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]:

```
'2021-11-07'
```

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

List all columns:

In [8]:
```
vaccinations.columns
```

Out[8]:
```
Index(['date', 'dosen_kumulativ', 'dosen_biontech_kumulativ',
       'dosen_biontech_erst_kumulativ', 'dosen_biontech_zweit_kumulativ',
       'dosen_biontech_dritt_kumulativ', 'dosen_moderna_kumulativ',
       'dosen_moderna_erst_kumulativ', 'dosen_moderna_zweit_kumulativ',
       'dosen_moderna_dritt_kumulativ', 'dosen_astra_kumulativ',
       'dosen_astra_erst_kumulativ', 'dosen_astra_zweit_kumulativ',
       'dosen_astra_dritt_kumulativ', 'dosen_johnson_kumulativ',
       'dosen_johnson_erst_kumulativ', 'dosen_johnson_zweit_kumulativ',
       'dosen_johnson_dritt_kumulativ', 'dosen_erst_kumulativ',
       'dosen_zweit_kumulativ', 'dosen_dritt_kumulativ',
       'dosen_differenz_zum_vortag', 'dosen_erst_differenz_zum_vortag',
       'dosen_zweit_differenz_zum_vortag', 'dosen_dritt_differenz_zum_vortag',
       'dosen_vollstaendig_differenz_zum_vortag', 'personen_erst_kumulativ',
       'personen_voll_kumulativ', 'personen_auffrisch_kumulativ',
       'impf_quote_erst', 'impf_quote_voll', 'dosen_dim_kumulativ',
       'dosen_kbv_kumulativ', 'indikation_alter_dosen',
       'indikation_beruf_dosen', 'indikation_medizinisch_dosen',
       'indikation_pflegeheim_dosen', 'indikation_alter_erst',
       'indikation_beruf_erst', 'indikation_medizinisch_erst',
       'indikation_pflegeheim_erst', 'indikation_alter_voll',
       'indikation_beruf_voll', 'indikation_medizinisch_voll',
       'indikation_pflegeheim_voll'],
      dtype='object')
```

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

In [9]:
```
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 [10]:

```
more_cols_to_drop = ['dosen_biontech_erst_kumulativ', 'dosen_biontech_zweit_kumulativ',
                    'dosen_moderna_erst_kumulativ', 'dosen_moderna_zweit_kumulativ',
                    'dosen_astra_erst_kumulativ', 'dosen_astra_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 [11]:

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

Convert datatype of date column

In [12]:

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

Show Data

In [13]:

```
vaccinations.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 314 entries, 0 to 313
Data columns (total 25 columns):
 #   Column                           Non-Null Count  Dtype
---  ------                           --------------  -----
 0   date                             314 non-null    datetime64[ns]
 1   dosen_kumulativ                  314 non-null    int64
 2   dosen_biontech_kumulativ         314 non-null    int64
 3   dosen_biontech_dritt_kumulativ   314 non-null    int64
 4   dosen_moderna_kumulativ          314 non-null    int64
 5   dosen_moderna_dritt_kumulativ    314 non-null    int64
 6   dosen_astra_kumulativ            314 non-null    int64
 7   dosen_astra_dritt_kumulativ      314 non-null    int64
 8   dosen_johnson_kumulativ          314 non-null    int64
 9   dosen_johnson_erst_kumulativ     314 non-null    int64
 10  dosen_johnson_zweit_kumulativ    314 non-null    int64
 11  dosen_johnson_dritt_kumulativ    314 non-null    int64
 12  dosen_erst_kumulativ             314 non-null    int64
 13  dosen_zweit_kumulativ            314 non-null    int64
 14  dosen_dritt_kumulativ            314 non-null    int64
 15  dosen_differenz_zum_vortag       314 non-null    int64
 16  dosen_erst_differenz_zum_vortag         314 non-null    int64
 17  dosen_zweit_differenz_zum_vortag        314 non-null    int64
 18  dosen_dritt_differenz_zum_vortag        314 non-null    int64
 19  dosen_vollstaendig_differenz_zum_vortag 314 non-null    int64
 20  personen_erst_kumulativ                 314 non-null    int64
 21  personen_voll_kumulativ                 314 non-null    int64
 22  personen_auffrisch_kumulativ            314 non-null    int64
 23  dosen_dim_kumulativ                     314 non-null    int64
 24  dosen_kbv_kumulativ                     314 non-null    int64
dtypes: datetime64[ns](1), int64(24)
memory usage: 61.5 KB
```

In [14]:

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

Out[14]:

	date	dosen_kumulativ	dosen_biontech_kumulativ	dosen_biontech_dritt_kumulativ	dosen_moderna_kumulativ	dosen_moderna_dritt_kumulativ	do
311	2021-11-03	112550798	86718162	2283853	9808117	88837	
312	2021-11-04	112837962	86994453	2443983	9815394	94048	
313	2021-11-05	113066234	87212765	2574415	9821822	98913	

3 rows × 25 columns

Check Validity

In [15]:

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

In [16]:

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

Out[16]:

```
313    113066234
Name: dosen_kumulativ, dtype: int64
```

In [17]:

```
# 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 [18]:

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

Out[18]:

```
313    2674527
dtype: int64
```

In [19]:

```
result_substraction ==  0
```

Out[19]:

```
313    False
dtype: bool
```

Calculate columns

In [20]:

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

In [21]:

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

In [22]:

```
vaccinations.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 314 entries, 0 to 313
Data columns (total 27 columns):
 #   Column                                 Non-Null Count  Dtype         
---  ------                                 --------------  -----         
 0   date                                   314 non-null    datetime64[ns]
 1   dosen_kumulativ                        314 non-null    int64         
 2   dosen_biontech_kumulativ               314 non-null    int64         
 3   dosen_biontech_dritt_kumulativ         314 non-null    int64         
 4   dosen_moderna_kumulativ                314 non-null    int64         
 5   dosen_moderna_dritt_kumulativ          314 non-null    int64         
 6   dosen_astra_kumulativ                  314 non-null    int64         
 7   dosen_astra_dritt_kumulativ            314 non-null    int64         
 8   dosen_johnson_kumulativ                314 non-null    int64         
 9   dosen_johnson_erst_kumulativ           314 non-null    int64         
 10  dosen_johnson_zweit_kumulativ          314 non-null    int64         
 11  dosen_johnson_dritt_kumulativ          314 non-null    int64         
 12  dosen_erst_kumulativ                    314 non-null    int64
 13  dosen_zweit_kumulativ                   314 non-null    int64
 14  dosen_dritt_kumulativ                   314 non-null    int64
 15  dosen_differenz_zum_vortag              314 non-null    int64
 16  dosen_erst_differenz_zum_vortag         314 non-null    int64
 17  dosen_zweit_differenz_zum_vortag        314 non-null    int64
 18  dosen_dritt_differenz_zum_vortag        314 non-null    int64
 19  dosen_vollstaendig_differenz_zum_vortag 314 non-null    int64
 20  personen_erst_kumulativ                 314 non-null    int64
 21  personen_voll_kumulativ                 314 non-null    int64
 22  personen_auffrisch_kumulativ            314 non-null    int64
 23  dosen_dim_kumulativ                     314 non-null    int64
 24  dosen_kbv_kumulativ                     314 non-null    int64
 25  partly vaccinated                       314 non-null    float64
 26  fully vaccinated                        314 non-null    float64
dtypes: datetime64[ns](1), float64(2), int64(24)
memory usage: 66.4 KB
```

In [23]:

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

Out[23]:

	date	dosen_kumulativ	dosen_biontech_kumulativ	dosen_biontech_dritt_kumulativ	dosen_moderna_kumulativ	dosen_moderna_dritt_kumulativ
311	2021-11-03	112550798	86718162	2283853	9808117	88837
312	2021-11-04	112837962	86994453	2443983	9815394	94048
313	2021-11-05	113066234	87212765	2574415	9821822	98913

3 rows × 27 columns

Last Update

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

In [24]:

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

Out[24]:

```
'2021-11-05'
```

Doses Used

In [25]:

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

In [26]:

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

Doses Daily

In [27]:

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

Out[27]:

	doses used
date	
2021-11-05	0.228272

In [28]:

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

Out[28]:

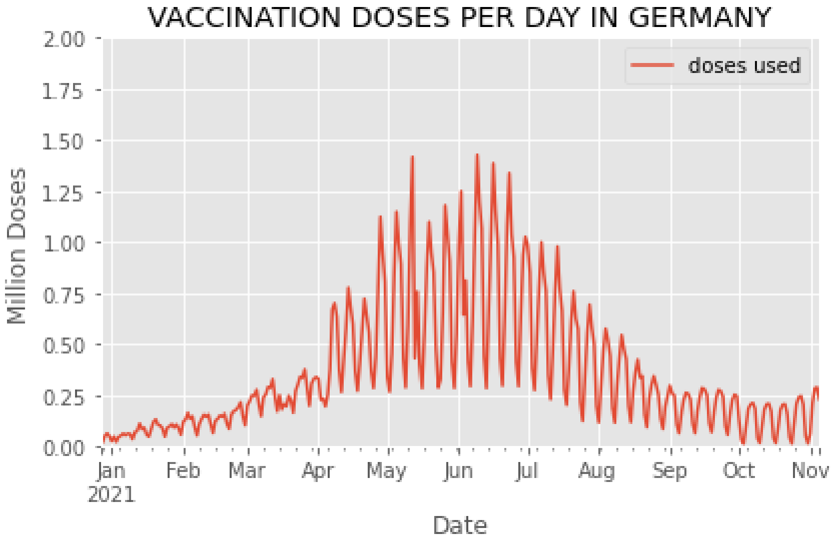
```
1.428416
```

In [29]:

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

Out[29]:

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



Doses per Weekday (in the last 6 weeks)

In [30]:
```
last_6_weeks = doses.tail(42)
```

In [31]:
```
# 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-31-45013977109e>: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 [32]:
```
# check:
last_6_weeks.tail(3)
```

Out[32]:

	date	doses used	weekday
311	2021-11-03	0.282927	Wednesday
312	2021-11-04	0.287164	Thursday
313	2021-11-05	0.228272	Friday

In [33]:
```
# drop the date column
last_6_weeks = last_6_weeks.drop(labels=['date'], axis=1)
```

In [34]:
```
#last_6_weeks.set_index('weekday', inplace=True)
last_6_weeks.tail(3)
```

Out[34]:
```
     doses used    weekday
311    0.282927  Wednesday
312    0.287164   Thursday
313    0.228272     Friday
```

In [35]:
```
pivot_table =last_6_weeks.pivot(columns='weekday', values='doses used')
pivot_table.tail()
```

Out[35]:
```
weekday    Friday    Monday  Saturday  Sunday  Thursday   Tuesday  Wednesday
    309       NaN  0.062063       NaN     NaN       NaN       NaN        NaN
    310       NaN       NaN       NaN     NaN       NaN  0.208674        NaN
    311       NaN       NaN       NaN     NaN       NaN       NaN   0.282927
    312       NaN       NaN       NaN     NaN  0.287164       NaN        NaN
    313  0.228272       NaN       NaN     NaN       NaN       NaN        NaN
```

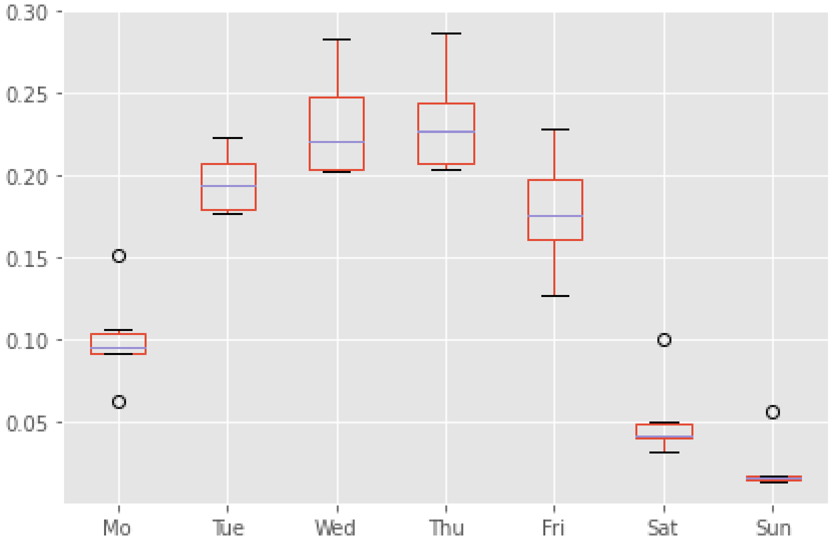
In [36]:
```
# Reorder the columns
pivot_table = pivot_table[['Monday', 'Tuesday', 'Wednesday', 'Thursday', 'Friday', 'Saturday', 'Sunday']]
# Rename the columns
pivot_table.columns=['Mo', 'Tue', 'Wed', 'Thu', 'Fri', 'Sat', 'Sun']
pivot_table.tail()
```

Out[36]:
```
           Mo       Tue       Wed       Thu  Fri  Sat  Sun
309  0.062063       NaN       NaN       NaN  NaN  NaN  NaN
310       NaN  0.208674       NaN       NaN  NaN  NaN  NaN
311       NaN       NaN  0.282927       NaN  NaN  NaN  NaN
312       NaN       NaN       NaN  0.287164  NaN  NaN  NaN
```

	Mo	Tue	Wed	Thu	Fri	Sat	Sun
313	NaN	NaN	NaN	NaN	0.228272	NaN	NaN

In [37]:

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



In [38]:

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

Doses per Week

In [39]:

```
# 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[39]:

	million doses used
date	
2021-10-11	0.932776
2021-10-18	0.908431

	million doses used
date	
2021-10-25	0.905592
2021-11-01	1.020849
2021-11-08	1.007037

In [40]:

```
# 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[40]:

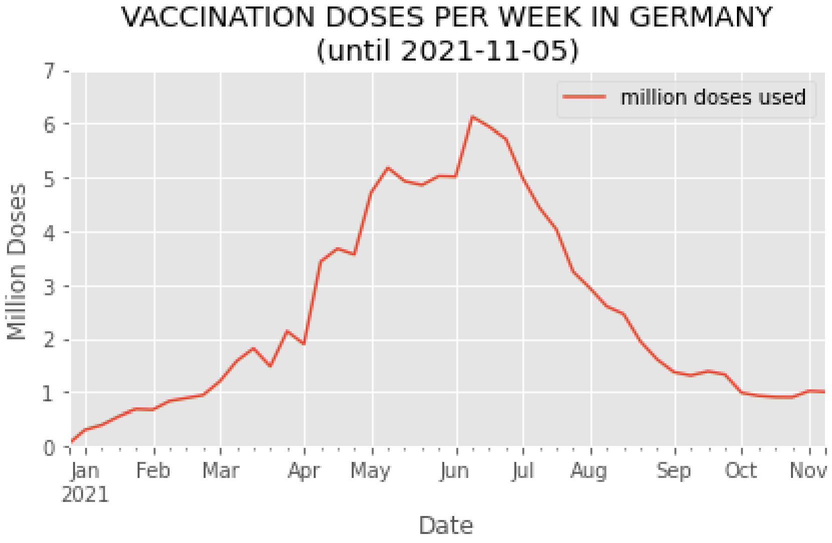
```
6.125437
```

In [41]:

```
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[41]:

```
<AxesSubplot:title={'center':'VACCINATION DOSES PER WEEK IN GERMANY\n(until 2021-11-05)'}, xlabel='Date', ylabel='Milli
on Doses'>
```



Doses per Month

In [42]:

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

Out[42]:

	doses used
date	
2021-07-31	17.266882
2021-08-31	9.271630
2021-09-30	5.877683
2021-10-31	3.973742
2021-11-30	1.069100

In [43]:

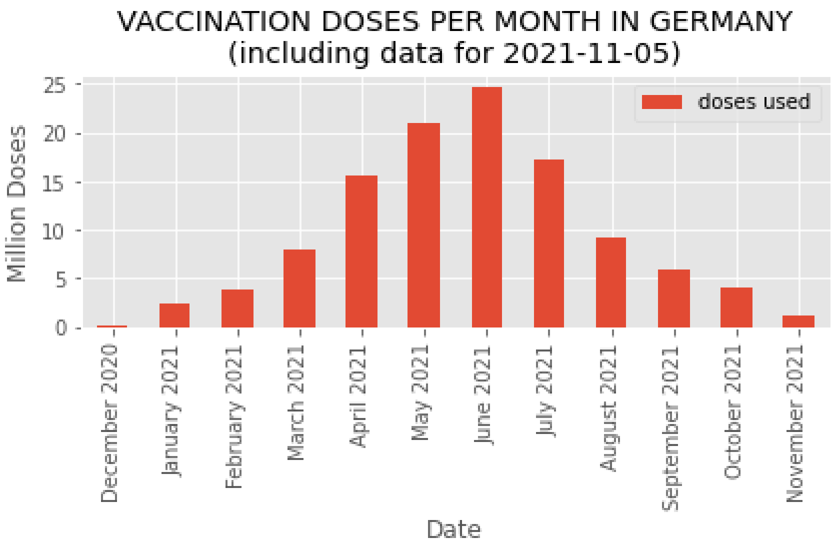
```
max_doses_monthly = max(doses_monthly['doses used'])
max_doses_monthly
doses_monthly['month'] = doses_monthly.index.strftime('%B')
doses_monthly['year'] =  doses_monthly.index.strftime('%Y')
doses_monthly['label'] = doses_monthly['month'] + ' ' + doses_monthly['year']
doses_monthly.drop(columns=['month',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

Out[43]:

	doses used
label	
June 2021	24.761480
July 2021	17.266882
August 2021	9.271630
September 2021	5.877683
October 2021	3.973742
November 2021	1.069100

In [44]:

```
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 [45]:

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

Vaccination Campaign Progress

In [46]:

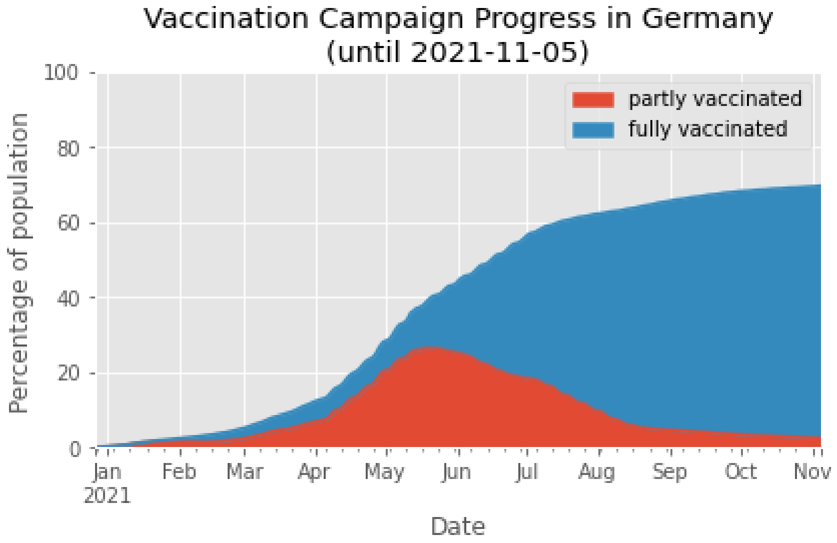
```
doses_cumulative = vaccinations.loc[ : , ['date', 'partly vaccinated', 'fully vaccinated']]
doses_cumulative.set_index('date', inplace=True)
doses_cumulative.tail(3)
```

Out[46]:

	partly vaccinated	fully vaccinated
date		
2021-11-03	2.63	66.89
2021-11-04	2.60	66.98
2021-11-05	2.58	67.05

In [47]:

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

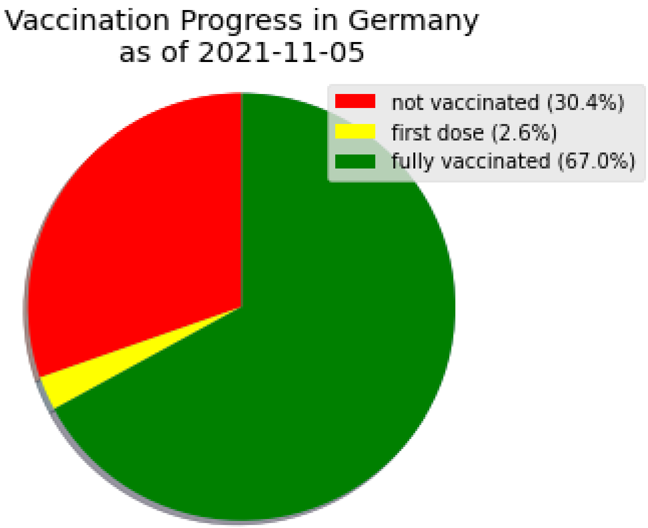
As of Today

```
In [49]: # get the last line of the data
         current_state = doses_cumulative.iloc[-1]
         current_state
```

```
Out[49]: partly vaccinated     2.58
         fully vaccinated     67.05
         Name: 2021-11-05 00:00:00, dtype: float64
```

```
In [50]: 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 [51]:

```
vaccinations.columns
```

Out[51]:

```
Index(['date', 'dosen_kumulativ', 'dosen_biontech_kumulativ',
       'dosen_biontech_dritt_kumulativ', 'dosen_moderna_kumulativ',
       'dosen_moderna_dritt_kumulativ', 'dosen_astra_kumulativ',
       'dosen_astra_dritt_kumulativ', 'dosen_johnson_kumulativ',
       'dosen_johnson_erst_kumulativ', 'dosen_johnson_zweit_kumulativ',
       'dosen_johnson_dritt_kumulativ', 'dosen_erst_kumulativ',
       'dosen_zweit_kumulativ', 'dosen_dritt_kumulativ',
       'dosen_differenz_zum_vortag', 'dosen_erst_differenz_zum_vortag',
       'dosen_zweit_differenz_zum_vortag', 'dosen_dritt_differenz_zum_vortag',
       'dosen_vollstaendig_differenz_zum_vortag', 'personen_erst_kumulativ',
       'personen_voll_kumulativ', 'personen_auffrisch_kumulativ',
       'dosen_dim_kumulativ', 'dosen_kbv_kumulativ', 'partly vaccinated',
       'fully vaccinated'],
      dtype='object')
```

In [52]:

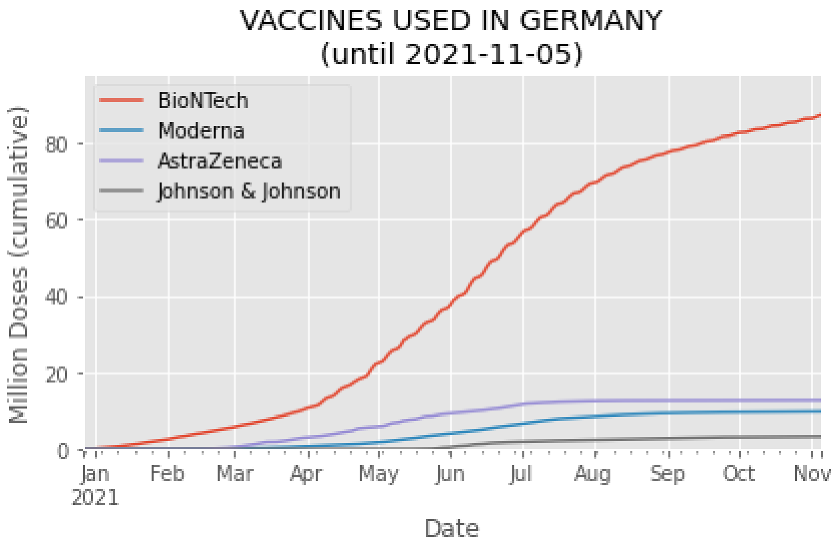
```
vaccine_use = vaccinations.loc[ : , ['date', 'dosen_biontech_kumulativ',
                                     'dosen_moderna_kumulativ',
                                     'dosen_astra_kumulativ',
                                     'dosen_johnson_kumulativ']]
# Rename columns
vaccine_use.columns = ['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[52]:

	BioNTech	Moderna	AstraZeneca	Johnson & Johnson
date				
2021-11-03	86.718162	9.808117	12.707866	3.316653
2021-11-04	86.994453	9.815394	12.708143	3.319972
2021-11-05	87.212765	9.821822	12.708271	3.323376

In [53]:

```
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 [54]:

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