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 [66]:
```
# standard library
import datetime
import math
```

In [67]:
```
# 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 [68]:
```
today = datetime.datetime.today().strftime('%Y-%m-%d')
today
```

Out[68]:
```
'2021-07-06'
```

Set Defaults

In [69]:
```
# style like ggplot in R
plt.style.use('ggplot')
```

In [70]:
```
# 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 [71]:
```
population_germany = 83_200_000
```

Get and Transform Data

In [72]:
```
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 [73]:
```
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 [74]:
```
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 [75]:
```
vaccinations.drop(columns=['impf_quote_erst', 'impf_quote_voll'], inplace=True)
```

Convert datatype of date column

In [76]:
```
vaccinations.iloc[ : , [0]] = vaccinations.iloc[ : , [0]].apply(pd.to_datetime)
```

Show Data

In [77]:
```
vaccinations.info()
```

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

```
RangeIndex: 191 entries, 0 to 190
Data columns (total 15 columns):
 #   Column                          Non-Null Count  Dtype
---  ------                          --------------  -----
 0   date                            191 non-null    datetime64[ns]
 1   dosen_kumulativ                 191 non-null    int64
 2   dosen_differenz_zum_vortag      191 non-null    int64
 3   dosen_erst_differenz_zum_vortag 191 non-null    int64
 4   dosen_zweit_differenz_zum_vortag 191 non-null   int64
 5   dosen_biontech_kumulativ        191 non-null    int64
 6   dosen_moderna_kumulativ         191 non-null    int64
 7   dosen_astrazeneca_kumulativ     191 non-null    int64
 8   personen_erst_kumulativ         191 non-null    int64
 9   personen_voll_kumulativ         191 non-null    int64
 10  dosen_dim_kumulativ             191 non-null    int64
 11  dosen_kbv_kumulativ             191 non-null    int64
 12  dosen_johnson_kumulativ         191 non-null    int64
 13  dosen_erst_kumulativ            191 non-null    int64
 14  dosen_zweit_kumulativ           191 non-null    int64
dtypes: datetime64[ns](1), int64(14)
memory usage: 22.5 KB
```

In [78]:
```
vaccinations.tail(3)
```

Out[78]:

	date	dosen_kumulativ	dosen_differenz_zum_vortag	dosen_erst_differenz_zum_vortag	dosen_zweit_differenz_zum_vortag	dosen_biontech_kumulati
188	2021-07-03	77143635	367759	145559	222200	5664917
189	2021-07-04	77413178	269543	92171	177372	5682863
190	2021-07-05	77892414	479236	177738	301498	5717559

Check Validity

In [79]:
```
# get the last row / the newest available data
last_row = vaccinations.tail(1)
```

In [80]:
```
doses_used = last_row['dosen_kumulativ']
doses_used
```

Out[80]:
```
190    77892414
Name: dosen_kumulativ, dtype: int64
```

In [81]:
```
# 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 [82]:
```
# Must be exactly 0
doses_used - partially_vaccinated_people - (fully_vaccinated_people - johnson_doses) * 2 - johnson_doses ==  0
```

Out[82]:
```
190    True
dtype: bool
```

Calculate columns

In [83]:
```
vaccinations['partly vaccinated'] = round(
    (vaccinations['personen_erst_kumulativ'] - vaccinations['personen_voll_kumulativ']) * 100 / population_germany,
    2)
```

In [84]:
```
vaccinations['fully vaccinated'] = round(
    vaccinations['personen_voll_kumulativ'] * 100 / population_germany,
    2)
```

In [85]:
```
vaccinations.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 191 entries, 0 to 190
Data columns (total 17 columns):
 #   Column                            Non-Null Count  Dtype
---  ------                            --------------  -----
 0   date                              191 non-null    datetime64[ns]
 1   dosen_kumulativ                   191 non-null    int64
 2   dosen_differenz_zum_vortag        191 non-null    int64
 3   dosen_erst_differenz_zum_vortag   191 non-null    int64
 4   dosen_zweit_differenz_zum_vortag  191 non-null    int64
 5   dosen_biontech_kumulativ          191 non-null    int64
 6   dosen_moderna_kumulativ           191 non-null    int64
 7   dosen_astrazeneca_kumulativ       191 non-null    int64
 8   personen_erst_kumulativ           191 non-null    int64
 9   personen_voll_kumulativ           191 non-null    int64
 10  dosen_dim_kumulativ               191 non-null    int64
```

```
 11  dosen_kbv_kumulativ               191 non-null    int64
 12  dosen_johnson_kumulativ           191 non-null    int64
 13  dosen_erst_kumulativ              191 non-null    int64
 14  dosen_zweit_kumulativ             191 non-null    int64
 15  partly vaccinated                 191 non-null    float64
 16  fully vaccinated                  191 non-null    float64
dtypes: datetime64[ns](1), float64(2), int64(14)
memory usage: 25.5 KB
```

In [86]:
```
vaccinations.tail(3)
```

Out[86]:

	date	dosen_kumulativ	dosen_differenz_zum_vortag	dosen_erst_differenz_zum_vortag	dosen_zweit_differenz_zum_vortag	dosen_biontech_kumulati
188	2021-07-03	77143635	367759	145559	222200	5664917
189	2021-07-04	77413178	269543	92171	177372	5682863
190	2021-07-05	77892414	479236	177738	301498	5717559

Last Update

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

In [87]:
```
last_update = vaccinations.loc[vaccinations.index[-1], "date"].strftime('%Y-%m-%d')
last_update
```

Out[87]:
```
'2021-07-05'
```

Doses Used

In [88]:
```
doses = vaccinations.loc[ : , ['date', 'dosen_differenz_zum_vortag']]
# Rename columns
doses.columns = ['date', 'doses used']
```

In [89]:
```
# Scale number of doses as millions
doses['doses used'] = doses['doses used'] / 1_000_000
```

Doses Daily

In [90]:
```
doses_daily = doses.set_index('date', inplace=False)
doses_daily.tail(1)
```

Out[90]:

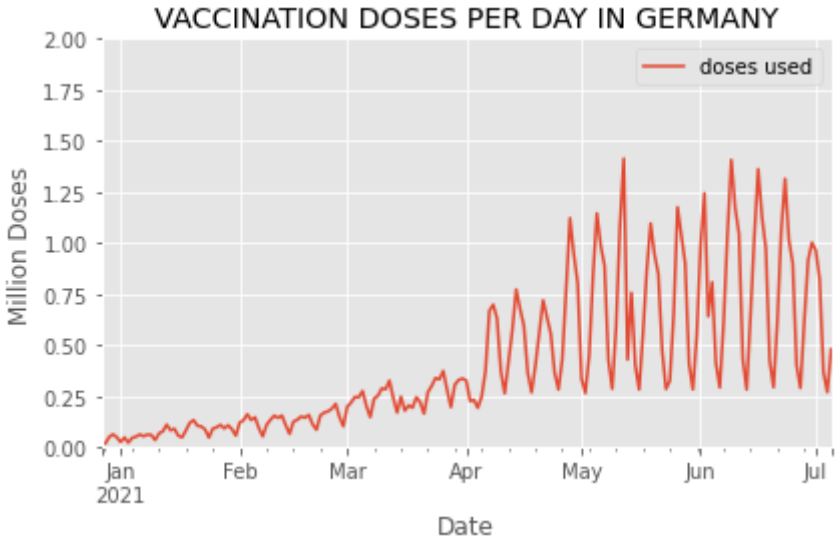
date	doses used
2021-07-05	0.479236

In [91]:
```
# What is the highest number of doses used in a day?
max_doses_daily = max(doses_daily['doses used'])
max_doses_daily
```

Out[91]: 1.413819

In [92]:
```
doses_daily.plot(
    ylim=(0,math.ceil(max_doses_daily)),
    xlabel='Date',
    ylabel='Million Doses',
    title='VACCINATION DOSES PER DAY IN GERMANY')
```

Out[92]: <AxesSubplot:title={'center':'VACCINATION DOSES PER DAY IN GERMANY'}, xlabel='Date', ylabel='Million Doses'>



Doses per Weekday (in the last 6 weeks)

In [93]:
```
last_6_weeks = doses.tail(42)
```

In [94]:
```
# 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-94-45013977109e>: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 [95]:
```
# check:
last_6_weeks.tail(3)
```

Out[95]:

	date	doses used	weekday
188	2021-07-03	0.367759	Saturday
189	2021-07-04	0.269543	Sunday
190	2021-07-05	0.479236	Monday

In [96]:
```
# drop the date column
last_6_weeks = last_6_weeks.drop(labels=['date'], axis=1)
```

In [97]:
```
#last_6_weeks.set_index('weekday', inplace=True)
last_6_weeks.tail(3)
```

Out[97]:

	doses used	weekday
188	0.367759	Saturday
189	0.269543	Sunday
190	0.479236	Monday

In [98]:
```
pivot_table =last_6_weeks.pivot(columns='weekday', values='doses used')
pivot_table.tail()
```

Out[98]:

weekday	Friday	Monday	Saturday	Sunday	Thursday	Tuesday	Wednesday
186	NaN	NaN	NaN	NaN	0.96364	NaN	NaN
187	0.823183	NaN	NaN	NaN	NaN	NaN	NaN
188	NaN	NaN	0.367759	NaN	NaN	NaN	NaN
189	NaN	NaN	NaN	0.269543	NaN	NaN	NaN
190	NaN	0.479236	NaN	NaN	NaN	NaN	NaN

In [99]:

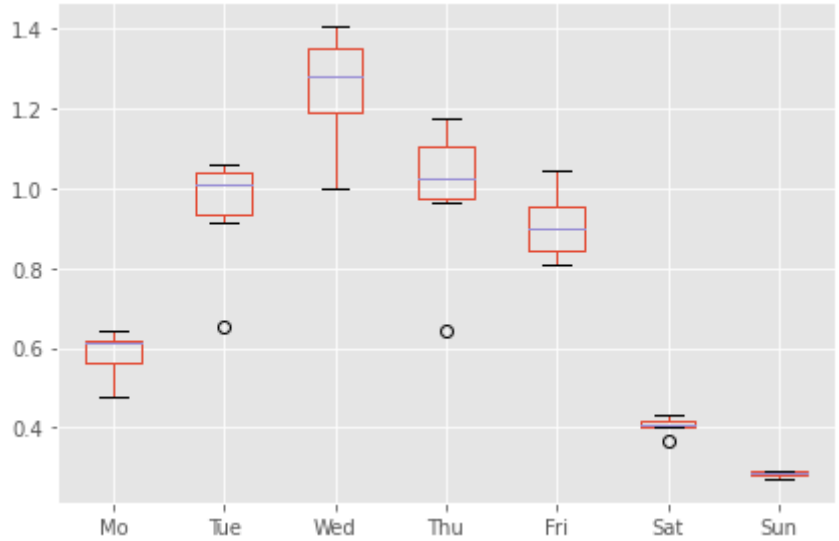
```
# Reorder the columns
pivot_table = pivot_table[['Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday', 'Saturday', 'Sunday']]
# Rename the columns
pivot_table.columns=['Mo', 'Tue', 'Wed', 'Thu', 'Fri', 'Sat', 'Sun']
pivot_table.tail()
```

Out[99]:

	Mo	Tue	Wed	Thu	Fri	Sat	Sun
186	NaN	NaN	NaN	0.96364	NaN	NaN	NaN
187	NaN	NaN	NaN	NaN	0.823183	NaN	NaN
188	NaN	NaN	NaN	NaN	NaN	0.367759	NaN
189	NaN	NaN	NaN	NaN	NaN	NaN	0.269543
190	0.479236	NaN	NaN	NaN	NaN	NaN	NaN

In [100…

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



In [101…
```
fig = weekday_boxplot.get_figure()
fig.savefig('img/weekday_boxplot.png')
```

Doses per Week

In [102…
```
# 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[102…

date	million doses used
2021-06-07	4.992039
2021-06-14	6.027193
2021-06-21	5.829297
2021-06-28	5.595919
2021-07-05	4.821469

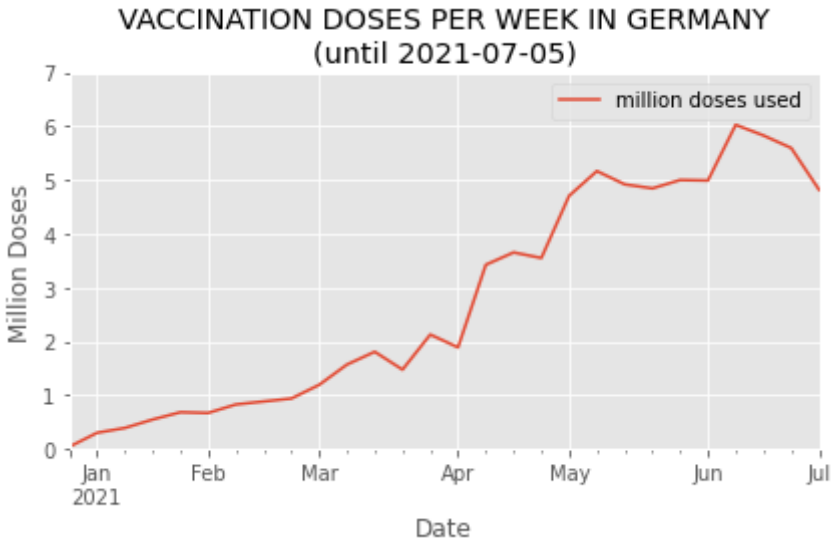
In [103…
```
# What is the highest number of doses used in a week?
```

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

Out[103…] 6.0271930000000005

In [104…]
```
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[104…] <AxesSubplot:title={'center':'VACCINATION DOSES PER WEEK IN GERMANY\n(until 2021-07-05)'}, xlabel='Date', ylabel='Million Doses'>



Doses per Month

In [105…]
```
# M = month end frequency
doses_monthly = doses.groupby(pd.Grouper(key='date',freq='M')).sum()
doses_monthly.tail()
```

Out[105…]

	doses used
date	
2021-03-31	7.845374

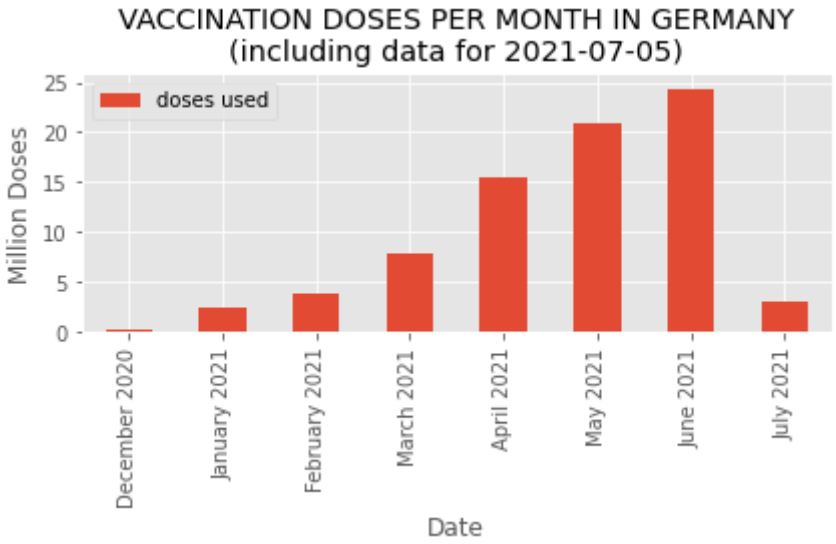
date	doses used
2021-04-30	15.510076
2021-05-31	20.986025
2021-06-30	24.362556
2021-07-31	2.903361

In [106…
```
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[106…

label	doses used
February 2021	3.767672
March 2021	7.845374
April 2021	15.510076
May 2021	20.986025
June 2021	24.362556
July 2021	2.903361

In [107…
```
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 [108…
```
fig = monthly_plot.get_figure()
fig.savefig('img/monthly_doses_germany.png')
```

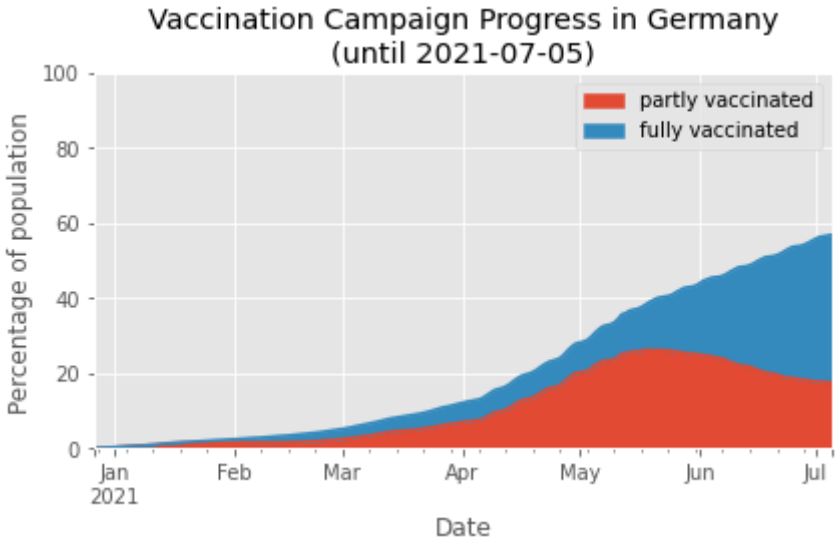
Vaccination Campaign Progress

In [109…
```
doses_cumulative = vaccinations.loc[ : , ['date', 'partly vaccinated', 'fully vaccinated']]
doses_cumulative.set_index('date', inplace=True)
doses_cumulative.tail(3)
```

Out[109…

date	partly vaccinated	fully vaccinated
2021-07-03	17.67	38.72
2021-07-04	17.58	38.94
2021-07-05	17.45	39.30

In [110…
```
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 [111…
```
fig = doses_area_plot.get_figure()
fig.savefig('img/vaccinations_germany_area_plot.png')
```

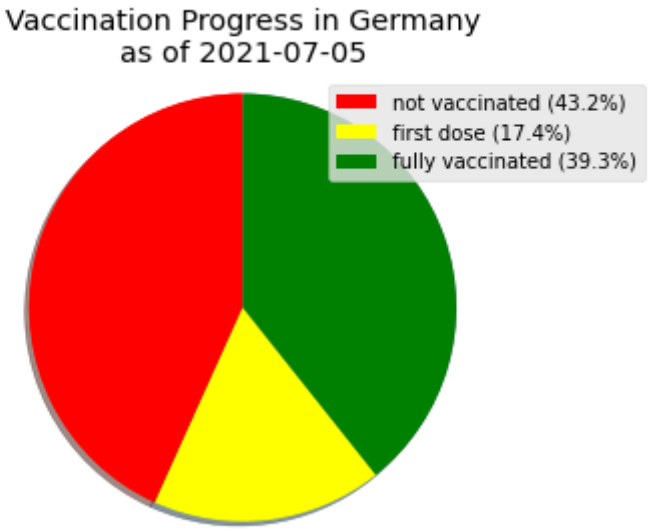
As of Today

In [112…
```
# get the last line of the data
current_state = doses_cumulative.iloc[-1]
current_state
```

Out[112…
```
partly vaccinated    17.45
fully vaccinated     39.30
Name: 2021-07-05 00:00:00, dtype: float64
```

In [113…
```
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 [114…

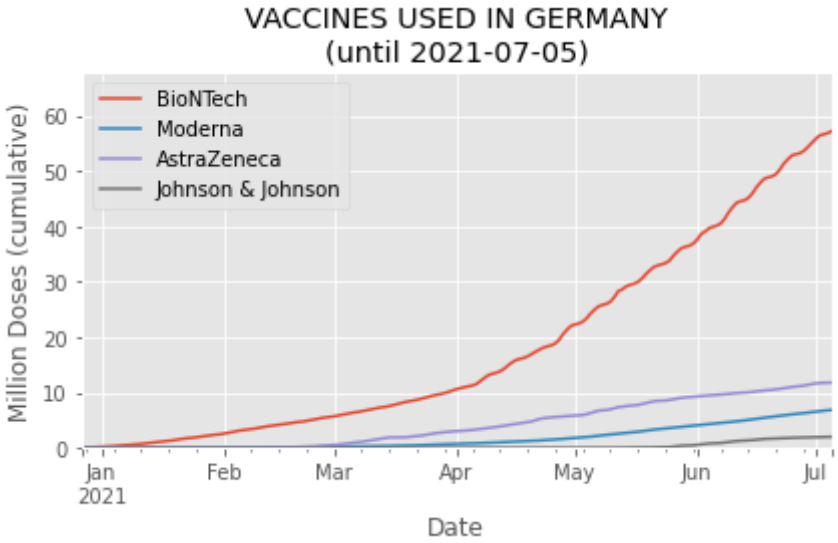
```
vaccine_use = vaccinations.loc[ : , ['date', 'dosen_biontech_kumulativ',
                                     'dosen_moderna_kumulativ',
                                     'dosen_astrazeneca_kumulativ',
                                     'dosen_johnson_kumulativ']]
# Rename columns
vaccine_use.columns = ['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[114…

date	BioNTech	Moderna	AstraZeneca	Johnson & Johnson
2021-07-03	56.649170	6.730319	11.768373	1.995773
2021-07-04	56.828632	6.797720	11.782825	2.004001
2021-07-05	57.175595	6.878939	11.821152	2.016728

In [115…

```
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 [116…

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

Vaccination Centers versus Doctor’s Practices

In [117…

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

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

In [118…
```
by_place['vaccination centers daily'] = by_place['vaccination centers'].diff()
by_place['practices daily'] = by_place['practices'].diff()
```

In [119…
```
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 [120…
```
# make 'date' an index
by_place.set_index('date', inplace=True)
```

In [121…
```
by_place
```

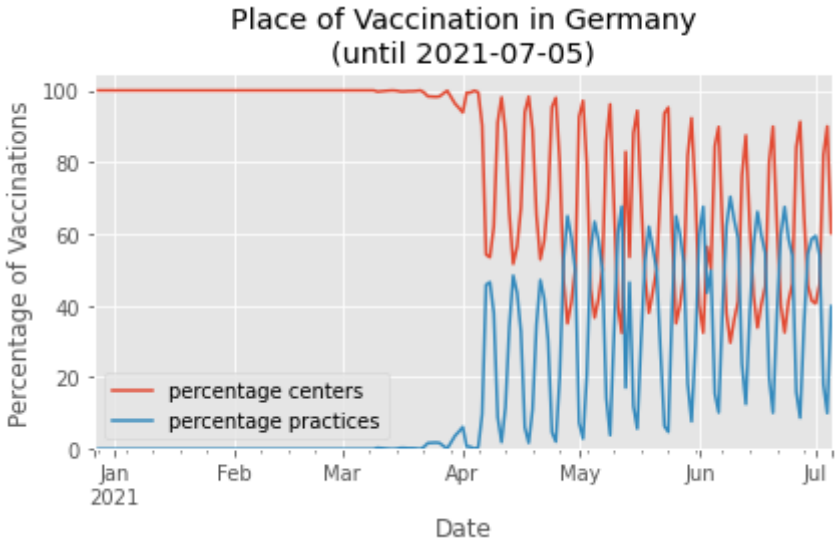
Out[121…

date	vaccination centers	practices	vaccination centers daily	practices daily	percentage practices	percentage centers
2020-12-27	23454	0	NaN	NaN	NaN	NaN
2020-12-28	41259	0	17805.0	0.0	0.00	100.00
2020-12-29	90593	0	49334.0	0.0	0.00	100.00
2020-12-30	153300	0	62707.0	0.0	0.00	100.00
2020-12-31	202493	0	49193.0	0.0	0.00	100.00
...	...	...	...	...	...	...
2021-07-01	47617578	28268207	389071.0	570245.0	59.44	40.56
2021-07-02	47995624	28709971	378046.0	441764.0	53.89	46.11
2021-07-03	48296386	28776252	300762.0	66281.0	18.06	81.94
2021-07-04	48538410	28803194	242024.0	26942.0	10.02	89.98
2021-07-05	48825591	28993153	287181.0	189959.0	39.81	60.19

191 rows × 6 columns

In [122…
```
share = by_place.loc[ : , ['percentage centers', 'percentage practices']]
```

In [123…
```
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 [124…
```
fig = vacc_shares.get_figure()
fig.savefig('img/vaccinations_germany_by_place.png')
```

Other units of Time

In [125…
```
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 [126…
```
by_place_monthly = by_place_daily.groupby(pd.Grouper(key='date',freq='M')).sum()
by_place_monthly.tail()
```

Out[126…

date	vaccination centers	practices

date	vaccination centers	practices
2021-03-31	7779140.0	66234.0
2021-04-30	10180936.0	5329140.0
2021-05-31	11502437.0	9483588.0
2021-06-30	11480972.0	12819000.0
2021-07-31	1597084.0	1295191.0

Scale:

In [127…
```
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

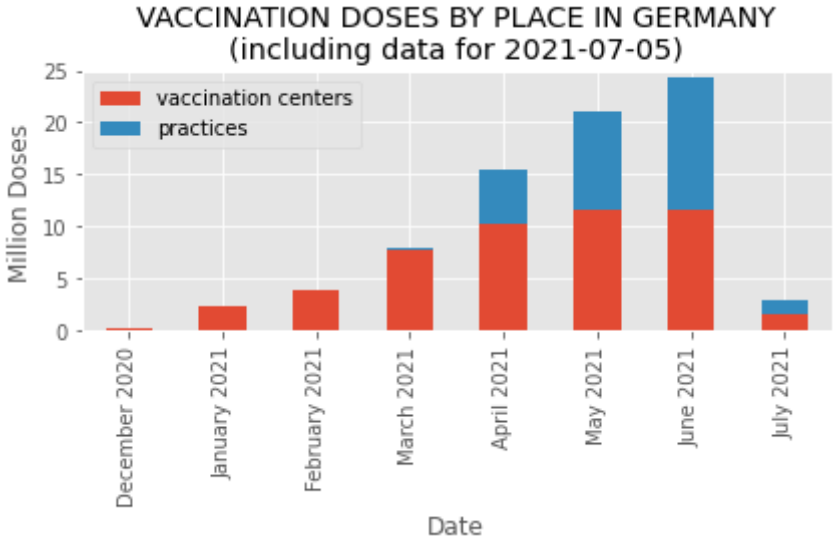
In [128…
```
by_place_monthly['month'] = by_place_monthly.index.strftime('%B')
by_place_monthly['year'] =  by_place_monthly.index.strftime('%Y')
by_place_monthly['label'] = by_place_monthly['month'] + ' ' + by_place_monthly['year']
by_place_monthly.drop(columns=['month', 'year'], inplace=True)
by_place_monthly.set_index('label', inplace=True)
by_place_monthly.tail(6)
```

Out[128…

label	vaccination centers	practices
February 2021	3.767672	0.000000
March 2021	7.779140	0.066234
April 2021	10.180936	5.329140
May 2021	11.502437	9.483588
June 2021	11.480972	12.819000
July 2021	1.597084	1.295191

In [129…
```
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 [130…

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