



IN² Final Report

TO: Wells Fargo IN2 Board of Directors

FROM: NREL

DATE: 9/30/2022

IN² Company Name: Turntide



I Technology Description

It is estimated that 38.4% of the total U.S. electrical energy consumption is used to run motors.¹ Annually, 45 billion kWh are used by 1-10 horsepower motors, alone. Even a small increase in motor efficiency could greatly reduce energy consumption. Turntide has developed a patented High Rotor-Pole Switched Reluctance Motor (HRSRM) system that can achieve up to 95% peak motor efficiency and maintain similarly high levels of performance over a wide range of operating speeds. Figure 1 shows the Turntide switched reluctance motor.



Figure 1. Turntide high-rotor pole switched reluctance motor

¹ J. Douglas and G. McCoy, 2014 *Premium Efficiency Motor Selection and Application Guide: A Handbook for Industry*. (Advanced Manufacturing Office: U.S. Department of Energy, 2014, DOE/GO-102014-4107).

From the beginning, Turntide has focused on retrofit applications for heating, ventilating, and air-conditioning (HVAC) systems including commercial rooftop units (RTUs). Its 1-10 horsepower product line is well-positioned to replace most commercial RTU supply fan motors.

Turntide reports that its motor peak and part-load efficiencies are superior to induction motors and electronically commutated motors, which are the most common RTU supply fan motors. As a requirement for HRSRMs, Turntide has developed a motor controller with the ability to operate a single motor, whose operation can be coordinated with up to nine motors using a master controller known as a supervisor. In addition, the built-in input/output (I/O) terminals and logic engines in these controllers and supervisors can be used to coordinate or control other systems such as the functions of an HVAC RTU. The company has begun to take advantage of its controller and supervisor platform to provide additional energy savings for RTU retrofit applications. For this reason, Turntide decided to use the National Renewable Energy Laboratory’s (NREL’s) expertise in advanced HVAC control to develop control strategies so it could provide both inherently highly efficient motors and advanced control strategies. In the original IN² project with Turntide, NREL created seven unique strategies for improving RTU performance by leveraging the Turntide motor to control the supply fan and the HVAC mode (heating, cooling or ventilation). This follow-on funding took three of these strategies and evaluated the expected energy savings for various climates compared to a typical induction motor that is commonly found in commercial RTUs.

At a high-level, Table 1 describes the baseline and advanced controls evaluated for this project:

Table 1. Description of the baseline and three advanced controls evaluated during the IN² project

Strategy	Fan Operation	Description
Baseline	Constant speed operation	Single speed induction motor with 31% fan efficiency
1	Staged fan speeds	Reduce the fan speed to save energy. Fan efficiency (includes the fan and motor) ranged from 36-44% based on the fan speed
2	Continuous fan modulation	Continuously change fan speed leveraging the HRSRM variable speed capabilities to improve RTU conditioning and energy savings

3	Continuous fan modulation with smart dehumidification	Adjust supply air temperature of RTU based on relative humidity in the zone
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According to a PNNL study², strategy #1 can provide significant savings simply by reducing the fan speed for ventilation mode from 100% down to 40%. Less significant savings were reported by reducing the fan speeds for cooling and heating mode. In the initial IN2 project with Turntide, NREL developed strategies #2 and #3 in an attempt to improve the controls and energy savings Turntide can provide to customers.

II Project Description

As with many startups, Turntide needed assistance finding the ideal customers to sell their product. One key barrier is understanding the savings potential by climate – any one individual building is a result of thousands of potential input combinations. NREL and Turntide narrowed these thousands of combinations into a manageable scope by focusing on the three unique strategies considering 16 different U.S. climates.

This provided Turntide with high-quality data detailing the energy and cost savings for each modeled strategy. NREL determined that the best path forward to provide the specific outcome was to leverage the DOE commercial prototype building models³ for this effort. In particular, NREL and Turntide chose a retail strip-mall building model to better exploit the energy savings provided by the Turntide innovative technology.

NREL then coded models of each Turntide control strategy in the EnergyPlus runtime language and programmatically applied each strategy to the chosen DOE prototype building, ultimately creating a unique model for each climate.

III Project Outcomes

NREL provided the following outcomes:

- Code that programmatically changes the control strategies and climate
- 64 unique model runs providing annual energy and cost savings
- 64 source code EnergyPlus models for Turntide to run additional modeling analysis.
- ~200 graphics to visualize the results.

Table 2 summarizes the detailed annual electric savings results for the three unique advanced control strategies, for each climate zone. The most important metric in Table 2 is the relative annual energy savings. This provides a relative percent of savings compared to the baseline. The other metrics reported were absolute electric energy

² Wang et. al. “Advanced Rooftop Control Retrofit: Field-Test Results”.

https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-22656.pdf

³ DOE prototype building models.

https://www.energycodes.gov/development/commercial/prototype_models

savings. While also useful, absolute values can be deceptive. For example, a large office consumes roughly 200 times the energy of a small office. Therefore, even small relative savings for big buildings can appear to be large absolute savings. These absolute energy savings were for the DOE prototype retail strip mall, which is 22,500 ft².

On average, Strategy #1 provides ~16.7% annual savings across all climates with respect to the baseline settings. Strategy #2 provides ~17.3% of energy savings. Strategy #3 slightly decreases the annual savings, ~16.2%; however, acting on the humidity control, this strategy provides higher thermal comfort.

The main electric savings are given to the reduction in fan energy; however, the electricity used for cooling is also reduced, progressively with each strategy with respect to the baseline.

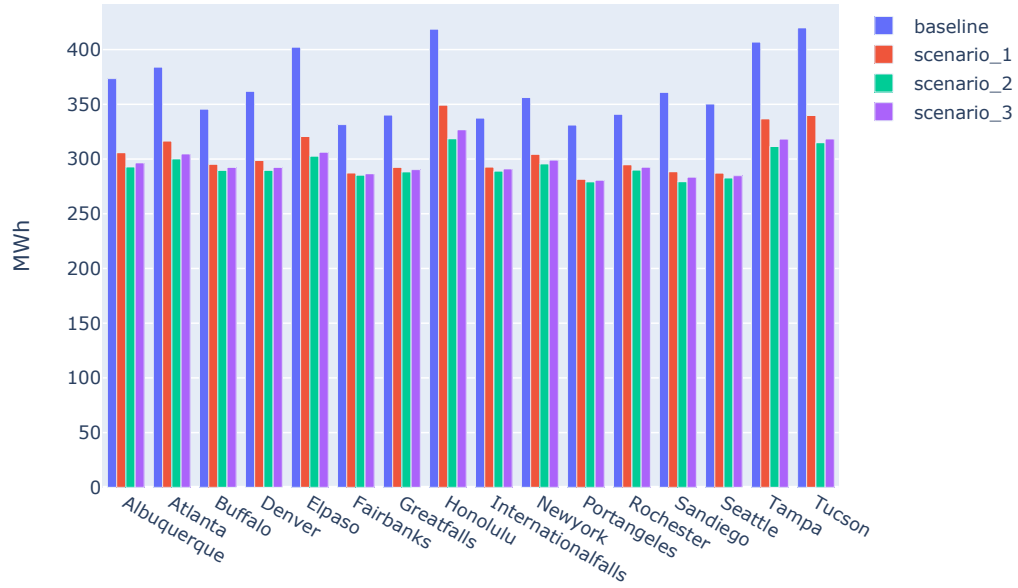
Table 2. Annual saving per climate zone for the three advanced control strategies for a retail strip mall

Representative Cities	Strategy 1		Strategy 2		Strategy 3	
	Energy Savings with respect to the baseline		Energy Savings with respect to baseline		Energy Savings with respect to the baseline	
	MWh	%	MWh	%	MWh	%
Albuquerque, NM	66.2	18.4	68.1	18.9	63.9	17.7
Atlanta, GA	66.6	18.2	69.4	18.9	64.5	17.6
Denver, CO	49.8	14.6	50.9	14.9	48.4	14.2
Buffalo, NY	62.2	17.6	63.6	18.0	60.3	17.0
Fairbanks, AK	80.5	21.2	82.9	21.8	77.8	20.4
El Paso, TX	43.4	13.2	44.0	13.3	42.6	12.9
Honolulu, HI	46.5	13.9	46.6	13.9	44.6	13.3
Great Falls, MT	69.3	17.9	73.5	19.0	64.8	16.7
New York, NY	43.9	13.1	44.9	13.4	42.7	12.8
International Falls, MN	51.2	14.7	53.2	15.3	49.8	14.3
Rochester, NY	48.6	14.7	49.4	15.0	47.8	14.5
Port Angeles, WA	45.3	13.4	46.5	13.8	44.0	13.1
Seattle, WA	72.3	20.4	74.8	21.1	70.5	19.9
San Diego, CA	61.8	17.8	63.0	18.2	60.9	17.5
Tucson, AR	70.0	18.4	74.8	19.6	67.6	17.7
Tampa, FL	80.3	20.6	84.0	21.5	77.1	19.7

A reduction in fan energy results in less fan motor heat dispersion. This has a small adverse effect on indoor heating, slightly increasing natural gas consumption for each strategy in each climate zone.

Results are also summarized in Figure 2, detailed for electric and natural gas consumption.

Facility Electric Consumption



Natural Gas Consumption

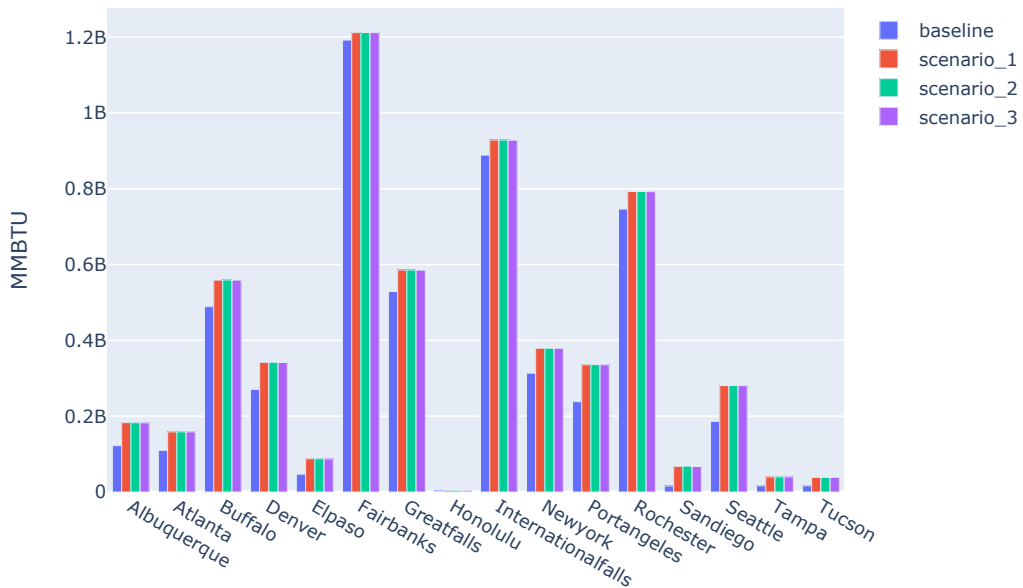


Figure 2: Annual electric and NG consumption comparisons for the 3 advanced control strategies implemented by NREL. Each strategy has been tested for 16 different U.S. climates.