Covid-19 Vaccination Campaign in Germany

The data used here were provided by Robert Koch Institute and the German federal ministry of Health.

These institutions publish the datasets and some analysis on the page impfdashboard.de.

Setup

Imports

In [419…

```
# standard library
import datetime
import math
```

In [420…

```
# third party
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import requests
import seaborn
```

Date this Notebook was run

In [421…

```
today = datetime.datetime.today().strftime('%Y-%m-%d')
today
```

Out[421…

```
'2021-05-09'
```

Set Defaults

In [422…

```
# style like ggplot in R
plt.style.use('ggplot')
```

In [423…

```
# Avoid cutting off part of the axis labels, see:
# https://stackoverflow.com/questions/6774086/why-is-my-xlabel-cut-off-in-my-matplotlib-plot
plt.rcParams.update({'figure.autolayout': True})
```

In [424…

```
population_germany = 83_200_000
```

Get and Transform Data

In [425…

```
vaccination_data_permalink = 'https://impfdashboard.de/static/data/germany_vaccinations_timeseries_v2.tsv'
vaccinations = pd.read_csv(
    vaccination_data_permalink,
    sep="\t")
```

Drop unnecessary / misleading columns

Columns with names starting with 'indikation_' will not be analyzed as the data providers stopped updating them.

In [426…

```
cols_to_drop = vaccinations.columns[vaccinations.columns.str.contains('indikation_')]
vaccinations.drop(columns=cols_to_drop, inplace=True)
```

Some more columns can be dropped, as there is no interest in analyzing differences on a vaccine level - especially since in some cases vaccines were mixed.

In [427…

```
more_cols_to_drop = ['dosen_biontech_erst_kumulativ', 'dosen_biontech_zweit_kumulativ',
                    'dosen_moderna_erst_kumulativ', 'dosen_moderna_zweit_kumulativ',
                    'dosen_astrazeneca_erst_kumulativ', 'dosen_astrazeneca_zweit_kumulativ']
vaccinations.drop(columns=more_cols_to_drop, inplace=True)
```

Some columns are labeled misleadingly. As stated by the data provider the columns `personen_erst_kumulativ` and `impf_quote_erst` contain people vaccinated with the Johnson & Johnson vaccine. As this requires only one shot. the same persons are included in `personen_voll_kumulativ` . Therefore more columns are dropped and recalculated later.

In [428…

```
vaccinations.drop(columns=['impf_quote_erst', 'impf_quote_voll'], inplace=True)
```

Convert datatype of date column

In [429…

```
vaccinations.iloc[ : , [0]] = vaccinations.iloc[ : , [0]].apply(pd.to_datetime)
```

Show Data

In [430…

```
vaccinations.info()
```

```
<class 'pandas.core.frame.DataFrame'>
```

```
RangeIndex: 132 entries, 0 to 131
Data columns (total 13 columns):
 #   Column                          Non-Null Count  Dtype         
---  ------                          --------------  -----         
 0   date                            132 non-null    datetime64[ns]
 1   dosen_kumulativ                 132 non-null    int64         
 2   dosen_differenz_zum_vortag      132 non-null    int64         
 3   dosen_erst_differenz_zum_vortag  132 non-null    int64         
 4   dosen_zweit_differenz_zum_vortag 132 non-null    int64         
 5   dosen_biontech_kumulativ        132 non-null    int64         
 6   dosen_moderna_kumulativ         132 non-null    int64         
 7   dosen_astrazeneca_kumulativ     132 non-null    int64         
 8   personen_erst_kumulativ         132 non-null    int64         
 9   personen_voll_kumulativ         132 non-null    int64         
 10  dosen_dim_kumulativ             132 non-null    int64         
 11  dosen_kbv_kumulativ             132 non-null    int64         
 12  dosen_johnson_kumulativ         132 non-null    int64         
dtypes: datetime64[ns](1), int64(12)
memory usage: 13.5 KB
```

In [431…

```
vaccinations.tail(3)
```

Out[431…

	date	dosen_kumulativ	dosen_differenz_zum_vortag	dosen_erst_differenz_zum_vortag	dosen_zweit_differenz_zum_vortag	dosen_biontech_kumulati
129	2021-05-05	32652324	1115886	898480	217406	2427062
130	2021-05-06	33594803	942479	737564	204915	2493674
131	2021-05-07	34408840	814037	617514	196523	2548032

Check Validity

In [432…

```
# get the last row / the newest available data
last_row = vaccinations.tail(1)
```

In [433…

```
doses_used = last_row['dosen_kumulativ']
doses_used
```

Out[433…

```
131    34408840
Name: dosen_kumulativ, dtype: int64
```

In [434…

```
# The number of person having been vaccinated at least once, includes those fully vaccinated
at_least_once = last_row['personen_erst_kumulativ']
fully_vaccinated_people = last_row['personen_voll_kumulativ']
partially_vaccinated_people = at_least_once - fully_vaccinated_people
# The johnson & Johnson vaccine is the only one used in Germany that only needs a single shot:
johnson_doses = last_row['dosen_johnson_kumulativ']
```

In [435…

```
# Must be exactly 0
doses_used - partially_vaccinated_people - (fully_vaccinated_people - johnson_doses) * 2 - johnson_doses ==  0
```

Out[435…

```
131    True
dtype: bool
```

Calculate columns

In [436…

```
vaccinations['partly vaccinated'] = round(
    (vaccinations['personen_erst_kumulativ'] - vaccinations['personen_voll_kumulativ']) * 100 / population_germany,
    2)
```

In [437…

```
vaccinations['fully vaccinated'] = round(
    vaccinations['personen_voll_kumulativ'] * 100 / population_germany,
    2)
```

In [438…

```
vaccinations.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 132 entries, 0 to 131
Data columns (total 15 columns):
 #   Column                         Non-Null Count  Dtype         
---  ------                         --------------  -----         
 0   date                           132 non-null    datetime64[ns]
 1   dosen_kumulativ                132 non-null    int64         
 2   dosen_differenz_zum_vortag     132 non-null    int64         
 3   dosen_erst_differenz_zum_vortag  132 non-null    int64         
 4   dosen_zweit_differenz_zum_vortag 132 non-null    int64         
 5   dosen_biontech_kumulativ       132 non-null    int64         
 6   dosen_moderna_kumulativ        132 non-null    int64         
 7   dosen_astrazeneca_kumulativ    132 non-null    int64         
 8   personen_erst_kumulativ        132 non-null    int64         
 9   personen_voll_kumulativ        132 non-null    int64         
 10  dosen_dim_kumulativ            132 non-null    int64         
 11  dosen_kbv_kumulativ            132 non-null    int64         
 12  dosen_johnson_kumulativ        132 non-null    int64         
 13  partly vaccinated              132 non-null    float64       
 14  fully vaccinated                   132 non-null    float64
dtypes: datetime64[ns](1), float64(2), int64(12)
memory usage: 15.6 KB
```

In [439…

```
vaccinations.tail(3)
```

Out[439…

	date	dosen_kumulativ	dosen_differenz_zum_vortag	dosen_erst_differenz_zum_vortag	dosen_zweit_differenz_zum_vortag	dosen_biontech_kumulati
129	2021-05-05	32652324	1115886	898480	217406	2427062
130	2021-05-06	33594803	942479	737564	204915	2493674
131	2021-05-07	34408840	814037	617514	196523	2548032

Last Update

Often the data is not updated on weekends, so get the highest date in the dataset.

In [440…

```
last_update = vaccinations.loc[vaccinations.index[-1], "date"].strftime('%Y-%m-%d')
last_update
```

Out[440…

```
'2021-05-07'
```

Doses Used

In [441…

```
doses = vaccinations.loc[ : , ['date', 'dosen_differenz_zum_vortag']]
# Rename columns
doses.columns = ['date', 'doses used']
```

In [442…

```
# Scale number of doses as millions
doses['doses used'] = doses['doses used'] / 1_000_000
```

Doses Daily

In [443…

```
doses_daily = doses.set_index('date', inplace=False)
doses_daily.tail(1)
```

Out[443…

	doses used
date	
2021-05-07	0.814037

In [444…

```
# What is the highest number of doses used in a day?
max_doses_daily = max(doses_daily['doses used'])
max_doses_daily
```

Out[444…

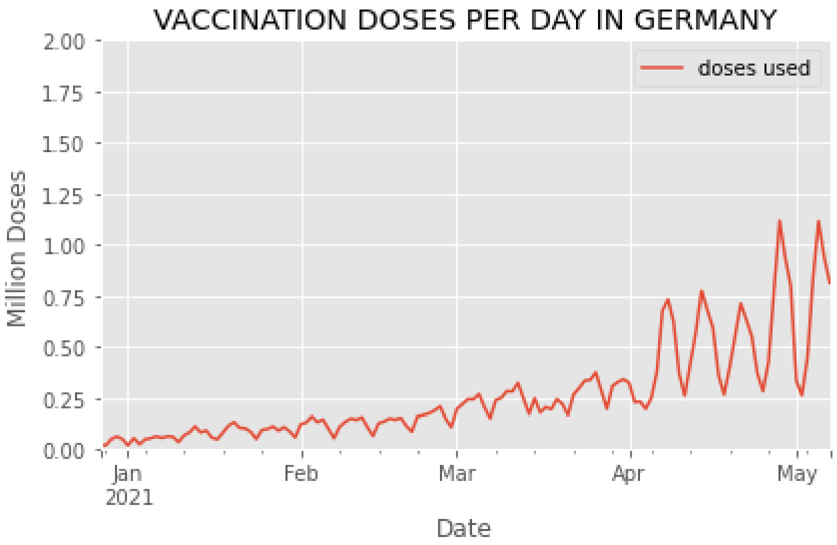
```
1.117913
```

In [445…

```
doses_daily.plot(
    ylim=(0,math.ceil(max_doses_daily)),
    xlabel='Date',
    ylabel='Million Doses',
    title='VACCINATION DOSES PER DAY IN GERMANY')
```

Out[445…

```
<AxesSubplot:title={'center':'VACCINATION DOSES PER DAY IN GERMANY'}, xlabel='Date', ylabel='Million Doses'>
```



Doses per Weekday (in the last 6 weeks)

In [446…

```
last_6_weeks = doses.tail(42)
```

In [447…

```
# Yields a warning, but exactly like the docs prescribe and it works
# https://pandas.pydata.org/docs/getting_started/intro_tutorials/05_add_columns.html
last_6_weeks['weekday'] = last_6_weeks['date'].dt.day_name()
```

```
<ipython-input-447-45013977109e>:3: SettingWithCopyWarning:
A value is trying to be set on a copy of a slice from a DataFrame.
Try using .loc[row_indexer,col_indexer] = value instead

See the caveats in the documentation: https://pandas.pydata.org/pandas-docs/stable/user_guide/indexing.html#returning-a
-view-versus-a-copy
  last_6_weeks['weekday'] = last_6_weeks['date'].dt.day_name()
```

In [448…

```
# check:
last_6_weeks.tail(3)
```

Out[448…

	date	doses used	weekday
129	2021-05-05	1.115886	Wednesday
130	2021-05-06	0.942479	Thursday
131	2021-05-07	0.814037	Friday

In [449…

```
# drop the date column
last_6_weeks = last_6_weeks.drop(labels=['date'], axis=1)
```

In [450…

```
#last_6_weeks.set_index('weekday', inplace=True)
last_6_weeks.tail(3)
```

Out[450…

	doses used	weekday
129	1.115886	Wednesday
130	0.942479	Thursday
131	0.814037	Friday

In [451…

```
pivot_table =last_6_weeks.pivot(columns='weekday', values='doses used')
pivot_table.tail()
```

Out[451…

weekday	Friday	Monday	Saturday	Sunday	Thursday	Tuesday	Wednesday
127	NaN	0.445775	NaN	NaN	NaN	NaN	NaN
128	NaN	NaN	NaN	NaN	NaN	0.833265	NaN

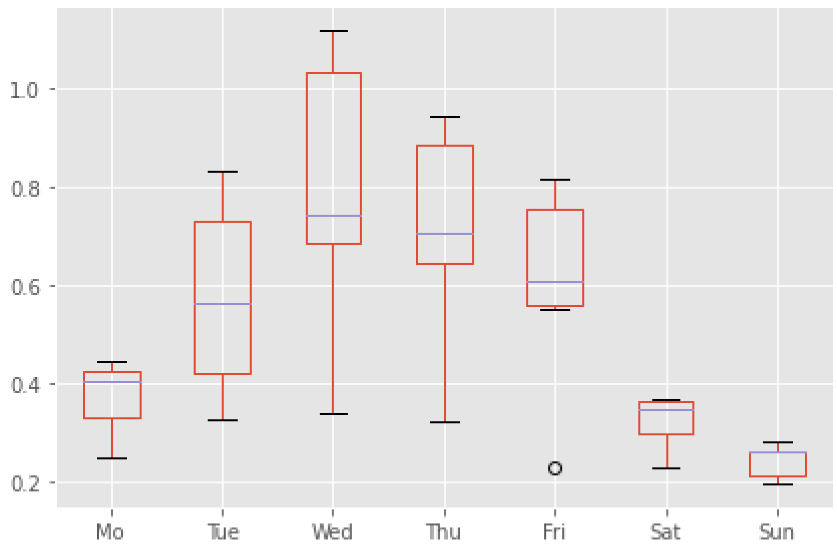
weekday	Friday	Monday	Saturday	Sunday	Thursday	Tuesday	Wednesday
129	NaN	NaN	NaN	NaN	NaN	NaN	1.115886
130	NaN	NaN	NaN	NaN	0.942479	NaN	NaN
131	0.814037	NaN	NaN	NaN	NaN	NaN	NaN

```
In [452…
# Reorder the columns
pivot_table = pivot_table[['Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday', 'Saturday', 'Sunday']]
# Rename the columns
pivot_table.columns=['Mo', 'Tue', 'Wed', 'Thu', 'Fri', 'Sat', 'Sun']
pivot_table.tail()
```

Out[452…

	Mo	Tue	Wed	Thu	Fri	Sat	Sun
127	0.445775	NaN	NaN	NaN	NaN	NaN	NaN
128	NaN	0.833265	NaN	NaN	NaN	NaN	NaN
129	NaN	NaN	1.115886	NaN	NaN	NaN	NaN
130	NaN	NaN	NaN	0.942479	NaN	NaN	NaN
131	NaN	NaN	NaN	NaN	0.814037	NaN	NaN

```
In [453…
weekday_boxplot = pivot_table.boxplot()
```



In [454…

```
fig = weekday_boxplot.get_figure()
fig.savefig('img/weekday_boxplot.png')
```

Doses per Week

In [455…

```
# W-Mon in order to start the week on a Monday, see:
# https://pandas.pydata.org/pandas-docs/stable/user_guide/timeseries.html#anchored-offsets
doses_weekly = doses.groupby(pd.Grouper(key='date',freq='W-Mon')).sum()
doses_weekly.columns = ['million doses used']
doses_weekly.tail()
```

Out[455…

	million doses used
date	
2021-04-12	3.455424
2021-04-19	3.642918
2021-04-26	3.528553
2021-05-03	4.675651
2021-05-10	3.705667

In [456…

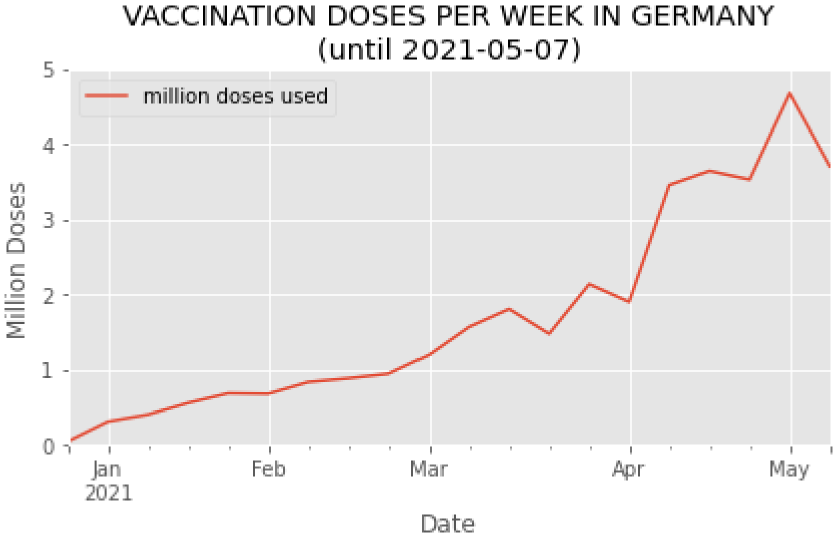
```
# What is the highest number of doses used in a week?
```

```
max_million_doses_weekly = max(doses_weekly['million doses used'])
max_million_doses_weekly
```

```
Out[456…  4.675651
```

```
In [457…  doses_weekly.plot(
              ylim=(0, math.ceil(max_million_doses_weekly)),
              xlabel='Date',
              ylabel='Million Doses',
              title=f"VACCINATION DOSES PER WEEK IN GERMANY\n(until {last_update})")
```

```
Out[457…  <AxesSubplot:title={'center':'VACCINATION DOSES PER WEEK IN GERMANY\n(until 2021-05-07)'}, xlabel='Date', ylabel='Milli
          on Doses'>
```



Doses per Month

```
In [458…  # M = month end frequency
          doses_monthly = doses.groupby(pd.Grouper(key='date',freq='M')).sum()
          doses_monthly.tail()
```

Out[458…

	doses used
date	
2021-01-31	2.343091

date	doses used
2021-02-28	3.776292
2021-03-31	7.845951
2021-04-30	15.492020
2021-05-31	4.746485

In [459…

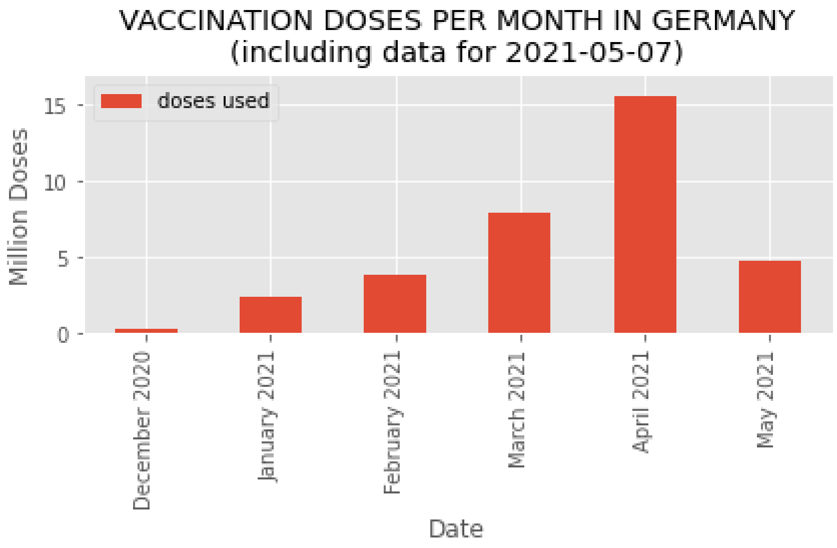
```
max_doses_monthly = max(doses_monthly['doses used'])
max_doses_monthly
doses_monthly['month'] = doses_monthly.index.strftime('%B')
doses_monthly['year'] =  doses_monthly.index.strftime('%Y')
doses_monthly['label'] = doses_monthly['month'] + ' ' + doses_monthly['year']
doses_monthly.drop(columns=['month', 'year'], inplace=True)
doses_monthly.set_index('label', inplace=True)
doses_monthly.tail(6)
```

Out[459…

label	doses used
December 2020	0.205001
January 2021	2.343091
February 2021	3.776292
March 2021	7.845951
April 2021	15.492020
May 2021	4.746485

In [460…

```
monthly_plot = doses_monthly.plot.bar(
    ylim=(0,math.ceil(max_doses_monthly) + 1),
    xlabel='Date',
    ylabel='Million Doses',
    title=f"VACCINATION DOSES PER MONTH IN GERMANY\n(including data for {last_update})")
```



In [461…

```
fig = monthly_plot.get_figure()
fig.savefig('img/monthly_doses_germany.png')
```

Vaccination Campaign Progress

In [462…

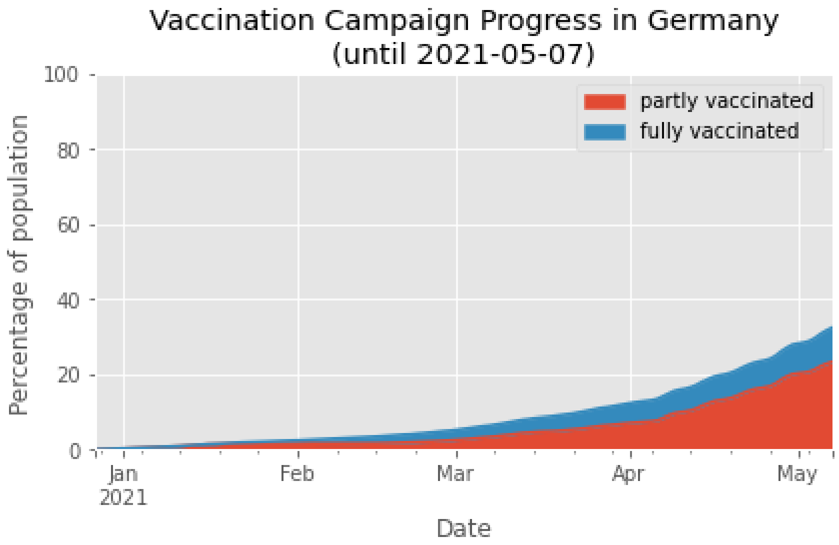
```
doses_cumulative = vaccinations.loc[ : , ['date', 'partly vaccinated', 'fully vaccinated']]
doses_cumulative.set_index('date', inplace=True)
doses_cumulative.tail(3)
```

Out[462…

	partly vaccinated	fully vaccinated
date		
2021-05-05	22.03	8.62
2021-05-06	22.67	8.87
2021-05-07	23.18	9.10

In [463…

```
doses_area_plot = doses_cumulative.plot.area(
    ylim=(0,100),
    xlabel='Date',
    ylabel='Percentage of population',
    title=f"Vaccination Campaign Progress in Germany\n(until {last_update})")
```



In [464…

```
fig = doses_area_plot.get_figure()
fig.savefig('img/vaccinations_germany_area_plot.png')
```

As of Today

In [465…

```
# get the last line of the data
current_state = doses_cumulative.iloc[-1]
current_state
```

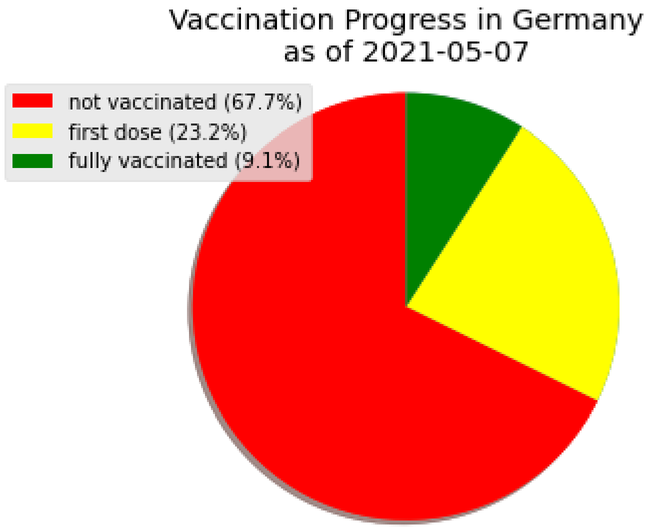
Out[465…

```
partly vaccinated    23.18
fully vaccinated      9.10
Name: 2021-05-07 00:00:00, dtype: float64
```

In [466…

```
percentage_not_vacc = 100 - current_state['partly vaccinated'] - current_state['fully vaccinated']
labels = [f"not vaccinated ({round(percentage_not_vacc, 1)}%)",
          f"first dose ({round(current_state['partly vaccinated'], 1)}%)",
          f"fully vaccinated ({round(current_state['fully vaccinated'], 1)}%)"]
colors = ['red', 'yellow', 'green']
sizes = [percentage_not_vacc,
         current_state['partly vaccinated'],
         current_state['fully vaccinated']]
fig1, ax1 = plt.subplots()
ax1.pie(sizes, shadow=True, startangle=90)
ax1.axis('equal')  # Equal aspect ratio ensures that pie is drawn as a circle.
patches, texts = plt.pie(sizes, colors=colors, startangle=90)
```

```
plt.legend(patches, labels, loc="best")
plt.title(f"Vaccination Progress in Germany\nas of {last_update}")
# plt.savefig must be before show()
# BEWARE plt.savefig must be in the same Jupyter code cell that creates the graph!
# See comment by ijoseph here:
# https://stackoverflow.com/questions/9012487/matplotlib-pyplot-savefig-outputs-blank-image
plt.savefig('img/vaccination_in_germany_pie.png', bbox_inches='tight')
plt.show()
```



Vaccines in Use

In [467…

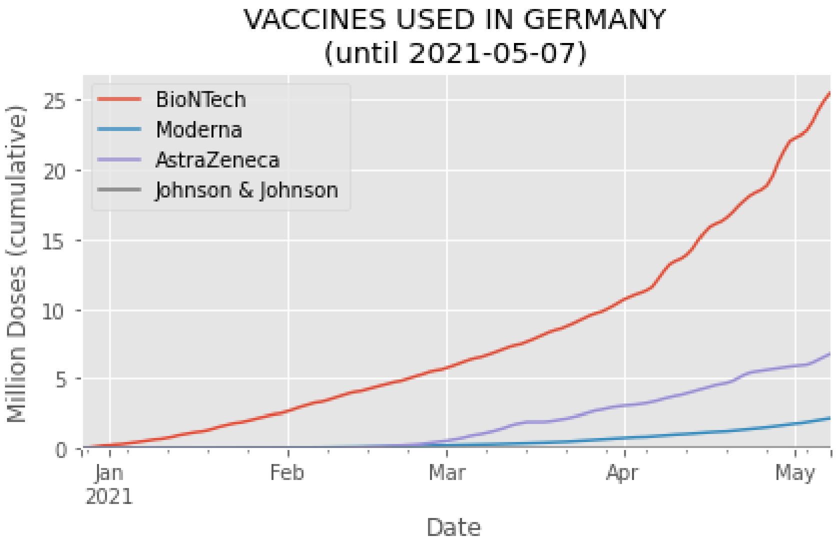
```
vaccine_use = vaccinations.loc[ : , ['date', 'dosen_biontech_kumulativ',
                                     'dosen_moderna_kumulativ',
                                     'dosen_astrazeneca_kumulativ',
                                     'dosen_johnson_kumulativ']]
# Rename columns
vaccine_use.columns = ['date', 'BioNTech', 'Moderna', 'AstraZeneca', 'Johnson & Johnson']
# make 'date' an index
vaccine_use.set_index('date', inplace=True)
# divide columns by 1 million
vaccine_use["BioNTech"] = vaccine_use["BioNTech"] / 1_000_000
vaccine_use["Moderna"] = vaccine_use["Moderna"] / 1_000_000
vaccine_use["AstraZeneca"] = vaccine_use["AstraZeneca"] / 1_000_000
vaccine_use["Johnson & Johnson"] = vaccine_use["Johnson & Johnson"] / 1_000_000
vaccine_use.tail(3)
```

Out[467…

date	BioNTech	Moderna	AstraZeneca	Johnson & Johnson
2021-05-05	24.270629	2.021713	6.345802	0.014180
2021-05-06	24.936747	2.098797	6.543104	0.016155
2021-05-07	25.480329	2.164352	6.746226	0.017933

In [468…

```
vaccines_used = vaccine_use.plot(
    # as it is cumulative, the last row must contain the single highest number
    ylim=(0,math.ceil(max(vaccine_use.iloc[-1]))+1),
    xlabel='Date',
    ylabel='Million Doses (cumulative)',
    title=f"VACCINES USED IN GERMANY\n(until {last_update})")
```



In [469…

```
fig = vaccines_used.get_figure()
fig.savefig('img/vaccines_used_in_germany.png')
```