Work Paper WPSCGNRWH170313A

**Revision 0**

**Southern California Gas Company**

**Commercial Recirculation Pump Time Clock**

# At-a-Glance Summary

|  |  |
| --- | --- |
| **Measure Codes** | TBD |
| **Measure Description** | Time clock control added to recirculation loop in commercial building types (Cnc, Fhc, OfL, OfS, EPr, ESe). The measure turns the recirculation pump off when hot water is not needed, i.e. when the commercial building is unoccupied. The energy savings come from both turning off the pump (electric savings) and by reducing the heat loss in the recirculation loop (gas savings) by not allowing the temperature in the loop to drop below the set point during unoccupied hours when the building has no demand for hot water (gas savings). With the pump off, the hot water heater will not fire to keep the loop at the set point until the building opens and hot water demand resumes. The timeclock requires 7-day (or better) scheduling capabilities. |
| **Base Case Description** | Industry Standard - constant flow recirculation pump, operating 24 hours per day. |
| **Units** | Installation |
| **Energy Savings** | Refer to Attachment A. Energy Savings Model Results |
| **Full Measure Cost ($/unit)** | $414 per installation |
| **Incremental Measure Cost ($/unit)** | $414 per installation (same as full measure cost) |
| **Effective Useful Life** | 15 years (DEER EUL ID: Wtr-Ht-Timeclock) |
| **Measure Installation Type** | Retrofit Add-on (REA) |
| **Net-to-Gross Ratio** | 0.7 (DEER NTGR ID: All-Default<=2yrs) |
| **Important Comments** | This work paper has a complementary Ex Ante Database data set that will be provided in a separate submission to the California Public Utilities Commission (CPUC). |

# Revision History

|  |  |  |  |
| --- | --- | --- | --- |
| **Rev** | **Date** | **Author** | **Summary of Changes** |
| 0 | 9/12/17 | Ariana Trabucco (Navigant Consulting, Inc.) | Original work paper |

# Commission Staff and Cal TF Comments

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Rev** | **Party** | **Submittal Date** | **Comment Date** | **Comments** | **WP Developer Response** |
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# Section 1. General Measure & Baseline Data

## 1.1 Measure Description & Background

This work paper details the base case and energy efficiency measure case for a time clock add-on to a recirculation loop in a subset of existing commercial buildings. The base case is a gas-fired hot water loop with a recirculation pump that operates continuously. The measure case is a retrofit add-on measure that adds a time clock to the system which shuts off the pump when hot water is not needed, i.e. after operating hours.

Annual energy measure savings in units of therms and kWh are provided on a per-unit installed basis for hot water heating for six commercial building types and three different pump horsepower ranges totaling 18 measures. This measure is not climate zone dependent because the only temperature variable is the change in water temperature from the hot water set point of 140°F to the indoor air temperature outside of the loop. The energy savings for each of these measures is provided in attachment A. Energy Savings Model Results.

Table 1 and Table 2 provide summaries of the base case, measure case, and of the relevant DEER measures and their Source Descriptions as taken from DEER READI v.2.4.7.

Table - Base, Standard, and Measure Cases

| **Case** | **Description of Typical Scenario** |
| --- | --- |
| Measure | Time clock control added to recirculation loop in commercial buildings. The measure turns the recirculation pump off when hot water is not needed, i.e. when the commercial building is unoccupied. The energy savings come from both turning off the pump (electric savings) and by reducing the heat loss in the recirculation loop (gas savings) by not allowing the temperature in the loop to drop below the set point during unoccupied hours when the building has no demand for hot water (gas savings). With the pump off, the hot water heater will not fire to keep the loop at the set point until the building opens and hot water demand resumes. The timeclock requires 7-day (or better) scheduling capabilities. |
| Existing Condition | Constant flow recirculation pump operating 24 hours per day. |
| Code/Standard | Code for newly constructed buildings, additions to existing buildings, and alterations to existing buildings: Recirculation pumps with automatic shut off controls to turn off the service hot water system. |
| Industry Standard Practice | Constant flow recirculation pump, operates 24 hours per day. |

Table - Measures and Codes

| **Measure Codes** | | | | **Measure Name** |
| --- | --- | --- | --- | --- |
| SCG | SDG&E | SCE | PG&E |
| 540519  540521  540522 | TBD | TBD | TBD | RecirtTimePumpClock-<=1/12 Hp Pump  RecirtTimePumpClock->1/12 and <=1/3 Hp Pump  RecirtTimePumpClock->1/3 Hp Pump |

**Eligibility requirements:**

* Applicable to existing buildings only; newly constructed buildings, additions to existing buildings, and alterations to existing buildings are excluded.
* Applicable to buildings with hot water recirculation systems that can be turned-off entirely for a set period of the day/week.
* Applicable to those buildings with centralized, gas-fired, hot-water system with a constant-flow, fractional-horsepower, uncontrolled recirculation pump.
* Applies to all California Building Climate Zone Areas.

**Implementation and installation requirements:**

* Gas savings from this measure are limited to six commercial building types with set occupancy schedules including: primary and secondary education, fitness centers, small and large office buildings, and outpatient healthcare facilities, which are unoccupied for a period of time each day. The measure may be applicable in other building types, but they are excluded from this work paper. Note that hot water is still available when the recirculation pump is off, but requires more time to heat up.
* The time clock product requires 7-day (or better) scheduling capabilities.
* There is no restriction on manufacturer or brand-naming.

## 1.2 Technical Description

This work paper details a time clock add-on to an existing recirculation pump in commercial buildings with defined operating hours. The addition of a time clock to the system allows the pump to shut off for a scheduled period when the building is unoccupied and hot water is no longer needed on demand.

The illustration in Figure 1 depicts a simple recirculation loop that is typical of the commercial building types examined in this measure. This measure reduces electricity use by turning off the pump, thereby stopping the continued supply of hot water to the recirculation system when the building is unoccupied. Anytime the recirculation loop is maintained at the set point, heat is lost to the surrounding air; shutting off the pump and letting the temperature in the loop drop will reduce the heat loss. Savings are dependent on pump and piping system characteristics, and building operating hours.

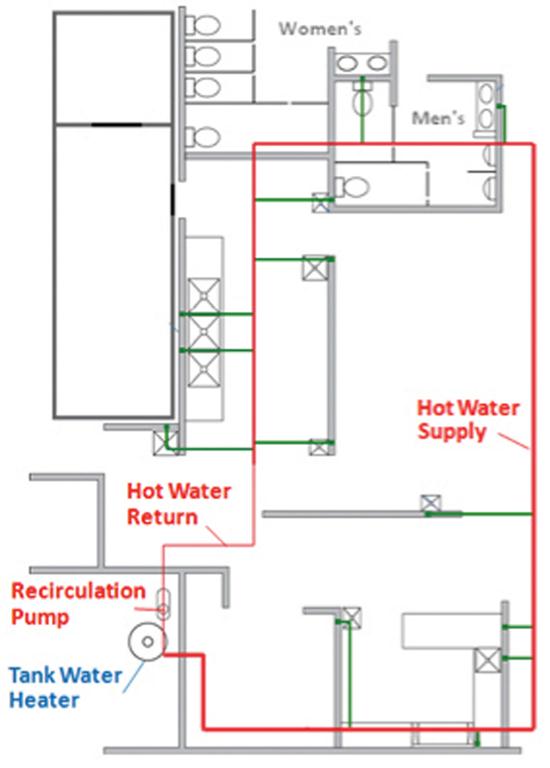


Figure – Example Hot Water Recirculation Loop in a Commercial Building[[1]](#endnote-1)

Recirculation pumps are used to circulate hot water in buildings having central hot water heaters in order to provide hot water instantly or shortly after the draw is initiated, even at remote locations in the building. In typical, one-way plumbing without a recirculation pump, water is simply piped from the water heater through the pipes to the tap. Once the tap is shut off, the water remaining in the pipes cools and results in a wait for hot water the next time the tap is opened. All the cool water in the pipe must go down the drain before the hot water from the tank reaches the fixture. By adding a circulator pump and constantly circulating hot water through the pipes from the water heater to the farthest fixture and back to the heater, the water in the pipes is always hot, and no water is wasted during the wait. While a recirculation pump saves water, it uses energy by continuously operating the pump and increasing the heat loss from the system, even when hot water is not in demand.

This measure consists of a time clock installed on an existing recirculation pump; the timeclock must be programmed with the appropriate occupancy schedules for the building. Once properly installed, this measure will continue to operate without customer intervention so long as the occupancy hours do not change. The base case for this measure is a continuously operating recirculation pump. It ensures hot water is always available at the fixture, irrespective of hot water loop temperature or system demand. The energy savings come from the heat that would have been lost from the hot water as it is circulated continuously through the recirculation loop during unoccupied hours.

## 1.3 Installation Types and Delivery Mechanisms

The installation type for this energy efficiency measure,indicated inTable 3, is a *Retrofit Add-on (REA)*. The measure includes the installation of a 7-day programmable electric timer to an existing recirculation pump with no adjustments required to the plumbing of the recirculation system.

Table - Installation Type Descriptions

| **Installation Type** | **Savings** | | **Life** | |
| --- | --- | --- | --- | --- |
| 1st Baseline (BL) | 2nd BL | 1st BL | 2nd BL |
| **Retrofit Add-on (REA)** | **Above Customer Existing** | **N/A** | **RUL** | **N/A** |

Applicable delivery and incentive methods are described in Table 4andTable 5**.**

Table - Delivery Method Descriptions

|  |  |
| --- | --- |
| **Delivery Method** | **Description** |
| Financial Support | The program motivates customers, through financial incentives such as rebates or low interest loans, to implement energy efficient measures or projects. |

Table - Incentive Method Descriptions

|  |  |
| --- | --- |
| **Incentive Method** | **Description** |
| Down-Stream Incentive | The customer installs qualifying energy efficient equipment and submits an incentive application to the utility program. Upon application approval, the utility program pays an incentive to the customer. |

## 1.4 Measure Parameters

### 1.4.1 DEER Data

The energy efficiency measure detailed in this work paper was included in the 2005 Database of Energy Efficiency Resources (DEER). The measure (D03-095 – Circulation Pump Timeclock Retrofit) adds a time clock to the existing circulation pump, which provides on/off pump control based on building occupancy and meets the requirements of the California Building Energy Efficiency Standards. However, the energy impacts of D03-095 have not been updated since 2005, and were only focused on calculating the electricity savings in units of area footprint.

The DEER 2015 Small Storage and Small Instantaneous Water Heater Energy Use Calculator[[2]](#endnote-2) includes data on hot water load (gallons per minute) at a set tank temperature by Building Type. Operating hours were calculated for this work paper based on the hours per year that the hot water load was greater than zero. Data was only available for four of the six building types included in this work paper (Primary and Secondary Education and Large and Small Office).

A summary of DEER differences is presented in Table 6.

Table - DEER Difference Summary

| **DEER Item** | **Used for Work paper?** |
| --- | --- |
| Modified DEER methodology | No |
| Scaled DEER measure | No |
| DEER Base Case | No |
| DEER Measure Case | No |
| DEER Building Types | Yes, except for Fitness Centers |
| DEER Operating Hours | Yes, except for Outpatient Healthcare and Fitness Centers |
| DEER eQUEST Prototypes | No |
| DEER Version | N/A |
| Reason for Deviation from DEER | DEER calculates electricity savings only |
| DEER Measure IDs Used | N/A |

**Net-to-Gross Ratio**

The Net-to-Gross (NTG) Ratio value was obtained using the DEER READI tool, version v.2.4.7*[[3]](#endnote-3)*. The relevant NTG value for the measure in this work paper is provided in Table 7and applies to both electric (kWh) and natural gas (therms) savings in all 16 California Building Climate Zone Areas.

Table - Net-to-Gross Ratio

| **NTGR ID** | **Description** | **Sector** | **BldgType** | **Measure Delivery** | **NTGR** |
| --- | --- | --- | --- | --- | --- |
| All-Default<=2yrs | All other EEM with no evaluated NTGR; new technology in program for 2 or fewer years | All | Any | Any | 0.7 |

Note: Direct install measures that are not hard-to-reach will use the default NTG value.

**Spillage Rate**

Spillage rates are not tracked in work papers; they are tracked in an external document which will be supplied to the Commission Staff.

**Installation Rate**

The (installation rate) IR values were obtained using the DEER READI tool, version v.2.4.7. The relevant IR values for the measures in this work paper are in Table 8**.**

Table – Installation Rate

| **GSIA ID** | **Description** | **Sector** | **BldgType** | **ProgDelivID** | **GSIAValue** |
| --- | --- | --- | --- | --- | --- |
| Def-GSIA | Default GSIA values | Any | Any | Any | 1 |

**Effective and Remaining Useful Life**

The EUL and RUL values were obtained using the DEER READI tool, version v.2.4.7. The relevant EUL and RUL values for the measures in this work paper are in Table 9.

Table - Effective Useful Life

| **EUL ID** | **Description** | **Sector** | **UseCategory** | **EUL (Years)** | **RUL (Years)** |
| --- | --- | --- | --- | --- | --- |
| Wtr-Ht-Timeclock | Circulation Pump Timeclock Retrofit | Com | SHW | 15 | 5 |

### 1.4.2 Codes and Standards Analysis

There are no federal, state, or regional codes or standards that regulate commercial hot-water recirculation pumps in existing buildings. Recirculation systems are regulated by California’s Building Energy Efficiency Standards for both new construction and building alterations and therefore inform, but do not impact, this Retrofit Add-on (REA) measure. Table 10outlines the codes and standards researched, and it is followed by a summary of the relevant code and its requirements.

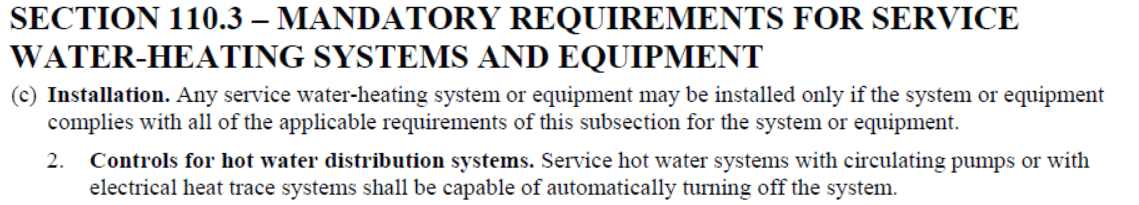
Table - Code Summary

| **Code** | **Reference** | **Effective Dates** |
| --- | --- | --- |
| Title 24 (2016)[[4]](#endnote-4) | Building Energy Efficiency Standards | January 1, 2017 |
| Title 20 (2015)[[5]](#endnote-5) | Appliance Efficiency Regulations | July 1, 2014 |
| DOE 10 CFR Part 430[[6]](#endnote-6) | Federal Register | January 20, 2004 |

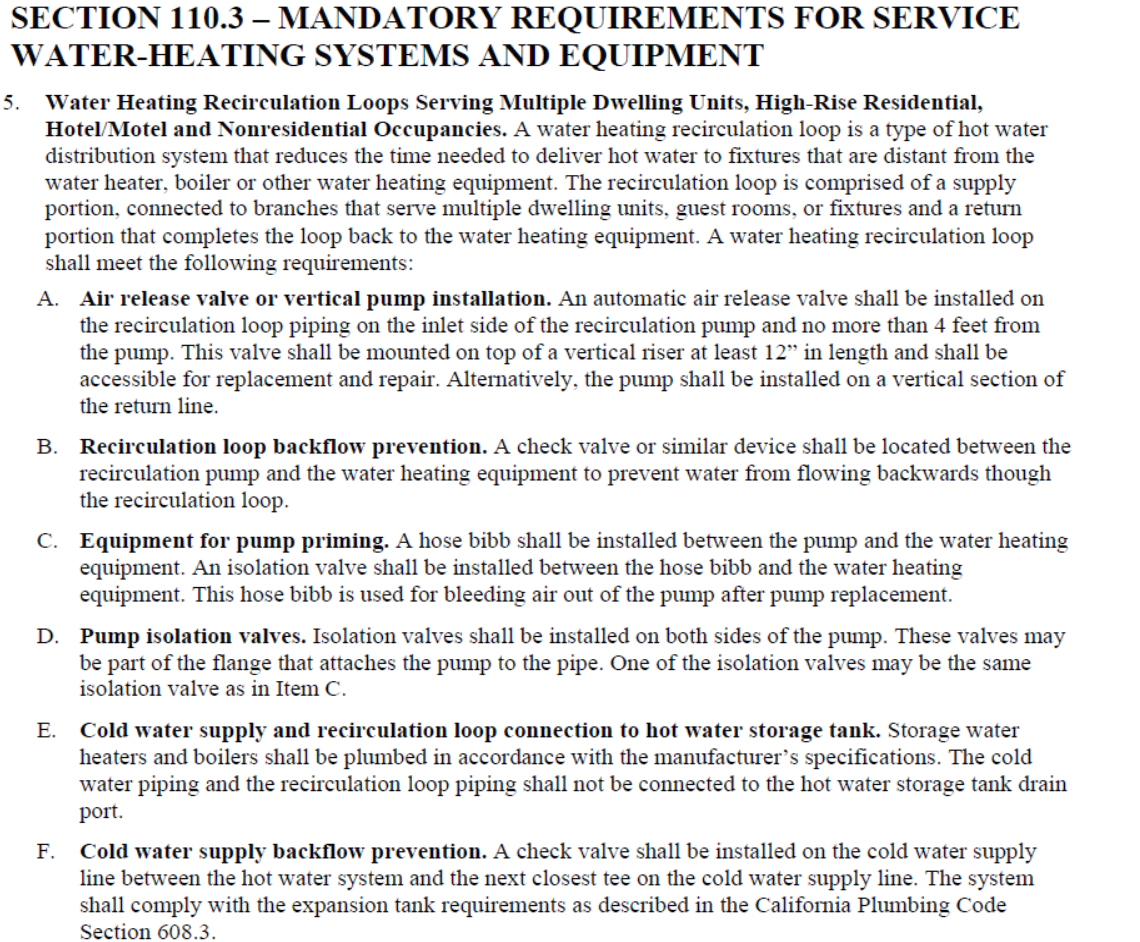
**California’s Title 24 Building Energy Efficiency Standards (2016)**

The California Building Energy Efficiency Standard provides mandatory, prescriptive and performance requirements for hot water recirculation systems in newly constructed buildings, additions to existing buildings, and alterations to existing buildings. Both the mandatory and prescriptive sections are relevant for informing this measure; the sections include: automatic shut off pump controls, general system installation, and pipe insulation requirements for all building types. These code requirements are summarized below:

* **Section 110.3(c) 2, Page 101:** This section requires hot water systems with recirculation pumps in all building types have automatic shut off controls to turn off the service hot water system.



* **Section 110.3(c) 5, Page 101-102:** This section applies to all building types. It provides mandatory requirements for the installation of how water recirculation systems but does not address recirculation pump control.



* **Section 120.3, Page 131:** This section provides requirements for hot water pipe insulation in all building types. It requires service hot water systems above 105°F be insulated with a material meeting a minimum level of thermal conductivity, based on nominal pipe diameter. This section is relevant insomuch as to inform model input assumptions such as the assumption that the hot water circulation loop is insulated. The normal operation heat rates used in development of the measure case correspond to the requirements consistent with data from the 2015 ASHRAE Handbook on HVAC Applications.[[7]](#endnote-7)



**Title 10 of Electronic Code of Federal Regulations**

There are no federal regulations for hot water recirculation pumps.

**California’s Title 20 Appliance Efficiency Regulations (2015)**

The California appliance efficiency standards do not regulate hot water recirculation pumps.

## 1.5 EM&V, Market Potential, and Other Studies – Base Case and Measure Case Information

Relevant studies that influenced this work paper are summarized below.

### 1.5.1 Recirculation Pump Time Clock Field Testing Report

* **Tech Source (field report):** Navigant Consulting, Inc. for Southern California Gas Company, Recirculation Pump Time Clock Field Testing Report, April 2017. (Attachment C.)
* **Market Covered:** 150,000 sq. ft. commercial office building
* **Timeframe:** December 2013 – May 2014
* **Techniques used:** Field test; installation and data logging.
* **Technology:** A time clock installed on a service hot water recirculation pump programmed with occupancy schedule.
* **Relevance:** Field test for same technology as the measure defined in this work paper.
* **Assessment:** This field test provides a single data point for savings associated with a recirculation pump timeclock. Accordingly, the data is insufficient for the purposes of statistically validating the model. Further, due to the multitude of variables that impact the heat loss in a hot water recirculation system, and therefore the magnitude of the gas savings, it is difficult to compare the savings in the field test to the savings in this work paper.

The methodology defined in this work paper uses supported assumptions about building and piping characteristics and temperature based on knowledge of the service territory. Several inputs can be adjusted in the model that are associated with this work paper, including: building type, pump horsepower range, pipe insulation thickness and water temperature set point. In the field report, only pump horsepower and temperature set point were confirmed. As a result, assumptions must be made for all other variables and based on the possible range of inputs, the resulting gas savings can fall above or below the logged savings value reported in the field study. Despite the limited insights that can be gleaned from the final savings value, other lessons learned from the field study can support the measure in this work paper, including:

* + The field data showed limited, intermittent hot water usage overnight, when the pump was off. It is believed that this is due to either cleaning crew or security use. These unexpected draws would increase heat losses (i.e., decrease the gas savings) compared to no hot water use for the duration of the unoccupied hours because with increased hot water temperature in the pipe (drawn from the hot water heater), comes higher heat loss rates to the surrounding air. Without consistent, or predictable expectations for draws during unoccupied hours, this work paper assumes no hot water use during unoccupied hours.
  + The observed installation from the field study found that an adapter was used between the pump and the recirculation supply line to the building. Therefore, it should be clarified that the hot water supply pipe size input variable in this work paper refers to the size of the piping that loops through the building and excludes the size of the adapters that may have been used to match to the pump flange size.

### 1.5.2 Energy-Efficiency with Domestic Water Heating in Commercial Buildings Paper

* **Tech Source (paper):** 2010 American Council for an Energy Efficiency Economy (ACEEE) Summer Study on Energy Efficiency in Buildings, Energy-Efficiency with Domestic Water Heating in Commercial Buildings.[[8]](#endnote-8)
* **Market Covered:** 267,000 sq. ft. Commercial office building
* **Timeframe:** N/A
* **Techniques used:** Savings analysis based on field test; installation and data logging.
* **Technology:** Installation of either a manually programmable timer or connection of the pump to a building energy management system to control the on/off times based on building occupancy.
* **Relevance:** Field data for similar measure as defined in this work paper.
* **Assessment:** Savings in this report are different than the expected savings (as documented in this work paper).
  + The same reasoning can be drawn from the field data in this paper as was drawn from the field report referenced in Section 1.5.1

## 1.6 Future Data Needs

There is currently enough data available to confidently estimate savings. The quality of the data referenced in Section 1.5.1 and 1.5.2 can be considered credible. If additional data becomes available on the measure described in this work paper, it should be considered relevant and therefore reviewed and applied to this paper.

The existing data in DEER for the *D03-095 – Circulation Pump Timeclock Retrofit* measure was referenced but was found to only calculate electricity savings and has not been updated since 2005.

# Section 2. Calculation Methodology

Energy efficiency measure savings were developed through a combination of research and engineering calculations. The approach used to develop the deemed savings estimates in this work paper is described below.

## Approach

The energy savings of this measure is dependent on the amount of heat lost from the recirculation loop when the recirculation pump is turned off versus the amount of heat lost during normal pump operation. We assume that the savings in these applications is independent of the rate of heat loss (btu/hr) (which changes over time based on the difference in temperature between the pipe and the ambient air) because the unoccupied hours are sufficiently long that the loop temperature consistently will approach the ambient air temperature by the time the pump restarts. Therefore, instead of analyzing the dynamic heat loss that occurs when the pump is shut off, it is simpler to calculate the steady state heat loss during baseline operation (pump constantly circulating) and then subtract the energy required to reheat the recirculation loop when the system is turned back on in the morning. The full analysis is implemented in an engineering model in Excel, which calculates the final energy savings for all possible measures. The resulting final gas savings calculation used is provided in Equation 1.

Equation – Gas Savings Calculation

Figure 2 depicts the approach used for this measure to calculate the annual unit therm savings with illustrative water and air temperatures.

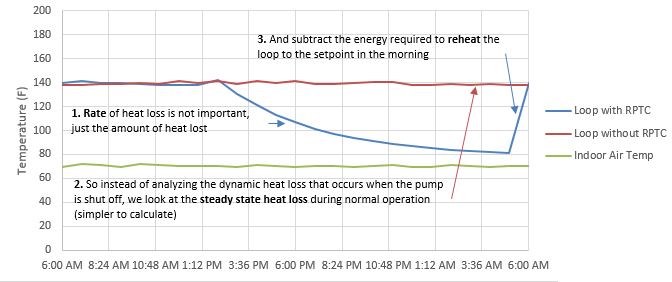


Figure – Conceptual Illustration

## Model Methodology

A model was developed to run the necessary engineering calculations for all variables of this measure. See Attachment B. Engineering Calculations. As there are a multitude of variables that can impact the heat loss of an operational hot water recirculation system, some inputs had to be fixed based upon knowledge of the subset of building types in the service territory.

The model uses two input variables to characterize the measure: building type and recirculation pump horsepower range. Table 11 summarize the inputs (variables and constants) required for the model. Further detail is provided for each required input below the table.

Table – Model Inputs

| **System Parameters** | | **Value(s)** | **Sources** |
| --- | --- | --- | --- |
| Variable Building Inputs *(varies by customer)* | Building Type | Primary Education  Secondary Education  Fitness Centers  Small Office  Large Office  Outpatient Healthcare | See paragraph (1) below |
| Recirculation Pump Range | ≤ 1/12 HP  > 1/12 and ≤ 1/3 HP  > 1/3 HP | See paragraph (2) below |
| Required Building Characteristics *(based off variable inputs)* | Hot Water Supply Pipe Diameter[[9]](#footnote-1) – Assumed | 1.25"  1.5"  2" | Value based on input pump range selected, see paragraph (3) below |
| Pipe Insulation | 1/2" | Fixed assumption, see paragraph (4) below |
| Gas Water Heater Efficiency ( | 83.49% | Fixed value, see paragraph (5) below |
| Annual Hours of Vacancy ( | 6180, 6180, 2936, 5479, 3973, 5900 | Value based on input building type selected, see paragraph (1) below |
| Days open per week (days) | 5, 7 |
| Annual Number of Shutdown Periods ( | 260, 364 |
| Hot Water System Characteristics *(based off variable inputs)* | Pump Horsepower – Assumed (HP) | 1/25, 1/6, 1/2 | Value based on input pump range selected, see paragraph (2) below |
| Return Pipe Nom Diameter – Assumed (in.) | 0.75, 1, 1.25 | Value based on supply pipe diameter, see paragraph (3) below |
| Supply Pipe ID | 0.785, 1.025, 1.265, 1.505, 1.985 | Lookup based on supply pipe diameter, see paragraph (6) below |
| Return Pipe ID |
| Supply Pipe OD | 0.875, 1.125, 1.375, 1.625, 2.125, |
| Return Pipe OD |
| Pipe Heat Loss - Supply Pipe ( | 23.4, 25.4, 29.6 | Lookup based on supply pipe diameter, see paragraph (7) below |
| Pipe Heat Loss - Return Pipe ( | 15.2, 17.4, 20.1 |
| Estimated Total Pipe Length ( | 620, 1500, 2600 | Lookup based on input pump range selected, see paragraph (8) below |
|  | Pump Average Input Power () | 0.072, 0.216, 0.441 | Lookup based on input pump range selected, see paragraph (9) below |

1. The six building types included in this measure were selected based on the criteria below.

Table – Building Type Criteria

| **Criteria** | **Detail** |
| --- | --- |
| Existing hot water recirculation loop | The building type is likely to have a recirculation loop (i.e., large number of bathrooms and/or sinks). Excluding building types that would be reasonably believed to have a loop that is less than approximately 150-feet long. |
| Hours of vacancy | The building type has approximately 50 or more hours per week of non-operating time. |
| Defined operating hours | The building type has defined operating hours that could be programmed in the timer. |

For Primary and Secondary Education and Large and Small Office building types, operating hours are based on data from the DEER 2015 Small Storage and Small Instantaneous Water Heater Energy Use Calculator. The data provides hot water load (gallons per minute) at a set tank temperature by Building Type for each hour of the year. Operating hours were calculated based on the hours per year that the hot water load was greater than zero, assuming hot water load is greater than zero for all occupied hours. This source did not have data for Outpatient Healthcare and Fitness Center building types.

For Outpatient Healthcare and Fitness Center building types, annual hours of vacancy and days open per week are based on the Energy Information Administration’s (EIA) Commercial Building Energy Consumption Survey (CBECS)[[10]](#endnote-9) data. Annual hours of vacancy values used in the model were adjusted from the original CBECS data for two reasons; 1) to be conservative in model calculations of energy savings as the energy saved is directly proportional to the hours that the pump is off, and 2) to account for the fact that the recirculation pump should be turned back on in advance of operating hours to allow the water in the loop to reach the set point before occupants arrive. The values used are presented in Table 13.

Table – Building Type Characteristics

| **Building Type** | **Vacant Hours/yr.** | **Days/wk open** | **Hrs open/day** | **Source** |
| --- | --- | --- | --- | --- |
| Outpatient Healthcare (Cnc) | 5,900 | 5 | 11 | CBECS adjusted |
| Service – Fitness (Fhc) | 2,936 | 7 | 16 | CBECS adjusted |
| Large Office (OfL) | 3,973 | 5 |  | DEER HW Calculator |
| Small Office (OfS) | 5,479 | 5 |  | DEER HW Calculator |
| Education Primary (EPr) | 6,180 | 5 |  | DEER HW Calculator |
| Education Secondary (ESe) | 6,180 | 5 |  | DEER HW Calculator |

CBECS does not provide data for fitness centers specifically so the annual hours of vacancy and days open per week are adjusted from the CBECS data for service buildings (which includes fitness centers) based on a sample of operating hours from local businesses.

The number of shutdown periods is equivalent to the number of times the pump turns back on. This is calculated in the model by multiplying the number of days per week the building type is open by 52 weeks per year.

1. Manufacturer materials (websites, catalogs, data sheets) indicate the vast majority of pumps used for hot water recirculation applications are ≤1 horsepower. The analysis for this work paper suggests that the distribution is heavily weighted towards units that are ≤1/3 HP. Both points are supported by the data that was available and compiled from multiple studies on building recirculation characteristics in SCG territory, including the Recirculation Pump Time Clock Field Testing Report described in Section 1.5.1 of this work paper. Therefore, the ranges selected for this work paper, ≤ 1/12, > 1/12 and ≤ 1/3, and > 1/3 HP, support an even distribution of the likelihood of pump size in SCG buildings.

The representative (assumed) horsepower values for each pump range aim to be representative of the entire group, but, if anything, slightly conservative in terms of resulting energy savings.

1. The representative (assumed) hot water supply pipe diameter selected for each representative pump is based on the head loss calculator and horsepower-to-loop-length overlay described in 8a and 8b below. The pipe diameters selected for this work paper represent a balance of the head loss and the flow rate at the three representative pump sizes. The values selected represent the middle of the potential size range of available flange sizes and fall along the moderately sloped portions of the performance charts, ensuring that errors due to estimation of the pipe diameter do not dramatically change the results.

The return diameters also align with the pipe specifications for the pumps sizes selected.

1. A conservative estimated insulation thickness of 1/2" is used in the model. According to a ACEEE study[[11]](#endnote-10), most multifamily residences do not have insulation on the recirculation system, as it has only recently been included in code and retrofits can be cost-prohibitive and impractical due to pipe access. Although Title 24 requires thicker insulation, this measure is not eligible for new construction and the baseline is not assumed to be up to code.
2. The 2014 and 2015 Nonresidential Downstream ESPI Deemed Pipe Insulation Impact Evaluation prepared by Itron,[[12]](#endnote-11),[[13]](#endnote-12) provide a general hot water boiler combustion efficiency for units in California. The mean ex post combustion efficiency, including skin losses, is 83.49% for hot water boilers.
3. Supply and return pipe specifications follow the ASTM B88 Standard for seamless copper water tube[[14]](#endnote-13) based on the supply and return nominal diameter selected.
4. Pipe heat loss values come from ASHRAE[[15]](#endnote-14) and are a factor of supply pipe diameter and water temperature. The approximate heat loss values in btu/hr-ft presented by ASHRAE are based on copper tubing with 0.5 in glass fiber insulation. The temperature at the inlet of the pipe is 140°F and ambient temperature is 70°F[[16]](#footnote-2). All heat loss calculations from the supply pipe assume fixed hot water temperature 140°F and fixed indoor air temperature 70°F.

The return pipe for this measure was assumed to be at a temperature of 130°F. The 10-degree temperature drop is based on a common approximation used to estimate head loss when sizing recirculation pumps. A 10-degree drop was assumed for all head loss calculations performed for this measure. As a result, the heat loss values from ASHRAE were proportionately de-rated to determine the return-pipe heat loss.

1. The total length of the recirculation loop was estimated based on the pump size and supply pipe diameter through a series of two separate models:
   1. **Head Loss Calculator** - The expected head loss was calculated by summing the head loss from an estimated number of fittings, fixtures, valves, and other restrictions throughout the loop along with the head loss per foot of piping. The model determined total head loss in the loop and flow rate based on the density and viscosity of water, the flow velocity through the pipe, the Reynolds number of the fluid flow, and roughness and friction factor of copper tubing. The model calculated values for the full range of potential loop lengths and pipe diameters.
   2. HpH**Horsepower-to-loop-length Overlay** - The total head loss values from the Head Loss Calculator model were overlaid with pump performance curves from a circulator manufacturer (two different sets of common pumps). This overlay allowed the estimation of loop length for each given combination of pipe diameter and pump horsepower. The overlay accounted for modest oversizing of pumps, which is common in the industry to ensure that pressure and temperature are maintained in the system (and leads to more conservative savings calculations).
2. The recirculation pump average input power is used to calculate the electricity saved while the pump is turned off. The average input power of the pump is a fixed value associated with each horsepower rating. These values were derived from data presented at the Department of Energy’s Circulator’s Rulemaking Negotiation Working Group Meetings.[[17]](#footnote-3),[[18]](#endnote-15)
   1. **Circulator Input Power Analysis** - To find the average wattage for each pump horsepower rating included in this work paper, the pump curves referenced in (8)b **Horsepower-to-loop-length Overlay**, were compared to the pump curves of the DOE working group representative units.[[19]](#footnote-4) When pump curves were similar, the pump energy rating wattage from the analogous DOE representative units was used. When pump curves fell well between DOE representative unit curves, the wattages were interpolated based on horsepower.

## Model Calculations

**Gas Savings Calculations**

Equations 2 through 9 represent the intermediate calculations performed by the model prior to determining the final energy savings. Table 14 presents the assumptions and constants used in these equations. Table 15 defines several variables used in these equations.

Table – Energy Savings Assumptions and Constants

|  | **Value** | **Unit** | **Definition** |
| --- | --- | --- | --- |
|  | 140 | °F | Hot Water Heater Set point |
|  | 78[[20]](#footnote-5) | °F | Pipe Temperature Prior to Reheat |
|  | 62.4 | lb/ft3 | Water Density |
|  | 1.0 | btu/lb-°F | Water Specific Heat |
|  | 557.9 | lb/in3 | Copper Density |
|  | 0.092 | btu/lb/°F | Copper Specific Heat |

Table – Variable Definitions

| **Variable Name** | **Definition** |
| --- | --- |
|  | Heat loss in supply pipe [Btuh/ft] |
|  | Heat loss in return pipe [Btuh/ft] |
|  | Inner diameter of supply pipe [inches] |
|  | Inner diameter of return pipe [inches] |
|  | Outer diameter of supply pipe [inches] |
|  | Outer diameter of return pipe [inches] |
|  | Gas that would have been used to maintain water temperature in supply pipe during vacancy hours [Btu] |
|  | Gas that would have been used to maintain water temperature in return pipe during vacancy hours [Btu] |
|  | Gas required to reheat supply pipe [Btu] |
|  | Gas required to reheat return pipe [Btu] |

Equation –Gas saved when the pump is off, Supply

Equation –Gas saved when the pump is off, Return

The calculated vacancy gas (in Btu), represents the gas that would have been used to maintain the water temperature in the loop during vacancy hours. The same equation was used to calculate the supply and return vacancy gas, but the heat loss variable of the pipes differs. For vacancy gas calculations, the supply and return pipe are each assumed to be 50% of full length, which is why the pipe length variable is divided by 2.

Equation – Mass of Water, Supply

Equation – Mass of Water, Return

The mass of water in the supply and return pipe in units of lbs. is calculated similarly except the inner diameter values differ between supply and return. The mass of water is required to calculate the reheat gas.

Equation – Mass of Copper, Supply

Equation – Mass of Copper, Return

The mass of copper in the supply and return pipe in units of lbs. is calculated similarly except the inner and outer diameter values differ between supply and return. The mass of copper is required to calculate the reheat gas.

Equation – Reheat Gas, Supply

Equation – Reheat Gas, Return

The calculated reheat gas in units of Btu, represents the gas required to reheat the water in the loop after the pump has been turned off during hours of vacancy. The same equation was used to calculate the supply and return reheat gas, but the mass variables differ.

Equation 10 and Equation 11 represent the final calculations for annual gas and electricity savings respectively. Equation 10 is a reiteration of Equation 1.

Equation – Annual Gas Savings

**Electricity Savings Calculations**

Electricity savings does not rely on the steady state heat loss through the system. Electricity savings accounts for the power of the pump (a fixed value associated with each horsepower rating) and the number of hours the pump is shut off. This measure generates electric savings as load is being removed from the grid.

Equation – Annual Electricity Savings

## Example

Using an example building type and customer site-specific building characteristics, the input and output values of the model are shown in Table 16.

Table - Example Energy Savings Model Outputs

| **Parameter** | **Description** | **Value** | **Unit** | **Eq. Ref.** |
| --- | --- | --- | --- | --- |
| Selection from dropdown list | Building Type | Large Office (OfL) |  |  |
| Recirculation Pump Range | >1/3 | horsepower |  |
| Pipe Insulation | 1/2 | inches |  |
| Lookup based on selection above | Recirculation Pump HP (decimal) | 0.500 | horsepower |  |
| Hot Water Supply Pipe Diameter | 2.00 | inches |  |
|  | Gas Water Heater Efficiency | 83.49 | % | 2, 3, 8, 9 |
|  | Annual Hours of Vacancy | 3,973 | hours | 2, 3 |
|  | Days open per week | 5 | days/week |  |
|  | Annual Number of Shutdown Periods | 260 | events/year | 8, 9 |
|  | Supply Pipe ID | 1.985 | inches | 4, 6 |
|  | Supply Pipe OD | 2.125 | inches | 6 |
|  | Return Pipe ID | 1.265 | inches | 5, 7 |
|  | Return Pipe OD | 1.375 | inches | 7 |
|  | Pipe Heat Loss - Supply Pipe | 29.6 | Btu/(hr\*ft) | 2 |
|  | Pipe Heat Loss - Return Pipe | 20.1 | Btu/(hr\*ft) | 3 |
|  | Estimated Total Pipe Length | 2,600 | feet | 2 - 7 |
|  | Pump Average Input Power | 0.441 | kW | 11 |
|  | Gas saved when the pump is off, Supply | 183,112,996 | Btu | 2 |
|  | Gas saved when the pump is off, Return | 124,078,497 | Btu | 3 |
|  | Mass of Water, Supply | 1,743 | lb. | 4 |
|  | Mass of Water, Return | 708 | lb. | 5 |
|  | Mass of Copper, Supply | 2,276 | lb. | 6 |
|  | Mass of Copper, Return | 1,149 | lb. | 7 |
|  | Reheat Gas, Supply | 37,702,233 | Btu | 8 |
|  | Reheat Gas, Return | 15,710,316 | Btu | 9 |
|  | **Annual Gas Savings** | **2,538** | **therms/year** | 10 |
|  | **Annual Electricity Savings** | **1,752** | **kWh/year** | 11 |

# Section 3. Load Shapes

The ideal load shape for net benefits estimates would represent the difference between the base case and measure case. The closest load shapes that are applicable to the measures in this work paper are listed in the table below.

Load Shape data from READI v.2.4.7 (Current Ex Ante data) database tables: ElecImpProfiles.[[21]](#endnote-16)

Building Types and Load Shapes

|  |  |  |
| --- | --- | --- |
| **Building Type** | **Load Shape** | **E3 Alternate Building Type** |
| Outpatient Healthcare | Misc.\_Commercial:DHW HtPmp | Misc.\_Commercial |
| Service - Fitness | Misc.\_Commercial:DHW HtPmp | Misc.\_Commercial |
| Office | Misc.\_Commercial:DHW HtPmp | Misc.\_Commercial |
| Education | Misc.\_Commercial:DHW HtPmp | Misc.\_Commercial |

# Section 4. Costs

As there are many time clock products available from several manufacturers, costs for this measure were based on average available costs for these products. The range in pricing is due to the extent of programming capabilities that the products offer. The minimum programming capabilities for this measure would be 7-day independent scheduling.

## 4.1 Base Case Cost

The base case hot water recirculation system includes a constant flow recirculation pump, operating 24 hours per day. Because this is a retrofit add-on measure, there is no base case cost and measure costs are evaluated as full costs (rather than incremental costs) according to the *Ex Ante Measure Cost Study Research Plan[[22]](#endnote-17)*.

## 4.2 Measure Case Cost

Implementation of the hot water recirculation pump time clock requires an electric connection to be made between the timer and the existing pump. Therefore, the full measure cost includes the material cost of the timer plus the electrician labor associated with the installation of the timer including mounting, electrical connection, and programming.

Table 17shows the itemized assumptions made to achieve a full measure cost estimate of $325 per unit installed, including materials and labor. The average timer cost is based on available online pricing and catalogs for various timer product options. The installation man hours and labor rates come from the 2008 DEER Measure Cost Summary[[23]](#endnote-18). No costs are provided for the *DHW Timeclock* case, so the *Time Clocks (heating/cooling)* case was used assuming the labor for installing time clocks would be similar. The Labor Base Wage Rate Reference for this case is NR-MISC, and the hourly rate is about $74 per hour.

Table - Measure Costs

|  |  |  |  |
| --- | --- | --- | --- |
| Average Timer Cost | Installation Labor Hours - Retrofit | Installation Labor Cost - Retrofit | Total Unit Cost |
| $ 230 | 2.5 | $ 184 | $ 414 |

## 4.3 Full and Incremental Measure Cost

Measure cost equations and values are provided in Table 18and Table 19, respectively.

Table - Full and Incremental Measure Cost Equations

|  |  |  |  |
| --- | --- | --- | --- |
| **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| REA | MEC + MLC | MEC + MLC | N/A |

MEC = Measure Equipment Cost; MLC = Measure Labor Cost

BEC = Base Case Equipment Cost; BLC = Base Case Labor Cost

Table - Full and Incremental Costs

|  |  |  |  |
| --- | --- | --- | --- |
| **Installation Type** | **Incremental Measure Cost** | **Full Measure Cost** | |
| **1st Baseline** | **2nd Baseline** |
| REA | $230 + $184 = **$414 per installation** | **$414 per installation** | N/A |

# Attachments

1. **WPSCGNRWH170313A — Energy Savings Model Results** – this file includes a full list of annual gas and annual electricity savings values per unit for all 18 possible measures included in this work paper labeled with measure code and measure name.
2. **WPSCGNRWH170313A — Engineering Calculations –** this file is the full model developed for this workpaper included engineering calculations and the results summary from Attachment A.
3. **WPSCGNRWH170313A — Recirculation Pump Time Clock Field Testing Report** – this file is the field report referenced in Section 1.5.1 prepared by Navigant Consulting, Inc.
4. **WPSCGNRWH170313A — DEER Data** – this file includes measure data extracted from the DEER READI tool and includes the EUL/RUL and NTG, discussed in Section 1.4.1 of this workpaper. Records and data fields relevant to this workpaper are filtered and/or highlighted.
5. **WPSCGNRWH170313A — Recirculation Pump Time Clock Measure Summary Table** – this file includes a comprehensive summary table for all 18 measures included in this work paper.

# References

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2. California Public Utilities Commission, Database of Energy Efficiency Resources (DEER), *DEER2015 Small Storage and Small Instantaneous Water Heater Energy Use Calculator*, October 2014. [↑](#endnote-ref-2)
3. California Public Utilities Commission, Database of Energy Efficiency Resources (DEER) Updates, DEER2016 and Uncertain Measure Updates, Retrieved from: <http://www.cpuc.ca.gov/General.aspx?id=2017> [↑](#endnote-ref-3)
4. California Energy Commission (CEC), 2016 Building Energy Efficiency Standards for Residential and Nonresidential Buildings – For the 2016 Building Energy Efficiency Standards - Title 24, Part 6 and Associated Administrative Regulations in Part 1, CEC-400-2015-037-CMF, June 2015. Retrieved from: <http://www.energy.ca.gov/title24/2016standards/> [↑](#endnote-ref-4)
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8. Mukesh Khattar and Ankit Somani, Oracle America Inc. Energy-Efficiency with Domestic Water Heating in Commercial Buildings. *2010 American Council for an Energy Efficiency Economy (ACEEE) Summer Study on Energy Efficiency in Buildings*. Retrieved from: <http://aceee.org/files/proceedings/2010/data/papers/2220.pdf> [↑](#endnote-ref-8)
9. The hot water supply pipe diameter input refers to the size of the piping that loops through the building to the hot water demand points. It excludes the size of any adapters that may be used to match the circulation piping to the pump flange size. [↑](#footnote-ref-1)
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11. Gabriel D. Ayala and Derek Zobrist, Enovative Group, Inc. Best Practices for Efficient Hot Water Distribution in Multifamily Buildings. *2012 ACEEE Summer Study on Energy Efficiency in Buildings.* Retrieved from: <http://aceee.org/files/proceedings/2012/data/papers/0193-000030.pdf> [↑](#endnote-ref-10)
12. Itron, Inc. (2016, Feb 23). 2014 Nonresidential Downstream Deemed ESPI Pipe Insulation Impact Evaluation Report. [↑](#endnote-ref-11)
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14. American Society for Testing and Materials (ASTM) (2016). B88-16, Standard Specification for Seamless Copper Water Tube. Retrieved from: <http://www.engineeringtoolbox.com/astm-copper-tubes-d_779.html> [↑](#endnote-ref-13)
15. Rinnai, Hot Water System Design Manual. *R-TRWH-E-02 Rev E.* Retrieved from: <https://www.rinnai.us/documentation/downloads/R-TRWH-E-02.pdf> (originally from 2015 ASHRAE Handbook HVAC Applications) [↑](#endnote-ref-14)
16. The 70-degree indoor air temperature is the standard value used by ASHRAE to develop the heat loss rates that were used in the engineering calculations for this work paper. The value originates from the 2015 ASHRAE Handbook HVAC Applications. (see reference vii) [↑](#footnote-ref-2)
17. Raw data from the DOE Circulator’s Rulemaking Negotiation Working Group Meetings was used for the analysis in this work paper. Navigant owns this data, but the meeting presentation is publicly available. [↑](#footnote-ref-3)
18. Department of Energy, Working Group Presentation (November 71 2016). *Circulator Pumps Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) Working Group, Ninth Meeting; Analysis Post-meeting.* Retrieved from: <https://www.regulations.gov/document?D=EERE-2016-BT-STD-0004-0076> [↑](#endnote-ref-15)
19. As a part of the negotiations, the working group defined a variety of “representative units” and “efficiency levels.” Efficiency levels ranged from bottom of the market efficiency to maximum achievable efficiency. Navigant believes that Efficiency level 1, which represents single-speed induction motor-driven circulators, represents the vast majority of recent-year shipments, and therefore appropriately represents the equipment within this work paper. For each combination of representative unit and efficiency level, the working group defined a “pump energy rating” (PER), which represents the average power draw at 25, 50, 75, and 100% of best efficiency flow. Navigant believes that this PER value is representative of typical power draw, as circulator pumps are designed to operate over a wide range of flows. [↑](#footnote-ref-4)
20. The 78-degree minimum water temperature was the minimum temperature that the return loop reached per data from the Recirculation Pump Time Clock field test performed by Navigant. (see Section 1.5.1 and Attachment C) [↑](#footnote-ref-5)
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