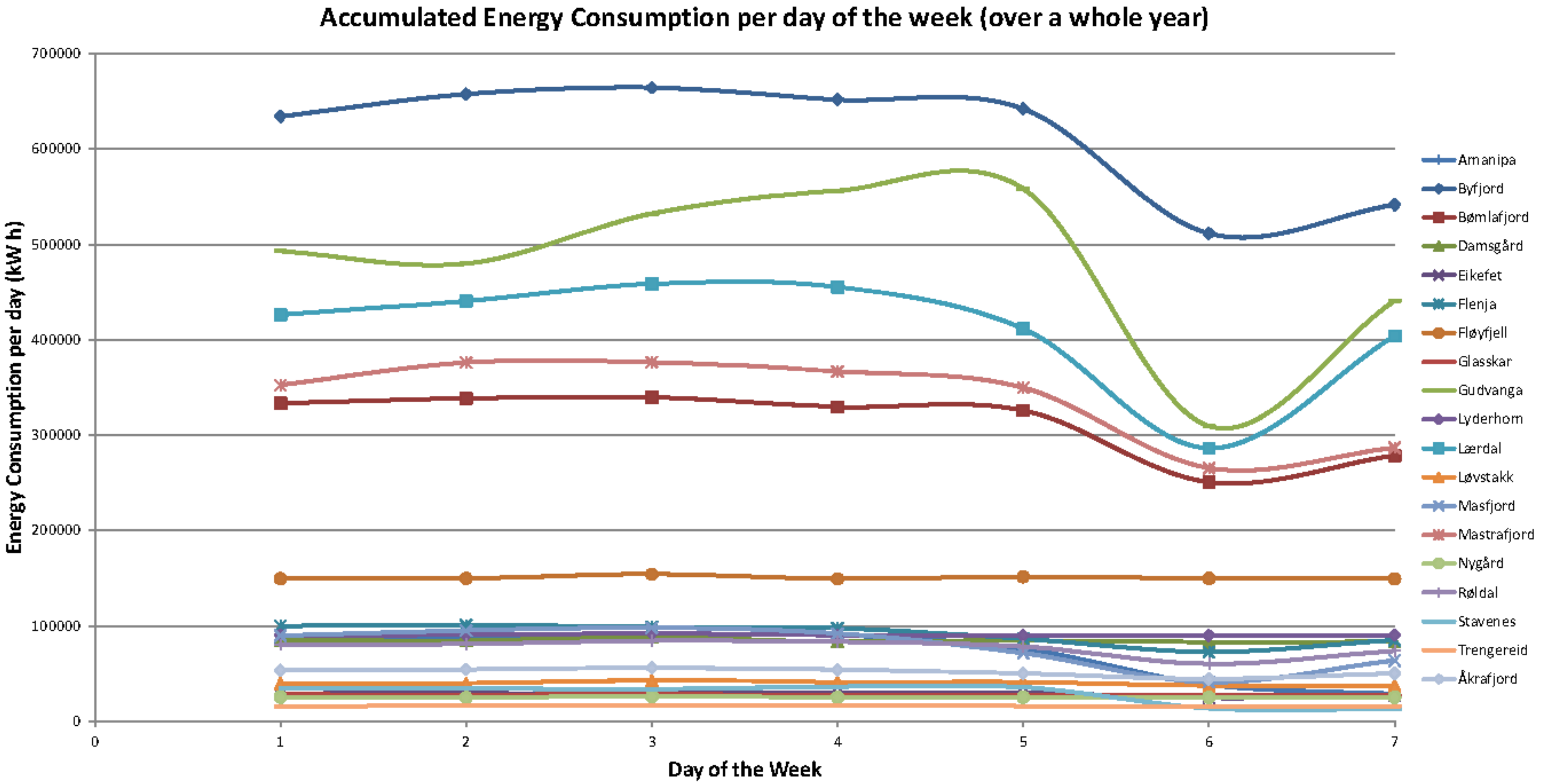


Figure 4.4.1.I. – Accumulated Energy Consumption per day of the week.

The following criteria have been adopted in the **Figure 4.4.1.I**:

- Day 1: Monday.
- Day 2: Tuesday.
- Day 3: Wednesday.
- Day 4: Thursday.
- Day 5: Friday.
- Day 6: Saturday.
- Day 7: Sunday.

The **Figure 4.4.1.I** permits to appreciate the tendency of consumption of all the tunnels:

On the one hand, some of the tunnels have a higher consumption rate during the working days (from Monday to Friday), while the weekend the consumption reaches lower values.

The tunnels that integrate this first group are the following ones (**Group 1**):

Arnanipa
Byfjord
Bømlafjord
Eikefet
Flenja
Gudvanga
Lærdal
Masfjord
Mastrafjord
Røldal
Stavenes
Åkrafjord

Table 4.4.1.I. - Tunnels that integrate Group 1

On the other hand, other tunnels have a tendency which is rather constant through the week, with differences that may be globally neglected. The tunnels that integrate this group are the following ones (**Group 2**):

Damsgård
Fløyfjell
Glasskar
Lyderhorn
Løvstakk
Nygård
Trengereid

Table 4.4.1.II. - Tunnels that integrate Group 2

This sort of graphic presents the difficulty of not having the same order of magnitude for every tunnel, what provokes complexity when it comes to comparing each tunnel with the rest and, therefore, a harder effort for setting a pattern.

For this reason, another factor has been calculated: the Average Energy Consumption per day of the week. This way, the remarks about the shape of the curves will have more consistency.

Given that the Energy Consumption per day of the week is compared with the weekly average, the result will have the same order of magnitude for each tunnel, which is a key factor to try to establish a pattern.

The **Figure 4.4.1.II** shows the comparison of the Energy Consumption percentage for all the tunnels analysed:

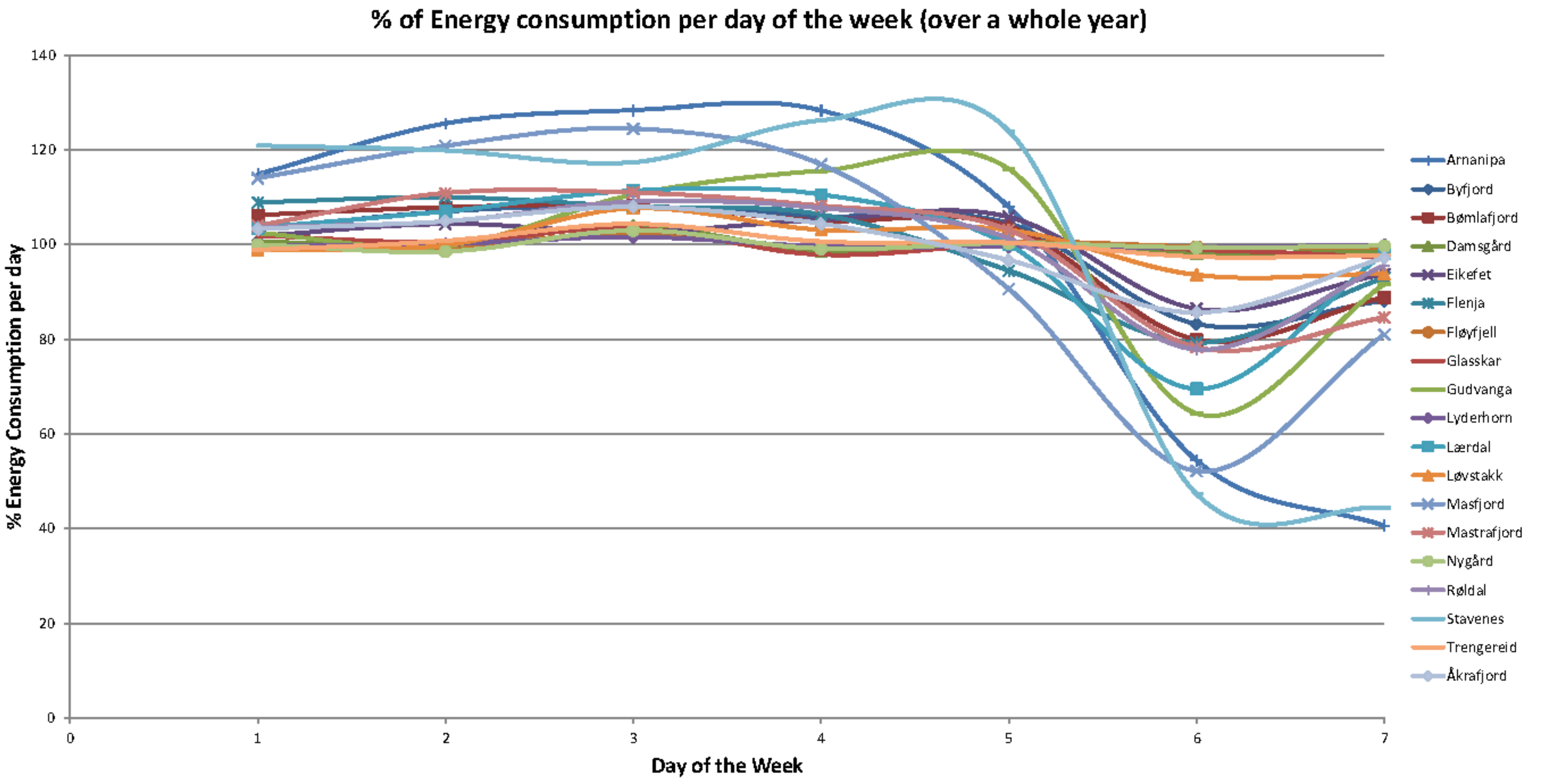


Figure 4.4.1.II. – Energy Consumption accumulated per day of the week.

The **Figure 4.4.1.II** allows us to make a more precise analysis of the curves that represent the Energy Consumption percentage per day of the week.

The **Figure 4.4.1.II** shows the same two remarkable tendencies for the Energy Consumption percentage as stated in the previous section 4.3.1 "***Energy Consumption depending on the day of the week***".

Thanks to the possibility of seeing the order of magnitude, a more precise assessment can be carried out with the **Figure 4.4.1.II** about the shape of the curves.

- Group 1: tunnels with a higher Energy Consumption during the working days

On the one hand, for several tunnels the Energy Consumption percentage overpasses the 100% rate during the working days (from Monday to Friday) and it's below the 100% rate during the weekends.

The tunnels that integrate this group (called **Group 1** in the previous section) are the same ones indicated in the previous section, adding the Lovstakk tunnel.

The particular case of the Stavenes tunnel should be highlighted: this ratio varies strongly through the week, increasing its value from Monday to Thursday to reach a 126,23% and then continuing with a sharp decreasing from this moment on, reaching the lowest value on Sunday, with a 44,34%.

This tendency is the same for the tunnels that integrate this group, with the exception that the changes are sharper or less notorious, depending on the tunnel.

The reason to explain this is the same as the one given in the section **4.3.I "*ENERGY CONSUMPTION DEPENDING ON THE DAY OF THE WEEK*"**.

That is, the traffic rate and the rate of Heavy Goods Vehicles over the total vehicles are directly related to the level of pollution. When the level of pollution overpasses the admissible margins, then the ventilation system is activated automatically, what means that the Energy Consumption reaches higher values.

This reason can explain the lower values of the Energy Consumption during the working days with respect to the values obtained for the weekends. This means that, either the traffic rate is lower during the weekends, either the rate of Heavy Goods Vehicles are lower during the weekends.

The tunnels that integrate the Group 1 are presented in the **Table 4.4.1.III**:

Arnanipa
Byfjord
Bømlafjord
Eikefet
Flenja
Gudvanga
Lærdal
Lovstakk
Masfjord
Mastrafjord
Røldal
Stavenes
Åkrafjord

Table 4.4.1.III. - Tunnels that integrate Group 1

- Group 2: tunnels with constant Energy Consumption during the week

After analysing the **Figure 4.4.1.I**, it possible to state that the tunnels that integrate this group are the same ones as defined in the previous section (defined as **Group 2**), with the exception of the Lovstakk tunnel, that has to be included in the Group 1.

The tunnels that integrate the Group 2 are included in the **Table 4.4.1.IV**:

Damsgård
Fløyfjell
Glasskar
Lyderhorn
Nygård
Trengereid

Table 4.4.1.IV. - Tunnels that integrate Group 2

3.4.2. ENERGY CONSUMPTION DEPENDING ON THE WEEK OF THE YEAR.

In this section it will first be developed the analysis carried out for the distribution of the Energy Consumption per month, with the aim of verifying whether the epoch of the year has relevant influence over the Energy Consumption.

The **Figure 4.4.2.I** shows the Energy Consumption per month:

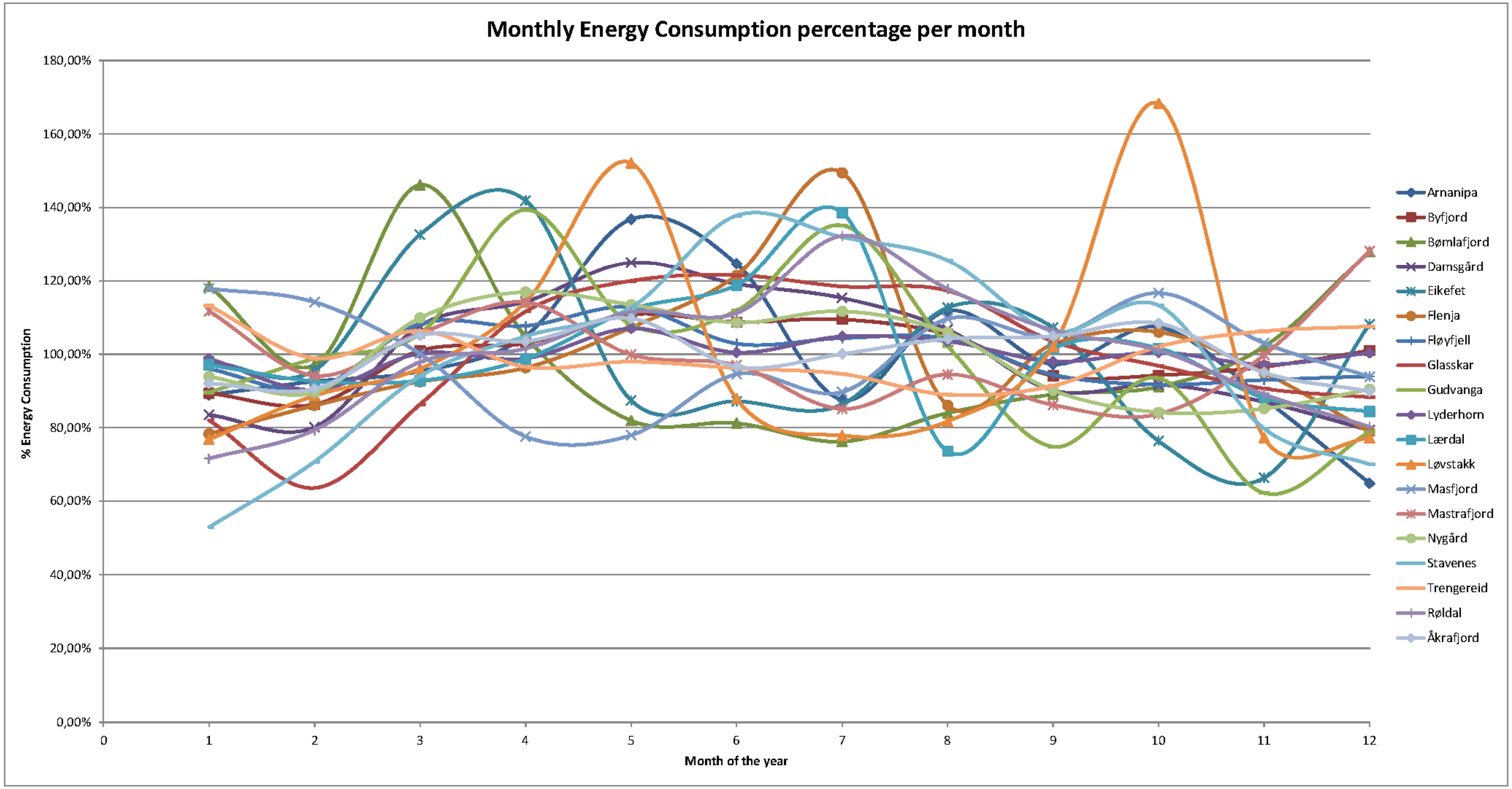


Figure 4.4.2.I. – Energy Consumption percentage per month.

As seen in the **Figure 4.4.2.I**, the results are rough with a monthly discretisation. In order to have more precision, the same graphical representation has been realised but with a weekly discretisation.

The results are shown in the **Figure 4.4.2.II**:

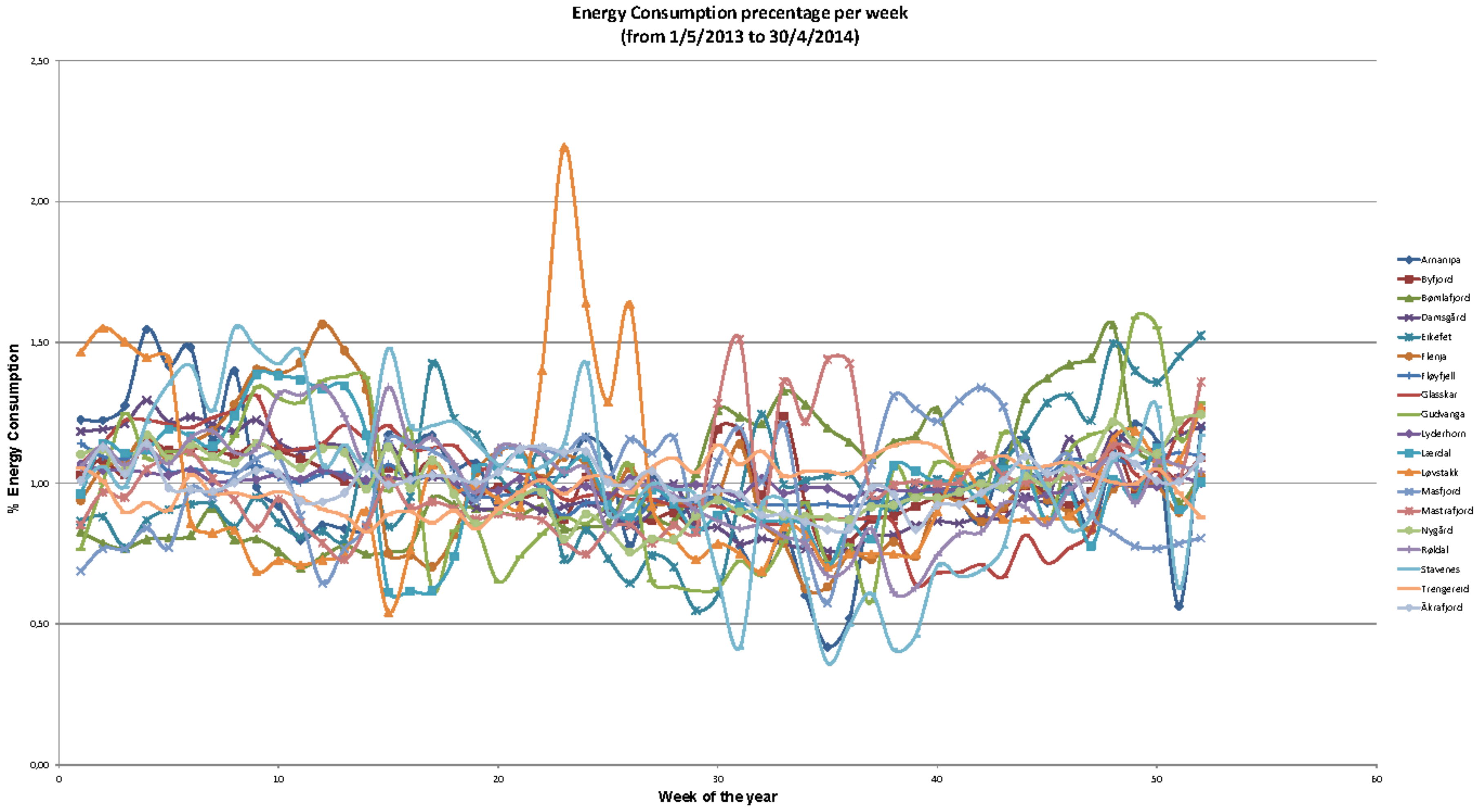


Figure 4.4.2.II. – Energy Consumption percentage per week.

The **Figure 4.4.2.II** shows the influence of every month and week over the global energy expenditure during a whole year.

Due to the fact that there are quite a lot of curves represented, it is more useful to analyse every tunnel on its own. In the **Annexe 2** attached to this report there are the data represented in the **Figure 4.4.2.II** separately for every tunnel.

The examination of the **Annexe 2** reveals, among other, the following information:

Tunnel	Week with Consumption Peak
Arnanipa	21
Bømlafjord	13
Byfjord	50
Damsgård	21
Eikefet	17
Flenja	29
Fløyfjell	18
Glasskar	26
Gudvanga	14
Lyderhorn	18
Lærdal	26
Løvstakk	40
Masfjord	7
Mastrafjord	48
Nygård	17
Røldal	29
Stavenes	25
Trengereid	4
Åkrafjord	21

Table 4.4.2.II. – Month with Peak of Energy Consumption

The distribution of the Energy Consumption per week is not revealing, but it presents rather a random distribution.

Further information is required to reach to solid conclusions that would allow finding somehow a pattern depending on the week of the year. This information is detailed in the section C "***Further studies to develop***".

3.4.3. ENERGY CONSUMPTION DEPENDING ON THE DAY OF THE WEEK BY ILLUMINATED SURFACE.

In this section, another graphical representation is shown: the accumulated Energy Consumption per day by illuminated surface in a whole year.

In most of the Spanish road tunnels, the Energy Consumption is directly related to the illuminated surface, which means that the preponderant source of consumption is the lighting system.

The aim of the study carried out in this section is to verify whether or not this tendency is the same for the Norwegian road tunnels.

The **Table 4.4.3.I** outlines the illuminated surface for each tunnel:

Tunnel	Length (m)	nº of tubes	nºof lanes tube 1	nºof lanes tube 2	Illum. Surface (m2)
Arnanipa	2.133	1	2	0	14 931
Bømlafjord	7.888	1	3	0	82 824
Byfjord	5.875	1	3	0	61 687,5
Damsgård	2.702	2	2	3	47 285
Eikefet	4.910	1	2	0	34 370
Flenja	5.053	1	2	0	35 371
Fløyfjell	7.020	2	2	2	98 280
Glasskar	1.172	2	2	2	16 408
Gudvanga	11.425	1	2	0	79 975
Lyderhorn	2.202	2	2	2	30 828
Lærdal	24.509	1	2	0	171 563
Løvstakk	2.045	1	2	0	14 315
Masfjord	4.110	1	2	0	28 770
Mastrafjord	4.424	1	3	0	46 452
Nygård	1.728	2	3	2	30 240
Risnes	1.718	1	2	0	12 026
Røldal	4.657	1	2	0	32 599
Stavenes	2.771	1	2	0	19 397
Trengereid	1.770	1	2	0	12 390
Åkrafjord	7.404	1	2	0	51 828

Table 4.4.3.I. – Illuminated surface of each tunnel aimed to be studied

This graphical representation is shown in the following lines:

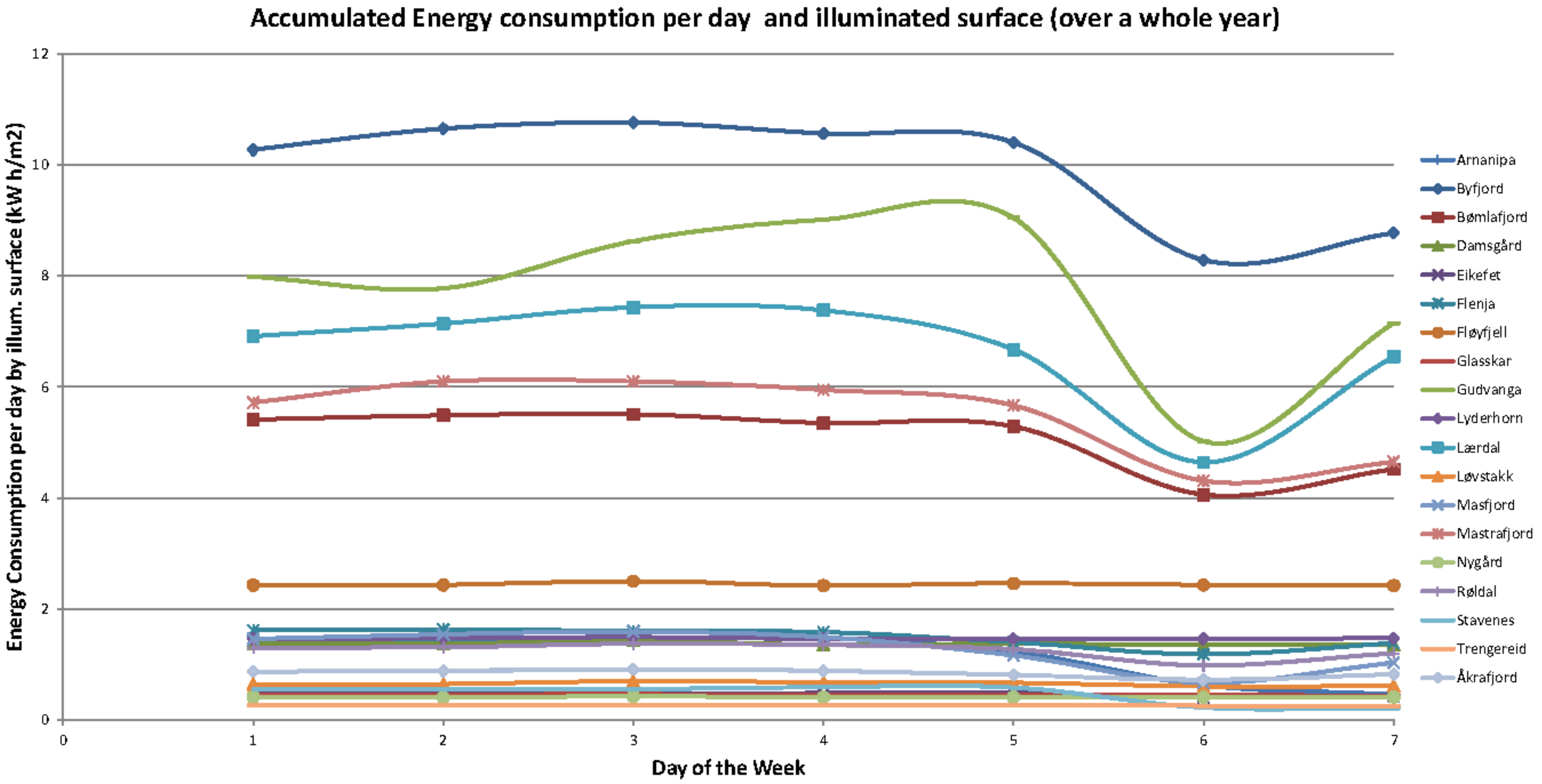


Figure 4.4.3.I. – Accumulated Energy Consumption per day and per illuminated surface.

The **Figure 4.4.3.I** presents the Energy Consumption accumulated per day of the week by illuminated surface of the tunnel.

The first conclusion to extract is that these curves shapes are similar to the ones represented on the **Figure 4.4.1.I**, and **4.4.1.II**, what was expected to have as a result.

Furthermore, it has to be remarked that if there was a constant link between the Energy Consumption rate and the illuminated surface, all the curves should be practically in the same position, what apparently doesn't happen.

Therefore, the link between the Energy Consumption rate and the illuminated surface is not the same for all the tunnels, what means that other sources of expenditures must be taken into account.

For this report, this additional information wasn't available, what means that the study will need to be continued in future reports. The required information is detailed in the section C "***Further studies to develop***".

4. FURTHER STUDIES TO DEVELOP.

In this section it will be specified the additional information required to continue the Energy Consumption analysis and to have more solid conclusions.

4.1. MISSING INFORMATION IN THE DOWNLOADED DATA.

After examination of the available data provided by the NPRA, it is necessary to point out that some information wasn't available on the online website http://www.entro.no/nohovedside.aspx, more specifically:

Tunnel	Missing information
Gudvanga	F1G measure equipment data
Risnes	Measure equipment data
Røldal	K2 measure equipment data

Table 5.1.I. - Missing information in the available data

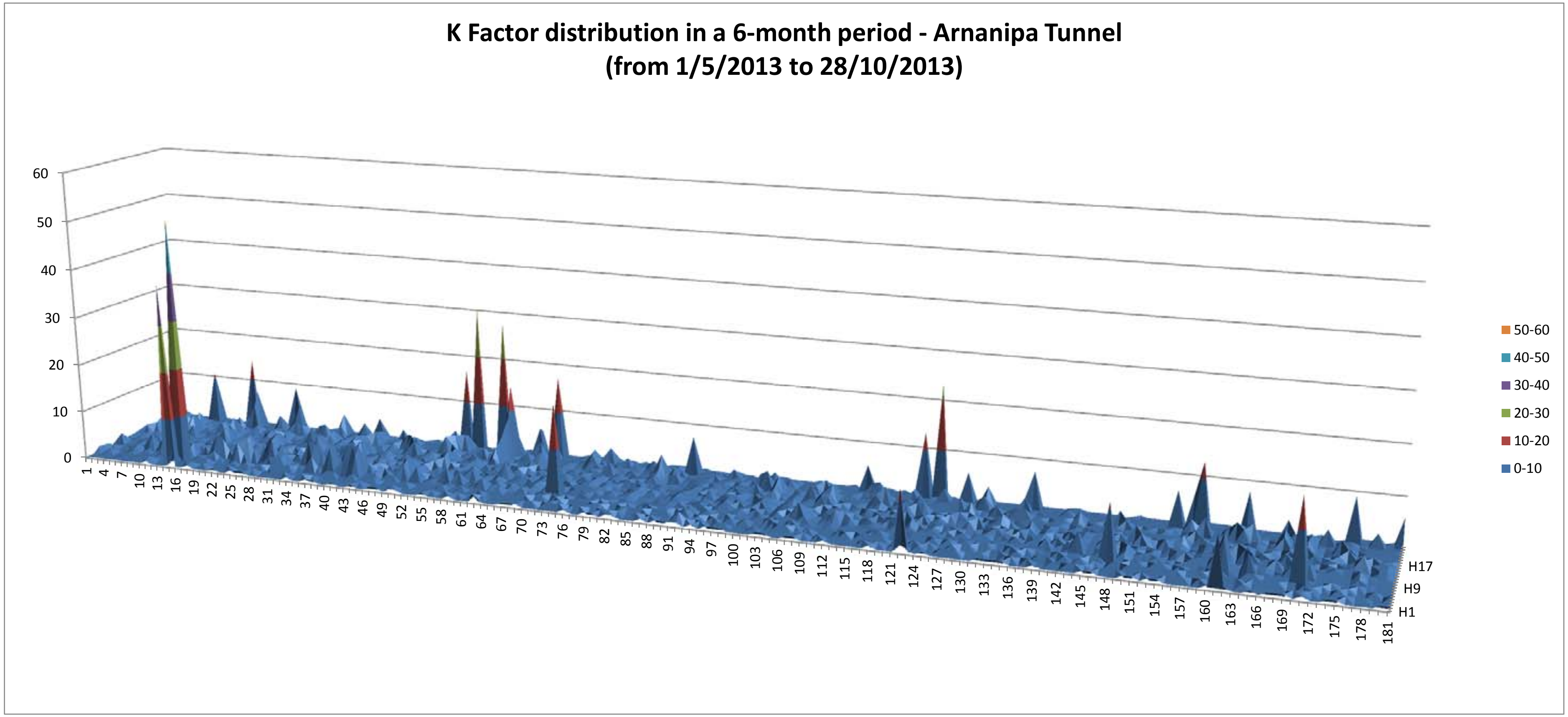
4.2. FURTHER INFORMATION REQUIRED.

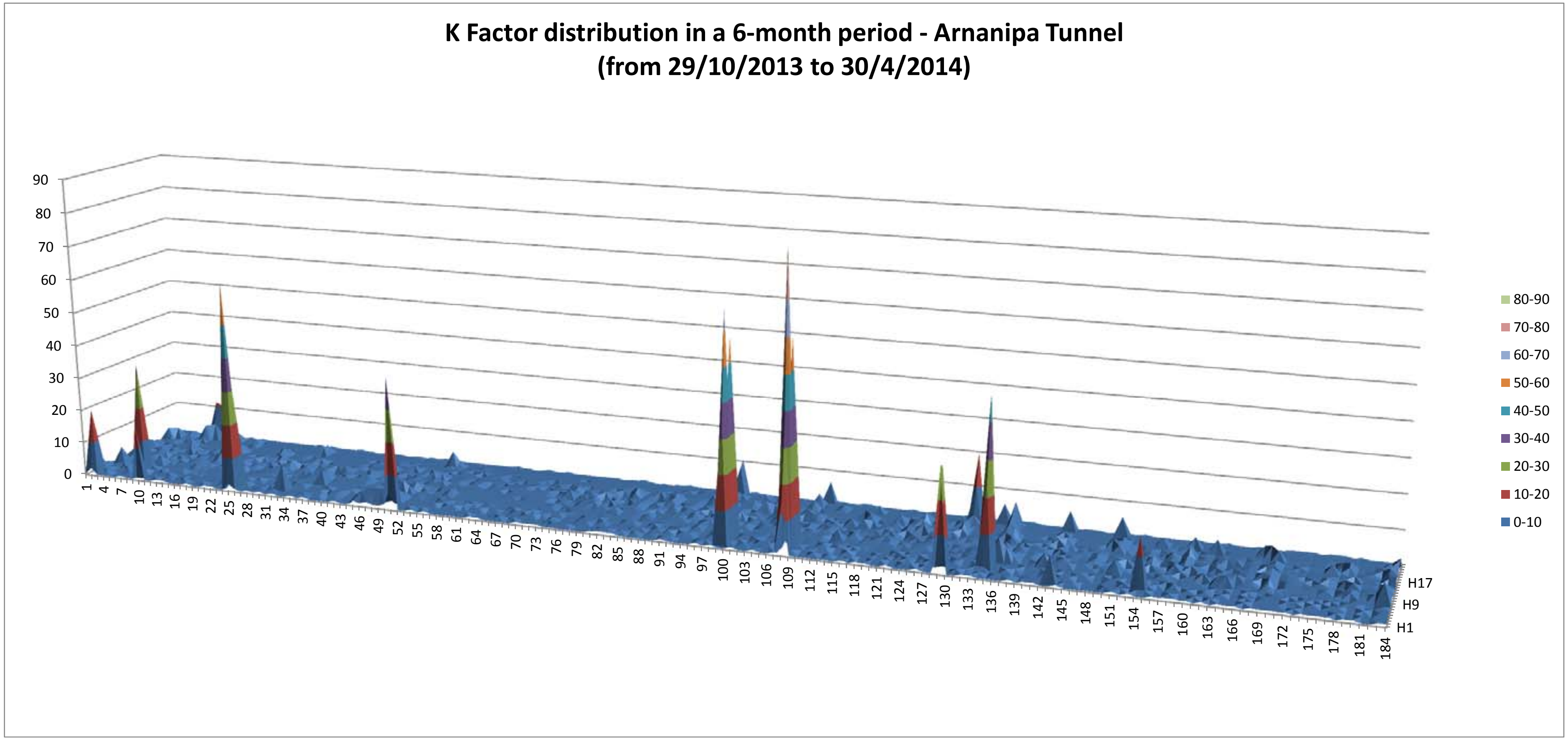
As it has been mentioned in previous sections, further information about each tunnel is required in order to have more solid conclusions.

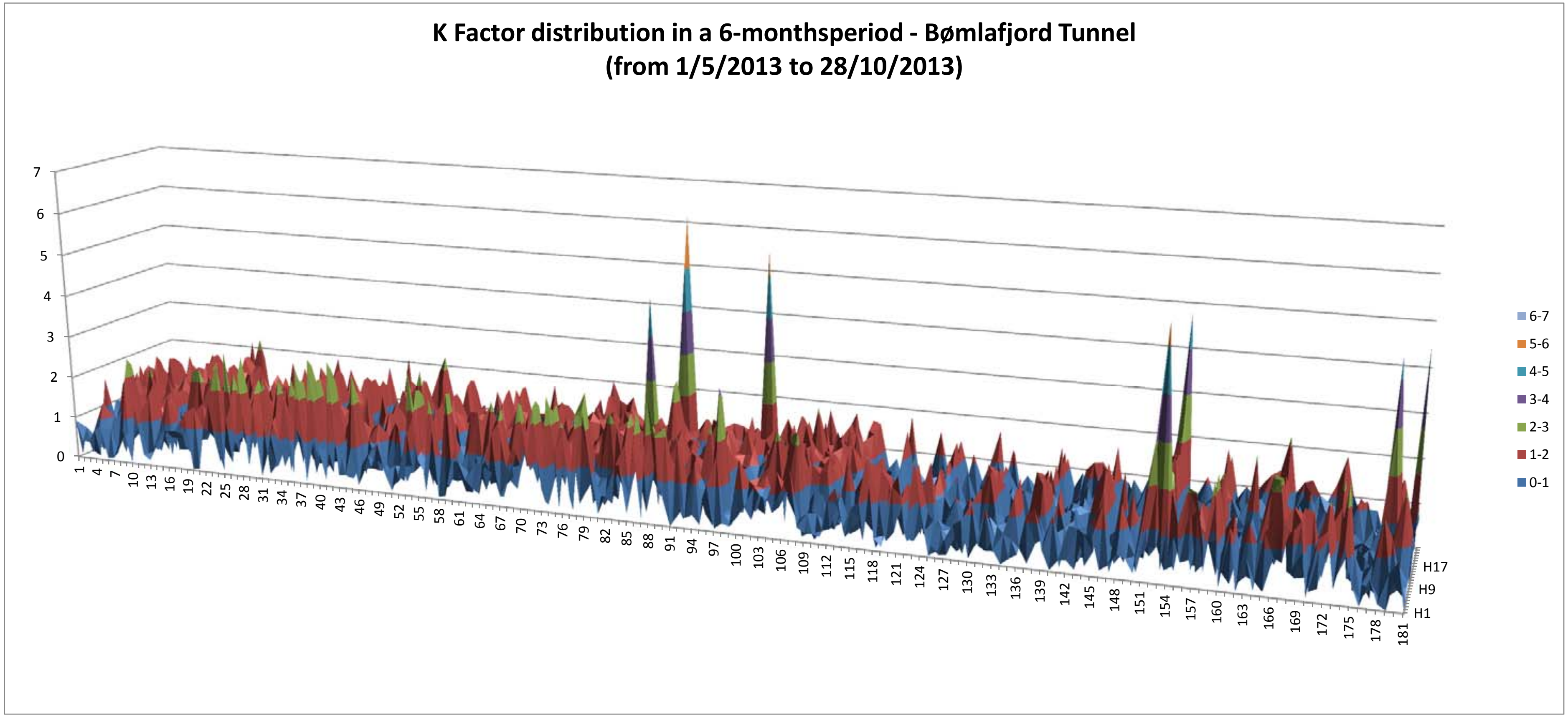
The additional information required to carry out further studies and analyses is detailed in the following lines:

- Traffic typology: unidirectional / bidirectional.
- Nº of tubes.
- Road width (m).
- Nº of lanes.
- Length of the tunnel (m).
- Traffic rate (veh/day).
- Ventilation system installed power (W).
- Ventilation system typology: longitudinal / transversal / semi transversal.
- Lighting system installed power (W).
- Daily lighting installed power (W).

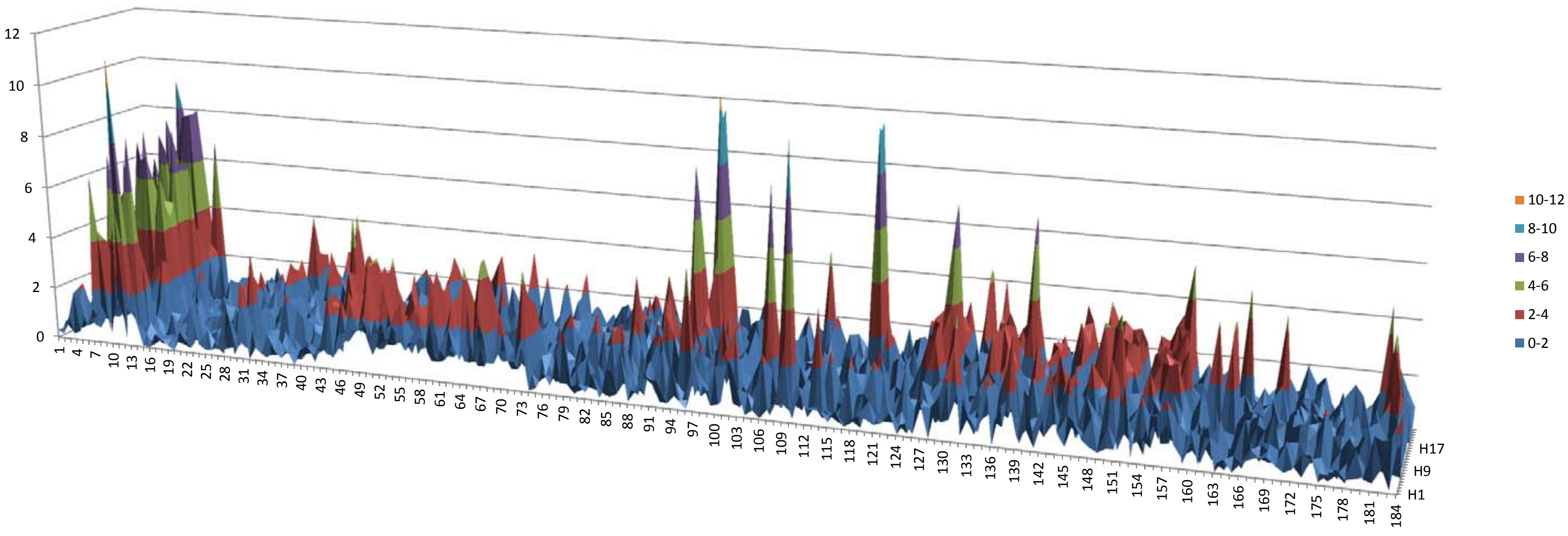
- Permanent lighting installed power (W).
- Existence of lighting power reduction?
- Lamp typology.
- Existence of lighting regulation?


K Factor distribution in a 6-month period - Arnanipa Tunnel
(from 1/5/2013 to 28/10/2013)
60
50
40
30
20
10
0
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79
82
85
88
91
94
97
100
103
106
109
112
115
118
121
124
127
130
133
136
139
142
145
148
151
154
157
160
163
166
169
172
175
178
181
H17
H9
H1
50-60
40-50
30-40
20-30
10-20
0-10

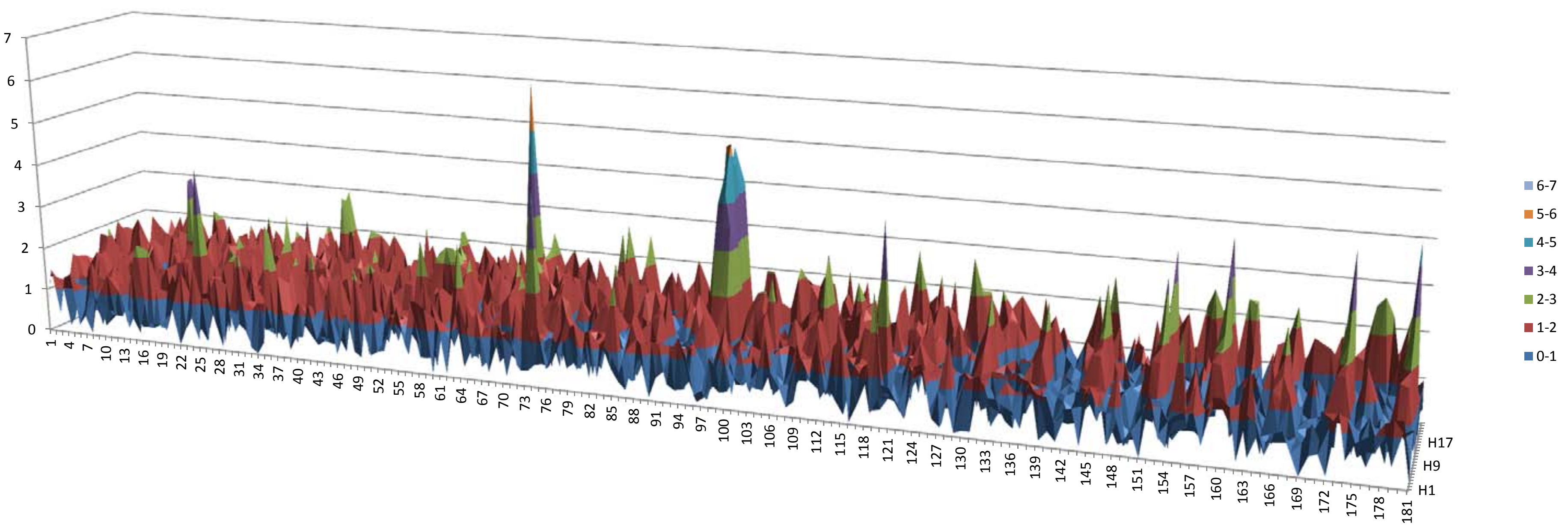

K Factor distribution in a 6-month period - Arnanipa Tunnel
(from 29/10/2013 to 30/4/2014)
90
80
70
60
50
40
30
20
10
0
80-90
70-80
60-70
50-60
40-50
30-40
20-30
10-20
0-10
H17
H9
H1

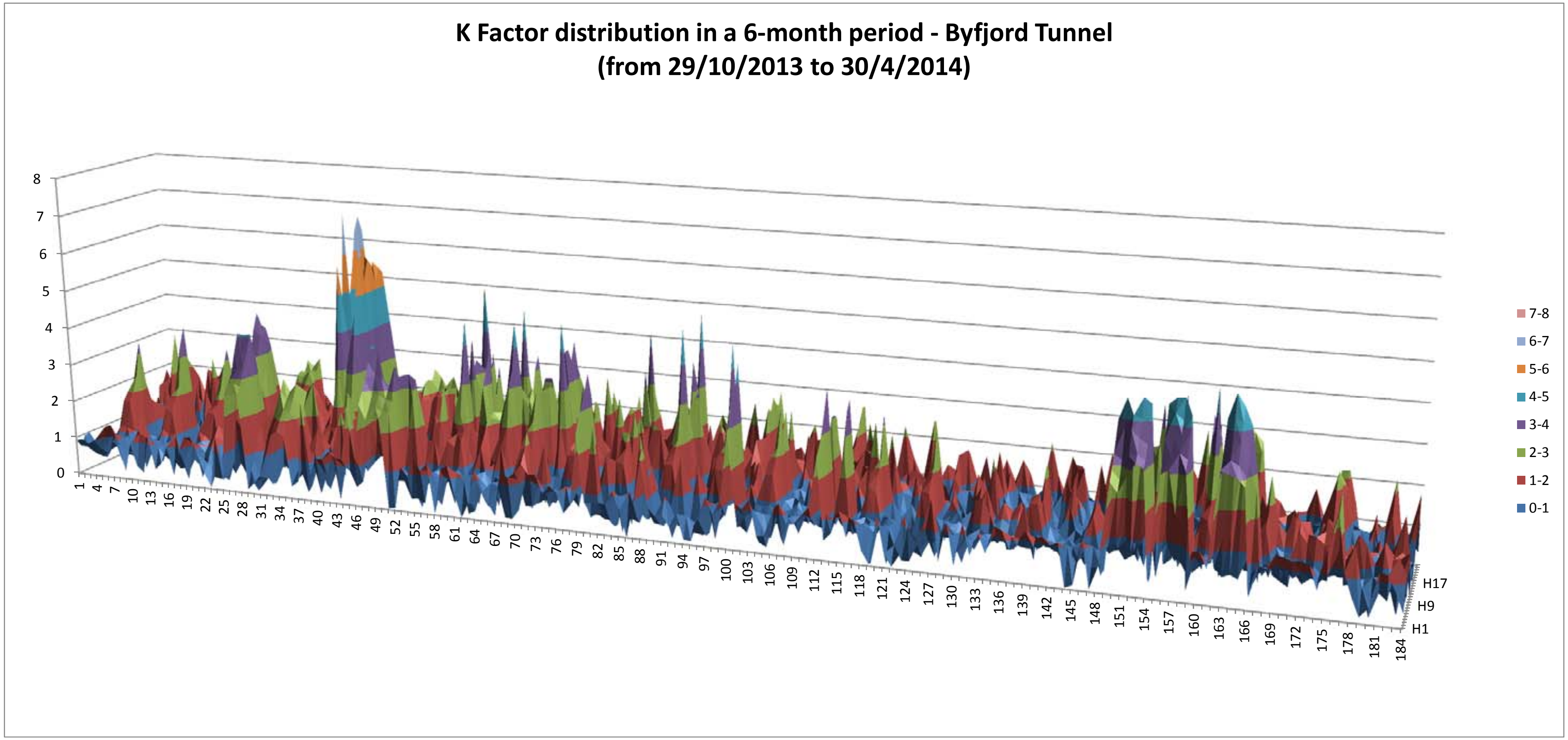

K Factor distribution in a 6-monthsperiod - Bømlafjord Tunnel
(from 1/5/2013 to 28/10/2013)
6-7
5-6
4-5
3-4
2-3
1-2
0-1
H17
H9
H1

K Factor distribution in a 6-monthsperiod - Bømlafjord Tunnel
(from 29/10/2013 to 30/4/2014)

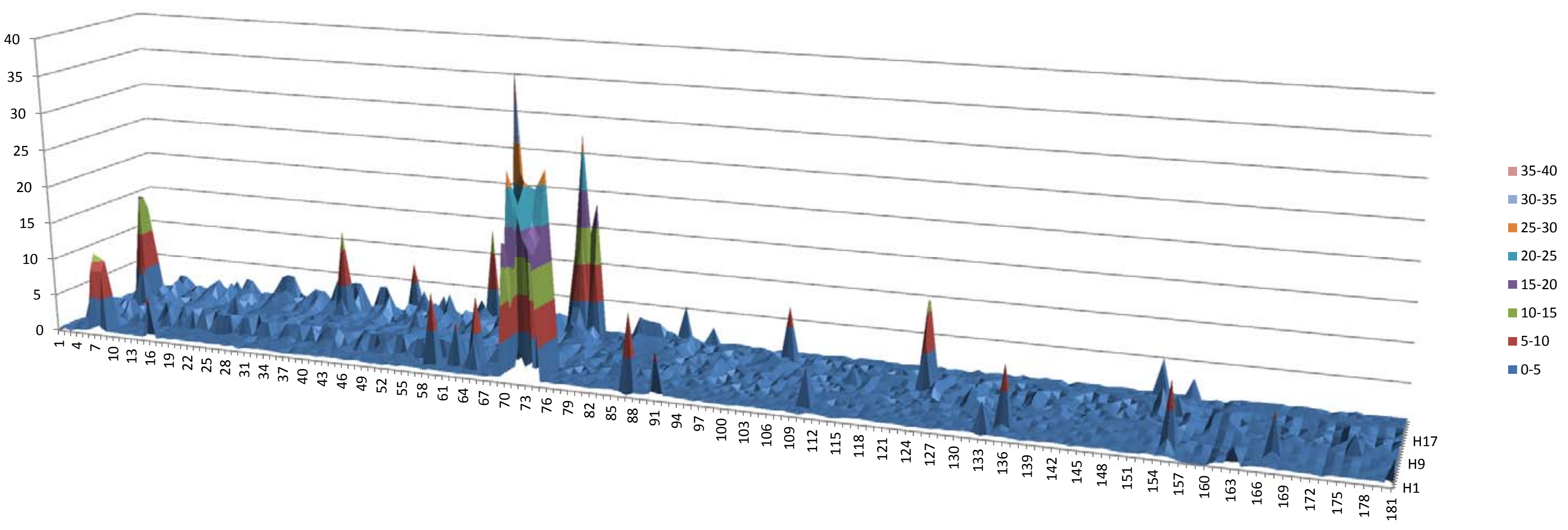


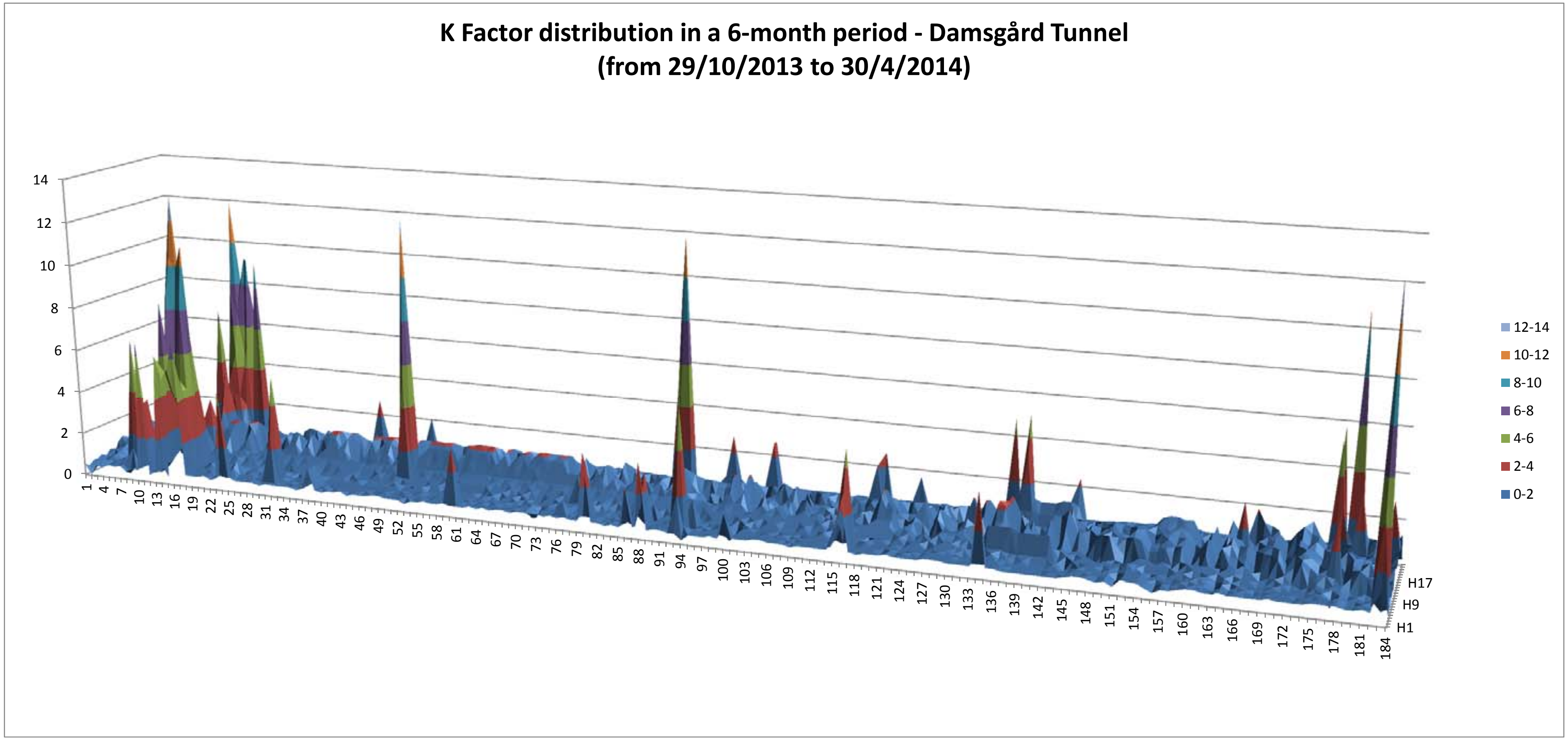
K Factor distribution in a 6-month period - Byfjord Tunnel
(from 1/5/2013 to 28/10/2013)




K Factor distribution in a 6-month period - Byfjord Tunnel
(from 29/10/2013 to 30/4/2014)
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1
H17
H9
H1

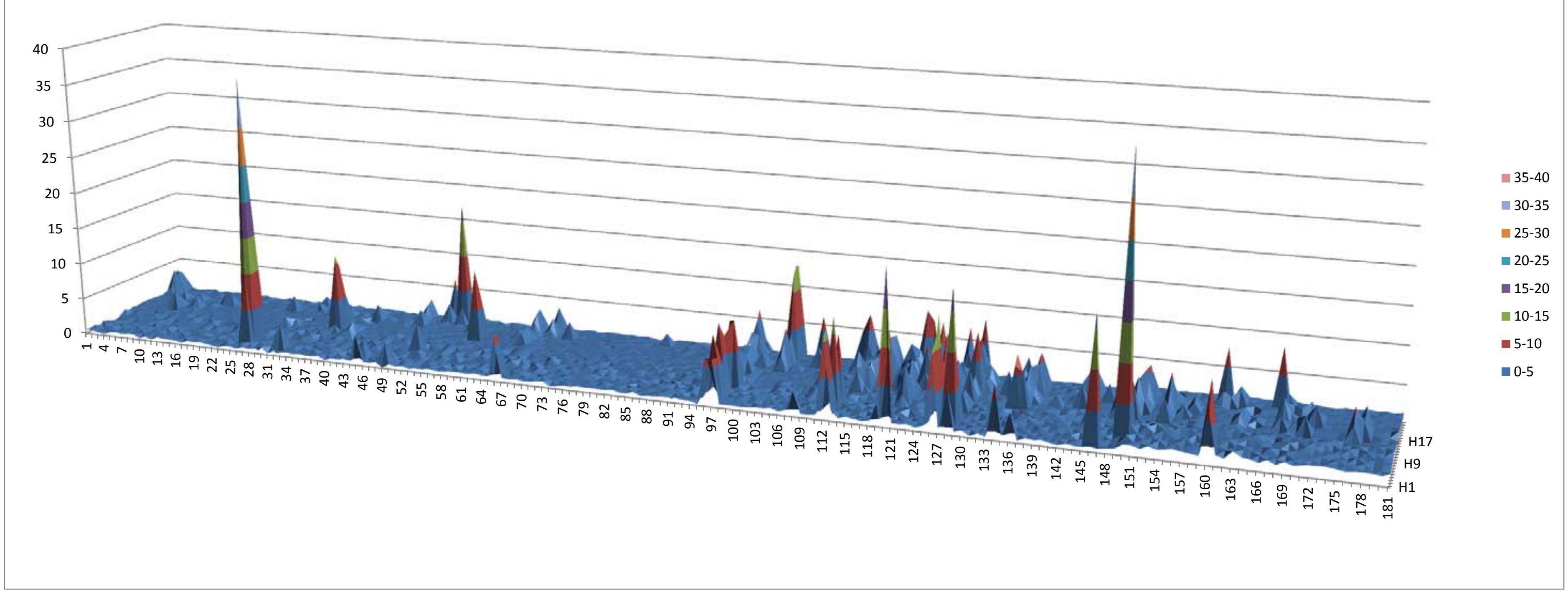
K Factor distribution in a 6-month period - Damsgård Tunnek (from 1/5/2013 to 28/10/2013)

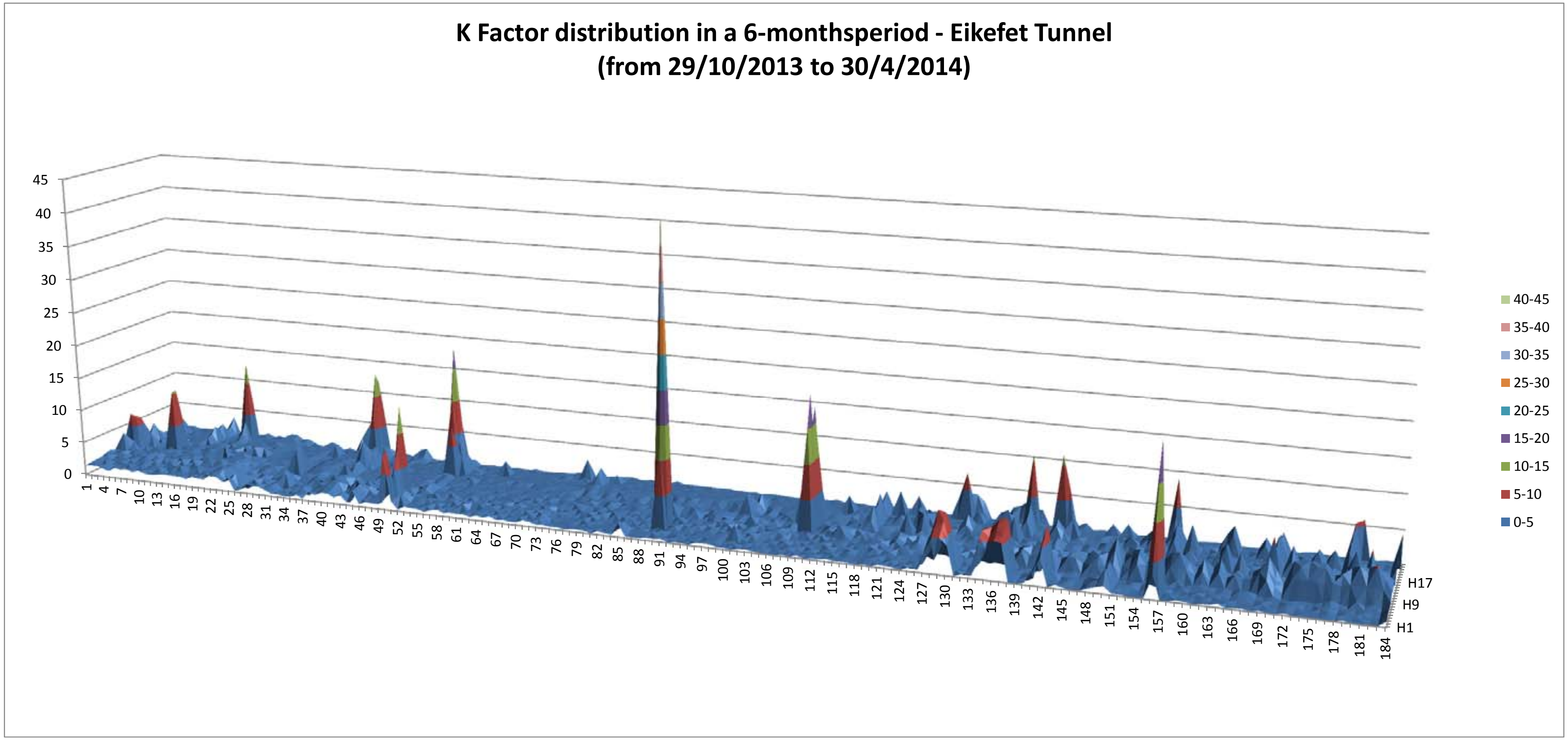


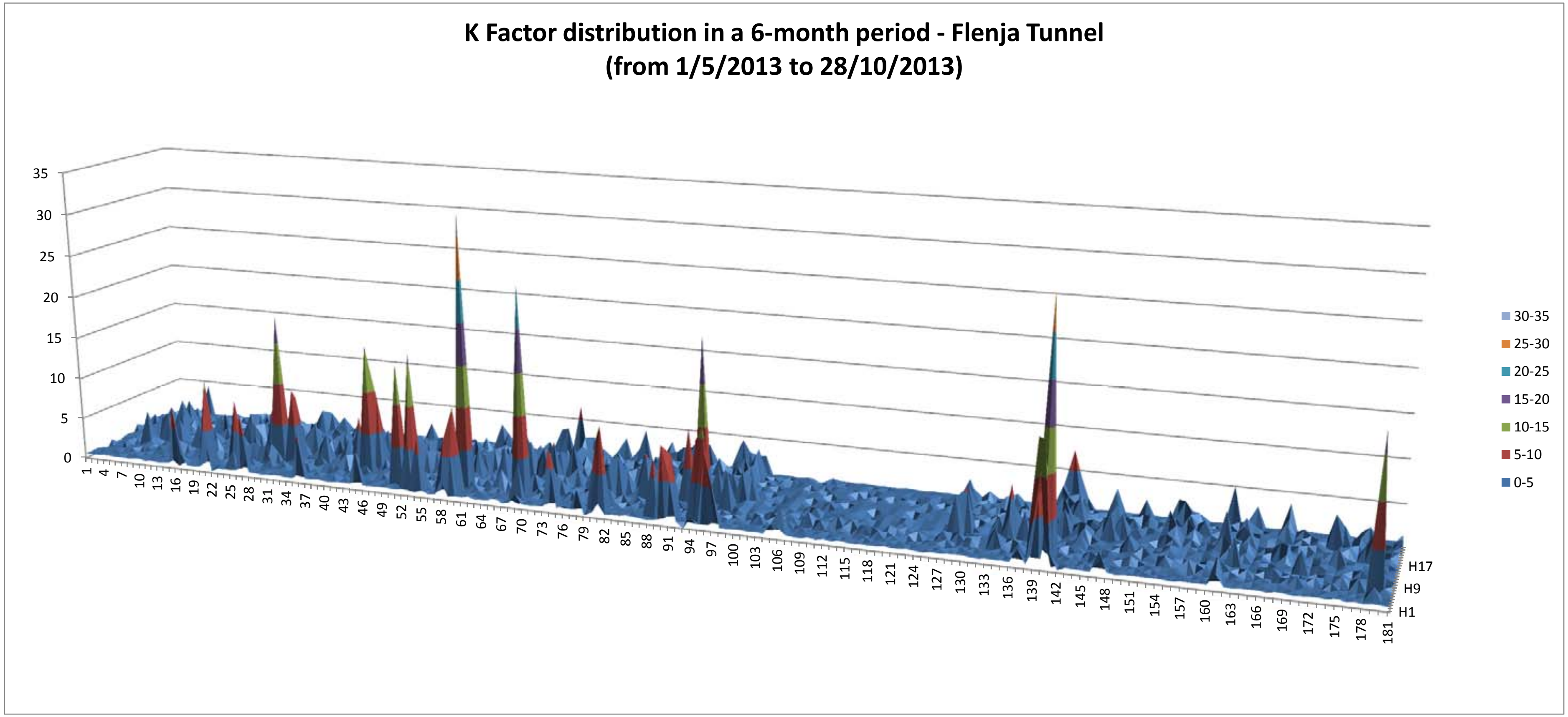


K Factor distribution in a 6-month period - Damsgård Tunnel
(from 29/10/2013 to 30/4/2014)
14
12
10
8
6
4
2
0
12-14
10-12
8-10
6-8
4-6
2-4
0-2
H17
H9
H1

K Factor distribution in a 6-month period - Eikefet Tunnel
(from 1/5/2013 to 28/10/2013)

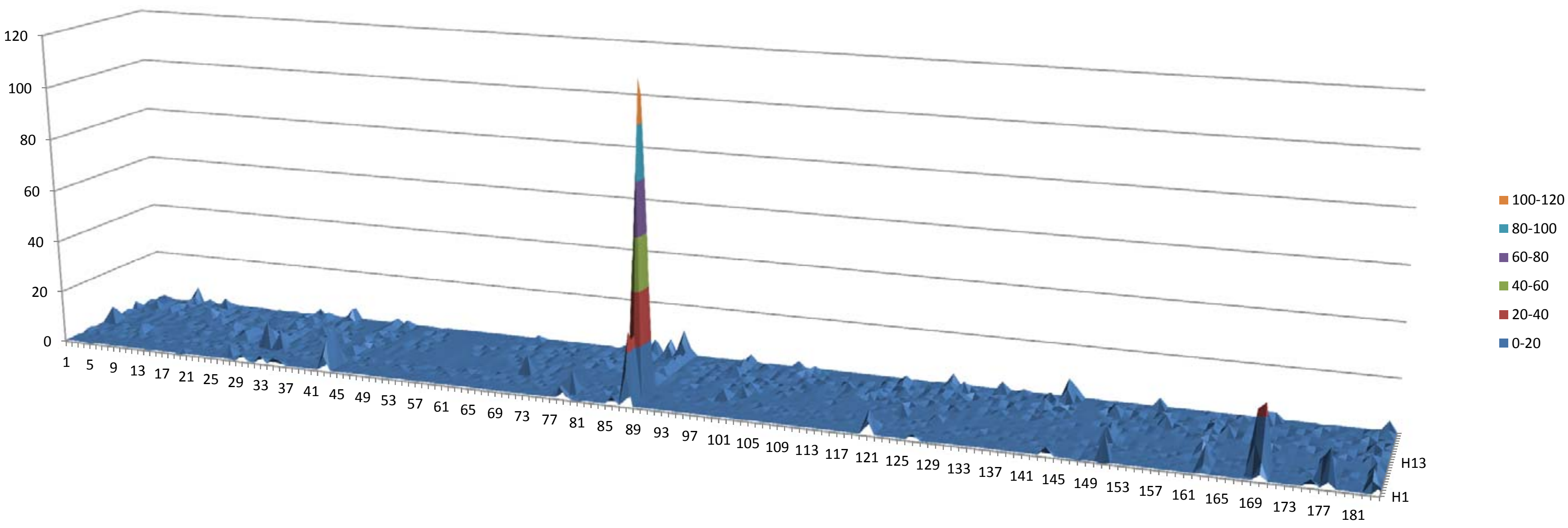



K Factor distribution in a 6-monthsperiod - Eikefet Tunnel
(from 29/10/2013 to 30/4/2014)
0
5
10
15
20
25
30
35
40
45
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97 100 103 106 109 112 115 118 121 124 127 130 133 136 139 142 145 148 151 154 157 160 163 166 169 172 175 178 181 184
H1
H9
H17
40-45
35-40
30-35
25-30
20-25
15-20
10-15
5-10
0-5

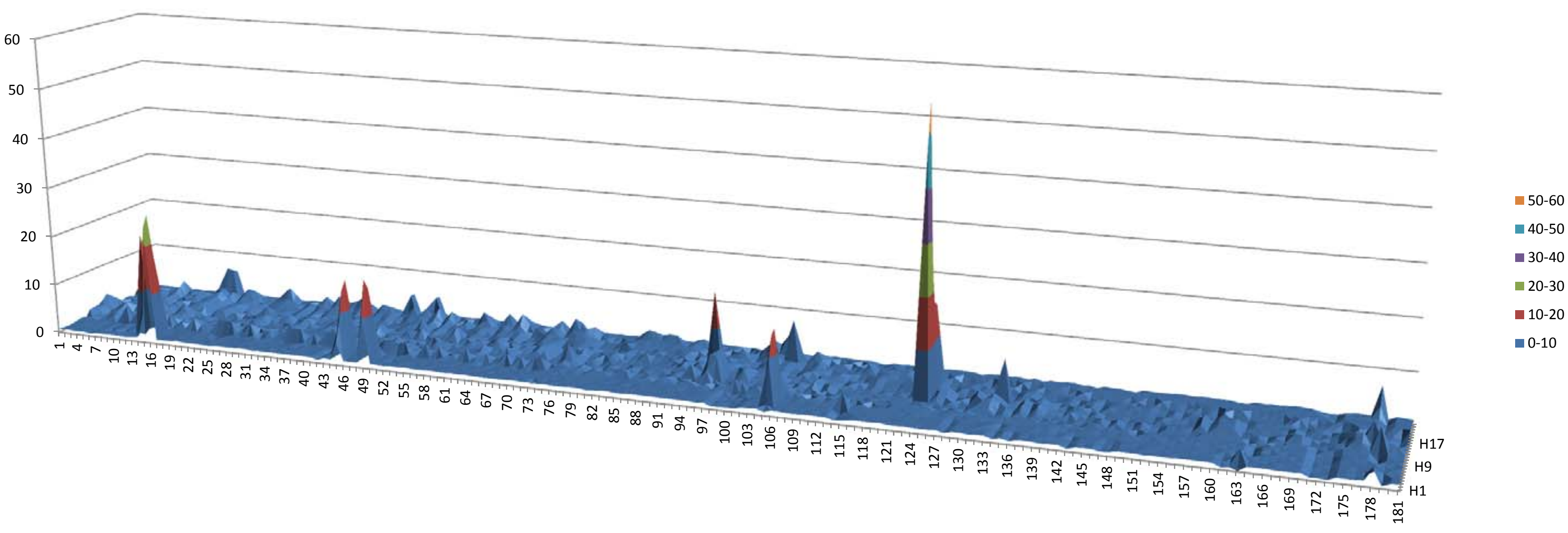


K Factor distribution in a 6-month period - Flenja Tunnel
(from 1/5/2013 to 28/10/2013)
30-35
25-30
20-25
15-20
10-15
5-10
0-5
H17
H9
H1

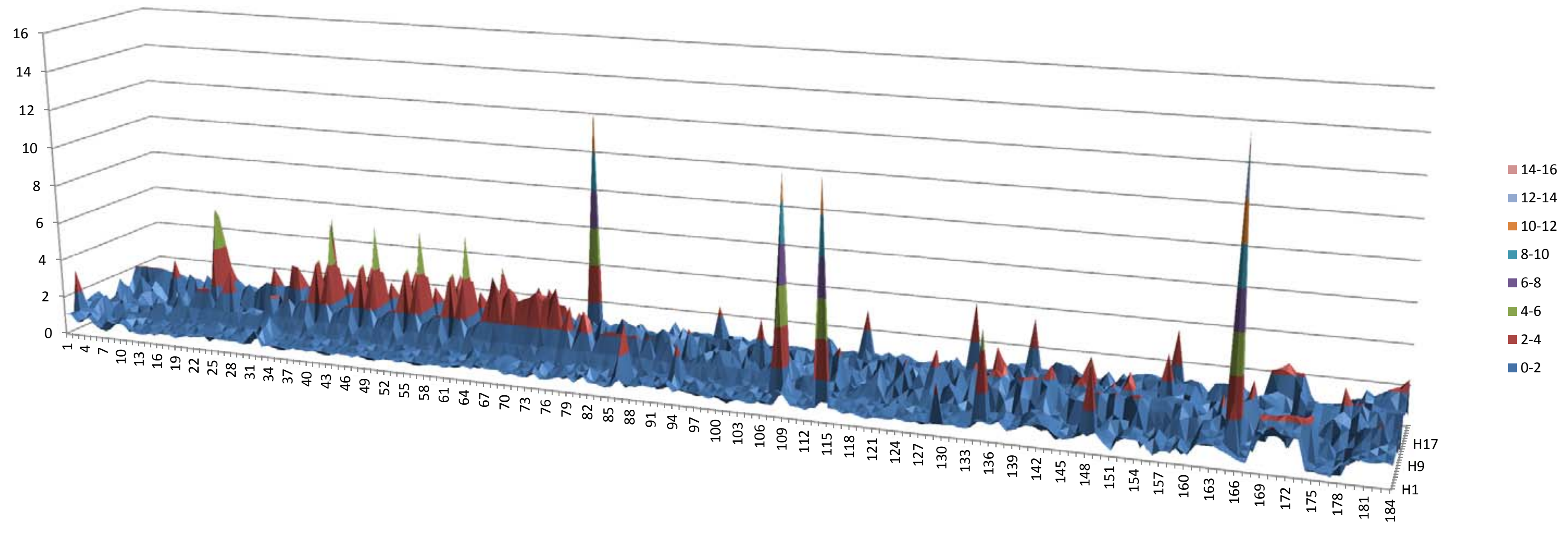
K Factor distribution in a 6-month period - Flenja Tunnel
(from 29/10/2013 to 30/4/2014)

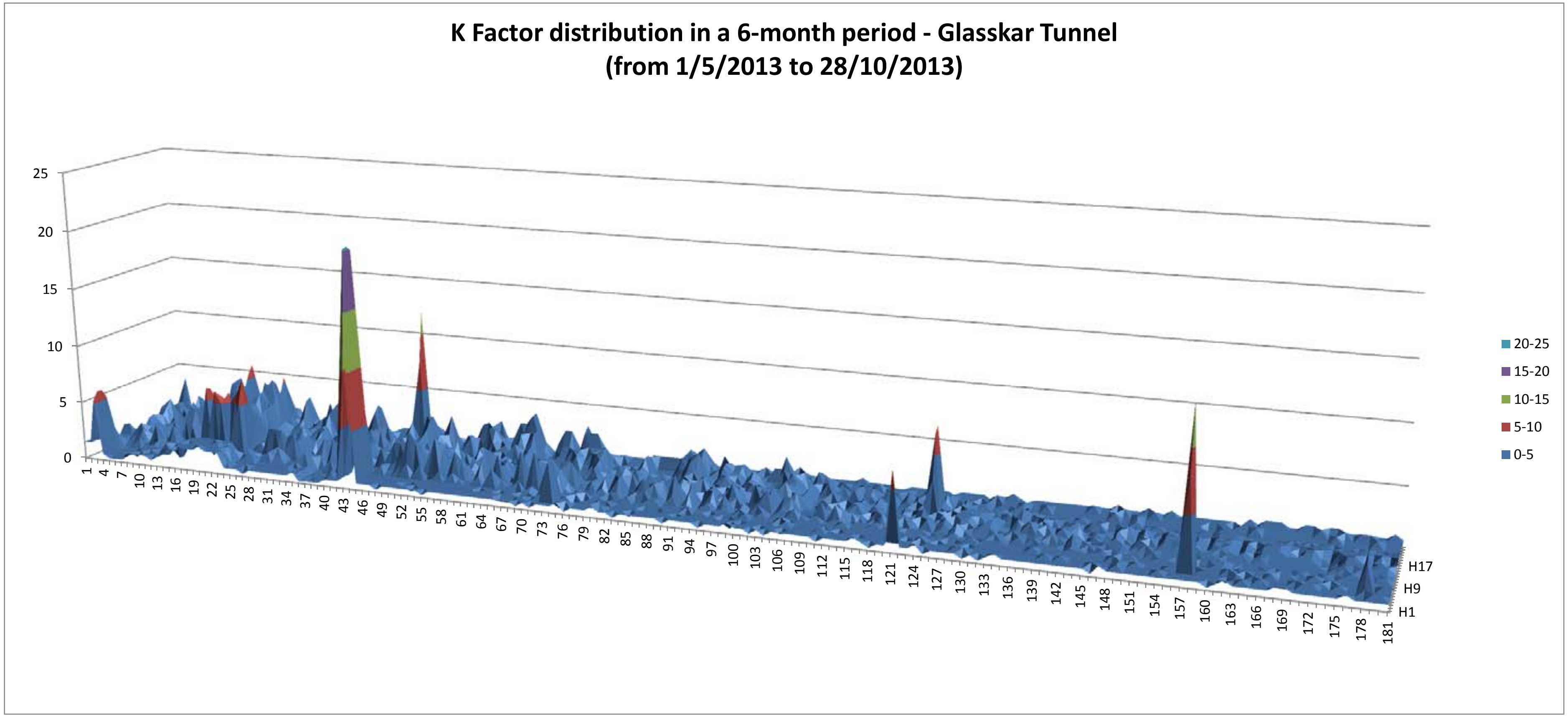


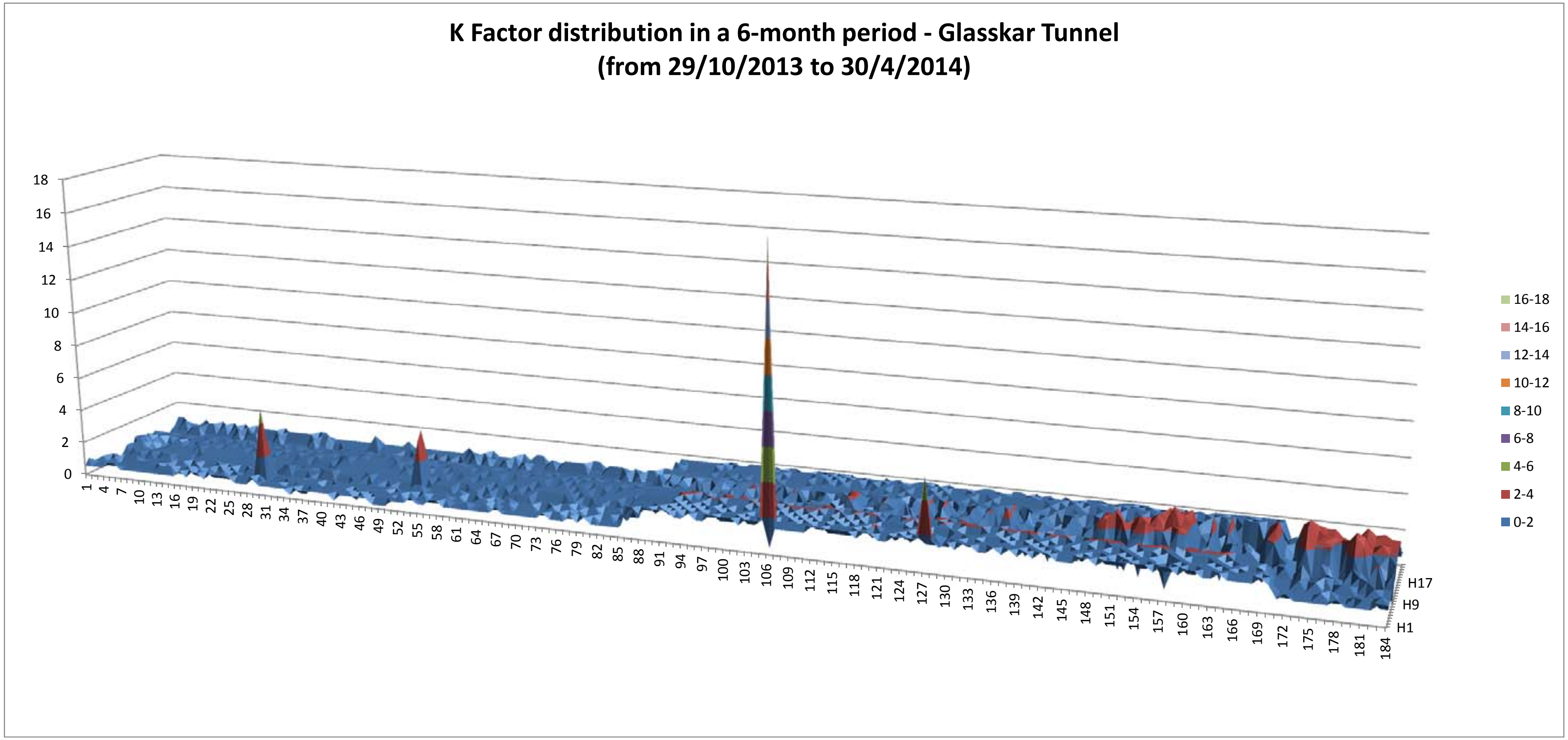
K Factor distribution in a 6-month period - Fløyfjell Tunnel
(from 1/5/2013 to 28/10/2013)



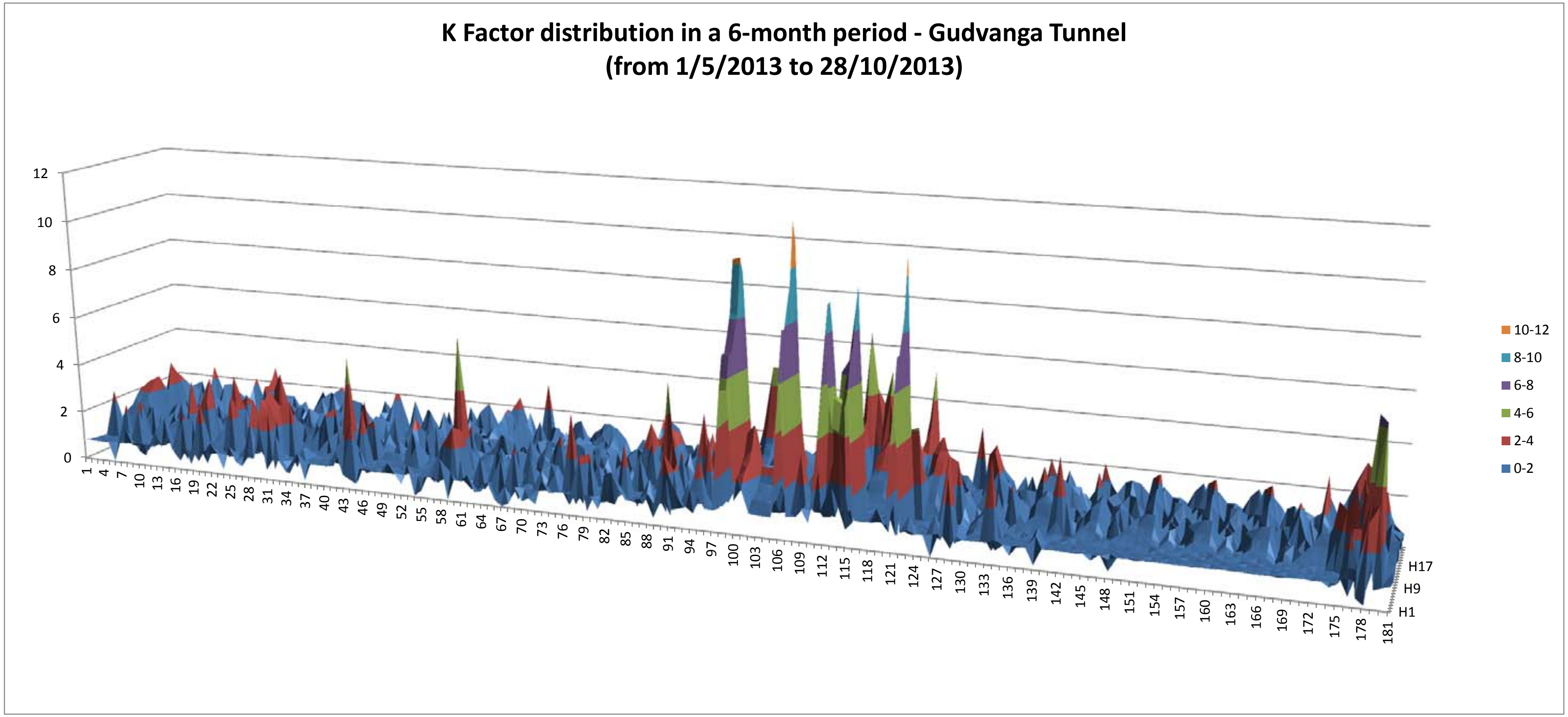
K Factor distribution in a 6-month period - Fløyfjell Tunnel (from 29/10/2013 to 30/4/2014)

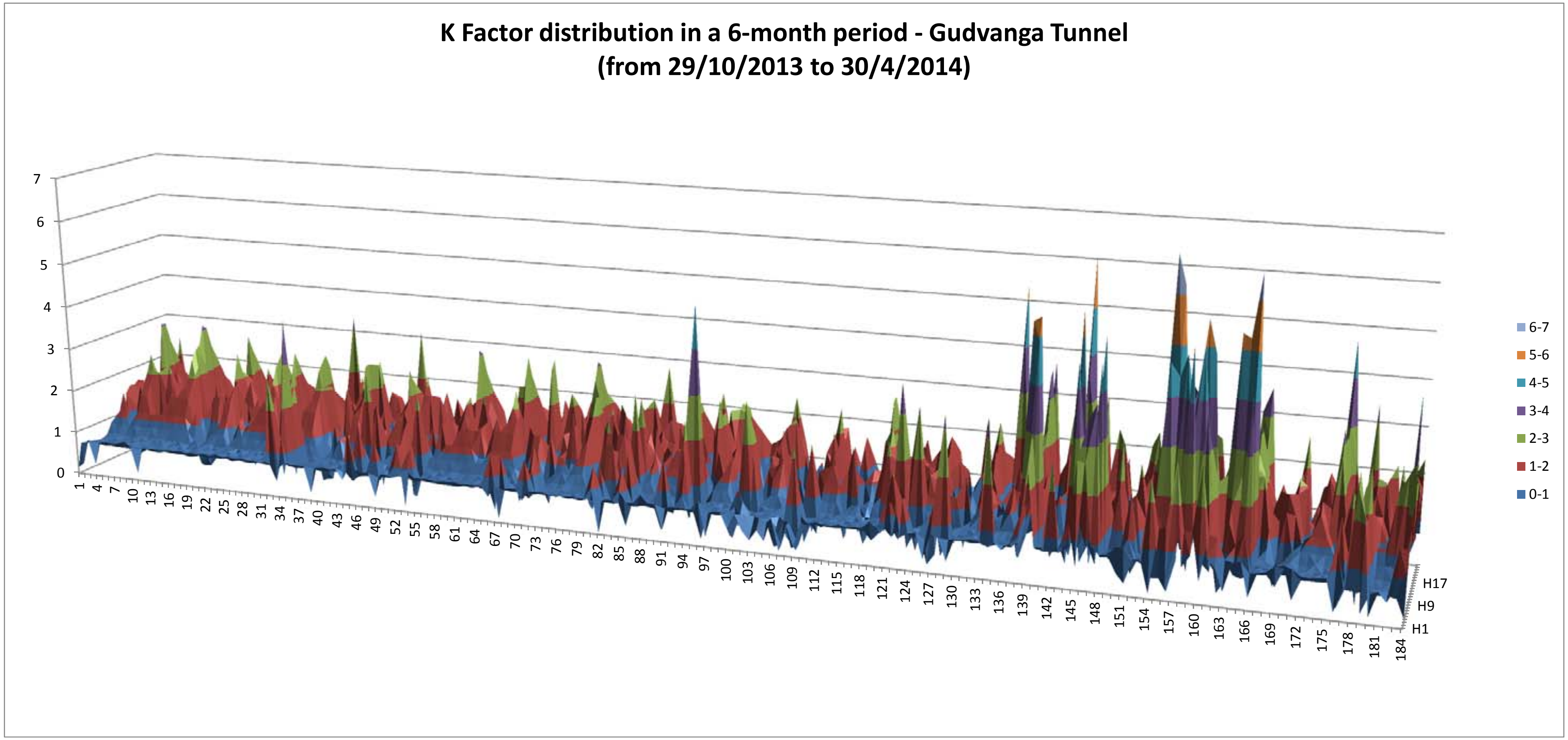



K Factor distribution in a 6-month period - Glasskar Tunnel
(from 1/5/2013 to 28/10/2013)
25
20
15
10
5
0
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79
82
85
88
91
94
97
100
103
106
109
112
115
118
121
124
127
130
133
136
139
142
145
148
151
154
157
160
163
166
169
172
175
178
181
H17
H9
H1
20-25
15-20
10-15
5-10
0-5

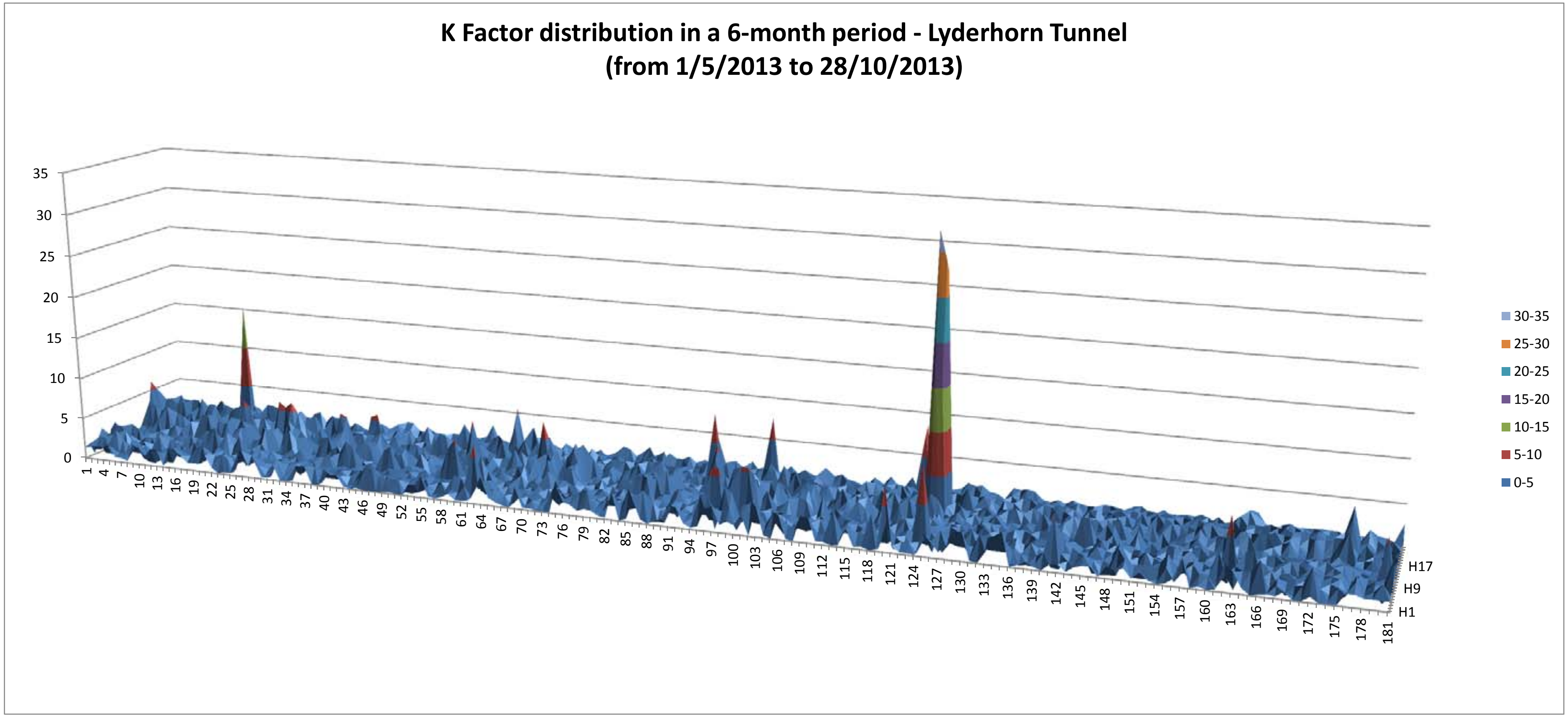


K Factor distribution in a 6-month period - Glasskar Tunnel
(from 29/10/2013 to 30/4/2014)
18
16
14
12
10
8
6
4
2
0
16-18
14-16
12-14
10-12
8-10
6-8
4-6
2-4
0-2
H17
H9
H1


K Factor distribution in a 6-month period - Gudvanga Tunnel
(from 1/5/2013 to 28/10/2013)
0
2
4
6
8
10
12
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97 100 103 106 109 112 115 118 121 124 127 130 133 136 139 142 145 148 151 154 157 160 163 166 169 172 175 178 181
H1
H9
H17
10-12
8-10
6-8
4-6
2-4
0-2

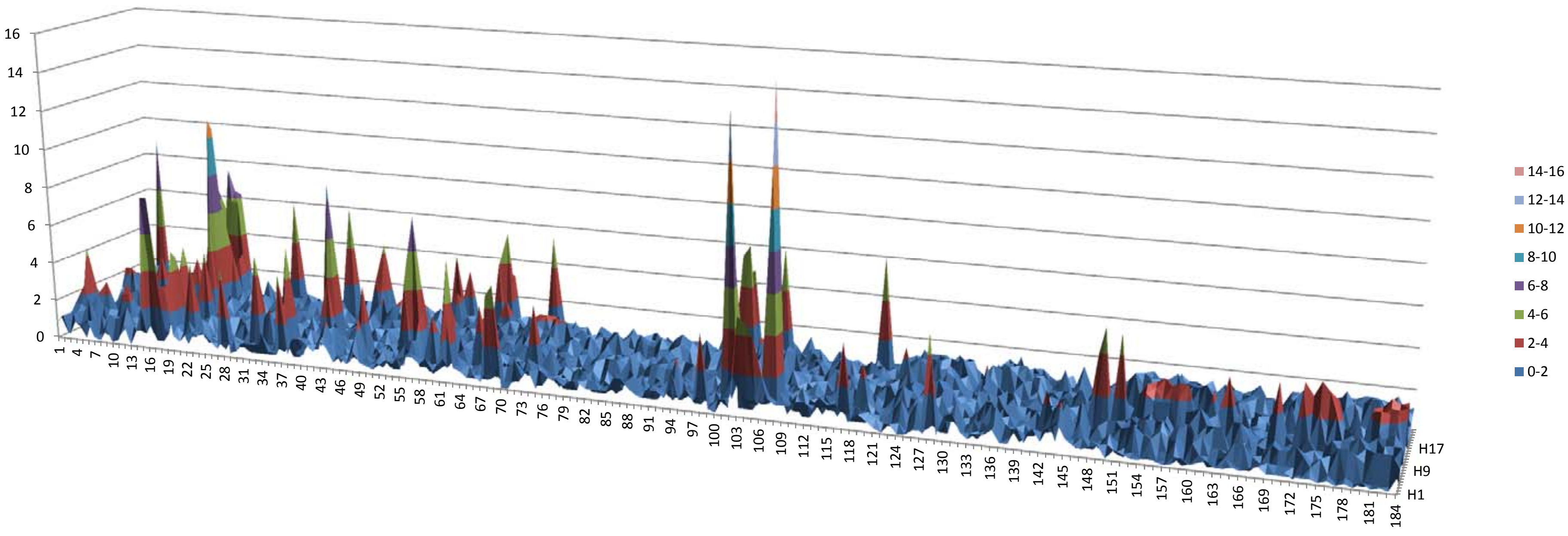


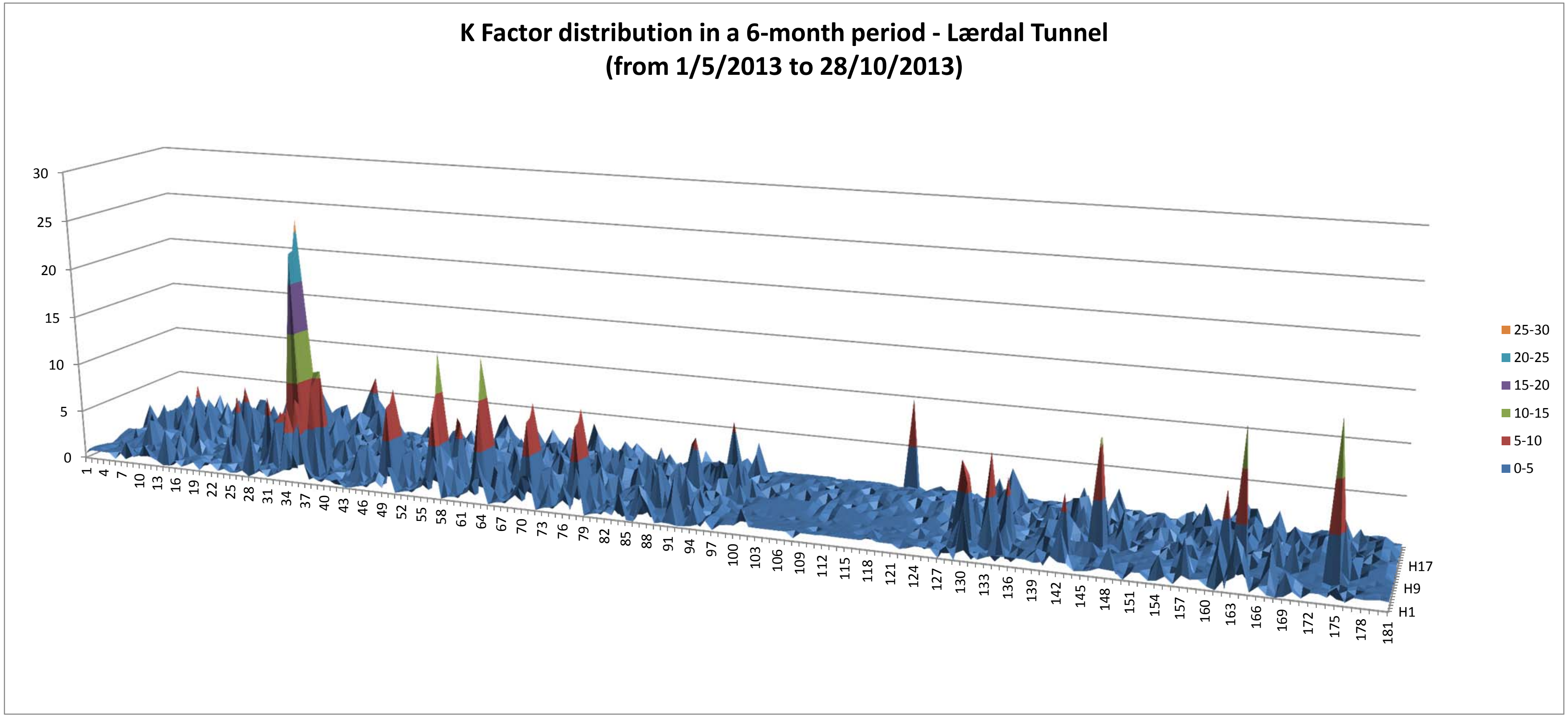
K Factor distribution in a 6-month period - Gudvanga Tunnel
(from 29/10/2013 to 30/4/2014)
0
1
2
3
4
5
6
7
6-7
5-6
4-5
3-4
2-3
1-2
0-1
H1
H9
H17



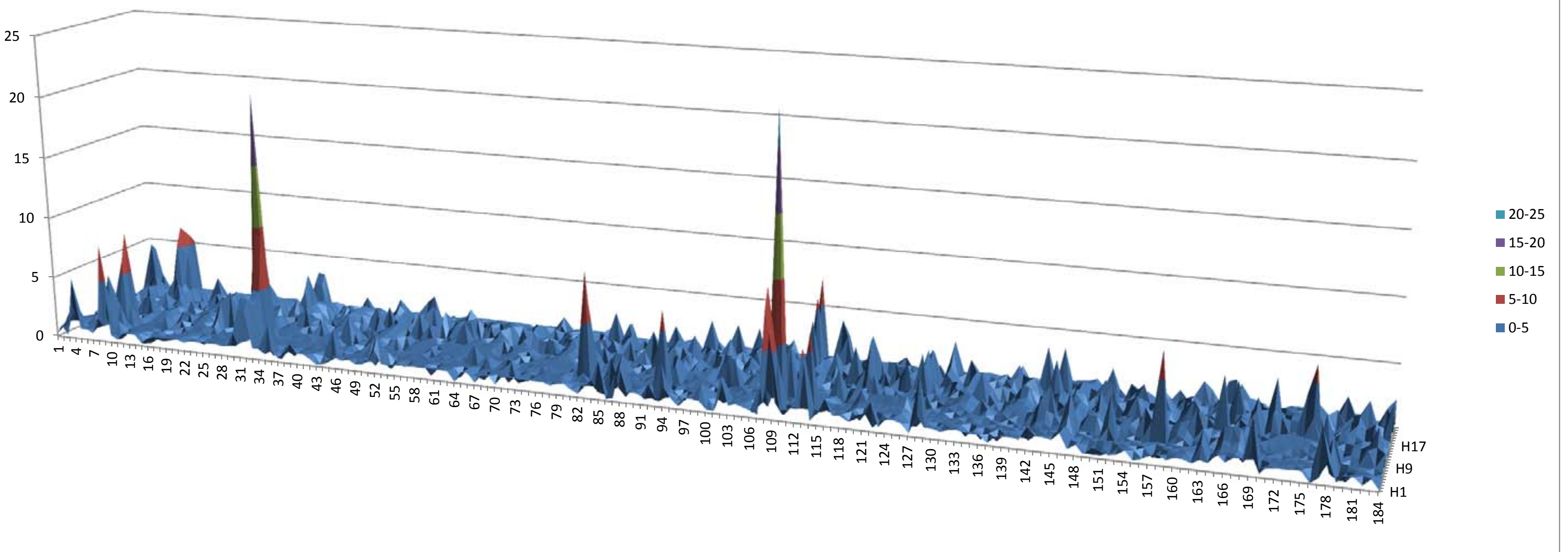
K Factor distribution in a 6-month period - Lyderhorn Tunnel
(from 1/5/2013 to 28/10/2013)
30-35
25-30
20-25
15-20
10-15
5-10
0-5
H17
H9
H1

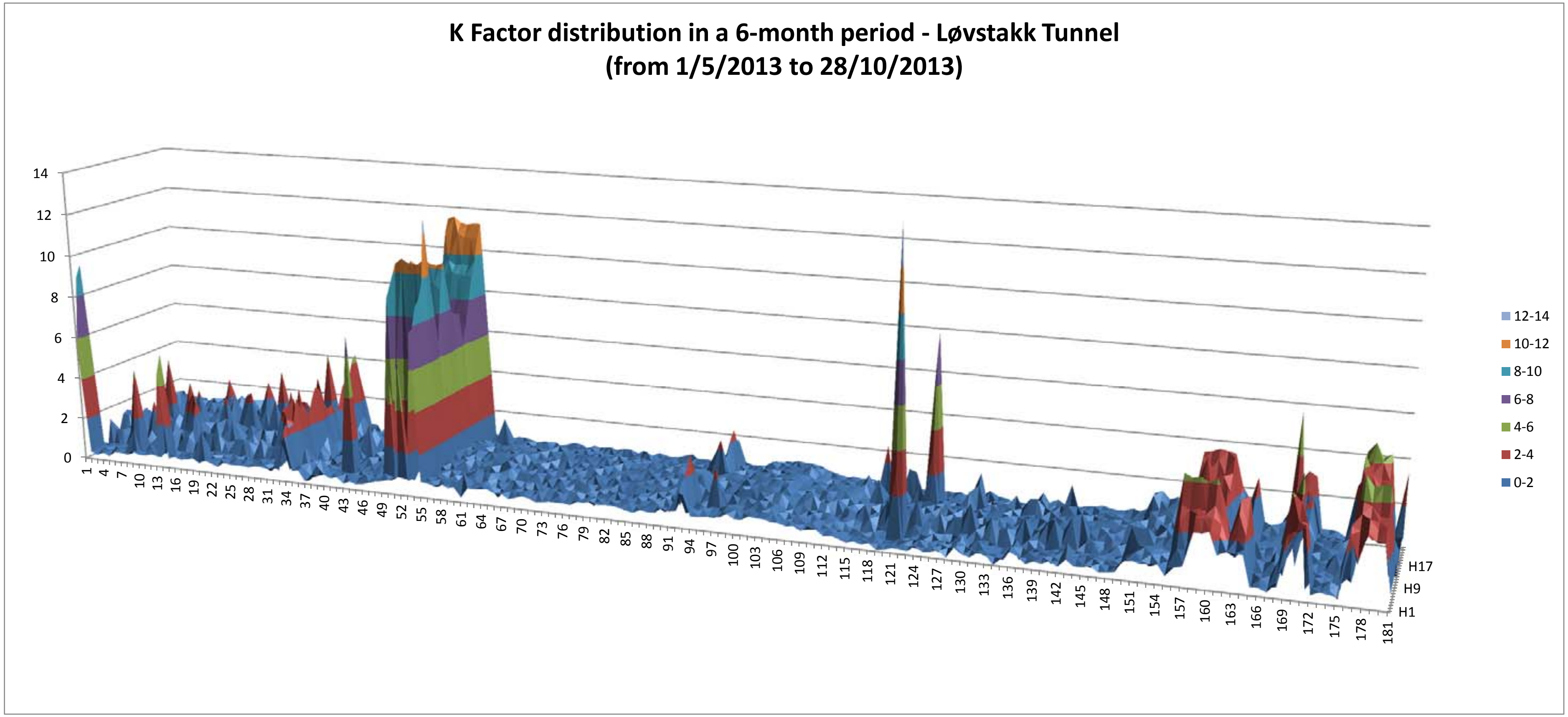
K Factor distribution in a 6-month period - Lyderhorn Tunnel
(from 29/10/2013 to 30/4/2014)




K Factor distribution in a 6-month period - Lærdal Tunnel
(from 1/5/2013 to 28/10/2013)
0
5
10
15
20
25
30
25-30
20-25
15-20
10-15
5-10
0-5
H1
H9
H17
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79
82
85
88
91
94
97
100
103
106
109
112
115
118
121
124
127
130
133
136
139
142
145
148
151
154
157
160
163
166
169
172
175
178
181

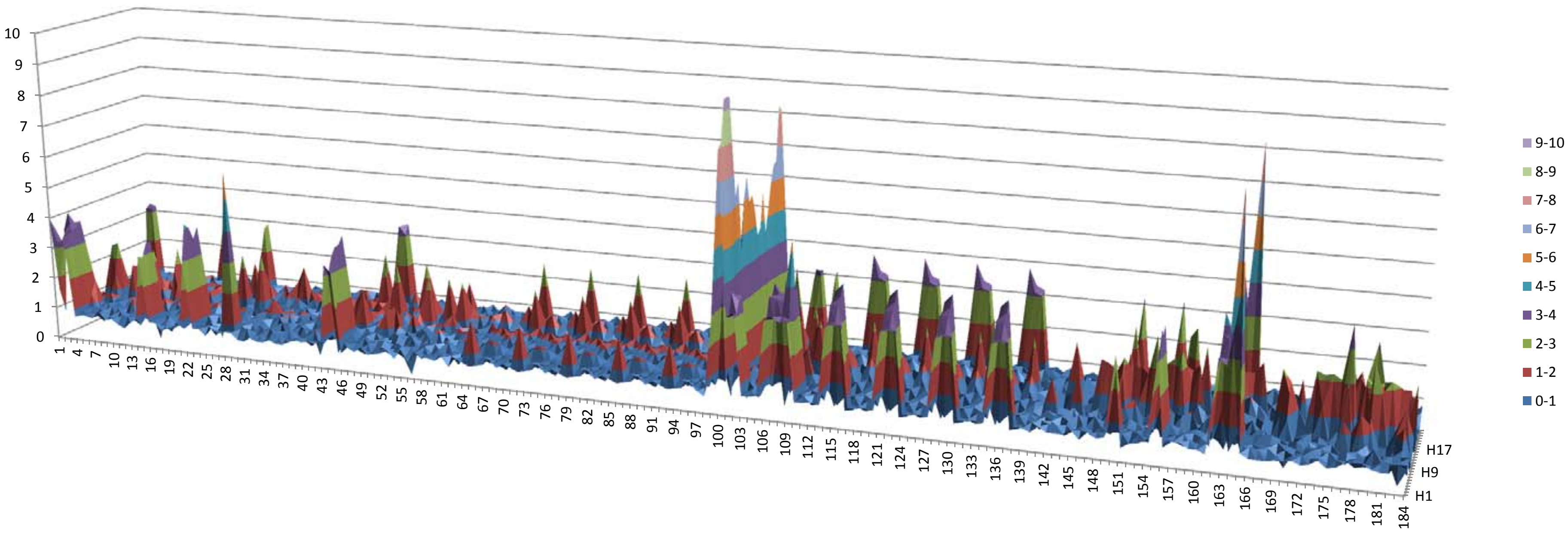
K Factor distribution in a 6-month period - Lærdal Tunnel
(from 29/10/2013 to 30/4/2014)

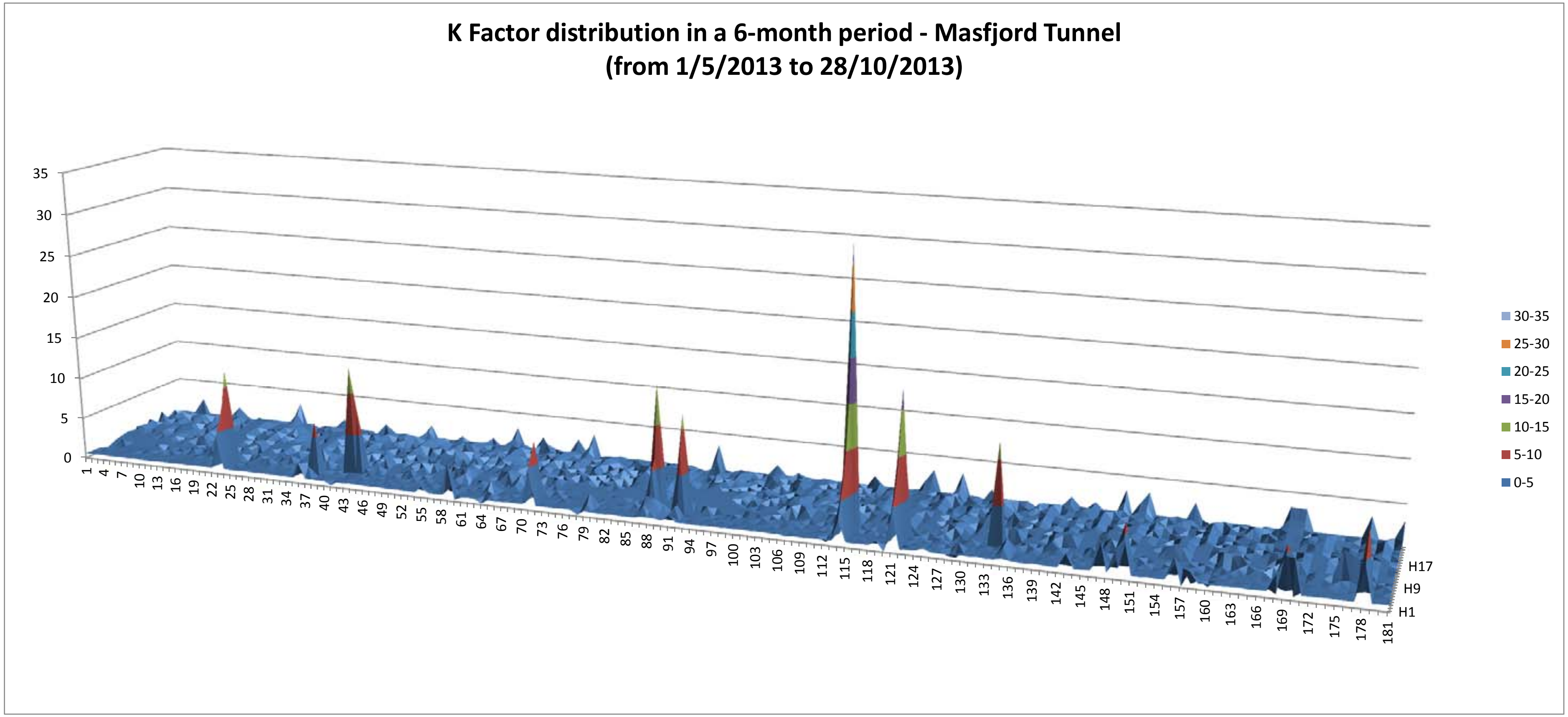


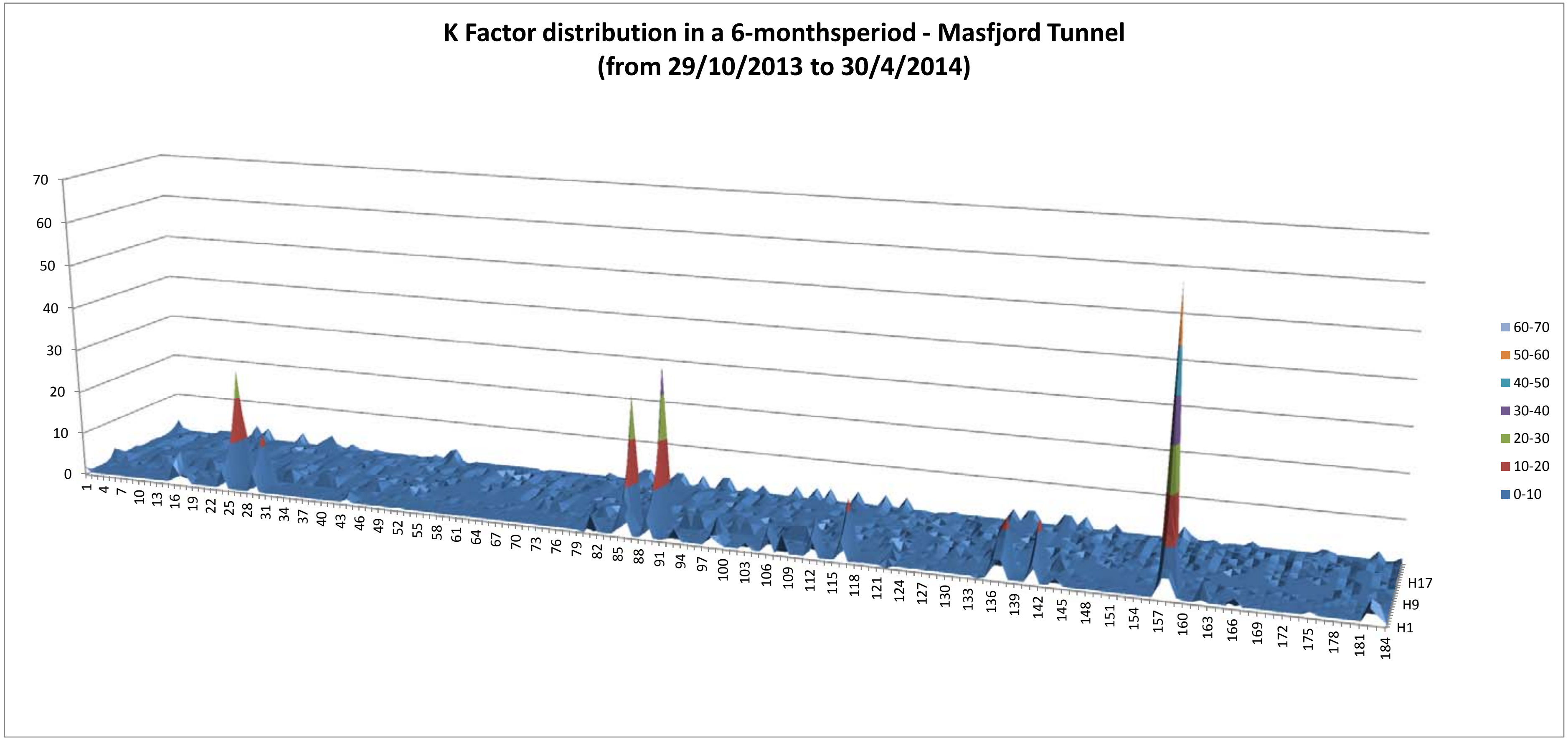


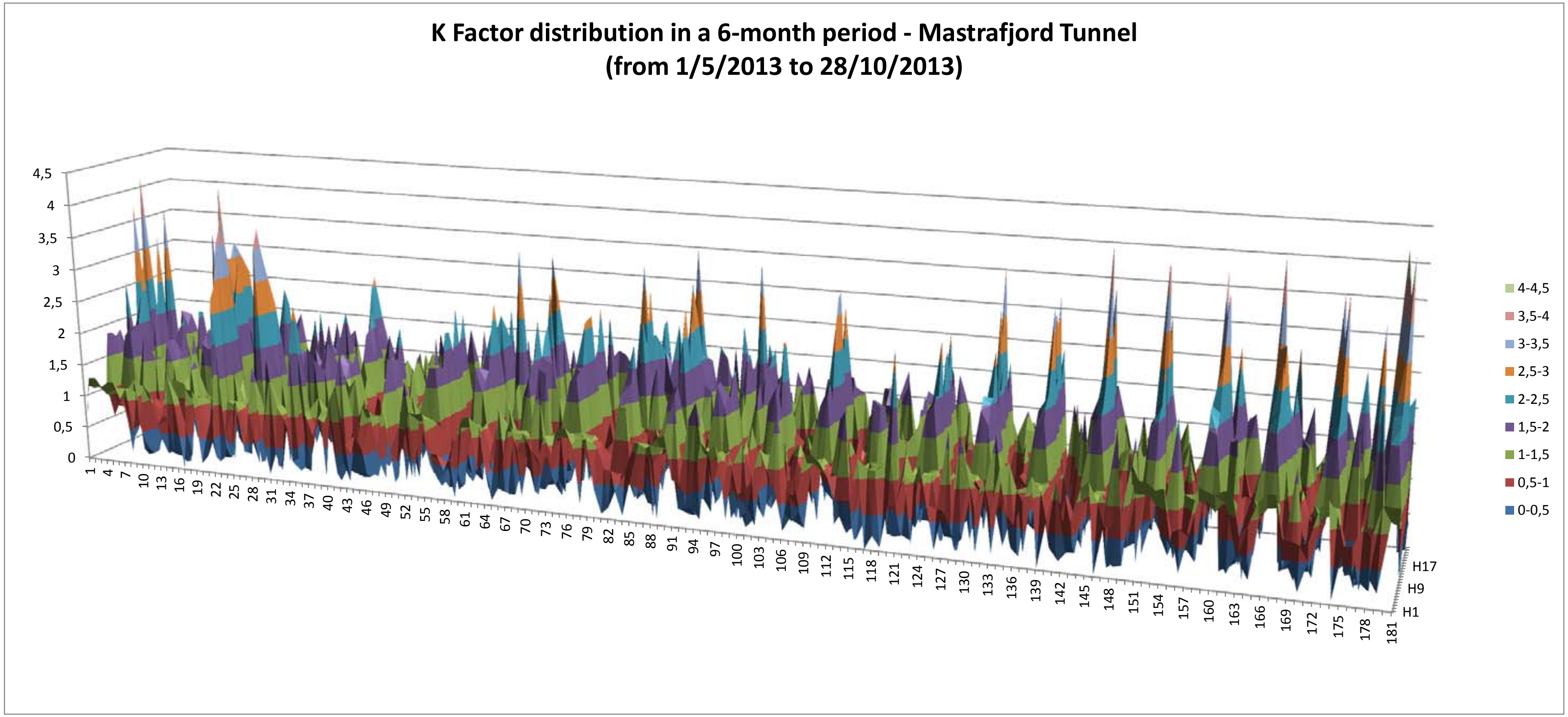
K Factor distribution in a 6-month period - Løvstakk Tunnel
(from 1/5/2013 to 28/10/2013)
14
12
10
8
6
4
2
0
12-14
10-12
8-10
6-8
4-6
2-4
0-2
H17
H9
H1
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79
82
85
88
91
94
97
100
103
106
109
112
115
118
121
124
127
130
133
136
139
142
145
148
151
154
157
160
163
166
169
172
175
178
181

K Factor distribution in a 6-month period - Løvstakk tunnel
(from 29/10/2013 to 30/4/2014)

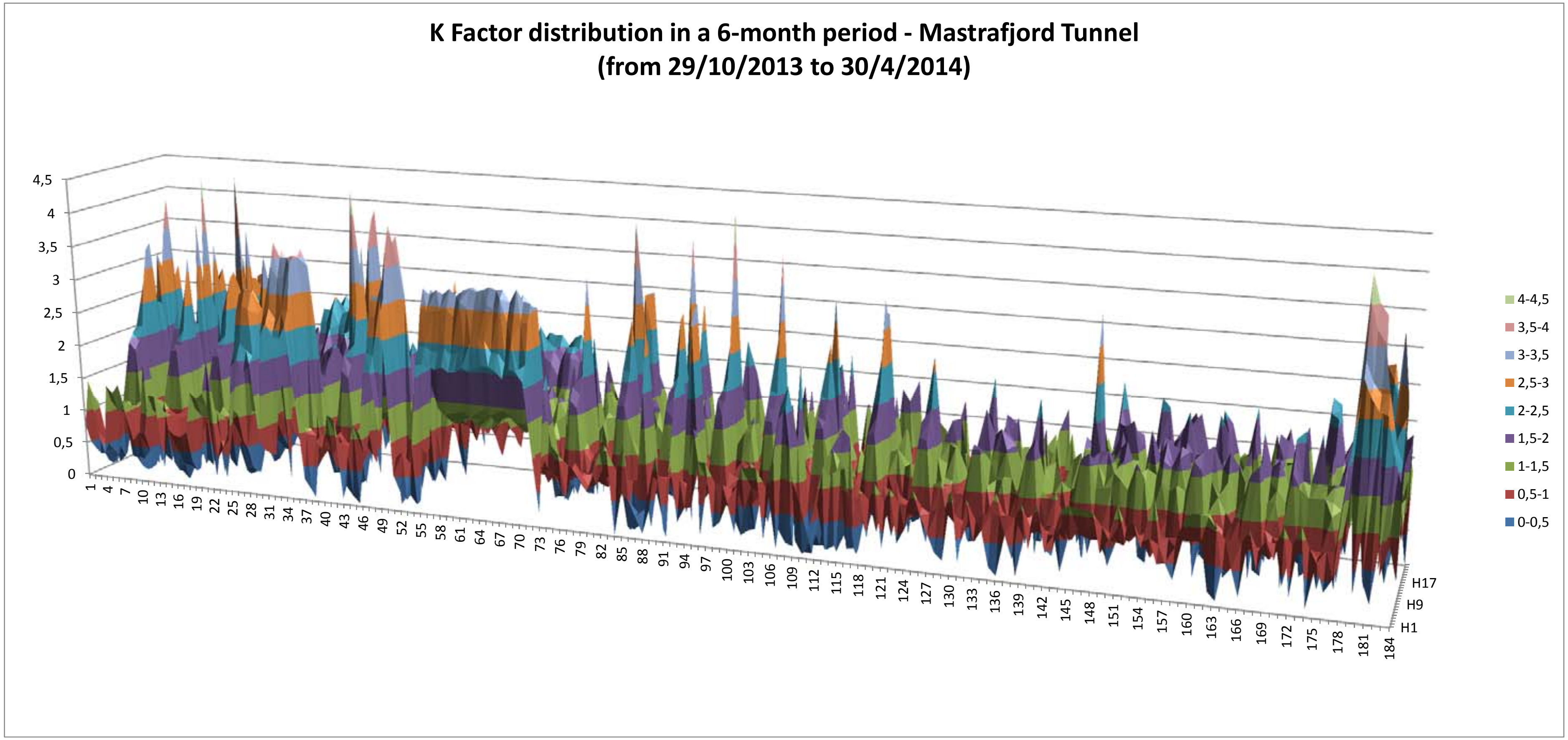


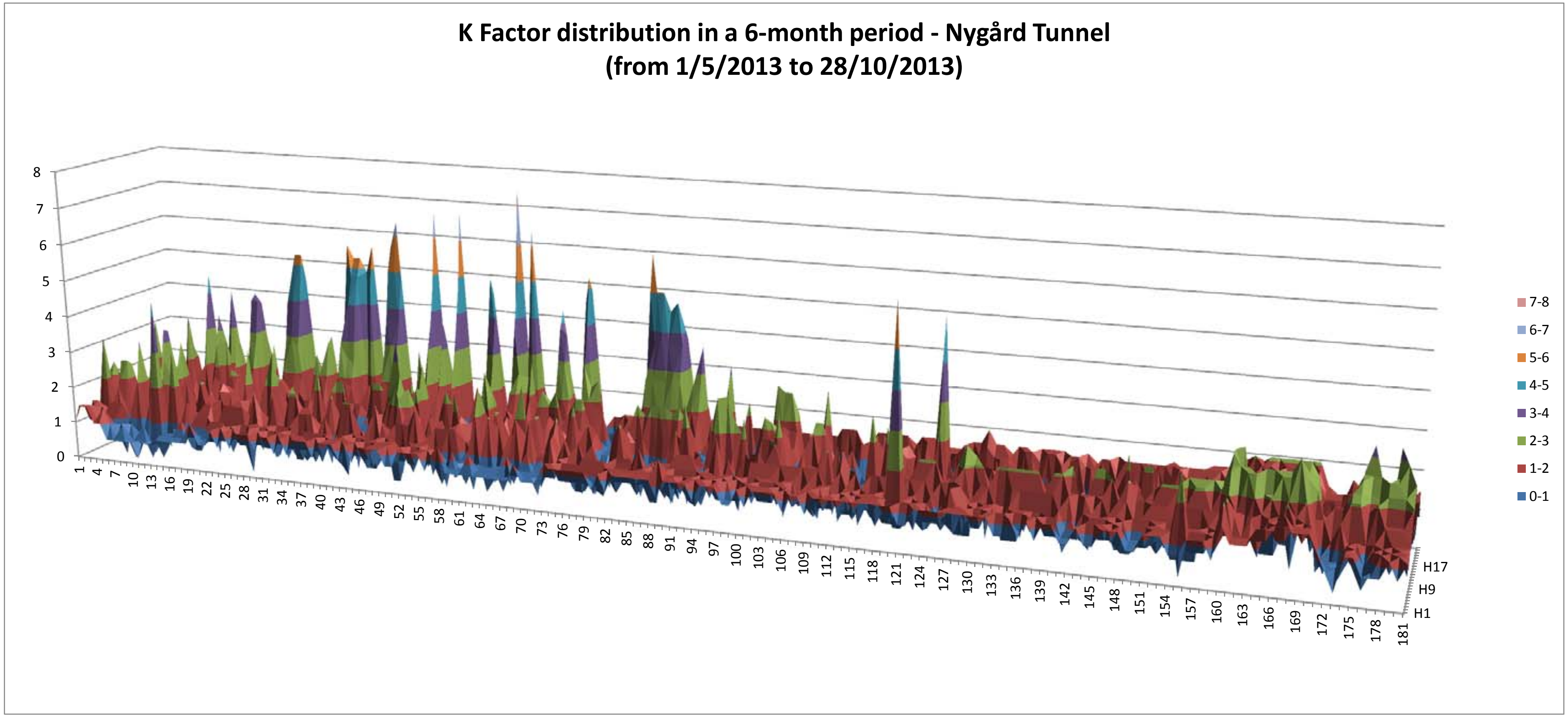

K Factor distribution in a 6-month period - Masfjord Tunnel
(from 1/5/2013 to 28/10/2013)
0
5
10
15
20
25
30
35
H1
H9
H17
30-35
25-30
20-25
15-20
10-15
5-10
0-5


K Factor distribution in a 6-monthsperiod - Masfjord Tunnel
(from 29/10/2013 to 30/4/2014)
70
60
50
40
30
20
10
0
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79
82
85
88
91
94
97
100
103
106
109
112
115
118
121
124
127
130
133
136
139
142
145
148
151
154
157
160
163
166
169
172
175
178
181
184
H17
H9
H1
60-70
50-60
40-50
30-40
20-30
10-20
0-10

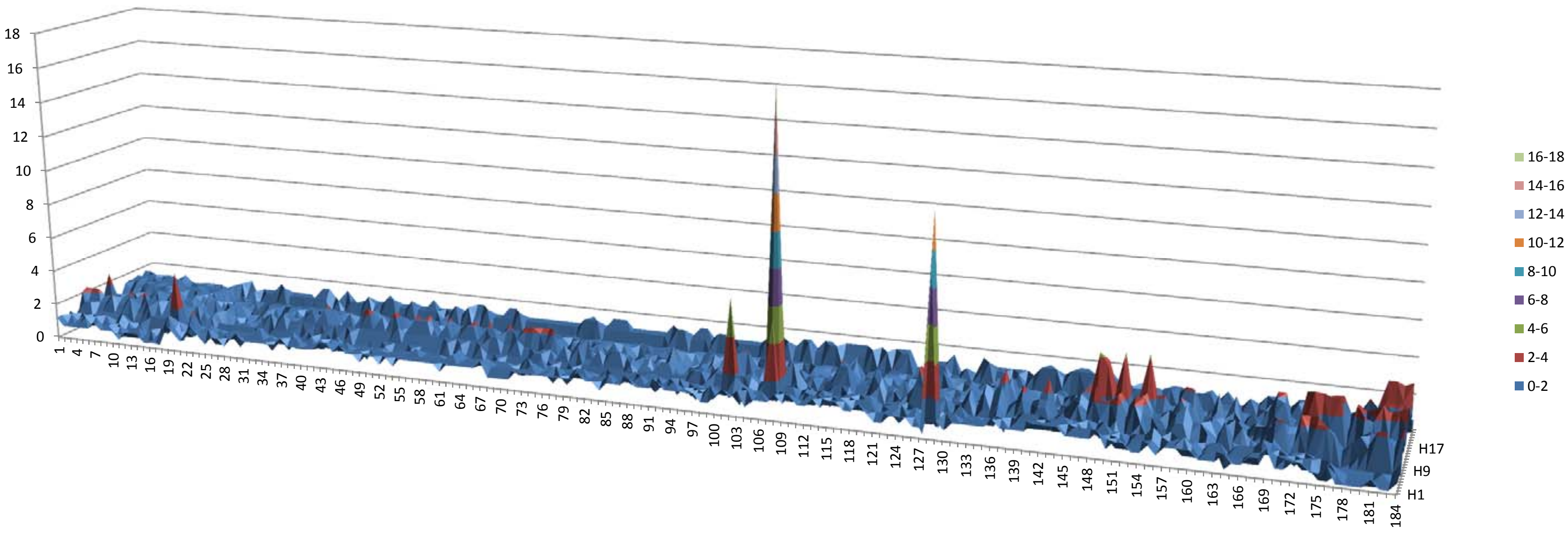


K Factor distribution in a 6-month period - Mastrafjord Tunnel
(from 1/5/2013 to 28/10/2013)
4-4,5
3,5-4
3-3,5
2,5-3
2-2,5
1,5-2
1-1,5
0,5-1
0-0,5
H17
H9
H1

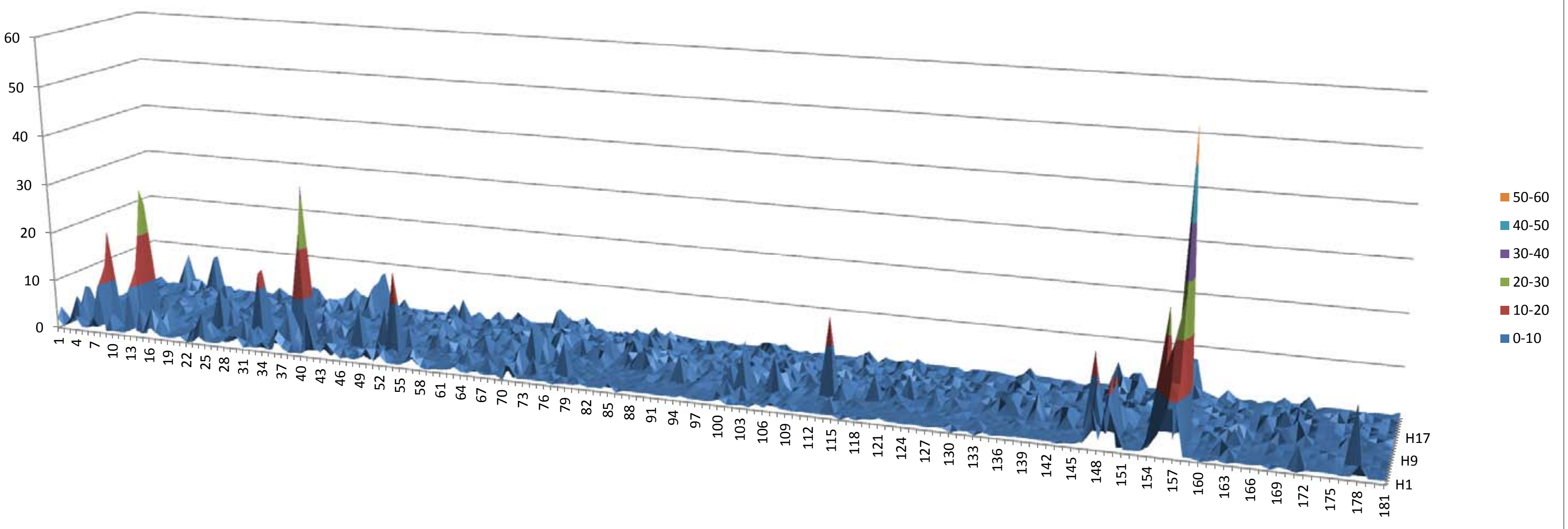

K Factor distribution in a 6-month period - Mastrafjord Tunnel
(from 29/10/2013 to 30/4/2014)
4,5
4
3,5
3
2,5
2
1,5
1
0,5
0
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97 100 103 106 109 112 115 118 121 124 127 130 133 136 139 142 145 148 151 154 157 160 163 166 169 172 175 178 181 184
H17
H9
H1
4-4,5
3,5-4
3-3,5
2,5-3
2-2,5
1,5-2
1-1,5
0,5-1
0-0,5

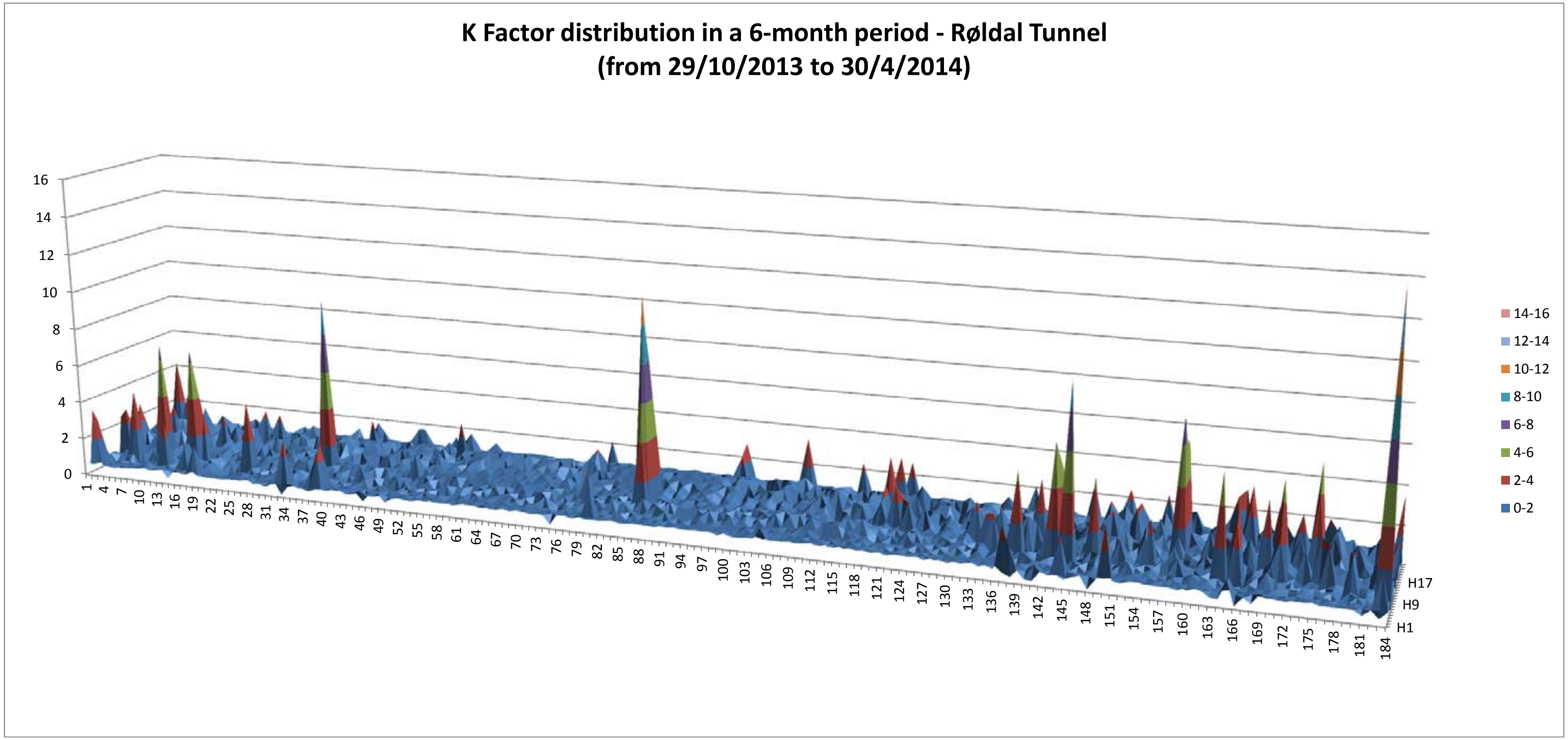

K Factor distribution in a 6-month period - Nygård Tunnel
(from 1/5/2013 to 28/10/2013)
0
1
2
3
4
5
6
7
8
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97 100 103 106 109 112 115 118 121 124 127 130 133 136 139 142 145 148 151 154 157 160 163 166 169 172 175 178 181
H1
H9
H17
7-8
6-7
5-6
4-5
3-4
2-3
1-2
0-1

K Factor distribution in a 6-month period - Nygård Tunnel
(from 29/10/2013 to 30/4/2014)

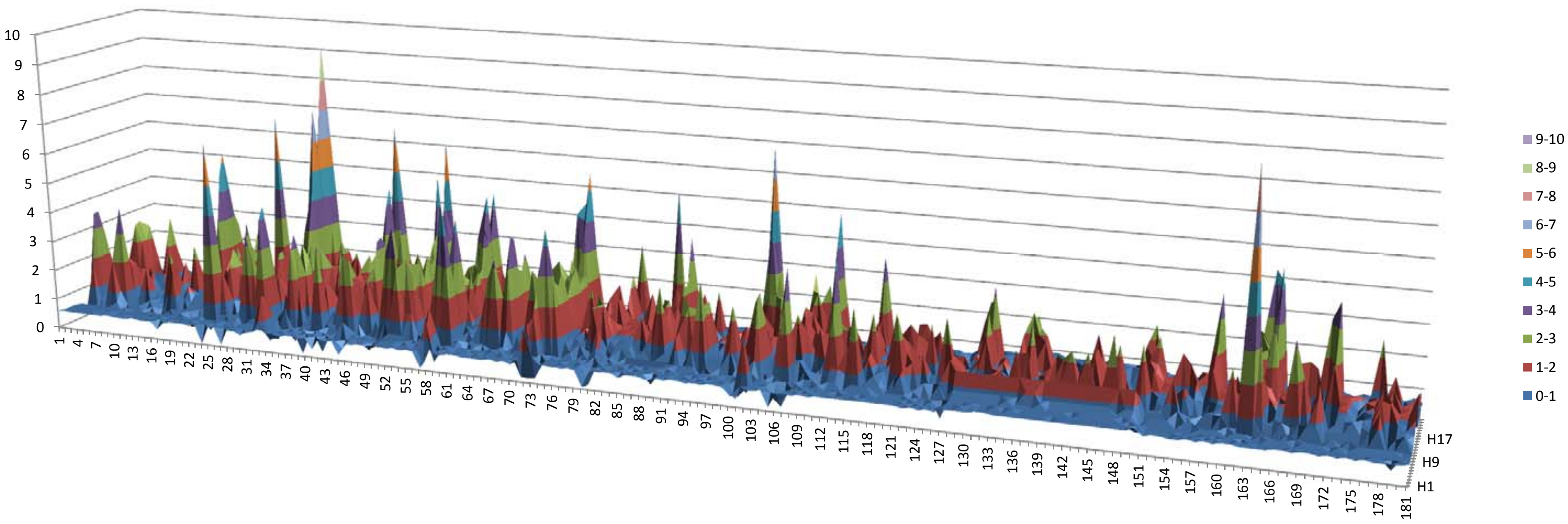


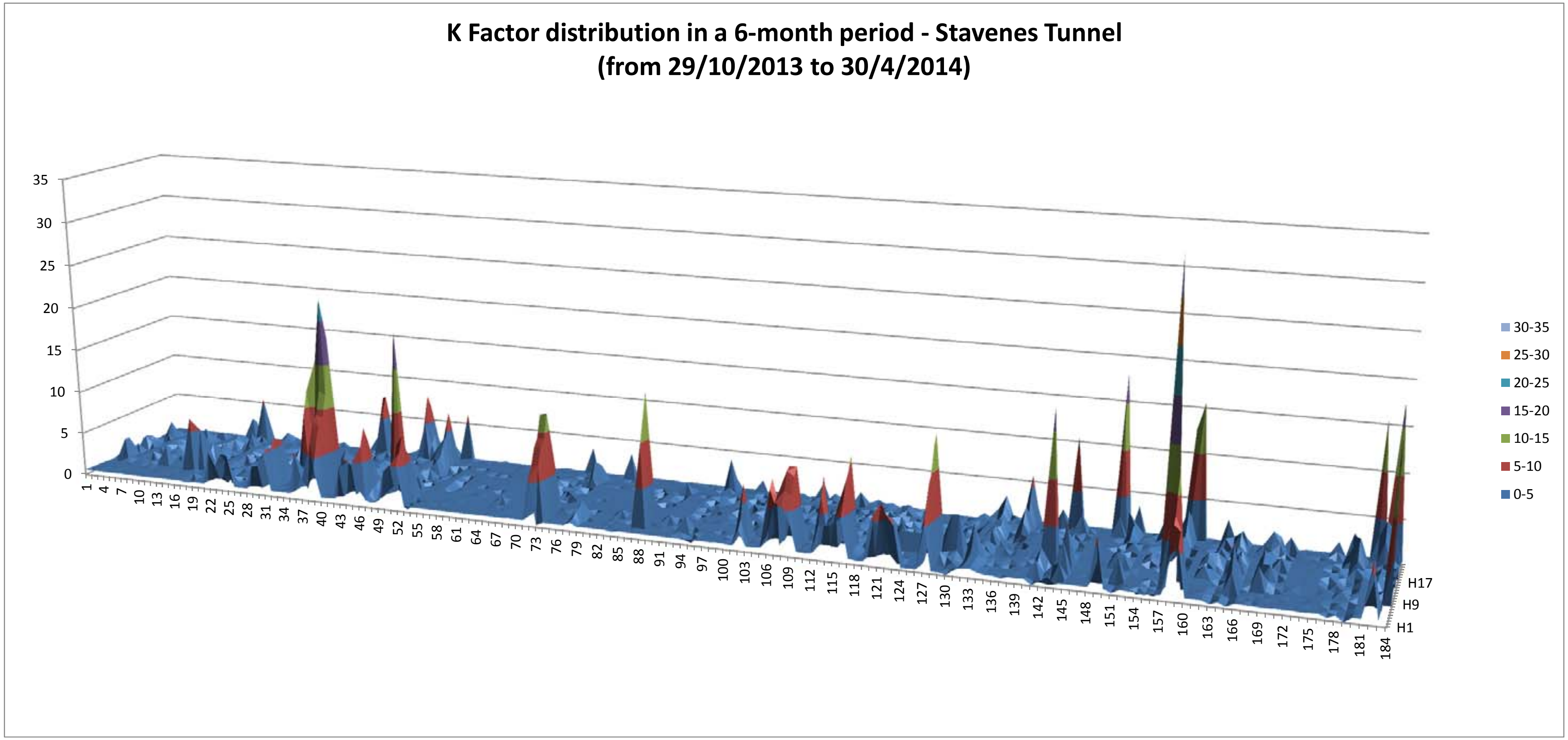
K Factor distribution in a 6-month period - Røldal Tunnel (from 1/5/2013 to 28/10/2013)



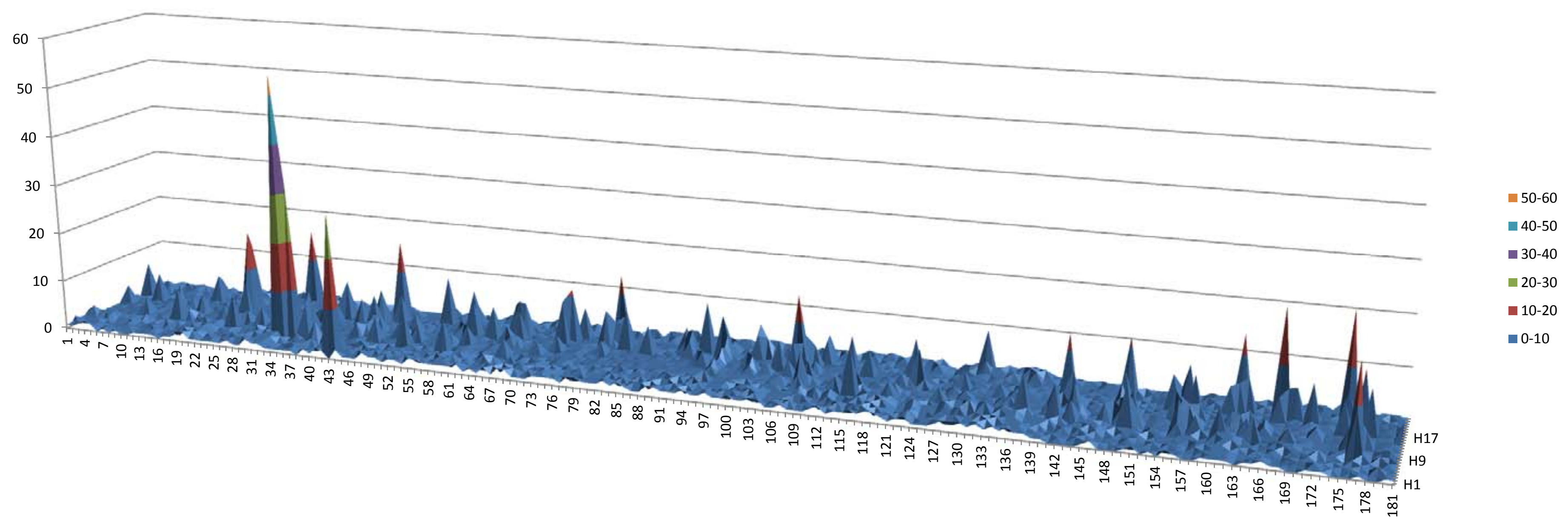

K Factor distribution in a 6-month period - Røldal Tunnel
(from 29/10/2013 to 30/4/2014)
0
2
4
6
8
10
12
14
16
14-16
12-14
10-12
8-10
6-8
4-6
2-4
0-2
H1
H9
H17
1
4
7
10
13
16
19
22
25
28
31
34
37
40
43
46
49
52
55
58
61
64
67
70
73
76
79
82
85
88
91
94
97
100
103
106
109
112
115
118
121
124
127
130
133
136
139
142
145
148
151
154
157
160
163
166
169
172
175
178
181
184

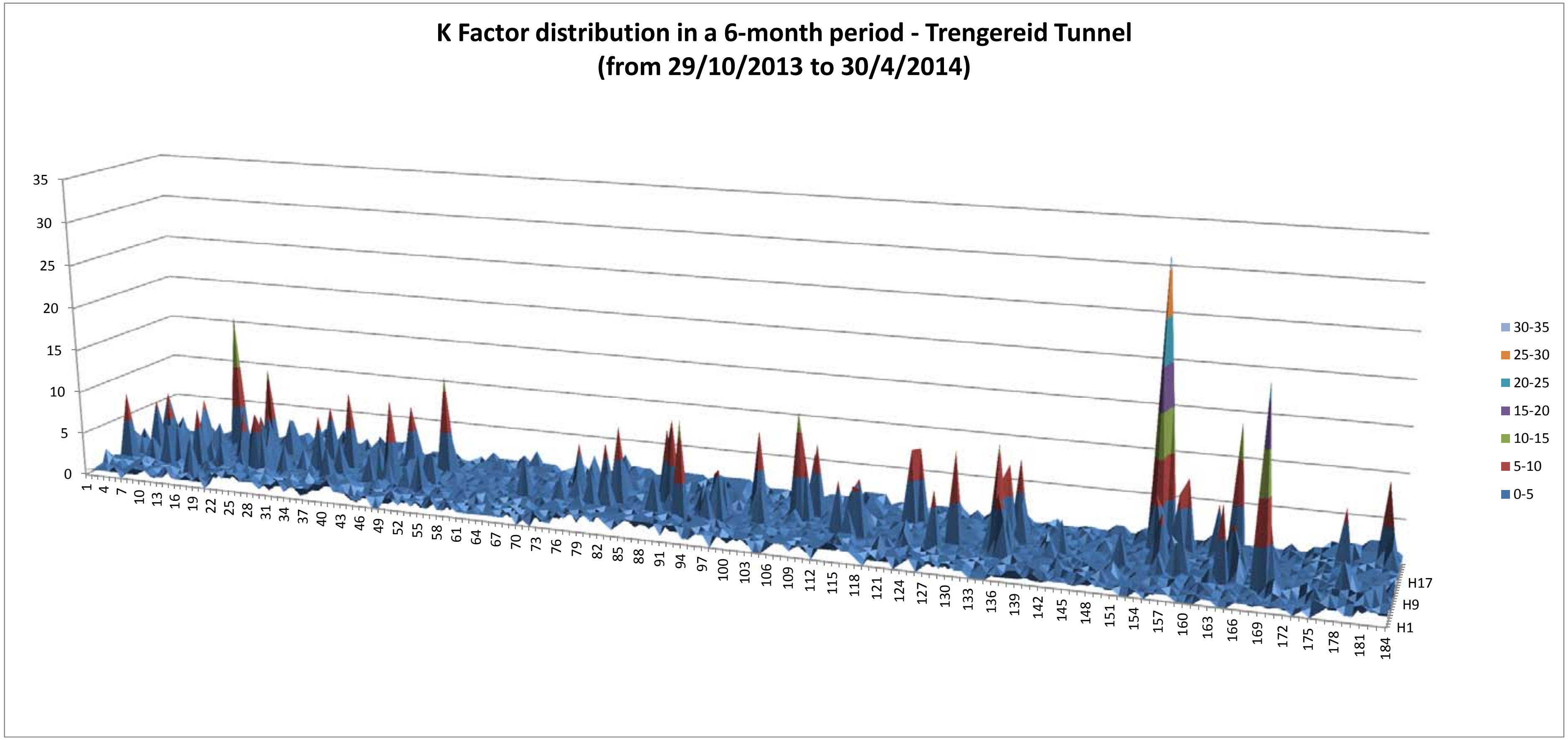
K Factor distribution in a 6-month period - Stavenes Tunnel
(from 1/5/2013 to 28/10/2013)



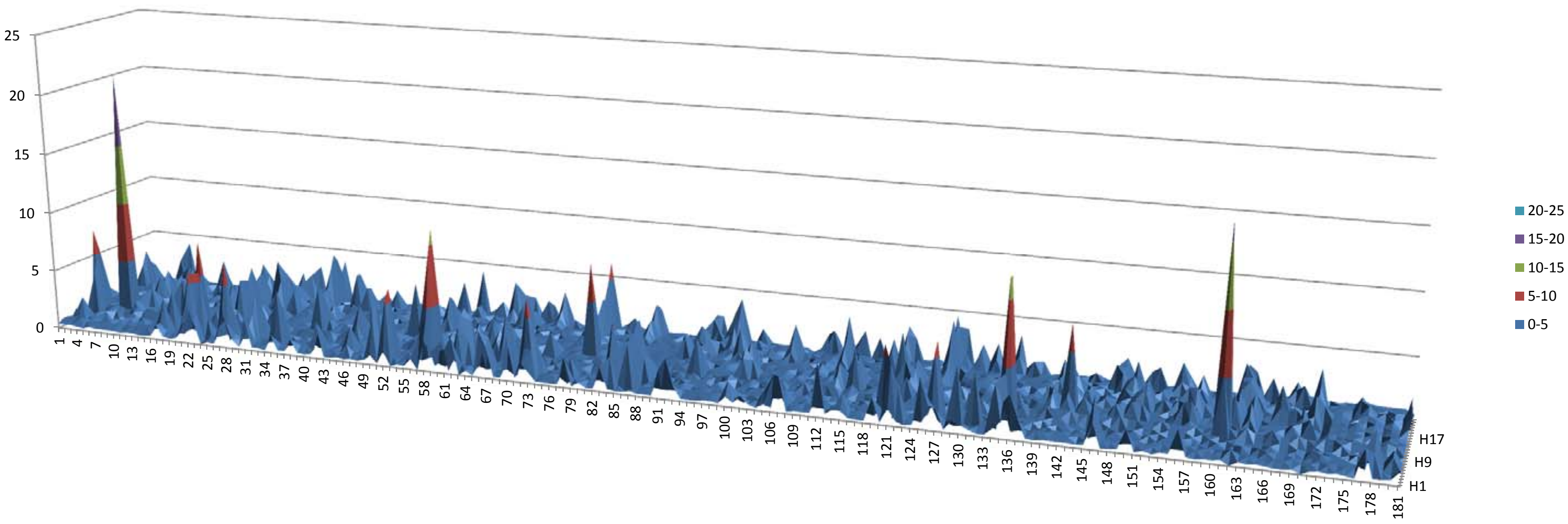

K Factor distribution in a 6-month period - Stavenes Tunnel
(from 29/10/2013 to 30/4/2014)
0
5
10
15
20
25
30
35
30-35
25-30
20-25
15-20
10-15
5-10
0-5
H17
H9
H1
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58 61 64 67 70 73 76 79 82 85 88 91 94 97 100 103 106 109 112 115 118 121 124 127 130 133 136 139 142 145 148 151 154 157 160 163 166 169 172 175 178 181 184

K Factor distribution in a 6-month period - Trengereid Tunnel (from 1/5/2013 to 28/10/2013)

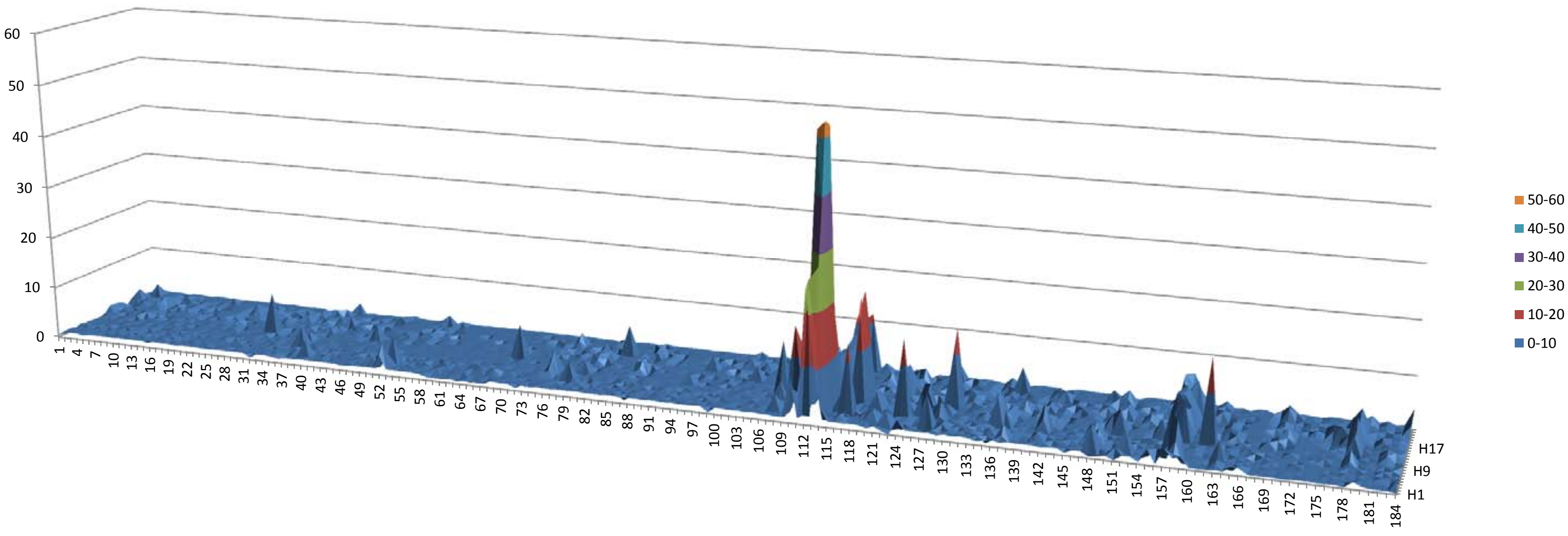



K Factor distribution in a 6-month period - Trengereid Tunnel
(from 29/10/2013 to 30/4/2014)
0
5
10
15
20
25
30
35
30-35
25-30
20-25
15-20
10-15
5-10
0-5
H1
H9
H17
1
184

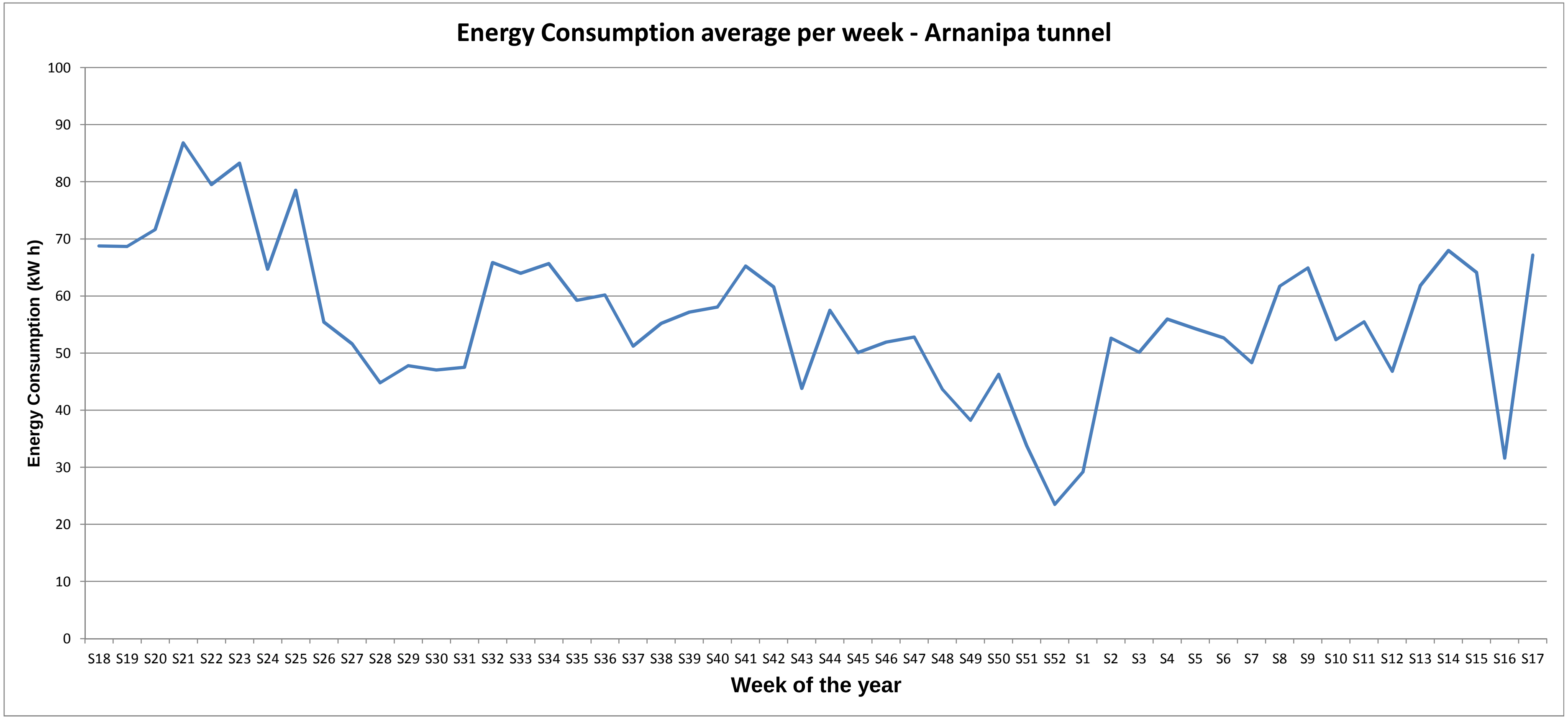
K Factor distribution in a 6-month period - Åkrafjord Tunnel
(from 1/5/2013 to 28/10/2013)



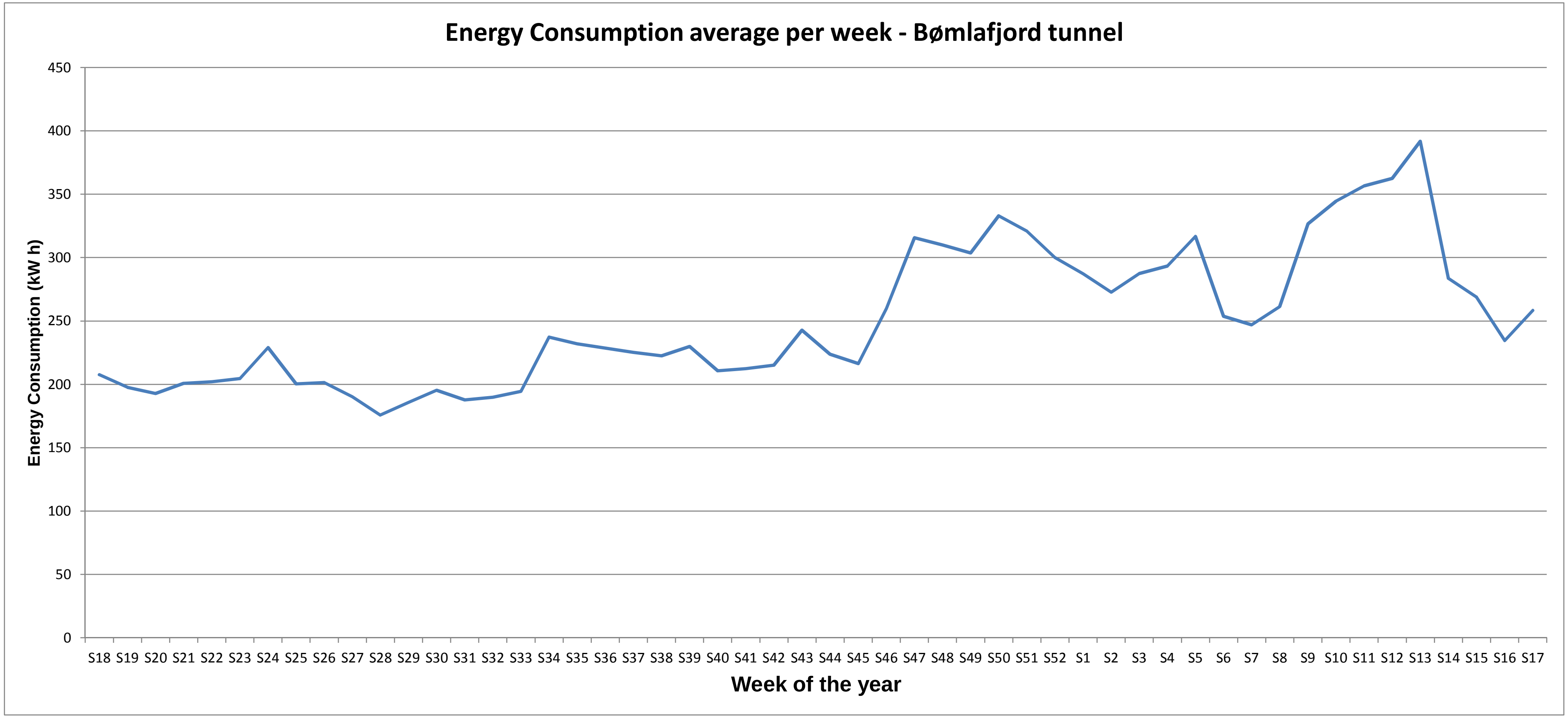
K Factor distribution in a 6-month period - Åkrafjord Tunnel
(from 29/10/2013 to 30/4/2014)

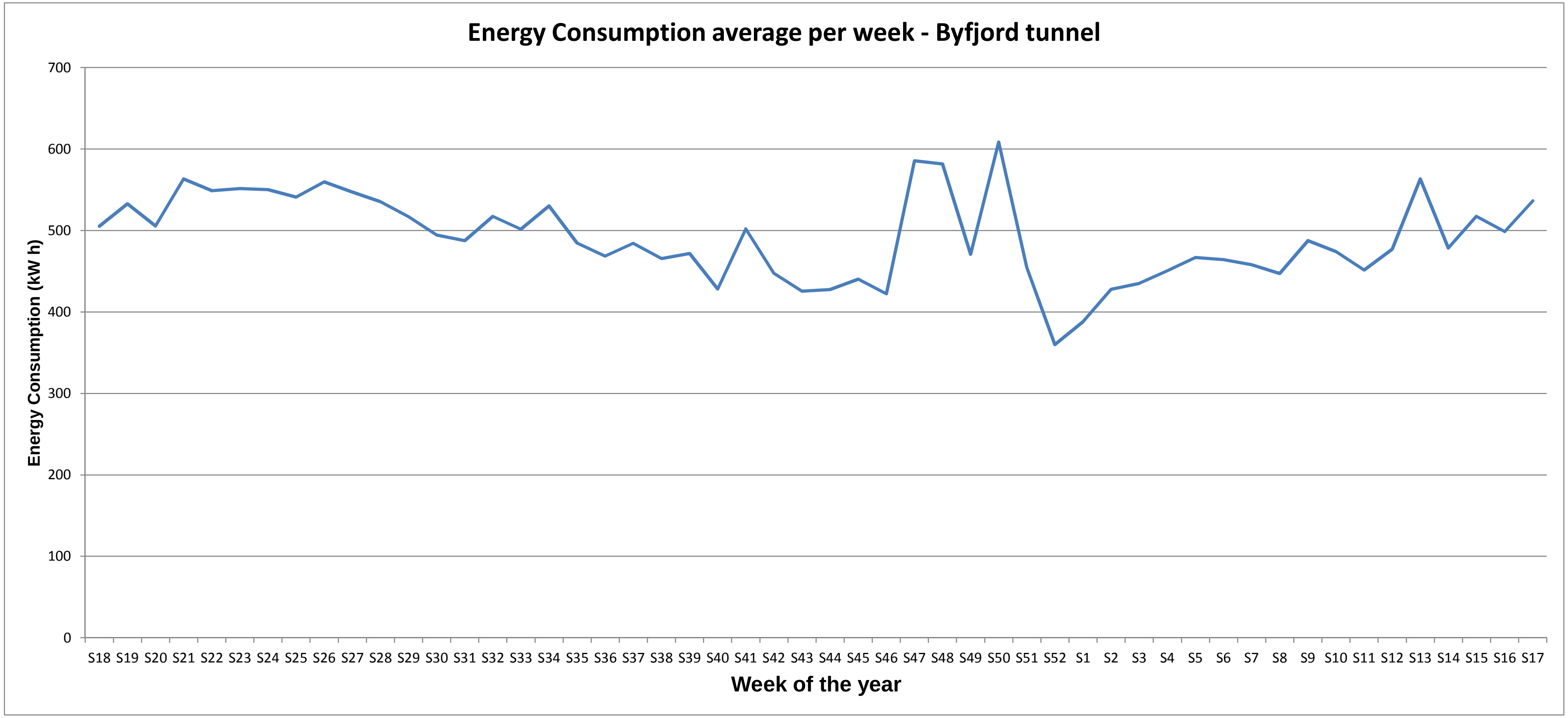


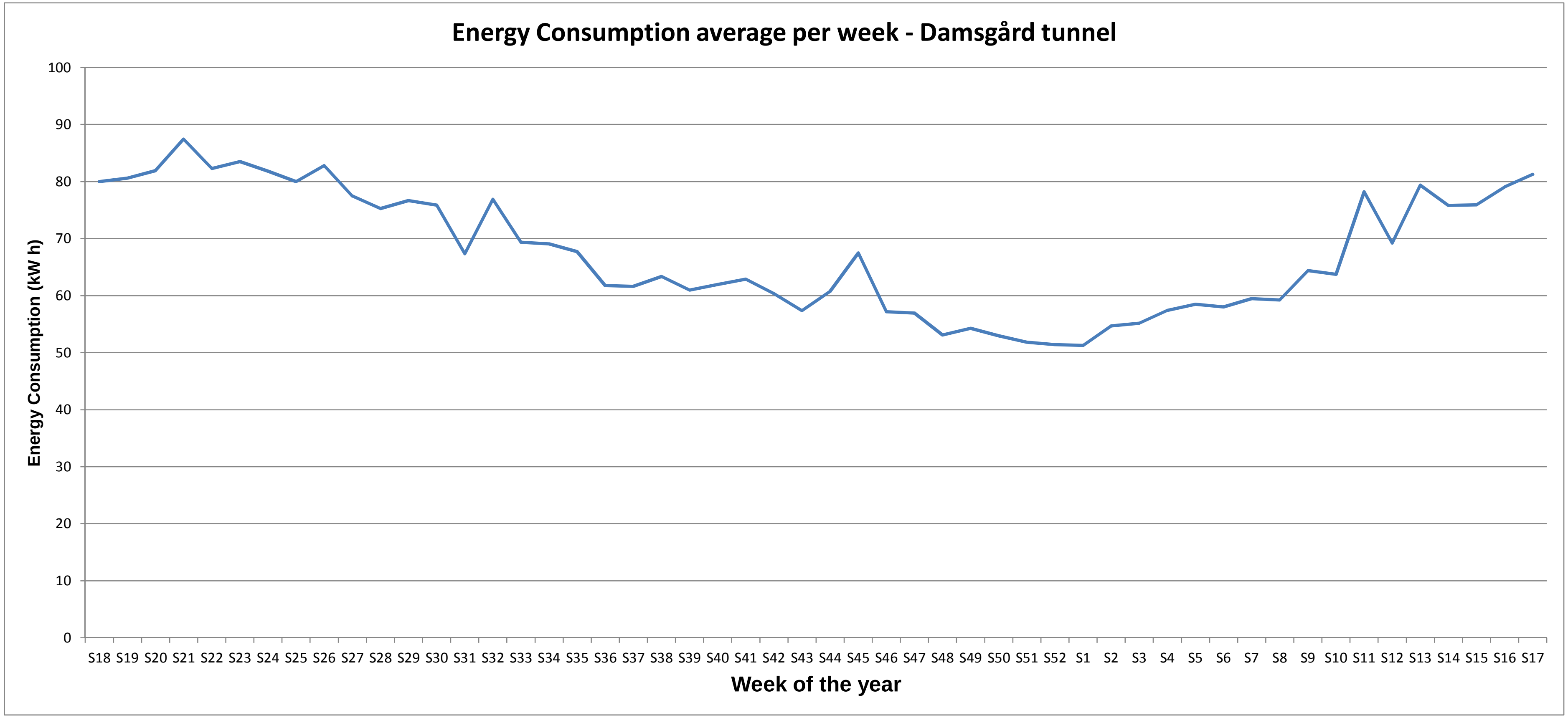
ANNEXE 2

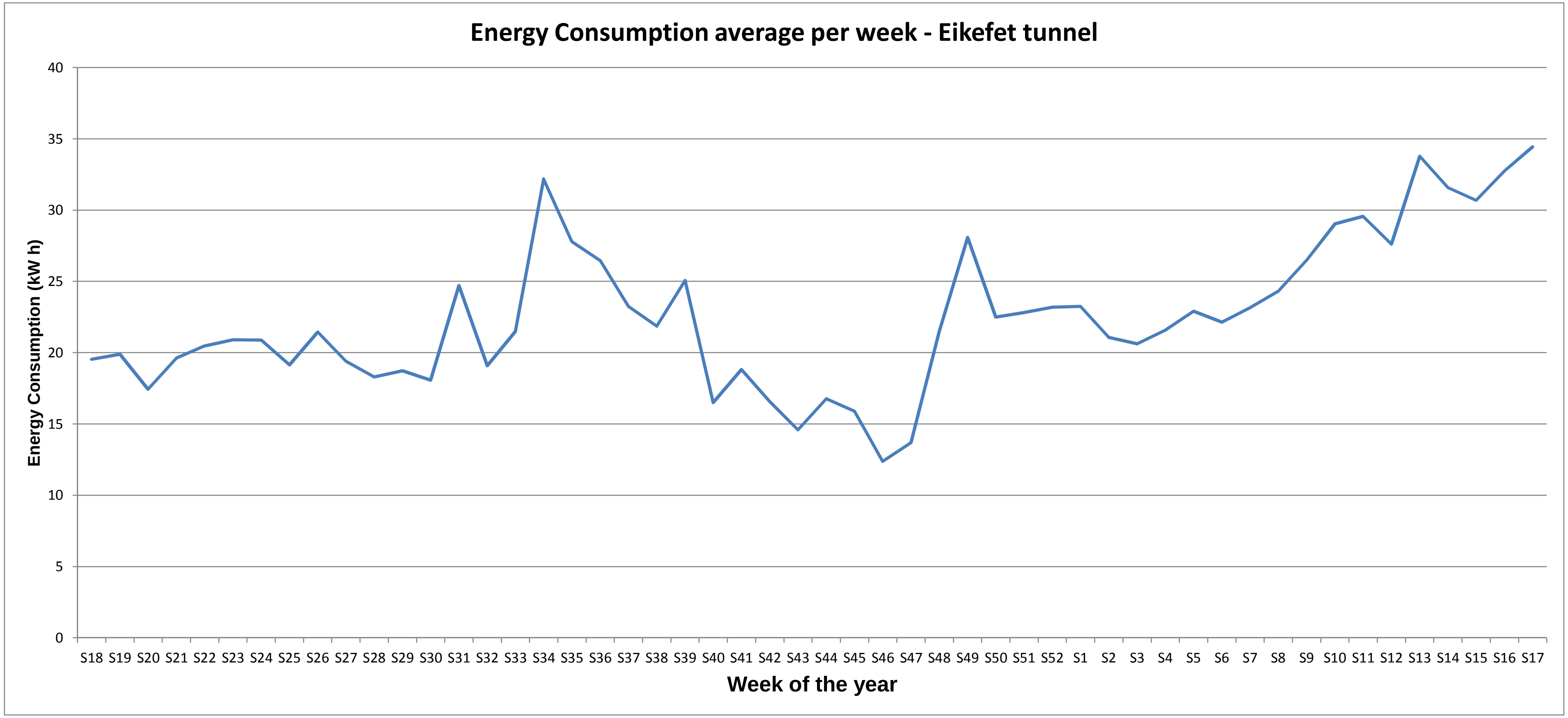


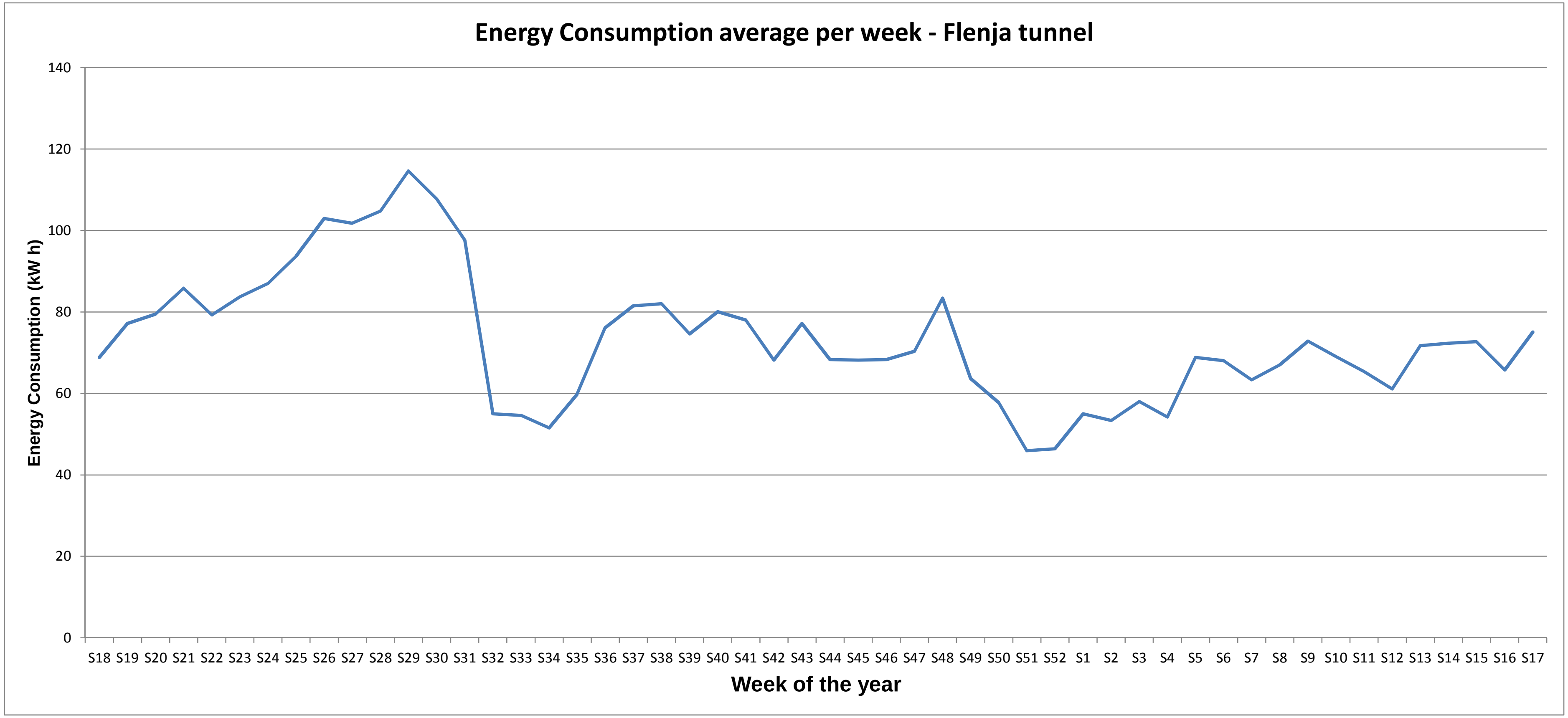
Energy Consumption average per week - Arnanipa tunnel
Energy Consumption (kW h)
0
10
20
30
40
50
60
70
80
90
100
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year

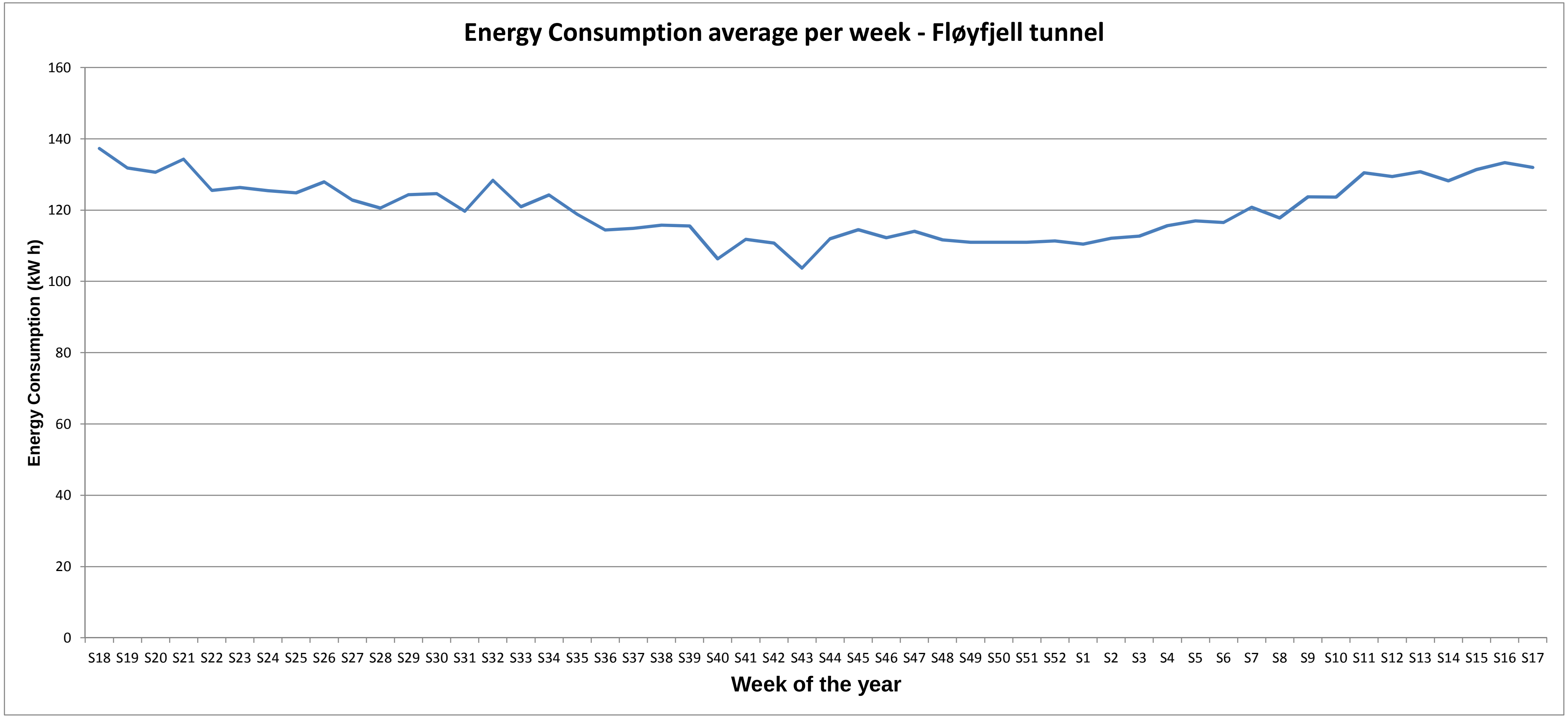

Energy Consumption average per week - Bømlafjord tunnel
Energy Consumption (kW h)
0
50
100
150
200
250
300
350
400
450
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year

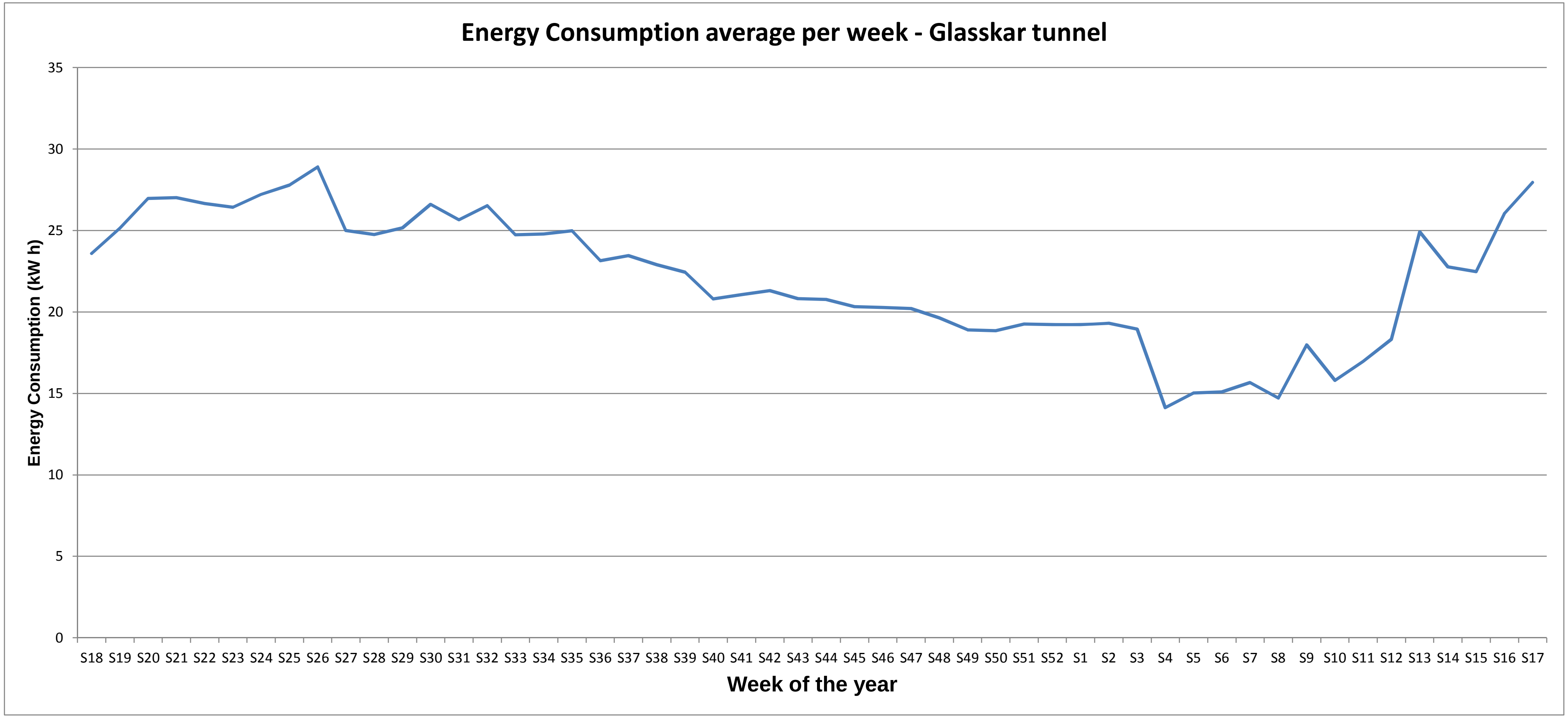

Energy Consumption average per week - Byfjord tunnel
Energy Consumption (kW h)
700
600
500
400
300
200
100
0
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year


Energy Consumption average per week - Damsgård tunnel
Energy Consumption (kW h)
100
90
80
70
60
50
40
30
20
10
0
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year

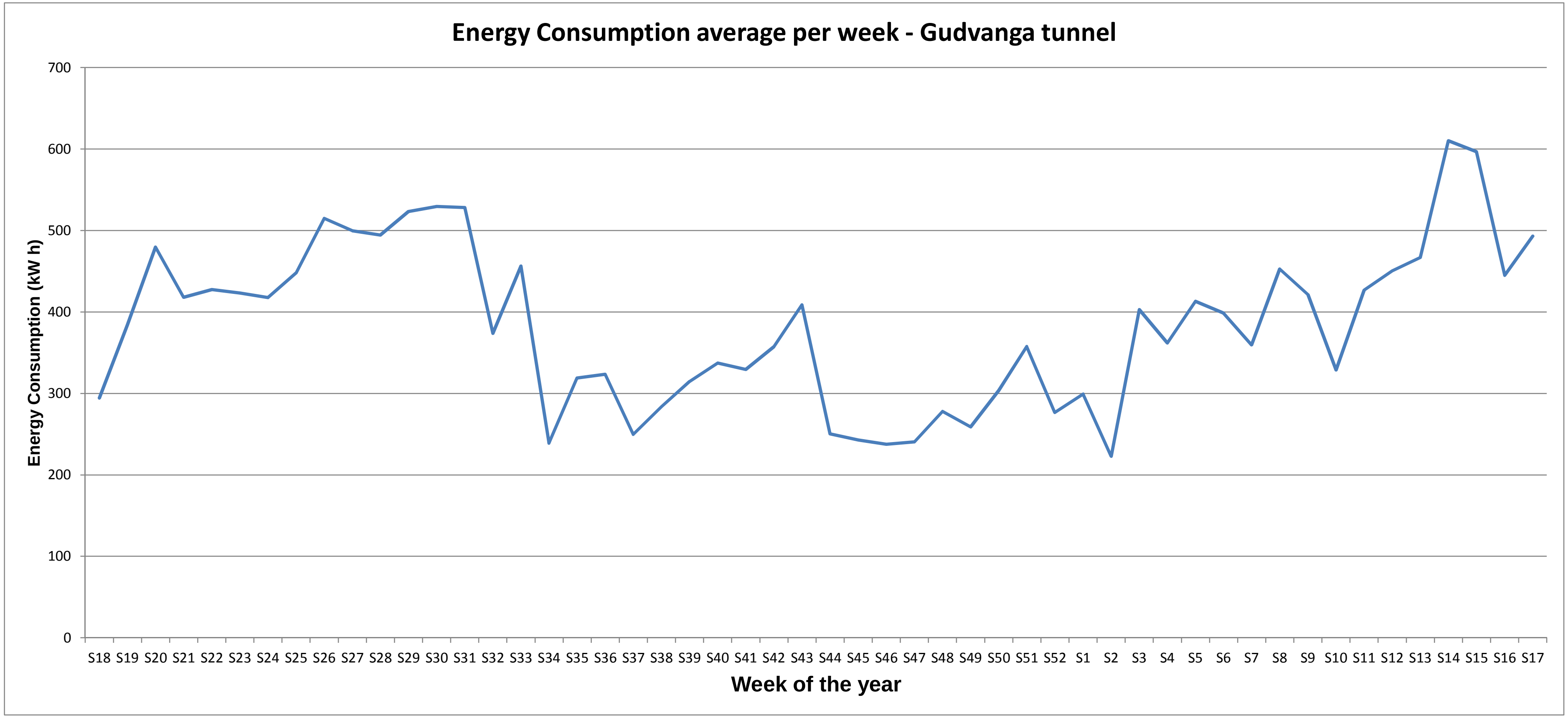

Energy Consumption average per week - Eikefet tunnel
Energy Consumption (kW h)
0
5
10
15
20
25
30
35
40
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year

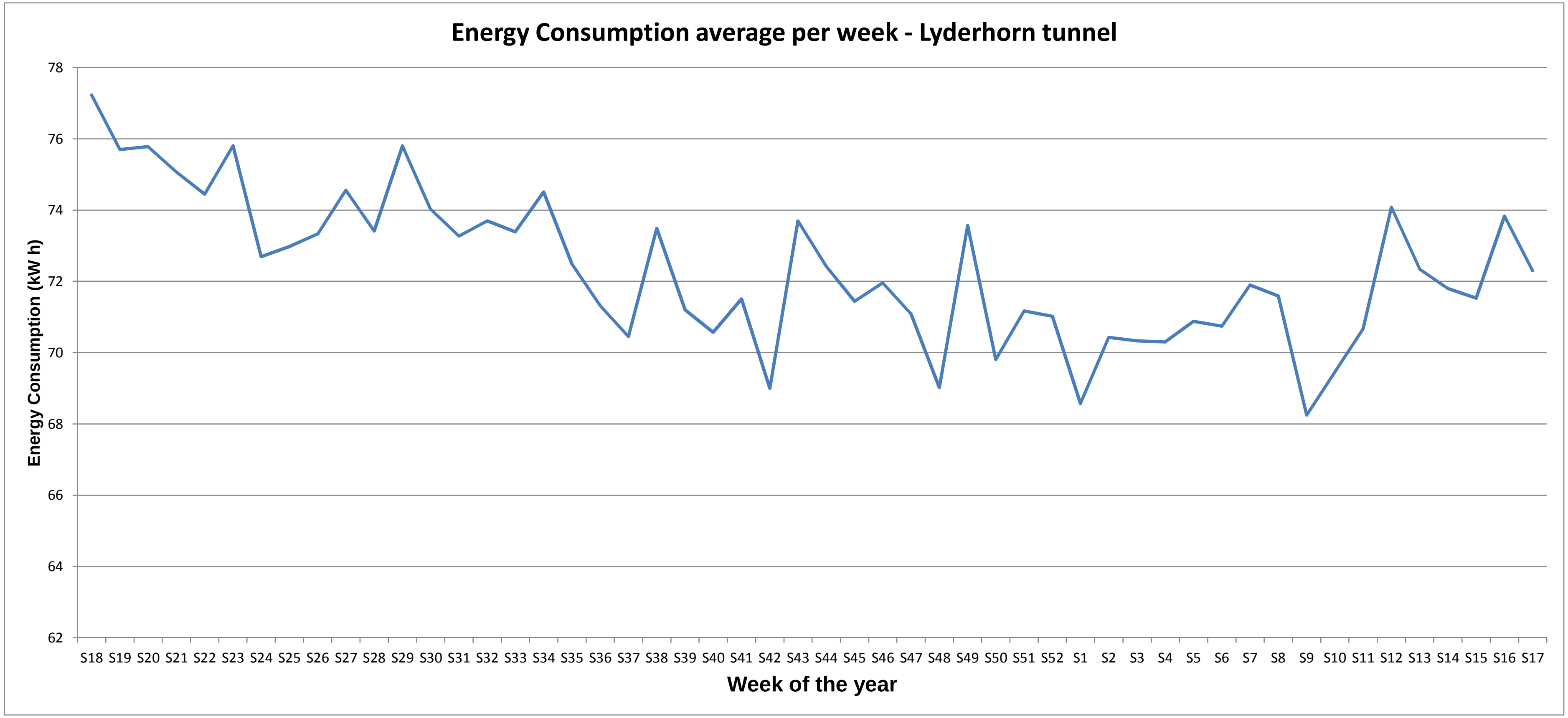

Energy Consumption average per week - Flenja tunnel
Energy Consumption (kW h)
0
20
40
60
80
100
120
140
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year


Energy Consumption average per week - Fløyfjell tunnel
Energy Consumption (kW h)
0
20
40
60
80
100
120
140
160
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year

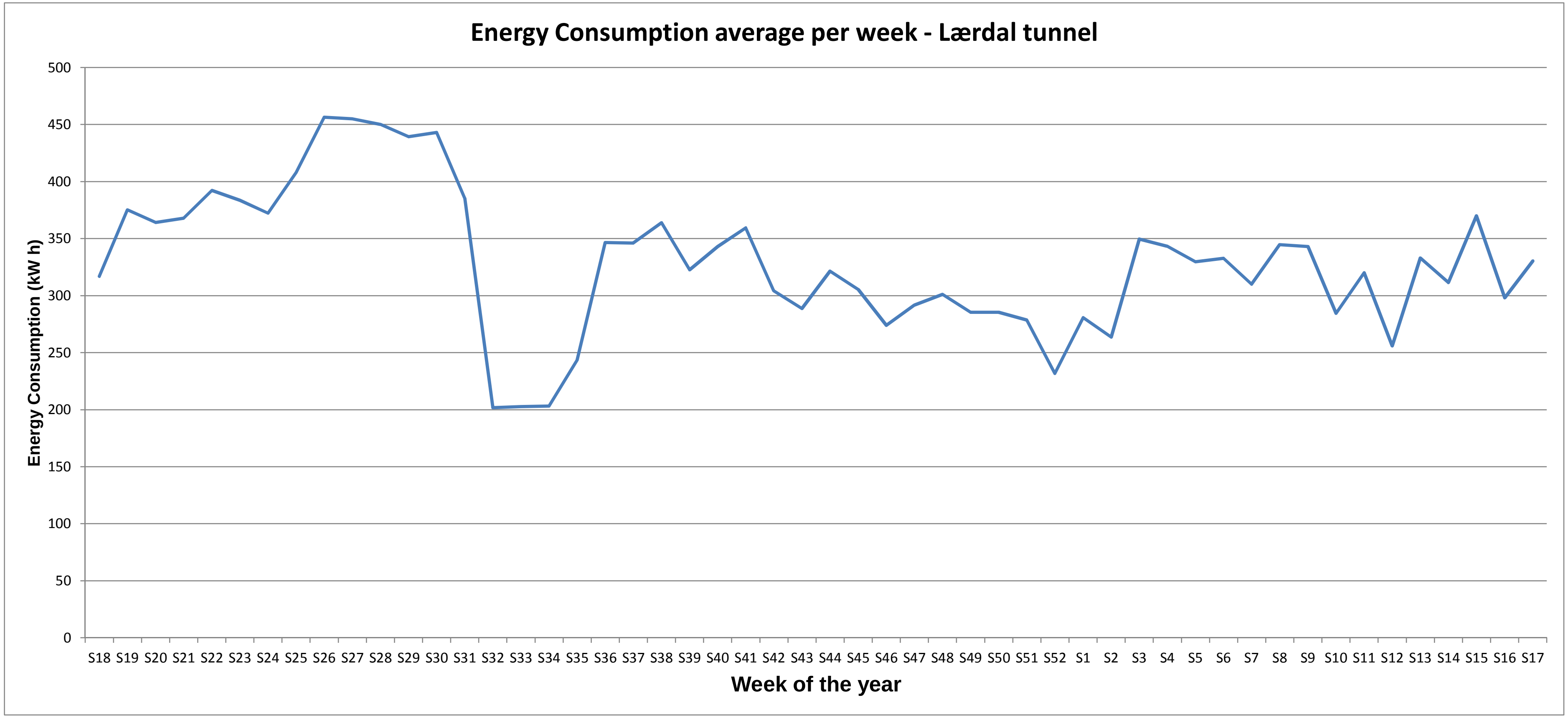


Energy Consumption average per week - Glasskar tunnel
Energy Consumption (kW h)
0
5
10
15
20
25
30
35
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year

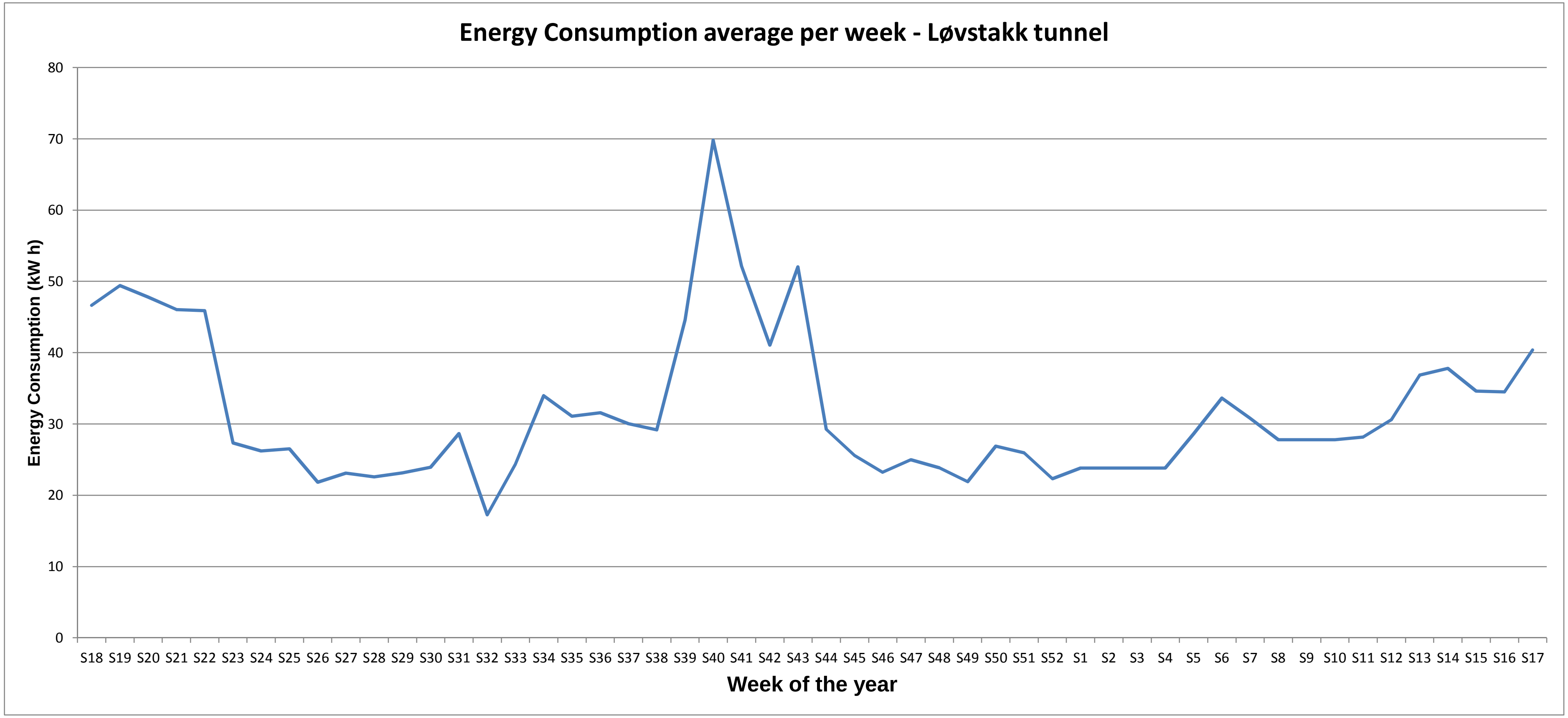

Energy Consumption average per week - Gudvanga tunnel
Energy Consumption (kW h)
0
100
200
300
400
500
600
700
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year

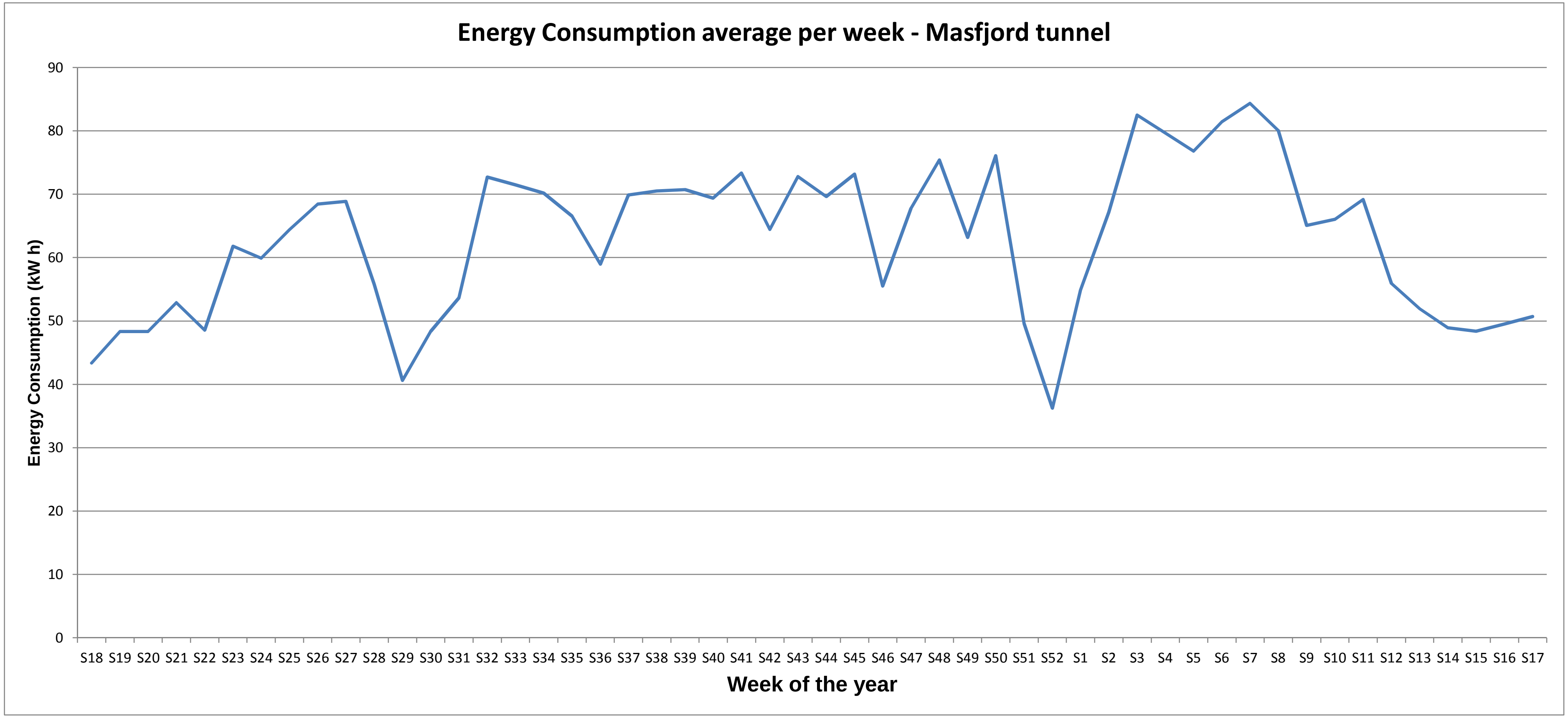


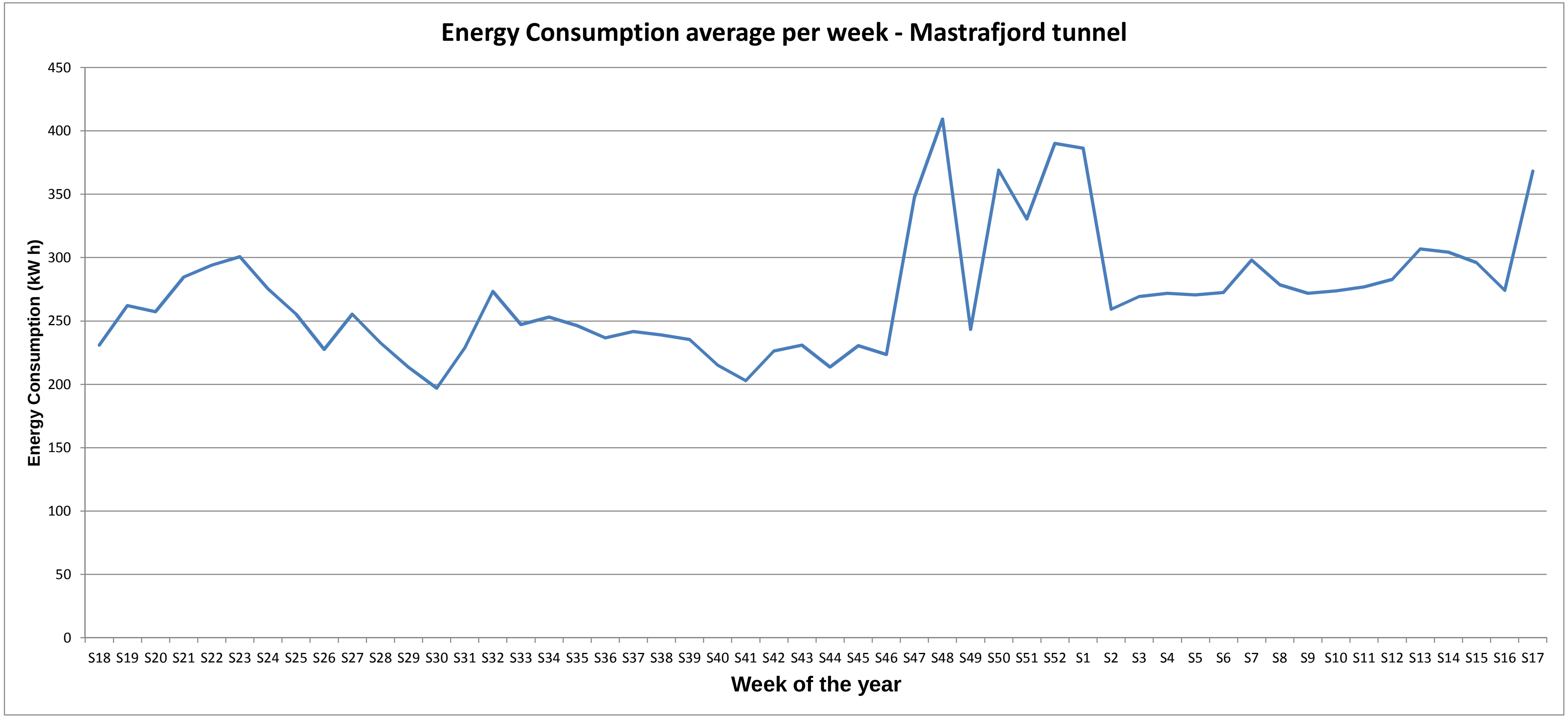
Energy Consumption average per week - Lyderhorn tunnel
Energy Consumption (kW h)
78
76
74
72
70
68
66
64
62
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year



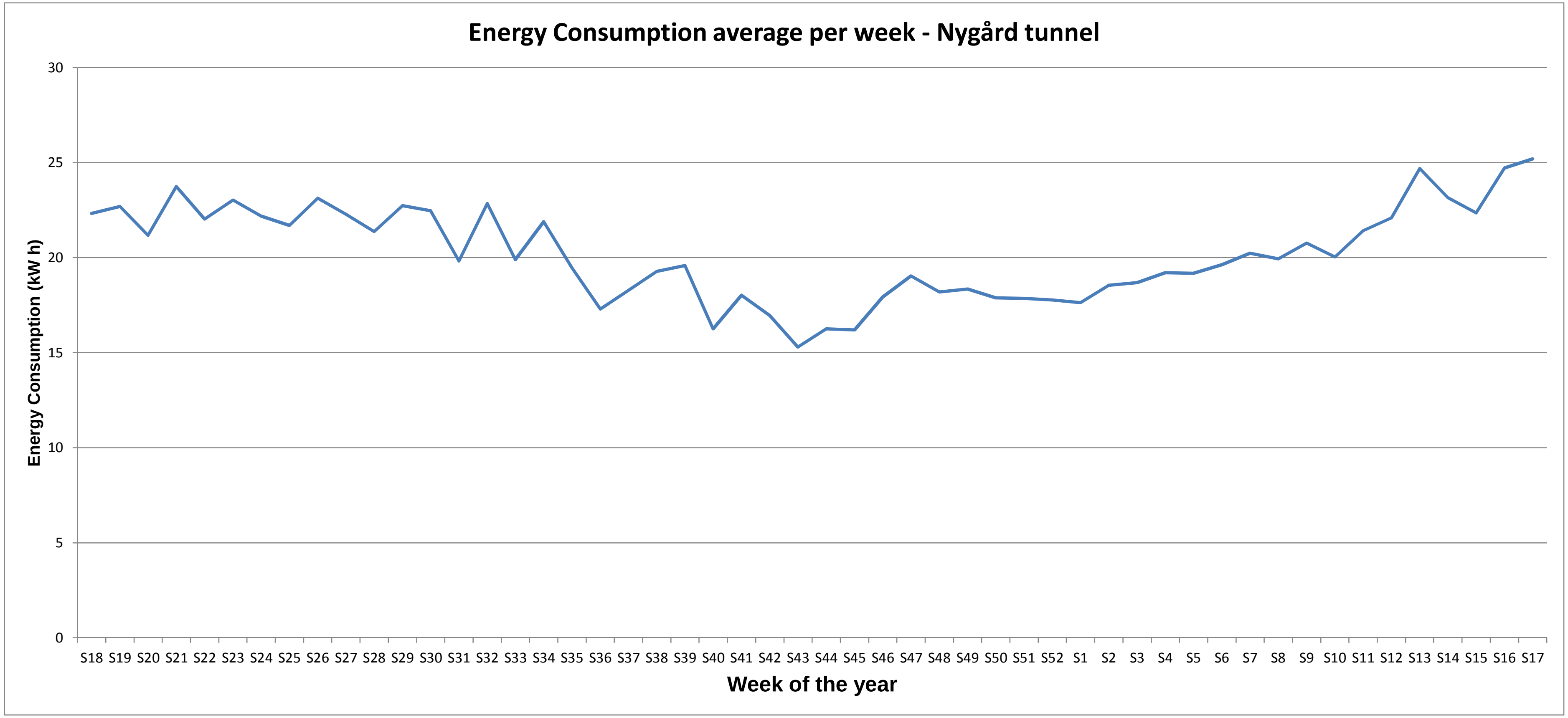
Energy Consumption average per week - Lærdal tunnel
Energy Consumption (kW h)
0
50
100
150
200
250
300
350
400
450
500
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year


Energy Consumption average per week - Løvstakk tunnel
Energy Consumption (kW h)
80
70
60
50
40
30
20
10
0
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year

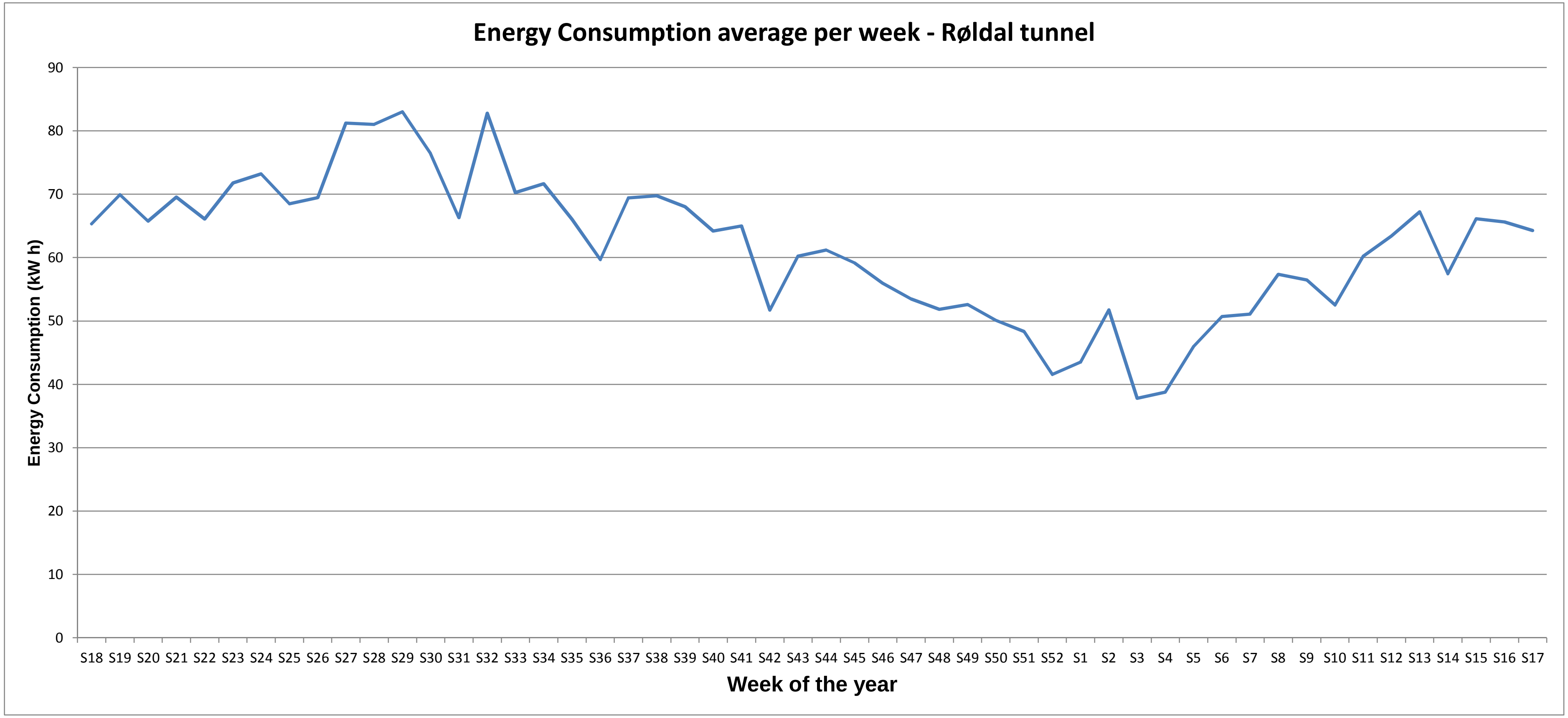

Energy Consumption average per week - Masfjord tunnel
Energy Consumption (kW h)
0
10
20
30
40
50
60
70
80
90
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year



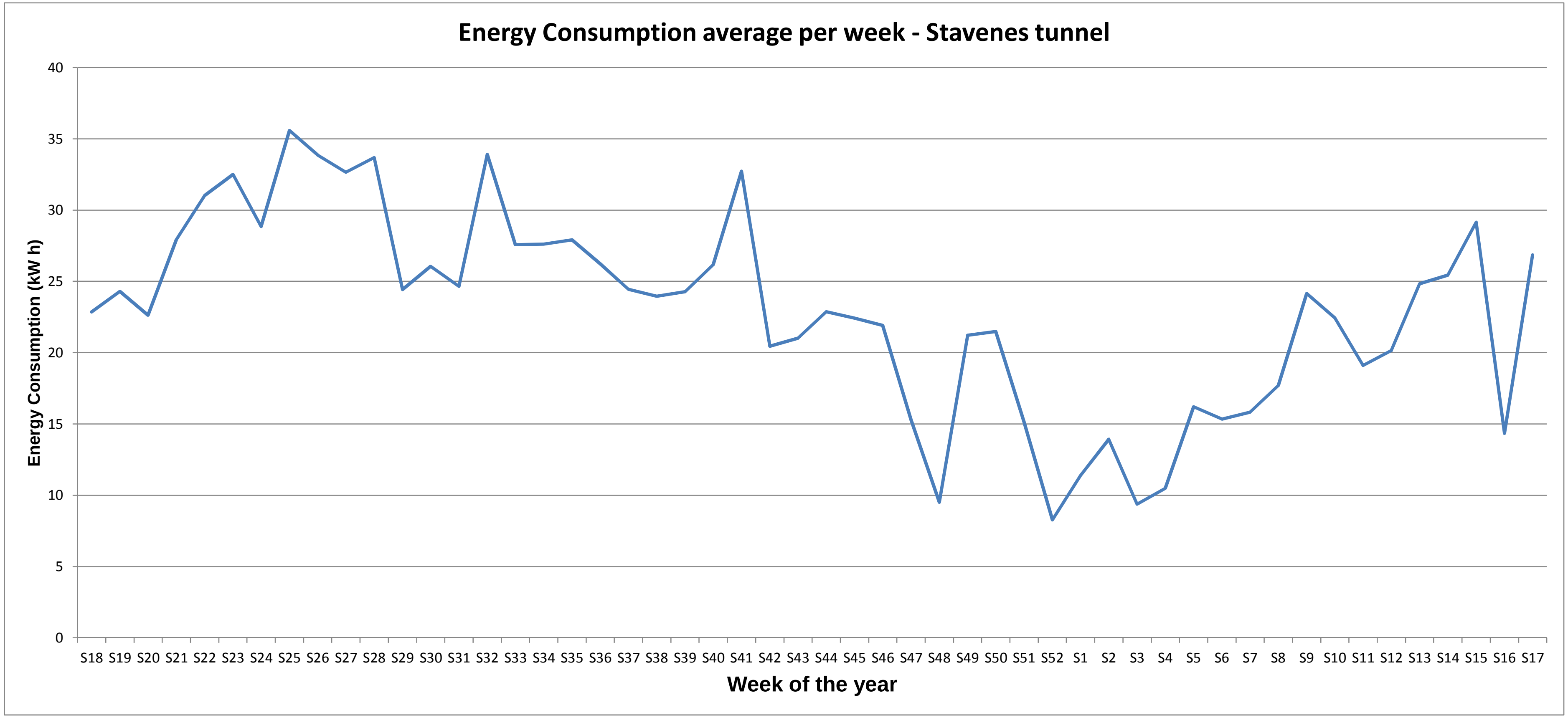
Energy Consumption average per week - Mastrafjord tunnel
Energy Consumption (kW h)
450
400
350
300
250
200
150
100
50
0
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year



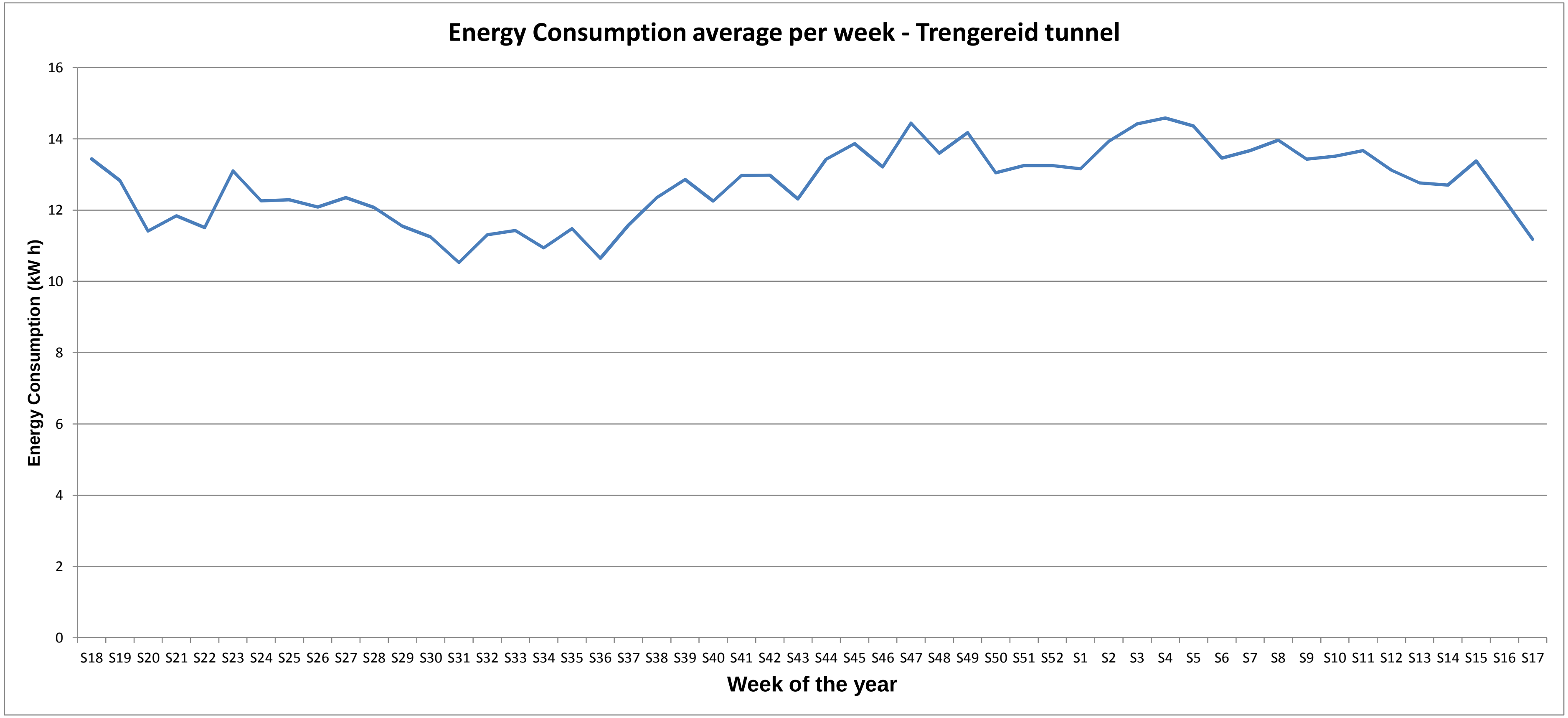
Energy Consumption average per week - Nygård tunnel
Energy Consumption (kW h)
30
25
20
15
10
5
0
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year

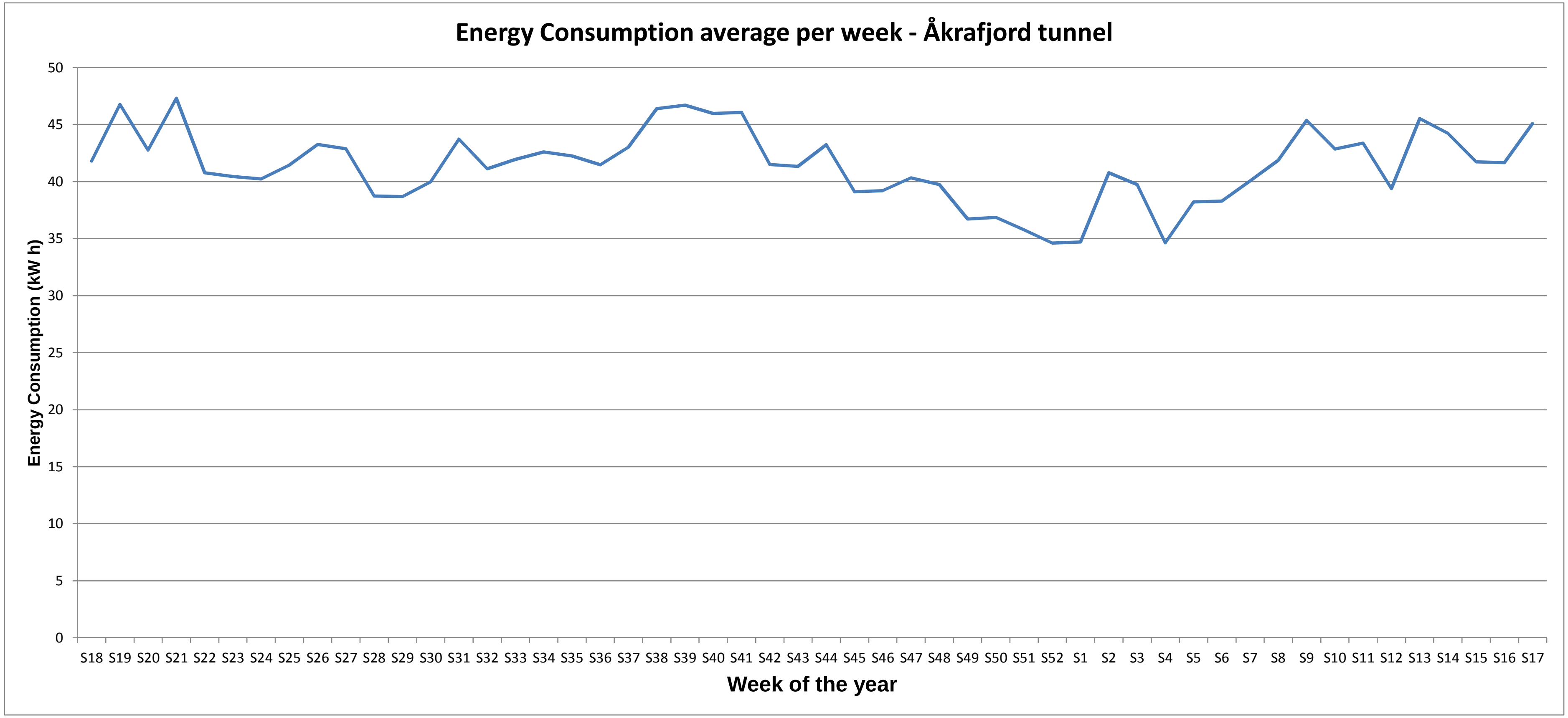


Energy Consumption average per week - Røldal tunnel
Energy Consumption (kW h)
0
10
20
30
40
50
60
70
80
90
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year

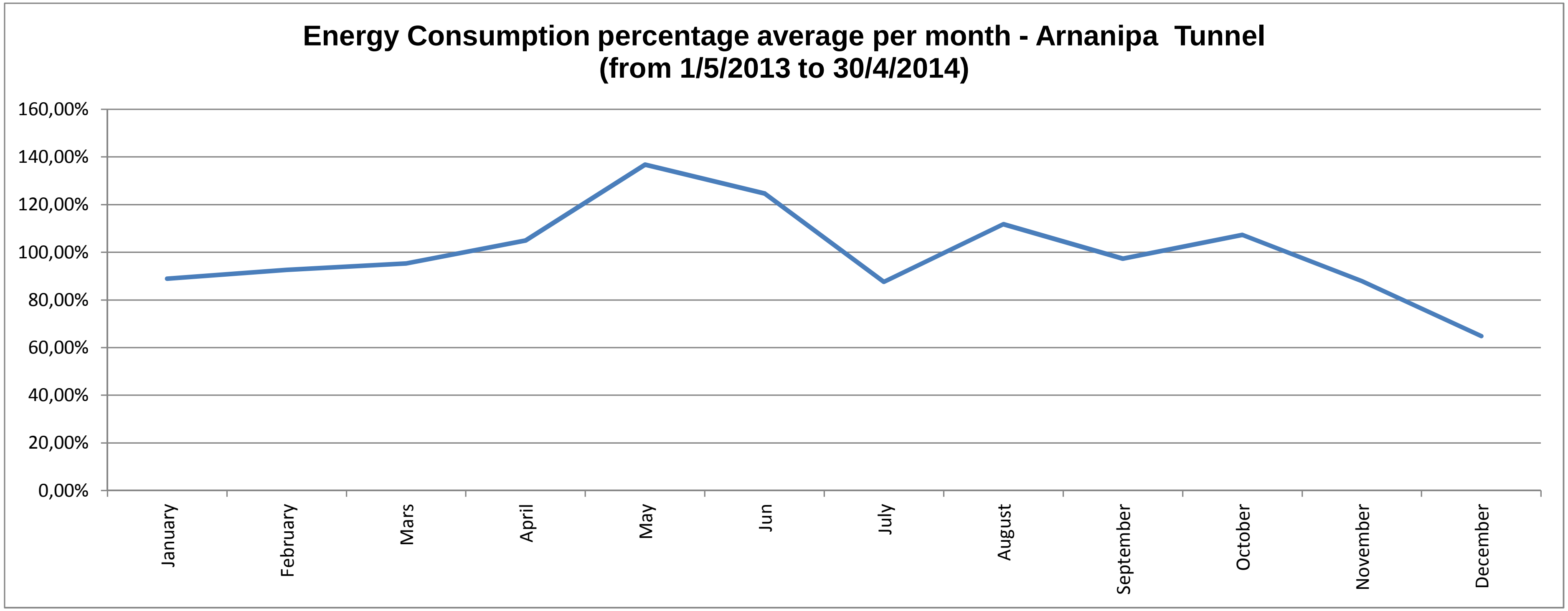


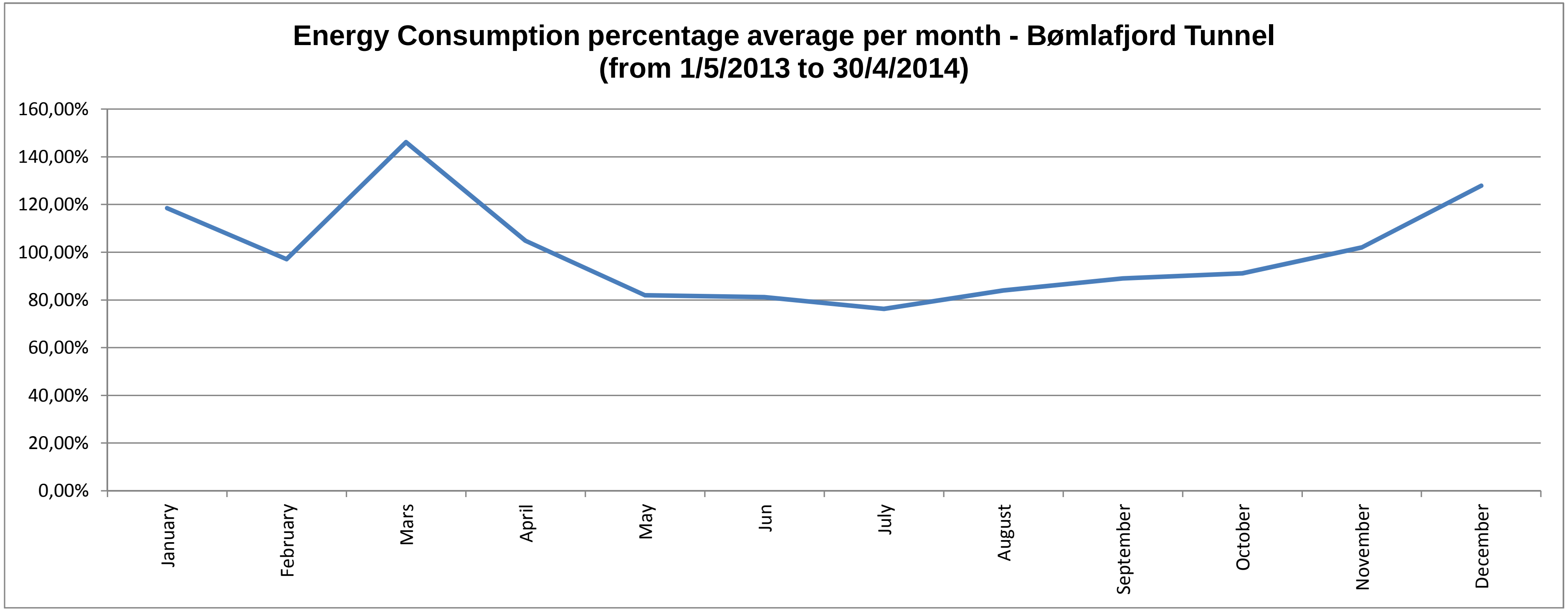
Energy Consumption average per week - Stavenes tunnel
Energy Consumption (kW h)
0
5
10
15
20
25
30
35
40
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year

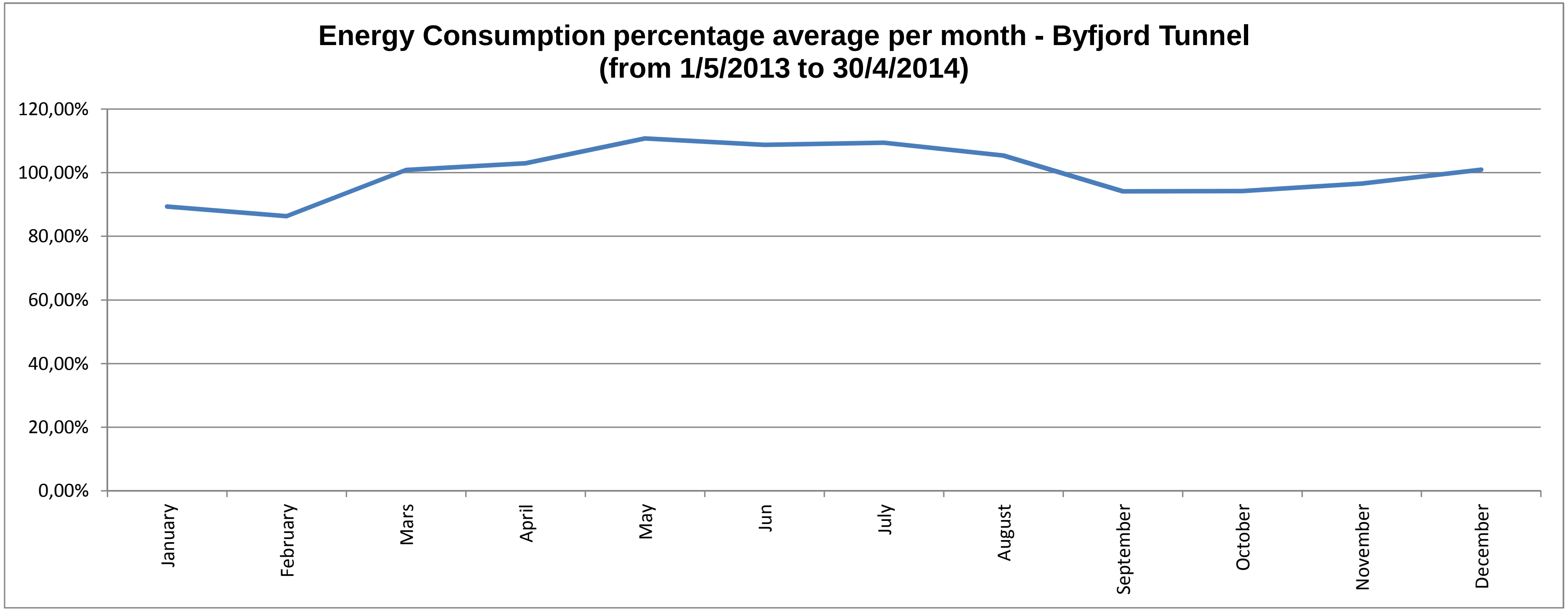

Energy Consumption average per week - Trengereid tunnel
Energy Consumption (kW h)
0
2
4
6
8
10
12
14
16
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year

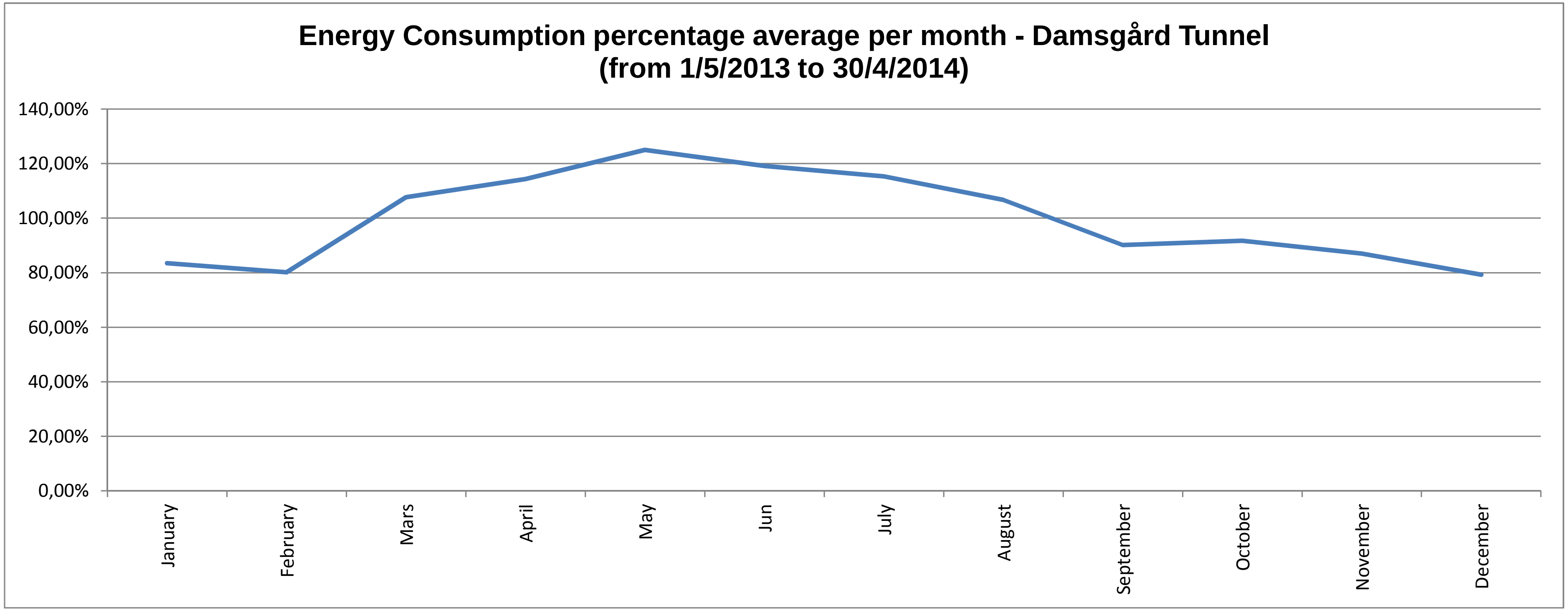

Energy Consumption average per week - Åkrafjord tunnel
Energy Consumption (kW h)
0
5
10
15
20
25
30
35
40
45
50
S18 S19 S20 S21 S22 S23 S24 S25 S26 S27 S28 S29 S30 S31 S32 S33 S34 S35 S36 S37 S38 S39 S40 S41 S42 S43 S44 S45 S46 S47 S48 S49 S50 S51 S52 S1 S2 S3 S4 S5 S6 S7 S8 S9 S10 S11 S12 S13 S14 S15 S16 S17
Week of the year

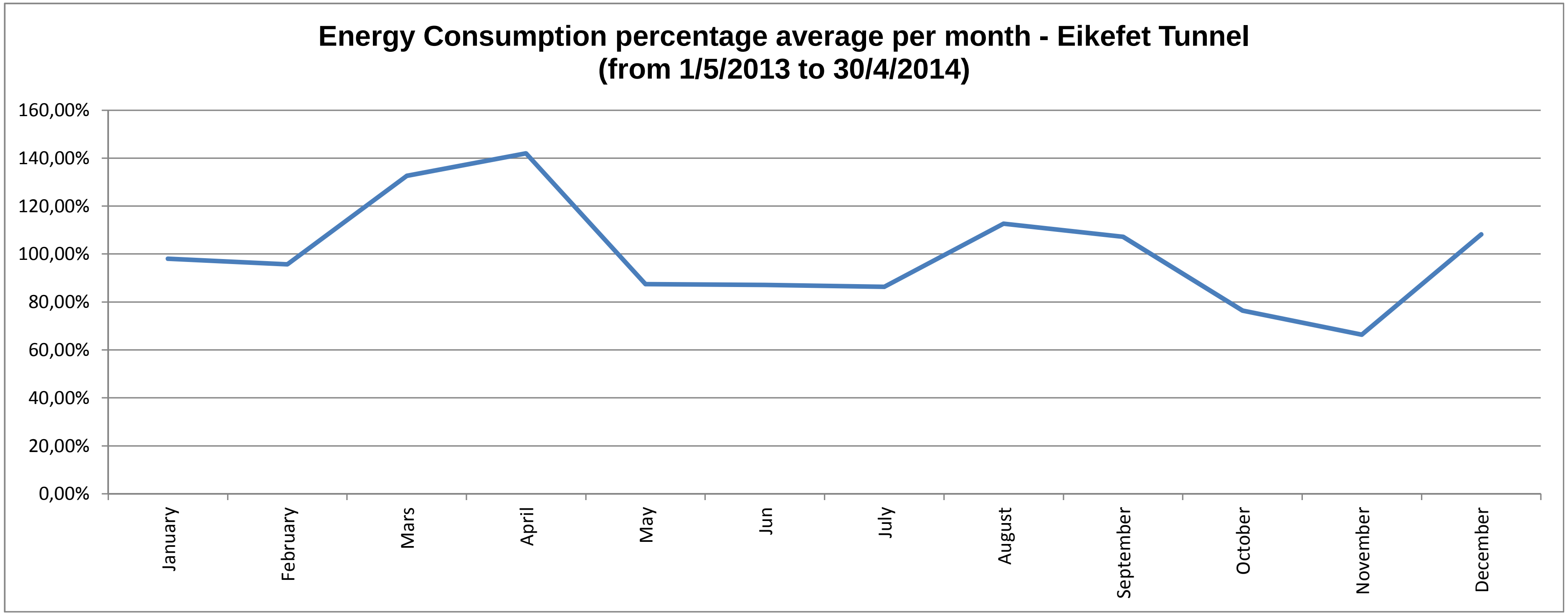
ANNEXE 3


Energy Consumption percentage average per month - Arnanipa Tunnel
(from 1/5/2013 to 30/4/2014)
160,00%
140,00%
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December

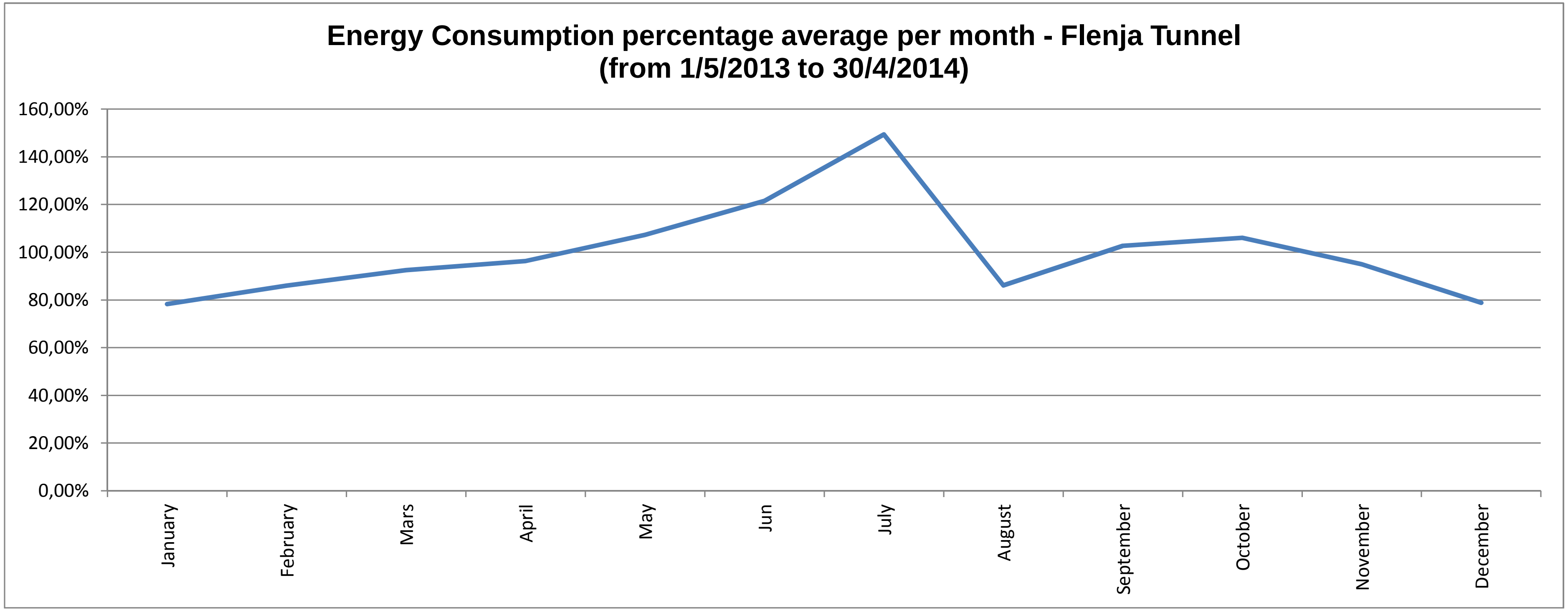

Energy Consumption percentage average per month - Bømlafjord Tunnel
(from 1/5/2013 to 30/4/2014)
160,00%
140,00%
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December


Energy Consumption percentage average per month - Byfjord Tunnel
(from 1/5/2013 to 30/4/2014)
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December

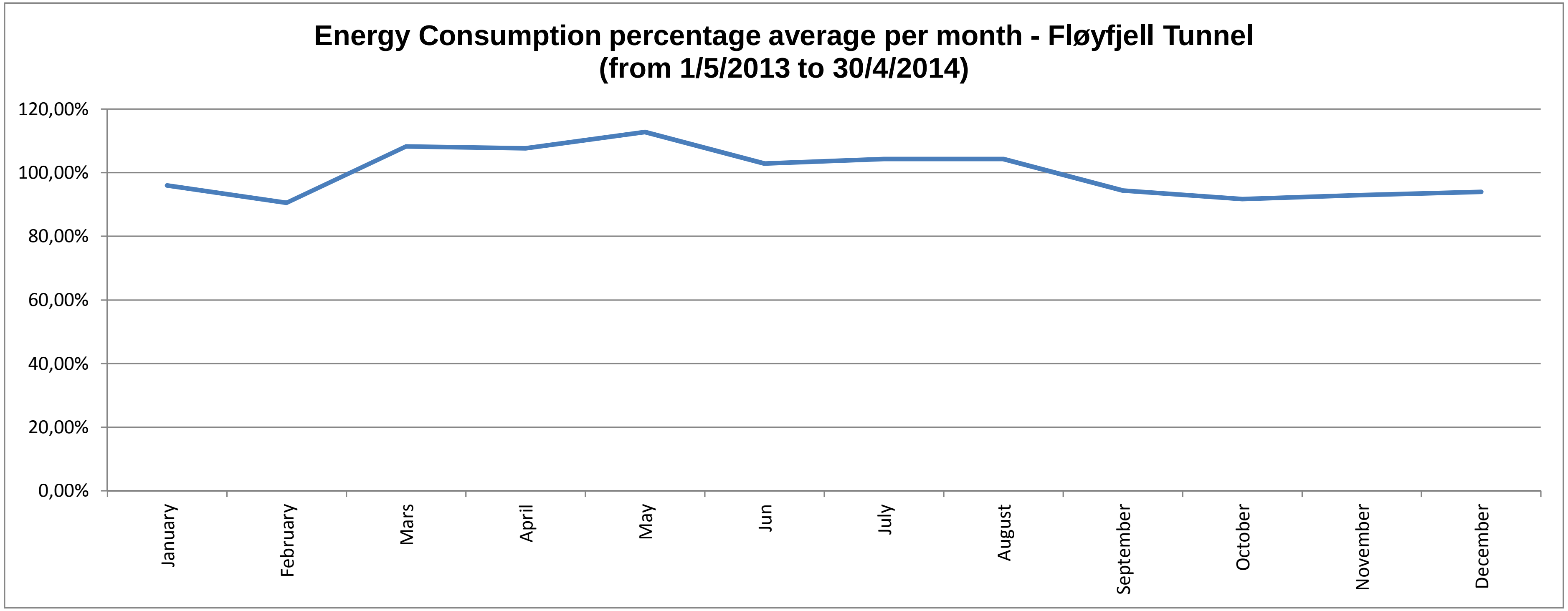

Energy Consumption percentage average per month - Damsgård Tunnel
(from 1/5/2013 to 30/4/2014)
140,00%
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December



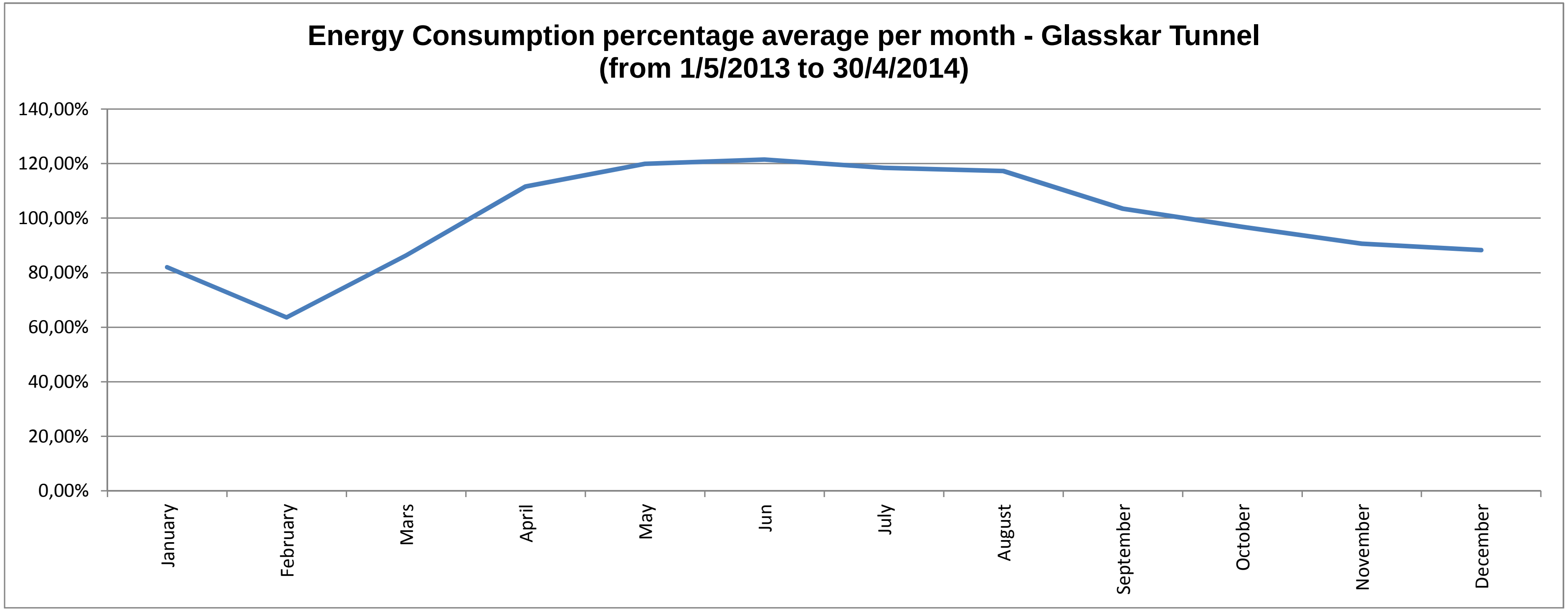
Energy Consumption percentage average per month - Eikefet Tunnel
(from 1/5/2013 to 30/4/2014)
160,00%
140,00%
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December

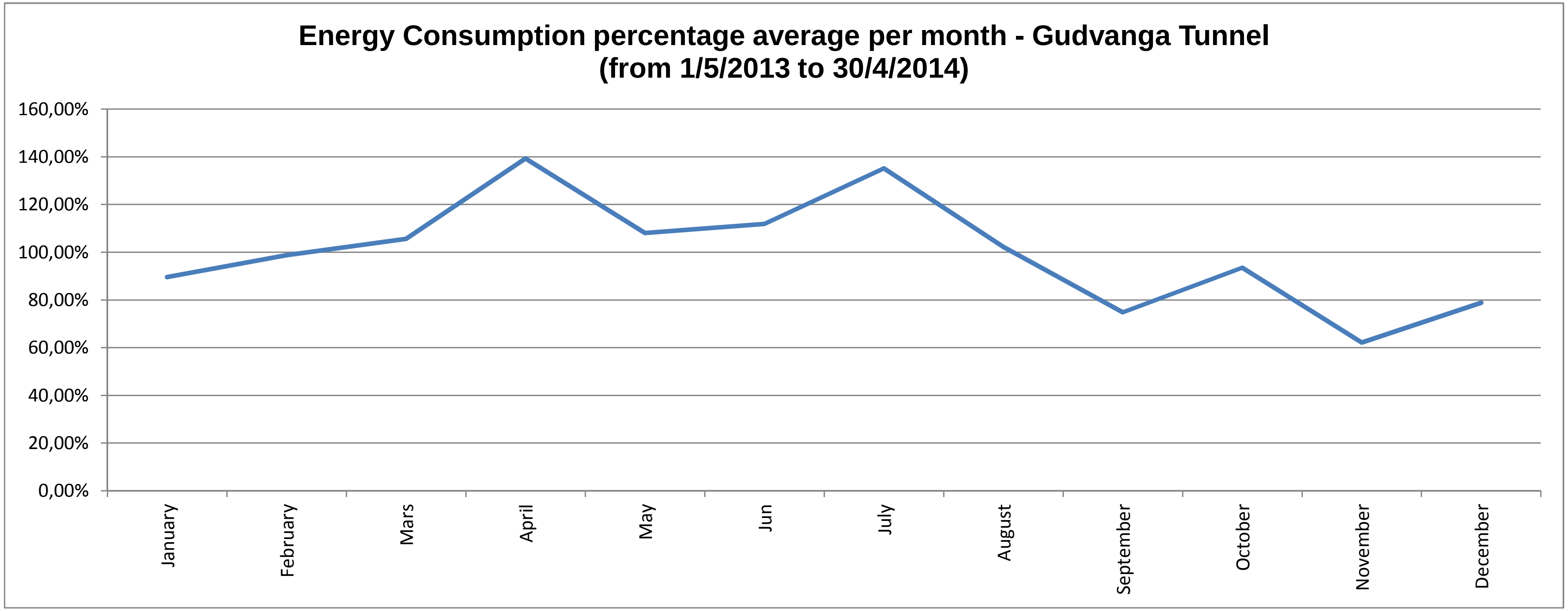


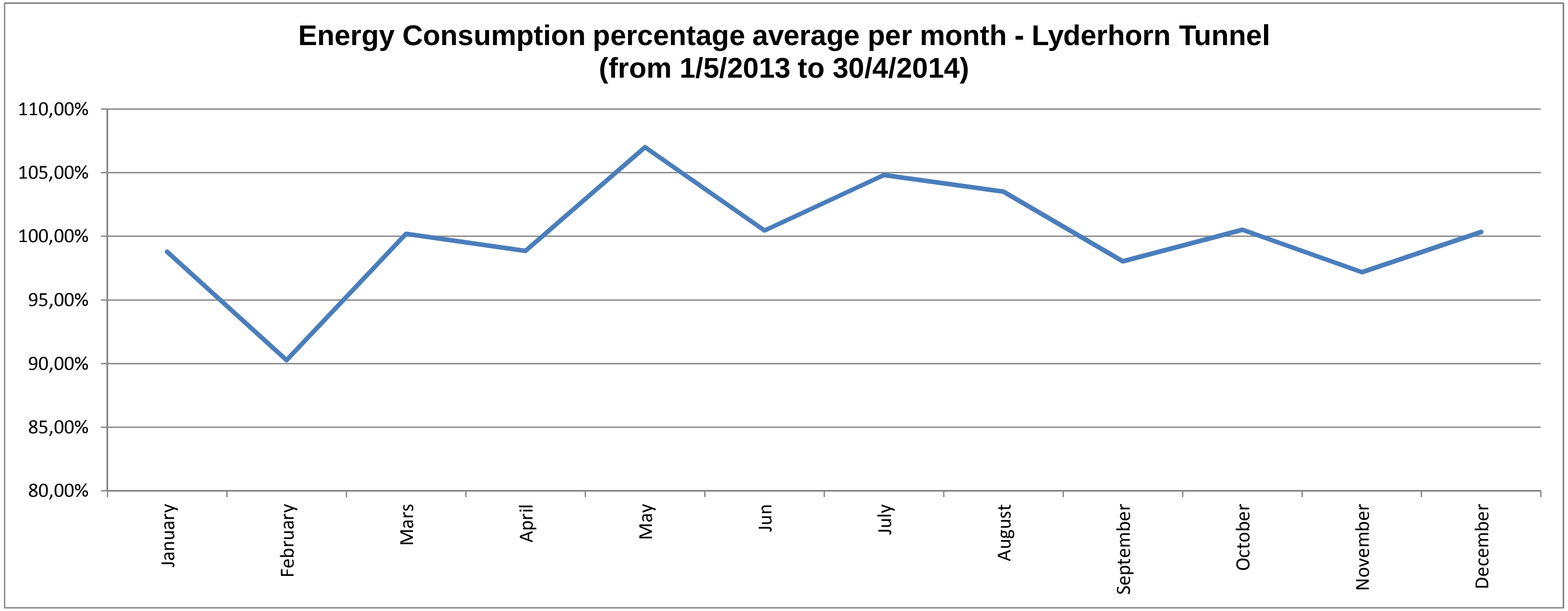
Energy Consumption percentage average per month - Flenja Tunnel
(from 1/5/2013 to 30/4/2014)
160,00%
140,00%
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December



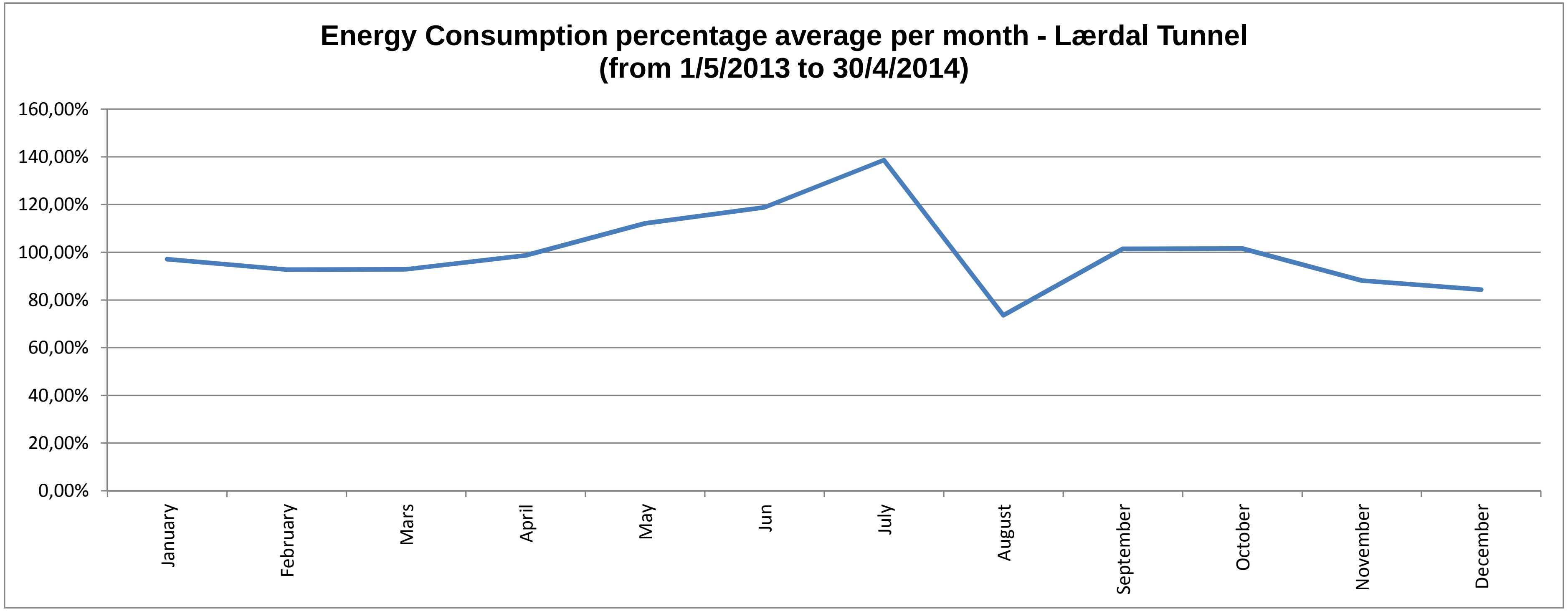
Energy Consumption percentage average per month - Fløyfjell Tunnel
(from 1/5/2013 to 30/4/2014)
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December


Energy Consumption percentage average per month - Glasskar Tunnel
(from 1/5/2013 to 30/4/2014)
140,00%
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December

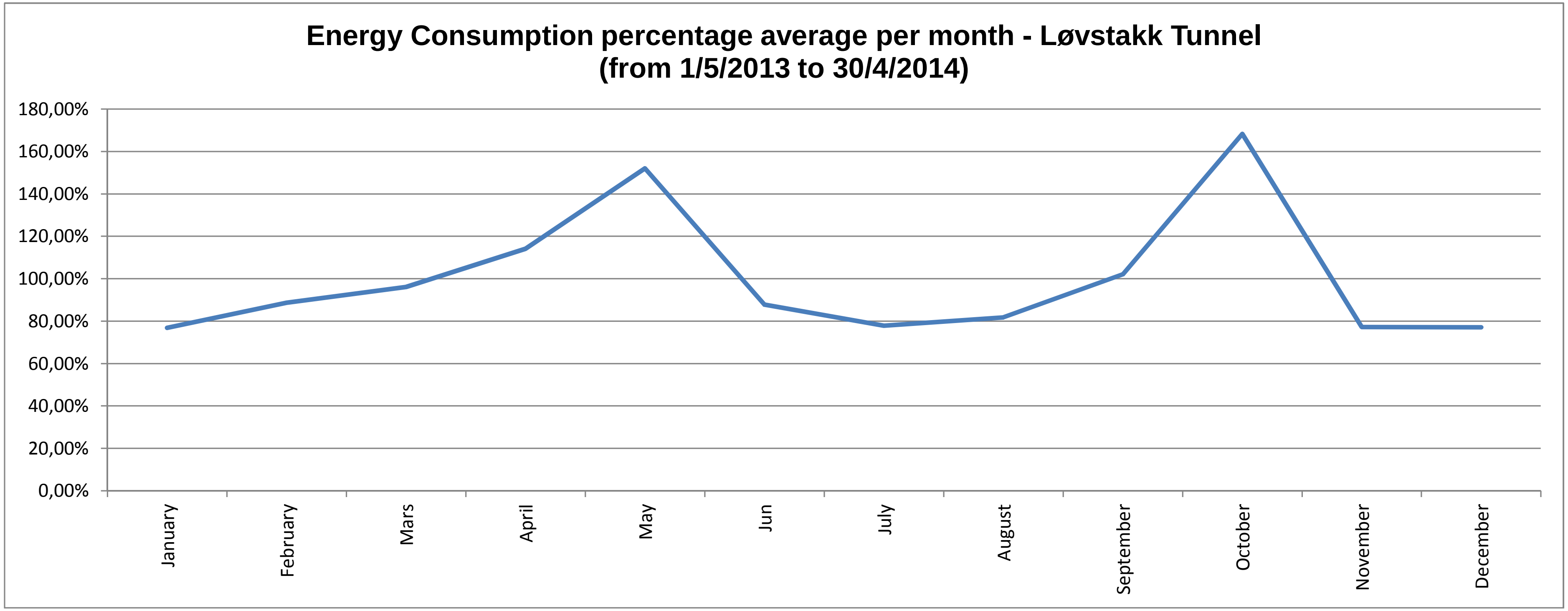

Energy Consumption percentage average per month - Gudvanga Tunnel
(from 1/5/2013 to 30/4/2014)
160,00%
140,00%
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December

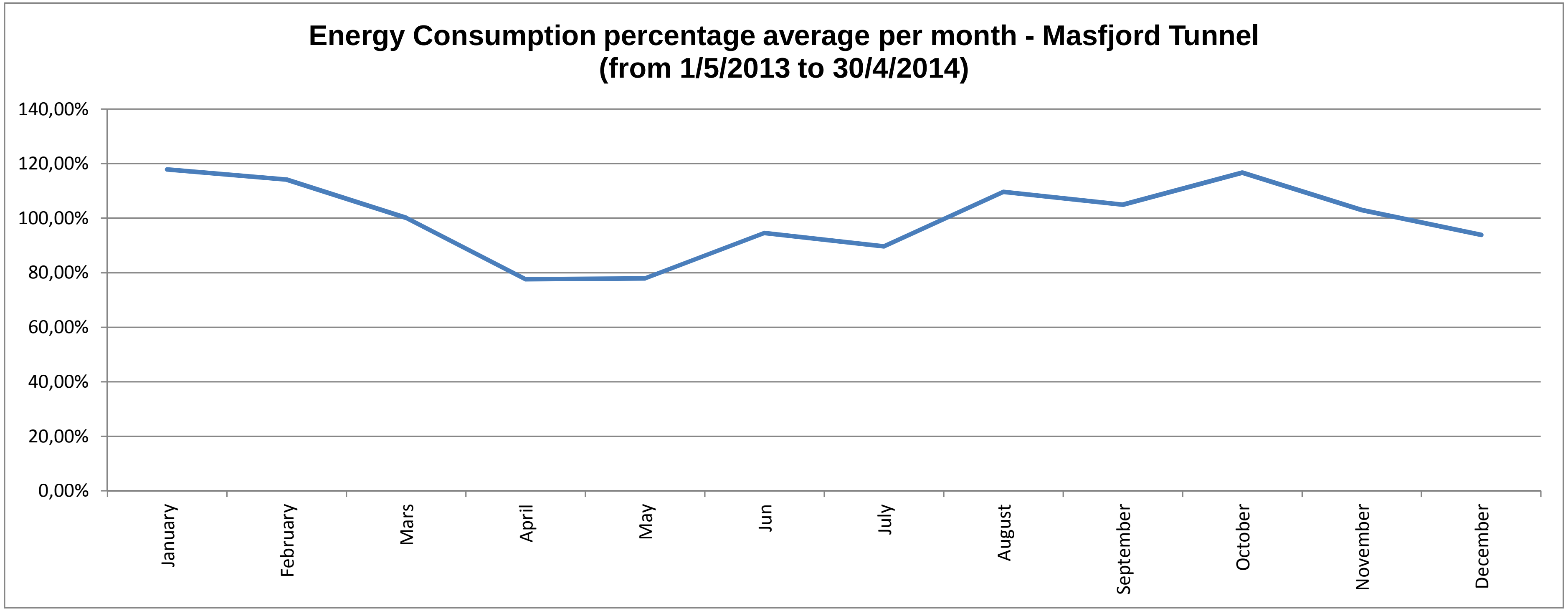


Energy Consumption percentage average per month - Lyderhorn Tunnel
(from 1/5/2013 to 30/4/2014)
110,00%
105,00%
100,00%
95,00%
90,00%
85,00%
80,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December

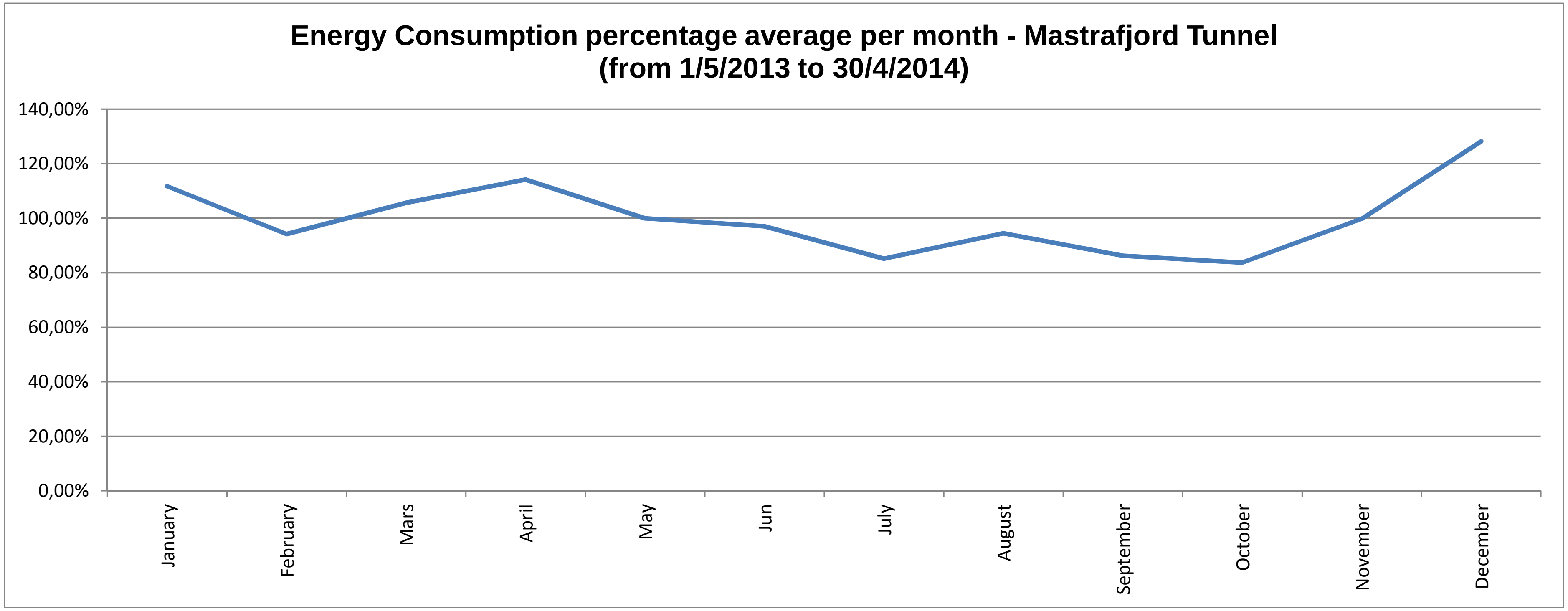


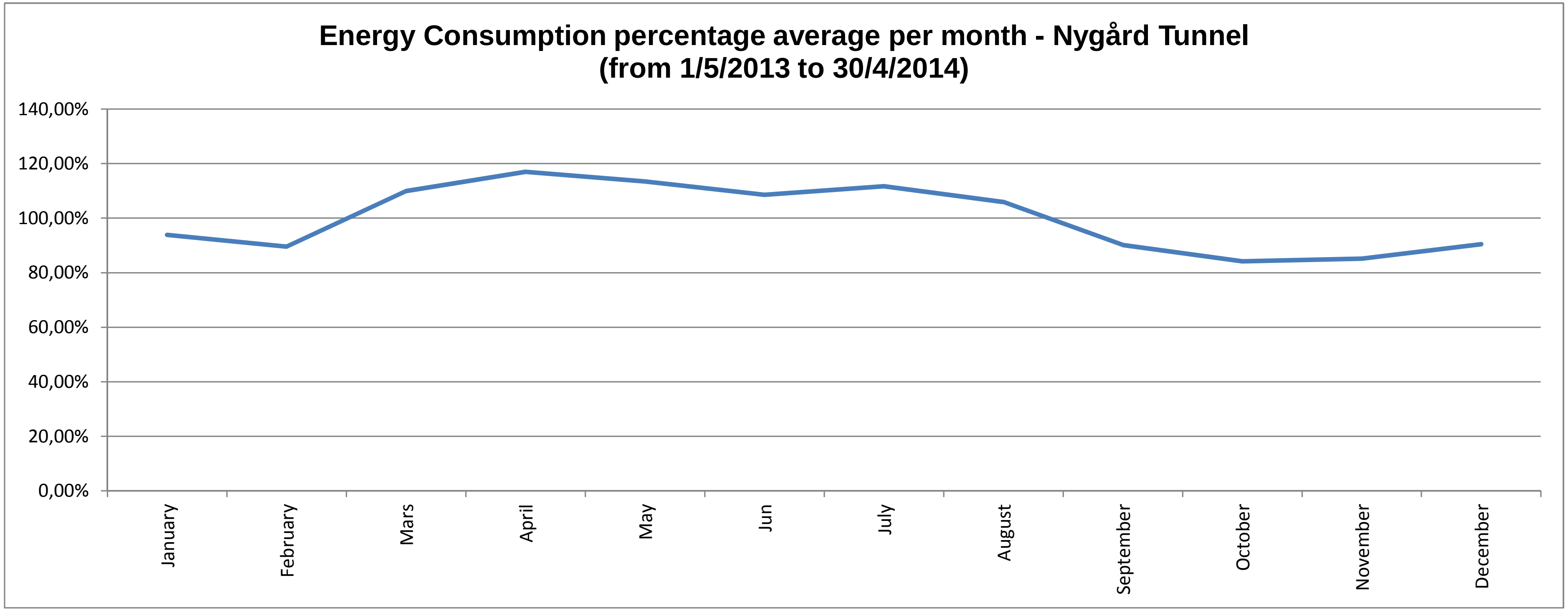
Energy Consumption percentage average per month - Lærdal Tunnel
(from 1/5/2013 to 30/4/2014)
160,00%
140,00%
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December

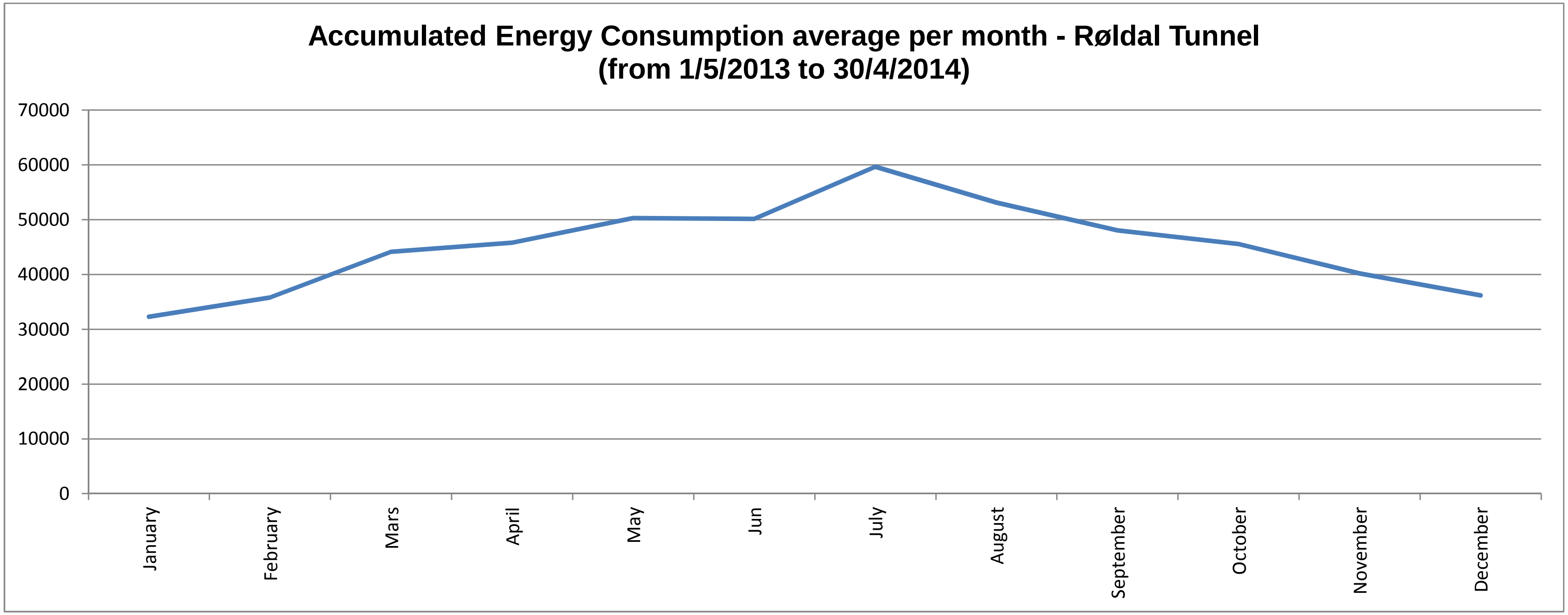

Energy Consumption percentage average per month - Løvstakk Tunnel
(from 1/5/2013 to 30/4/2014)
180,00%
160,00%
140,00%
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December

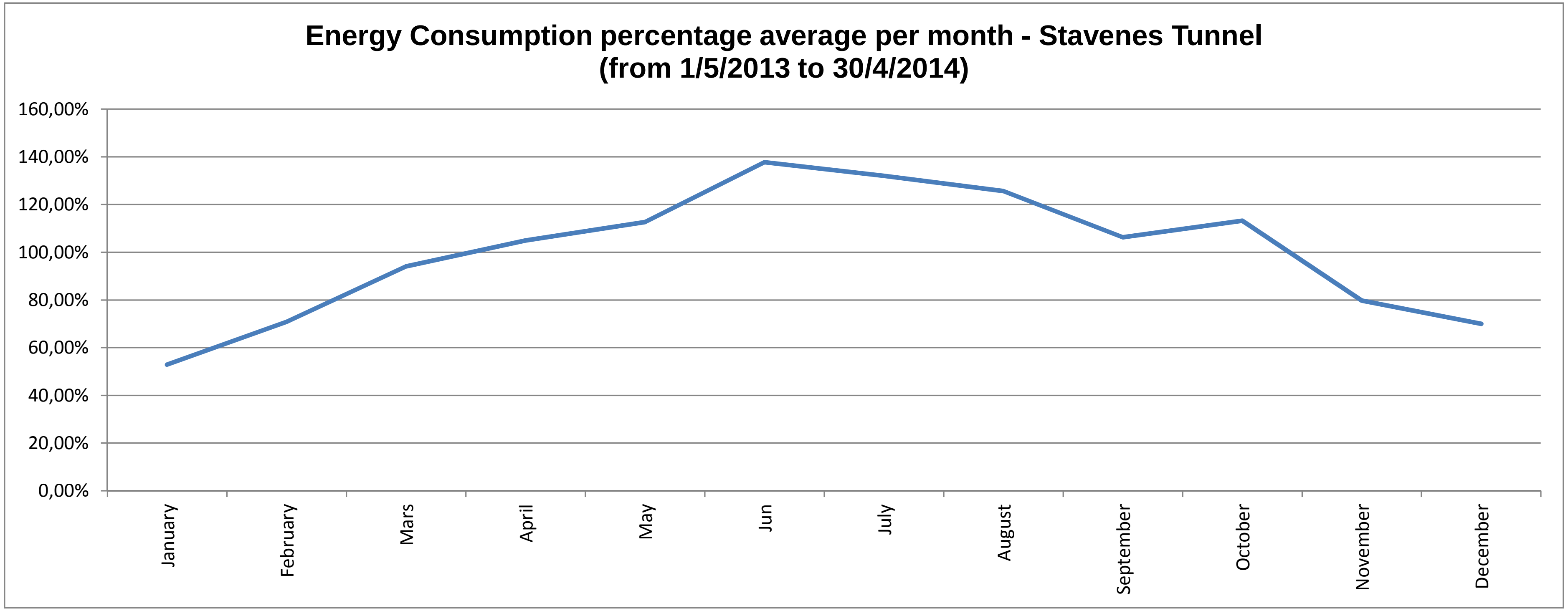


Energy Consumption percentage average per month - Masfjord Tunnel
(from 1/5/2013 to 30/4/2014)
140,00%
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December

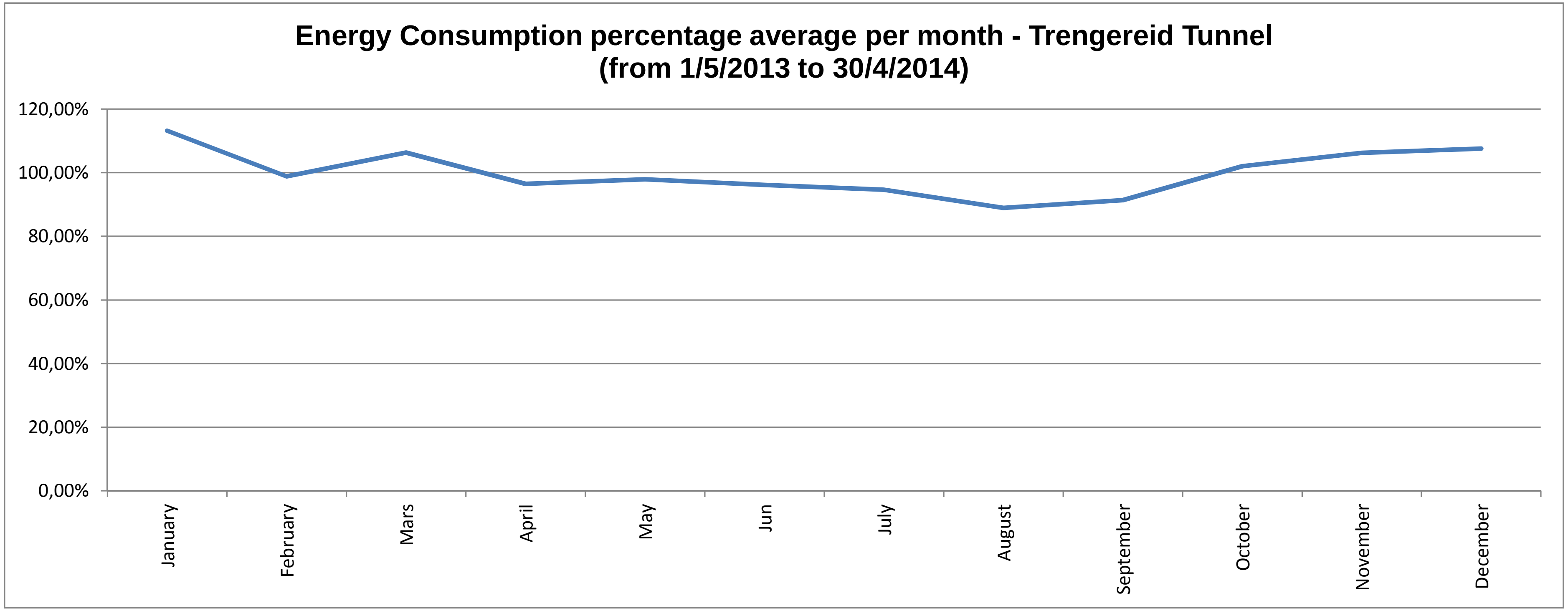

Energy Consumption percentage average per month - Mastrafjord Tunnel
(from 1/5/2013 to 30/4/2014)
140,00%
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December

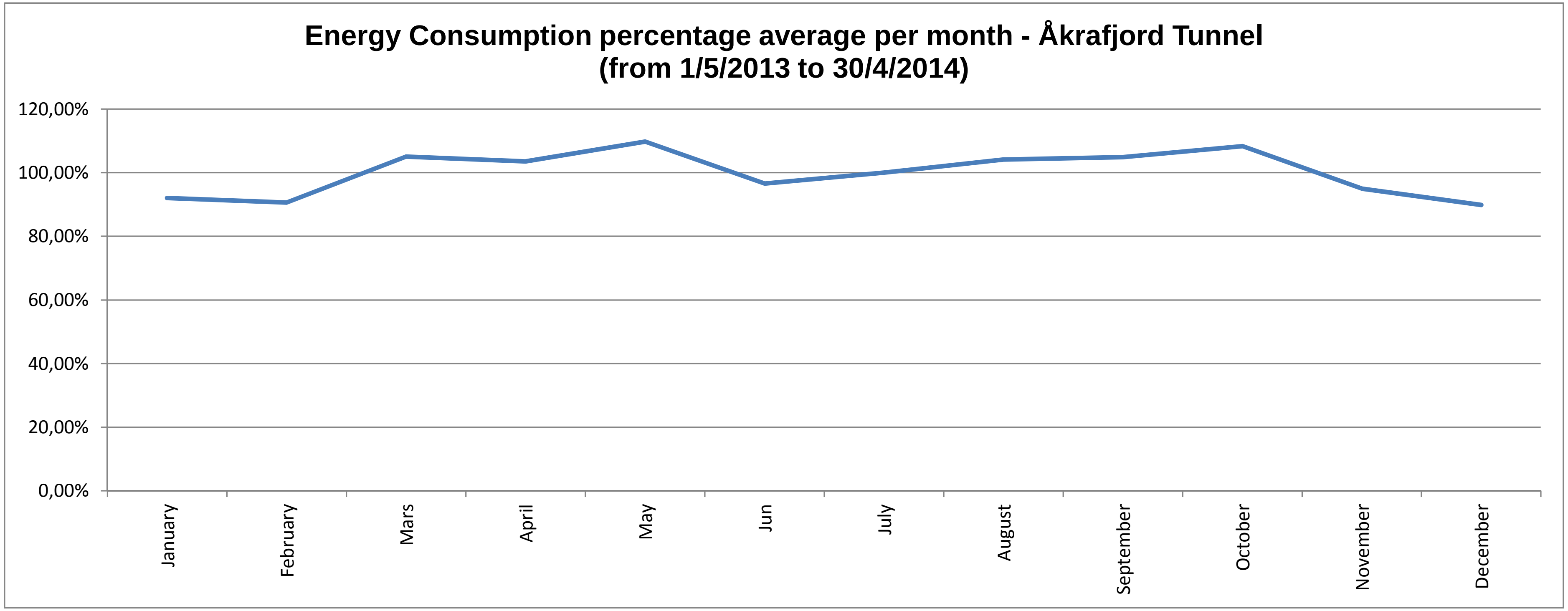

Energy Consumption percentage average per month - Nygård Tunnel
(from 1/5/2013 to 30/4/2014)
140,00%
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December


Accumulated Energy Consumption average per month - Røldal Tunnel
(from 1/5/2013 to 30/4/2014)
70000
60000
50000
40000
30000
20000
10000
0
January
February
Mars
April
May
Jun
July
August
September
October
November
December



Energy Consumption percentage average per month - Stavenes Tunnel
(from 1/5/2013 to 30/4/2014)
160,00%
140,00%
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December


Energy Consumption percentage average per month - Trengereid Tunnel
(from 1/5/2013 to 30/4/2014)
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December


Energy Consumption percentage average per month - Åkrafjord Tunnel
(from 1/5/2013 to 30/4/2014)
120,00%
100,00%
80,00%
60,00%
40,00%
20,00%
0,00%
January
February
Mars
April
May
Jun
July
August
September
October
November
December

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