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 [1]:

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

In [2]:

```
# 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 [3]:

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

Out[3]:

```
'2021-07-03'
```

Set Defaults

In [4]:

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

In [5]:

```
# 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 [6]:

```
population_germany = 83_200_000
```

Get and Transform Data

In [7]:

```
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 [8]:

```
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 [9]:

```
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 [10]:

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

Convert datatype of date column

In [11]:

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

Show Data

In [12]:

```
vaccinations.info()
```

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

```
RangeIndex: 187 entries, 0 to 186
Data columns (total 15 columns):
 #   Column                          Non-Null Count  Dtype         
---  ------                          --------------  -----         
 0   date                            187 non-null    datetime64[ns]
 1   dosen_kumulativ                 187 non-null    int64         
 2   dosen_differenz_zum_vortag      187 non-null    int64         
 3   dosen_erst_differenz_zum_vortag  187 non-null    int64         
 4   dosen_zweit_differenz_zum_vortag 187 non-null    int64         
 5   dosen_biontech_kumulativ        187 non-null    int64         
 6   dosen_moderna_kumulativ         187 non-null    int64         
 7   dosen_astrazeneca_kumulativ     187 non-null    int64         
 8   personen_erst_kumulativ         187 non-null    int64         
 9   personen_voll_kumulativ         187 non-null    int64         
 10  dosen_dim_kumulativ             187 non-null    int64         
 11  dosen_kbv_kumulativ             187 non-null    int64         
 12  dosen_johnson_kumulativ         187 non-null    int64         
 13  dosen_erst_kumulativ            187 non-null    int64         
 14  dosen_zweit_kumulativ           187 non-null    int64         
dtypes: datetime64[ns](1), int64(14)
memory usage: 22.0 KB
```

In [13]:

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

Out[13]:

	date	dosen_kumulativ	dosen_differenz_zum_vortag	dosen_erst_differenz_zum_vortag	dosen_zweit_differenz_zum_vortag	dosen_biontech_kumulati
184	2021-06-29	73865822	908772	373247	535525	5419471
185	2021-06-30	74854941	989119	429901	559218	5493724
186	2021-07-01	75781404	926463	424872	501591	5564090

Check Validity

In [14]:

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

In [15]:

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

```
Out[15]: 186    75781404
         Name: dosen_kumulativ, dtype: int64
```

```
In [16]: # 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 [17]: # Must be exactly 0
         doses_used - partially_vaccinated_people - (fully_vaccinated_people - johnson_doses) * 2 - johnson_doses ==  0
```

```
Out[17]: 186    True
         dtype: bool
```

Calculate columns

```
In [18]: vaccinations['partly vaccinated'] = round(
             (vaccinations['personen_erst_kumulativ'] - vaccinations['personen_voll_kumulativ']) * 100 / population_germany,
             2)
```

```
In [19]: vaccinations['fully vaccinated'] = round(
             vaccinations['personen_voll_kumulativ'] * 100 / population_germany,
             2)
```

```
In [20]: vaccinations.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 187 entries, 0 to 186
Data columns (total 17 columns):
 #   Column                          Non-Null Count  Dtype
---  ------                          --------------  -----
 0   date                            187 non-null    datetime64[ns]
 1   dosen_kumulativ                 187 non-null    int64
 2   dosen_differenz_zum_vortag      187 non-null    int64
 3   dosen_erst_differenz_zum_vortag 187 non-null    int64
 4   dosen_zweit_differenz_zum_vortag 187 non-null   int64
 5   dosen_biontech_kumulativ        187 non-null    int64
 6   dosen_moderna_kumulativ         187 non-null    int64
 7   dosen_astrazeneca_kumulativ     187 non-null    int64
 8   personen_erst_kumulativ         187 non-null    int64
 9   personen_voll_kumulativ         187 non-null    int64
 10  dosen_dim_kumulativ             187 non-null    int64
 11  dosen_kbv_kumulativ                  187 non-null    int64
 12  dosen_johnson_kumulativ              187 non-null    int64
 13  dosen_erst_kumulativ                 187 non-null    int64
 14  dosen_zweit_kumulativ                187 non-null    int64
 15  partly vaccinated                    187 non-null    float64
 16  fully vaccinated                     187 non-null    float64
dtypes: datetime64[ns](1), float64(2), int64(14)
memory usage: 25.0 KB
```

In [21]:

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

Out[21]:

	date	dosen_kumulativ	dosen_differenz_zum_vortag	dosen_erst_differenz_zum_vortag	dosen_zweit_differenz_zum_vortag	dosen_biontech_kumulati
184	2021-06-29	73865822	908772	373247	535525	5419471
185	2021-06-30	74854941	989119	429901	559218	5493724
186	2021-07-01	75781404	926463	424872	501591	5564090

Last Update

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

In [22]:

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

Out[22]:

```
'2021-07-01'
```

Doses Used

In [23]:

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

In [24]:

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

Doses Daily

In [25]:

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

Out[25]:

	doses used
date	
2021-07-01	0.926463

In [26]:

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

Out[26]:

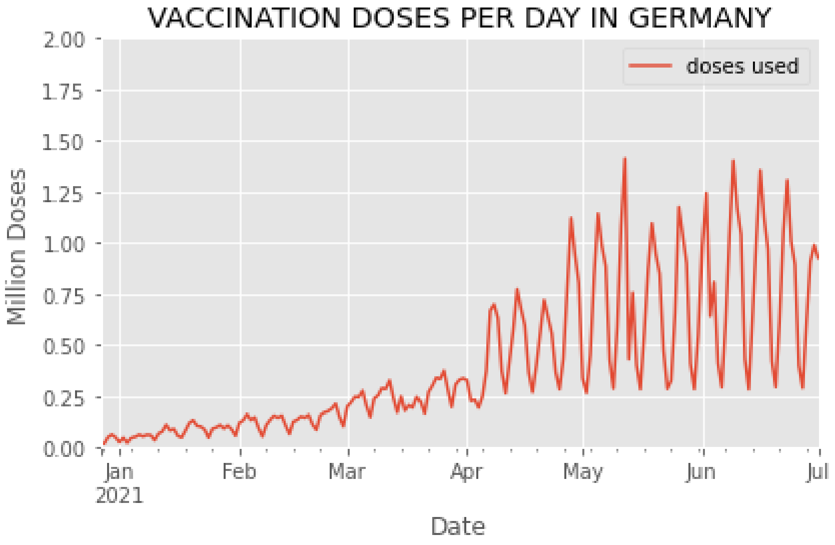
```
1.413646
```

In [27]:

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

Out[27]:

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



Doses per Weekday (in the last 6 weeks)

In [28]:

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

In [29]:

```
# 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-29-45013977109e>: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 [30]:

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

Out[30]:

	date	doses used	weekday
184	2021-06-29	0.908772	Tuesday
185	2021-06-30	0.989119	Wednesday
186	2021-07-01	0.926463	Thursday

In [31]:

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

In [32]:

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

Out[32]:

	doses used	weekday
184	0.908772	Tuesday
185	0.989119	Wednesday
186	0.926463	Thursday

In [33]:

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

Out[33]:

weekday	Friday	Monday	Saturday	Sunday	Thursday	Tuesday	Wednesday
182	NaN	NaN	NaN	0.288759	NaN	NaN	NaN
183	NaN	0.613821	NaN	NaN	NaN	NaN	NaN
184	NaN	NaN	NaN	NaN	NaN	0.908772	NaN
185	NaN	NaN	NaN	NaN	NaN	NaN	0.989119
186	NaN	NaN	NaN	NaN	0.926463	NaN	NaN

In [34]:

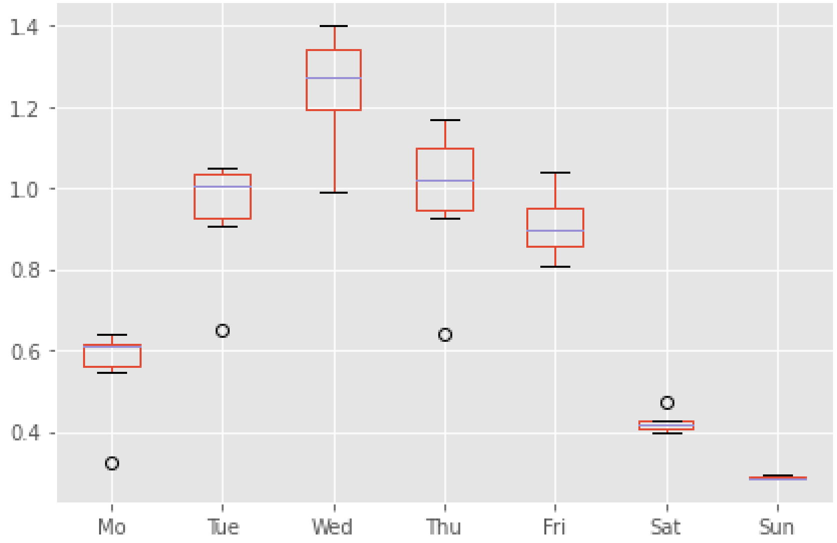
```
# Reorder the columns
pivot_table = pivot_table[['Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday', 'Saturday', 'Sunday']]
# Rename the columns
pivot_table.columns=['Mo', 'Tue', 'Wed', 'Thu', 'Fri', 'Sat', 'Sun']
pivot_table.tail()
```

Out[34]:

	Mo	Tue	Wed	Thu	Fri	Sat	Sun
182	NaN	NaN	NaN	NaN	NaN	NaN	0.288759
183	0.613821	NaN	NaN	NaN	NaN	NaN	NaN
184	NaN	0.908772	NaN	NaN	NaN	NaN	NaN
185	NaN	NaN	0.989119	NaN	NaN	NaN	NaN
186	NaN	NaN	NaN	0.926463	NaN	NaN	NaN

In [35]:

```
weekday_boxplot = pivot_table.boxplot()
```



In [36]:

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

Doses per Week

In [37]:

```
# 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[37]:

	million doses used
date	
2021-06-07	4.990707
2021-06-14	6.006792
2021-06-21	5.799164
2021-06-28	5.561382
2021-07-05	2.824354

In [38]:

```
# 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[38]:

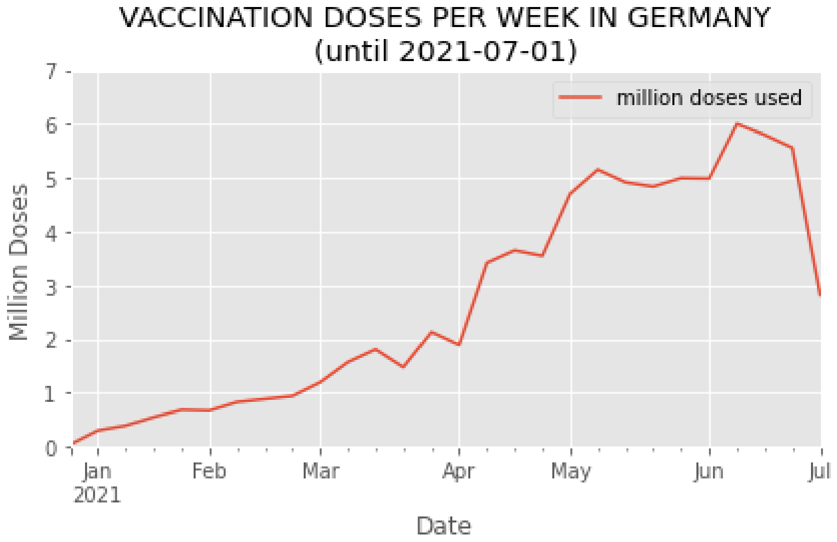
```
6.006792000000001
```

In [39]:

```
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[39]:

```
<AxesSubplot:title={'center':'VACCINATION DOSES PER WEEK IN GERMANY\n(until 2021-07-01)'}, xlabel='Date', ylabel='Milli
on Doses'>
```



Doses per Month

In [40]:

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

Out[40]:

	doses used
date	
2021-03-31	7.843539

	doses used
date	
2021-04-30	15.502145
2021-05-31	20.968321
2021-06-30	24.255936
2021-07-31	0.926463

In [41]:

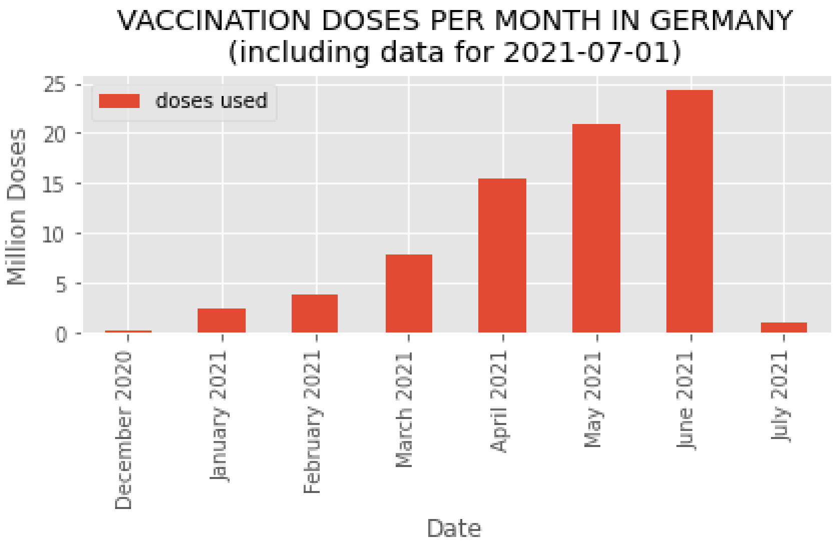
```
max_doses_monthly = max(doses_monthly['doses used'])
max_doses_monthly
doses_monthly['month'] = doses_monthly.index.strftime('%B')
doses_monthly['year'] =  doses_monthly.index.strftime('%Y')
doses_monthly['label'] = doses_monthly['month'] + ' ' + doses_monthly['year']
doses_monthly.drop(columns=['month',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

Out[41]:

	doses used
label	
February 2021	3.767732
March 2021	7.843539
April 2021	15.502145
May 2021	20.968321
June 2021	24.255936
July 2021	0.926463

In [42]:

```
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 [43]:
```
fig = monthly_plot.get_figure()
fig.savefig('img/monthly_doses_germany.png')
```

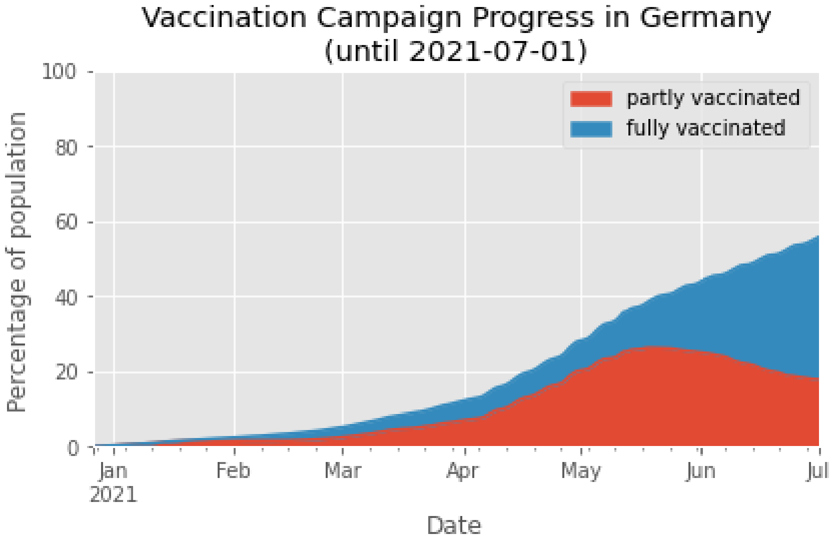
Vaccination Campaign Progress

In [44]:
```
doses_cumulative = vaccinations.loc[ : , ['date', 'partly vaccinated', 'fully vaccinated']]
doses_cumulative.set_index('date', inplace=True)
doses_cumulative.tail(3)
```

Out[44]:

	partly vaccinated	fully vaccinated
date		
2021-06-29	17.94	36.57
2021-06-30	17.81	37.24
2021-07-01	17.74	37.85

In [45]:
```
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 [46]: fig = doses_area_plot.get_figure()
         fig.savefig('img/vaccinations_germany_area_plot.png')
```

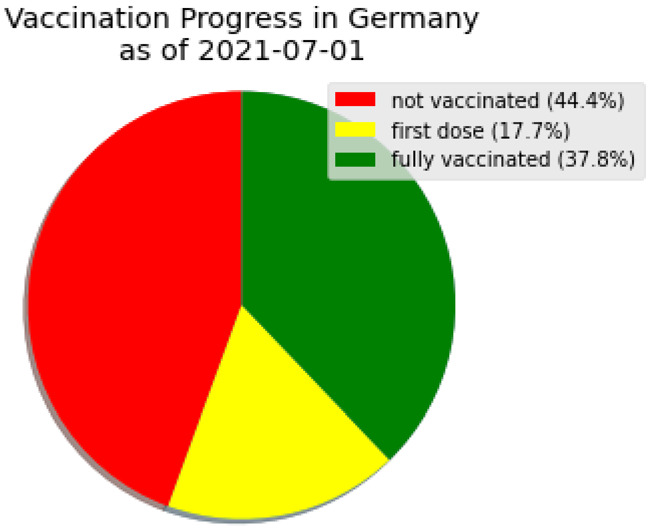
As of Today

```
In [47]: # get the last line of the data
         current_state = doses_cumulative.iloc[-1]
         current_state
```

```
Out[47]: partly vaccinated    17.74
         fully vaccinated     37.85
         Name: 2021-07-01 00:00:00, dtype: float64
```

```
In [48]: 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 [49]:

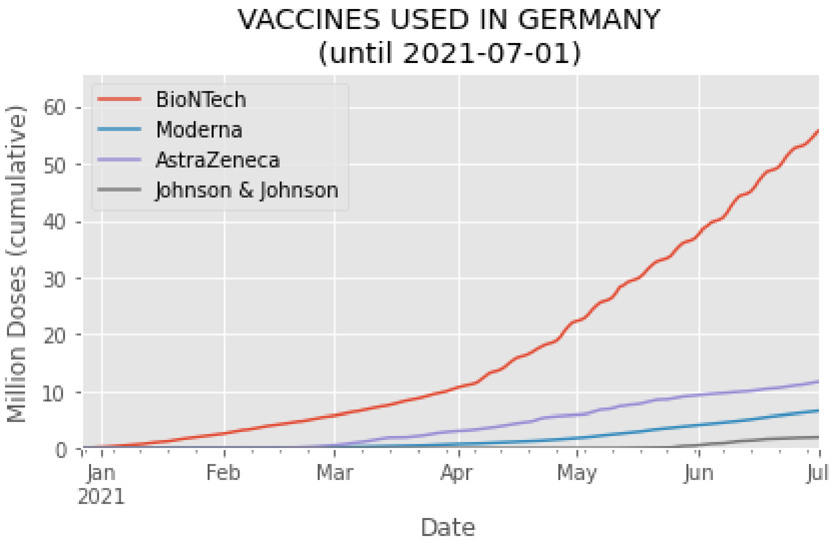
```
vaccine_use = vaccinations.loc[ : , ['date', 'dosen_biontech_kumulativ',
                                     'dosen_moderna_kumulativ',
                                     'dosen_astrazeneca_kumulativ',
                                     'dosen_johnson_kumulativ']]
# Rename columns
vaccine_use.columns = ['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[49]:

date	BioNTech	Moderna	AstraZeneca	Johnson & Johnson
2021-06-29	54.194714	6.378859	11.379271	1.912978
2021-06-30	54.937243	6.469857	11.513474	1.934367
2021-07-01	55.640907	6.545065	11.639900	1.955532

In [50]:

```python
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]))+10),
    xlabel='Date',
    ylabel='Million Doses (cumulative)',
    title=f"VACCINES USED IN GERMANY\n(until {last_update})")
```



In [51]:

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

Vaccination Centers versus Doctor’s Practices

In [52]:

```python
by_place = vaccinations.loc[ : , ['date', 'dosen_dim_kumulativ', 'dosen_kbv_kumulativ']]
```

```
by_place.columns = ['date', 'vaccination centers', 'practices']
```

In [53]:

```
by_place['vaccination centers daily'] = by_place['vaccination centers'].diff()
by_place['practices daily'] = by_place['practices'].diff()
```

In [54]:

```
by_place['percentage practices'] =  round(
    by_place['practices daily'] * 100 /
    (by_place['vaccination centers daily'] + by_place['practices daily']), 2)

by_place['percentage centers'] = 100 - by_place['percentage practices']
```

In [55]:

```
# make 'date' an index
by_place.set_index('date', inplace=True)
```

In [56]:

```
by_place
```

Out[56]:

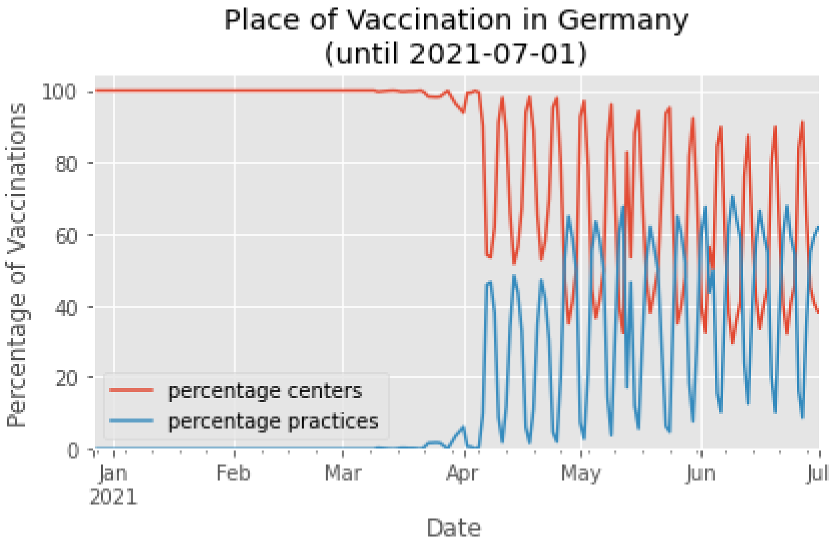
	vaccination centers	practices	vaccination centers daily	practices daily	percentage practices	percentage centers
date						
2020-12-27	23453	0	NaN	NaN	NaN	NaN
2020-12-28	41257	0	17804.0	0.0	0.00	100.00
2020-12-29	90591	0	49334.0	0.0	0.00	100.00
2020-12-30	153293	0	62702.0	0.0	0.00	100.00
2020-12-31	202486	0	49193.0	0.0	0.00	100.00
...	...	...	...	...	...	...
2021-06-27	45889179	26403445	262686.0	25220.0	8.76	91.24
2021-06-28	46286506	26617843	397327.0	214398.0	35.05	64.95
2021-06-29	46694636	27113831	408130.0	495988.0	54.86	45.14
2021-06-30	47094395	27697962	399759.0	584131.0	59.37	40.63
2021-07-01	47446289	28268207	351894.0	570245.0	61.84	38.16

187 rows × 6 columns

In [57]:

```
share = by_place.loc[ : , ['percentage centers', 'percentage practices']]
```

```
In [58]: vacc_shares = share.plot(
             # as it is cumulative, the last row must contain the single highest number
             ylim=(0, 105),  # above 100 to see the line
             xlabel='Date',
             ylabel='Percentage of Vaccinations',
             title=f"Place of Vaccination in Germany\n(until {last_update})")
```



```
In [59]: fig = vacc_shares.get_figure()
         fig.savefig('img/vaccinations_germany_by_place.png')
```

Other units of Time

```
In [60]: by_place_daily = by_place.loc[ : , ['vaccination centers daily', 'practices daily']]
         by_place_daily.columns = ['vaccination centers', 'practices']
         by_place_daily.reset_index(inplace=True)
```

Monthly

```
In [61]: by_place_monthly = by_place_daily.groupby(pd.Grouper(key='date',freq='M')).sum()
         by_place_monthly.tail()
```

Out[61]:

	vaccination centers	practices
date		

	vaccination centers	practices
date		
2021-03-31	7777305.0	66234.0
2021-04-30	10173005.0	5329140.0
2021-05-31	11484733.0	9483588.0
2021-06-30	11374352.0	12819000.0
2021-07-31	351894.0	570245.0

Scale:

In [62]:

```
by_place_monthly['vaccination centers'] = by_place_monthly['vaccination centers'] / 1_000_000
by_place_monthly['practices'] = by_place_monthly['practices'] / 1_000_000
```

Rename the columns

In [63]:

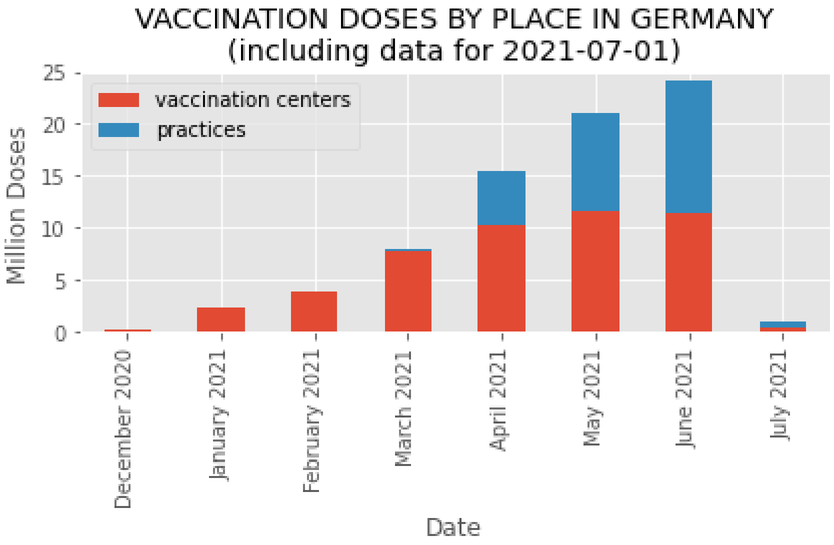
```
by_place_monthly['month'] = by_place_monthly.index.strftime('%B')
by_place_monthly['year'] =  by_place_monthly.index.strftime('%Y')
by_place_monthly['label'] = by_place_monthly['month'] + ' ' + by_place_monthly['year']
by_place_monthly.drop(columns=['month', 'year'], inplace=True)
by_place_monthly.set_index('label',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

Out[63]:

	vaccination centers	practices
label		
February 2021	3.767732	0.000000
March 2021	7.777305	0.066234
April 2021	10.173005	5.329140
May 2021	11.484733	9.483588
June 2021	11.374352	12.819000
July 2021	0.351894	0.570245

In [64]:

```
monthly_plot = by_place_monthly.plot.bar(
    stacked=True,
    ylim=(0, 25),
    xlabel='Date',
    ylabel='Million Doses',
    title=f"VACCINATION DOSES BY PLACE IN GERMANY\n(including data for {last_update})")
```



In [65]:

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