Unlocking Low Carbon Economy Through Buildings

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Identifying the Problem

According to the International Energy Agency and Architecture2030.org, carbon emissions play a key role in escalating global warming. **Buildings in particular contribute to 35-60% of global carbon emissions**. British Columbia follows the same trend.

Getting to net zero will require **tremendous**, rapid change and large-scale technology deployment across industries.

Given how significantly buildings impact carbon emissions in BC, through this policy we aim to make environment conservation and economic development two sides of the same coin.

Buildings account for **11%** of total emissions in British Columbia

- BC Building Electrification Road Map Final Apr2021

The Building sector represents one of the most straightforward opportunities for a rapid transition to a low-carbon market sector

Buildings in British Columbia (BC) emit approximately 6.9 million tonnes of GHG emissions on an annual basis[1]. This represents approximately 10.7% of the provinces' total emissions, and makes the building sector one of the highest sector emitters – exceeded only by road transportation (27.1%) and the oil and gas sector (17.6%)[2].

The building sector, unlike transportation and oil and gas, is regulated entirely by provincial and local governments. It, therefore, represents one of the most straightforward opportunities for a rapid transition to a low-carbon market sector.

At the community scale, the GHG emissions attributed to buildings make up an even greater proportion of total GHG emissions (Table 1). For communities working to reduce their overall GHG emissions, rapidly reducing GHG emissions from the building sector is therefore a key strategy.

In recognition of this important sector, jurisdictions across BC have included a concerted focus on decarbonizing the building sector as a key part of meeting their ambitious emissions reduction goals and targets.

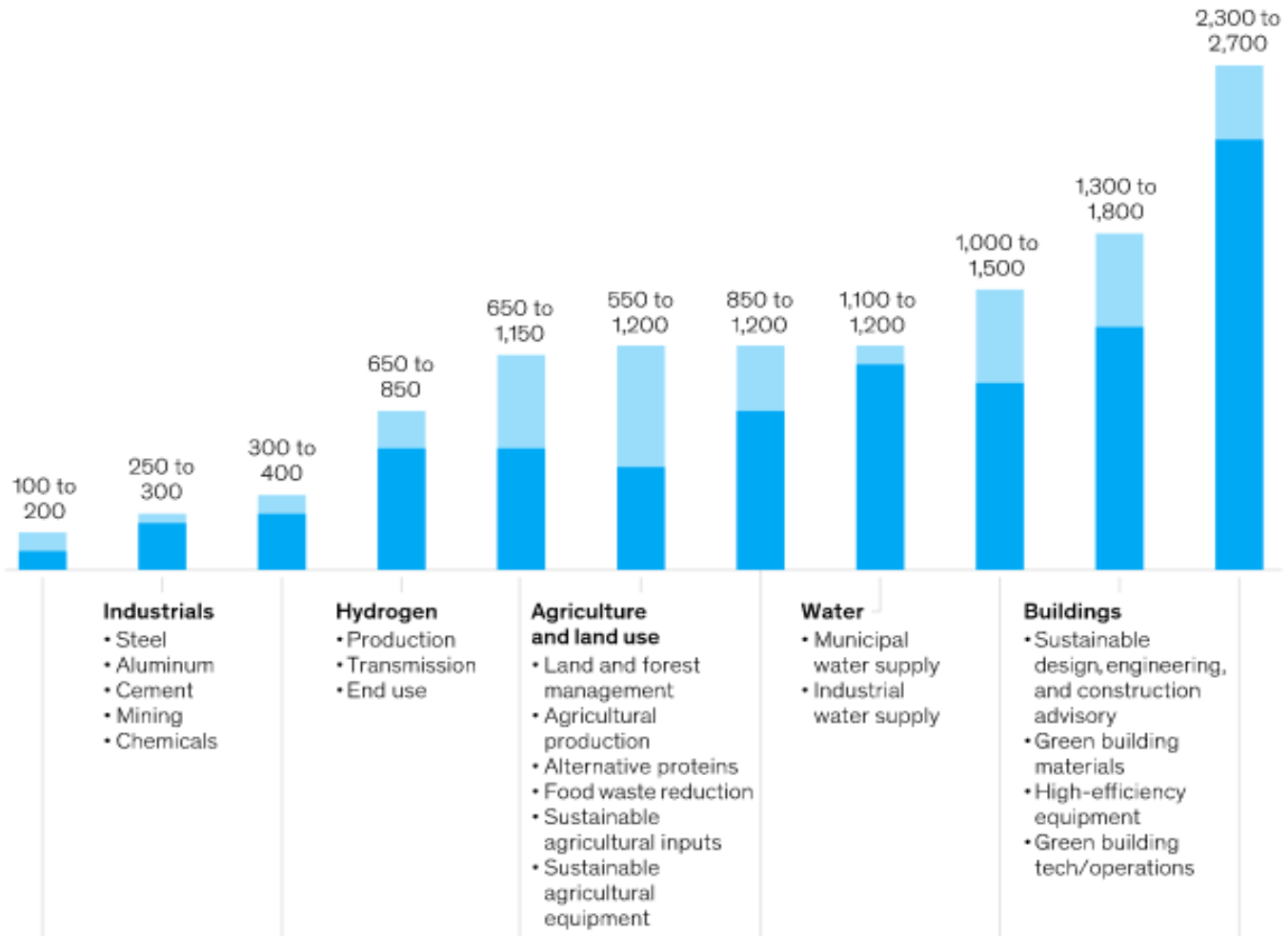
Table 1 Building Greenhouse Gas Emissions as Percentage of Total Community Emission by Major Region in BC[3]

Region	Community Emissions from Buildings
Vancouver Island & Coastal	30%
Lower Mainland	42%
Southern Interior	39%
Kootenay & Boundary	42%
North Central	38%

Why Buildings?

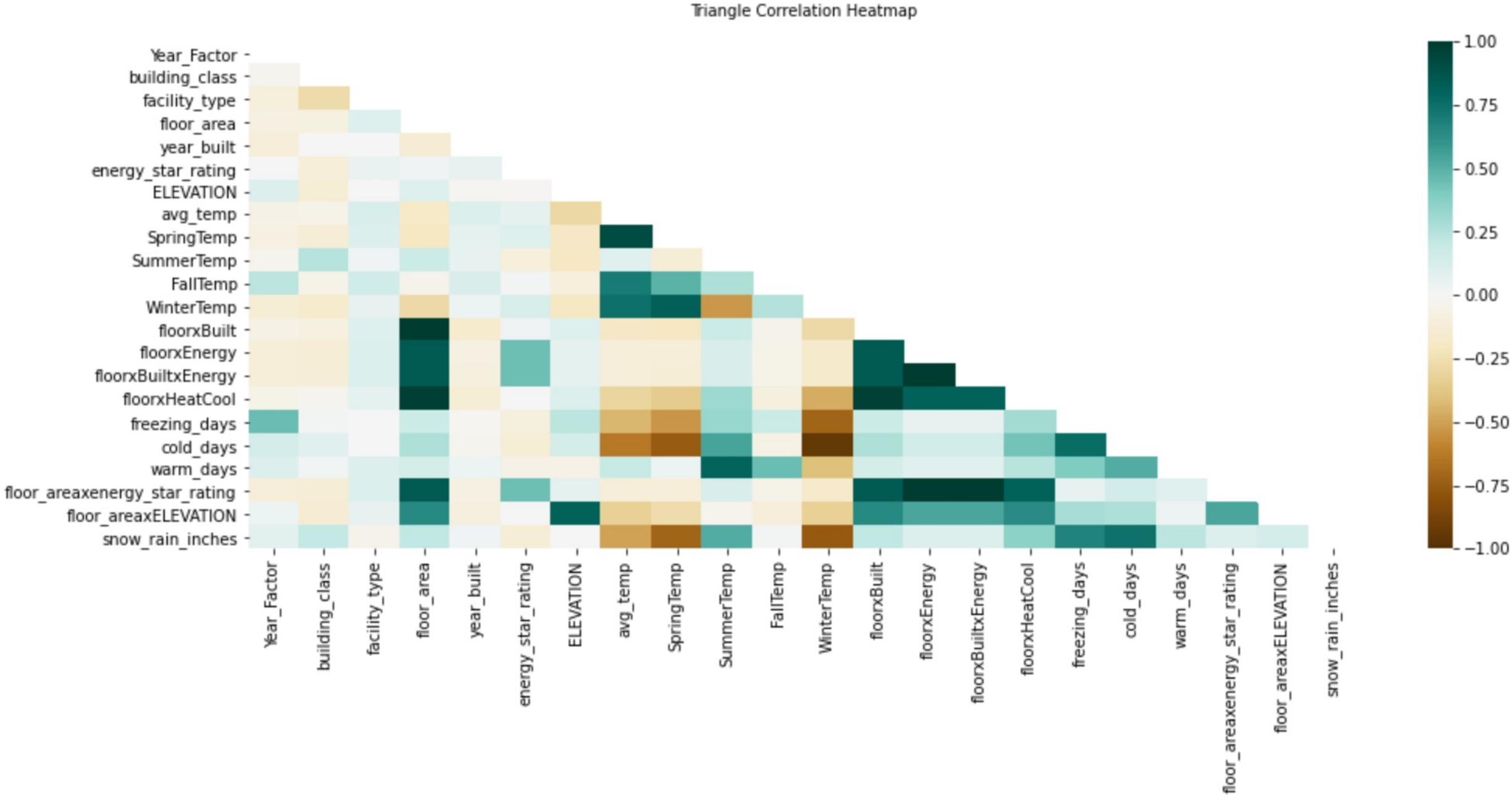
Eleven high-potential value pools could be worth more than $12 trillion of yearly revenues by 2030 as the net-zero transition advances.

Addressable market size in 2030, selected categories, $ billion



Even though buildings are a big contributor to global CO2 emissions, they present a unique avenue for revenue generation, if tackled properly.


Machine Learning Model


Triangle Correlation Heatmap
Year_Factor
building_class
facility_type
floor_area
year_built
energy_star_rating
ELEVATION
avg_temp
SpringTemp
SummerTemp
FallTemp
WinterTemp
floorxBuilt
floorxEnergy
floorxBuiltxEnergy
floorxHeatCool
freezing_days
cold_days
warm_days
floor_areaxenergy_star_rating
floor_areaxELEVATION
snow_rain_inches
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00

```python
def validate_model(X_train, y_train, X_test, y_test) -> pd.DataFrame:

    dfs = []
    models = [
         ('Stack', stack()),
          ('XGB', XGBRegressor(n_estimators = 100, max_depth = 10, learning_rate = 0.05)),
          ('LGBM', LGBMRegressor(num_leaves = 300, feature_fraction = 1, bagging_freq = 100, learning = 0.05)),
          ('GBR', GradientBoostingRegressor(n_estimators = 200, max_depth = 5,learning_rate=0.05)),
          ('SVR', SVR(C = 1000)),
          ('ElNet', ElasticNet(alpha=6.428073117284319e-05, l1_ratio=0.8, max_iter=5))
#           ('CATB', CatBoostRegressor(n_estimators = 500, max_depth = 4, learning_rate = 0.1)),)
    ]
    results = []
    names = []
    scoring = ['neg_mean_squared_error', 'neg_mean_absolute_error', 'r2']

    for name, model in models:
        kfold = model_selection.RepeatedKFold(n_splits=5, n_repeats = 3, random_state=90210)
        cv_results = model_selection.cross_validate(model, X_train, y_train, cv=kfold, scoring=scoring)
        clf = model.fit(X_train, y_train)
        f = 'models/{}.sav'.format(name)
        pickle.dump(model, open(f, 'wb'))
        y_pred = clf.predict(X_test)
        print(name)
        print(mean_squared_error(y_test, y_pred, squared = False))

        results.append(cv_results)
        names.append(name)

        this_df = pd.DataFrame(cv_results)
        this_df['model'] = name
        dfs.append(this_df)

        final = pd.concat(dfs, ignore_index=True)
```

Solutions

Threshold Creation

Provide negative and positive reinforcement to citizens by creating an upper and lower limit to CO2 emissions

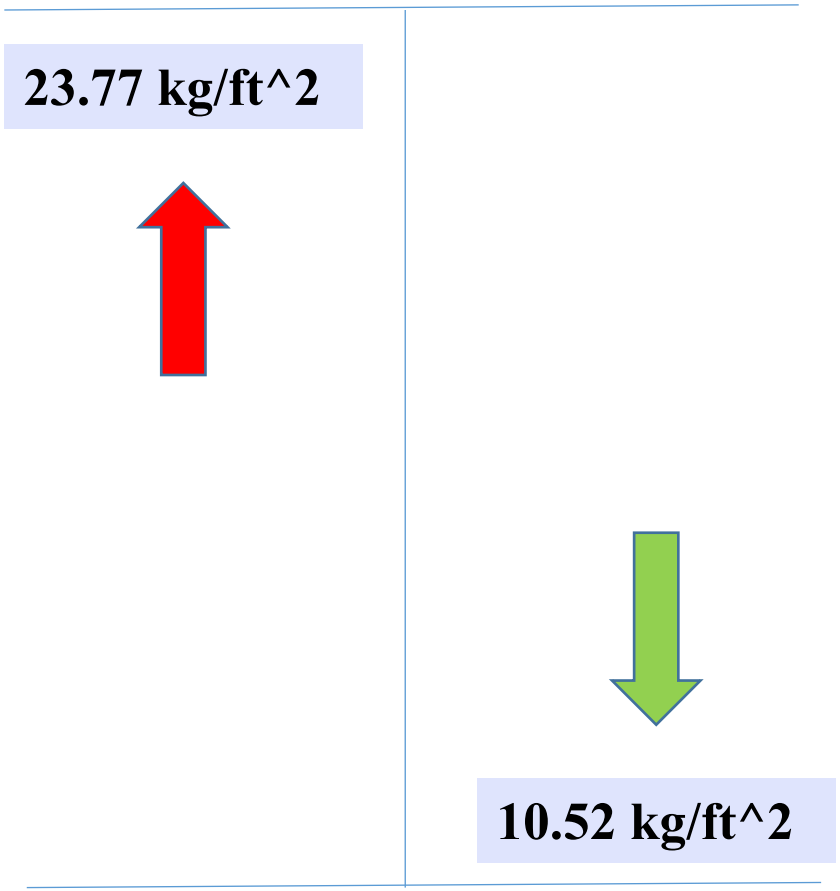
Three Step Residential Pricing

Change BC Hydro’s current 2 step residential electricity pricing to 3 step

University Program + Scholarship

Offer programs and scholarships that allow students to develop the necessary skills needed in today's green tech environment

Threshold Creation



- Corporations with annual CO2 emissions higher than 23.77kg/ft^2, would be required to invest **5 %** of their revenue to green tech startups

- Corporations and households with annual CO2 emissions lower than 10.52kg/ft^2, would get benefits that would make their energy bill negligible, making housing more affordable.

Math Behind Threshold Approximation

$$61,700,000 \text{ tons of carbon emissions in BC}$$

$$2,077\ ft^2 \text{ average building size in BC}$$

$$1,881,970 \text{ buildings in BC,}$$

$$\therefore \text{Total area} = 1881970 \times 2077 = 3,908,851,690\ ft^2$$

$$\text{Hence carbon emission (in mass per unit area)} = \frac{61700000 \times 1000}{3908851690} = 15.78\ \text{kg}ft^{-2}$$

$$\text{Lower Bound} = \frac{15.78}{1.5} = 10.52\ \text{kg}ft^{-2}$$

$$\text{Upper Bound} = 15.78 \times 1.5 = 23.77\ \text{kg}ft^{-2}$$

```
pd.DataFrame(df['site_eui']).boxplot()
```

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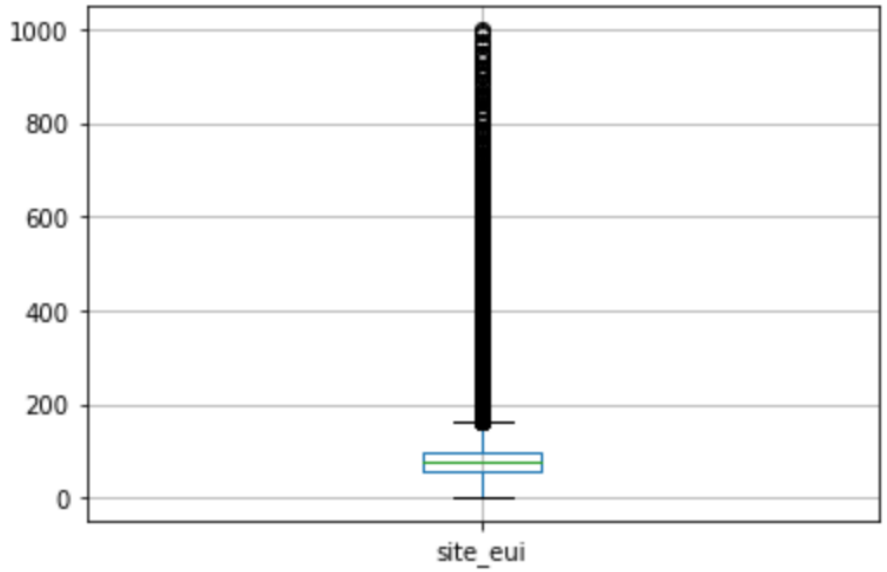
<matplotlib.axes._subplots.AxesSubplot at 0x7fc201780460>
```




```
## Using IQR (Interquartile Range) method to remove outlier from the dataset
for x in ['site_eui']:
    q75, q25 = np.percentile(df.loc[:,x],[75,25])
    intr_qr = q75-q25

    ul = q75+(1.5*intr_qr)
    ll = q25-(1.5*intr_qr)

    df.loc[df[x]<ll,x] = np.nan
    df.loc[df[x]>ul,x] = np.nan

## Number of outliers
df['site_eui'].isnull().sum()
```

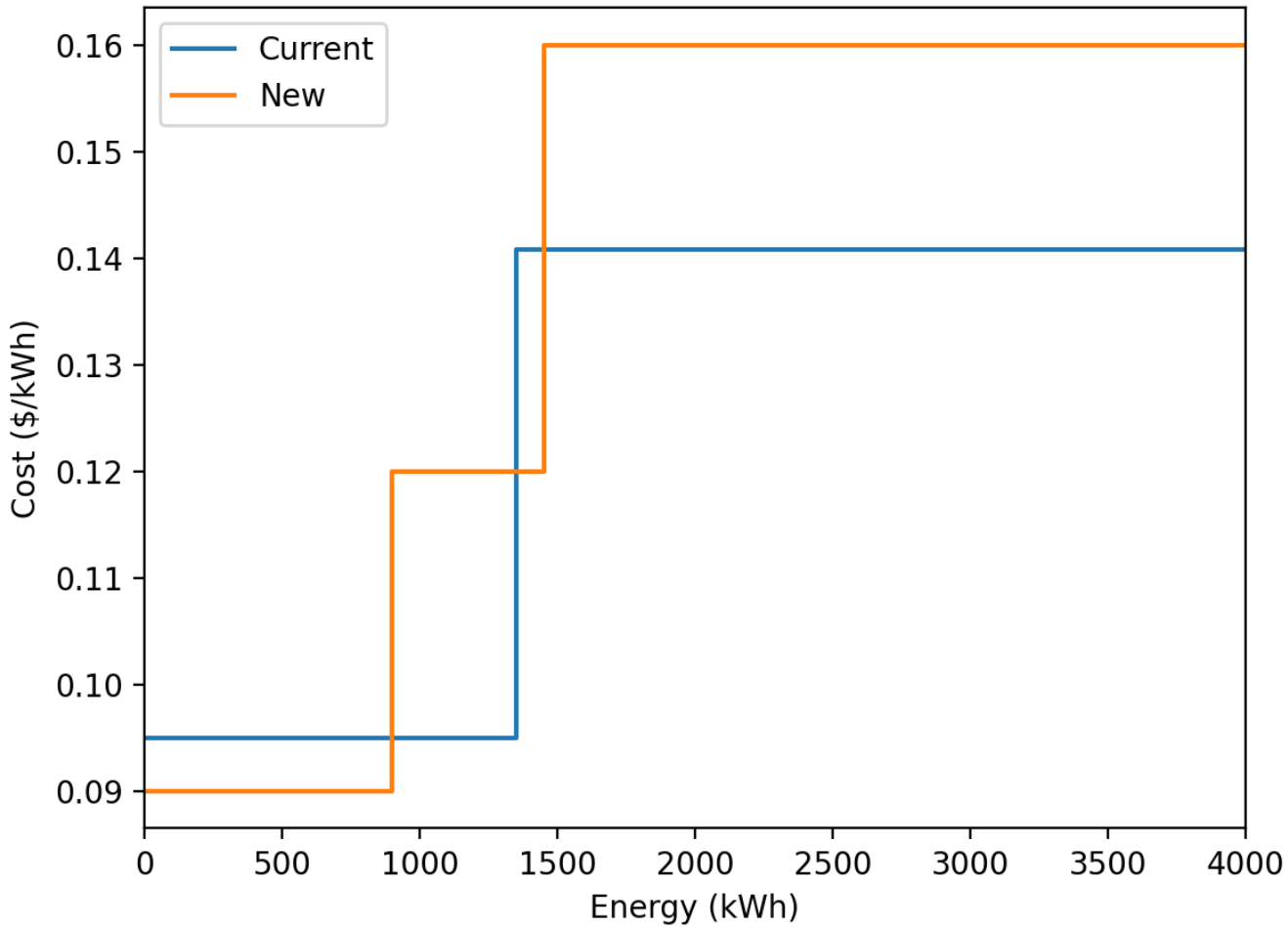
```
3845
```

Biggest Takeaways:

1. There are 3845 households that are consuming significantly large amount of energy. This would create a good revenue pool for our upper-bound strategy, making it economical.

2. There is **NO** household that is currently producing lower than the threshold. As a result, the cost of implementing the lower-bound strategy would be negligible.

Three Step Residential Pricing



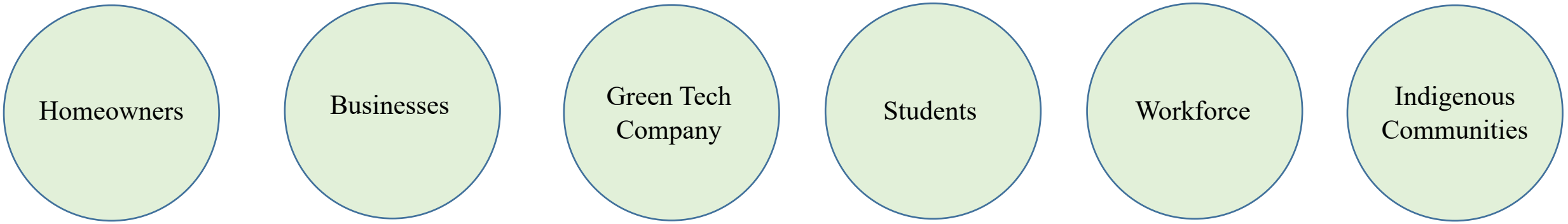
BC Hydro's current 2-step pricing for residential buildings would be upgraded to a 3-step pricing system. Through that system, buildings with significantly low energy consumption would pay low cost for energy. Buildings with significantly high energy consumption would pay a much higher cost.

University Program

- Offering university courses designed to help students gain necessary skills to succeed in today's green tech industry
- Creating competitions for students where they have to ideate new green tech models
- Offering top 5 winners scholarships and/or placements in startups linked to the competition
- Promoting such courses and competitions especially amongst the indigenous communities and ensuring that diversity is reflected in the winners

Stakeholders

Economic Growth



Homeowners	Businesses	Green Tech Company	Students	Workforce	Indigenous Communities
Making housing more affordable (lower threshold + three step pricing)	Nudging them to increase their energy efficiency and rewarding them through lower threshold benefits	Increasing investments and market demand	University programs, placements and scholarships	Job creation in green tech industry	Ensuring their inclusion in university scholarship programs and placement opportunities

Financial Analysis

Given the historic trend of energy consumption presented by the boxplot shown on the right:

- We expect 3845/75757 = 5% of the buildings to have excessive energy consumption (over the upper limit threshold). This would ensure a healthy investment into the green tech industry by corporations.

- Secondly, there are not a lot of buildings (if any) that lie below the lower threshold. This suggests that, at the moment, the cost of implementing this policy is not significant. However, we do expect the number to rise in the future. Then, the policy would have to be changed accordingly.

```
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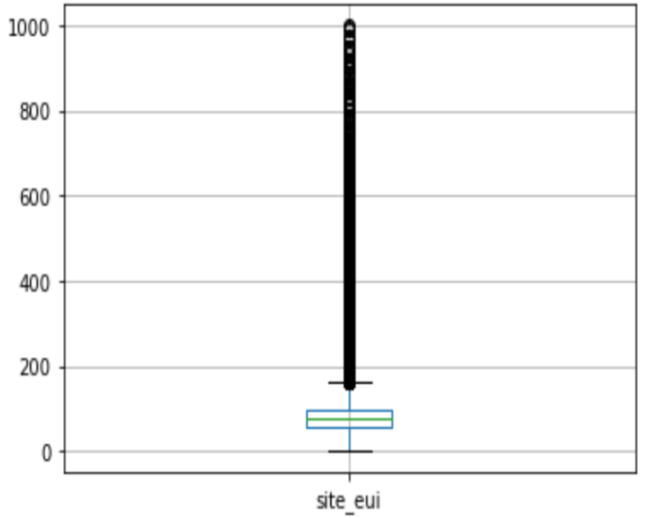


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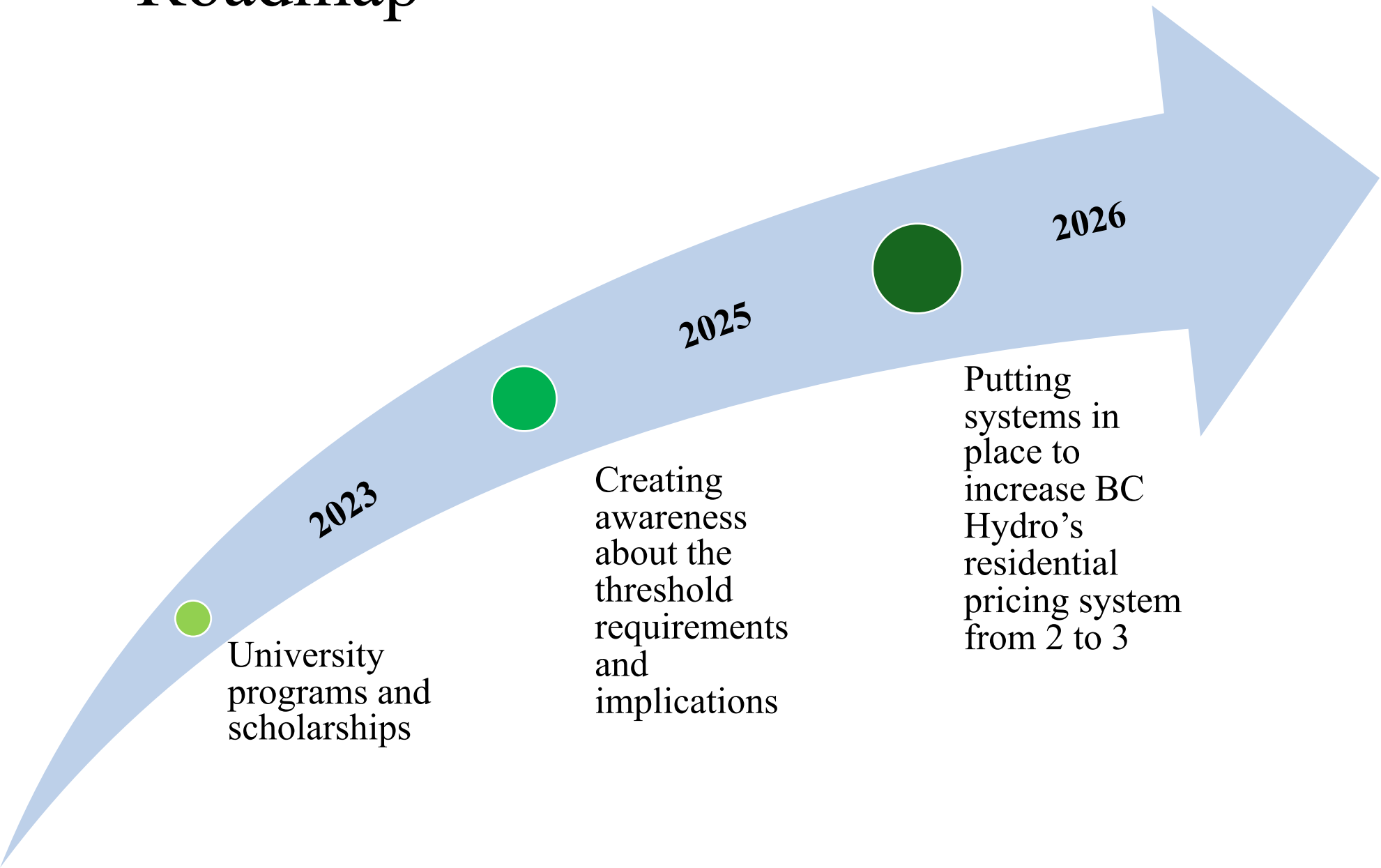
Roadmap



OUTCOMES (2030)

1. Expanding consumer base for green technology
2. Improving the knowledge and readiness of students (future workforce)
3. Encouraging the use of low carbon materials in building construction
4. Making green housing more affordable in BC

Risk Assessment

Risk Identification

- Corporations that exceed the upper level threshold could attempt to not truly invest in green technology by setting up smaller sister companies and transferring 5% of their revenue there.
- This would ensure that the money would stay within the big corporation and not get invested in technology development

Risk Mitigation

- Government could release a list of certified green tech startups that corporations would have to invest in should they exceed the upper limit
- It would be mandatory for the corporations to disclose the money transferred to government certified startups
- It would be mandatory for startups to show what they have done with the investment


Thank You