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WattTime Validation and Technology Primer

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Transforming global energy use to create a clean, prosperous, and secure low-carbon future.

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Purpose of this document

- WattTime is a nonprofit organization that invented a novel means to reduce GHG and other emissions, known as Automated Emissions Reduction (AER).
- Rocky Mountain Institute (RMI), an independent third-party with a 35-year history of leadership in efficiency and renewable energy, evaluated WattTime's technique and AER's impact potential and found it to be a uniquely powerful, additional means of driving large amounts of environmental benefit.
- Unlike most high-impact sustainability technologies, AER can scale in the cloud, and has the potential to rapidly and automatically reduce emissions from an estimated 23 billion devices.
- Driven by this unique opportunity, RMI decided to offer to incorporate WattTime as a subsidiary organization after careful vetting to drive rapid adoption of this technology.
- This document reflects key findings from RMI's due diligence process and, also serves as an introduction to AER technology.
- Additional information about WattTime is available at www.WattTime.org.

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About WattTime

- Nonprofit tech startup spinning out of UC Berkeley research
- Built by > 200 volunteers from MIT, Climate Corp, DOE, etc.
- Technology lets customers source more electricity from cleaner power plants, automatically
- Works in any building, any utility, any type of energy contract

greentechmedia: Clean Technica Forbes Chicago Tribune

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Executive Summary

WattTime, a technology nonprofit, has developed a fundamentally new approach to significantly reduce emissions from power plants using software known as *Automated Emissions Reduction (AER).*

What is AER?

AER enables internet-enabled, electricity consuming devices to seamlessly reduce emissions by combining:

- real-time grid data on power plant emissions, and
- internet-enabled control of electricity-consuming devices using new comfort and cost algorithms

Customer demand and technology trends create an emerging opportunity

- With 23 billion "smart" devices expected worldwide by 2020, a rapidly growing share of electricity consumption is capable of supporting AER
- Current-generation AER has the capability to reduce CO_2 emissions by the equivalent of 1 million cars
- As technology matures, impacts per device will grow

AER can create value across multiple sectors

- AER offers institutional and residential energy users a new source of rapid, low-cost emissions reductions
- AER also offers ancillary benefits to numerous other energy sector actors
- Strong potential for new entrants and business models

Overview:

What is Automated Emissions Reduction?

Defining Automated Emissions Reduction

Automated emissions reduction (AER) combines leading-edge research on grid emissions with new algorithms to seamlessly shift loads in response, thus minimizing grid emissions associated with loads without reducing performance

Marginal emissions research

- New data analytics approach allow an accurate estimate of the marginal emissions intensity of the grid, at a specific location and time
- This approach can provide, for the first time, accurate visibility into the impacts of individual or institutional decisions about energy use on total emissions

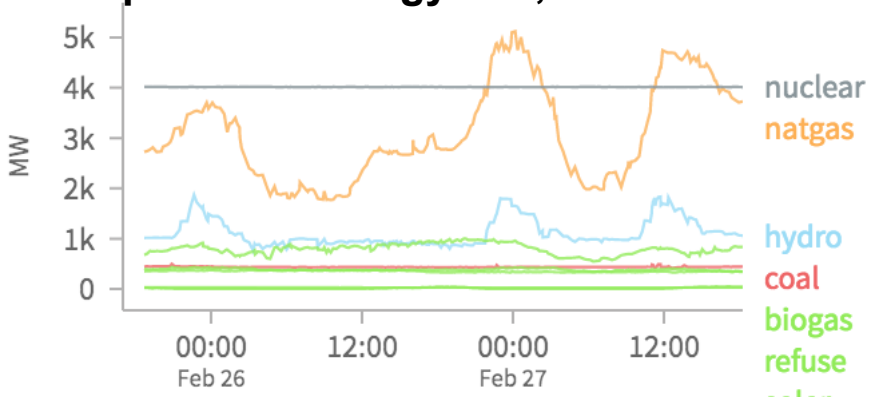
Internet-connected control of load timing

- The increasing prevalence of Internet-connected devices and building systems mean that many loads can be controlled in response to marginal emissions data
- Sophisticated control algorithms let users minimize the emissions associated with their load automatically and seamlessly

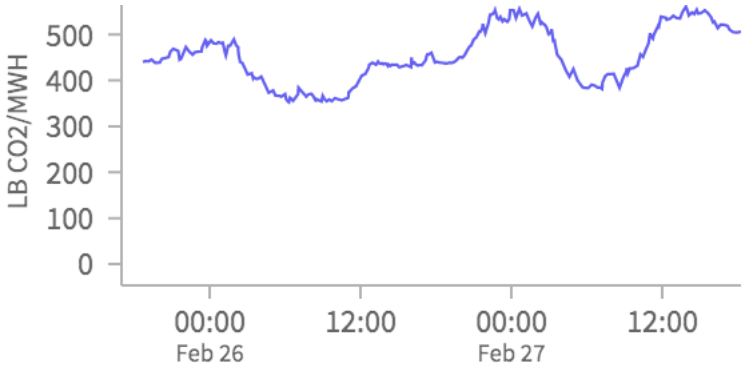
WattTime software monitors grid operations in real-time, allowing users to identify variations in marginal emissions

The fuel mix and emissions factors in regional grids can be calculated every 5 minutes

Example: Grid energy mix, NYISO



Average carbon intensity, NYISO



Marginal emissions provide detailed insight into a user's actual impact

Average emissions: Average emissions are calculated by dividing total emissions by total energy output, and are generally used today to measure carbon footprints.

However, if a user turns on or off a particular device, in reality only one or two power plants would increase or decrease production; thus the average value is not the most accurate or relevant figure.

Marginal emissions: In contrast, WattTime can now calculate the marginal emissions, which more precisely represent the change in overall emissions if load increases or decreases at any given time.

Source: WattTIme.org

Real-time emissions signals enable load shifting for seamless, cheap, and measurable emissions reductions

Loads with flexibility or energy storage mechanisms can moderate their electricity usage with little or no impact on performance

- **HVAC and refrigeration systems** can slightly pre-cool or temporarily delay running in order to reduce energy-related emissions.
- **Electric water heaters** can use their storage tank like a battery, enabling flexible operation.
- **Electric vehicles** charging overnight can fluctuate the timing of their to take advantage of low-emissions periods.

Providers can take advantage of the flexible nature of loads and the scalable nature of software to enable programs that are:

- **Seamless:** Program operators can take advantage of natural flexibility to reduce emissions without impacting customer satisfaction.
- **Low cost:** Programs can offer these benefits at minimal incremental cost, given that control capability is often already present.
- **Measurable:** The environmental benefits gained can be quantified using widely accepted methodologies.

Impact:

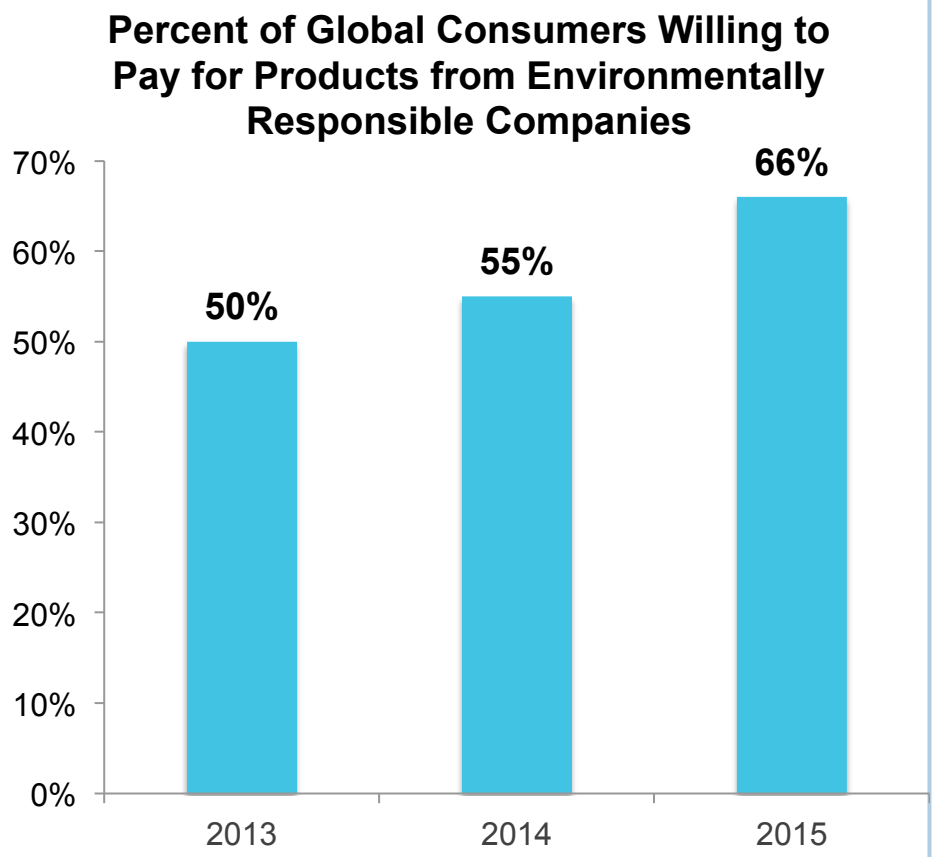
What is the potential for AER to reduce emissions?

Individual consumers are expecting more environmentally friendly options, and are willing to pay for them

Consumers in America want and expect more sustainable solutions

- A survey of 1,500 customers conducted by SmartEnergy IP found that 32% expect their utility to adopt automation technologies to save energy[1]
- A 2016 Gallup poll revealed that 73% of Americans want to emphasize alternative energy instead of oil and gas production[2]

Consumers are increasingly willing to pay for environmentally conscious brands[3]



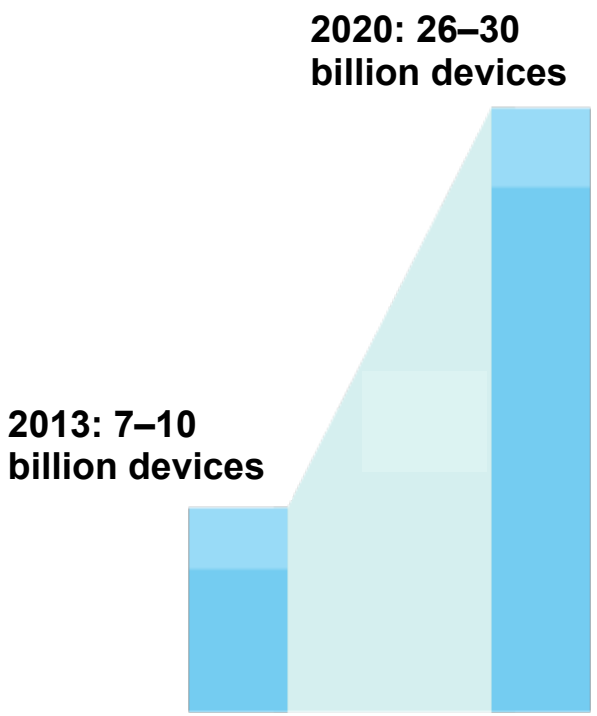
Source: [1] Navigant Research; [2] Gallup; [3] Nielsen.

Customers are also increasingly demanding communicating, controllable, and "smart" devices and control systems

Smart devices, appliances, and controls are growing in availability and popularity

- The smart thermostat market is projected to quadruple in size, reaching a $4.4 billion dollar industry by 2025.[1]
- Large consumer technology companies are now competing for market share in the growing "smart home" space.
- In institutional, commercial, and industrial facilities, business priorities are driving customers to demand connected, intelligent control systems to manage loads.

Some 30 billion devices may be connected to the Internet of Things (IoT) by 2020[2]



Source: [1] Navigant Consulting; [2] McKinsey, December 2014

As the IoT expands, greater connectivity offers new opportunities to capture value from connected devices

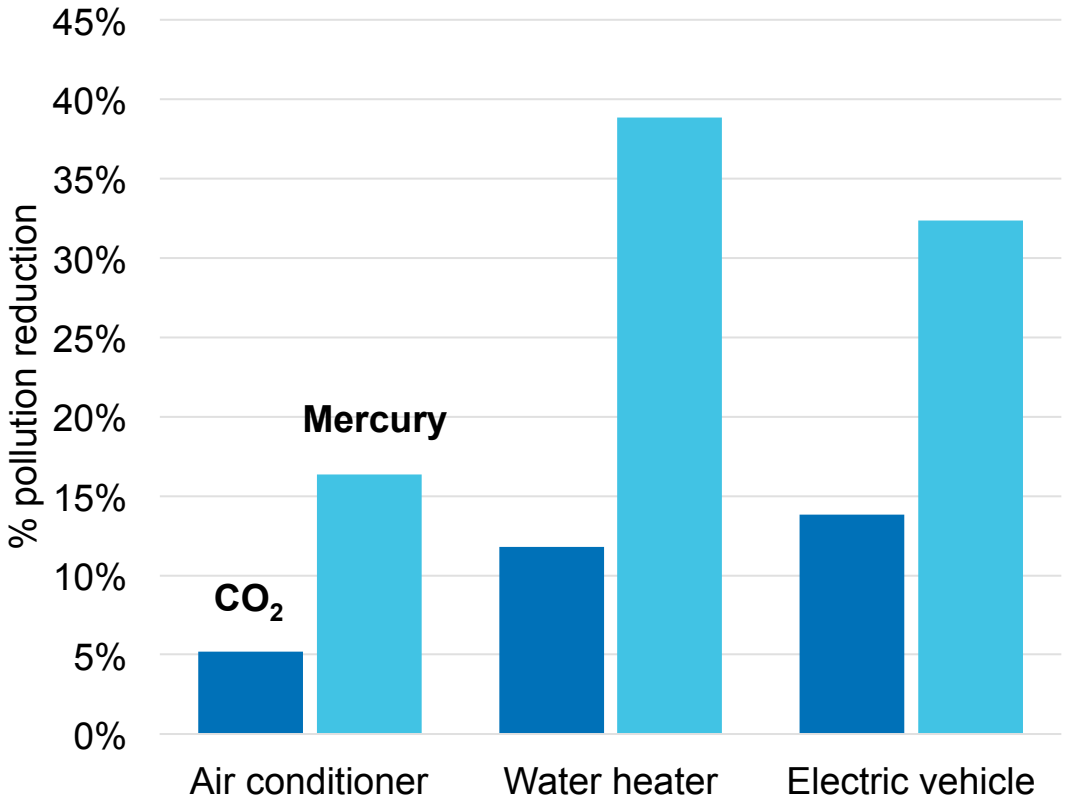
	Connectivity and control allow energy-using devices to be optimized against several criteria. Devices can be programmed to:
Existing capabilities	• **Reduce peak demand** by shifting the timing of electricity usage to non-peak hours. Existing programs in the United States are already capable of reducing peak loads by up to 32 GW. • **Lower energy costs** by scheduling load to take advantage of relatively low-cost electricity at different times of day. U.S. utilities currently have over 7.5 million customers enrolled in some form of dynamic pricing program, which directly incentivize this temporal flexibility.
Emerging opportunity	• **Reduce emissions** by shifting load to coincide with renewable energy production, or cleaner, more-efficient conventional generators.

Using current technology, **it is possible to stack the value of these use cases**, achieving both cost reductions for capacity and energy, as well as emissions reductions.

Source: EIA

Adjusting loads to minimize CO_2 and mercury emissions can reduce pollution by 5–40%, using current generation data

Simulated emissions impact of AER using residential loads in Chicago with negligible impact on service quality

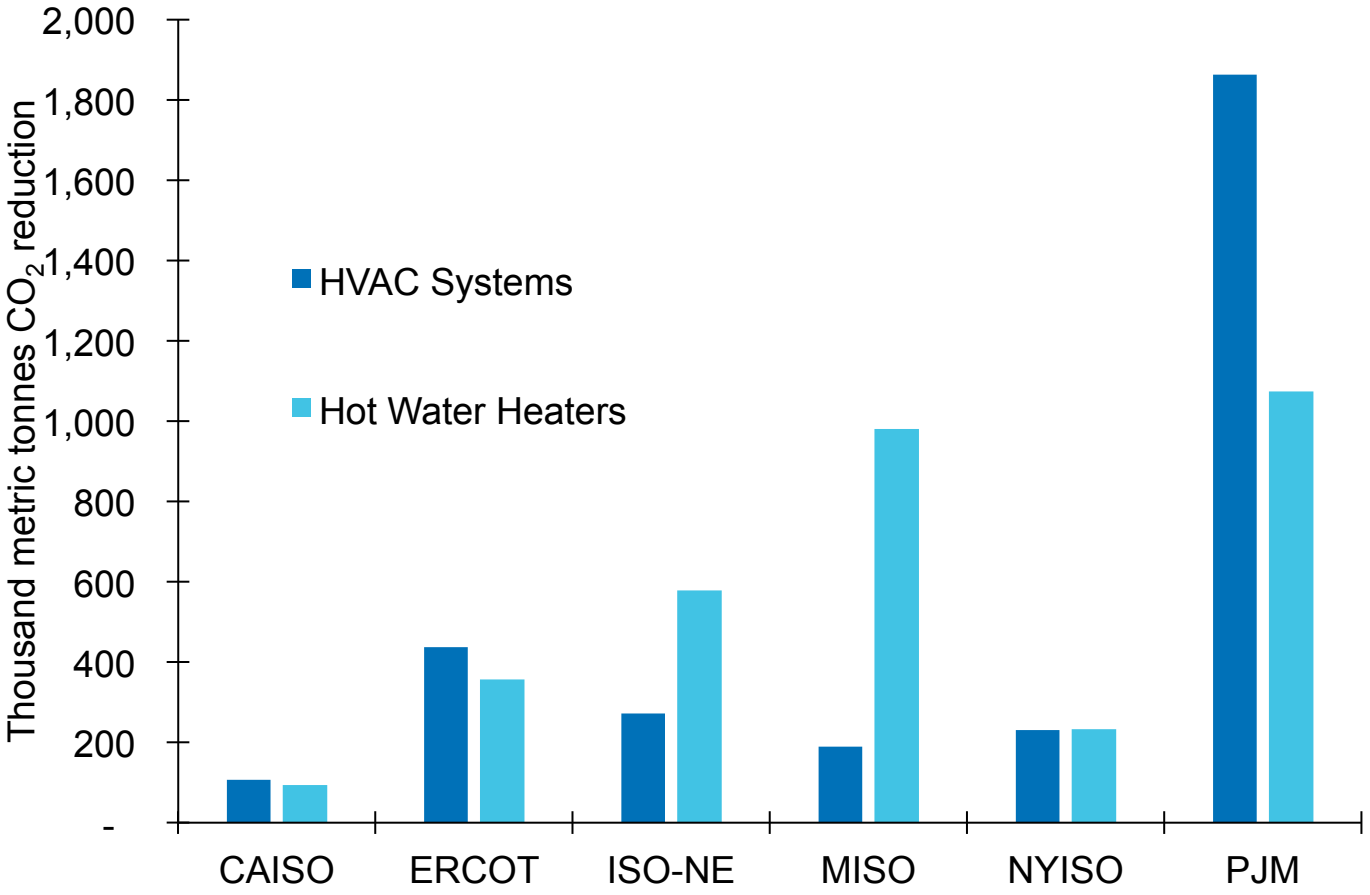


- Strategies to reduce emissions rely on flexibility and/or physical storage inherent in end-use loads.
- Electric water heaters and electric vehicles have flexibility over longer time scales, and thus greater emissions savings potential than air conditioning loads.

Source: WattTime and E2i emissions data, RMI simulation

Residential AC and water heating in six markets in the U.S. can reduce emissions by the equivalent of 1 million autos

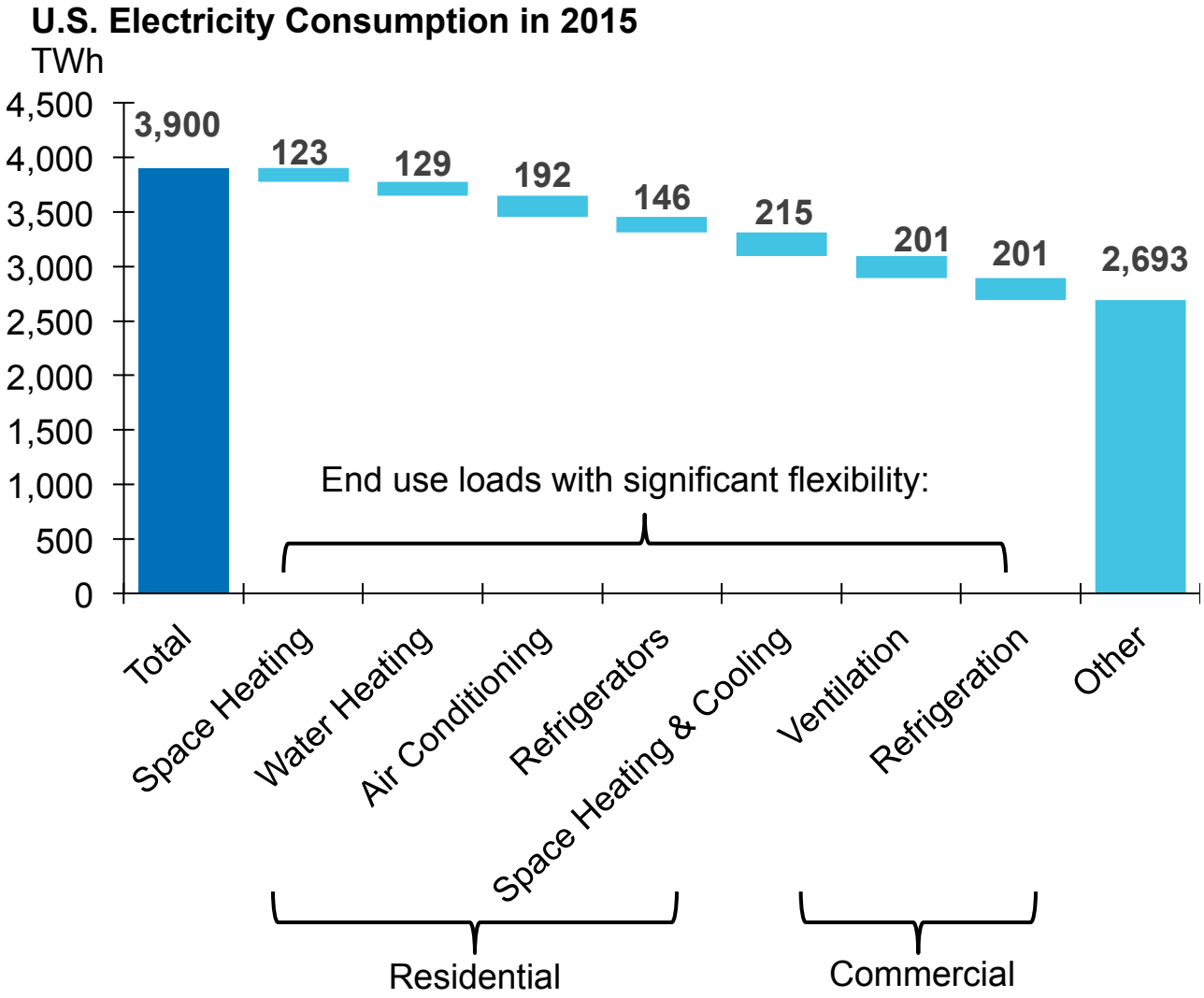
Estimated annual impact of AER technology in residential buildings across six U.S. ISO/RTOs



- Savings potential depends on both the patterns of marginal carbon intensity in regional grids, and the number of flexible devices in each region.
- Non-wholesale market regions and non-residential loads would lead to greater savings potential.

Source: RMI analysis; WattTime and E2i emissions data; EPA; EIA

AER technology can expand to additional loads with flexibility and use newly-available data to amplify its impact

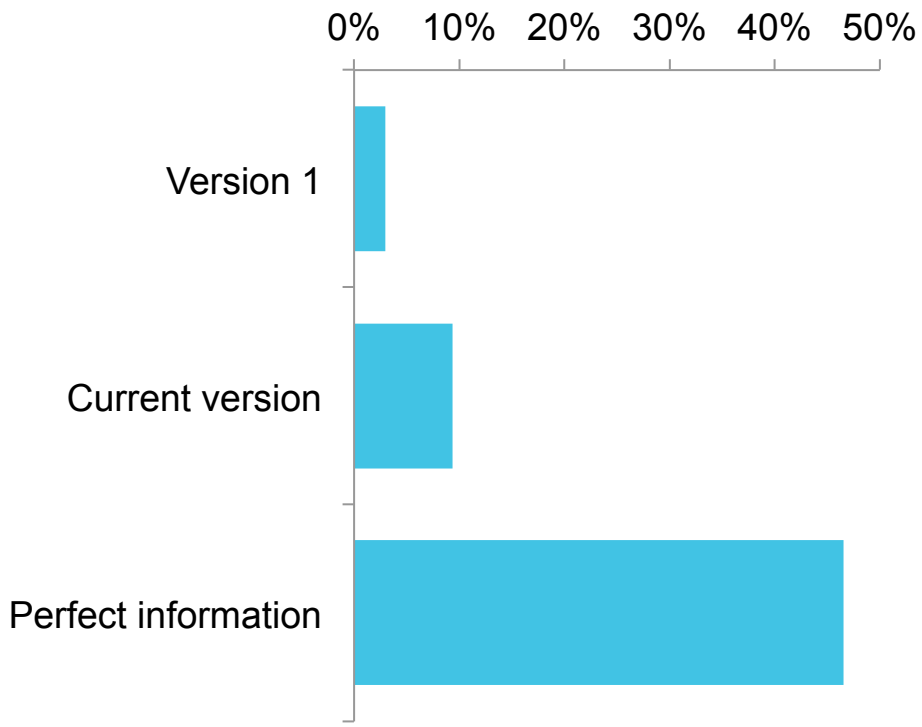


- At least 30% of total U.S. load has significant inherent flexibility appropriate for AER
- There is likely significant untapped flexibility potential in the remaining 70% (e.g. some industrial loads, behavioral response)

Source: EIA; RMI analysis

Emerging data sources can lead to more dramatic emissions reductions

Comparison of emissions savings possible for water heaters in MISO using different generations of marginal emissions data

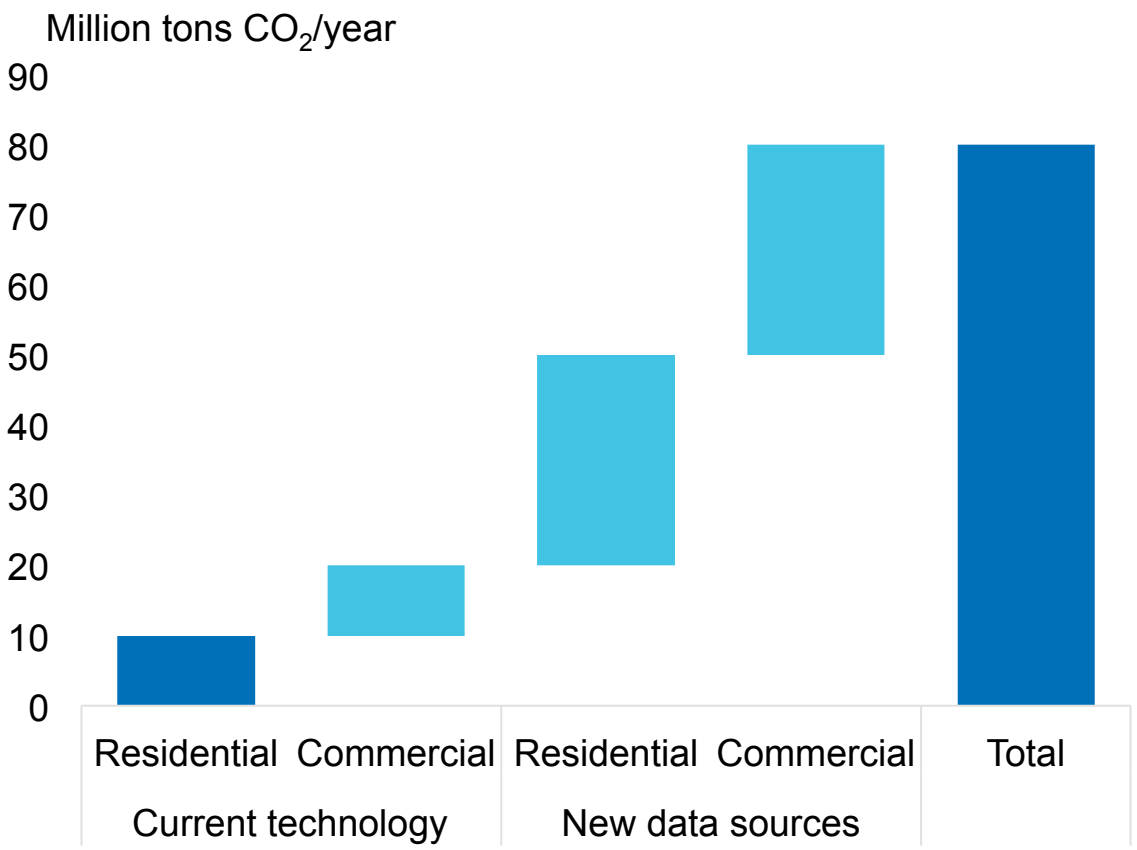


- The first generation of marginal emissions data allowed a 3% CO_2 reduction.
- Current-generation models, using more and different data sources, increase savings potential to ~10%.
- With emerging data sources (e.g. direct integration with system operators), it may be possible to measure marginal CO_2 perfectly, reducing annual emissions by an estimated 40%.

Source: WattTime, E2i, MISO, RMI simulation

AER can provide significant savings if deployed at scale with increased access to refined data sources

Estimated US potential of CO_2 emissions reduction from AER



- Current AER technology, used in just well-suited residential loads (AC and water heating), could save on the order of 10 $MTCO_2$/y
- Expanding to commercial loads could double that savings potential
- Incorporating new data sources to capture larger swings in marginal emissions rates would approximately quadruple the savings

Source: RMI analysis

The impact of small changes on the margin today can add up to major emissions reductions over time

Planning for next kilowatt-hour…

- Using current technology and data about marginal emissions, individual customers are **empowered to make informed decisions about their next unit of energy consumption.**
- These immediate emissions savings are verifiable, easily demonstrated, and simple to quantify.

... leads to grid operational changes …

- As more customers make incremental changes to their usage, there will be an **emerging opportunity to adjust the control signals and directly impact power plant operational decisions** (i.e., unit commitment).
- While harder to quantify, these savings can be much greater (e.g., targeted shifting to eliminate the need for coal plant operation).

… and eventually impacts resource investment

- As these operational impacts are reflected in system operations, spot prices, and forward capacity prices, **emissions-aware load shifting can drive emissions-reducing investment decisions.**
- These impacts are difficult to forecast, but could materially increase investment in renewable energy resources.

Data Validation:

RMI's evaluation of WattTime's algorithms

RMI independently evaluated WattTime's marginal emissions algorithms

- WattTime's algorithms to determine the marginal emissions rate in real time have been built on peer-reviewed academic research, but have gone significantly further to provide additional granularity and real-time capabilities.
- The resulting algorithms are proprietary IP.
- As part of its due diligence, RMI staff conducted a deep technical verification of the validity of the WattTime algorithms.
- RMI staff found the WattTime algorithms to not only be accurate, but to be likely *underestimating* the emissions savings resulting from deploying them for AER.
- Based on this finding, RMI decided to incorporate WattTime as a subsidiary organization.

Source: RMI assessment of proprietary WattTime methodology

Finding 1: WattTime algorithms rely on empirical methods, not structural models

Theory is a bad predictor

- Observed historical data do not match predictions from economic theory-based models (e.g. economic dispatch based on marginal supply curves)
- In public power grid data identified by WattTime, neither emissions rates nor renewable curtailment data match expected behavior

Empirical advantages

- WattTime's empirical approach is still capable of capturing the structural drivers of marginal emissions, but does not rely on theory-based models to do so
- Using a rich historical data set, it is possible to derive estimates of marginal emissions rates that are well-constrained by real data

Source: RMI assessment of proprietary WattTime methodology

Finding 2: WattTime's approach is a statistically accurate approach to estimating marginal emissions

Empirical basis

- The core statistical approach uses validated empirical techniques that improve on leading-edge research
- The WattTime approach relies on vetted data sets from providers of record

Conservative approach

- WattTime combines historical and real-time data to identify a robust estimate for marginal emissions
- The WattTime approach adds new data to core model only when their inclusion can be empirically justified

Roadmap for improvement

- The empirical approach using historical data captures the vast majority of variation that causes changes in marginal emissions intensity
- Accuracy will increase with additional testing and incorporating additional data sources already in the WattTime product roadmap

Source: RMI assessment of proprietary WattTime methodology

Finding 3: Due to the conservative nature of WattTime's approach, AER is a robust emissions reduction tool

Emissions savings are statistically certain

- The design of the marginal emissions model ensures that identified changes in time of the emissions intensity are statistically robust
- Therefore, control signals that use these estimates are virtually certain to reduce emissions

Emissions reductions are likely higher than reported

- The conservatism of the WattTime data feed results in a estimates of marginal emissions that likely vary much less than the true variation on the grid
- Thus, because WattTime-enabled devices outputs are robust in their identification of changes, the actual savings associated with WattTime's control signal are likely higher than estimated by WattTime itself

Source: RMI assessment of proprietary WattTime methodology

Use Cases:

How AER drives value for adopters

Institutional and residential energy users: sources of value

Financial savings	Public relations and marketing benefits	Customer experience
• Lowest-cost method to achieve GHG reduction targets • Enables optimization of GHG impacts per dollar	• ***External****:* Company can publicize corporate stewardship effort • ***Internal:*** Improves employee health and happiness	• ***Residential*****:** feeling of control increases consumer engagement • ***Institutional****:* control rests with facility manager, providing greater reliability than with conventional DR

Institutional and residential customers: use cases

Energy-smart buildings

- AER integrated directly into building-level controls can enable the whole building to minimize emissions
- Unlocks additional savings from the buildings' existing equipment installations

Technical integration into existing devices

- Integration of AER into existing smart devices makes technology available at zero incremental cost
- Survey data finds consumers are more likely to purchase a smart device if it includes AER capability

Integration with demand response

- For "dumb" buildings, combining AER with automated demand response (ADR) mitigates equipment costs
- Same financials as conventional ADR, but greater environmental impact

Utilities and policy: sources of value

Improving customer engagement	Meeting utility-level sustainability objectives	Achieving emissions goals
• Lower customer acquisition costs • Increase satisfaction • Increase scale of demand side management programs	• Sell emissions credits • Mitigate operational challenges • Avoid renewable energy curtailment	• AER can be a low-cost lever to reach goals of existing policy • For example, state-level renewable portfolio and air quality standards can be bolstered by AER

AER providers: use cases

Utilities: integration with demand response

- AER adoption can deliver cost savings per program participant greater than those of real-time pricing
- Survey data suggest that AER can reduce customer acquisition costs for utility demand response
- Integration with an existing program would limit overhead costs of a new implementation

Policy: emissions reductions

- Policy can direct deployment of AER towards specific cases where it will have the greatest impact
- Deploying AER at small (~1-2%) participation levels, if targeted well, could reduce local pollutants by ~40%

Key Conclusions and Next Steps

- We are confident that WattTime's cutting-edge technology is proven and validated thanks to early adopters and RMI analysis
- RMI and WattTime expect this technology to be more broadly used to accelerate corporate sustainability efforts, improve the profitability of distributed energy resource companies and retail energy providers by lowering customer acquisition costs, and improving the way that carbon emissions are measured worldwide.

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