In [1]:

```python
import pandas as pd
import matplotlib.pyplot as plt
import numpy as np
import seaborn as sns
%matplotlib inline

# set the font globally
plt.rcParams["axes.edgecolor"] = "black"
plt.rcParams["axes.linewidth"] = 2
# update the overall font size
plt.rcParams.update({'font.size':9})

from sklearn.tree import DecisionTreeClassifier
from sklearn.ensemble import RandomForestClassifier
from xgboost import XGBClassifier
from sklearn.model_selection import GridSearchCV, train_test_split
from sklearn import tree
from sklearn.metrics import accuracy_score, confusion_matrix, classification_report, mean_squared_error

from sklearn.tree import DecisionTreeRegressor
from sklearn.ensemble import RandomForestRegressor
from xgboost import XGBRegressor
```

Question 1

Load Data

Load the dataset. Separate 70% of the rows to be training data and the rest to be testing data.

In [2]:

```python
# Load data
data = pd.read_csv('transfusion.csv')
```

In [3]:

```python
data.head()
```

Out[3]:

	Recency (months)	Frequency (times)	Monetary (c.c. blood)	Time (months)	whether he/she donated blood in March 2007
0	2	50	12500	98	1
1	0	13	3250	28	1
2	1	16	4000	35	1
3	2	20	5000	45	1
4	1	24	6000	77	0

In [4]:

```python
# Define features and target variable
X = data.drop('whether he/she donated blood in March 2007', axis=1)
y = data['whether he/she donated blood in March 2007']
```

In [5]:

```python
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=42)
```

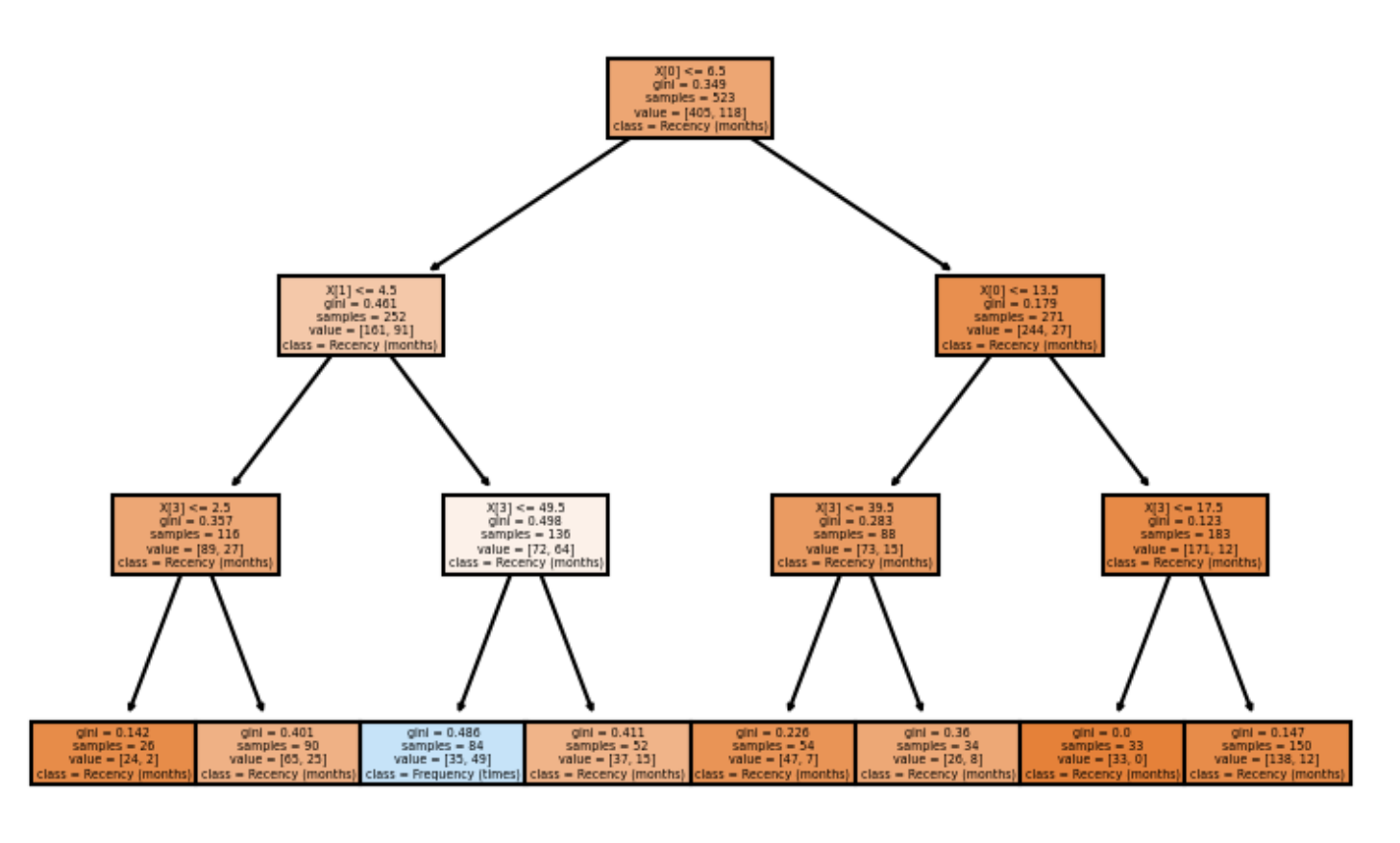
Decision Tree

Use the training data to fit a decision tree model where the dependent is the last column variable 'whether he/she donated blood in March 2007'. Then produce a plot of the fitted tree. Afterwards find the accuracy of the predictions on the testing data

In [6]:

```python
# Define hyperparameter grid
param_grid = {'criterion': ['gini', 'entropy'],
              'max_depth': [3, 5, 7, 10]}

# Fit decision tree model using grid search
model = DecisionTreeClassifier()
grid_search = GridSearchCV(model, param_grid, cv=10, n_jobs = -1)
grid_search.fit(X_train, y_train)

# Print best hyperparameters
print(grid_search.best_params_)

# Plot decision tree with best hyperparameters
plt.figure(figsize=(6,4), dpi=150)
model = grid_search.best_estimator_
plot = tree.plot_tree(model, filled=True, class_names = X_train.columns)
plt.tight_layout()
plt.savefig("figs/DT_Tree.png")

# Evaluate model on test set
y_pred = model.predict(X_test)
accuracy = accuracy_score(y_test, y_pred)
print(confusion_matrix(y_test, y_pred))
print(classification_report(y_test, y_pred))
print(f'Test set accuracy: {accuracy:.5f}')
```

```
{'criterion': 'gini', 'max_depth': 3}
[[153  12]
 [ 37  23]]
              precision    recall  f1-score   support

           0       0.81      0.93      0.86       165
           1       0.66      0.38      0.48        60

    accuracy                           0.78       225
   macro avg       0.73      0.66      0.67       225
weighted avg       0.77      0.78      0.76       225

Test set accuracy: 0.78222
```



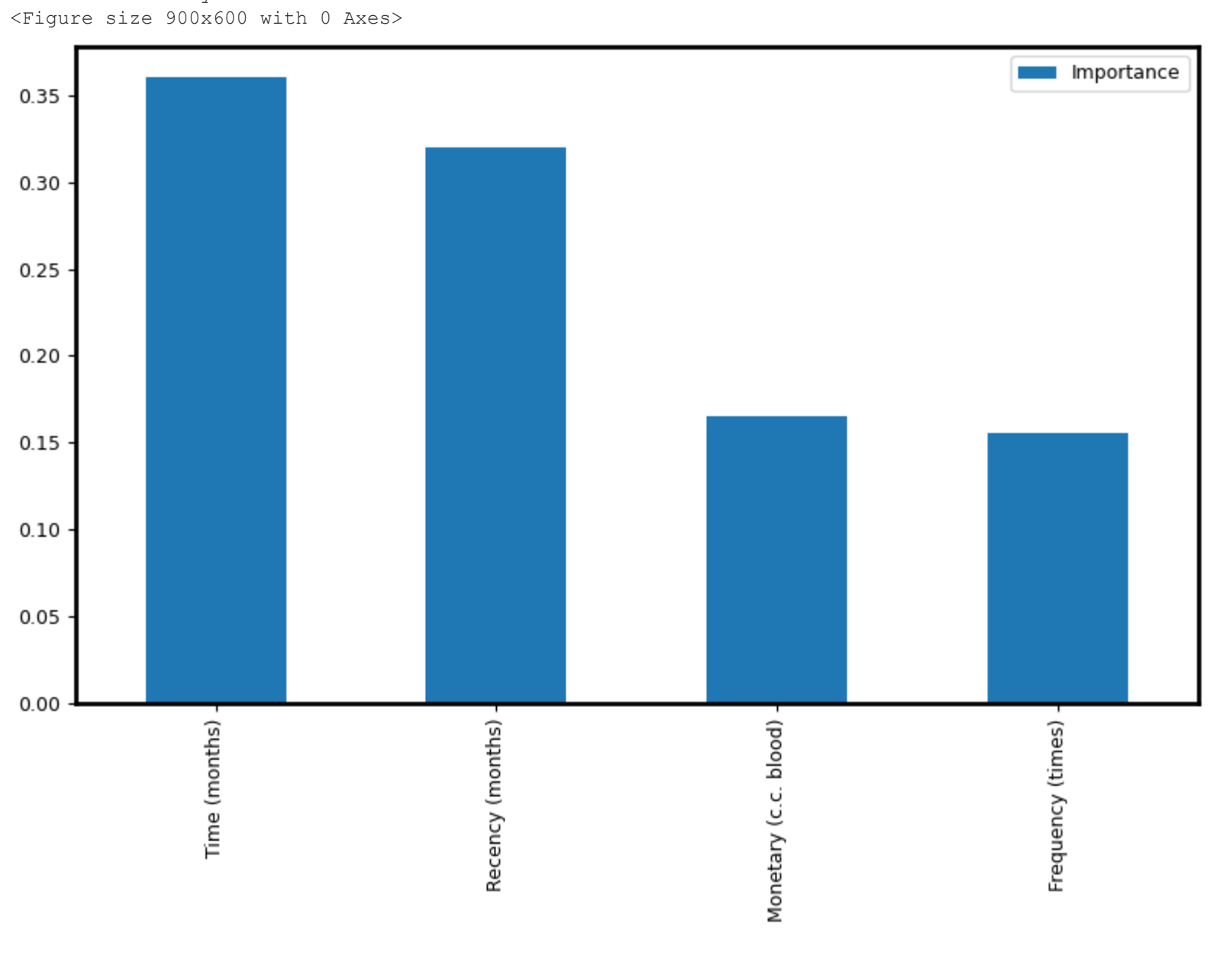
Random Forest

Use the training data to fit a random forests model where the dependent is the last column variable 'whether he/she donated blood in March 2007'. Then produce a plot of the variable importance. Afterwards find the accuracy of the predictions on the testing data.

In [7]:

```python
# Define hyperparameter grid
param_grid = {'n_estimators': [10, 50, 100],
              'max_depth': [3, 5, 7]}

# Fit random forest model using grid search
model = RandomForestClassifier()
grid_search = GridSearchCV(model, param_grid, cv=10, n_jobs = -1)
grid_search.fit(X_train, y_train)

# Print best hyperparameters
print(grid_search.best_params_)

# Plot feature importance of best model
plt.figure(figsize=(6,4), dpi = 150)
model = grid_search.best_estimator_
feat_importances = pd.DataFrame(model.feature_importances_, index=X_train.columns, columns=["Importance"])
feat_importances.sort_values(by='Importance', ascending=False, inplace=True)
feat_importances.plot(kind='bar', figsize=(8,6))
plt.tight_layout()
plt.savefig("figs/RF_FeatureImportance.svg")

# Evaluate model on test set
y_pred = model.predict(X_test)
accuracy = accuracy_score(y_test, y_pred)
print(confusion_matrix(y_test, y_pred))
print(classification_report(y_test, y_pred))
print(f'Test set accuracy: {accuracy:.5f}')
```

```
{'max_depth': 7, 'n_estimators': 50}
[[151  14]
 [ 44  16]]
              precision    recall  f1-score   support

           0       0.77      0.92      0.84       165
           1       0.53      0.27      0.36        60

    accuracy                           0.74       225
   macro avg       0.65      0.59      0.60       225
weighted avg       0.71      0.74      0.71       225

Test set accuracy: 0.74222
<Figure size 900x600 with 0 Axes>
```



XGBoost

Use the training data to fit a XGBoost model where the dependent is the last column variable 'whether he/she donated blood in March 2007'. Afterwards find the accuracy of the predictions on the testing data

In [8]:

```python
# Define hyperparameter grid
param_grid = {'learning_rate': [0.1, 0.5, 1],
              'max_depth': [3, 5, 7]}

# Fit XGBoost model using grid search
model = XGBClassifier()
grid_search = GridSearchCV(model, param_grid, cv=10, n_jobs = -1)
grid_search.fit(X_train, y_train)

# Print best hyperparameters
print(grid_search.best_params_)

# Evaluate model on test set
model = grid_search.best_estimator_
y_pred = model.predict(X_test)
accuracy = accuracy_score(y_test, y_pred)
print(confusion_matrix(y_test, y_pred))
print(classification_report(y_test, y_pred))
print(f'Test set accuracy: {accuracy:.5f}')
```

```
/opt/conda/envs/rapids/lib/python3.8/site-packages/sklearn/model_selection/_search.py:922: UserWarning: One or more of the test scores are non-finite: [       nan        nan 0.75921626 0.76306241 0.74764151 0.74386792
 0.74764151 0.73232946 0.73428882]
  warnings.warn(
{'learning_rate': 0.5, 'max_depth': 3}
[[145  20]
 [ 43  17]]
              precision    recall  f1-score   support

           0       0.77      0.88      0.82       165
           1       0.46      0.28      0.35        60

    accuracy                           0.72       225
   macro avg       0.62      0.58      0.59       225
weighted avg       0.69      0.72      0.70       225

Test set accuracy: 0.72000
```

Discussion

Given the previous results, how do you gauge and compare the performances of the various models? (mention the accuracies)

Given the small Size of the Dataset, purely using accuracy scores would not give a proper assessment of the models. All models performed well in classifying the negative case but struggled with the postive case. While there were not many Instances where true negatives were being classified as positive (as indicated by the precision score), there were many false negatives (extremely low recall). This could be both due to an imballance in the dataset along a small sample size as well. Overall, the Decision Tree performed the best as it had the highest recall of positives.

Question 2

Load Data

Load the dataset. Produce a training and testing dataset on a 70-30 split (randomized selections)

In [9]:

```python
# Load data
data = pd.read_csv('LifeExpectancy.csv', delimiter = ";")
```

In [10]:

```python
data.head()
```

Out[10]:

	Country	Year	Continent	Least Developed	Life Expectancy	Population	CO2 emissions	Health expenditure	Electric power consumption	Forest area	GDP per capita	Individuals using the Internet
0	Albania	2000	Europe	False	73.955	3089027	1.026213	7.233370	1414.703784	28.076642	3860.804627	0.114097
1	Albania	2001	Europe	False	74.288	3060173	1.055496	7.139524	1449.647413	28.123248	4299.546493	0.325798
2	Albania	2002	Europe	False	74.579	3051010	1.232379	6.909341	1351.230796	28.169854	4661.402695	0.390081
3	Albania	2003	Europe	False	74.828	3039616	1.338985	7.063490	1578.165919	28.216460	5000.049363	0.971900
4	Albania	2004	Europe	False	75.039	3026939	1.404059	6.773372	1469.264539	28.263066	5427.732662	2.420388

In [11]:

```python
X = data.iloc[:, 5:]
y = data.iloc[:, 4:5]
```

In [12]:

```python
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_state=42)
```

Modeling

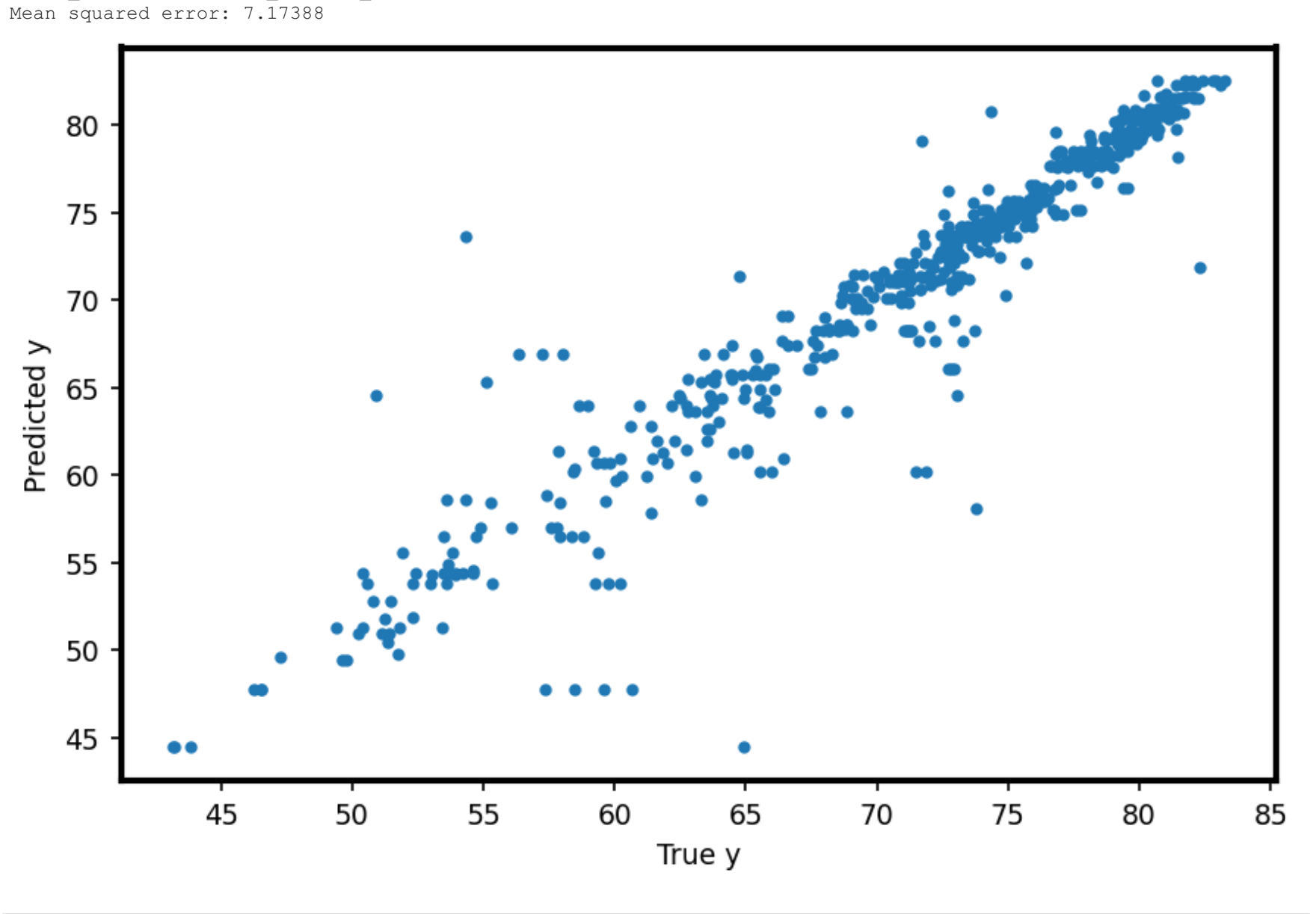
Decision Tree

Produce a decision tree model to predict the life expectancy, excluding the first 4 columns (Country/Year/Continent/Least Developed), using the training data, and find the MSE on the testing data.

In [13]:

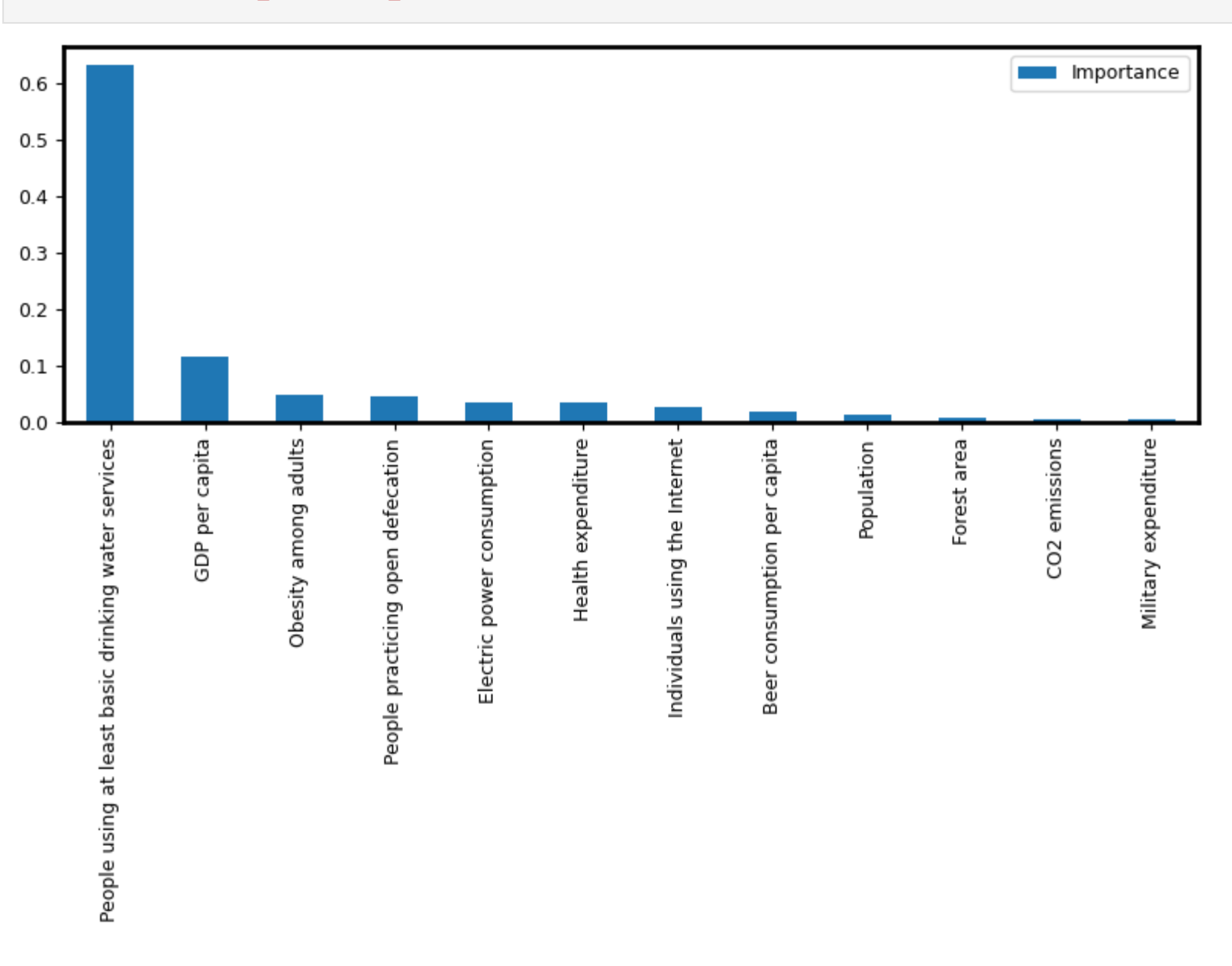
```python
# Define hyperparameter grid
param_grid = {'max_depth': np.arange(3, 31, 2),
              'min_samples_leaf': [5, 10, 20]}

# Fit decision tree regression model using grid search
model = DecisionTreeRegressor()
grid_search = GridSearchCV(model, param_grid, cv=10, n_jobs = -1)
grid_search.fit(X_train, y_train)

# Print best hyperparameters
print(grid_search.best_params_)

# Make predictions on test set
model = grid_search.best_estimator_
y_pred = model.predict(X_test)

# Calculate MSE
mse = mean_squared_error(y_test, y_pred)

# Print MSE
print(f'Mean squared error: {mse:.5f}')

# Plot true and predicted y values
plt.figure(figsize=(6,4), dpi = 150)
plt.plot(y_test, y_pred, '.')
plt.xlabel('True y')
plt.ylabel('Predicted y')
plt.tight_layout()
plt.savefig("figs/DT_Regression.svg")
```

```
{'max_depth': 15, 'min_samples_leaf': 5}
Mean squared error: 7.17388
```



In [14]:

```python
feat_importances = pd.DataFrame(model.feature_importances_, index=X_train.columns, columns=["Importance"])
feat_importances.sort_values(by='Importance', ascending=False, inplace=True)
feat_importances.plot(kind='bar', figsize=(8,6))
plt.tight_layout()
plt.savefig("figs/DT_Regression_FeatureImportance.svg")
```



Random Forest

Produce a random forest model to predict the life expectancy excluding the first 4 columns (Country/Year/Continent/Least Developed), using the training data, and find the MSE on the testing data.

In [15]:

```python
# Define hyperparameter grid
param_grid = {'n_estimators': [10, 50, 100],
              'max_depth': np.arange(3, 31, 2)}

# Fit random forest regression model using grid search
model = RandomForestRegressor()
grid_search = GridSearchCV(model, param_grid, cv=10, n_jobs = -1)
grid_search.fit(X_train, np.ravel(y_train))

# Print best hyperparameters
print(grid_search.best_params_)

# Make predictions on test set using best model
model = grid_search.best_estimator_
y_pred = model.predict(X_test)

# Calculate MSE
mse = mean_squared_error(y_test, y_pred)

# Print MSE
print(f'Mean squared error: {mse:.5f}')

# Plot true and predicted y values
plt.figure(figsize=(6,4), dpi = 150)
plt.plot(y_test, y_pred, '.')
plt.xlabel('True y')
plt.ylabel('Predicted y')
plt.tight_layout()
plt.savefig("figs/RF_Regression.svg")
```

```
/opt/conda/envs/rapids/lib/python3.8/site-packages/joblib/externals/loky/process_executor.py:700: UserWarning: A worker stopped while some jobs were given to the executor. This can be caused by a too short worker timeout or by a memory leak.
  warnings.warn(
/opt/conda/envs/rapids/lib/python3.8/site-packages/sklearn/model_selection/_validation.py:615: FitFailedWarning: Estimator fit failed. The score on this train-test partition for these parameters will be set to nan. Details:
Traceback (most recent call last):
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/sklearn/model_selection/_validation.py", line 598, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/xgboost/core.py", line 575, in inner_f
    return f(**kwargs)
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/xgboost/sklearn.py", line 1337, in fit
    if _is_cudf_df(y) or _is_cudf_ser(y):
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/xgboost/data.py", line 703, in _is_cudf_ser
    import cudf
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/cudf/__init__.py", line 5, in <module>
    validate_setup()
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/cudf/utils/gpu_utils.py", line 55, in validate_setup
    raise e
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/cudf/utils/gpu_utils.py", line 52, in validate_setup
    gpus_count = getDeviceCount()
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/rmm/_cuda/gpu.py", line 101, in getDeviceCount
    raise CUDARuntimeError(status)
rmm._cuda.gpu.CUDARuntimeError: cudaErrorInitializationError: initialization error

  warnings.warn("Estimator fit failed. The score on this train-test"
/opt/conda/envs/rapids/lib/python3.8/site-packages/sklearn/model_selection/_validation.py:615: FitFailedWarning: Estimator fit failed. The score on this train-test partition for these parameters will be set to nan. Details:
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    estimator.fit(X_train, y_train, **fit_params)
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/xgboost/core.py", line 575, in inner_f
    return f(**kwargs)
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/xgboost/sklearn.py", line 1337, in fit
    if _is_cudf_df(y) or _is_cudf_ser(y):
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/xgboost/data.py", line 703, in _is_cudf_ser
    import cudf
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/cudf/__init__.py", line 5, in <module>
    validate_setup()
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/cudf/utils/gpu_utils.py", line 55, in validate_setup
    raise e
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/cudf/utils/gpu_utils.py", line 52, in validate_setup
    gpus_count = getDeviceCount()
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/rmm/_cuda/gpu.py", line 101, in getDeviceCount
    raise CUDARuntimeError(status)
rmm._cuda.gpu.CUDARuntimeError: cudaErrorInitializationError: initialization error

  warnings.warn("Estimator fit failed. The score on this train-test"
/opt/conda/envs/rapids/lib/python3.8/site-packages/sklearn/model_selection/_validation.py:615: FitFailedWarning: Estimator fit failed. The score on this train-test partition for these parameters will be set to nan. Details:
Traceback (most recent call last):
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/sklearn/model_selection/_validation.py", line 598, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/xgboost/core.py", line 575, in inner_f
    return f(**kwargs)
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/xgboost/sklearn.py", line 1337, in fit
    if _is_cudf_df(y) or _is_cudf_ser(y):
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/xgboost/data.py", line 703, in _is_cudf_ser
    import cudf
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/cudf/__init__.py", line 5, in <module>
    validate_setup()
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/cudf/utils/gpu_utils.py", line 55, in validate_setup
    raise e
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/cudf/utils/gpu_utils.py", line 52, in validate_setup
    gpus_count = getDeviceCount()
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/rmm/_cuda/gpu.py", line 101, in getDeviceCount
    raise CUDARuntimeError(status)
rmm._cuda.gpu.CUDARuntimeError: cudaErrorInitializationError: initialization error

  warnings.warn("Estimator fit failed. The score on this train-test"
/opt/conda/envs/rapids/lib/python3.8/site-packages/sklearn/model_selection/_validation.py:615: FitFailedWarning: Estimator fit failed. The score on this train-test partition for these parameters will be set to nan. Details:
Traceback (most recent call last):
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/sklearn/model_selection/_validation.py", line 598, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/xgboost/core.py", line 575, in inner_f
    return f(**kwargs)
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/xgboost/sklearn.py", line 1337, in fit
    if _is_cudf_df(y) or _is_cudf_ser(y):
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/xgboost/data.py", line 703, in _is_cudf_ser
    import cudf
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/cudf/__init__.py", line 5, in <module>
    validate_setup()
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/cudf/utils/gpu_utils.py", line 55, in validate_setup
    raise e
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/cudf/utils/gpu_utils.py", line 52, in validate_setup
    gpus_count = getDeviceCount()
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/rmm/_cuda/gpu.py", line 101, in getDeviceCount
    raise CUDARuntimeError(status)
rmm._cuda.gpu.CUDARuntimeError: cudaErrorInitializationError: initialization error

  warnings.warn("Estimator fit failed. The score on this train-test"
/opt/conda/envs/rapids/lib/python3.8/site-packages/sklearn/model_selection/_validation.py:615: FitFailedWarning: Estimator fit failed. The score on this train-test partition for these parameters will be set to nan. Details:
Traceback (most recent call last):
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/sklearn/model_selection/_validation.py", line 598, in _fit_and_score
    estimator.fit(X_train, y_train, **fit_params)
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/xgboost/core.py", line 575, in inner_f
    return f(**kwargs)
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/xgboost/sklearn.py", line 1337, in fit
    if _is_cudf_df(y) or _is_cudf_ser(y):
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/xgboost/data.py", line 703, in _is_cudf_ser
    import cudf
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/cudf/__init__.py", line 5, in <module>
    validate_setup()
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/cudf/utils/gpu_utils.py", line 55, in validate_setup
    raise e
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/cudf/utils/gpu_utils.py", line 52, in validate_setup
    gpus_count = getDeviceCount()
  File "/opt/conda/envs/rapids/lib/python3.8/site-packages/rmm/_cuda/gpu.py", line 101, in getDeviceCount
    raise CUDARuntimeError(status)
rmm._cuda.gpu.CUDARuntimeError: cudaErrorInitializationError: initialization error

  warnings.warn("Estimator fit failed. The score on this train-test"
{'max_depth': 29, 'n_estimators': 50}
Mean squared error: 1.57368
```
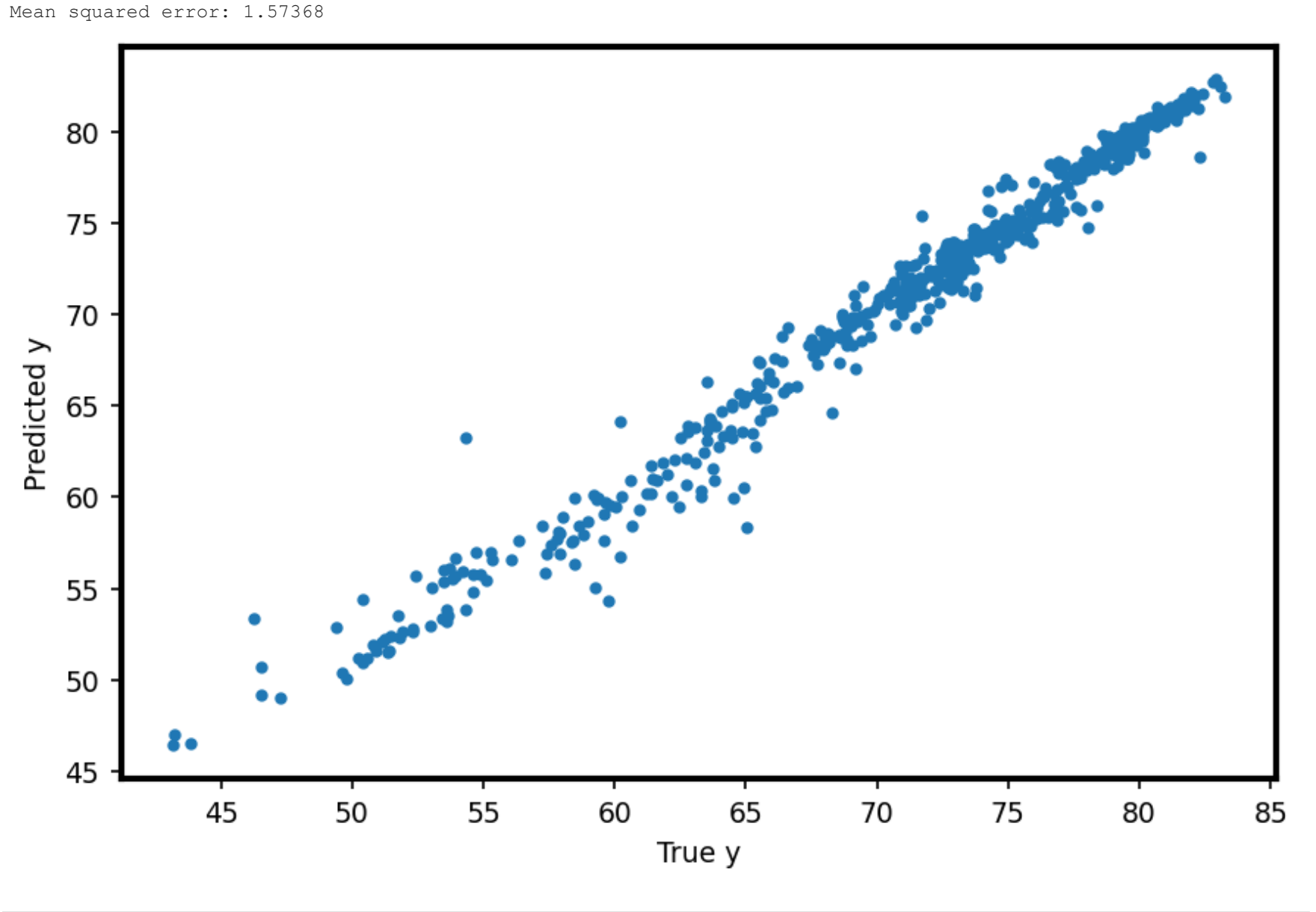
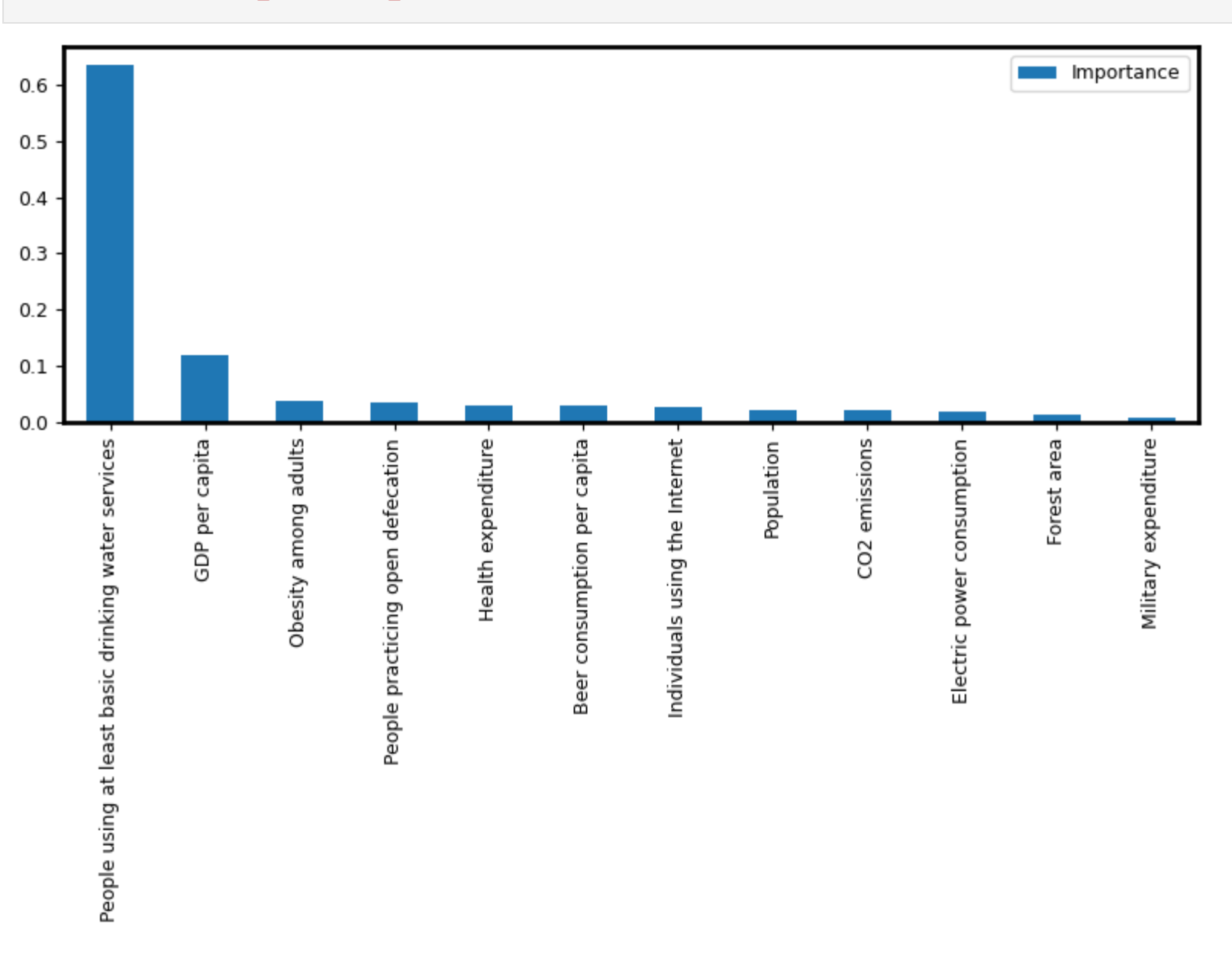



In [16]:

```python
feat_importances = pd.DataFrame(model.feature_importances_, index=X_train.columns, columns=["Importance"])
feat_importances.sort_values(by='Importance', ascending=False, inplace=True)
feat_importances.plot(kind='bar', figsize=(8,6))
plt.tight_layout()
plt.savefig("figs/RF_Regression_FeatureImportance.svg")
```



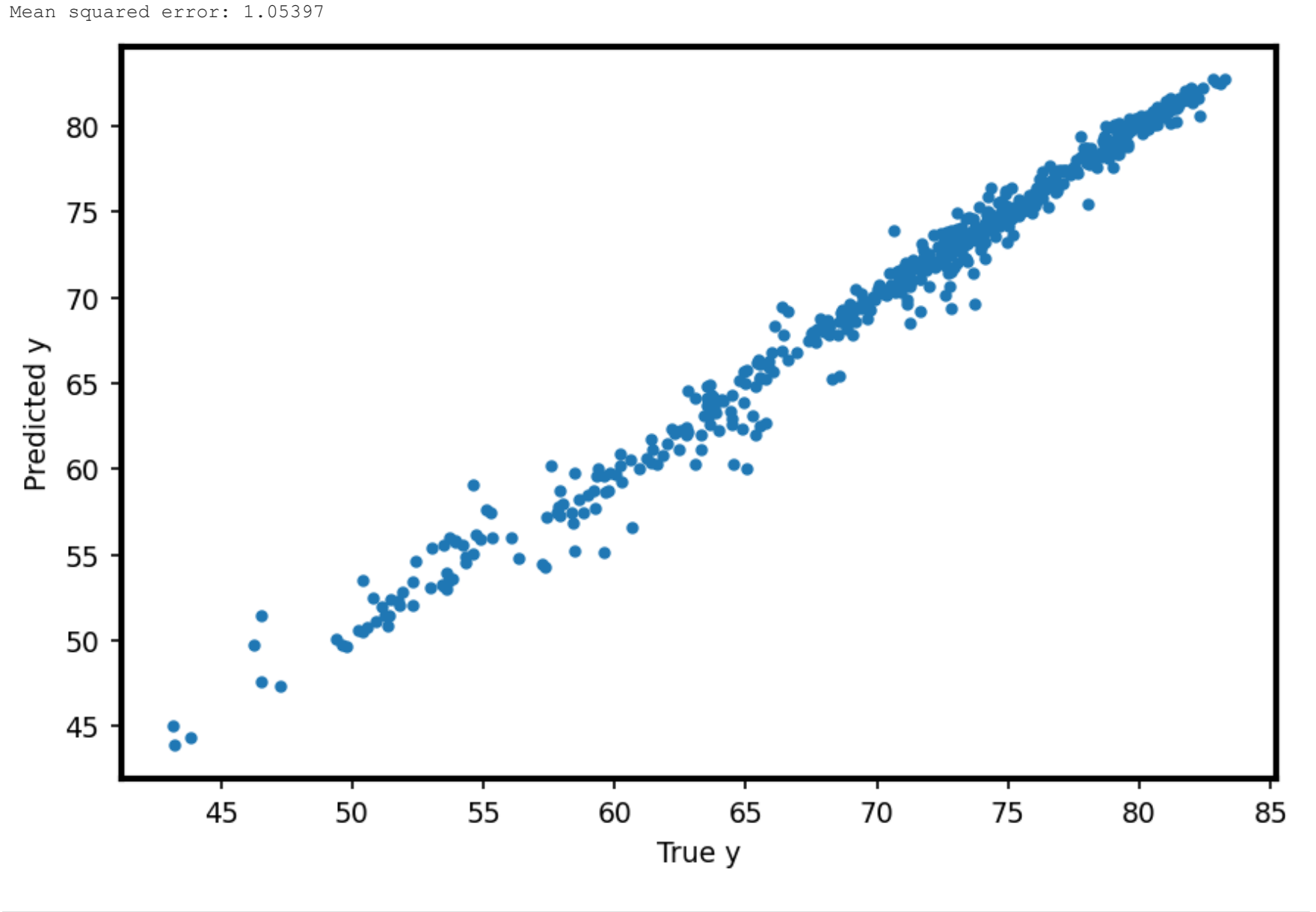
XGBoost

Produce an XGBoost model to predict the life expectancy excluding the first 4 columns, (Country/Year/Continent/Least Developed), using the training data, and find the MSE on the testing data.

In [17]:

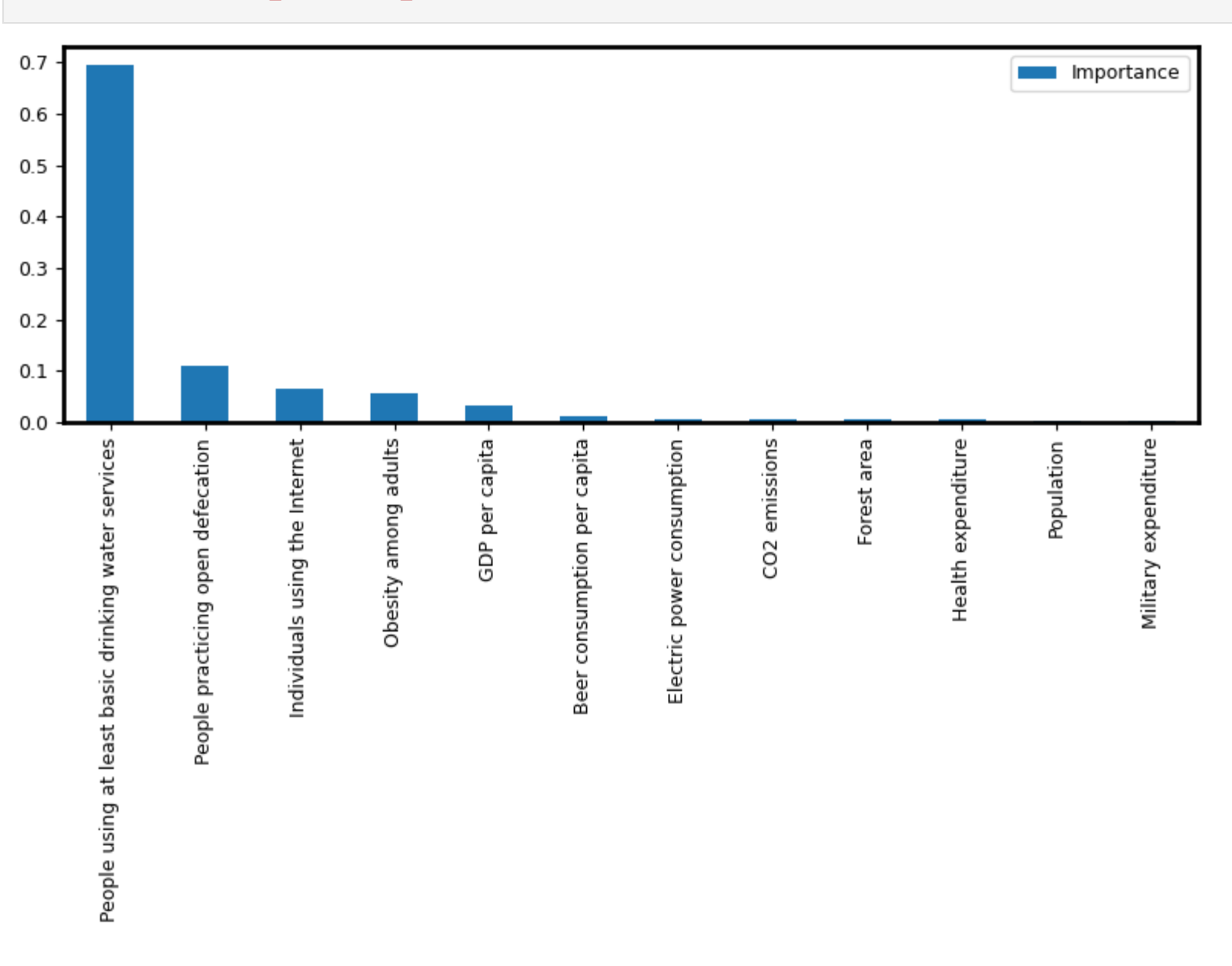
```python
# Define hyperparameter grid
param_grid = {'learning_rate': [0.1, 0.5, 1],
              'max_depth': np.arange(3, 31, 2)}

# Fit XGB regression model using grid search
model = XGBRegressor()
grid_search = GridSearchCV(model, param_grid, cv=5)
grid_search.fit(X_train, y_train)

# Print best hyperparameters
print(grid_search.best_params_)

# Make predictions on test set using best model
model = grid_search.best_estimator_
y_pred = model.predict(X_test)

# Calculate MSE
mse = mean_squared_error(y_test, y_pred)

# Print MSE
print(f'Mean squared error: {mse:.5f}')

# Plot true and predicted y values
plt.figure(figsize=(6,4), dpi = 150)
plt.plot(y_test, y_pred, '.')
plt.xlabel('True y')
plt.ylabel('Predicted y')
plt.tight_layout()
plt.savefig("figs/XGB_Regression.svg")
plt.show()
```

```
{'learning_rate': 0.1, 'max_depth': 15}
Mean squared error: 1.05397
```



In [18]:

```python
feat_importances = pd.DataFrame(model.feature_importances_, index=X_train.columns, columns=["Importance"])
feat_importances.sort_values(by='Importance', ascending=False, inplace=True)
feat_importances.plot(kind='bar', figsize=(8,6))
plt.tight_layout()
plt.savefig("figs/XGB_Regression_FeatureImportance.svg")
```



Discussion

Discuss the merits of each model based upon the MSE. Use your models to then discuss the most important variables for the predictions

The more complex models had better performance than the decision tree using MSE to compare. The best feature in all models was using basic Drinking Water Services. This seems logical because water services is one of the most important infrastuctures. Not having clean drinking water can increase the risk for disease, thus decreasing life expectency. Open defacation can also be a sign of poor infrastructure while usage on internet can be a sign of good infrastructure. This is why these features are so important to the model.

Load Data in SQL

Place the data (LifeExpectancy.csv), into an SQL data base.

In [19]:

```python
from sqlalchemy.types import String, Integer, Float, Boolean
import sqlalchemy
import psycopg2
from sqlalchemy import create_engine
```

In [20]:

```python
engine = create_engine('postgresql://admin:secret@db_final:5432/life_expectancy')
```

In [21]:

```python
data.head()
```

Out[21]:

	Country	Year	Continent	Least Developed	Life Expectancy	Population	CO2 emissions	Health expenditure	Electric power consumption	Forest area	GDP per capita	Individuals using the Internet
0	Albania	2000	Europe	False	73.955	3089027	1.026213	7.233370	1414.703784	28.076642	3860.804627	0.114097
1	Albania	2001	Europe	False	74.288	3060173	1.055496	7.139524	1449.647413	28.123248	4299.546493	0.325798
2	Albania	2002	Europe	False	74.579	3051010	1.232379	6.909341	1351.230796	28.169854	4661.402695	0.390081
3	Albania	2003	Europe	False	74.828	3039616	1.338985	7.063490	1578.165919	28.216460	5000.049363	0.971900
4	Albania	2004	Europe	False	75.039	3026939	1.404059	6.773372	1469.264539	28.263066	5427.732662	2.420388

In [22]:

```python
dtypes={"country": String(), "year": Integer(), "continent": String(), "least_developed": Boolean(), "life_expe
                    "co2_emissions": Float(), "health_spending": Float(), "electric_power": Float(), "forest_area'
                    "internet": Float(), "military_spending": Float(), "open_defaction": Float(), "basic_water": F
                    "beer_consumption": Float()}
```

In [23]:

```python
dtypes.keys()
```

Out[23]:

```
dict_keys(['country', 'year', 'continent', 'least_developed', 'life_expectancy', 'population', 'co2_emissions',
'health_spending', 'electric_power', 'forest_area', 'gdp', 'internet', 'military_spending', 'open_defaction',
'basic_water', 'obesity', 'beer_consumption'])
```

In [24]:

```python
data.columns = list(dtypes.keys())
```

In [25]:

```python
data.to_sql('life',
            engine,
            if_exists='replace',
            index=False,
            dtype=dtypes )
```

Out[25]:

```
904
```

Visualize Life Expectancy Before and After 2008

Extract all the life expectancy values, from the DB where the year is greater than 2008, and then less than 2008 into 2 separate variables. Then produce a histogram to show the distribution of the values from the 2 variables. Afterwards conduct a t-test to assess whether they have a significant mean difference or not.

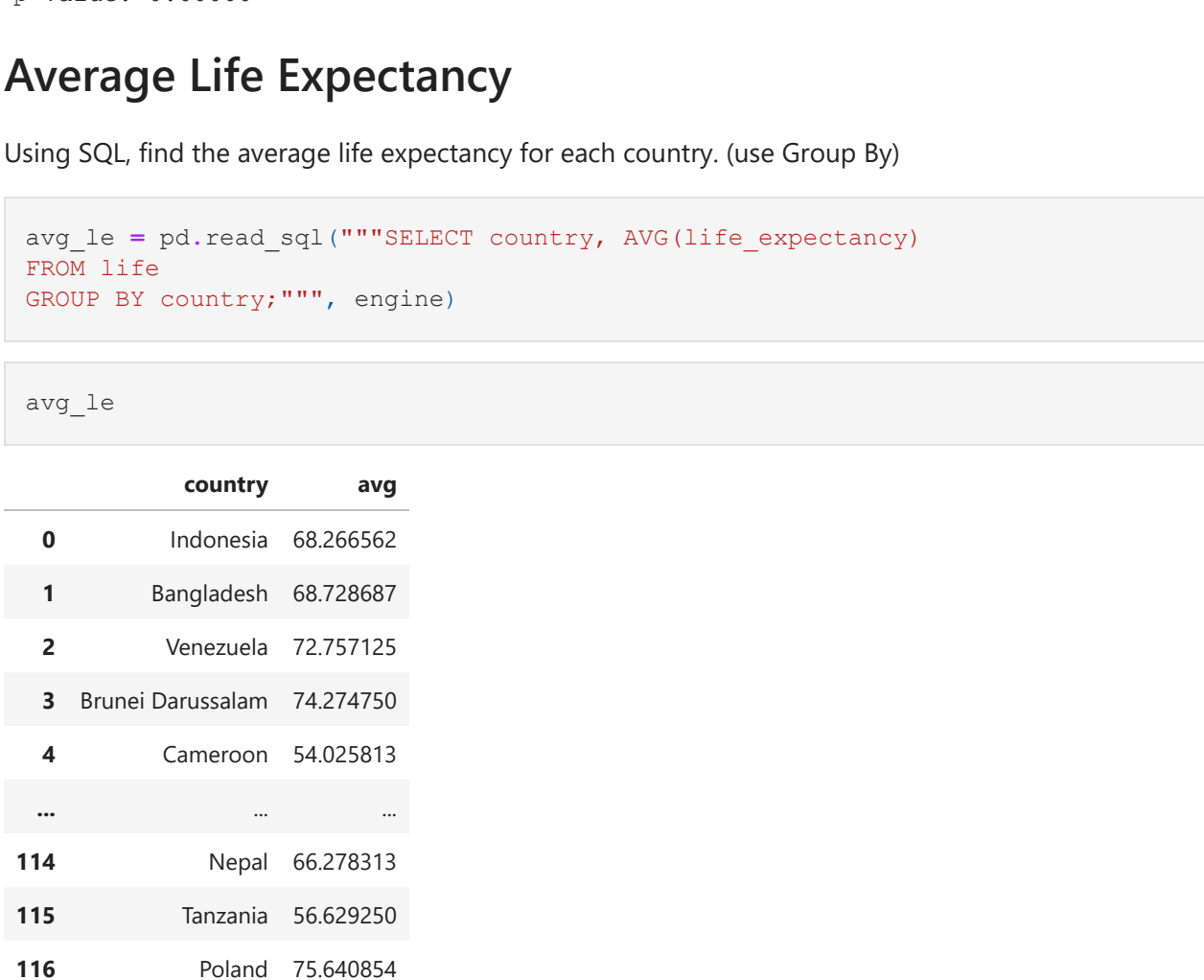
In [26]:

```
pre2008 = pd.read_sql_query("""SELECT life_expectancy
            FROM life
            WHERE year < 2008;""", engine)

post2008 = pd.read_sql_query("""SELECT life_expectancy
            FROM life
            WHERE year > 2008;""", engine)
```

In [27]:

```
plt.figure(figsize=(6,3), dpi = 150)
fig, (ax1, ax2) = plt.subplots(nrows=1, ncols=2)

# Plot histogram of x on left subplot
ax1.hist(pre2008)
ax1.set_xlabel('Life Expectancy (Pre-2008)')
ax1.set_ylabel('Frequency')

# Plot histogram of y on right subplot
ax2.hist(post2008)
ax2.set_xlabel('Life Expectancy (Post-2008)')
ax2.set_ylabel('Frequency')

plt.tight_layout()
plt.savefig("figs/Life_Expectancy.svg")
```

```
<Figure size 900x450 with 0 Axes>
```



In [28]:

```
from scipy.stats import ttest_ind
```

In [29]:

```
# Conduct t-test
t, p = ttest_ind(pre2008, post2008)

# Print t-statistic and p-value
print(f't-statistic: {t[0]:.5f}')
print(f'p-value: {p[0]:.5f}')
```

```
t-statistic: -7.48032
p-value: 0.00000
```

Average Life Expectancy

Using SQL, find the average life expectancy for each country. (use Group By)

In [30]:

```
avg_le = pd.read_sql("""SELECT country, AVG(life_expectancy)
FROM life
GROUP BY country;""", engine)
```

In [31]:

```
avg_le
```

Out[31]:

	country	avg
0	Indonesia	68.266562
1	Bangladesh	68.728687
2	Venezuela	72.757125
3	Brunei Darussalam	74.274750
4	Cameroon	54.025813
...	...	...
114	Nepal	66.278313
115	Tanzania	56.629250
116	Poland	75.640854
117	Costa Rica	78.465875
118	Czechia	76.777134

119 rows × 2 columns

In [32]:

```
avg_le.to_csv("avg_life_expectancy (2000-2015).csv", index = False)
```