July 2, 2022

A Building Efficiency Analysis: The Economic and Environmental Impact

---

Introduction: This report will take a look into building science and how crucial it can be that a building is built efficiently. The two main focus points that must be taken into consideration is the cost, which includes upfront cost and long-term savings, and also the emissions that come from the use of energy. Many factors play a role in building science such as materials, appliances, and overall building tightness which describes the air leakage throughout a building's thermal enclosure. The more efficient a building is, the less air that can escape from the conditioned space to the outside. A building that is built more efficiently will reduce cost and emissions, be more durable, provide a comfortable environment, and have improved air quality.

Procedure: The energy modeling was completed through REM/Rate comparing an actual apartment to one with altered figures to demonstrate how slight changes can have a massive economical and environmental impact. The altered figures were applied to the Non-Energy Efficient Apartment; such as increased U-value and decreased R-value properties, less efficient mechanical equipment and appliances, and a higher blower door result which means it does not hold air within the conditioned space as well. For a full list of changes please view table 2.

The two apartments will be distinguished by one being the Energy Efficient Apartment, and the Non-Energy Efficient Apartment. The Non-Energy Efficient Apartment has a HERS score of 100 which is considered a standard reference home, yet this does not mean it cannot be built better.

**Energy Modeling completed through REM/Rate*

The rating system used for this analysis is the Home Energy Rating System (HERS index) which is the industry standard to measure a building's energy efficiency. A score of 100 is the average for a new home on the market, although the lower the score, the more efficient it will be. A score of zero is possible which would be a Net Zero Building where there is a net zero of energy consumption as renewable energy would counter the energy usage. (HERS Index Guide)

Energy Efficient Apartment		Non-Energy Efficient Apartment	
Hers Index	46	Hers Index	100
Conditioned Area	937 sq. ft	Conditioned Area	937 sq. ft
Conditioned Volume	7496 Cuft	Conditioned Volume	7496 Cuft
Bedrooms	2	Bedrooms	2
House type	Apartment, end unit	House type	Apartment, end unit
Foundation	Apartment over cond. space	Foundation	Apartment over cond. space
Electricity	Xcel SD 10 2020	Electricity	Xcel SD 10 2020
Natural Gas	Midamer2020	Natural Gas	N/A

Table 1: Apartment general information

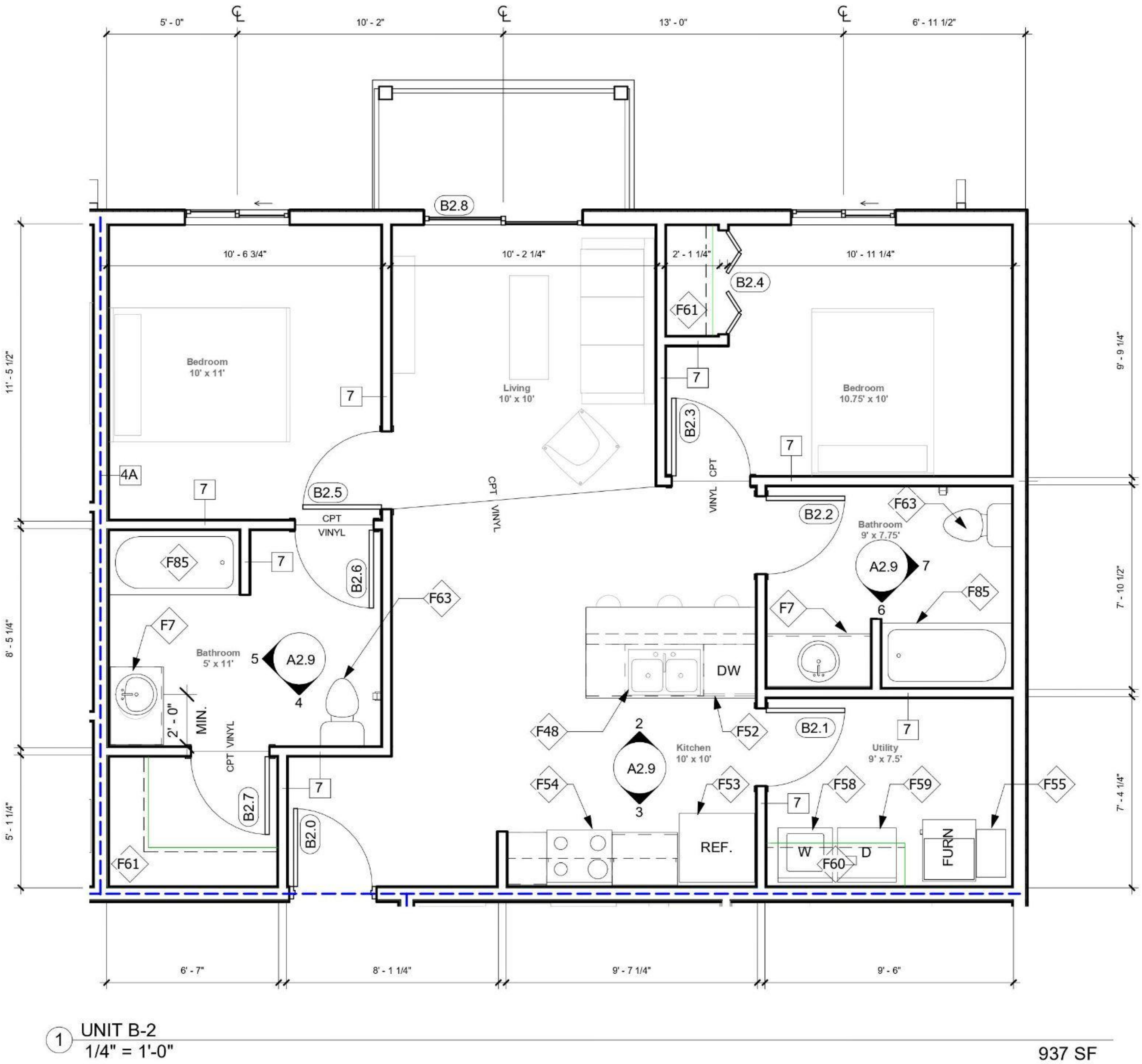


Figure 1: Floorplan of the apartment used for the energy analysis

The unit used for this energy analysis is a two bedroom apartment on the third level which is the top floor. The blue dashed line represents walls that are connected to conditioned space (another apartment). There are two sides of the perimeter that leads to the exterior environment as this is a corner apartment which plays a role in an apartment's ability to retain air within the building envelope.

Building Component	Energy Efficient Apartment	Non-Energy Efficient Apartment
Above-Grade Wall Properties	Lower U-value Higher R-value Cavity Insulation Grade 1	Higher U-value Lower R-value Cavity Insulation Grade 3
Window and Glass Door Properties	U-Value: 0.23 Solar Heat Gain Coefficient: 0.29	U-Value: 0.36 Solar Heat Gain Coefficient: 0.52
Ceiling Properties	R-50 Blown, Attic Continuous Insulation R-Value: 37 Cavity Insulation R-Value: 13 U-Value: 0.020	R-38 Blown Attic Continuous Insulation R-Value: 25 Cavity Insulation R-Value: 13 U-Value: 0.027
Mechanical Equipment Properties	Air Source Heat Pump: 16 SEER ● Efficiency: 8.5 Water Heating: Conventional ● Fuel Type: Natural Gas ● Energy Factor: 0.93 ● Recovery Efficiency: 0.97 ● Tank Size: 40 Gallons	Space Cooling: 9 SEER Electric ● Rated Output: 24 kBTuh Space Heating: Electric Baseboard ● Rated Output: 41 kBTuh Water Heating: Conventional ● Fuel Type: Electric ● Energy Factor: 0.91 ● Recovery Efficiency: 0.98 ● Tank Size: 40 Gallons
Domestic Hot Water Efficiencies	All bath faucets & showers ≤ 2 gpm All DHW pipes fully insulated ≥ R-3	All bath faucets & showers ≥ 2 gpm All DHW pipes fully insulated ≤ R-3
Duct System	80 CFM @ 25 pa	N/A
Whole Dwelling Insulation	Blower Door: 477 CFM @ 50 pa Mechanical Ventilation system: ● Rate: 35 cfm ● Fan watts: 12.8	Blower Door: 1500 CFM @ 50 pa Mechanical Ventilation system: ● Rate: 55 cfm ● Fan watts: 20
Appliance Ratings	Refrigerator: ● Total Consumption: 383 kWh/yr Dishwasher ● kWh/yr: 270 Dryer Fuel: Electric ● Dryer CEF: 3.93 ● Moisture sensing Washer presets: ● IMEF: 2.060 ● LER: 175 kWh/yr Capacity Cu.Ft: 4.6	Refrigerator: ● Total Consumption: 673 kWh/yr Dishwasher ● kWh/yr: 467 Dryer Fuel: Electric ● Dryer CEF: 2.62 Washer presets: ● IMEF: 0.331 ● LER: 704 kWh/yr Capacity Cu.Ft: 2.874

Table 2: The components changed between apartments

Energy Efficient Apartment		
Estimated Annual Energy Cost		
use	MMBtu	Cost ($)
Heating	8.8	193
Cooling	1.1	29
Hot Water	7.8	36
Lights/ Appliances	10.5	248
Service Charges		195
Total	28.2	701

Table 3: Estimated annual energy cost for good apartment

Non-Energy Efficient Apartment		
Estimated Annual Energy Cost		
use	MMBtu	Cost ($)
Heating	21.4	463
Cooling	2.2	58
Hot Water	9.5	222
Lights/ Appliances	13.7	321
Service Charges		99
Total	46.8	1,163

Table 4: estimated annual energy cost for poor apartment

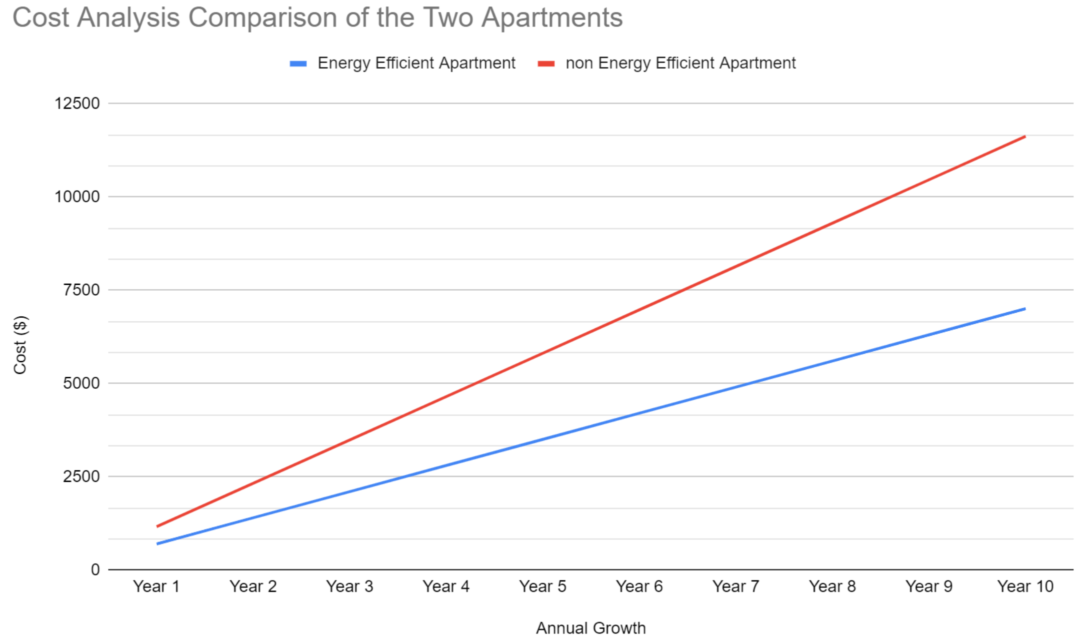
Energy Efficient Apartment Cost over 10 years ($)										
Use	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Heating	193	386	579	772	965	1,158	1,351	1,544	1,737	1,930
Cooling	29	58	87	116	145	174	203	232	261	290
Hot Water	36	72	108	144	180	216	252	288	324	360
Lights/ Appliances	248	496	744	992	1,240	1,488	1,736	1,984	2,232	2,480
Service Charges	195	390	585	780	975	1,170	1,365	1,560	1,755	1,950
Total	701	1,402	2,103	2,804	3,505	4,206	4,907	5,608	6,309	7,010

Table 5: Energy efficient apartment cost over 10 years

Non-Energy Efficient Apartment Cost over 10 years ($)										
Use	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Heating	463	926	1,389	1,852	2,315	2,778	3,241	3,704	4,167	4,630
Cooling	58	116	174	232	290	348	406	464	522	580
Hot Water	222	444	666	888	1,110	1,332	1,554	1,776	1,998	2,220
Lights/ Appliances	321	642	963	1,284	1,605	1,926	2,247	2,568	2,889	3,210
Service Charges	99	198	297	396	495	594	693	792	891	990
Total	1,163	2,326	3,489	4,652	5,815	6,979	8,141	9,304	10,467	11,630

Table 6: Non-energy efficient apartment cost over 10 years

Tables 3-6 demonstrate how an apartment building that is built more efficiently will save an estimated $4,620 over the course of the first 10 years. This takes into consideration each use of energy and the rates of use. Graph 1 (view below) shows how these costs grow apart significantly fast as an apartment is expected to be used for longer than 10 years; it can significantly add up over time and the Non-Energy Efficient apartment may grow exponentially as the appliances are not built to last as long.



Graph 1: Cost analysis of a good vs. poor apartment over the first 10 years

	Energy Efficient Apartment		Non-Energy Efficient Apartment	
	Per 100 Apartments			
Use	Year 10	Year 30	Year 10	Year 30
Heating ($)	193,000	579,000	463,000	1,389,000
Cooling ($)	29,000	87,000	58,000	174,000
Hot Water ($)	36,000	108,000	222,000	666,000
Lights/ Appliances ($)	248,000	744,000	321,000	963,000
Service Charges ($)	195,000	585,000	99,000	297,000
Total ($)	701,000	**2,103,000**	1,163,000	**3,489,000**

Table 7: Compares the cost of two apartments over 10 years and 30 years for 100 apartments

Table 7 uses a 100 apartment building to demonstrate how building efficiency can greatly matter on a larger scale. Over the course of 30 years an apartment building that is built more energy efficient will have saved **$1,386,000.**

The energy efficient apartment will be **39.72%** less expensive than the non-energy efficient apartment. This number will increase exponentially over the years as the better apartment will maintain its durability and appliance efficiency, whereas the other apartment will begin to lose the building integrity and appliance durability.

Future predictions can often be difficult due to a changing inflation rate and the consumer price index can be difficult to predict in the energy sector due to many factors. As the availability of energy generation sources depletes in fossil fuel based energy and rises in renewable energy, the exact cost over the time frame of 30 years used for this analysis will vary quite significantly during this time frame as it is a changing market. The main elements of heating, cooling, hot water, lights, appliances, and service charges are all subject to change as time passes which is why it is of utmost importance to begin using energy efficient appliances and build a home that can retain the conditioned space. As the energy market is on the brink of a large change from fossil fuels to renewable energy the future of the energy market is hard to predict so choosing the options of the future now will save money. Due to these factors the previous numbers from table 7 will be adjusted based on an average inflation rate of 3%. This future prediction was completed through the Consumer Price Index Inflation Calculator at https://www.officialdata.org/.

	Energy Efficient Apartment	Non-Energy Efficient Apartment	
Cost	100 Apartments over 30 years		Cost Difference ($)
Cost Before Inflation ($)	2,103,000	3,489,000	1,386,000
Cost After 3% Inflation ($)	5,257,669	8,722,780	3,465,111

Table 8: Inflation cost adjustment for 100 apartments over 30 years

Table 8 applies a 3% inflation rate applied to the final cost of 100 apartments over a 30 year time period before any other factors are taken into account. These numbers are subject to change based on the supply and demand of the energy market, yet based purely on inflation rate it can be noted that there is a large cost difference between the energy efficient apartment and the non-energy efficient apartment. Another factor that plays a role in the energy market is that the numbers used for this analysis for the electricity rates were taken from South Dakota which is often cheaper than the national average. The savings can already be seen to be quite significant and would only increase when building more efficiently in other states.

After inflation is accounted for, the savings of 100 energy efficient apartments over the course of 30 years rises from **$1,286,000** to **$3,465,111**

Energy Efficient Apartment	
Estimated Annual Emissions	
Carbon Dioxide	3.2 tons/year
Sulfur Dioxide	17.7 lbs/year
Nitrogen Oxide	19.5 lbs/year

Table 9: Estimated annual emissions for good apartment

Non-Energy Efficient Apartment	
Estimated Annual Emissions	
Carbon Dioxide	6.9 tons/year
Sulfur Dioxide	44.9 lbs/year
Nitrogen Oxide	46.4 lbs/year

Table 10: Estimated annual emissions for poor apartment

		Energy Efficient Apartment Emissions over 10 years									
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Carbon Dioxide	tons/yr	3.2	6.4	9.6	12.8	16	19.2	22.4	25.6	28.8	32
Sulfur Dioxide	lbs/yr	17.7	35.4	53.1	70.8	88.5	106.2	123.9	141.6	159.3	177
Nitrogen Oxide	lbs/yr	19.5	39	58.5	78	97.5	117	136.5	156	175.5	195

Table 11: Energy efficient apartment emissions over 10 years

		Non-Energy Efficient Apartment Emissions over 10 years									
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Carbon Dioxide	tons/yr	6.9	13.8	20.7	27.6	34.5	41.4	48.3	55.2	62.1	69
Sulfur Dioxide	lbs/yr	44.9	89.8	134.7	179.6	224.5	269.4	314.3	359.2	404.1	449
Nitrogen Oxide	lbs/yr	46.4	92.8	139.2	185.6	232	278.4	324.8	371.2	417.6	464

Table 12: Non-energy efficient apartment emission over 10 years

Tables 9-12 demonstrate how an apartment building that is built more efficiently will release significantly Fewer emissions than an apartment that is NOT built efficiently. The three emissions calculated are Carbon Dioxide, Sulfur Dioxide, and Nitrogen Oxide. This also demonstrates the linear growth that will occur over a 10 year usage of the apartments. It is also expected that the Non-Energy Efficient Apartment will turn into exponential growth as the appliances will become obsolete quicker than the appliances used in an energy efficient apartment (most likely ENERGY STAR)

	Energy Efficient Apartment		Non-Energy Efficient Apartment	
	Per 100 Apartments			
Emissions	Year 10	Year 30	Year 10	Year 30
Carbon Dioxide (Tons)	3,200	9,600	6,900	20,700
Sulfur Dioxide (lbs)	17,700	53,100	44,900	134,700
Nitrogen Oxide (lbs)	19,500	58,500	46,400	139,200

Table 13: Compares the cost of two apartments over 10 years and 30 years for 100 apartments

Emission	Energy Efficient Apartment	Non-Energy Efficient Apartment	Percentage (%)
Carbon Dioxide (tons/year)	3.2	6.9	2.156
Sulfur Dioxide (lbs/year)	17.7	44.9	2.537
Nitrogen Oxide (lbs/year)	19.5	46.4	2.379

Table 14: Compares the emissions between the two apartments

	100 Apartments over 30 years		
	Energy Efficient Apartment	Non-Energy Efficient Apartment	Difference
Cost ($)	2,103,000	3,489,000	1,386,000
Carbon Dioxide (Tons)	9,600	20,700	11,100
Sulfur Dioxide (lbs)	53,100	134,700	81,600
Nitrogen Oxide (lbs)	58,500	139,200	80,700

Table 15: Shows the difference of emissions between 100 apartments over 30 years

Table 15 demonstrates the importance of building efficiently as it takes into account 100 apartments cost and emissions over 30 years for the Energy Efficient model and Non-Energy Efficient model

An apartment building with 100 units built efficiently compared to one built inefficiently over 30 years will save…

$1,386,000 (Before Inflation)
$3,465,111 (After Inflation)
11,100 Tons of Carbon Dioxide
81,600 Pounds of Sulfur Dioxide
80,700 Pounds of Nitrogen Oxide

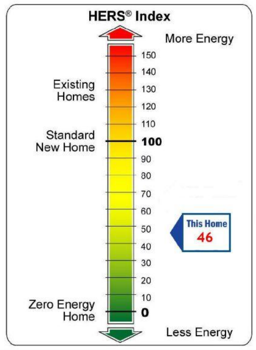
Building science is more than just saving money, It's also about doing our part in protecting the planet by building not just to local code but going above and beyond to cut down on cost and Greenhouse Gas Emissions. A building that undergoes certification will…

- Cost less to operate
- Be more comfortable to live in
- Boost your resale value
- Reduce environmental impact
- Be healthier to live in

JOHNSON ENVIRONMENTAL

July 2, 2022

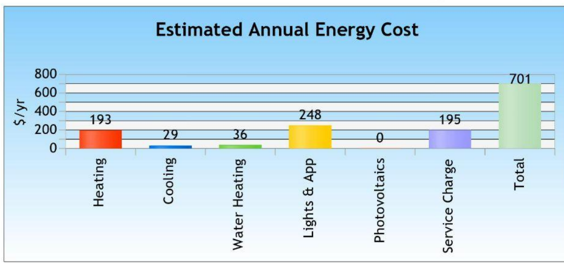
HERS PERFORMANCE

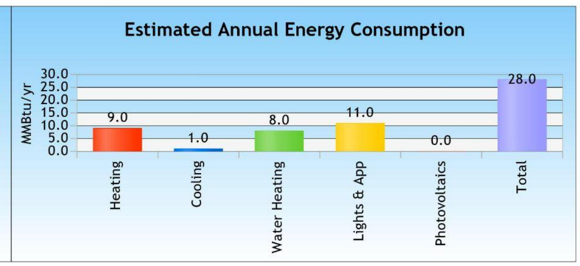


ENERGY RATING CERTIFICATE

JOHNSON ENVIRONMENTAL

Projected Rating: Based on Plans - Field Confirmation Required.

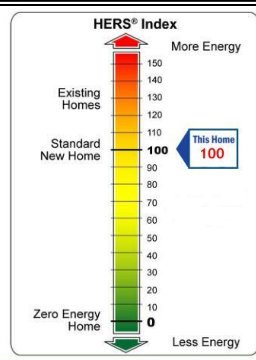




Address	4420 W 35th St N Apt	Annual Estimates*	Building Efficiency Resources, LLC	
	Sioux Falls, SD 57107	Electric(kWh): 5993	P.O. Box 1769	
House Type	Apartment, end unit	Natural gas(Therms): 78	Certified Rater	Chris Johnson
Cond. Area	937 sq. ft.	C02 emissions(Tons): 3	Rater ID	8875892
Rating No.		Annual Savings**: $612	Registry ID	
Issue Date	June 16, 2022	* Based on standard operating conditions	Rating Date	2021-06-25
Certification	Inspected and Tested	** Based on a HERS 130 Index Home		

REM/Rate - Residential Energy Analysis and Rating Software v16.0.6

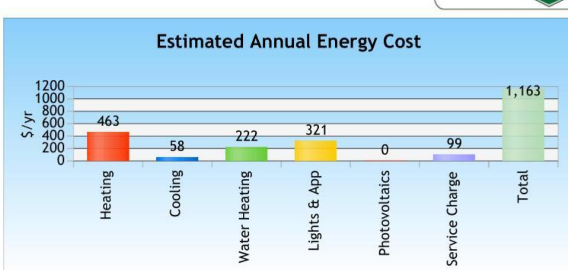
HERS PERFORMANCE

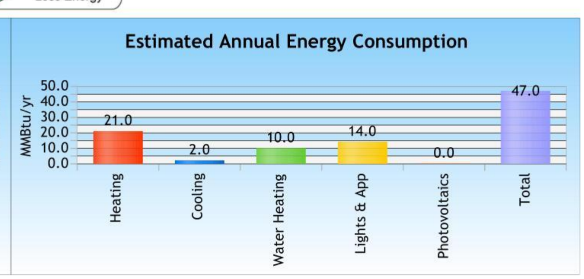


ENERGY RATING CERTIFICATE

JOHNSON ENVIRONMENTAL

Projected Rating: Based on Plans - Field Confirmation Required.





Address	4420 W 35th St N Apt	Annual Estimates*	Building Efficiency Resources, LLC	
	Sioux Falls, SD 57107	Electric(kWh): 13721	P.O. Box 1769	
House Type	Apartment, end unit	C02 emissions(Tons): 6	Certified Rater	Chris Johnson
Cond. Area	937 sq. ft.	Annual Savings**: $237	Rater ID	8875892
Rating No.		* Based on standard operating conditions	Registry ID	
Issue Date	June 16, 2022	** Based on a HERS 130 Index Home	Rating Date	2021-06-25
Certification	Inspected and Tested			

REM/Rate - Residential Energy Analysis and Rating Software v16.0.6