Water as a Grid Resource: How Smart DHW Controls can provide Savings

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ABSTRACT

Demand-controls for recirculating pumps offer a pragmatic and cost-effective solution for reducing energy use in new construction and retrofit multifamily buildings. Large multifamily buildings are one of the fastest growing residential building types in the United States. For these large buildings, domestic hot water represents nearly 30% of all energy used, tied for the highest end-use. To increase efficiency of part of this large end-use, 35 states have adopted energy codes requiring demand controls for domestic hot water recirculation pumps.

In this paper, several high-efficiency pump controls are explored to gain a further understanding of the measured and potential impact of beyond-code strategies. These strategies are available in both new construction and retrofit settings. A literature review showed 63% measured pump savings for systems that replace single-speed control with proportional head pressure controls. This small change has a technical potential of 3.3 GWh if applied to the new construction multifamily buildings.

Further developments in pumps and controls will open new doors for these systems to be developed as a grid resource. This paper will comprehensively cover the current code jurisdictions with demand controls for recirculating pumps, and recent research covering this topic. Also, we will discuss the potential for savings from this technology, and information will be provided to explore grid-connected solutions.

Background

Large multifamily buildings are the fastest growing multi-unit building type in the United States (US Census Bureau 2025). Development of buildings with 20-49 Units and 50+ Units has grown by 23% and 11%, respectively compared to 2004 construction levels. Conversely, development has dropped by >10% for multifamily buildings with 2-4 Units, 5-9 Units, and 10-19 Units (see Figure 1).

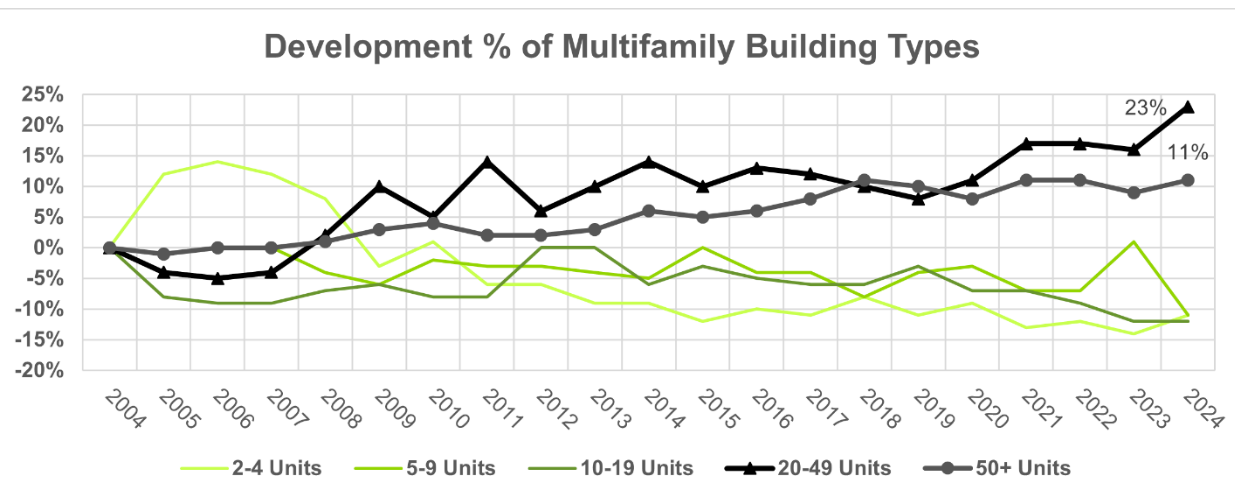

Figure 1: The multifamily building stock is changing to favor larger, 20+ unit buildings (Census Bureau)

As this burgeoning residential market grows, efficient design of major energy end-uses is a necessary priority. Recirculation pump controls are a cost-effective and accessible efficiency solution.

Multifamily Energy Consumption

To understand the high-impact multifamily energy end uses, we examine the Residential Energy Consumption Survey (RECS). RECS is conducted every 5 years by the Energy Information Administration (EIA). The results provide insight into the changing ways in which residential buildings use energy. Domestic hot water (DHW) is historically one of the highest end-uses for large multifamily buildings. Between 2015 and 2020, DHW grew as an percent end-use in multifamily buildings.

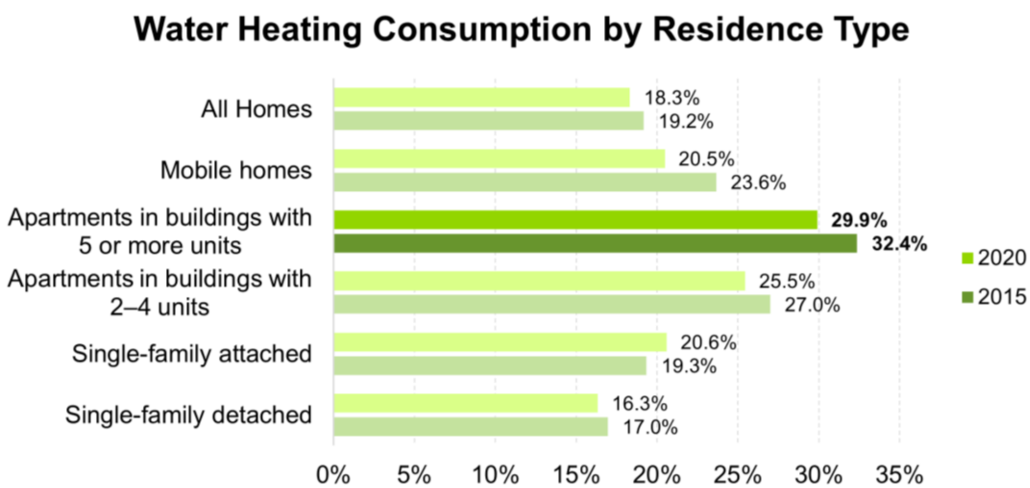

Figure 2: Percentage of energy used for water heating in residential buildings (EIA RECS 2018, 2023)

An analysis of the RECS data showed that the DHW end-use constituted 29.9% of multifamily energy in 2020, down from 32.4% in 2015 (EIA 2018 and EIA 2023). In 2020, DHW was the second-highest end-use, only 0.3% behind "Other" end-uses. Figure 2: Percentage of energy used for water heating in residential buildings (EIA RECS shows DHW consumption declining for all residential building types in this 5-year period, except for Single-family attached. However, this proportional decline in DHW use is somewhat misleading.

A closer examination of the large multifamily RECS dataset tells an interesting story concerning the shift in end-uses between 2015 and 2020. While energy for Space Cooling and Refrigeration increased dramatically, DHW consumption reduced only incrementally. From 2015 to 2020, the energy consumption for the Space Cooling and Refrigeration end-uses rose from 51 to 78 and 35 to 42 trillion BTUs, respectively. In the same time period, energy consumption for DHW only dropped from 234 to 230 trillion BTUs. This increase in Space Cooling and Refrigeration could be due to wider cooling system adoption, rising summer temperatures, or shorter and warmer winters. The results on an end-use basis, shown in Figure 3: Change in energy use on an end-use basis for multifamily buildings with 5+ units, show the drastic changes in Space Cooling and Refrigeration compared to DHW. With the introduction of more stringent DHW equipment and controls code standards, a larger decrease in end-use consumption could be expected. As an accessible technology, recirculating pump controls are a prime candidate to save further DHW energy in large multifamily buildings.

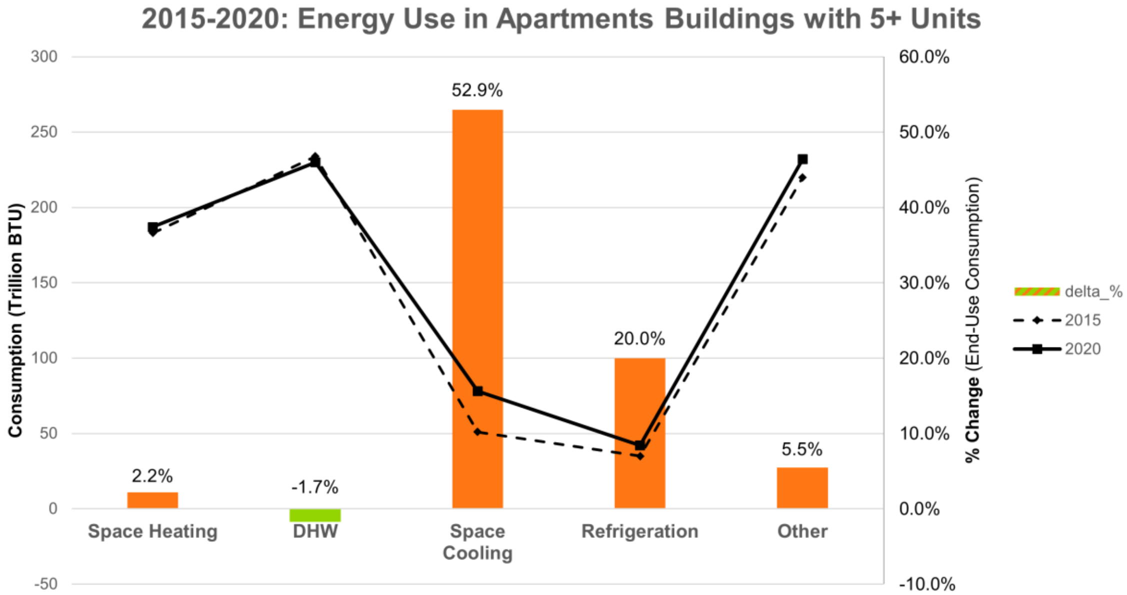

Figure 3: Change in energy use on an end-use basis for multifamily buildings with 5+ units[1] from 2015 to 2020 (EIA 2018, EIA 2023)

Energy Code Developments

Code and market developments have affirmed the relevance of DHW-focused efficiency research. Building Energy Performance Standard (BEPS) policies adopted in 50+ US jurisdictions have increased emphasis on systematic improvements in building energy performance, encouraging building owners to pursue scalable, incremental measures (IMT 2025). Additionally, energy codes have furthered adoption of recirculation pump controls. As of December 2025, 35 states have adopted International Energy Conservation Code 2015 or a newer equivalent code (IECC 2015+), as shown in Figure 4: States t below (DOE 2025). IECC 2015 was the first IECC code version to require recirculation controls. Our literature review showed that the control mandates in IECC 2015+ can be inexpensively improved upon to realize lower energy consumption.

[1] 5+ units is the largest multifamily residential building type that is measured in the RECS survey.

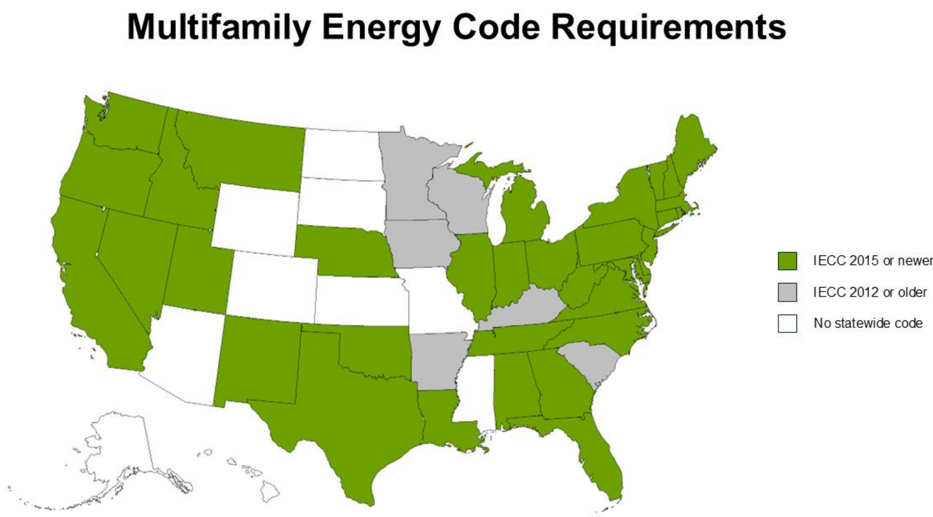

Figure 4: States that have adopted IECC 2015 (equivalent) or newer require recirculating demand controls

In spite of these improvements to energy code standards, gaps persist for recirculation pumps. IECC 2015+ has two requirements for hot water recirculation pump controls: “The controls shall automatically turn off the pump when the water in the circulation loop is at the desired temperature and when there is no demand for hot water.” (ICC 2016). On its face, this provision mandates the principle capabilities of demand controls for recirculation pumps. However, subsequent research including surveys with contractors has shown that controls are often installed in the least-effort way to meet code (Mertens 2026). This includes setting variable-speed pump motors to maximum speed instead of the design speed and foregoing proportional pressure controls integrated in recirculation pumps in favor of single-speed settings. Additionally, only 1% of the market specifies the more-efficient electrically commutated motor (ECM) pumps, often opting instead for the less efficient induction motors (DOE 2024). By falling short of requiring “smart”, integrated, or learning-based pump controls, IECC has left leeway for installers to continue installing “set it and forget it” single-speed, unbalanced recirculation pumps. This shortcoming within the energy code motivates a closer assessment of recirculation pump control strategies to understand the energy savings from beyond-code strategies.

Relevant Research

Changes in energy codes do not seem to have systemically mitigated large DHW consumption in the rapidly growing multifamily building stock. This paper now looks at two reports that have quantified the impact of higher-than-code efficiency recirculation pumps and controls. The first, a 2021 report by Energy Solutions, compared recirculation pumps and their controls, and produced preliminary savings calculations. The second, a 2026 report led by Pacific Gas & Electric (PG&E), focused solely on pump controls and produced much more comprehensive findings from surveys and field data. Both reports were commissioned in

California, the state with the strictest code requirements for demand-control recirculation pumps via Title 24[2].

2021 Energy Solutions Report

In their 2021 report titled "Research and Analysis of the Benefits of Appliance Standards for Domestic Hot Water Circulator Pumps", Energy Solutions focused on the incremental benefits of moving from continuous (24/7) recirculation to demand controls. The researchers calculated energy savings using pump performance from product specifications in conjunction with hours of operational use from a Department of Energy Circulator Pump report.

Table 1: Hours of operation and pump power for the two recirculation control sequences

Scenario	Control Type	Annual Hours of Use	Pump Power (W)	Notes
Baseline	No Control	8,760	84.2	Constant Operation
Efficient	On Demand	122	6.62	20 minutes/day

Methods

The researchers defined a baseline and efficient scenario, outlined in Table 1: Hours of operation and pump power for the two recirculation control sequences, to produce their savings estimates. The savings are a function of pump power and the annual hours of use for each control sequence. The baseline pump, a Grundfos 1529, was specified by identifying the most commonly purchased recirculation pump in the state of California. The efficient pump, a Grundfos 15-55HWR-D, was selected as a more efficient model provided by the same manufacturer. The baseline operational schedule assumes constant annual operation without a timer, aquastat, or on-demand controls. The efficient operational schedule assumes only 20 minutes of hot water demand per day from the pump. Both operational schedules were sourced from the Department of Energy Circulator Pump report.

Savings

Using their method, the researchers found that the efficient scenario saved 673 kWh per year compared to the baseline scenario. These savings reflect a retrofit scenario at an existing building where a large pump with continuous recirculation is replaced by a much smaller pump with highly efficient demand controls. This scenario is not reflective of a new construction, IECC 2015 baseline.

However, the method from this study can be repurposed to define a new construction scenario with an IECC 2015 baseline. First, the savings can be calculated as a function of a single pump power, which isolates the controls as the source of the savings. Assuming a 1/25 HP recirculation pump, a 90% pump efficiency, and an 80% load factor, the pump power is 25.1 W. This pump size is reflective of the average ECM motor power from a field study of more than 70 DHW recirculation pumps (Cadeo 2019). This pump power is used for both the baseline and proposed scenarios, shown in Table 2: New Construction (NC) scenario calculation with an IECC 2015 baseline below.

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[2] Current Title 24 requirements are defined in California's 2025 Building Energy Efficiency Standards: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2025-building-energy-efficiency.

Table 2: New Construction (NC) scenario calculation with an IECC 2015 baseline

Scenario	Control Type	Annual Hours of Use	Pump Power (W)	Notes
NC Baseline	Aquastat	1,095	25.1	3 hours/day
NC Efficient	On Demand	122	25.1	20 minutes/day

Next, the daily 3 hours of use for an aquastat controller are assigned as the baseline operational schedule. This control strategy reflects the two criteria required by IECC 2015. The daily 20 minutes of use for the on-demand controller is assigned as the efficient operational schedule. The hours of use for both of these strategies are defined in the Department of Energy Circulator Pump report.

$$kWh_{NC} = P_{pump} * (HOU_{base} - HOU_{ee}) \qquad \text{(Pump savings algorithm)}$$

Pump savings algorithm for a NC scenario

Where P_{pump} is the nameplate pump power in kilowatts, HOU_{base} is the number of annual hours of use in the baseline scenario, and HOU_{ee} is the number of annual hours of use in the efficient scenario.

Using Pump savings algorithm equation above, a much more conservative annual savings of 25.2 kWh is produced. This value is a theoretically more accurate representation of the savings per pump when comparing a highly-efficient demand controlled pump to an IECC 2015 code-minimum baseline.

2026 PG&E Report:

In a recent February 2026 report titled "Circulator Pump Controls Field Study", a research cohort from Pacific Gas & Electric (PG&E), West Monroe, TRC Companies, and the Association of Energy Affordability conducted an end-to-end study of recirculating pump demand controls in multifamily buildings in California. The researchers selected buildings that had recirculation pumps with installed, integrated controls. These integrated controls were tested to understand if savings are available from features integrated within the pump itself. Research methods included manufacturer and contractor interviews, baseline and efficient field data from the DHW and recirculation systems, and individualized savings using case-by-case measurement and verification (M&V) plans.

Methods

The sample for this study consisted of 5 sites: 4 multifamily buildings and 1 non-residential hotel. All 5 of the sites included heat pump water heaters with electric resistance swing tanks for reheat. Each site had a recirculation pump with the desired integrated controls for this study. The same pump was used at each site to measure the baseline and efficient energy consumption, and all scenarios, including the baseline, met the requirements defined in IECC 2015+.

From their survey of manufacturers and contractors, the researchers found an interesting difference in opinions. Manufacturers stated that increases in pump hardware could produce 50-60% energy savings and that controls could save an additional 30% savings. Contractors were reticent to comment on potential savings or stated they did not concern themselves with calculating savings as a scope of work. These responses showed diverging conceptions from stakeholders concerning their role in savings opportunities from these equipment and controls.

In their field study, the researchers measured the performance of these systems as-installed, and subsequently tested different controls integrated within the recirculation pumps. The control strategies differed from site to site depending on the system design and installed pump. The researchers tested 3 efficient-case integrated control strategies:

Table 3: Test scenarios[3]

Scenario	Control Strategy	Description
Baseline	Single-Speed Pump & Unbalanced	Measure how each building was found to be operating before interventions.
Efficient – Throttle	Single-Speed Pump & Balanced	All thermostatic balancing valves were set between 110-120°F, and the circulator pump remained on its baseline setting and speed. This step of balancing without upgrading the pump allowed for balancing and variable-speed pump savings to be disaggregated from proportional pressure and temperature controlled results.
Efficient – Proportional Pressure	Variable-Speed Pump & Balanced	The thermostatic balancing valves were closed to 110°F, the circulator pump was set to proportional pressure mode, and the pump proportional pressure ratio settings were adjusted to achieve a 110°F return water temperature.
Efficient – Temperature Controls	Variable-Speed Pump	All thermostatic balancing valves were opened to 140°F and the circulator pump was set to constant temperature (110°F) mode.

Pump energy consumption was measured using power logging meters attached to the recirculation pumps. Power data was collected at 1-minute intervals. The researchers targeted 14 days of sensor data for each of the tested control scenarios. They were only able to collect this duration of data for 14 of the 20 scenarios.

Savings

Researchers found that the integrated Proportional Pressure at 110 °F control resulted in pump savings at each of the 4 multifamily sites, with an average savings of 63%. This value aligned with the savings projected by manufacturers during the survey research. At the non-residential hotel, the researchers saw that constant thermostatic control at 115 °F resulted in 28% savings.

[3] Page 22 from the cited report.

sTable 4: Pump savings at each test site[4]

Site	Test	Pump Savings (kWh/day)	Pump Savings (kWh/year)*	Pump Savings (%)
MF 1	Throttle at 110 °F	0.0	0	0%
	Pressure at 95 °F	3.5	1,278	85%
	Pressure at 110 °F	2.8	1,022	69%
MF 2	Throttle at 110 °F	0.6	219	19%
	Pressure at 110 °F	3.0	1,095	91%
MF 3	Throttle at 110 °F	0.6	219	20%
	Pressure at 110 °F	2.2	803	74%
MF 4	Throttle at 110 °F	0.0	0	-1%
	Pressure at 110 °F	0.1	37	19%
NR - Hotel	Constant 115 °F	0.4	146	28%
	Constant 114 °F	0.6	219	41%
* Note: The annualized pump savings were not estimated by the original research team. We calculated them based on extrapolating the kWh/day savings over the analysis period to 365 days				

The average pump kWh savings from the proportional pressure 110 °F control at the four multifamily sites is 739 kWh per year, a 63% average improvement over the baseline. This finding supports the 673 kWh savings from the 2021 Energy Solutions report. That 2021 study assumed different pump sizes and run hours in the baseline and efficient cases. However, all of the participating sites in this 2026 study had efficient recirculation pumps in all scenarios (including the baseline), and the measured baseline was an accurate representation of code-minimum performance.

Research Findings

Initial attempts to understand demand-controlled recirculation pumps, like those from the 2021 Energy Solutions report, hinged on literature review and engineering algorithm savings calculations. The authors of that 2021 publication reported an annual savings of 673 kWh. Similarly, the authors of the 2026 publication from the PG&E-led research team reported annual savings of 739 kWh at multifamily sites. The 2026 Report used measurement and verification protocols to collect field data for baseline and efficient scenarios. Even with these differing methods, the results from both reports are similar. Also, the results from both reports are more conservative than deemed TRM savings for recirculation controls[5]. In the next section, a technical potential study of these controls strategies provides future-looking insight into the impact of these measures.

Technical Potential

Based on the findings from the literature review, we propose a range of future saving scenarios for beyond-code recirculation pump demand control strategies. We use two annual

[4] Combined results from Table 8 and Table 10 from the cited report.
[5] 1,103 kWh pump savings for "Controls for Central Domestic Hot Water" in Illinois Technical Review Manual Version 14.0 Volume 2 (2026).

savings values from our literature review to define the range of possible savings and our conservative savings estimate, outlined in Table 5: Range of annual savings for beyond-code demand recirculation strategies.

Table 5: Range of annual savings for beyond-code demand recirculation strategies

Source	Annual Savings (kWh)	Description
2021 Energy Solutions	673 kWh	Engineering algorithms, retrofit baseline
2026 PG&E	739 kWh	Measured and verified
Conservative Savings Estimate	25.2 kWh	Engineering algorithms, new construction IECC 2015 baseline

Next, we project the new construction multifamily building stock to be developed from 2025-2029 using historic construction data (U.S. Census Bureau 2025). For this projection, historic data from 2004-2024 was considered for new construction multifamily buildings 20-49 Units and 50+ Units. We are defining these two groups as the large multifamily building sample.

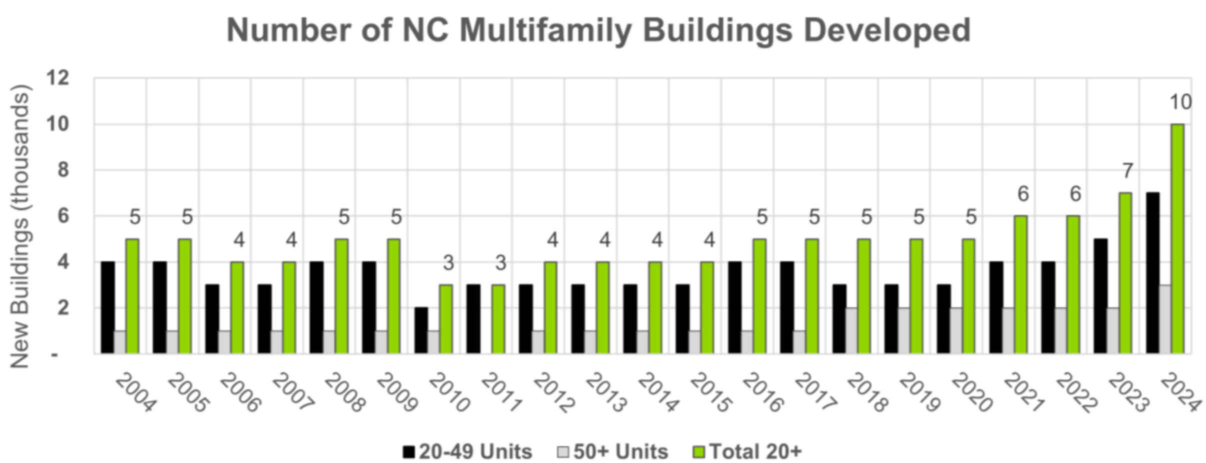

Figure 5: Gross number of new multifamily buildings 20+ Units (in thousands)

Over the last 20 years there have been two notable market fluctuations: a noticeable decrease after the 2008 Recession and a noticeable increase starting in 2021 after the COVID-19 pandemic. For this technical potential study, we assume 2 development scenarios over the next 5 years. For Scenario 1, we assume a business-as-usual case using the average number of 20+ multifamily buildings developed from 2004-2024. For Scenario 2, we assume an aggressive development case where a 10% year-on-year growth from 2024 values, 10,000 units, is extended out to 2029. This 10% growth is based on the development rate of large multifamily buildings from 2018 onwards, shown in Figure 1: The multifamily building stock is changing to favor larger, 20+ unit buildings (Census Bureau).

The annual 5-year potential savings are calculated assuming all new multifamily buildings in the United States adopt high-efficiency controls, not just areas that have adopted an IECC 2015 or newer code version. We leverage three annual savings estimates, From this technical potential study, we see a high degree of variability between the amended IECC 2015 baseline put forth by the author and the findings from the 2021 and 2026 reports. This savings estimate is based on commonly installed pump performance data and assumes efficient baseline recirculation pump controls.

Table 6: Technical potential assumptions and results

Source	Annual Savings (kWh)	Development Scenario 1 (Low)	Development Scenario 2 (High)	Scenario 1 - Low Cumulative 5-Yr Technical Potential (MWh)	Scenario 2- High Cumulative 5-Yr Technical Potential (MWh)
2021 Energy Solutions	673.0	24,762 MF Buildings	67,156 MF Buildings	16,664.76	45,196.06
2026 PG&E	739.0			18,299.05	49,628.36
Conservative Savings Estimate	25.2			624.00	1,692.33

Conclusions

Demand controls for recirculating pumps are becoming an increasingly important method for reducing energy consumption in multifamily buildings in the United States. While 35 states have adopted energy codes requiring recirculation pumps with controls, energy use for DHW has only incrementally dropped for multifamily buildings in the last 5 years. Code requirements and impending 2028 federal regulation updates have pushed manufacturers to develop integrated pump controls with high-efficiency capabilities. The preliminary results from studies on integrated demand controlled pumps show savings of 643-739 kWh per year, per pump installed. Assuming each newly constructed multifamily building over the next 5 years received a pumps with correctly installed on-demand controls, nationwide energy savings are likely to be at least 16,000 MWh.

Future Work

The potential study provided used the highest quality multifamily data that was available to the author for the United States. However, further data is required to disaggregate multifamily developments in the 35 states in Figure 4 from other areas in the United States. This data gap is one of the causes for the wide variance in 5-year potential savings.

Not included in this study are the potential co-benefits of reduced system heat loss from recirculating pump controls. The reduction in DHW system heat losses for heat pump water heaters is of special interest. HPWHs are complex systems whose cost-effectiveness is reliant on any reduction of electricity usage. The degree to which demand-controlled recirculation pumps could increase HPWH system efficiency and reduce overall operation costs is not clear.

Finally, with increased standardization of smart control protocols like CTA-2045, there are opportunities to understand the degree to which recirculation pump controls can optimize DHW systems for grid resiliency. Considering how substantial the DHW end-use is for large multifamily buildings, we believe there are considerable energy and demand savings available if these grid-integrated control strategies are explored further.

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AI-assisted tools used: [Copilot].
Used for: [proofreading].

Extent: [light editing].
Human review: The authors reviewed and verified all content, calculations, and citations.