COVID-19 RESPONSE:

ADAPTIVE WORKING BEHAVIOR AND IT'S IMPACT ON ENERGY AND CARBON PATTERNS

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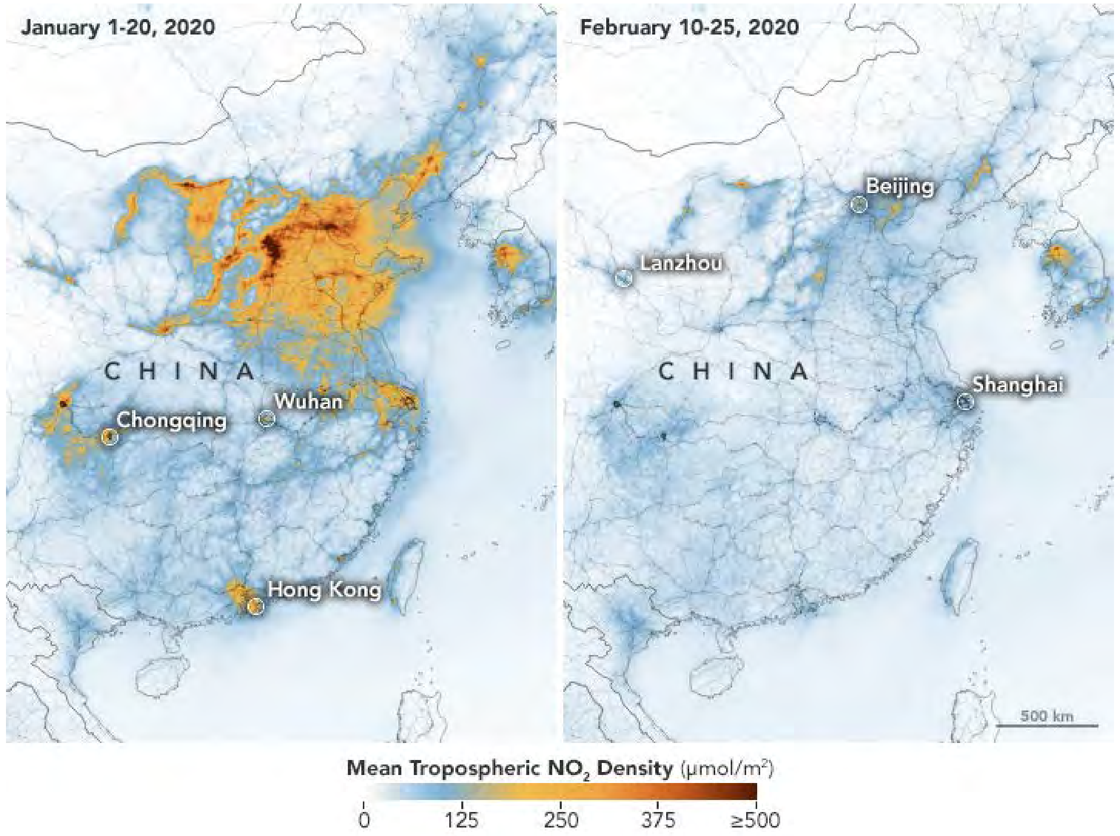
Perkins&Will

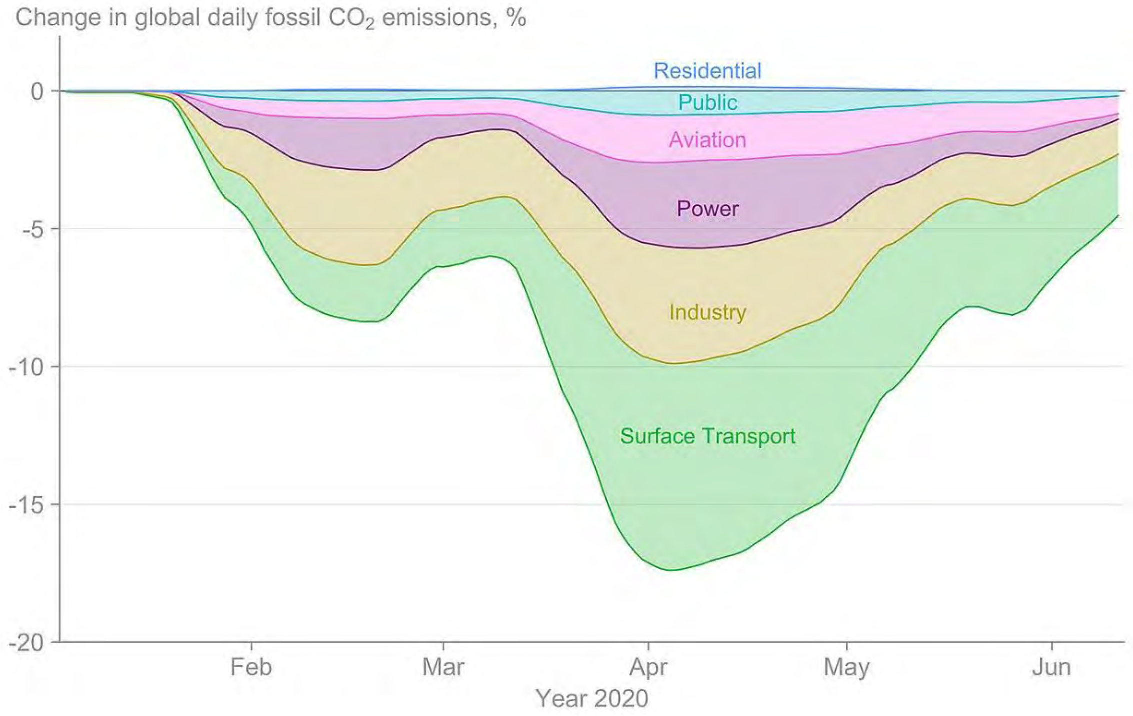
01 **INTRODUCTION**

Introduction

Due to the coronavirus outbreak's impact on travel and industry, many regions and the planet as a whole experienced a drop in air pollution and fossil CO_2 emissions. (short-term impact)

Societal shifts caused by the coronavirus lockdowns, such as widespread **telecommuting**, adoption of **remote work** policies, and the use of **virtual conference technology**, may have a more sustained impact beyond the short-term reduction of industrial activities and transportation usage.





https://en.wikipedia.org/wiki/Impact_of_the_COVID-19_pandemic_on_the_environment

Introduction

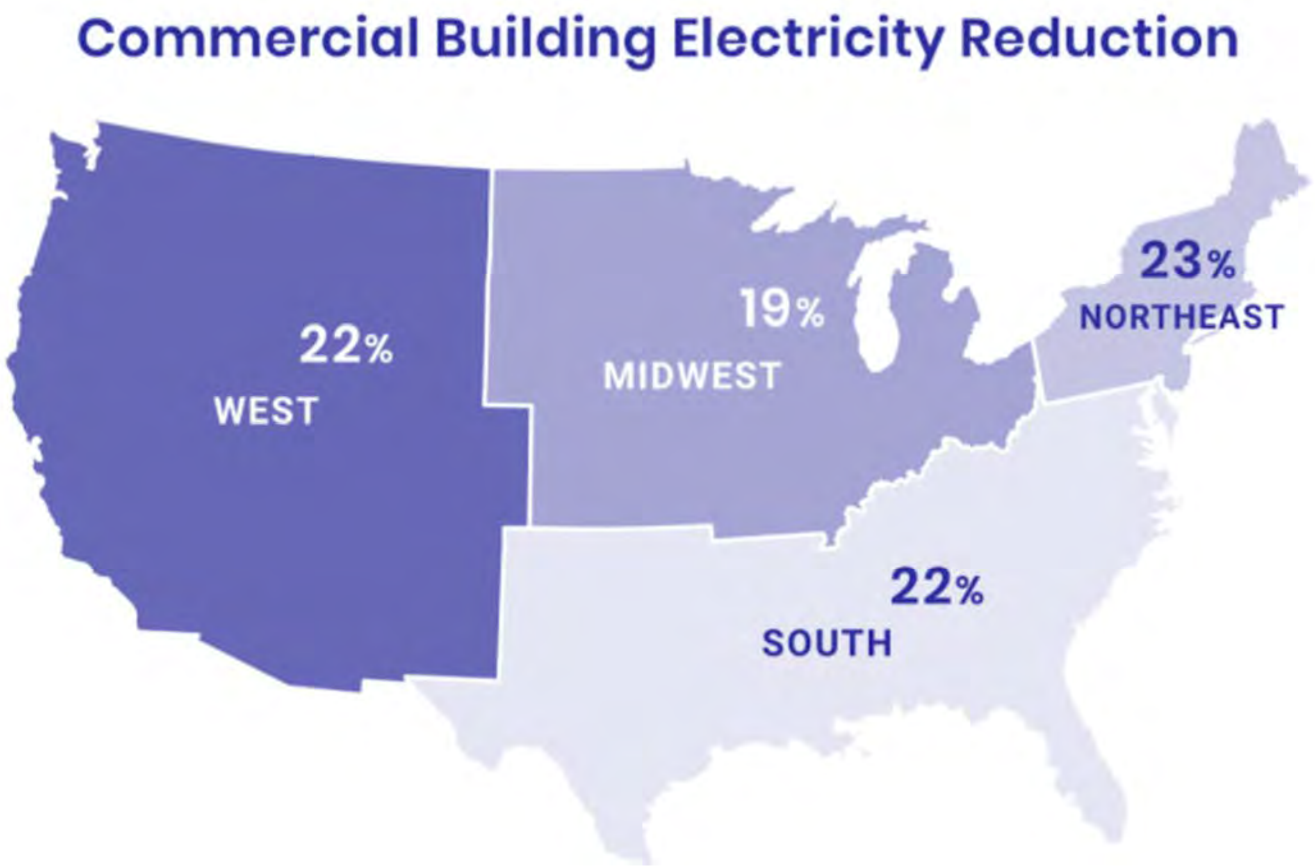
Google Community Mobility Reports aim to provide insights into what has changed in response to policies aimed at combating COVID-19. See how **dynamic** our community is moving around differently due to COVID-19

https://www.google.com/covid19/mobility/

Introduction

Hatch Data, a commercial real estate software company focused on building operations performance management, has studied how the coronavirus is affecting **operational practices** across buildings over 400 million square feet of occupied space. Their findings show electricity reduction is following the movement of stay-at-home orders.

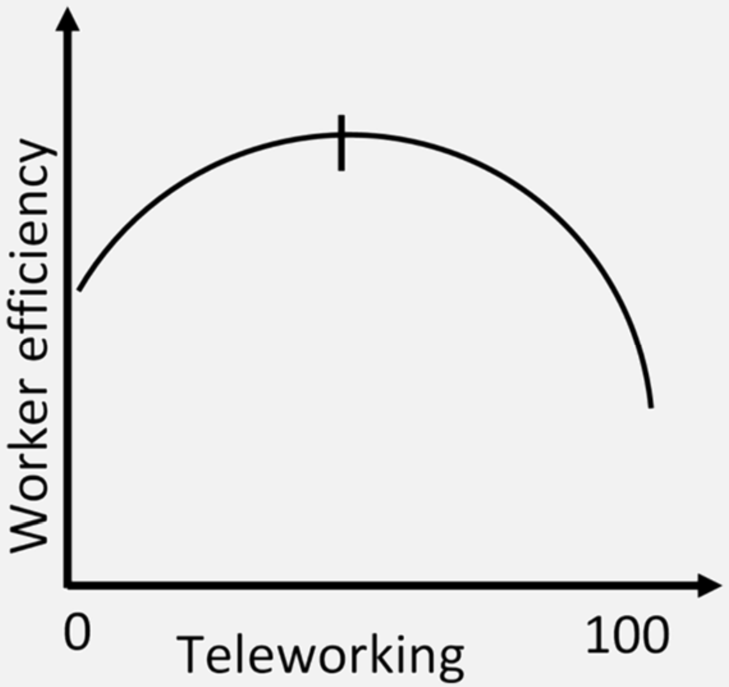
Source from http://www.hatchdata.com/



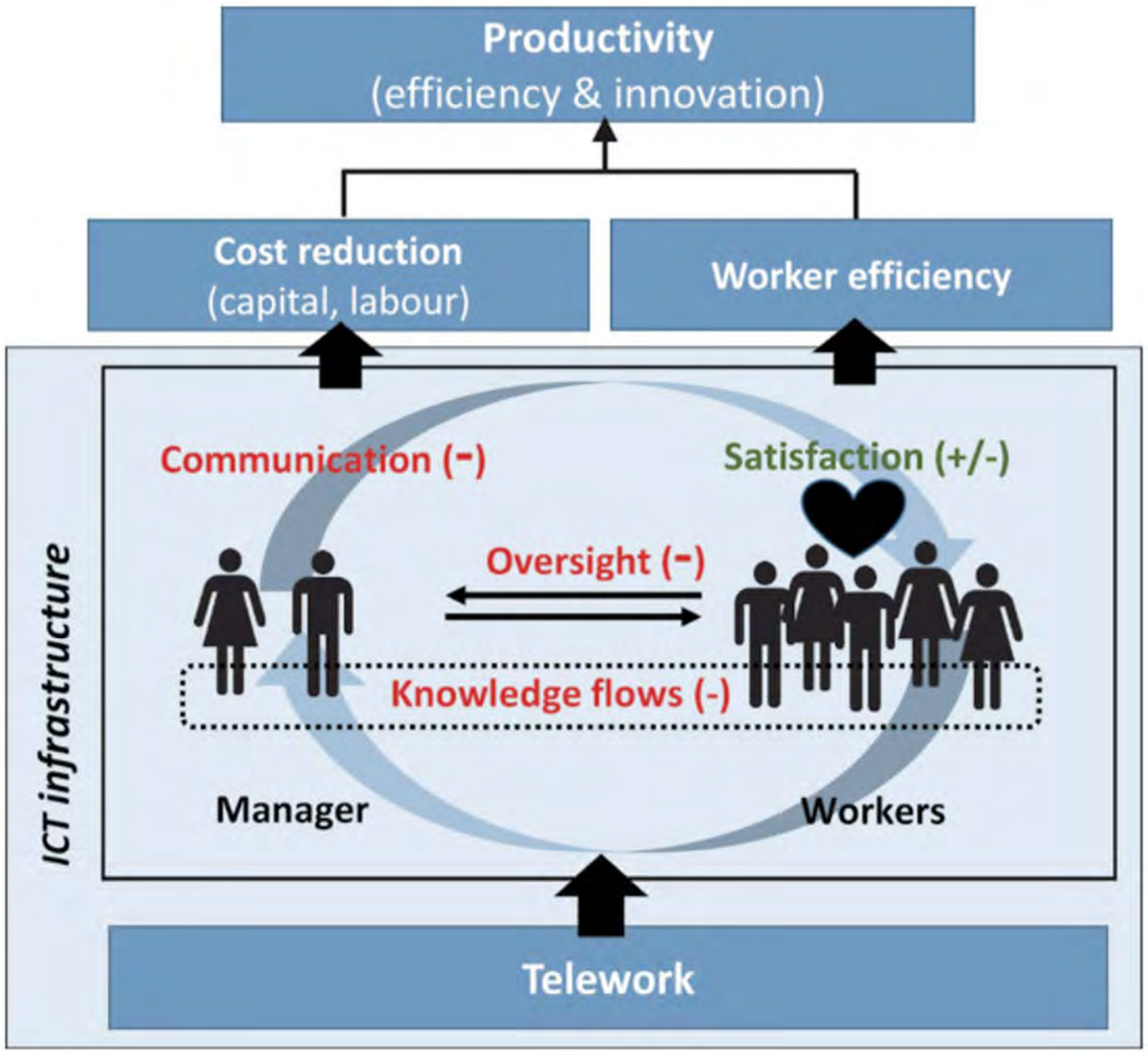
Introduction

It is crucial that **worker satisfaction** increases enough to offset the potentially negative effects on **communication**, **knowledge flows** and **managerial oversight**.

Worker efficiency improves with low levels of telework but might decrease with 'excessive telework', implying a 'sweet spot' where worker efficiency/productivity is balanced and maximized.



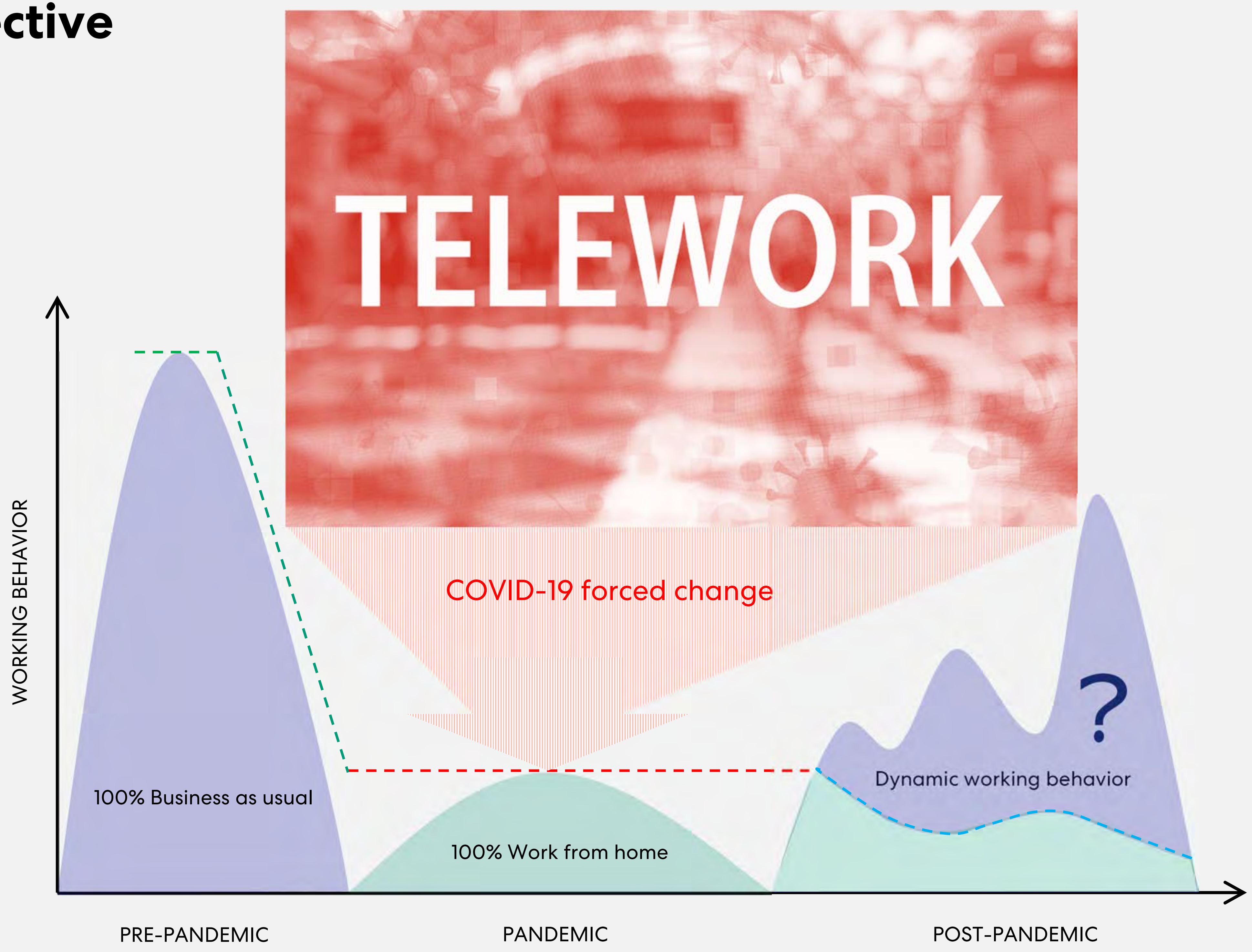
Source from https://www.oecd.org/coronavirus/policy-responses/productivity-gains-from-teleworking-in-the-post-covid-19-era-a5d52e99/



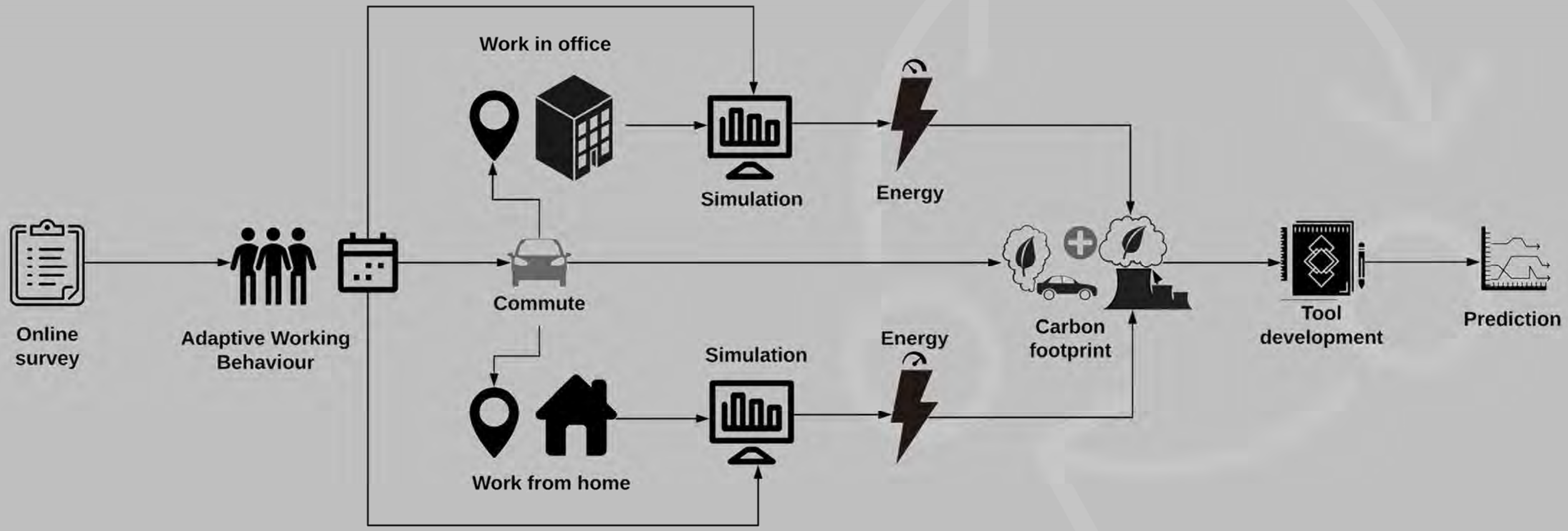
02 **RESEARCH OBJECTIVE**

To evaluate short-term and future behavior changes due to COVID-19 epidemic or telework demand & its impact on energy and $CO2$

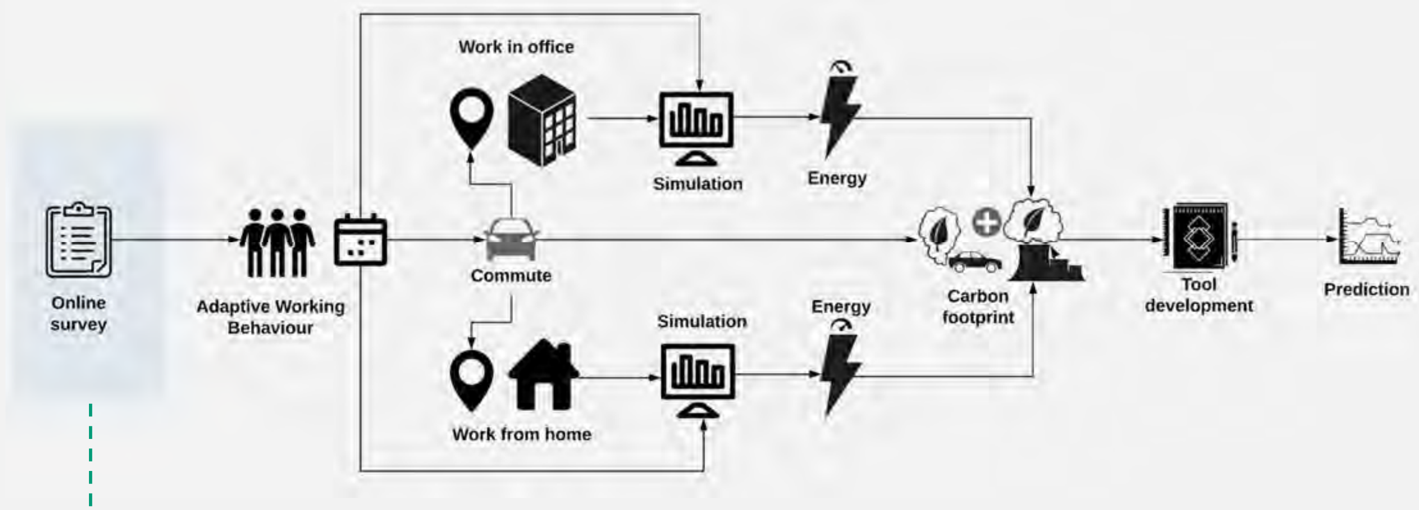
Research Objective



03 METHODOLOGY



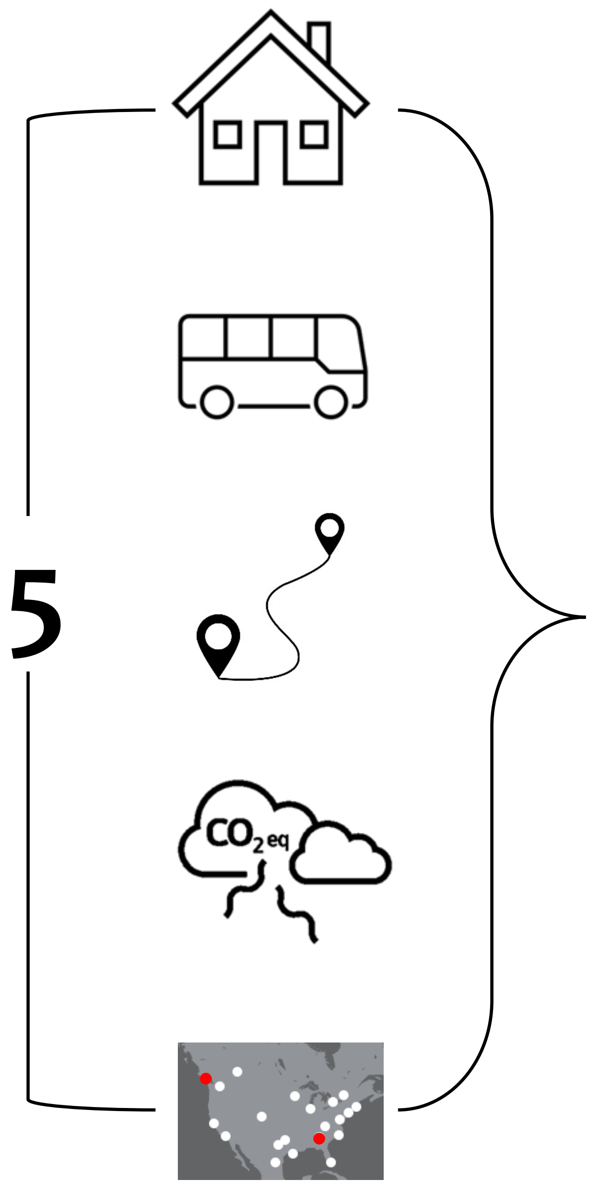
Methodology

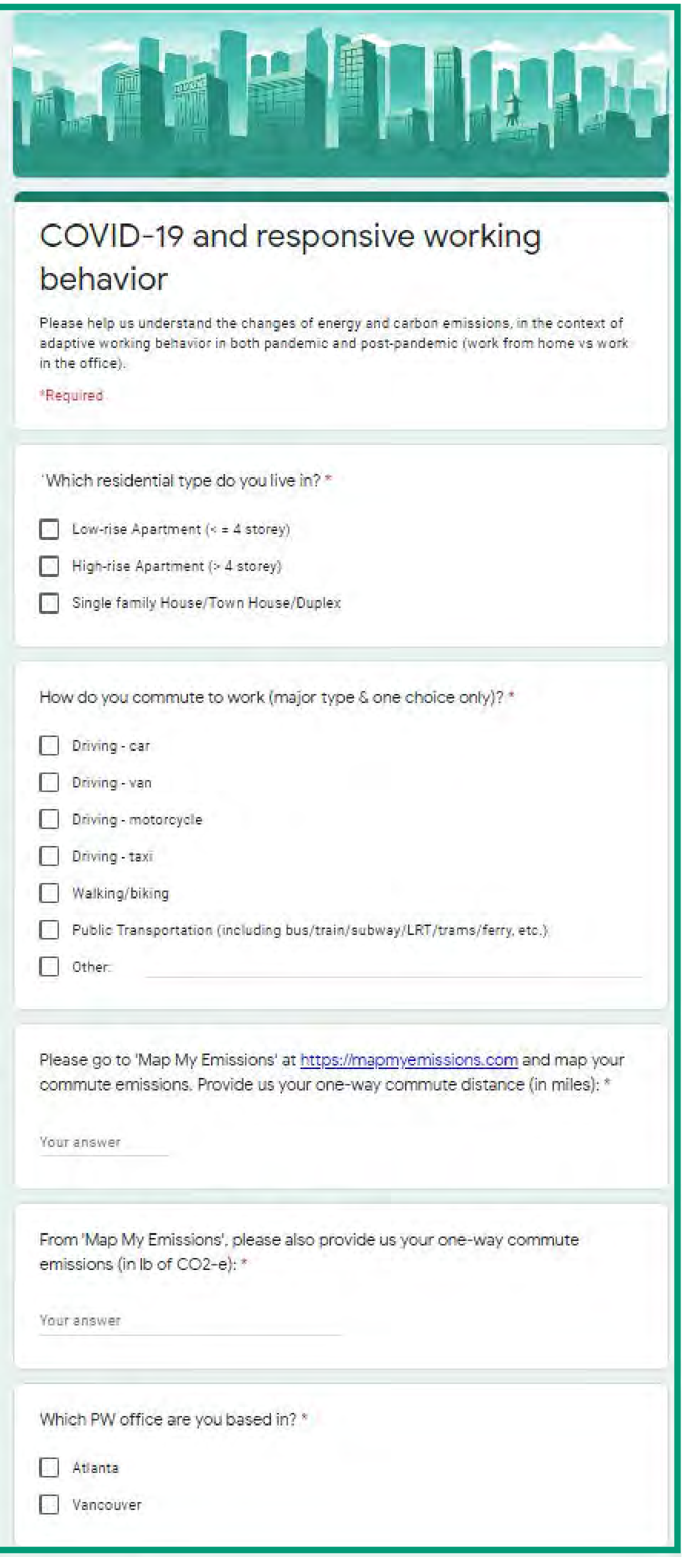


Residential Types Distributions & Commute Systems

Online survey is designed to collect employee's residential and commute information, in both Vancouver and Atlanta studios.

https://docs.google.com/forms/d/e/1FAIpQLSeZ4Ww5GoY0hARR977wXBiMqLIoRYSOqxHUjxuYyxsHyuElFw/viewform?vc=0&c=0&w=1





COVID-19 and responsive working behavior

Please help us understand the changes of energy and carbon emissions, in the context of adaptive working behavior in both pandemic and post-pandemic (work from home vs work in the office).

*Required

Which residential type do you live in? *

- [ ] Low-rise Apartment (< = 4 storey)
- [ ] High-rise Apartment (> 4 storey)
- [ ] Single family House/Town House/Duplex

How do you commute to work (major type & one choice only)? *

- [ ] Driving - car
- [ ] Driving - van
- [ ] Driving - motorcycle
- [ ] Driving - taxi
- [ ] Walking/biking
- [ ] Public Transportation (including bus/train/subway/LRT/trams/ferry, etc.)
- [ ] Other:

Please go to 'Map My Emissions' at https://mapmyemissions.com and map your commute emissions. Provide us your one-way commute distance (in miles): *

Your answer

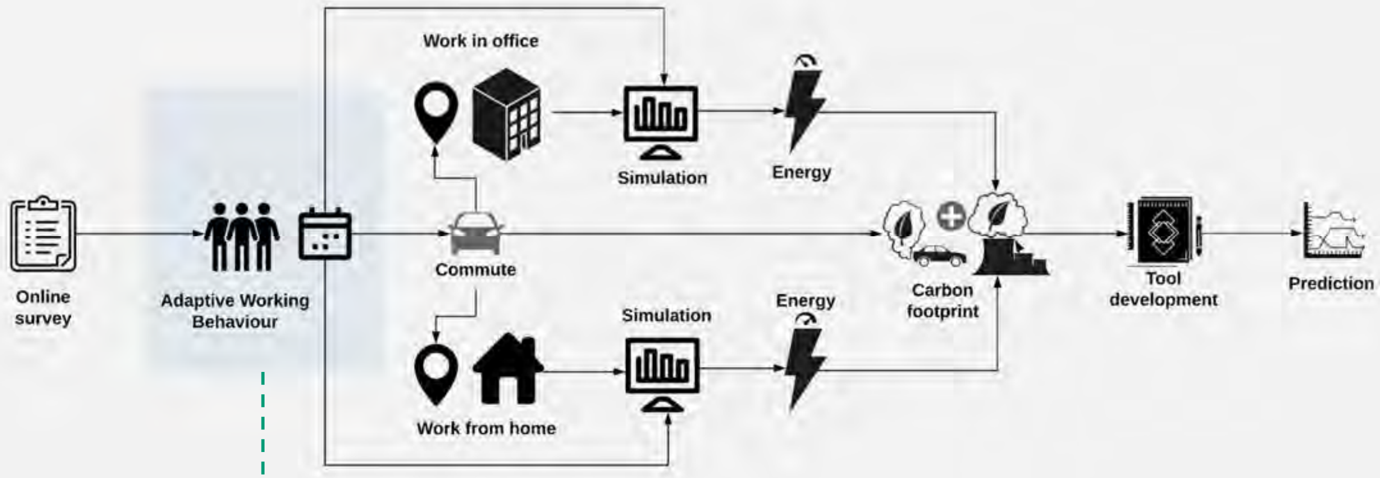
From 'Map My Emissions', please also provide us your one-way commute emissions (in lb of CO2-e): *

Your answer

Which PW office are you based in? *

- [ ] Atlanta
- [ ] Vancouver

Methodology



Adaptive Working Behavior

Dynamic weekly schedules and loads based on various occupancy scenario in commercial and residential buildings

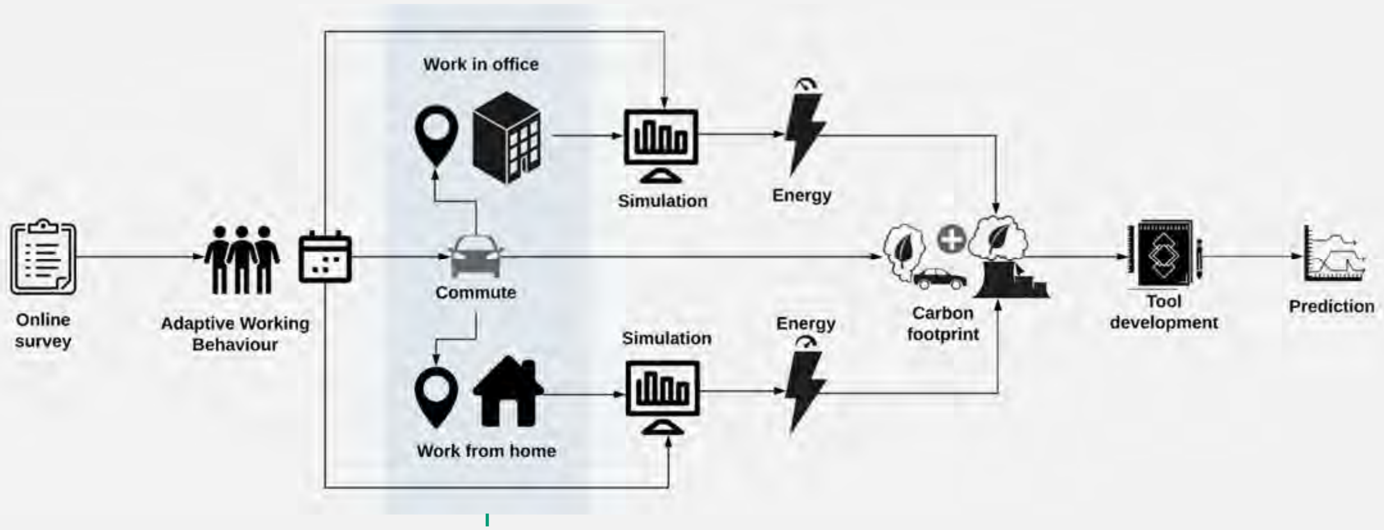
Schedule changes

Occupancy Scenario

0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%

Update Schedules	Update Loads
Occupancy Schedule	Occupancy Intensity
Lighting Schedule	Lighting Load
Equipment Schedule	Equipment Load
Ventilation Schedule	Ventilation Need

Methodology

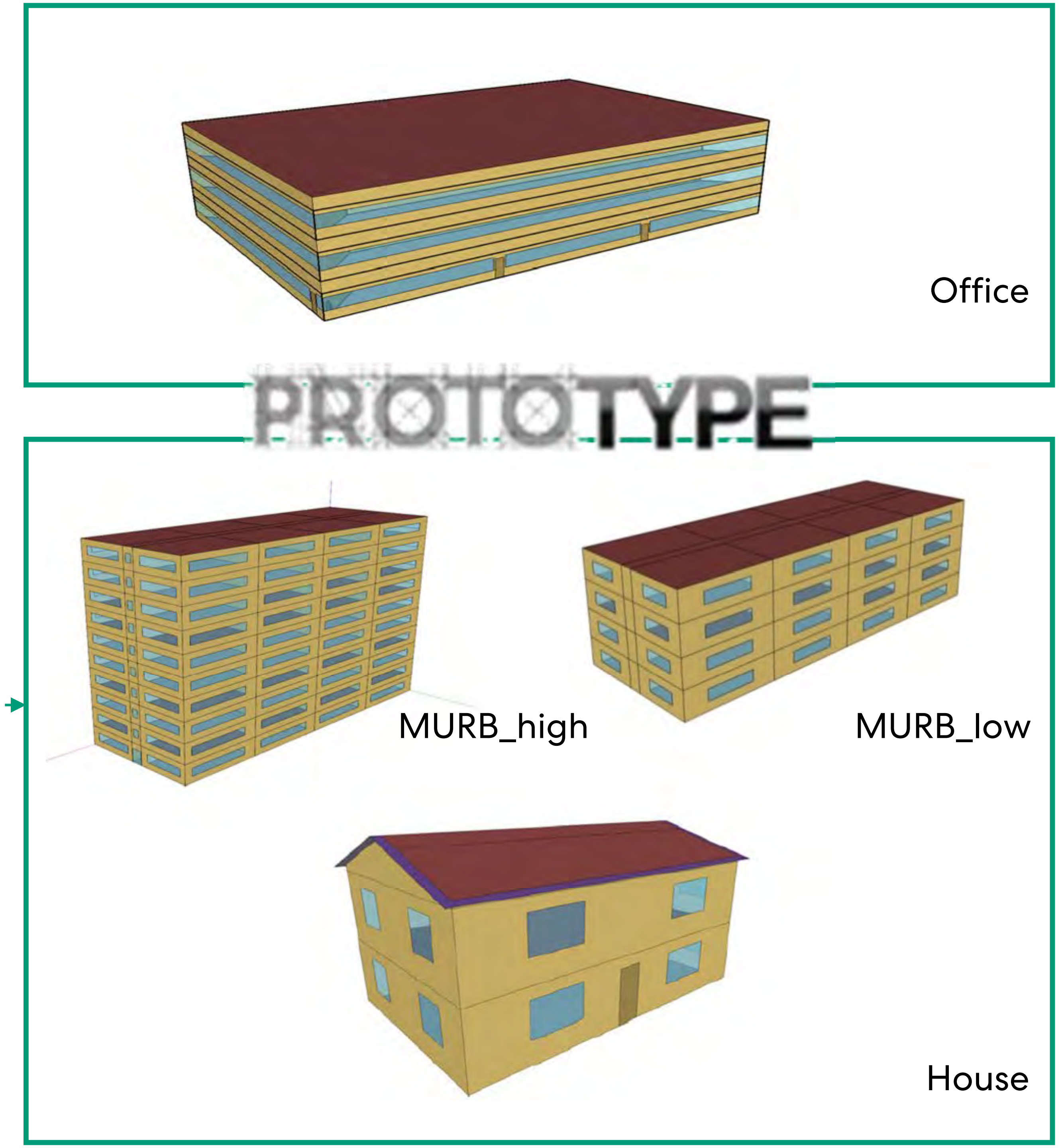


Identifying Prototype Buildings

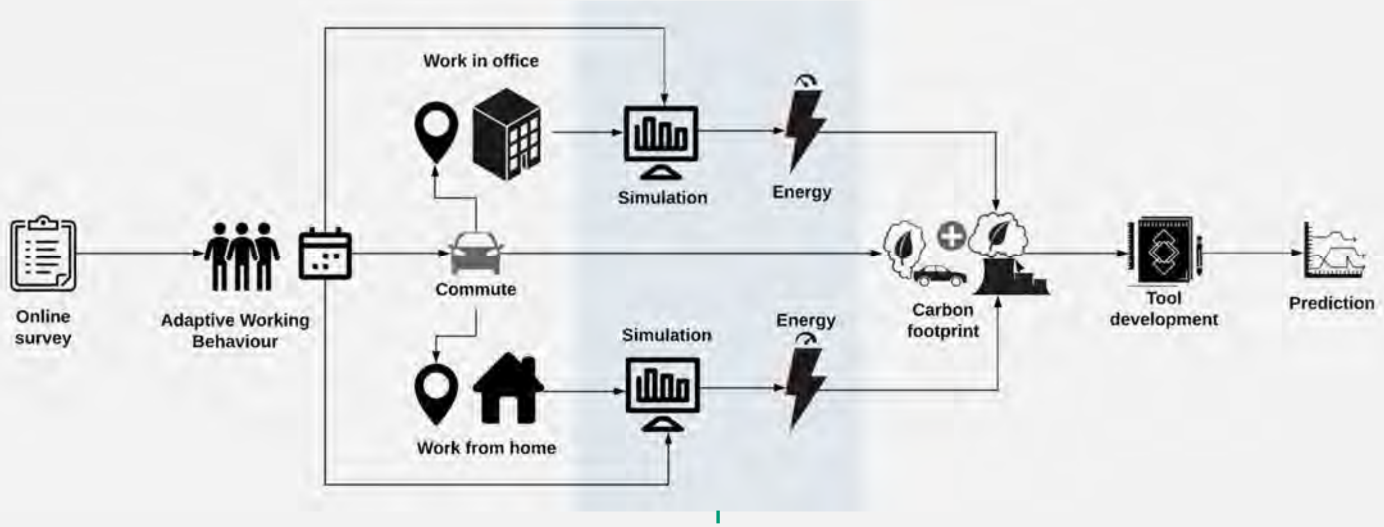
The U.S. Department of Energy (DOE) supports and participates in the model building energy code development for both commercial and residential buildings.

Four prototype models, office, MURB_high, MURB_low and house are used in this research.

https://www.energycodes.gov/development



Methodology

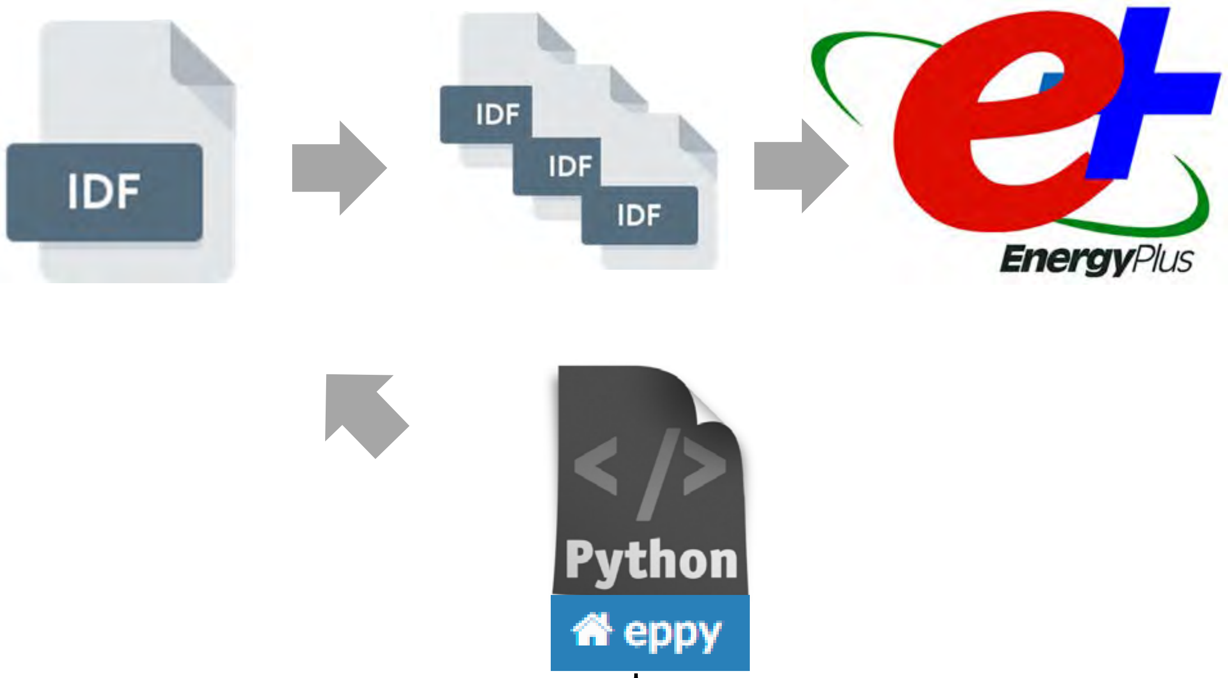


Energy Simulation

Eppy is a scripting language for E+ idf files, and E+ output files written in Python.

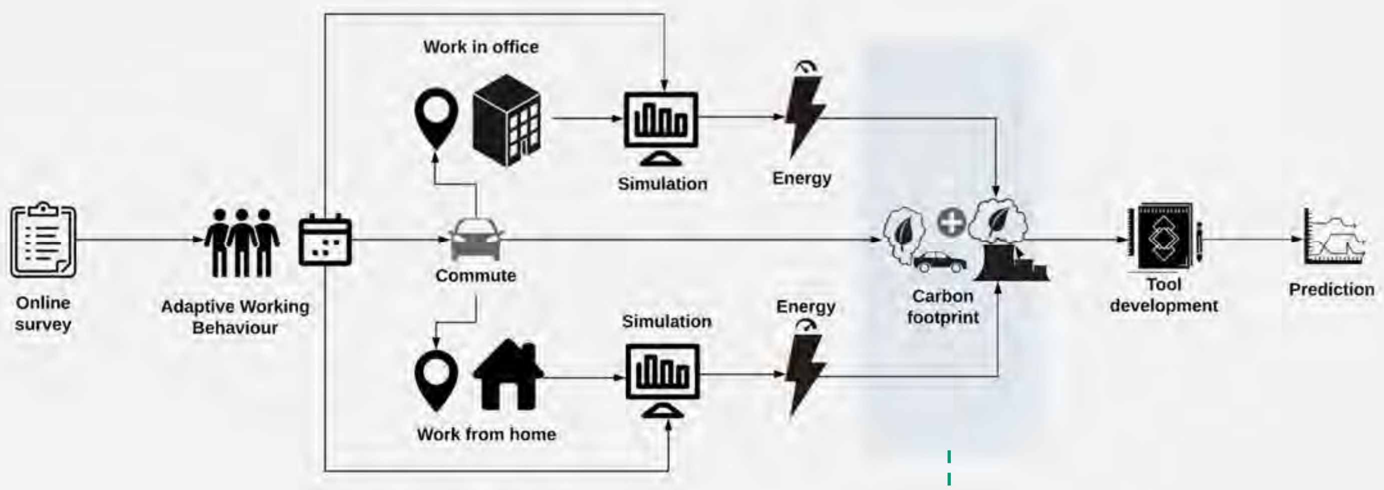
We modify all the schedule changes in E+ idf files through eppy and group simulate **88** iterations for all the prototype buildings with the different schedules.

https://eppy.readthedocs.io/




```python
from eppy import modeleditor
from eppy.modeleditor import IDF
idf_filepath=r"C:\Users\chench\OneDrive - Perkins & Will\Desktop\Incubatortest\office\ASHRAE901_OfficeMedium_STD2004_Van.idf"
idd_filepath=r"C:\EnergyPlusV9-0-1\Energy+.idd"
IDF.setiddname(idd_filepath)
idf1 = IDF(idf_filepath)
options=[0.0001,0.1,0.2,0.3,0.4,0.5,0.6,0.7,0.8,0.9]
all_ppl=idf1.idfobjects['people'.upper()]
all_eel=idf1.idfobjects['ElectricEquipment'.upper()]
all_dhl=idf1.idfobjects['WaterUse:Equipment'.upper()]
all_lpl=idf1.idfobjects['Lights'.upper()]
occupancy_densities=[ppl.Zone_Floor_Area_per_Person for ppl in all_ppl]
plug_densities=[eel.Design_Level for eel in all_eel]
dhw_densities=[dhl.Peak_Flow_Rate for dhl in all_dhl]
lpd_densities=[lpl.Watts_per_Zone_Floor_Area for lpl in all_lpl]
for option in options:
    for ppl,occ_density in zip(all_ppl,occupancy_densities):
        ppl.Zone_Floor_Area_per_Person=occ_density/option
    for eel,plug_density in zip(all_eel,plug_densities):
        eel.Design_Level=plug_density*option
    for dhl,dhw_density in zip(all_dhl,dhw_densities):
        dhl.Peak_Flow_Rate=dhw_density*option
    for lpl,lpd_density in zip(all_lpl,lpd_densities):
        lpl.Watts_per_Zone_Floor_Area=(lpd_density*0.77)+(lpd_density*0.23*option)
    output_filename=f'ASHRAE901_OfficeMedium_STD2004_{option}.idf'
    idf1.saveas(output_filename)
```

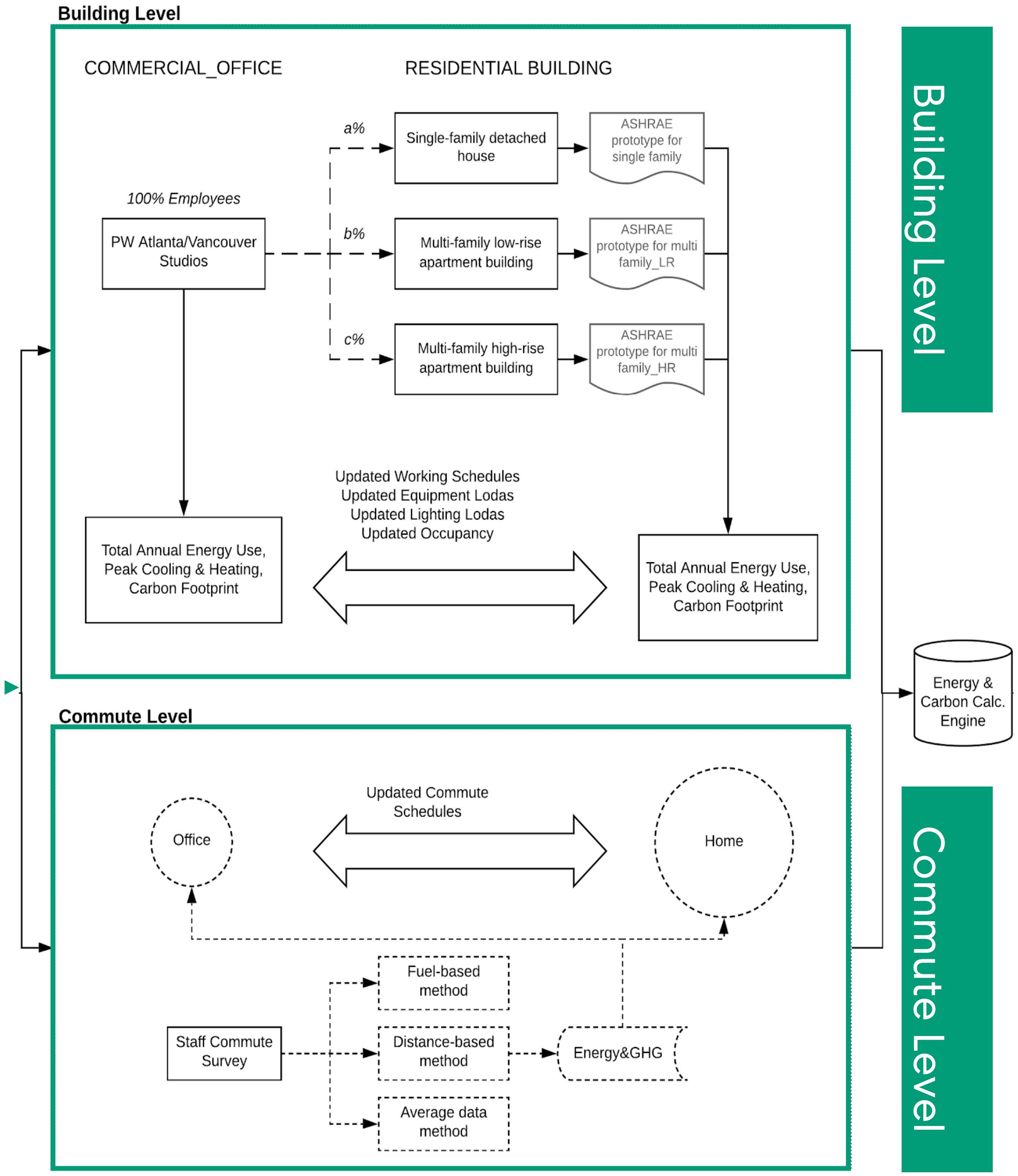
Methodology



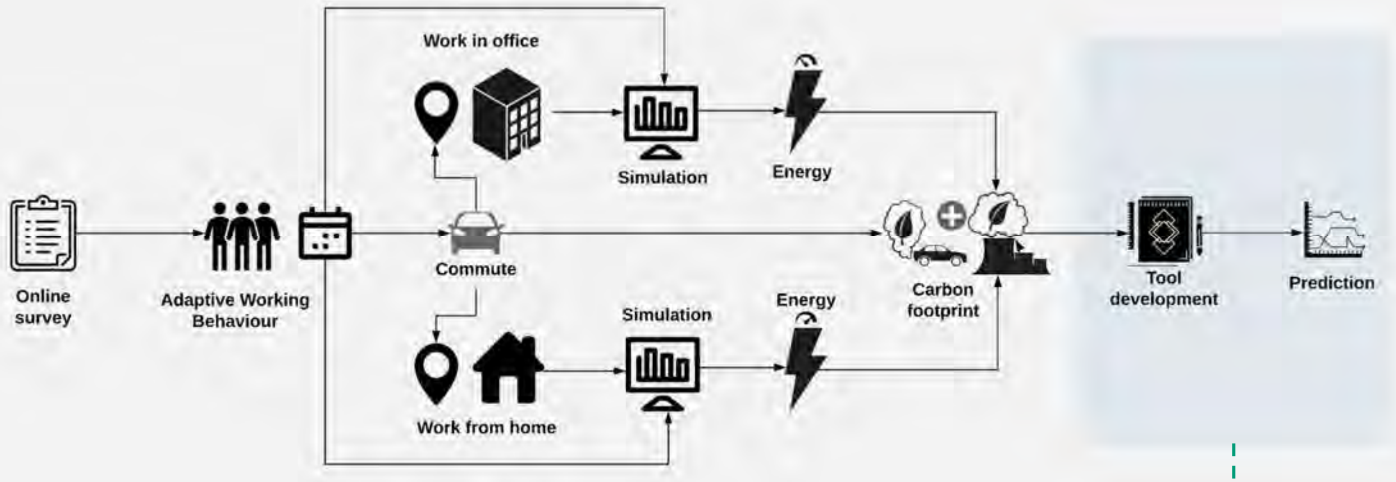
Data Integration

Integration of data and assessment of the total energy and carbon footprint of Buildings and commute systems.

Data integration chart



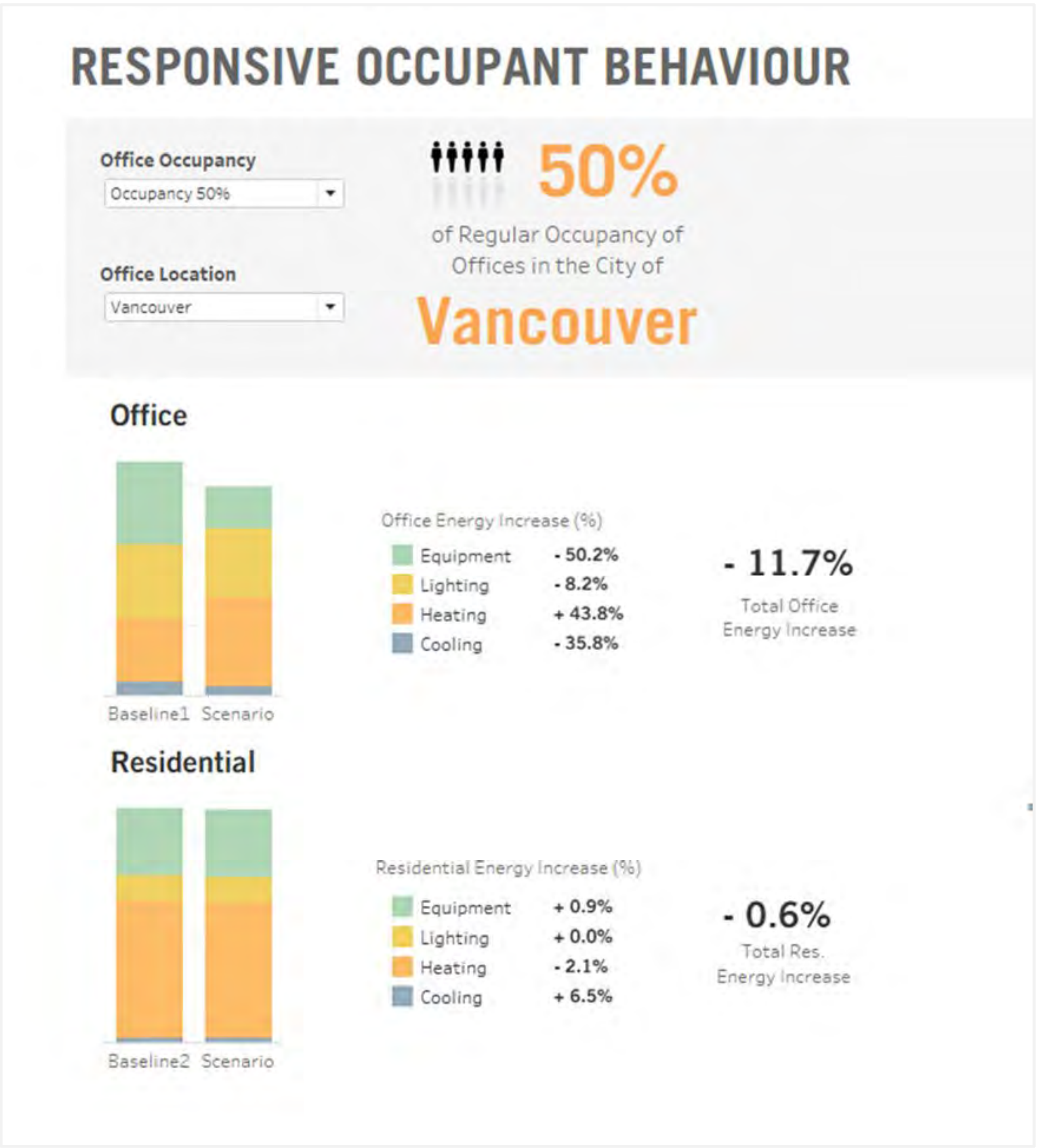
Methodology



Online Tool

Develop an online tool in Tableau to analyze, visualize, and predict the results

Online tool/dashboard



04 **ANALYSIS RESULTS**

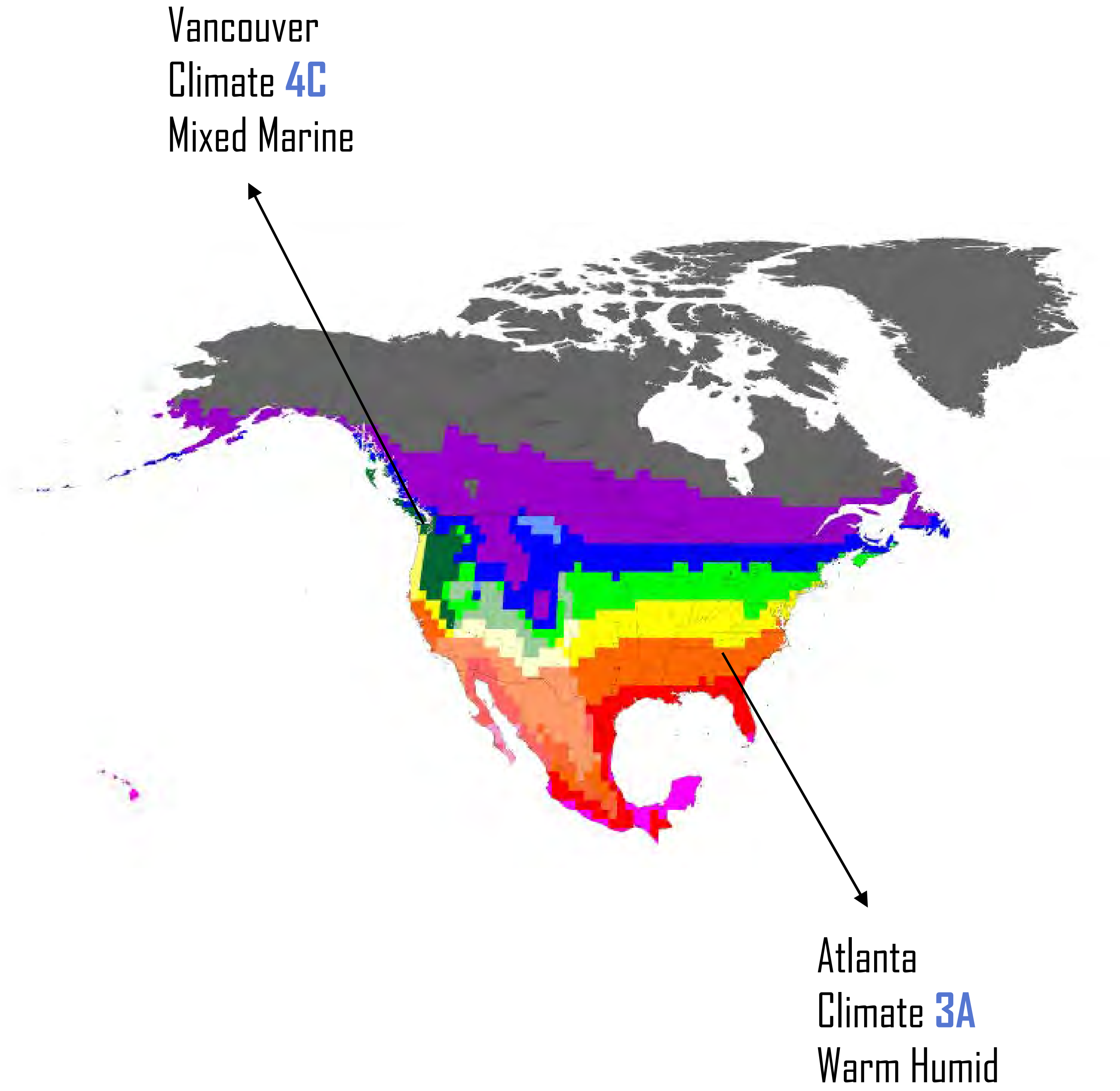
Climate

First, it is important to understand the climate difference between the two research cities:

Vancouver is a heating driven climate - Climate Zone 4C is defined as Mixed Marine with 2000 < HDD18ºC ≤ 3000 (3600 < HDD65ºF ≤ 5400);

Atlanta is a cooling driven climate - Climate Zone 3A is defined as Warm Humid with 2500 < CDD10ºC < 3500 (4500 < CDD50ºF ≤ 6300).

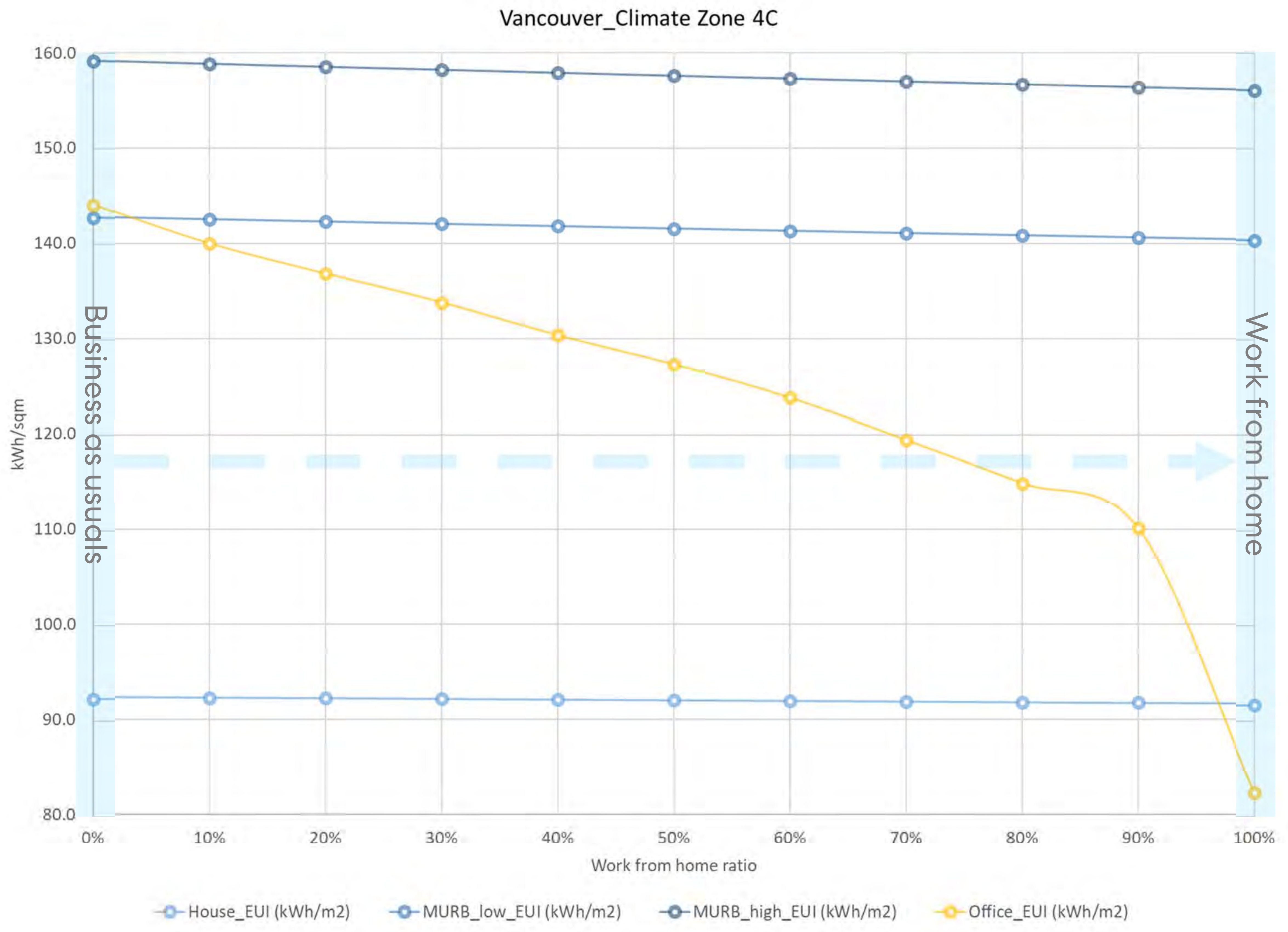
Two climate zones



Modeling Results

In Vancouver climate, with increased work from home ratio, all the EUI curves are in descending order.

Office has high gradient, but house has almost flat one.



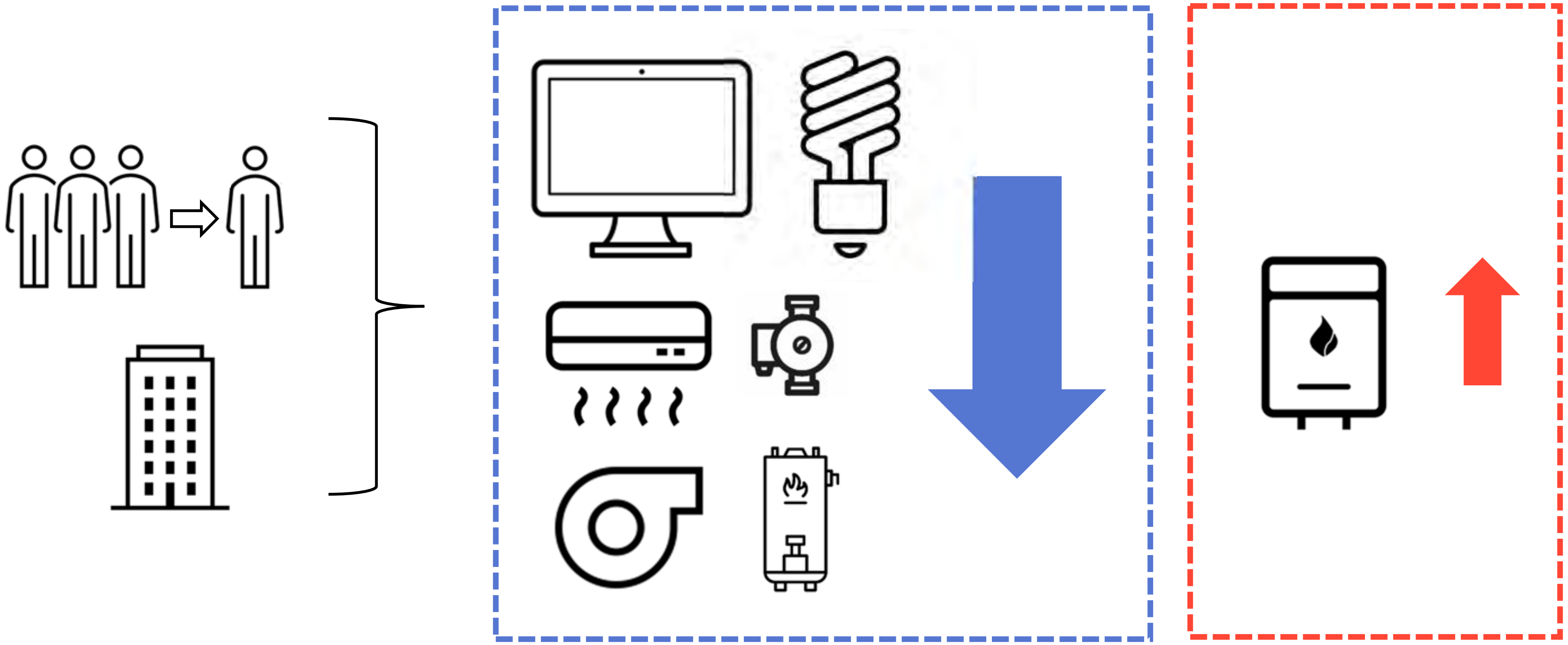
Vancouver EUI

Modeling Results

In Vancouver, office building with lower occupancy rate will trigger less cooling, lighting, equipment, fan, pump and DHW energy use.

The only energy increase, due to less internal heat gain, is heating energy.

Overall, energy use in an office building would be reduced significantly.



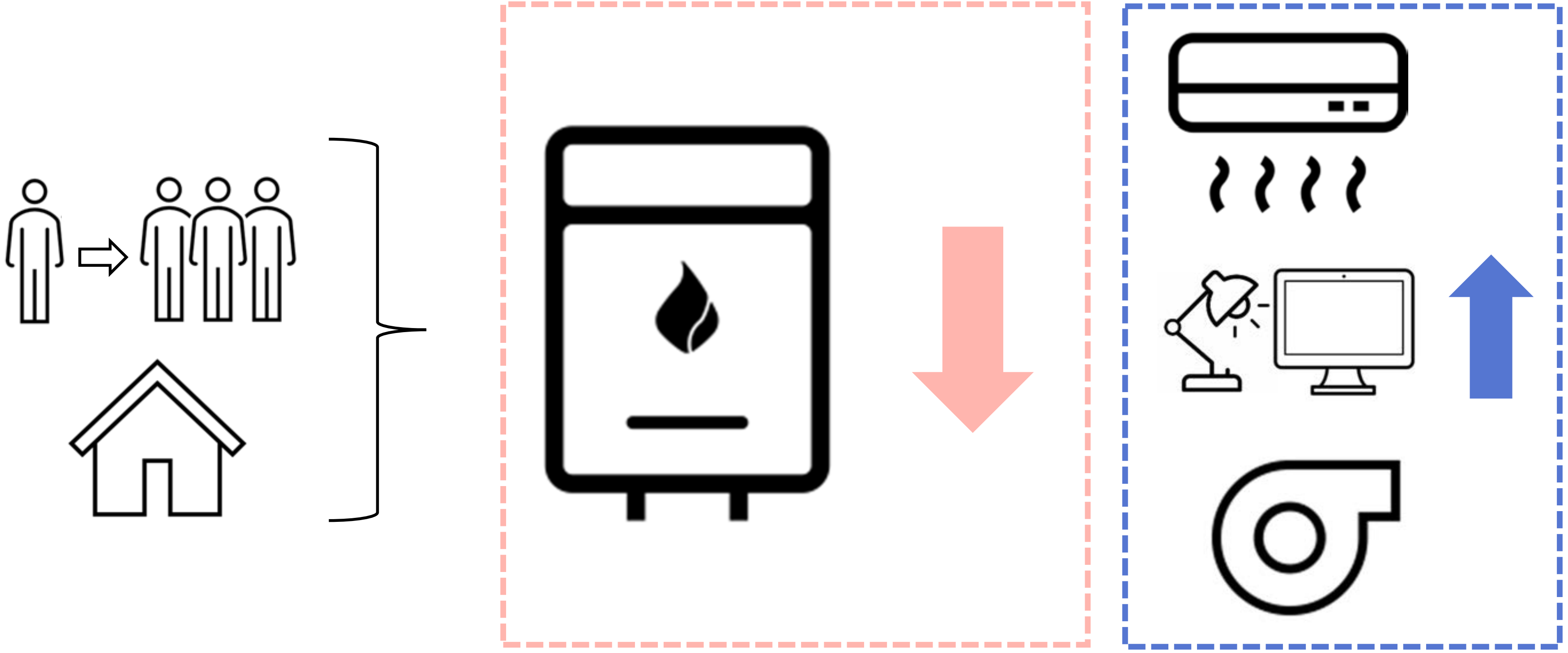
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Heating Energy (kWh)	309,319	286,369	281,508	274,866	267,237	254,663	239,095	224,113	206,851	189,846	177,075
Cooling Energy (kWh)	13,253	17,455	18,959	20,711	22,626	24,910	27,518	30,286	33,076	35,907	38,799
Lighting Energy (kWh)	73,881	184,232	187,763	191,295	194,827	198,358	201,890	205,421	208,953	212,484	216,016
Equipment Energy (kWh)	2,822	25,552	48,408	71,377	94,465	117,681	141,036	164,542	188,213	212,064	236,112
Fan Energy (kWh)	12,127	16,673	17,474	18,303	19,132	19,997	20,931	21,973	22,929	23,990	25,212
Pump Energy (kWh)	0	4	8	12	16	20	24	29	33	37	41
DHW Energy (kWh)	0	18,479	18,479	18,479	18,479	18,479	18,900	20,186	21,617	23,073	24,598
Total Electricity (kWh)	355,697	454,546	473,208	492,443	512,152	532,773	554,173	576,546	596,612	617,080	641,960
Total Gas (kWh)	55,705	94,217	99,391	102,599	104,629	101,335	95,220	90,004	85,059	80,320	75,894

Vancouver Office

Modeling Results

In Vancouver, residential building is still heating energy dominated. With higher occupancy rate in the dwelling space, internal heat gain increases, and heating energy (gas) reduces.

Although more cooling/equipment/fan energy (electricity) is required, the overall energy use would be reduced.



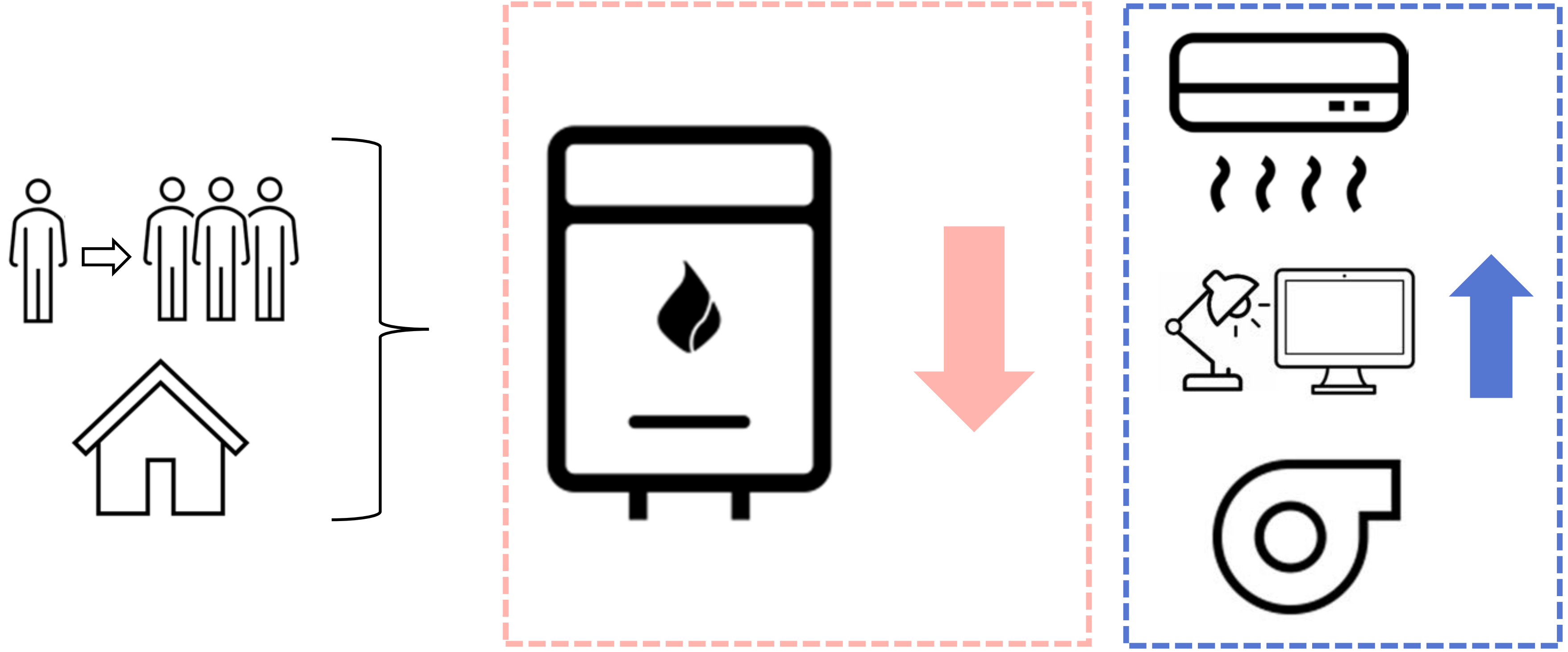
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Heating Energy (kWh)	371,484	368,524	365,577	362,666	359,741	356,832	353,986	351,141	348,257	345,448	342,627
Cooling Energy (kWh)	8,070	8,272	8,480	8,694	8,911	9,136	9,364	9,600	9,840	10,087	10,339
Lighting Energy (kWh)	152,061	152,061	152,061	152,061	152,061	152,061	152,061	152,061	152,061	152,061	152,061
Equipment Energy (kWh)	325,972	326,252	326,531	326,810	327,090	327,369	327,648	327,928	328,207	328,487	328,767
Fan Energy (kWh)	51,862	51,733	51,606	51,480	51,351	51,224	51,096	50,958	50,830	50,715	50,606
Pump Energy (kWh)	12,587	12,651	12,718	12,796	12,871	12,938	13,021	13,103	13,196	13,273	12,587
Heat Rejection (kWh)	387	396	406	416	426	436	446	457	468	479	491
DHW Energy (kWh)	325,113	325,113	325,111	325,112	325,111	325,112	325,114	325,111	325,112	325,112	325,112
Total Electricity (kWh)	631,057	630,870	630,694	630,543	630,394	630,251	630,144	630,027	629,938	629,872	629,812
Total Gas (kWh)	616,479	614,132	611,797	609,490	607,168	604,857	602,593	600,332	598,033	595,789	593,538

Vancouver MURB_high

Modeling Results

In Vancouver, residential building is still heating energy dominated. With higher occupancy rate in the dwelling space, internal heat gain increases, and heating energy (gas) reduces.

Although more cooling/equipment/fan energy (electricity) is required, the overall energy use would be reduced.



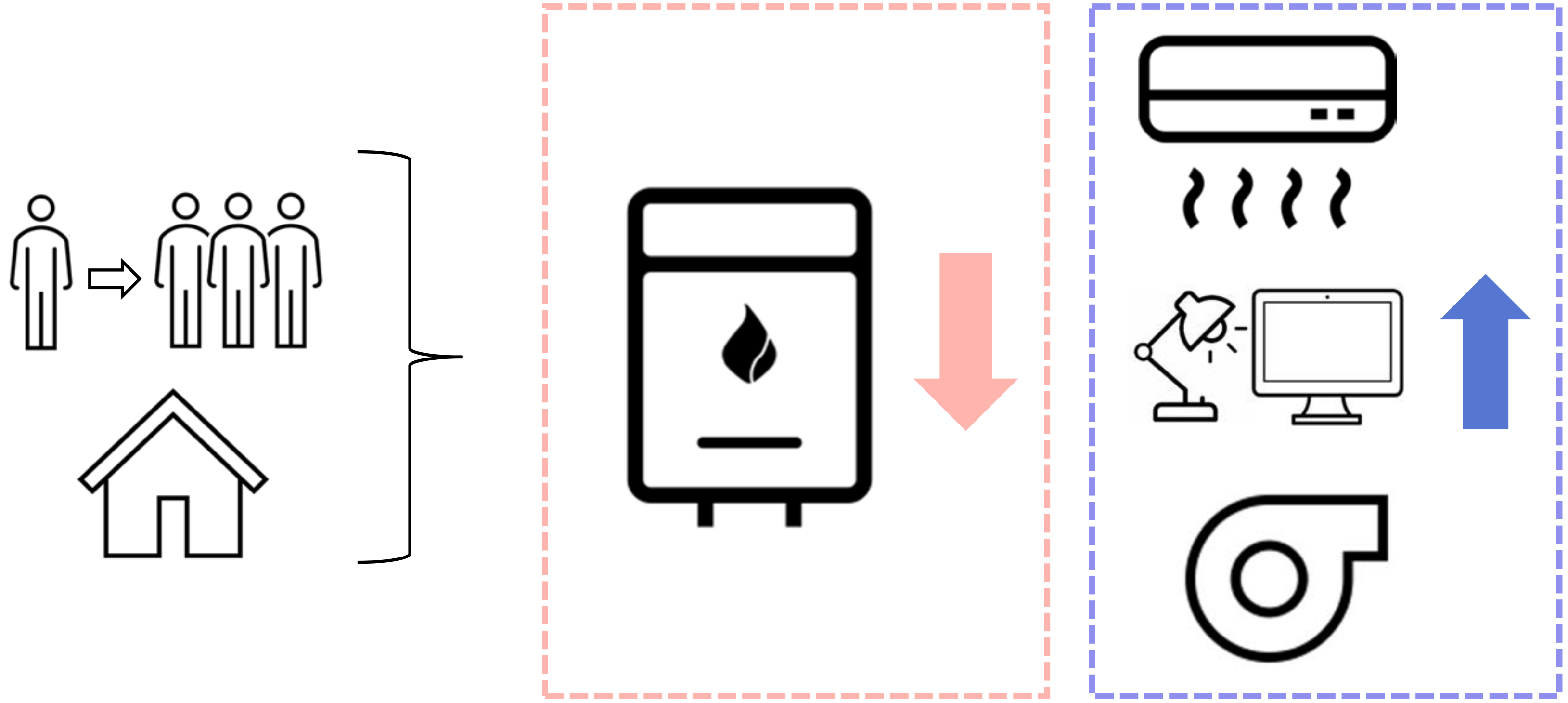
Vancouver MURB_low

	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Heating Energy (kWh)	101,137	100,066	99,001	97,936	96,882	95,835	94,793	93,760	92,737	91,719	90,714
Cooling Energy (kWh)	10,638	10,797	10,956	11,117	11,280	11,443	11,608	11,774	11,942	12,111	12,280
Lighting Energy (kWh)	58,964	58,964	58,964	58,964	58,964	58,964	58,964	58,964	58,964	58,964	58,964
Equipment Energy (kWh)	143,788	143,893	143,998	144,103	144,208	144,313	144,418	144,523	144,627	144,732	144,837
Fan Energy (kWh)	20,105	20,129	20,153	20,175	20,198	20,218	20,241	20,263	20,285	20,308	20,331
DHW Energy (kWh)	112,984	112,981	112,978	112,975	112,972	112,969	112,966	112,962	112,959	112,956	112,953
Total Electricity (kWh)	346,479	346,764	347,049	347,334	347,622	347,907	348,196	348,486	348,777	349,072	349,365
Total Gas (kWh)	101,137	100,066	99,001	97,936	96,882	95,835	94,793	93,760	92,737	91,719	90,714

Modeling Results

In Vancouver, house is heating energy dominated with minimal cooling requirement. With higher occupancy rate in the dwelling space, internal heat gain increases and heating energy (gas) reduces.

On the other hand, more cooling/equipment/fan energy (electricity) is required, the overall energy is sort of balanced.



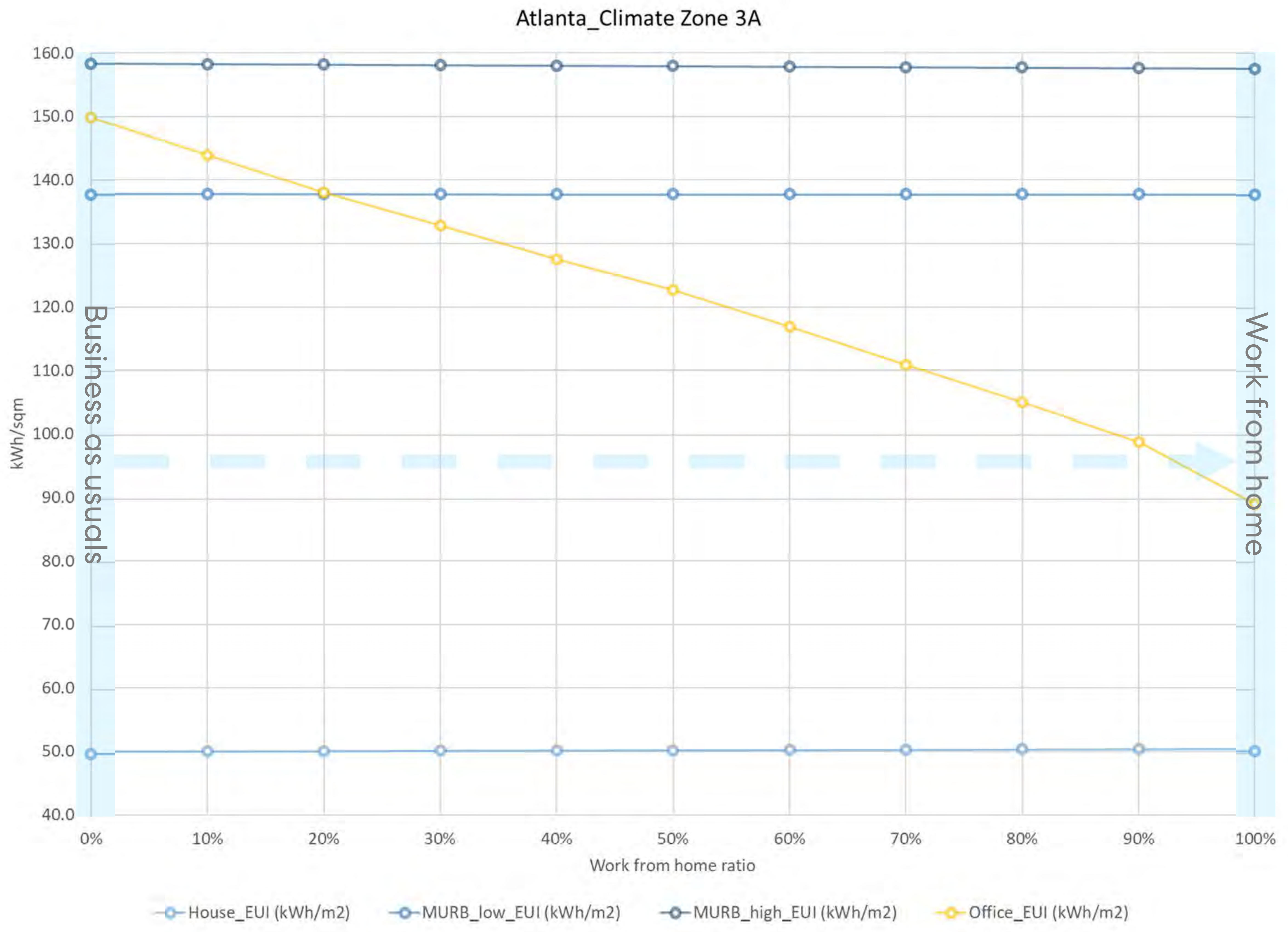
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Heating Energy (kWh)	21,028	20,970	20,913	20,856	20,800	20,744	20,688	20,632	20,576	20,521	20,466
Cooling Energy (kWh)	607	613	618	624	630	636	642	648	654	660	666
Lighting Energy (kWh)	2,003	2,003	2,003	2,003	2,003	2,003	2,003	2,003	2,003	2,003	2,003
Equipment Energy (kWh)	7,048	7,066	7,084	7,102	7,121	7,139	7,157	7,175	7,194	7,212	7,230
Fan Energy (kWh)	791	794	796	798	800	803	805	807	809	811	813
DHW Energy (kWh)	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,084	6,083	6,083
Total Electricity (kWh)	10,448	10,475	10,501	10,527	10,554	10,580	10,606	10,632	10,659	10,685	10,711
Total Gas (kWh)	30,338	30,281	30,225	30,169	30,114	30,058	30,004	29,949	29,894	29,840	29,786

Vancouver house

Modeling Results

In Atlanta climate, with increased work from home ratio, only office curve is in a clear descending order.

MURB_low and MURB-high EUI curves are almost flat and House EUI curve is actually in a slightly ascending order



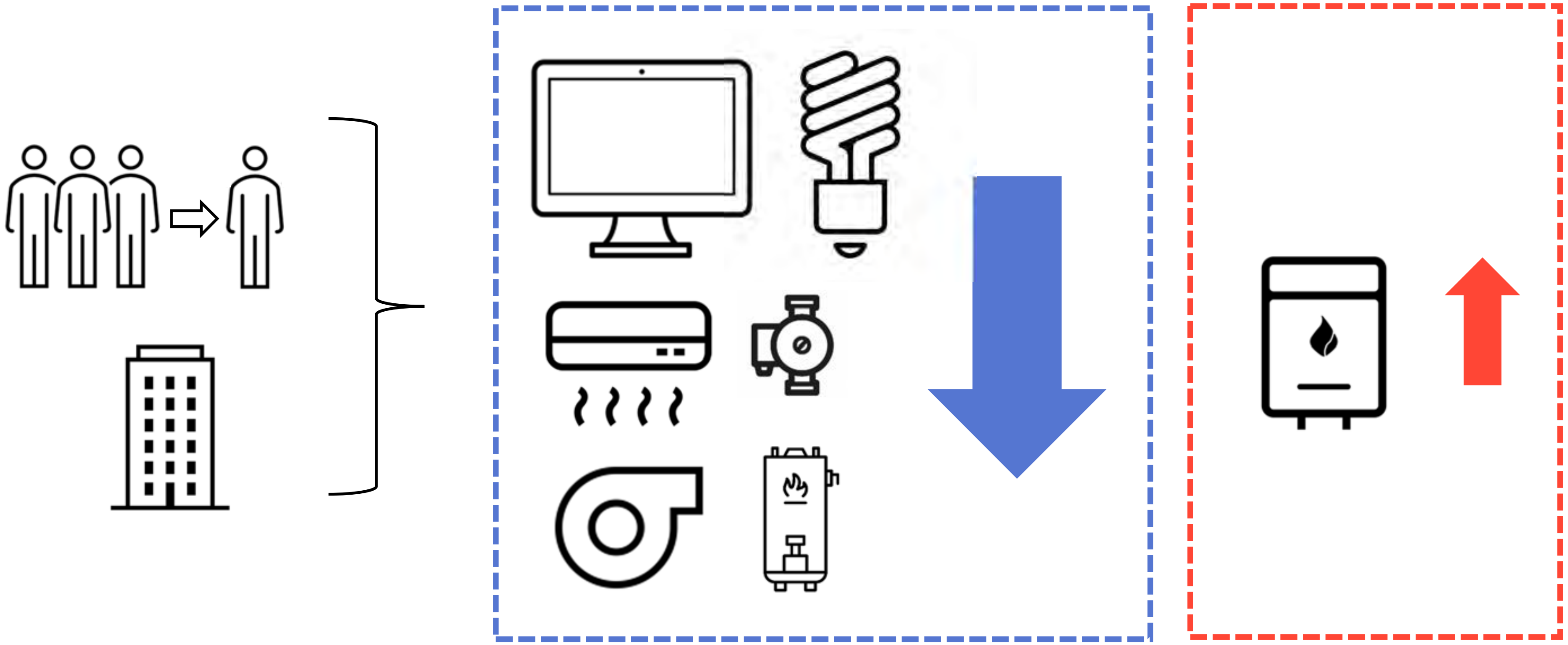
Atlanta EUI

Modeling Results

In Atlanta, office building with lower occupancy rate will trigger less cooling, lighting, equipment, fan, pump and DHW energy use.

The only significant energy increase, due to less internal heat gain, is heating.

Overall, energy use in an office building would be reduced and the building could be heating rather than cooling dominated.



	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Heating Energy (kWh)	159,854	156,215	152,392	147,776	143,311	138,306	127,847	118,881	108,495	100,785	93,711
Cooling Energy (kWh)	84,763	91,166	97,530	103,870	110,092	116,171	122,239	128,510	135,081	141,960	148,765
Lighting Energy (kWh)	180,864	184,392	187,924	191,455	194,987	198,518	202,050	205,581	209,113	212,645	216,176
Equipment Energy (kWh)	2,825	25,552	48,408	71,377	94,465	117,681	141,036	164,542	188,213	212,064	236,112
Fan Energy (kWh)	15,908	17,085	18,300	19,565	20,850	22,156	23,431	24,844	26,243	27,795	29,363
Pump Energy (kWh)	0	4	8	12	16	20	24	29	33	37	41
DHW Energy (kWh)	0	18,479	18,479	18,479	18,479	18,479	18,613	19,226	20,268	21,467	22,770
Total Electricity (kWh)	391,720	419,056	446,837	475,282	503,980	532,972	560,070	590,064	619,363	651,278	683,718
Total Gas (kWh)	52,494	73,836	76,203	77,251	78,218	78,359	75,170	71,547	68,083	65,473	63,219

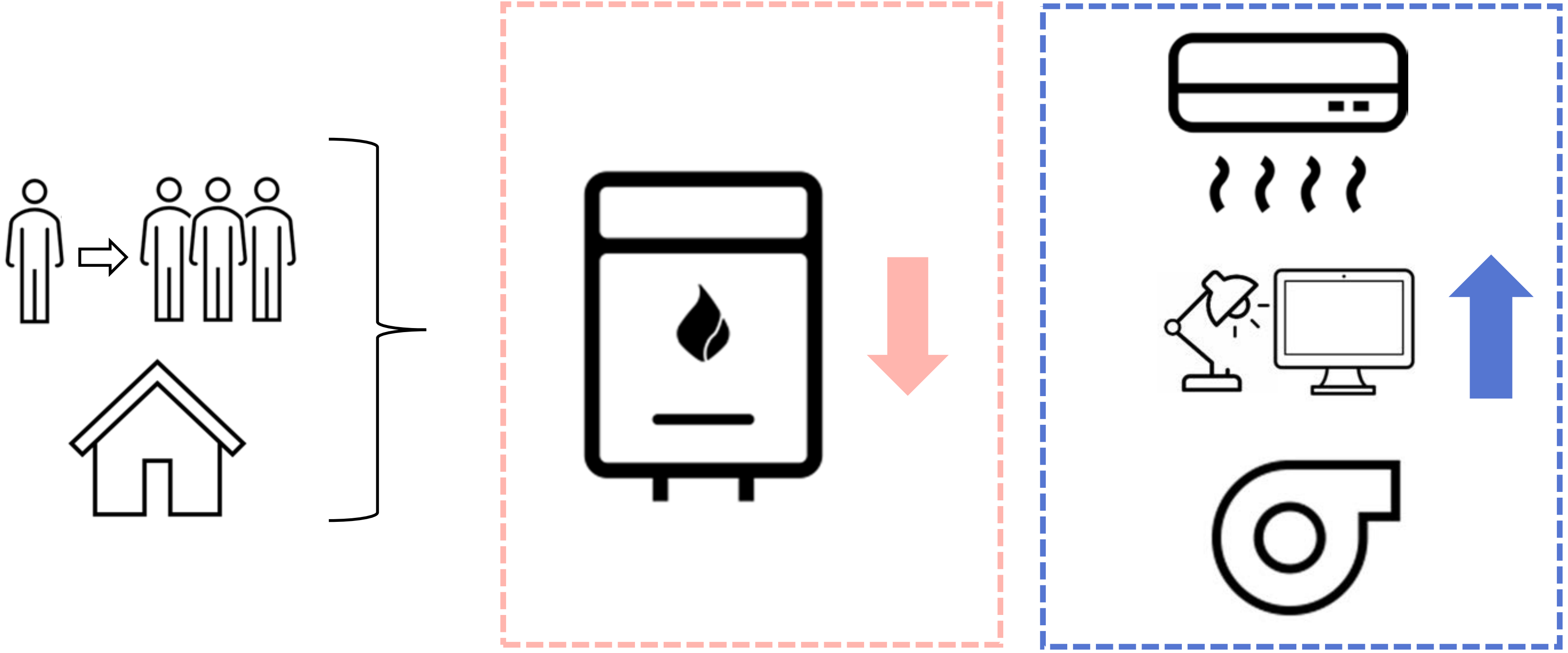
Modeling Results

In Atlanta, MURB building consumes more heating energy than cooling.

With higher occupancy rate in the dwelling space, more cooling/equipment/fan energy (electricity) is required. On the other hand, with internal heat gain increases, heating energy (gas) reduces.

They trade off and no big overall energy change is observed.

Atlanta MURB_high



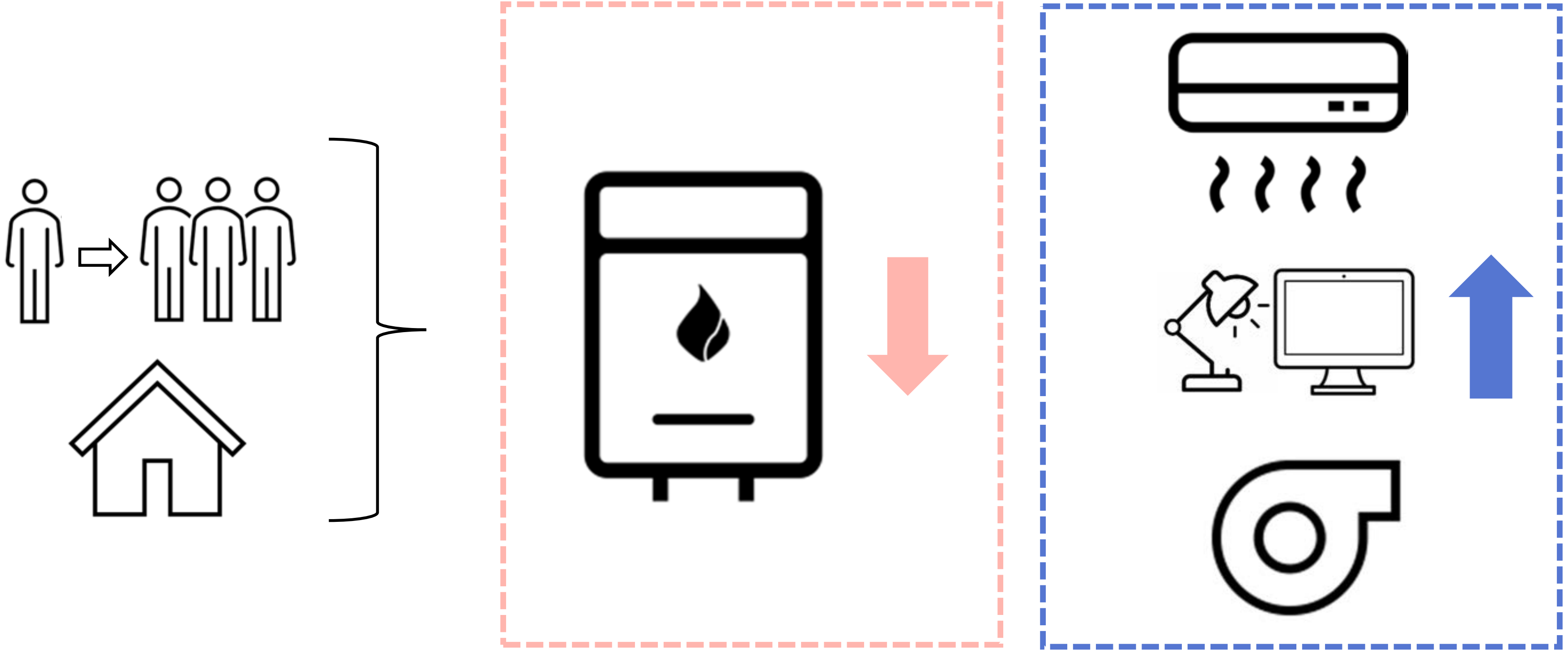
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Heating Energy (kWh)	248,610	246,653	244,737	242,807	240,882	238,975	237,090	235,223	233,355	231,459	229,610
Cooling Energy (kWh)	135,913	136,716	137,523	138,331	139,145	139,963	140,787	141,620	142,454	143,306	144,150
Lighting Energy (kWh)	152,213	152,213	152,213	152,213	152,213	152,213	152,213	152,213	152,213	152,213	152,213
Equipment Energy (kWh)	325,972	326,252	326,531	326,810	327,090	327,369	327,648	327,928	328,207	328,487	328,767
Fan Energy (kWh)	68,253	68,328	68,412	68,496	68,579	68,661	68,741	68,823	68,905	68,975	69,059
Pump Energy (kWh)	17,313	17,374	17,439	17,501	17,568	17,631	17,705	17,779	17,842	17,920	17,313
Heat Rejection (kWh)	6,400	6,435	6,470	6,506	6,542	6,578	6,615	6,653	6,691	6,731	6,771
DHW Energy (kWh)	286,269	286,266	286,264	286,264	286,266	286,266	286,266	286,266	286,266	286,266	286,266
Total Electricity (kWh)	760,405	761,264	762,144	763,022	763,913	764,806	765,723	766,654	767,573	768,512	769,474
Total Gas (kWh)	480,538	478,974	477,446	475,905	474,371	472,850	471,343	469,851	468,361	466,844	465,363

Modeling Results

In Atlanta, MURB building consumes more heating energy than cooling.

With higher occupancy rate in the dwelling space, more cooling/equipment/fan energy (electricity) is required. On the other hand, with internal heat gain increases, heating energy (gas) reduces.

They trade off and no big overall energy change is observed.



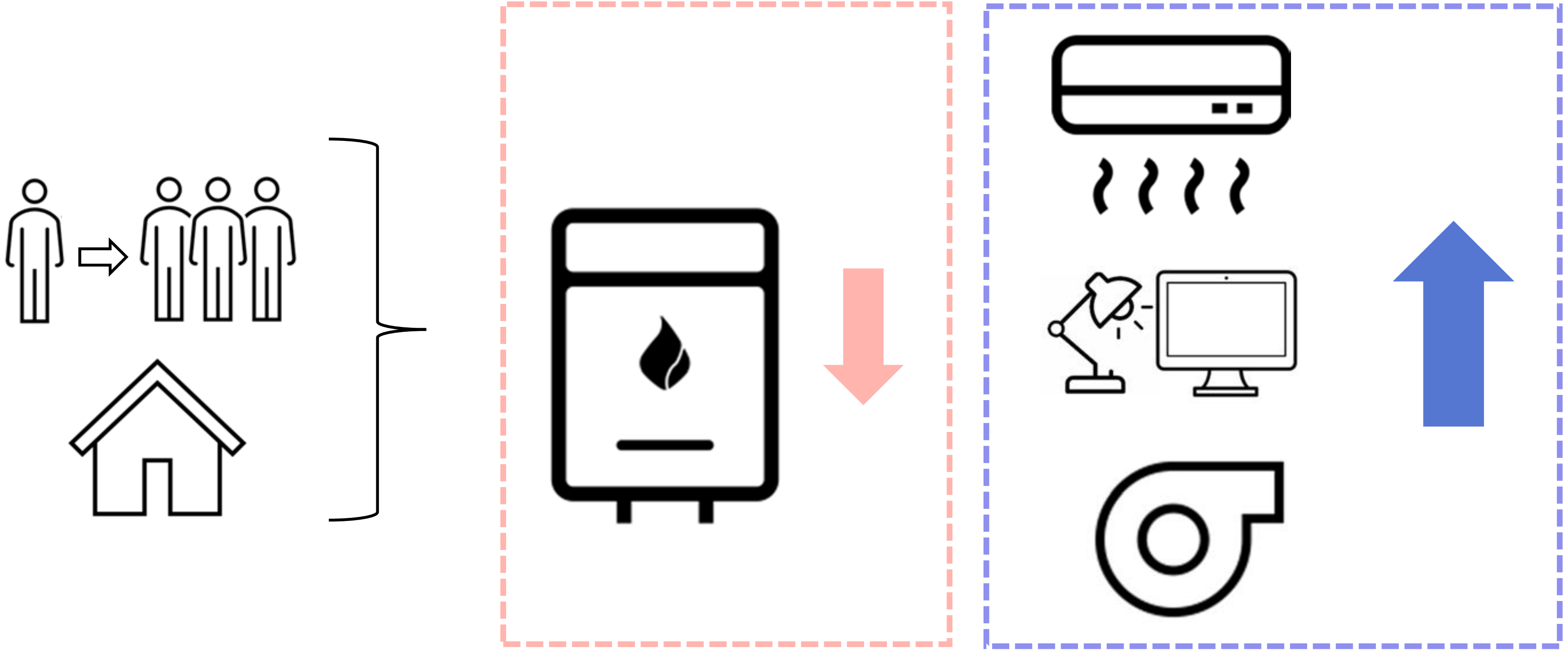
	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Heating Energy (kWh)	53,638	53,124	52,616	52,097	51,600	51,102	50,613	50,123	49,643	49,162	48,685
Cooling Energy (kWh)	48,653	48,960	49,266	49,572	49,900	50,214	50,525	50,837	51,148	51,458	51,770
Lighting Energy (kWh)	59,016	59,016	59,016	59,016	59,016	59,016	59,016	59,016	59,016	59,016	59,016
Equipment Energy (kWh)	143,788	143,893	143,998	144,103	144,208	144,313	144,418	144,523	144,627	144,732	144,837
Fan Energy (kWh)	26,036	26,099	26,161	26,224	26,268	26,329	26,392	26,455	26,519	26,579	26,644
DHW Energy (kWh)	100,912	100,910	100,908	100,906	100,904	100,901	100,899	100,896	100,894	100,893	100,891
Total Electricity (kWh)	378,406	378,878	379,349	379,821	380,295	380,772	381,249	381,727	382,205	382,679	383,159
Total Gas (kWh)	53,638	53,124	52,616	52,097	51,600	51,102	50,613	50,123	49,643	49,162	48,685

Atlanta MURB_low

Modeling Results

In Atlanta, residential building is still heating energy dominated. With higher occupancy rate in the dwelling space, internal heat gain increases, and heating energy (gas) reduces.

On the other hand, more cooling/equipment/fan energy (electricity) is required, the overall energy use is increased slightly.



	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Heating Energy (kWh)	5,161	5,150	5,139	5,128	5,118	5,107	5,096	5,084	5,074	5,063	5,053
Cooling Energy (kWh)	2,837	2,850	2,863	2,876	2,889	2,902	2,915	2,929	2,943	2,956	2,969
Lighting Energy (kWh)	2,003	2,003	2,003	2,003	2,003	2,003	2,003	2,003	2,003	2,003	2,003
Equipment Energy (kWh)	7,792	7,809	7,825	7,841	7,858	7,874	7,890	7,907	7,923	7,940	7,956
Fan Energy (kWh)	1,133	1,135	1,137	1,139	1,140	1,142	1,144	1,144	1,146	1,148	1,149
DHW Energy (kWh)	3,147	3,147	3,147	3,147	3,147	3,147	3,147	3,147	3,147	3,147	3,147
Total Electricity (kWh)	22,073	22,093	22,114	22,134	22,154	22,175	22,196	22,215	22,236	22,256	22,278
Total Gas (kWh)	0	0	0	0	0	0	0	0	0	0	0

Atlanta house

Survey results

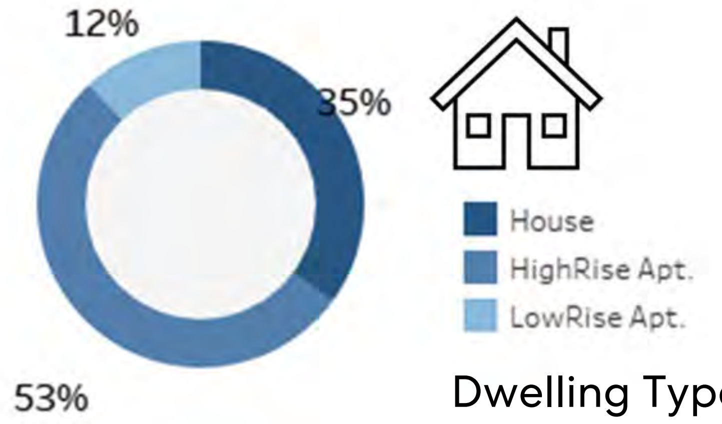
Vancouver studio

Total employee **124**

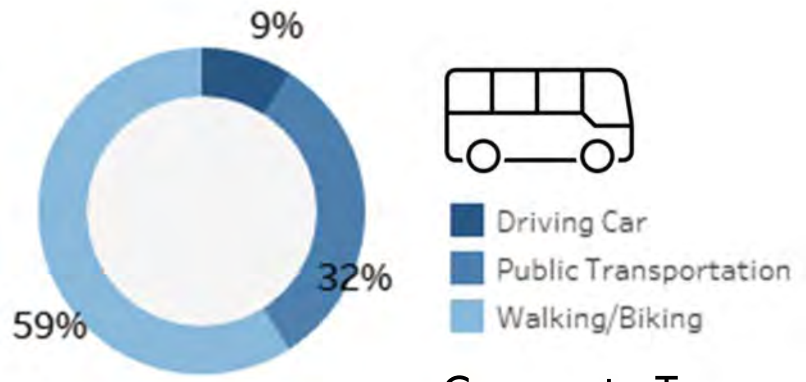
Response rate **54.8%**

Ave. commute distance (km) per day **15.4**

Ave. CO2-e per day (kg) **1.1**



Dwelling Type



Commute Type

Online survey Vancouver

Survey results

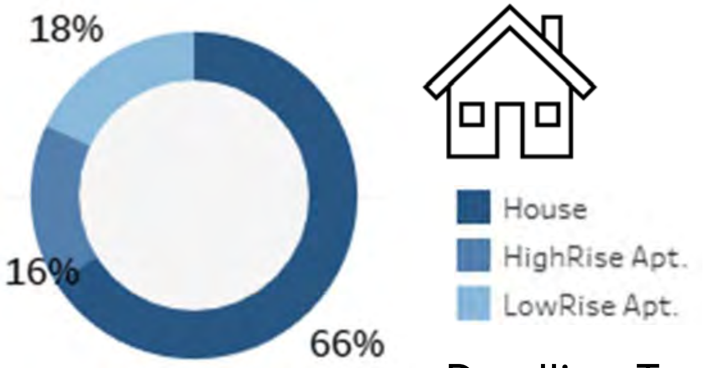
Atlanta studio

Total employee **158**

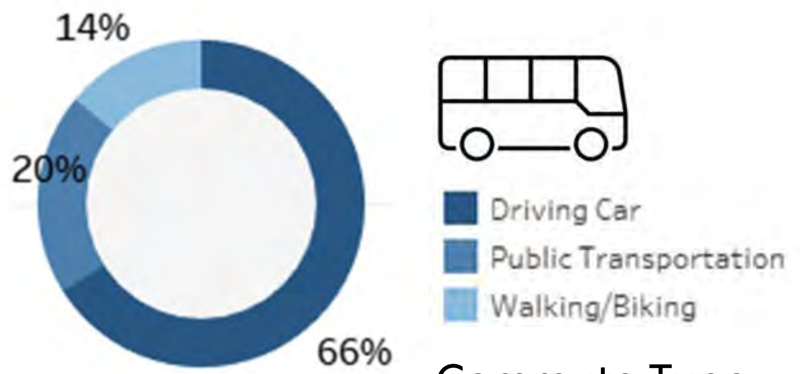
Response rate **55.7%**

Ave. commute distance (km) per day **31**

Ave. CO2-e per day (kg) **5.3**



Dwelling Type



Commute Type

Online survey Atlanta

05 **CONCLUSION**

Conclusion

Vancouver studio

Business as usual vs work form home

124 people

35% House

53% MURB High

12% MURB Low

15.4 Ave. distance per person (KM)

- Telework can result in decreasing buildings' total energy use, up to 42.7% in heating-dominated climates such as Vancouver, mostly due to the reduction in equipment and lighting loads.
- Working from home can also result in decreasing residential energy use, up to 1.2%, mostly due to decrease in heating loads.

- Telework decrease carbon emission in Vancouver, both from buildings operation and commute system.
- In Vancouver with walking culture, the decrease in CO2 emission is not huge, but still effective, up to 77 ton per year in the case studied.
- The environmental attributes of electric power in Vancouver is small, due to the green hydraulic plants in the region. Still telework can reduce CO2 up to 22 ton/year.
- In total, telework for a medium-size office can reduce CO2 emission of up to 13.9% in the city of Vancouver.

Vancouver summary

Conclusion

Atlanta studio

Business as usual vs work form home

Atlanta summary

158 people

66% House

18% MURB High

16% MURB Low

31 Ave. distance per person (KM)

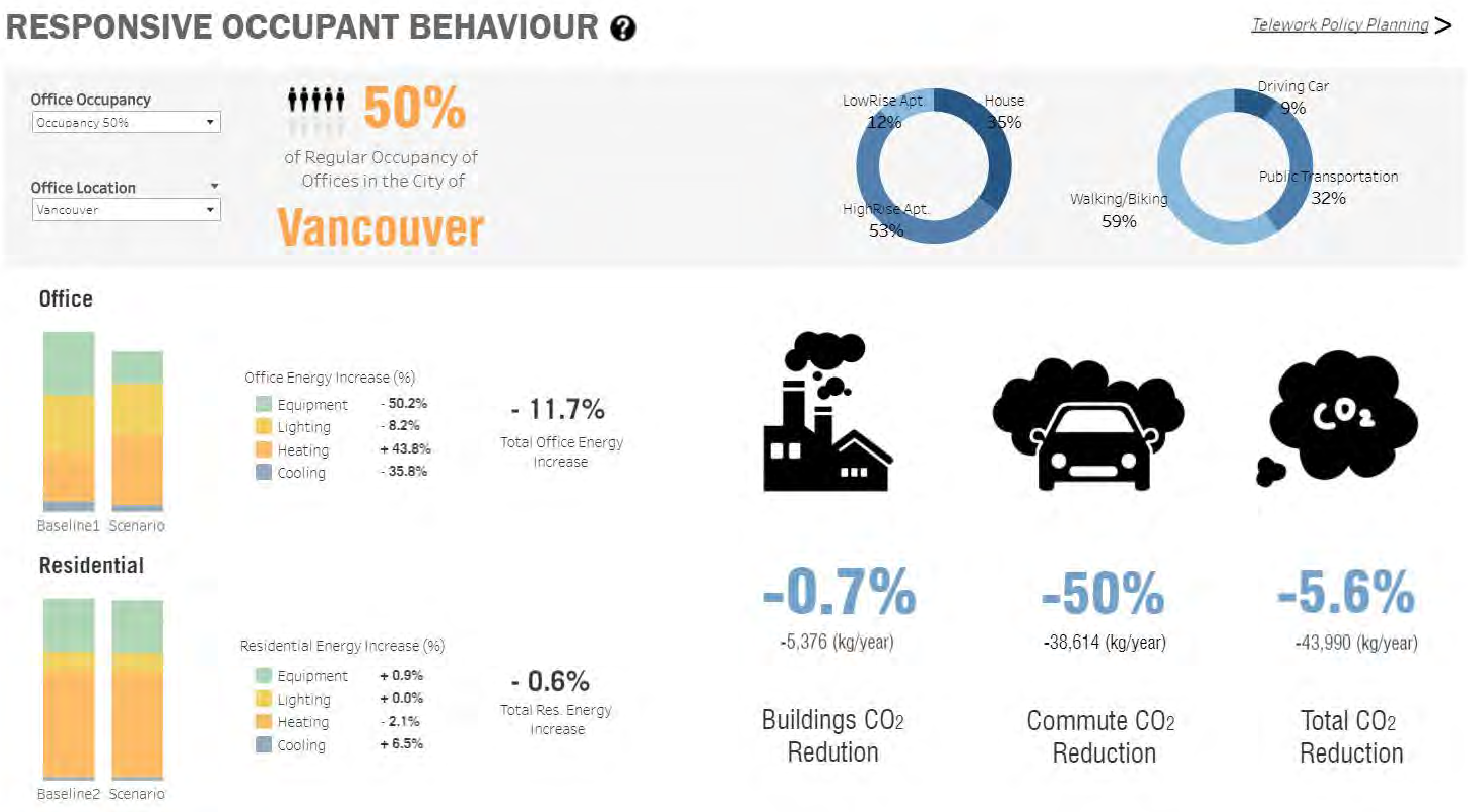
- Telework can result in decreasing total energy use, up to 40.5% in cooling-dominated climates such as Atlanta, mostly due to the reduction in equipment and cooling loads.
- Working from home can result in increasing residential energy use, up to 0.6%, mostly due to increase in equipment and cooling loads.

- Telework decrease carbon emission in Atlanta, both from buildings operation and commute system.
- In Atlanta with heavy reliance on driving personal cars, telework can decrease CO2 emission related to transportation dramatically, in our case study more than 360 ton/year.
- The environmental attributes of electric power in Atlanta is high, due to non-efficient plants and electric grid systems available in the region, therefore reduction in electricity will reduce CO2 emission effectively up to 120 ton/year.
- In total, telework for a medium-size office can reduce CO2 emission of up to 19.2% in the city of Atlanta.

Online tool

https://dashboard.perkinswill.com/views/COVID-19Response/ResponsiveOcc?:origin=card_share_link&:embed=n

Tableau Online



RESPONSIVE OCCUPANT BEHAVIOUR
Telework Policy Planning >
Office Occupancy
Occupancy 50%
Office Location
Vancouver
50%
of Regular Occupancy of Offices in the City of
Vancouver
LowRise Apt. 12%
House 35%
HighRise Apt. 53%
Driving Car 9%
Public Transportation 32%
Walking/Biking 59%
Office
Baseline1
Scenario
Office Energy Increase (%)
Equipment - 50.2%
Lighting - 8.2%
Heating + 43.8%
Cooling - 35.8%
- 11.7%
Total Office Energy Increase
Residential
Baseline2
Scenario
Residential Energy Increase (%)
Equipment + 0.9%
Lighting + 0.0%
Heating - 2.1%
Cooling + 6.5%
- 0.6%
Total Res. Energy Increase
CO2
-0.7%
-5,376 (kg/year)
Buildings CO2 Redution
-50%
-38,614 (kg/year)
Commute CO2 Reduction
-5.6%
-43,990 (kg/year)
Total CO2 Reduction

TELEWORK POLICY PLANNING

< *Responsive Occupants Behavior*

Your Office Location?

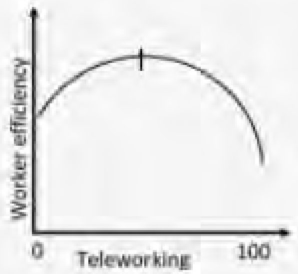
Vancouver

Your Office Area (ft2)?

25,000

"Sweet Spot" Occupancy

Occupancy 50%



UPDATED ENERGY USE INTENSITY(EUI)

127.3 kWh/m2/year

40.35 kBtu/ft2/year

OFFICE ENERGY USE REDUCTION

-39,060 kWh/year

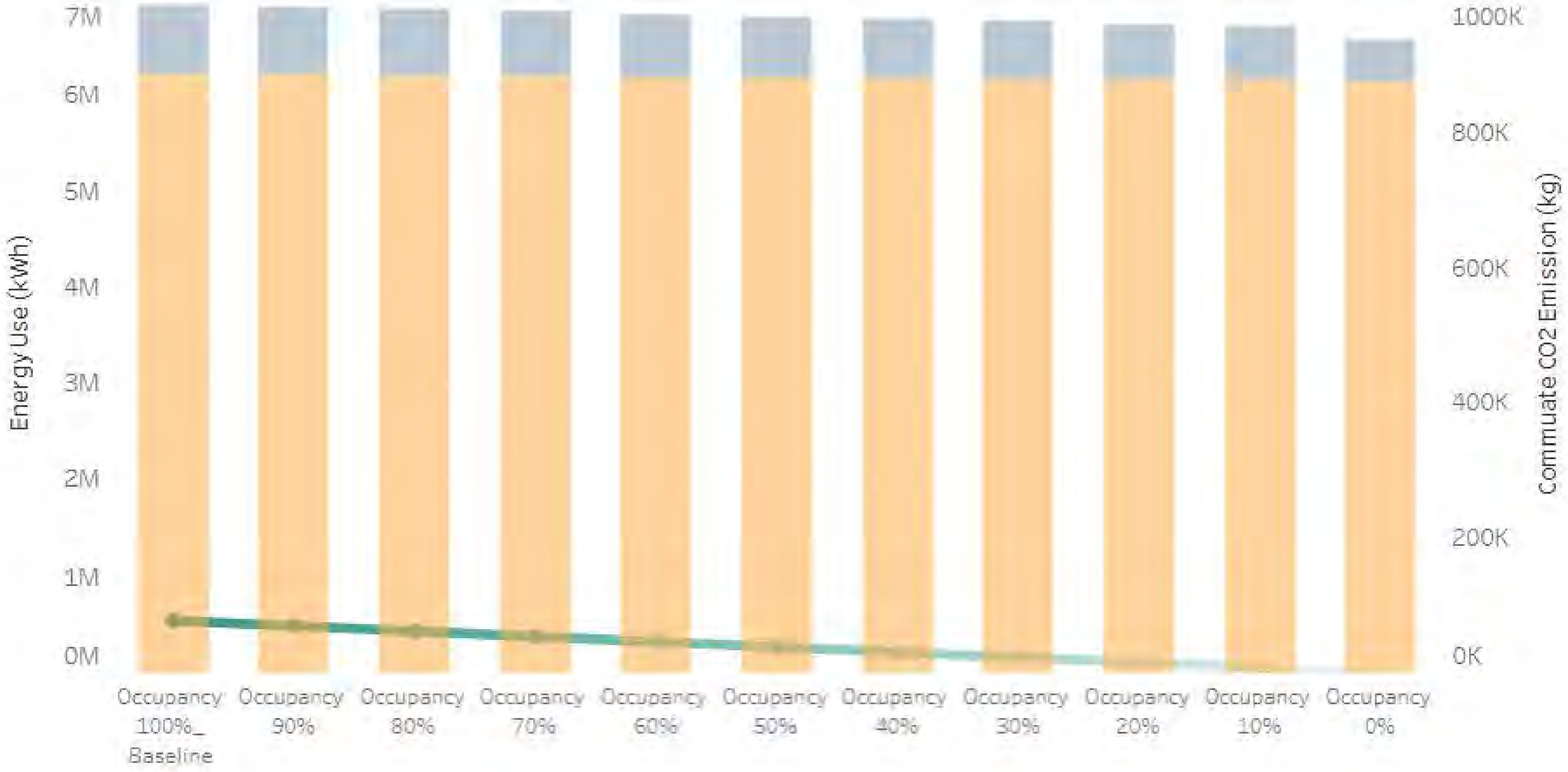
-133,265 kBtu/year

OFFICE OPERATION CO2 REDUCTION

-2,506 kg/year

COMMUTE TO-WORK CO2 REDUCTION

-18,010 kg/year



Energy Consumption Pattern

Average Office Energy Use

Average Residential Energy Use

Commute CO2 Emission Pattern

0 77,229

RESPONSIVE OCCUPANT BEHAVIOUR

Telework Policy Planning >

Office Occupancy

Occupancy 50%

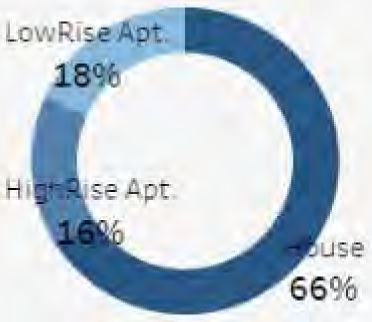
Office Location

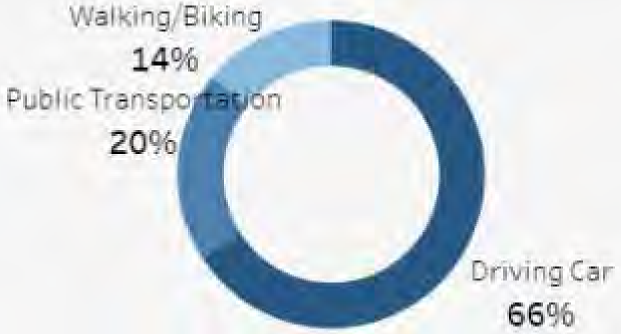
Atlanta

50%

of Regular Occupancy of Offices in the City of

Atlanta





Office

Office Energy Increase (%)

Equipment	- 50.2%
Lighting	- 8.2%
Heating	+ 47.6%
Cooling	- 21.9%

- 18.2%

Total Office Energy Increase

Residential

Residential Energy Increase (%)

Equipment	+ 0.9%
Lighting	+ 0.0%
Heating	- 1.6%
Cooling	+ 2.5%

+ 0.3%

Total Res. Energy Increase

-2.2%

-58,220 (kg/year)

Buildings CO_2 Redution

-50%

-181,071 (kg/year)

Commute CO_2 Reduction

-8.7%

-239,291 (kg/year)

Total CO_2 Reduction

TELEWORK POLICY PLANNING

< *Responsive Occupants Behavior*

Your Office Location?

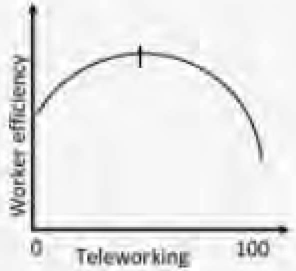
Atlanta

Your Office Area (ft2)?

25,000

"Sweet Spot" Occupancy

Occupancy 50%



UPDATED ENERGY USE INTENSITY(EUI)

122.7 kWh/m2/year

38.90 kBtu/ft2/year

OFFICE ENERGY USE REDUCTION

-63,249 kWh/year

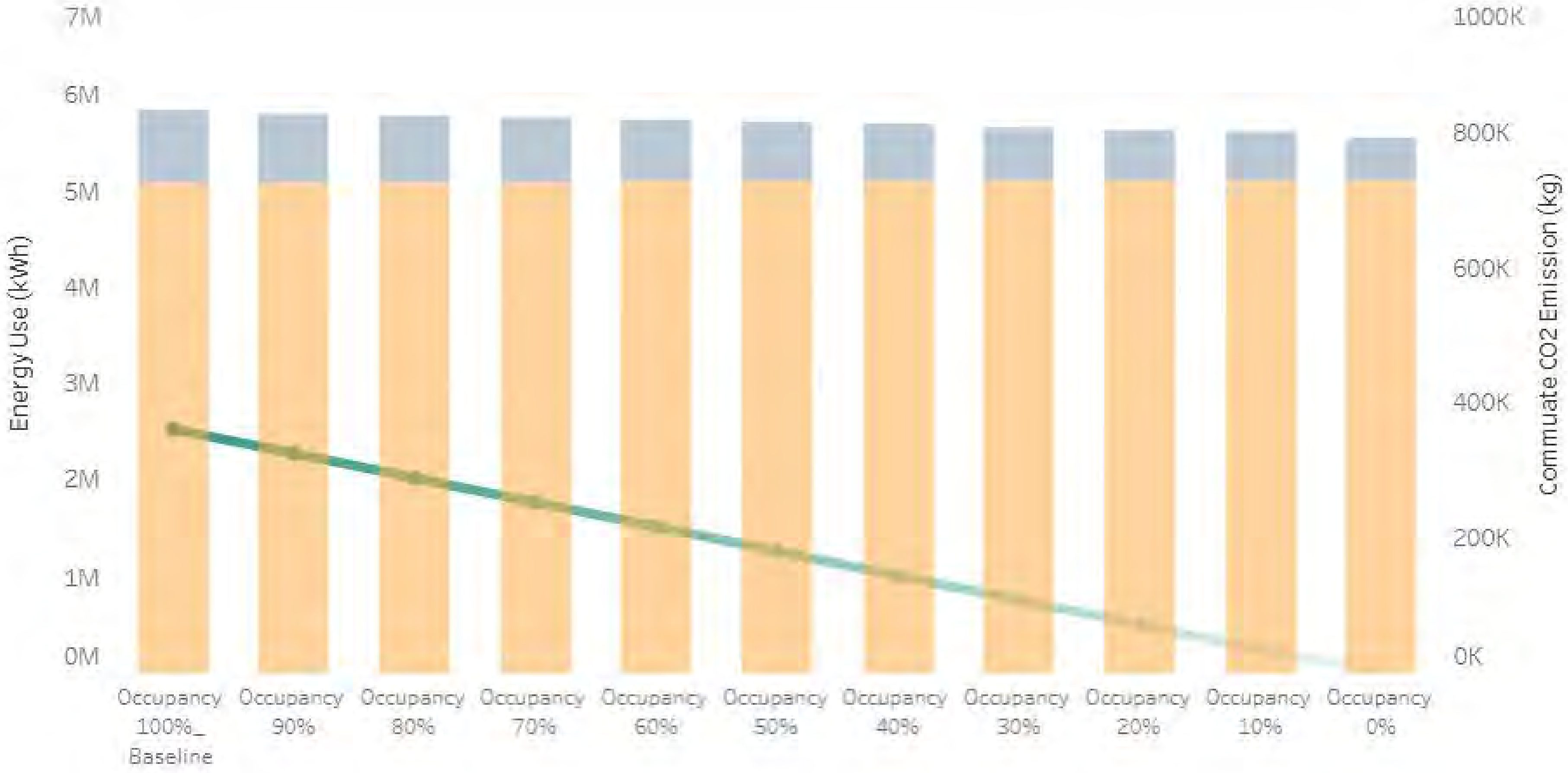
-215,794 kBtu/year

OFFICE OPERATION CO2 REDUCTION

-27,141 kg/year

COMMUTE TO-WORK CO2 REDUCTION

-84,455 kg/year



Energy Consumption Pattern

- Average Office Energy Use
- Average Residential Energy Use

Commuate CO2 Emission Pattern

0 – 362,141

06 **LIMITATIONS AND FUTURE WORK**

Limitations and future work

- Two climate zones
- Two studios
- Measurement and verification
- Social benefits

Research limitations

Limitations and future work

The use of smart building technology, IoT, can enable more efficient facilities management and help support a safe and healthy environment:

Desk occupancy Detect real-time desk occupancy and get updates when this changes. See live availability and better manage desk bookings, monitor usage for cleaning and track occupancy over time for space planning.

Doors and windows Monitor when these are open ore closed, tracking over time to automate building management processes.

Occupancy See live occupancy to manage space usage, implement demand-controlled HVAC and lighting systems.

Environment Monitor CO2 levels, ambient temperature and relative humidity in each area throughout the day.

Smart building upgrades

07 **REFERENCES**

References

1. Impact of the COVID-19 pandemic on the environment (2020) Retrieved from https://en.wikipedia.org/wiki/Impact_of_the_COVID-19_pandemic_on_the_environment
2. Google Community Mobility Reports (2020) Retrieved from https://www.google.com/covid19/mobility/
3. Your building is struggling under social distancing, too (2020) Retrieved from https://www.propmodo.com/your-building-is-struggling-under-social-distancing-too/
4. Productivity gains from teleworking in the post COVID-19 era : How can public policies make it happen? (2020) Retrieved from https://www.oecd.org/coronavirus/policy-responses/productivity-gains-from-teleworking-in-the-post-covid-19-era-a5d52e99/
5. Map My Emissions. (17th march 2020). Retrieved from https://mapmyemissions.com/home
6. Portfolio Manager/ Greenhouse Gas Emission: https://portfoliomanager.energystar.gov/pdf/reference/Emissions.pdf
7. Tracy Hadden Loh and Lara Fishbane. (17th march 2020). COVID-19 makes the benefits of telework obvious. Retrieved from https://www.brookings.edu/blog/the-avenue/2020/03/17/covid-19-makes-the-benefits-of-telework-obvious/
8. Shaikh, P.H.; Nor, N.B.M.; Nallagownden, P.; Elamvazuthi, I.; Ibrahim, T. A review on optimized control systems for building energy and comfort management of smart sustainable buildings. Renew. Sustain. Energy Rev. 2014, 34, 409–429.
9. Peng Wei, HaiXiao Pan. (2017). Research on individual carbon dioxide emissions of commuting in peri-urban area of metropolitan cities - an empirical study in Shanghai. Transportation Research Procedia Vol.25, 2017, Pages 3459-3478
10. Mathez, A., Manaugh, K., Chakour, V., El-Geneidy, A. & Hatzopoulou, M. (2013). How can we alter our carbon footprint? Estimating GHG emissions based on travel survey information. Transportation, 40(1), 131-149.
11. Selvacanabady, A., & Judd, K. S. (2017). The Influence of Occupancy on Building Energy Use Intensity and the Utility of an Occupancy-Adjusted Performance Metric. Pacific Northwest National Laboratory.