

Feature Engineering and Modelling

1. Import packages
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-

1. Import packages

```
In [1]: import warnings
warnings.filterwarnings("ignore", category=FutureWarning)
```

```
In [2]: import pandas as pd
import numpy as np
import seaborn as sns
from datetime import datetime
import matplotlib.pyplot as plt

# Shows plots in jupyter notebook
%matplotlib inline

# Set plot style
sns.set(color_codes=True)
```

2. Load data

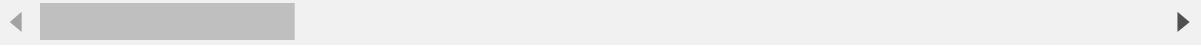
```
In [3]: df = pd.read_csv('./clean_data_after_eda.csv')
df["date_activ"] = pd.to_datetime(df["date_activ"], format='%Y-%m-%d')
df["date_end"] = pd.to_datetime(df["date_end"], format='%Y-%m-%d')
df["date_modif_prod"] = pd.to_datetime(df["date_modif_prod"], format='%Y-%m-%d')
df["date_renewal"] = pd.to_datetime(df["date_renewal"], format='%Y-%m-%d')
```

In [4]: `df.head(3)`

Out[4]:

			id	channel_sales	cons_12m	cons_gas_12m
0	24011ae4ebbe3035111d65fa7c15bc57	foosdfpkusacimwkcsothicdxkicaua		0	54946	
1	d29c2c54acc38ff3c0614d0a653813dd		MISSING	4660		
2	764c75f661154dac3a6c254cd082ea7d	foosdfpkusacimwkcsothicdxkicaua		544		

3 rows × 44 columns



3. Feature engineering

Difference between off-peak prices in December and preceding January

Below is the code created by your colleague to calculate the feature described above. Use this code to re-create this feature and then think about ways to build on this feature to create features with predictive power.

In [5]: `price_df = pd.read_csv('price_data.csv')
price_df["price_date"] = pd.to_datetime(price_df["price_date"], format='%Y-%m-%d')
price_df.head()`

Out[5]:

		id	price_date	price_off_peak_var	price_peak_var	price_mid
0	038af19179925da21a25619c5a24b745		2015-01-01	0.151367	0.0	
1	038af19179925da21a25619c5a24b745		2015-02-01	0.151367	0.0	
2	038af19179925da21a25619c5a24b745		2015-03-01	0.151367	0.0	
3	038af19179925da21a25619c5a24b745		2015-04-01	0.149626	0.0	
4	038af19179925da21a25619c5a24b745		2015-05-01	0.149626	0.0	



```
In [6]: # Group off-peak prices by companies and month
monthly_price_by_id = price_df.groupby(['id', 'price_date']).agg({'price_off_peak_var': 'mean'}).reset_index()

# Get january and december prices
jan_prices = monthly_price_by_id.groupby('id').first().reset_index()
dec_prices = monthly_price_by_id.groupby('id').last().reset_index()

# Calculate the difference
diff = pd.merge(dec_prices.rename(columns={'price_off_peak_var': 'dec_1', 'price_date': 'dec_1_date'}), jan_prices, on='id')
diff['offpeak_diff_dec_january_energy'] = diff['dec_1'] - diff['price_off_peak_var']
diff['offpeak_diff_dec_january_power'] = diff['dec_1'] - diff['price_off_peak_var']
diff = diff[['id', 'offpeak_diff_dec_january_energy', 'offpeak_diff_dec_january_power']]
diff.head()
```

```
Out[6]:
```

		id	offpeak_diff_dec_january_energy	offpeak_diff_dec_january_power
0	0002203ffbb812588b632b9e628cc38d		-0.006192	0.
1	0004351ebdd665e6ee664792efc4fd13		-0.004104	0.
2	0010bcc39e42b3c2131ed2ce55246e3c		0.050443	1.
3	0010ee3855fddea87602a5b7aba8e42de		-0.010018	0.
4	00114d74e963e47177db89bc70108537		-0.003994	-0.

```
In [7]: df = pd.merge(df, diff, on='id')
df.head()
```

```
Out[7]:
```

	id	channel_sales	cons_12m	cons_gas_1
0	24011ae4ebbe3035111d65fa7c15bc57	foosdfpkusacimwkcsothicdxkicaua	0	54!
1	d29c2c54acc38ff3c0614d0a653813dd	MISSING	4660	
2	764c75f661154dac3a6c254cd082ea7d	foosdfpkusacimwkcsothicdxkicaua	544	
3	bba03439a292a1e166f80264c16191cb	lmkebamcaclubfxadilmueccxoimlema	1584	
4	149d57cf92fc41cf94415803a877cb4b	MISSING	4425	

5 rows × 46 columns

Average price changes across periods

We can now enhance the feature that our colleague made by calculating the average price changes across individual periods, instead of the entire year.

```
In [8]: # Aggregate average prices per period by company
mean_prices = price_df.groupby(['id']).agg({
    'price_off_peak_var': 'mean',
    'price_peak_var': 'mean',
    'price_mid_peak_var': 'mean',
    'price_off_peak_fix': 'mean',
    'price_peak_fix': 'mean',
    'price_mid_peak_fix': 'mean'
}).reset_index()
```

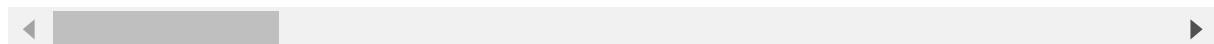
```
In [9]: # Calculate the mean difference between consecutive periods
mean_prices['off_peak_peak_var_mean_diff'] = mean_prices['price_off_peak_var'] - n
mean_prices['peak_mid_peak_var_mean_diff'] = mean_prices['price_peak_var'] - n
mean_prices['off_peak_mid_peak_var_mean_diff'] = mean_prices['price_off_peak_v'] - n
mean_prices['off_peak_peak_fix_mean_diff'] = mean_prices['price_off_peak_fix'] - n
mean_prices['peak_mid_peak_fix_mean_diff'] = mean_prices['price_peak_fix'] - n
mean_prices['off_peak_mid_peak_fix_mean_diff'] = mean_prices['price_off_peak_f'] - n
```

```
In [10]: columns = [
    'id',
    'off_peak_peak_var_mean_diff',
    'peak_mid_peak_var_mean_diff',
    'off_peak_mid_peak_var_mean_diff',
    'off_peak_peak_fix_mean_diff',
    'peak_mid_peak_fix_mean_diff',
    'off_peak_mid_peak_fix_mean_diff'
]
df = pd.merge(df, mean_prices[columns], on='id')
df.head()
```

Out[10]:

	id	channel_sales	cons_12m	cons_gas_1
0	24011ae4ebbe3035111d65fa7c15bc57	foosdfpkusacimwkcsothicdxkicaua	0	541
1	d29c2c54acc38ff3c0614d0a653813dd		MISSING	4660
2	764c75f661154dac3a6c254cd082ea7d	foosdfpkusacimwkcsothicdxkicaua	544	
3	bba03439a292a1e166f80264c16191cb	lmkebamcaaclubfxadlmueccxoimlema	1584	
4	149d57cf92fc41cf94415803a877cb4b		MISSING	4425

5 rows × 52 columns



This feature may be useful because it adds more granularity to the existing feature that my colleague found to be useful. Instead of looking at differences across an entire year, we have now created features that look at mean average price differences across different time periods

Max price changes across periods and months

Another way we can enhance the feature from our colleague is to look at the maximum change in prices across periods and months.

```
In [11]: # Aggregate average prices per period by company
mean_prices_by_month = price_df.groupby(['id', 'price_date']).agg({
    'price_off_peak_var': 'mean',
    'price_peak_var': 'mean',
    'price_mid_peak_var': 'mean',
    'price_off_peak_fix': 'mean',
    'price_peak_fix': 'mean',
    'price_mid_peak_fix': 'mean'
}).reset_index()
```

```
In [12]: # Calculate the mean difference between consecutive periods
mean_prices_by_month['off_peak_peak_var_mean_diff'] = mean_prices_by_month['pr
mean_prices_by_month['peak_mid_peak_var_mean_diff'] = mean_prices_by_month['pr
mean_prices_by_month['off_peak_mid_peak_var_mean_diff'] = mean_prices_by_month['pr
mean_prices_by_month['off_peak_peak_fix_mean_diff'] = mean_prices_by_month['pr
mean_prices_by_month['peak_mid_peak_fix_mean_diff'] = mean_prices_by_month['pr
mean_prices_by_month['off_peak_mid_peak_fix_mean_diff'] = mean_prices_by_month['pr
```

```
In [13]: # Calculate the maximum monthly difference across time periods
max_diff_across_periods_months = mean_prices_by_month.groupby(['id']).agg({
    'off_peak_peak_var_mean_diff': 'max',
    'peak_mid_peak_var_mean_diff': 'max',
    'off_peak_mid_peak_var_mean_diff': 'max',
    'off_peak_peak_fix_mean_diff': 'max',
    'peak_mid_peak_fix_mean_diff': 'max',
    'off_peak_mid_peak_fix_mean_diff': 'max'
}).reset_index().rename(
    columns={
        'off_peak_peak_var_mean_diff': 'off_peak_peak_var_max_monthly_diff',
        'peak_mid_peak_var_mean_diff': 'peak_mid_peak_var_max_monthly_diff',
        'off_peak_mid_peak_var_mean_diff': 'off_peak_mid_peak_var_max_monthly_',
        'off_peak_peak_fix_mean_diff': 'off_peak_peak_fix_max_monthly_diff',
        'peak_mid_peak_fix_mean_diff': 'peak_mid_peak_fix_max_monthly_diff',
        'off_peak_mid_peak_fix_mean_diff': 'off_peak_mid_peak_fix_max_monthly_'
    }
)
```

```
In [14]: columns = [
    'id',
    'off_peak_peak_var_max_monthly_diff',
    'peak_mid_peak_var_max_monthly_diff',
    'off_peak_mid_peak_var_max_monthly_diff',
    'off_peak_peak_fix_max_monthly_diff',
    'peak_mid_peak_fix_max_monthly_diff',
    'off_peak_mid_peak_fix_max_monthly_diff'
]

df = pd.merge(df, max_diff_across_periods_months[columns], on='id')
df.head()
```

Out[14]:

	id	channel_sales	cons_12m	cons_gas_1
0	24011ae4ebbe3035111d65fa7c15bc57	foosdfpkusacimwkcsothicdxkicaua	0	541
1	d29c2c54acc38ff3c0614d0a653813dd	MISSING	4660	
2	764c75f661154dac3a6c254cd082ea7d	foosdfpkusacimwkcsothicdxkicaua	544	
3	bba03439a292a1e166f80264c16191cb	lmkebamcaclubfxadlmueccxoimlema	1584	
4	149d57cf92fc41cf94415803a877cb4b	MISSING	4425	

5 rows × 58 columns

I thought that calculating the maximum price change between months and time periods would be a good feature to create because I was trying to think from the perspective of a PowerCo client. As a Utilities customer, there is nothing more annoying than sudden price changes between months, and a large increase in prices within a short time span would be an influencing factor in causing me to look at other utilities providers for a better deal. Since we are trying to predict churn for this use case, I thought this would be an interesting feature to include.

(BONUS) Further feature engineering

This section covers extra feature engineering that you may have thought of, as well as different ways you can transform your data to account for some of its statistical properties that we saw before, such as skewness.

Tenure

How long a company has been a client of PowerCo.

```
In [15]: df['tenure'] = ((df['date_end'] - df['date_activ']) / np.timedelta64(1, 'Y')).astype('int')
```

```
In [16]: df.groupby(['tenure']).agg({'churn': 'mean'}).sort_values(by='churn', ascending=False)
```

```
Out[16]:
```

```
churn
```

tenure	churn
3	0.143713
2	0.133080
4	0.125756
13	0.095238
5	0.085425
12	0.083333
6	0.080713
7	0.073394
11	0.063584
8	0.048000
9	0.024096
10	0.020000

We can see that companies who have only been a client for 4 or less months are much more likely to churn compared to companies that have been a client for longer. Interestingly, the difference between 4 and 5 months is about 4%, which represents a large jump in likelihood for a customer to churn compared to the other differences between ordered tenure values. Perhaps this reveals that getting a customer to over 4 months tenure is actually a large milestone with respect to keeping them as a long term customer.

This is an interesting feature to keep for modelling because clearly how long you've been a client, has an influence on the chance of a client churning.

Transforming dates into months

- months_activ = Number of months active until reference date (Jan 2016)
- months_to_end = Number of months of the contract left until reference date (Jan 2016)
- months_modif_prod = Number of months since last modification until reference date (Jan 2016)
- months_renewal = Number of months since last renewal until reference date (Jan 2016)

```
In [17]: def convert_months(reference_date, df, column):
    """
    Input a column with timedeltas and return months
    """
    time_delta = reference_date - df[column]
    months = (time_delta / np.timedelta64(1, 'M')).astype(int)
    return months
```

```
In [18]: # Create reference date
reference_date = datetime(2016, 1, 1)

# Create columns
df['months_activ'] = convert_months(reference_date, df, 'date_activ')
df['months_to_end'] = -convert_months(reference_date, df, 'date_end')
df['months_modif_prod'] = convert_months(reference_date, df, 'date_modif_prod')
df['months_renewal'] = convert_months(reference_date, df, 'date_renewal')
```

Dates as a datetime object are not useful for a predictive model, so we needed to use the datetimes to create some other features that may hold some predictive power.

Using intuition, you could assume that a client who has been an active client of PowerCo for a longer amount of time may have more loyalty to the brand and is more likely to stay. Whereas a newer client may be more volatile. Hence the addition of the `months_activ` feature.

As well as this, if we think from the perspective of a client with PowerCo, if you're coming toward the end of your contract with PowerCo your thoughts could go a few ways. You could be looking for better deals for when your contract ends, or you might want to see out your contract and sign another one. One the other hand if you've only just joined, you may have a period where you're allowed to leave if you're not satisfied. Furthermore, if you're in the middle of your contract, there may be charges if you wanted to leave, deterring clients from churning mid-way through their agreement. So, I think `months_to_end` will be an interesting feature because it may reveal patterns and behaviours about timing of churn.

My belief is that if a client has made recent updates to their contract, they are more likely to be satisfied or at least they have received a level of customer service to update or change their existing services. I believe this to be a positive sign, they are an engaged customer, and so I believe `months_modif_prod` will be an interesting feature to include because it shows the degree of how 'engaged' a client is with PowerCo.

Finally the number of months since a client last renewed a contract I believe will be an interesting feature because once again, it shows the degree to which that client is engaged. It also goes a step further than just engagement, it shows a level of commitment if a client renews their contract. For this reason, I believe `months_renewal` will be a good feature to include.

```
In [19]: # We no longer need the datetime columns that we used for feature engineering,
remove = [
    'date_activ',
    'date_end',
    'date_modif_prod',
    'date_renewal'
]

df = df.drop(columns=remove)
df.head()
```

Out[19]:

	id	channel_sales	cons_12m	cons_gas_1
0	24011ae4ebbe3035111d65fa7c15bc57	foosdfpkusacimwkcsothicdxkicaua	0	541
1	d29c2c54acc38ff3c0614d0a653813dd	MISSING	4660	
2	764c75f661154dac3a6c254cd082ea7d	foosdfpkusacimwkcsothicdxkicaua	544	
3	bba03439a292a1e166f80264c16191cb	lmkebamcaaclubfxadlmueccxoimlema	1584	
4	149d57cf92fc41cf94415803a877cb4b	MISSING	4425	

5 rows × 59 columns

Transforming Boolean data

has_gas

We simply want to transform this column from being categorical to being a binary flag

```
In [20]: df['has_gas'] = df['has_gas'].replace(['t', 'f'], [1, 0])
df.groupby(['has_gas']).agg({'churn': 'mean'})
```

Out[20]:

	churn
has_gas	
0	0.100544
1	0.081856

If a customer also buys gas from PowerCo, it shows that they have multiple products and are a loyal customer to the brand. Hence, it is no surprise that customers who do not buy gas are almost 2% more likely to churn than customers who also buy gas from PowerCo. Hence, this is a useful feature.

Transforming categorical data

A predictive model cannot accept categorical or string values, hence as a data scientist you need to encode categorical features into numerical representations in the most compact and discriminative way possible.

The simplest method is to map each category to an integer (label encoding), however this is not always appropriate because it then introduces the concept of an order into a feature which may not inherently be present $0 < 1 < 2 < 3 \dots$

Another way to encode categorical features is to use dummy variables AKA one hot encoding. This creates a new feature for every unique value of a categorical column, and fills this column with either a 1 or a 0 to indicate that this company does or does not belong to this category.

channel_sales

```
In [21]: # Transform into categorical type
df['channel_sales'] = df['channel_sales'].astype('category')

# Let's see how many categories are within this column
df['channel_sales'].value_counts()
```

```
Out[21]: foosdfpfkusacimwkcsovbcidxkicaua    6754
MISSING                                3725
lmkebamcaaclubfxadlmueccxoimlema    1843
usilxuppasemubllopkafesmlibmsdf    1375
ewpakwlliwiwiwdubdlfmalxowmwpc      893
sddiedcslfslkckwlfkdpoeailfpeds    11
epumfxlbckeskwekxbiuasklxalciuu      3
fixdbufsefwooaasfcxdxadsiekoceaa      2
Name: channel_sales, dtype: int64
```

We have 8 categories, so we will create 8 dummy variables from this column. However, as you can see the last 3 categories in the output above, show that they only have 11, 3 and 2 occurrences respectively. Considering that our dataset has about 14000 rows, this means that these dummy variables will be almost entirely 0 and so will not add much predictive power to the model at all (since they're almost entirely a constant value and provide very little).

For this reason, we will drop these 3 dummy variables.

```
In [22]: df = pd.get_dummies(df, columns=['channel_sales'], prefix='channel')
df = df.drop(columns=['channel_sddiedcslfslkckwlfkdpoeailfpeds', 'channel_epu'])
df.head()
```

```
Out[22]:
```

	id	cons_12m	cons_gas_12m	cons_last_month	forecast_con
0	24011ae4ebbe3035111d65fa7c15bc57	0	54946	0	
1	d29c2c54acc38ff3c0614d0a653813dd	4660	0	0	
2	764c75f661154dac3a6c254cd082ea7d	544	0	0	
3	bba03439a292a1e166f80264c16191cb	1584	0	0	
4	149d57cf92fc41cf94415803a877cb4b	4425	0	526	

5 rows \times 63 columns

origin_up

```
In [23]: # Transform into categorical type
df['origin_up'] = df['origin_up'].astype('category')

# Let's see how many categories are within this column
df['origin_up'].value_counts()
```

```
Out[23]: 1xidpiddsbxsbsboudacockeimpuepw    7097
kamkkxfxxuwbdslkwifmmcsiusiuosws    4294
1dkssxwpmemidmecebumciepifcamkci    3148
MISSING                                64
usapbepcfoloekilkwsdiboslwaxobdp      2
ewxeelcelemmiwuafmddpobolfxioce      1
Name: origin_up, dtype: int64
```

Similar to `channel_sales` the last 3 categories in the output above show very low frequency, so we will remove these from the features after creating dummy variables.

```
In [24]: df = pd.get_dummies(df, columns=['origin_up'], prefix='origin_up')
df = df.drop(columns=['origin_up_MISSING', 'origin_up_usapbepcfoloekilkwsdibos'])
df.head()
```

```
Out[24]:
```

	<code>id</code>	<code>cons_12m</code>	<code>cons_gas_12m</code>	<code>cons_last_month</code>	<code>forecast_cons</code>
0	24011ae4ebbe3035111d65fa7c15bc57	0	54946	0	
1	d29c2c54acc38ff3c0614d0a653813dd	4660	0	0	
2	764c75f661154dac3a6c254cd082ea7d	544	0	0	
3	bba03439a292a1e166f80264c16191cb	1584	0	0	
4	149d57cf92fc41cf94415803a877cb4b	4425	0	526	

5 rows × 65 columns

Transforming numerical data

In the previous exercise we saw that some variables were highly skewed. The reason why we need to treat skewness is because some predictive models have inherent assumptions about the distribution of the features that are being supplied to it. Such models are called `parametric` models, and they typically assume that all variables are both independent and normally distributed.

Skewness isn't always a bad thing, but as a rule of thumb it is always good practice to treat highly skewed variables because of the reason stated above, but also as it can improve the speed at which predictive models are able to converge to its best solution.

There are many ways that you can treat skewed variables. You can apply transformations such as:

- Square root
- Cubic root
- Logarithm

to a continuous numeric column and you will notice the distribution changes. For this use case we will use the 'Logarithm' transformation for the positively skewed features.

Note: We cannot apply log to a value of 0, so we will add a constant of 1 to all the values

First I want to see the statistics of the skewed features, so that we can compare before and after transformation

```
In [25]: skewed = [
    'cons_12m',
    'cons_gas_12m',
    'cons_last_month',
    'forecast_cons_12m',
    'forecast_cons_year',
    'forecast_discount_energy',
    'forecast_meter_rent_12m',
    'forecast_price_energy_off_peak',
    'forecast_price_energy_peak',
    'forecast_price_pow_off_peak'
]

df[skewed].describe()
```

	cons_12m	cons_gas_12m	cons_last_month	forecast_cons_12m	forecast_cons_year
count	1.460600e+04	1.460600e+04	14606.000000	14606.000000	14606.000000
mean	1.592203e+05	2.809238e+04	16090.269752	1868.614880	1399.762906
std	5.734653e+05	1.629731e+05	64364.196422	2387.571531	3247.786255
min	0.000000e+00	0.000000e+00	0.000000	0.000000	0.000000
25%	5.674750e+03	0.000000e+00	0.000000	494.995000	0.000000
50%	1.411550e+04	0.000000e+00	792.500000	1112.875000	314.000000
75%	4.076375e+04	0.000000e+00	3383.000000	2401.790000	1745.750000
max	6.207104e+06	4.154590e+06	771203.000000	82902.830000	175375.000000

We can see that the standard deviation for most of these features is quite high.

```
In [26]: # Apply Log10 transformation
df["cons_12m"] = np.log10(df["cons_12m"] + 1)
df["cons_gas_12m"] = np.log10(df["cons_gas_12m"] + 1)
df["cons_last_month"] = np.log10(df["cons_last_month"] + 1)
df["forecast_cons_12m"] = np.log10(df["forecast_cons_12m"] + 1)
df["forecast_cons_year"] = np.log10(df["forecast_cons_year"] + 1)
df["forecast_meter_rent_12m"] = np.log10(df["forecast_meter_rent_12m"] + 1)
df["imp_cons"] = np.log10(df["imp_cons"] + 1)
```

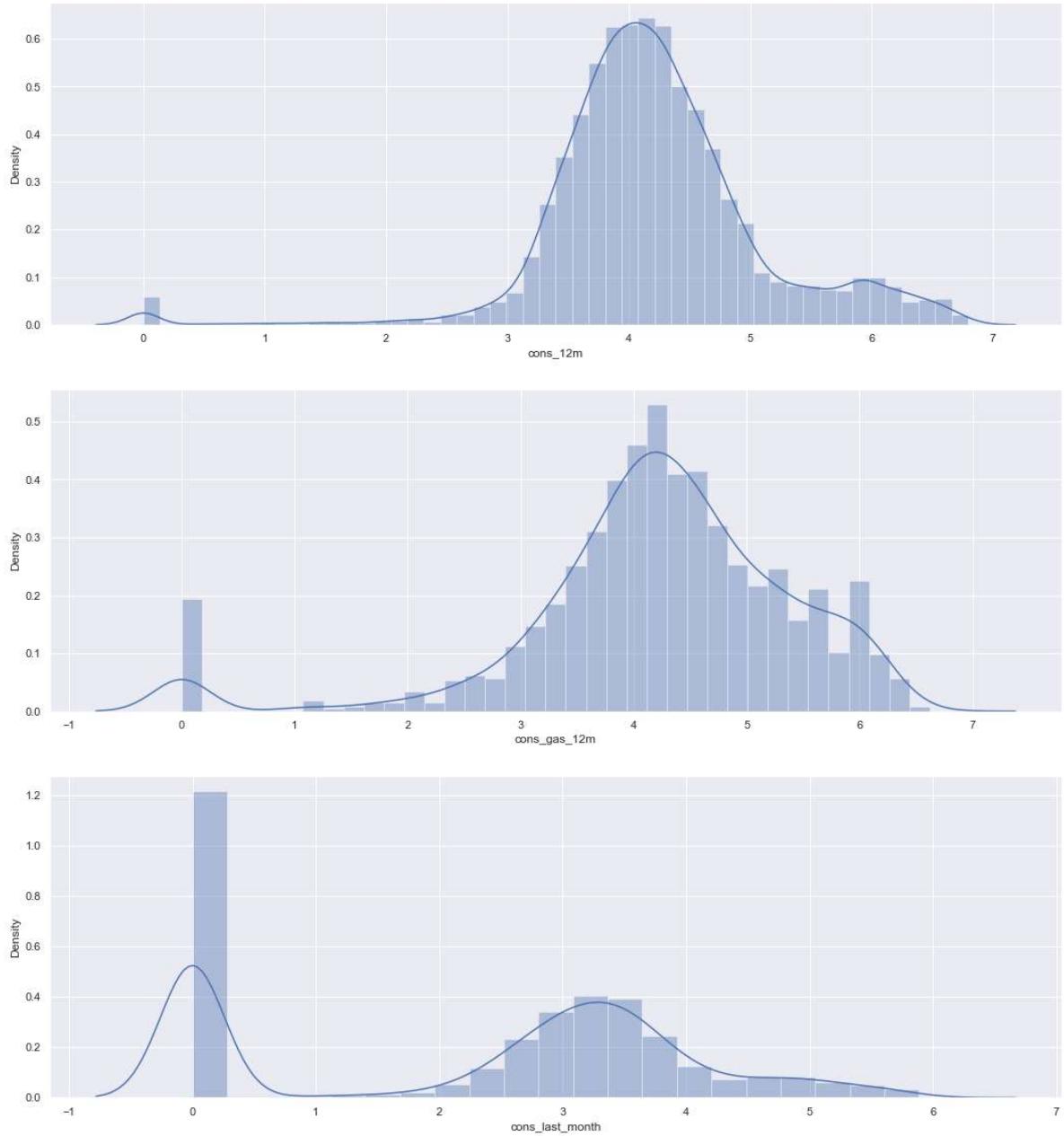
```
In [27]: df[skewed].describe()
```

	cons_12m	cons_gas_12m	cons_last_month	forecast_cons_12m	forecast_cons_year
count	14606.000000	14606.000000	14606.000000	14606.000000	14606.000000
mean	4.223939	0.779244	2.264646	2.962177	1.784610
std	0.884515	1.717071	1.769305	0.683592	1.584986
min	0.000000	0.000000	0.000000	0.000000	0.000000
25%	3.754023	0.000000	0.000000	2.695477	0.000000
50%	4.149727	0.000000	2.899547	3.046836	2.498311
75%	4.610285	0.000000	3.529430	3.380716	3.242231
max	6.792889	6.618528	5.887169	4.918575	5.243970

Now we can see that for the majority of the features, their standard deviation is much lower after transformation. This is a good thing, it shows that these features are more stable and predictable now.

Let's quickly check the distributions of some of these features too.

```
In [28]: fig, axs = plt.subplots(nrows=3, figsize=(18, 20))
# Plot histograms
sns.distplot((df["cons_12m"].dropna()), ax=axs[0])
sns.distplot((df[df["has_gas"]==1]["cons_gas_12m"].dropna()), ax=axs[1])
sns.distplot((df["cons_last_month"].dropna()), ax=axs[2])
plt.show()
```



Correlations

In terms of creating new features and transforming existing ones, it is very much a trial and error situation that requires iteration. Once we train a predictive model we can see which features work and don't work, we will also know how predictive this set of features is. Based on this, we can come back to feature engineering to enhance our model.

For now, we will leave feature engineering at this point. Another thing that is always useful to look at is how correlated all of the features are within your dataset.

This is important because it reveals the linear relationships between features. We want features to correlate with `churn`, as this will indicate that they are good predictors of it. However features that have a very high correlation can sometimes be suspicious. This is because 2 columns that have high correlation indicates that they may share a lot of the same information. One of the assumptions of any parametric predictive model (as stated earlier) is that all features must be independent.

For features to be independent, this means that each feature must have absolutely no dependence on any other feature. If two features are highly correlated and share similar information, this breaks this assumption.

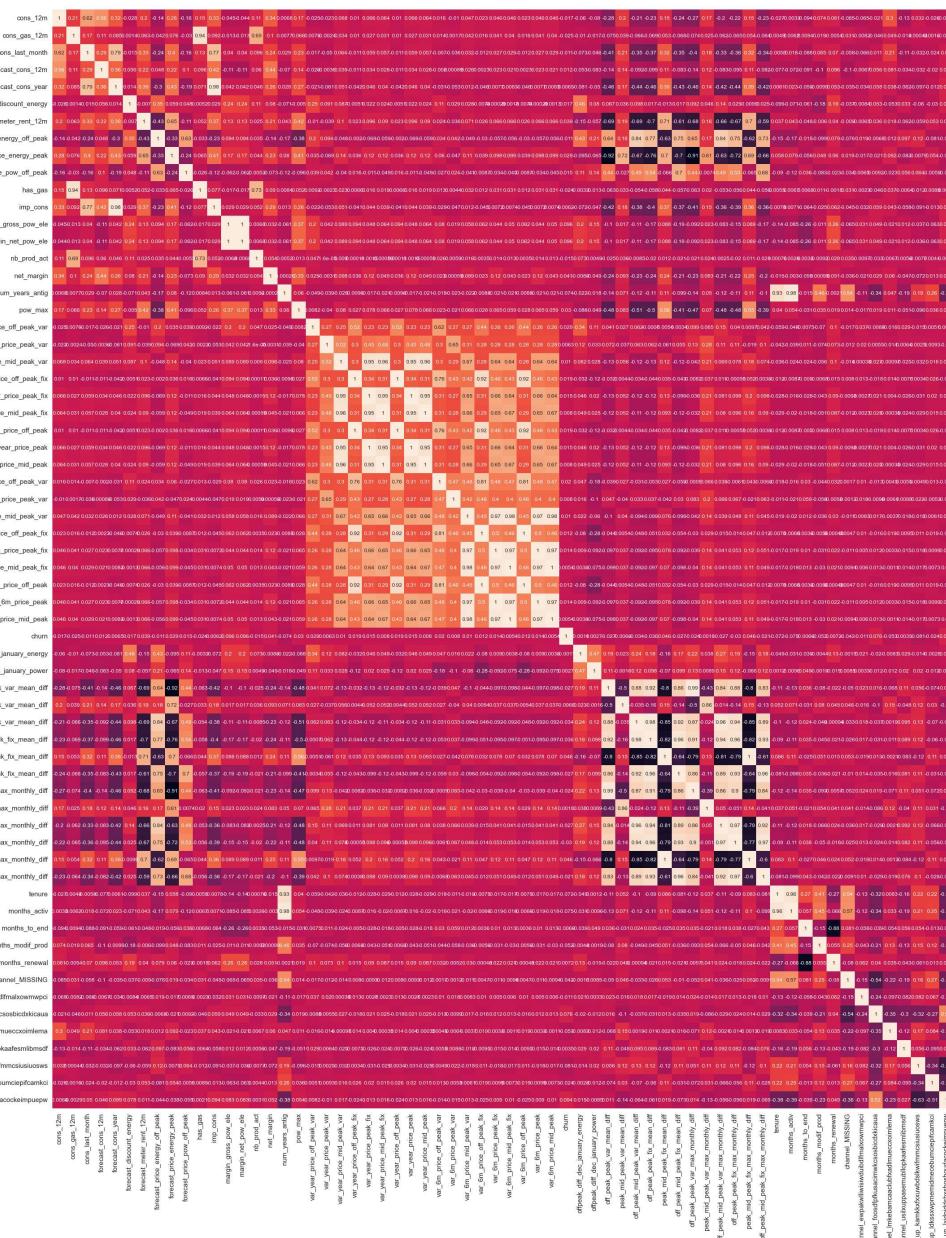
Ideally, you want a set of features that have 0 correlation with all of the independent variables (all features except our target variable) and a high correlation with the target variable (`churn`). However, this is very rarely the case and it is common to have a small degree of correlation between independent features.

So now let's look at how all the features within the model are correlated.

In [29]: `correlation = df.corr()`

```
In [30]: # Plot correlation
```

```
plt.figure(figsize=(45, 45))
sns.heatmap(
    correlation,
    xticklabels=correlation.columns.values,
    yticklabels=correlation.columns.values,
    annot=True,
    annot_kws={'size': 12}
)
# Axis ticks size
plt.xticks(fontsize=15)
plt.yticks(fontsize=15)
plt.show()
```



I will leave it as an exercise for yourself to decide which features to remove based on the correlation results (there are various methods you can use to decide which features to remove).

For now, I will remove two variables which exhibit a high correlation with other independent features.

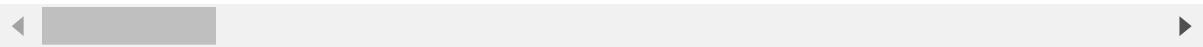
In [31]:

```
df = df.drop(columns=['num_years_antig', 'forecast_cons_year'])
df.head()
```

Out[31]:

		id	cons_12m	cons_gas_12m	cons_last_month	forecast_cons
0	24011ae4ebbe3035111d65fa7c15bc57		0.000000	4.739944	0.000000	0.
1	d29c2c54acc38ff3c0614d0a653813dd		3.668479	0.000000	0.000000	2.
2	764c75f661154dac3a6c254cd082ea7d		2.736397	0.000000	0.000000	1.
3	bba03439a292a1e166f80264c16191cb		3.200029	0.000000	0.000000	2.
4	149d57cf92fc41cf94415803a877cb4b		3.646011	0.000000	2.721811	2.

5 rows × 63 columns



5. Modelling

We now have a dataset containing features that we have engineered and we are ready to start training a predictive model. Remember, we only need to focus on training a Random Forest classifier.

In [32]:

```
from sklearn import metrics
from sklearn.model_selection import train_test_split
from sklearn.ensemble import RandomForestClassifier
```

Data sampling

The first thing we want to do is split our dataset into training and test samples. The reason why we do this, is so that we can simulate a real life situation by generating predictions for our test sample, without showing the predictive model these data points. This gives us the ability to see how well our model is able to generalise to new data, which is critical.

A typical % to dedicate to testing is between 20-30, for this example we will use a 75-25% split between train and test respectively.

```
In [33]: # Make a copy of our data
train_df = df.copy()

# Separate target variable from independent variables
y = df['churn']
X = df.drop(columns=['id', 'churn'])
print(X.shape)
print(y.shape)
```

```
(14606, 61)
(14606,)
```

```
In [34]: X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.25, random_state=42)
print(X_train.shape)
print(y_train.shape)
print(X_test.shape)
print(y_test.shape)
```

```
(10954, 61)
(10954,)
(3652, 61)
(3652,)
```

Model training

Once again, we are using a Random Forest classifier in this example. A Random Forest sits within the category of ensemble algorithms because internally the Forest refers to a collection of Decision Trees which are tree-based learning algorithms. As the data scientist, you can control how large the forest is (that is, how many decision trees you want to include).

The reason why an ensemble algorithm is powerful is because of the laws of averaging, weak learners and the central limit theorem. If we take a single decision tree and give it a sample of data and some parameters, it will learn patterns from the data. It may be overfit or it may be underfit, but that is now our only hope, that single algorithm.

With ensemble methods, instead of banking on 1 single trained model, we can train 1000's of decision trees, all using different splits of the data and learning different patterns. It would be like asking 1000 people to all learn how to code. You would end up with 1000 people with different answers, methods and styles! The weak learner notion applies here too, it has been found that if you train your learners not to overfit, but to learn weak patterns within the data and you have a lot of these weak learners, together they come together to form a highly predictive pool of knowledge! This is a real life application of many brains are better than 1.

Now instead of relying on 1 single decision tree for prediction, the random forest puts it to the overall views of the entire collection of decision trees. Some ensemble algorithms using a voting approach to decide which prediction is best, others using averaging.

As we increase the number of learners, the idea is that the random forest's performance should converge to its best possible solution.

Some additional advantages of the random forest classifier include:

- The random forest uses a rule-based approach instead of a distance calculation and so features do not need to be scaled
- It is able to handle non-linear parameters better than linear based models

On the flip side, some disadvantages of the random forest classifier include:

- The computational power needed to train a random forest on a large dataset is high, since we need to build a whole ensemble of estimators.
- Training time can be longer due to the increased complexity and size of the ensemble

```
In [35]: model = RandomForestClassifier(
    n_estimators=1000
)
model.fit(X_train, y_train)
```

```
Out[35]: RandomForestClassifier(n_estimators=1000)
```

The `scikit-learn` documentation: <https://scikit-learn.org/stable/modules/generated/sklearn.ensemble.RandomForestClassifier.html> (<https://scikit-learn.org/stable/modules/generated/sklearn.ensemble.RandomForestClassifier.html>), has a lot of information about the algorithm and the parameters that you can use when training a model.

For this example, I am using `n_estimators = 1000`. This means that my random forest will consist of 1000 decision trees. There are many more parameters that you can fine-tune within the random forest and finding the optimal combinations of parameters can be a manual task of exploration, trial and error, which will not be covered during this notebook.

Evaluation

Now let's evaluate how well this trained model is able to predict the values of the test dataset.

We are going to use 3 metrics to evaluate performance:

- Accuracy = the ratio of correctly predicted observations to the total observations
- Precision = the ability of the classifier to not label a negative sample as positive
- Recall = the ability of the classifier to find all the positive samples

The reason why we are using these three metrics is because a simple accuracy is not always a good measure to use. To give an example, let's say you're predicting heart failures with patients in a hospital and there were 100 patients out of 1000 that did have a heart failure.

If you predicted 80 out of 100 (80%) of the patients that did have a heart failure correctly, you might think that you've done well! However, this also means that you predicted 20 wrong and what may the implications of predicting these remaining 20 patients wrong? Maybe they miss out on getting vital treatment to save their lives.

As well as this, what about the impact of predicting negative cases as positive (people not having heart failure being predicted that they did), maybe a high number of false positives means that resources get used up on the wrong people and a lot of time is wasted when they

could have been helping the real heart failure sufferers.

This is just an example, but it illustrates why other performance metrics are necessary such as Precision and Recall, which are good measures to use in a classification scenario.

```
In [36]: predictions = model.predict(X_test)
tn, fp, fn, tp = metrics.confusion_matrix(y_test, predictions).ravel()
```

```
In [37]: y_test.value_counts()
```

```
Out[37]: 0    3286
1    366
Name: churn, dtype: int64
```

```
In [38]: print(f"True positives: {tp}")
print(f"False positives: {fp}")
print(f"True negatives: {tn}")
print(f"False negatives: {fn}\n")

print(f"Accuracy: {metrics.accuracy_score(y_test, predictions)}")
print(f"Precision: {metrics.precision_score(y_test, predictions)}")
print(f"Recall: {metrics.recall_score(y_test, predictions)}")
```

```
True positives: 18
False positives: 4
True negatives: 3282
False negatives: 348
```

```
Accuracy: 0.9036144578313253
Precision: 0.8181818181818182
Recall: 0.04918032786885246
```

Looking at these results there are a few things to point out:

Note: If you are running this notebook yourself, you may get slightly different answers!

- Within the test set about 10% of the rows are churners (churn = 1).
- Looking at the true negatives, we have 3282 out of 3286. This means that out of all the negative cases (churn = 0), we predicted 3282 as negative (hence the name True negative). This is great!
- Looking at the false negatives, this is where we have predicted a client to not churn (churn = 0) when in fact they did churn (churn = 1). This number is quite high at 348, we want to get the false negatives to as close to 0 as we can, so this would need to be addressed when improving the model.
- Looking at false positives, this is where we have predicted a client to churn when they actually didn't churn. For this value we can see there are 4 cases, which is great!
- With the true positives, we can see that in total we have 366 clients that churned in the test dataset. However, we are only able to correctly identify 18 of those 366, which is very poor.
- Looking at the accuracy score, this is very misleading! Hence the use of precision and recall is important. The accuracy score is high, but it does not tell us the whole story.
- Looking at the precision score, this shows us a score of 0.82 which is not bad, but could be improved.

- However, the recall shows us that the classifier has a very poor ability to identify positive samples. This would be the main concern for improving this model!

So overall, we're able to very accurately identify clients that do not churn, but we are not able to predict cases where clients do churn! What we are seeing is that a high % of clients are being identified as not churning when they should be identified as churning. This in turn tells me that the current set of features are not discriminative enough to clearly distinguish between churners and non-churners.

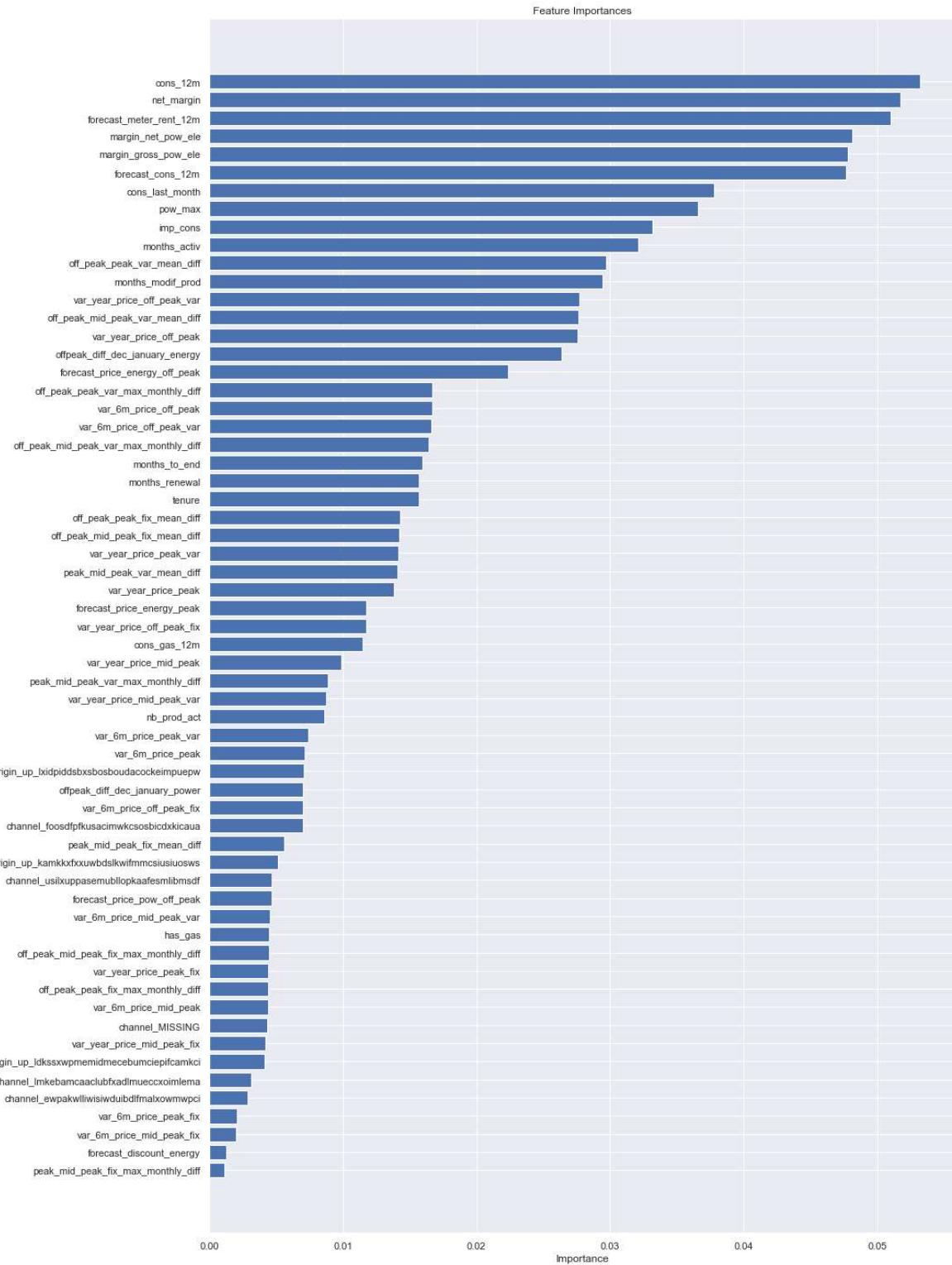
A data scientist at this point would go back to feature engineering to try and create more predictive features. They may also experiment with optimising the parameters within the model to improve performance. For now, lets dive into understanding the model a little more.

Model understanding

A simple way of understanding the results of a model is to look at feature importances. Feature importances indicate the importance of a feature within the predictive model, there are several ways to calculate feature importance, but with the Random Forest classifier, we're able to extract feature importances using the built-in method on the trained model. In the Random Forest case, the feature importance represents the number of times each feature is used for splitting across all trees.

```
In [39]: feature_importances = pd.DataFrame({
    'features': X_train.columns,
    'importance': model.feature_importances_
}).sort_values(by='importance', ascending=True).reset_index()
```

```
In [40]: plt.figure(figsize=(15, 25))
plt.title('Feature Importances')
plt.barh(range(len(feature_importances)), feature_importances['importance'], color='blue')
plt.yticks(range(len(feature_importances)), feature_importances['features'])
plt.xlabel('Importance')
plt.show()
```



From this chart, we can observe the following points:

- Net margin and consumption over 12 months is a top driver for churn in this model

- Margin on power subscription also is an influential driver
- Time seems to be an influential factor, especially the number of months they have been active, their tenure and the number of months since they updated their contract
- The feature that our colleague recommended is in the top half in terms of how influential it is and some of the features built off the back of this actually outperform it
- Our price sensitivity features are scattered around but are not the main driver for a customer churning

The last observation is important because this relates back to our original hypothesis:

> Is churn driven by the customers' price sensitivity?

Based on the output of the feature importances, it is not a main driver but it is a weak contributor. However, to arrive at a conclusive result, more experimentation is needed.

```
In [41]: proba_predictions = model.predict_proba(X_test)
probabilities = proba_predictions[:, 1]
```

```
In [42]: X_test = X_test.reset_index()
X_test.drop(columns='index', inplace=True)
```

```
In [43]: X_test['churn'] = predictions.tolist()
X_test['churn_probability'] = probabilities.tolist()
X_test.to_csv('out_of_sample_data_with_predictions.csv')
```

----- X X X X X X X X -----