IPS STUDY

WILLIAMS COMFORT PRODUCTS

Phase I Report

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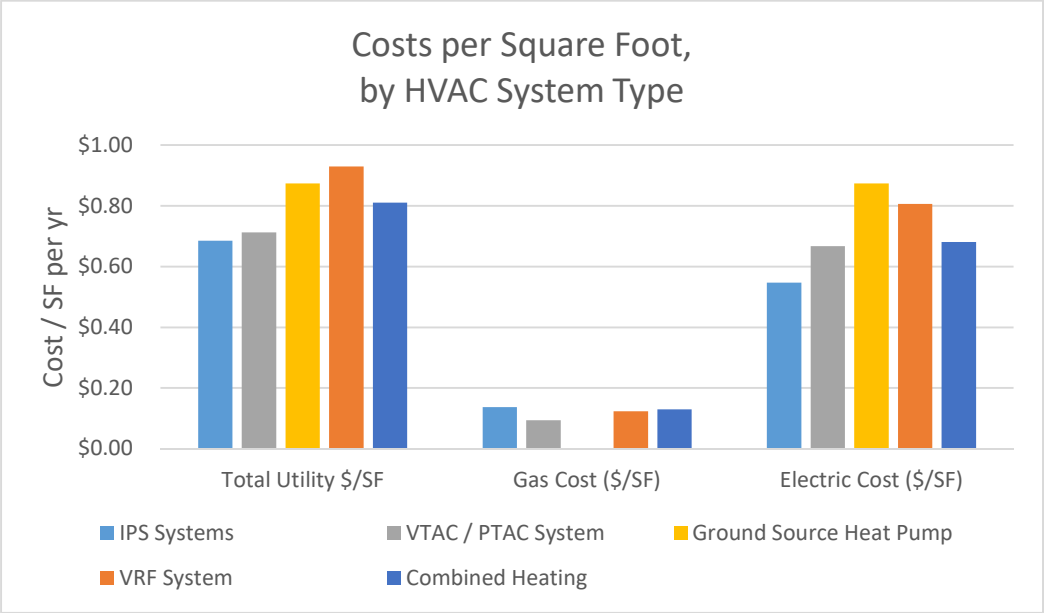
Table of Contents

Phase I Summary

Group14 has partnered with Williams Comfort Systems to study the cost effectiveness of Integrated Piping Systems (IPS) as compared to other mechanical systems typically installed in multifamily buildings in Denver, Colorado. The study investigates the annual natural gas and electric costs for multifamily buildings between 2015 and 2018 as well as estimated install and maintenance costs, if available. Buildings occupied in 2018 are still under warranty, so do not have full maintenance cost estimates.



The study lead us to the following observations on IPS in multifamily buildings in Denver:

- IPS utility costs are 15% lower than other systems studied.
- IPS gas costs are higher in the summer than the other buildings. This is unexpected and we will look at this in Phase 2. There appear to be opportunities to optimize the control strategies with IPS. It is not clear that IPS has been implemented as proposed. This is evident in comparing Mariposa III & VI, which have IPS, with the other buildings.
- DHA's maintenance costs were $0.05 - $0.10 less per square foot in buildings with IPS than other systems.
- Mechanical install costs for IPS systems in this study are comparable to VRF and VTAC systems and lower than ground source heat pump systems.

Buildings Characteristics

Table 1 provides detail on the space uses and Table 2 lists the mechanical system types in the buildings studied in Phase I. Unconditioned spaces are typically unheated parking garages. The differences in space uses can affect the energy consumption per square foot.

Table 1: Building Area Details

Building	Year Occupied	Number of Units	Conditioned Square Feet	Un-Conditioned Square Feet	Retail/ Common Area SF	Town Home SF	Exterior Parking SF
DHA Mariposa Phase II	2013	80 Units	107,658	17,615	8,824	-	7,799
DHA Mariposa Phase III	2014	87 Units	111,533	15,110	11,269	5,600	3,900
DHA Mariposa Phase IV	2014	77 Units	85,673	22,937	12,330	5,600	8,300
DHA Mariposa Phase VI	2016	94 Units	122,300	27,700	1,800	0	0
DHA Mariposa Phase VII*	2017	48 Units	52,170	0	6,830	6,000	9,700
Sanderson Apartments	2018	60 Units	48,078	0	4,290	0	13,800
2075 Broadway	2018	101 Units	74,243	11,500	8,779	0	0
Creekside West	2013	62 Units	77,467	24,460	3,861	0	0
Cityscape at Belmar	2015	126 Units	103,230	36,000	5,600	0	0
Lamar Station Crossing	2014	110 Units	104,453	0	3,184	0	36,300
Benedict Park Place 5B	2012	75 Units	78,441	0	17,728	0**	0
Combined Heating Building	2016	141 Units	172,000	52,800	55,707	0	0

** Mariposa Phase VII opened during the study period. We were able to get installed cost estimates but not utility bills or maintenance cost estimates.*

*** Town homes were built with Park Place 5B, but only utility bills for the 4-story multifamily building are included in the study.*

Table 2: Mechanical System Details

Building	Primary Residential Mechanical System	Primary Common Area Mechanical System	Primary Heat Source	DHW System
DHA Mariposa Phase II	VTAC	Furnace	Electric	Central Storage Water Heaters
DHA Mariposa Phase III	IPS	Furnace	Gas	Central Boiler with Storage Tanks
DHA Mariposa Phase IV	VRF	VRF	Electric	Central Boiler with Storage Tanks
DHA Mariposa Phase VI	IPS	Furnace	Gas	Central Storage Water Heaters
DHA Mariposa Phase VII*	GSHP	Furnace	Electric	Central Storage Water Heaters
Sanderson Apartments	IPS	4-Pipe Fan Coil	Gas	Central Boiler with Storage Tanks
2075 Broadway	IPS	Packaged RTU	Gas	Central Boiler with Storage Tanks
Creekside West	PTAC	Furnace	Electric	Central Storage Water Heaters and Solar
Cityscape at Belmar	PTAC	Domestic Hot Water Fan Coil	Electric	Central Storage Water Heaters
Lamar Station Crossing	PTAC	Furnace	Electric	Central Storage Water Heaters
Benedict Park Place 5B	GSHP	GSHP	Electric	Central Electric Heat Pump
Combined Heating Building	Combined Heating	Package Single Zones	Gas	Individual Gas Water Heaters

Energy Consumption Comparison

Integrated Piping Systems

Data Quality & Methodology

Group14 collected electricity and natural gas utility data for the buildings through various sources associated with the projects. A property management company provided utility bills and maintenance costs for the DHA buildings, although the data was incomplete for several of the buildings. In addition, a few of the buildings were not open during the entire study period from January 2016 - August 2018.

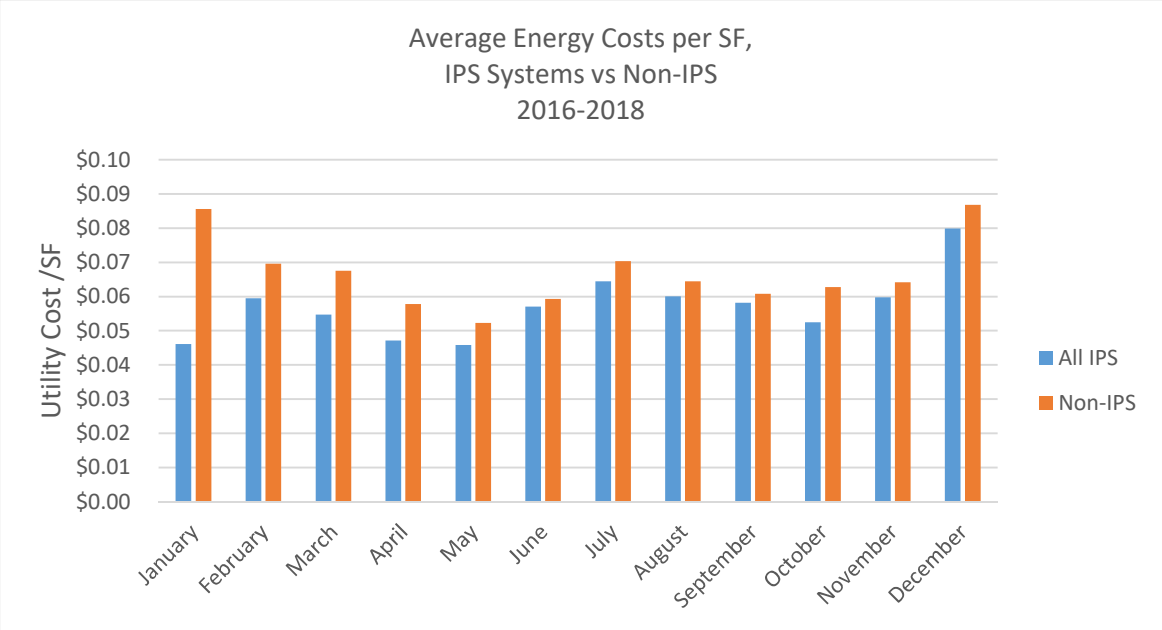
For months with only electricity and gas costs, we estimated the energy consumption using average utility rates specific to the site from months where consumption data was available to account for peak electric demand charges from Xcel's Secondary General Rate.

We also identified data entry errors and corrected the values by interpolating monthly data from the corresponding month in other years. All estimated or interpolated data is identified in the master tracking spreadsheet and can be made available upon request.

When reviewing utility costs consider that some of the buildings recently opened and utility bills can vary during the first couple years of operation. For example, bills can be unexpectedly low due to the building being partially occupied the first months, or can be unexpectedly high due to lingering construction activities or initial equipment startup and commissioning issues. If less than a year of utility data was available, the costs were omitted from the building-type averages to prevent recently-opened outliers from influencing the average costs.

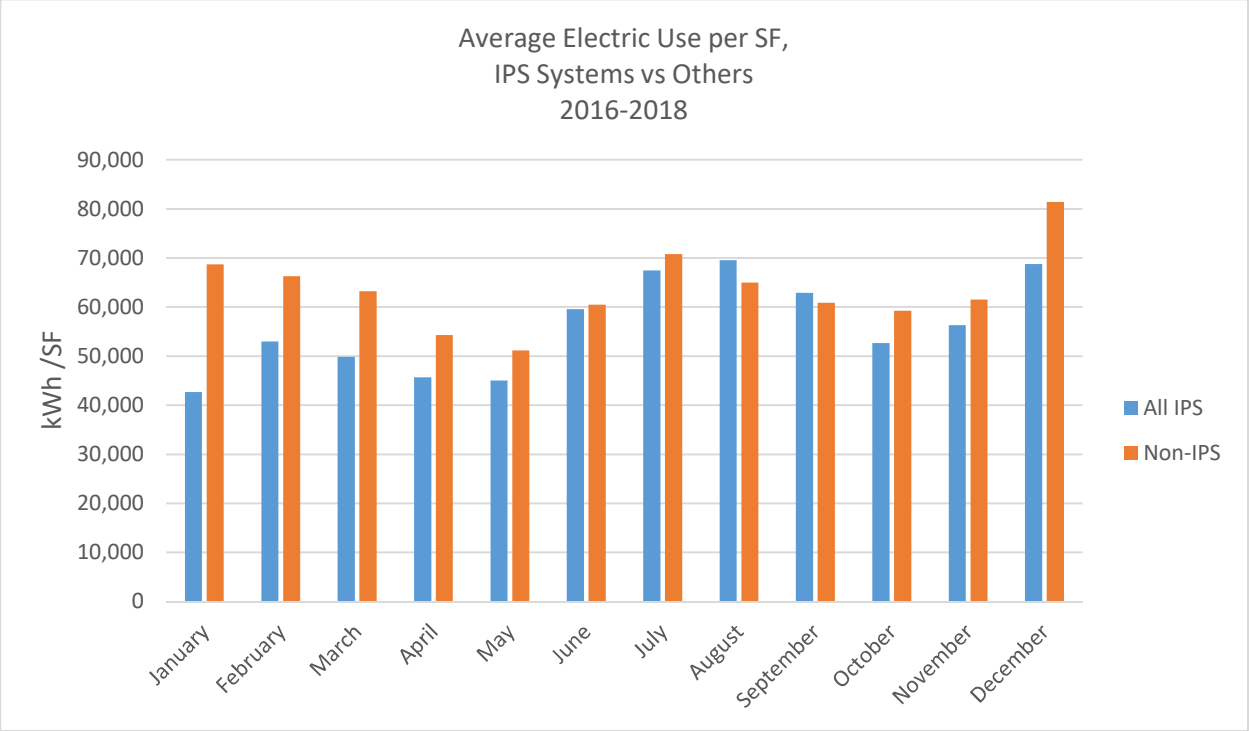
Comparison of Annual Energy Costs

The multifamily buildings with IPS that had enough utility data for a full comparison are Mariposa Phase III and Mariposa Phase VI. The Mariposa buildings with IPS had an average energy costs per square foot of $0.69/SF per year, while the other systems studied had an average of $0.80/SF. Sanderson Apartments, which has IPS, is excluded from this comparison because only one year of utility data is available. Note that this building has unusually high utility costs ($1.3/SF), is deemed an outlier and requires further investigation.



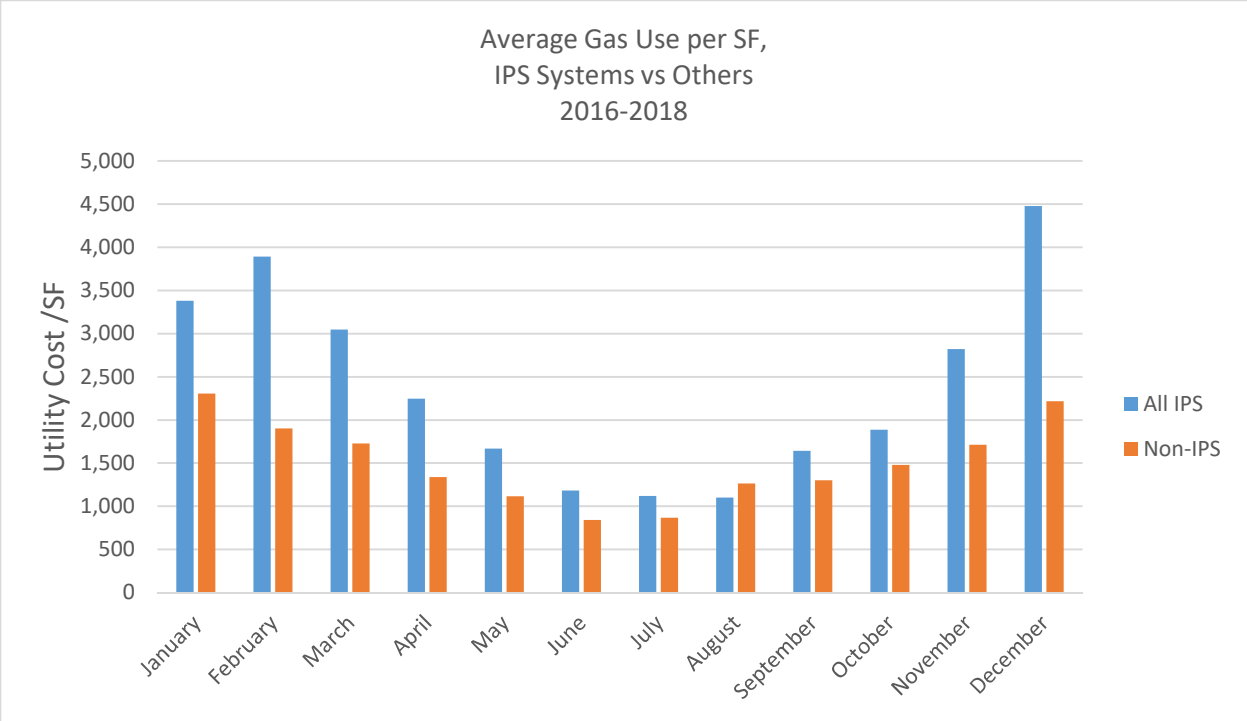
Electricity and Natural Gas Consumption

In terms of electricity and natural gas consumption, buildings with **IPS consumed 12% *less* electricity and 57% more gas per square foot than the buildings with other systems.** The main reason for these differences is that the buildings without IPS primarily have electric heat in the apartments. The buildings with electric heat have Vertical Terminal Air Conditioning with electric heat (VTAC), Variable Refrigerant Flow (VRF), Ground Source Heat Pumps (GSHPs), and Packaged Terminal Heat Pumps (PTACs).



Gas consumption is **25% higher during the summer months** (**May-September) in the buildings with IPS.** Note that most of the buildings have gas-fired central water heaters for domestic hot water, so the difference in gas consumption in June and July is somewhat unexpected. The buildings with IPS have gas heat and there may be some gas heating (or boilers idling) in the summer months. The combined heating building has individual gas water heaters. This building has less gas use per square foot than the IPS buildings because the water heaters are not creating domestic hot water constantly.

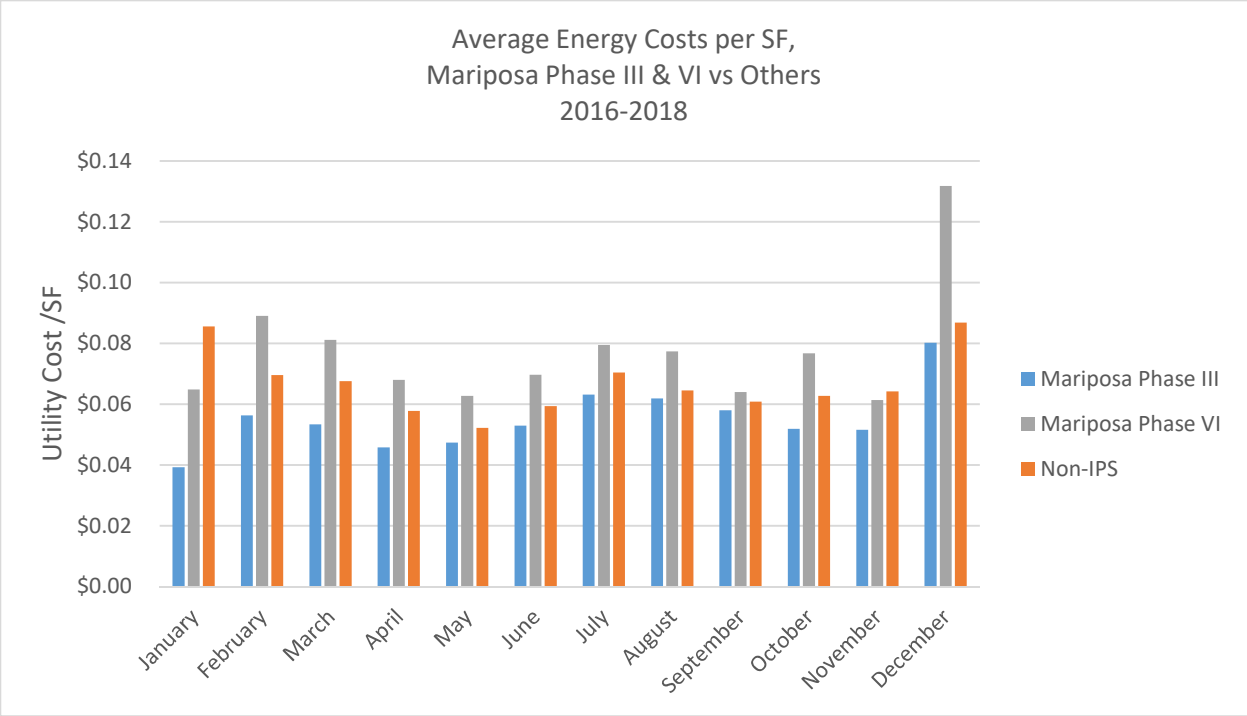
The higher gas consumption in the IPS buildings in the summer could also be because the chilled water loops are operated below their design chilled water temperature, resulting in the return chilled water temperature actually being colder than the incoming city water. Removal of estimated domestic hot water use from all buildings still shows increased gas consumption in the summer months in the IPS buildings. If the chillers over-cool the domestic cold water supply, there would be additional (unnecessary) heat in the IPS buildings. IPS is designed to operate at higher chilled water temperatures and correcting the chilled water supply temperature set point should result in the return chilled water being warmer than incoming city water and correct the issue. This will further be addressed in Phase II of the study.



Comparison of Buildings with IPS

Due to variations in building orientation, space types and operating set points, performance varies between the buildings with IPS. The charts below compare the average utility costs for Mariposa Phase III, Mariposa Phase VI and the non-IPS buildings in the study.

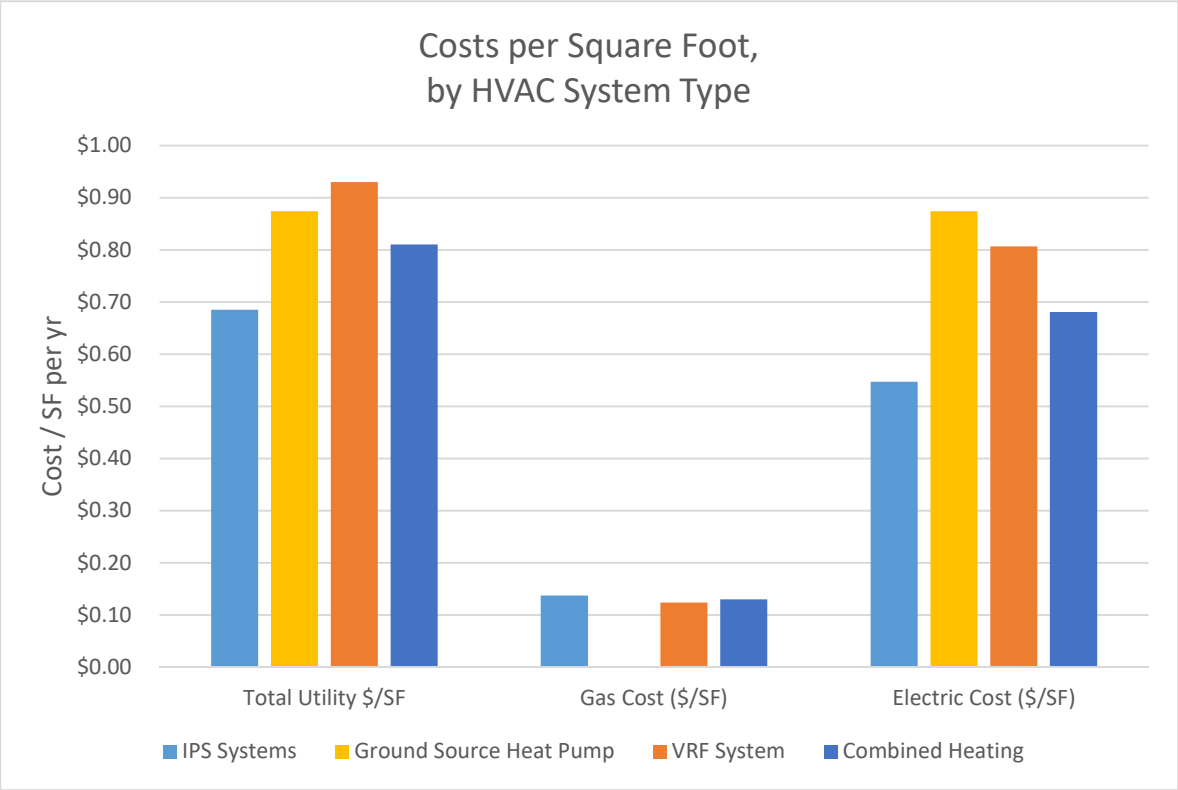
Mariposa Phase III has the lowest average utility costs at $0.66 per square foot per year. Mariposa Phase VI's utility costs are higher at $0.93 per square foot per year. Natural gas costs for the two IPS buildings are roughly equal; Phase VI has higher electric costs than Phase III.



Variation by System Type

We have three full years of utility data for one building with a variable refrigerant flow system (VRF), one building with a ground source heat pump (GSHP), four buildings with electric PTAC or VTAC units, one building with combined heating (gas) and split DX, and two buildings with IPS systems. The chart below shows that average annual costs per conditioned square foot for each building or buildings, grouped by system type. There are no gas costs for the ground source heat pump building (Benedict Park Place 5B) since the building heating and domestic hot water are served only by the ground source system and there is no back up gas heat.

The combined heating building uses domestic hot water for both space heating and domestic hot water uses. Residential units are provided with split condensing units. This building had a "high energy use" study completed in 2016. The findings of the study reduced the building's electric energy use by 8 percent.



Operations and Maintenece Costs

Denver Housing Authority projects (DHA) provided maintenance cost for their projects that have been open for greater than two years. Buildings are typically under warranty the first year of operation, so mechanical repairs and some of the required service are typically covered by the first year warranty. However, comparing buildings with the same property manager and similar maintenance contractors provides a relatively consistent comparison of maintenance costs.

While the data is limited, maintenance costs for DHA appear to be **roughly $0.05 – $0.10 cheaper per square foot per year for IPS** than the other systems studied, although maintenance costs can vary significantly from month to month depending on unpredictable service requirements. For the maintenance costs collected, savings from IPS system would be about $5,000 - $10,000 per year for a 100,00 square foot building, roughly the average size of a building in the study.

Building	Primary Mechanical System	Total 2016 HVAC Maintenance Costs	Total 2017 HVAC Maintenance Costs	Total 2018 HVAC Maintenance Costs (To Date)	Average Annual Cost per Square Foot 2016-2018*
DHA Mariposa Phase II	VTAC	$25,582	$23,216	$15,986	$0.22
DHA Mariposa Phase III	IPS	$18,123	$20,545	$11,551	$0.16
DHA Mariposa Phase IV	VRF	$15,181	$40,182	$16,421	$0.28
DHA Mariposa Phase VI	IPS	-	-	$7,917	$0.13**

* Costs for end of 2018 estimated to generate annual maintenance estimate

** Phase VI maintenance costs only estimated for 2018, after end of warranty period

First Costs & Payback Analysis

Group14 collected the final construction bids for each building in the study group except for 2075 Broadway, where construction costs are not yet available. We do not have access to records that break down individual mechanical costs, but for Mariposa Phase II and III we do have mechanical and plumbing costs broken out separately. For Mariposa Phase IV and VII we have the combined mechanical and plumbing bid, and for Sanderson Gulch only the total construction cost for the project.

Construction costs depend on the year built and the cost of labor and materials, building height, building codes, parking, etc. Construction costs for the project with ground source heat pumps, Mariposa Phase VII, are considerably higher than the other Mariposa projects. In addition to the high first costs of ground source heat pump systems, the construction costs are also higher because of the recent rising construction costs in the Denver metro area and because the townhome and high-rise components increase the cost per square foot for this development.

Mariposa Phase II, III and IV are four-story apartment buildings with comparable construction costs. For these, the mechanical construction costs for IPS are comparable to VRF, and lower than the mechanical costs for the buildings with VTAC and ground source heat pumps.

The total construction costs per square foot include parking structures, while the mechanical costs per square foot only consider conditioned square footage.

Building	Year Built	Primary Mechanical System	Construction Cost per Total Square Foot*	Mechanical and Plumbing Cost per Conditioned Square Foot
DHA Mariposa Phase II	2013	VTAC	$140	$25.42
DHA Mariposa Phase III	2014	IPS	$146	$19.04
DHA Mariposa Phase IV	2014	VRF	$146	$21.07
DHA Mariposa Phase VII	2016	GSHP	$223	$23.40
Sanderson Gulch	2018	IPS	$202	-

*Square footage includes unconditioned parking areas