METHODOLOGY FOR TIME-SHIFTED ELECTRICITY CONSUMPTION TARGETING LESS CARBON-INTENSIVE GENERATION

Document Prepared By WattTime

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Relationship to Approved or Pending Methodologies

Approved and pending methodologies under the VCS and approved GHG programs, that fall under the same energy demand sectoral scope, were reviewed to determine whether an existing methodology could be reasonably revised to meet the objective of this proposed methodology. 37 methodologies were identified, and are set out in Table 1 below.

Table 1: Similar Methodologies

Methodology	Title	GHG Program	Comments
AMS-II.C.	Demand-side energy efficiency activities for specific technologies --- Version 15.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-II.D.	Energy efficiency and fuel switching measures for industrial facilities --- Version 13.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-II.E.	Energy efficiency and fuel switching measures for buildings --- Version 10.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-II.F.	Energy efficiency and fuel switching measures for agricultural facilities and activities --- Version 10.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-II.G.	Energy efficiency measures in thermal applications of non-renewable biomass --- Version 9.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-II.J.	Demand-side activities for efficient lighting technologies --- Version 7.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-II.K.	Installation of co-generation or tri-generation systems supplying energy to commercial building --- Version 2.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-II.L.	Demand-side activities for efficient outdoor and street lighting technologies --- Version 2.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-II.M.	Demand-side energy efficiency activities for installation of low-flow hot water savings devices --- Version 2.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-II.N.	Demand-side energy efficiency activities for installation of energy efficient lighting and/or	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time

	controls in buildings --- Version 2.0		advisory service
AMS-II.O.	Dissemination of energy efficient household appliances --- Version 1.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-II.P.	Energy efficient pump-set for agriculture use --- Version 1.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-II.Q.	Energy efficiency and/or energy supply projects in commercial buildings --- Version 1.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-II.R	Energy efficiency space heating measures for residential buildings --- Version 1.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-II.S.	Energy efficiency in motor systems --- Version 1.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-III.X.	Energy Efficiency and HFC-134a Recovery in Residential Refrigerators --- Version 2.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-III.AE.	Energy efficiency and renewable energy measures in new residential buildings --- Version 1.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-III.AL.	Conversion from single cycle to combined cycle power generation --- Version 1.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AMS-III.AV.	Low greenhouse gas emitting safe drinking water production systems --- Version 5.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AM0017	Steam system efficiency improvements by replacing steam traps and returning condensate --- Version 2.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AM0018	Baseline methodology for steam optimization systems --- Version 4.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AM0020	Baseline methodology for water pumping efficiency improvements --- Version 2.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service

AM0046	Distribution of efficient light bulbs to households --- Version 2.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AM0060	Power saving through replacement by energy efficient chillers --- Version 2.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AM0068	Methodology for improved energy efficiency by modifying ferroalloy production facility --- Version 1.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AM0086	Distribution of zero energy water purification systems for safe drinking water --- Version 4.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AM0088	Air separation using cryogenic energy recovered from the vaporization of LNG --- Version 1.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AM0091	Energy efficiency technologies and fuel switching in new and existing buildings --- Version 3.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AM0105	Energy efficiency in data centres through dynamic power management --- Version 1.0.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
AM0113	Distribution of compact fluorescent lamps (CFL) and light-emitting diode (LED) lamps to households --- Version 1.0	CDM	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
VM0008	Weatherization of Single Family and Multi-Family Buildings, v1.1	VCS	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
VM0013	Calculating Emission Reductions from Jet Engine Washing, v1.0	VCS	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
VM0018	Energy Efficiency and Solid Waste Diversion Activities within a Sustainable Community, v1.0	VCS	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
VM0020	Transport Energy Efficiency from Lightweight Pallets, v1.0	VCS	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service
VM0025	Campus Clean Energy and	VCS	Doesn't allow time shifting to consume

	Energy Efficiency		power at times of lower operating margin based on signal from a real-time advisory service
VMR0005	Methodology for Installation of Low-Flow Water Devices, v1.0	VCS	Doesn't allow time shifting to consume power at times of lower operating margin based on signal from a real-time advisory service

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1. SOURCES

This methodology uses the latest version of CDM guidance document *Guidelines for sampling and surveys for CDM project activities and programme of activities*.

2. SUMMARY DESCRIPTION OF THE METHODOLOGY

This methodology applies to project activities that use a carbon advisory service to shift the electricity usage of devices from times of high carbon intensity to periods of lower carbon intensity. The time-shifting of consumption patterns from an electricity-consuming device or system is in response to signals from an advisory service based on the advisory service's calculation of the grid's real-time carbon intensity. Carbon intensity is measured according to the operating margin (i.e., the incremental carbon emissions per kilowatt-hour of additional load on the system at a given point in time). It is assumed that shifting the electricity usage of devices in time primarily affects the production of power plants that are "on the margin" and that are not the baseload power sources or the must-run resources (often hydro and nuclear). The operating margin usually consists of power plants that set the price of electricity in the real-time market. These are the last plants to be dispatched when demand increases and, when demand declines, the first to have output reduced.

Additionality and Crediting Method	
Additionality	Activity Method
Crediting Baseline	Project Method

3. DEFINITIONS

Carbon advisory service
The service, most likely powered by a software technology, to measure the carbon emissions associated with the marginal source or sources of grid power in real time and issue commands to time-shifting devices to consume power at the cleanest times

Device
The technology (e.g., EV chargers, thermostats, heating or cooling equipment, energy storage device) that consumes electricity from an electrical grid and is capable of being directed by a carbon advisory service to lower electricity usage during high-carbon intensity periods and shift that usage to periods of low-carbon intensity

Intended electricity consumption (IEC)
The electricity that would have been consumed at the original time interval had the device not used the carbon advisory service

Actual electricity consumption (AEC)
The electricity that was actually consumed at the less carbon-intensive time interval, when the device was using the carbon advisory service

Operating margin (OM)

The carbon intensity of the specific power plant or mix of power plants supplying a grid that are affected by the shifting of electricity usage from one time to another. The carbon intensity of the grid is measured in tons of CO_2 emitted per MWH.

4. APPLICABILITY CONDITIONS

This methodology applies to project activities that use a carbon advisory service to shift the electricity usage of devices from times of high carbon intensity to periods of lower carbon intensity. The methodology may also be applied to energy storage technology that stores electricity at times of low marginal carbon emissions and supplies energy to the grid at times the marginal source(s) of electricity are high carbon emitting.

This methodology is globally applicable under the following conditions:

- The project activity involves the use of a carbon advisory service to shift the electricity usage of a device (or system of devices) that draws electricity from an electrical grid;
- The device is compatible with a carbon advisory service to where its intended and actual electricity consumption can be reported to and accounted for by the carbon advisory service;
- The project activity uses a carbon advisory service that meets the following requirements:
    1) The carbon advisory service has enough information available to determine (or estimate with a high degree of confidence) the operating margin of the grid from which the relevant device (or system of devices) draws power. The carbon advisory service can use two methods to determine OM, by order of most preferred:
        a) Use of a direct API setup between the carbon advisory service and the grid provider;
        b) Use of a regression model in compliance with the model requirements in Section 4.1.6 of the *VCS Standard, v3.7*, validated against historical data.
    2) The carbon advisory service must be able to facilitate the issuance of signals to advise devices to shift their electricity consumption in time based on the OM;

This methodology is not applicable under the following conditions:

- A factor other than marginal carbon intensity (e.g., demand response based on electricity cost) is utilized by the project activity to determine the timing of electricity consumption.

5. PROJECT BOUNDARY

The spatial extent of the project boundary encompasses all of the devices included within the scope of the project activity's carbon advisory service and the regional grids to which these devices are connected. The greenhouse gases included in or excluded from the project boundary are shown in Table 2 below.

Table 2: GHG Sources Included In or Excluded From the Project Boundary

Source		Gas	Included?	Justification/Explanation
Baseline	CO_2 emissions from electricity generation used to power project devices	CO_2	Yes	Main emission source
		CH_4	No	Minor emission source, excluded for simplicity
		N_2O	No	Minor emission source, excluded for simplicity
		Other		NA
Project	CO_2 emissions from electricity generation used to power project devices	CO_2	Yes	Main emission source
		CH_4	No	Minor emission source, excluded for simplicity
		N_2O	No	Minor emission source, excluded for simplicity
		Other		NA

6. BASELINE SCENARIO

The project proponent must follow the step-wise approach specified in the CDM *Combined tool to identify the baseline scenario and demonstrate additionality* in order to determine the baseline scenario. The baseline scenario shall be determined by analyzing, at minimum, the following potential alternatives:

1. The project activity undertaken without being registered under the VCS Program
2. Use of real-time pricing and energy storage systems, which respond to real-time electricity cost data to time-shift the consumption of electricity on the basis of *pricing*
3. Business as usual (i.e., no modifications to the device or system are made to time-shift electricity consumption)

7. ADDITIONALITY

This methodology uses an activity method for the demonstration of additionality. Project activities that meet the applicability conditions of this methodology (see Section 3 above) and demonstrate regulatory surplus are deemed as additional.

Step 1: Regulatory Surplus

Project proponents must demonstrate regulatory surplus in accordance with the rules and requirements regarding regulatory surplus set out in the latest version of the *VCS Standard*.

Step 2: Positive List

The applicability conditions of this methodology represent the positive list. The project must demonstrate that it meets all of the applicability conditions, and in so doing, it is deemed as complying with the positive list.

The positive list was established using the activity penetration option (Option A) in the *VCS Standard*. Demonstration that the penetration of the project activity is less than 5 percent is set out in Appendix A.

8. QUANTIFICATION OF GHG EMISSION REDUCTIONS AND REMOVALS

8.1 Baseline Emissions

During a monitoring period, there will be periods of time when signals are communicated between the carbon advisory service and a given device. These signals shift the device's electricity usage from one set of time periods to another set of time periods. From the interaction of the carbon advisory service and the device, the project proponent must determine the time periods of the intended electricity consumption. Baseline emissions are quantified by a) modeling the electricity use that the project device/system would have consumed, had its consumption not been shifted, and then b) scaling all said electricity usage by the operating margin (OM) of the grid for each time period of electricity usage.

Multiplying the operating margin and baseline electricity consumption for each device and time period provides the baseline emissions for that device and time period. The baseline emissions for all time periods for all devices within a monitoring period are summed to provide the overall baseline emissions. In other words, the baseline emissions account for the time periods and MWhs of baseline electricity consumption of the device for a given time period. For all time periods in the monitoring period, the operating margin of the grid where the device is drawing power must also be measured or estimated.

The equations below must be followed to estimate baseline emissions.

$$BE_y = \sum_i BE_{D,i,y} \quad (1)$$

BE_y	=	Baseline emissions in year *y* (tCO_2/yr)
$BE_{D,i,y}$	=	Baseline emissions associated with the electricity consumption of all devices in the project boundary in year y (tCO_2/yr)

And where:

$$BE_{D,i,y} = \sum_{t,j} [(IEC_{D,i} / 1000) \times OM_{BL,y}] \quad (2)$$

$IEC_{D,j}$	=	Intended electricity consumption of device *i* for time interval *j (kWh)*
$OM_{BL,y}$	=	Operating margin for the grid in which the project takes place in tCO2/MWH during the time interval *j* when electricity consumption of device *i* is reduced and shifted to another time period (the baseline or BL)

Determining Intended Electricity Consumption ($IEC_{D,j}$)

The devices or systems operating under the applicability conditions of this methodology will not necessarily change the total amount of electricity they consume. Instead, the time periods in which that electricity is consumed will be shifted.

The baseline electricity consumption for the device is an estimate of the device's intended electricity consumption within the monitoring period. Project proponents must estimate intended electricity consumption using either of the options defined below, in order of preference.

Option 1: Direct Expression of Intended Consumption

In some cases, a device's intended consumption may be precisely measurable because the device's consumption patterns without time-shifting are clearly defined. For such a "direct expression" method to be valid under this methodology, the device software must have direct control over the device's electricity consumption. For each instance of intended consumption, the device and/or carbon advisory service must be able to track the total amount of the device's actual consumption.

In addition, the carbon advisory service must be able to determine both the intended electricity consumption and the actual electricity consumption. Given an amount of electricity consumed, the device's consumption pattern without time-shifting is defined and does not vary by more than 5 percent in the relevant time period (e.g., if a device shifts 10 kWh of usage to times of lower emissions in a 12 hour period, the kWh actually consumed during that 12 hour period should be within 5 percent of the 10 kWh that the device would have consumed in the baseline). If total consumption is deviates 5 percent or more during the typical usage cycle of the time shifted device, that period would not be eligible for crediting.

The baseline electricity consumption of a device under Option 1 is thus the total amount of electricity that it actually consumed in the clearly defined time periods that the electricity would have been consumed had the device's consumption not been time-shifted.

Example of Direct Expression of Intended Consumption

Typical electric vehicle charging software has direct control over the vehicle charging device. Without intervention from a carbon advisory service, the software will order the car to begin charging the moment it is first plugged in, and charge continuously and at some maximum rate (e.g., 12 kW/hr) until the EV battery is full. The battery's level of charge and total capacity define how much electricity is to be consumed, so the device's behavior is clearly defined and does not vary significantly.

In the case of a project using this methodology, the electric vehicle may be plugged in and the charger would communicate with the carbon advisory service, which tracks a new instance of intended consumption. The carbon advisory service would send a series of recommendations and the vehicle charges at various time-shifted times. Afterwards, the charger's actual consumption would ultimately be the same amount of electricity (e.g., 36 kWh) spread over some number of small time periods, which would then be tracked by the carbon advisory service.

The intended consumption of the electric vehicle charger would be the electricity the charger actually consumed (36 kWh), consumed continuously at its maximum rate (12kW). The baseline electricity consumption in this example is thus 12 kW for 3 hours, beginning at the time the device intended to begin charging. See Appendix B for a sample data set of time-shifted electricity consumption from an electric vehicle.

Option 2: Modeling of Intended Electricity Consumption

A device's intended electricity consumption may be estimated with a model based on empirical data recorded from similar devices and their contexts. This option requires that a sample of devices be monitored and the results extrapolated to the entire population of devices. The project proponent must use CDM guidance document *Guidelines for sampling and surveys for CDM project activities and programme of activities.* The project proponent must use this guidance to develop a sampling plan that meets the criteria specified in the guidance. Sampling activities must obtain enough samples to reach a 90/10 confidence/precision.

The CDM *Guidelines for sampling and surveys for CDM project activities and programme of activities* document provides guidance for how sampling should take place. As a first step, project proponents should decide what type of sampling protocol would be used, and this depends on the type and geographical distribution of the devices in the project boundary. The guidance describes four different types of approaches (simple random sampling, systematic sampling, stratified random sampling and cluster sampling), with the advantages and disadvantages of each provided in Table 1 of the CDM *Guidelines for sampling and surveys for CDM project activities and programme of activities* (version 04.0). See Section 2.1.1 of the CDM *Guidelines for sampling and surveys for CDM project activities and programme of activities* (version 04.0) as an example for determining the number of devices required to extrapolate intended electricity consumption to an entire population of devices.

Example of Modeling of Intended Electricity Consumption

A network of electric vehicle charging stations is studied to model their electricity consumption without any time-shifting behavior. The CDM *Guidelines for sampling and surveys for CDM project activities and programme of activities* is applied to estimate the baseline. Such a study finds that the sample average residential EV charger has a 12-hour window to supply power, charges 36 kWh per charge, requires 3 hours in that window to charge, and always uses the first 3 hours if not guided by a carbon advisory service.

In this case, the intended electricity consumption of an electric vehicle charging station can now be estimated using the model above, parameterized by the data in each specific instance.

Determining the Operating Margin ($OM_{BL,y}$)

The project proponent must obtain a measure of the OM at all times when the project device or system is consuming electricity (as well as during the times when the device would have been operating in the baseline scenario). The OM measurement must use the best method available of the methods defined below. The acceptable methods below are listed in order of preference.

Option 1: Real-time Marginal Emissions Data

Some grid operators will make real-time marginal emissions data available. This may be provided publicly via the operator's website or an API, and may be provided without cost or for a fee. Determining the OM for a given grid in this manner is simply a matter of using the marginal emissions values directly, and is preferred.

Option 2: Validated Model of a Grid's Operating Margin

A grid's operating margin may be determined using a regression model based on, and validated against, historical data. Various types of models may be appropriate depending on the observed relationship between covariates and response variables. However, the model must be fit using sound and well-documented statistical methods and take as input direct measures of power plant response to changes in demand to identify marginal generation unit(s).

The model must predict marginal emissions in tCO_2e/kWh (or units that can be converted appropriately) from some combination of measurable covariates available in the validation data set.

Model selection, fit, and validation against historical data must be evaluated as follows:

1. The validation data set for a given electrical grid will consist of:
    a. Covariates: At least 1 year of historical data for a given set of covariates.[1]
    b. Output: Marginal emissions or marginal fuel data over the same time period and at the same temporal frequency as the covariate data.
2. If marginal fuel data is used as output validation data, it will be transformed into marginal emissions data by multiplying the marginal fuel mix by an emissions factor per each fuel type, and then summing.
3. The regression model will take as its inputs real-time data of the same form as the covariates from the validation data set, and at a higher temporal frequency than that of the validation data set.
4. If run against the validation data set, the regression model will produce marginal emissions estimates with a root mean squared error of less than 1 percent of the average marginal emissions value over the entire validation data set.

Once validated, any regression model must not be relied upon to produce marginal emissions estimates at a higher temporal frequency than that of the validation data set. Once validated, the regression model may be applied to new monitoring periods in the same grid. It may also be

[1] Project proponents may wish to review the following guidance when considering the use of co-variates: "Considering Covariates" in http://database.v-c-s.org/sites/vcs.benfredaconsulting.com/files/Methodology%20for%20Coastal%20Wetland%20Creation%2C%2030%20JAN%202014_0.pdf)

applied to different grids, as long as the same covariates to the model are available at the same temporal frequency as the validation data set.

8.2 Project Emissions

During a monitoring period, the time-shifted electricity consumption must be recorded by the device software and/or the carbon advisory service for each device and shifted time period. Multiplying the operation margin and electricity consumption for each device and time-shifted time period provides the project emissions for that device and time-shifted period. The project emissions for all time-shifted time periods for all devices within a monitoring period are summed to provide the overall project emissions. The methods for calculating the operating margin are the same is described in the Section 8.1 above.

$$PE_y = \sum_i PE_{D,i,y}$$

Where: (3)

PE_y = Project emissions in year *y* (tCO_2/yr)

$PE_{D,i,y}$ = Project emissions associated with the electricity consumption of all devices within in the project boundary in year y (tCO_2/yr)

$$PE_{D,i,y} = \sum_{t,j} [(AEC_{D,i} / 1000) \times OM_{PS,y}] \quad (4)$$

Where:

$AEC_{D,j}$ = Actual electricity consumption of device *i* for entirety of time interval *j (kWh)*

$OM_{PS,y}$ = Operating margin for the grid in which each activity takes place in tCO2/MWH during the time interval *j* when the electricity consumption of device *i* is shifted and thus increased (the project scenario or PS)

Energy Storage: The use of energy storage is an eligible project activity under this methodology. However, when energy storage devices are charged and discharged, there is an efficiency loss, and this loss must be taken into account when considering actual electricity consumption. In the case where electricity is available from the grid during a period of low-carbon intensity, it can be used to store energy. The stored energy may then be discharged during a period of high-carbon intensity, displacing higher emissions electricity and thus resulting in lower emissions. For most devices, time shifting simply means electricity that would have been consumed at one time is consumed at another, though the pathway is the same. With an energy storage device, there is actually a separate pathway – from the grid to the storage unit and then back to the grid (or to some other point of electricity consumption). The additional path that electrons must travel results in some loss of energy. Most storage manufacturers provide estimates of “roundtrip” storage loss, and the manufacturer-provided information is sufficient to calculate these efficiency losses. Thus in the case of energy storage, an additional factor needs to be calculated.

For example, if a storage unit has an efficiency loss of 5 percent and it can charge 100 kWh, it would require 105 kWh of grid power to get 100 kWh. And when it discharges, 95 kWh is delivered. Thus the roundtrip efficiency is 90 percent. The variable for AEC is therefore increased by 10 percent but at the low-carbon operating margin (again, assuming the energy storage is charged from the grid when the grid is cleaner). Thus, in the case where the project includes storage, project emissions are calculated as follows:

$$PE_{D,i,y} = \sum_{t,j} [(AEC_{D,i} \times ((1 + EL_{i,y}) / 1000) \times OM_{PS,y}] \quad (5)$$

Where:

$EL_{i,y}$ = Roundtrip efficiency loss of the energy storage system

8.3 Leakage

No leakage emissions are considered under this methodology.

8.4 Net GHG Emission Reduction and Removals

Net GHG emission reductions and removals are calculated as follows:

$$ER_y = BE_y - PE_y - LE_y \quad (6)$$

Where:

ER_Y = Net GHG emissions reductions and removals in year y (tCO_2e)
BE_Y = Baseline emissions in year y (tCO_2e)
PE_y = Project emissions in year y (tCO_2e)
LE_y = Leakage in year y (tCO_2e)

9. MONITORING

9.1 Data and Parameters Available at Validation

Data / Parameter	EL,I,y
Data unit	Roundtrip efficiency loss of the energy storage system
Description	Takes into account when project scenario electricity consumption increases due to the fact that there is energy loss when energy storage devices are charged and discharged.
Equations	Equation 5
Source of data	Estimation from energy storage manufacturer
Value applied	N/A
Justification of choice of data or description of measurement methods and procedures applied	The energy storage manufacturer is the most reliable source of data for an estimate of roundtrip efficiency.
Purpose of Data	Calculation of project emissions

Comments	Roundtrip efficiency loss of the energy storage system should be available at validation if the project proponent is using the manufacturer's specifications. This figure may be static or may change depending on information provided by the battery manufacturer. For example, the manufacturer may state that the roundtrip efficiency may be 85 percent but that efficiency is expected to degrade at 1 percent per year. In this case, EL,i,y should be adjusted by 2 percent each year (1 percent degradation each way).

9.2 Data and Parameters Monitored

Data / Parameter:	i
Data unit:	Number
Description:	Inventory of devices, which can change from year to year
Equations	Equations 1-3
Source of data:	Carbon advisory service
Description of measurement methods and procedures to be applied:	Determined by project proponent
Frequency of monitoring/recording:	Monitored continuously
QA/QC procedures to be applied:	All devices will be entered into a spreadsheet, which can be reviewed by a verifier upon request
Purpose of data:	Calculation of baseline and project emissions
Calculation method:	NA
Comments:	Provide any additional comments

Data / Parameter:	$IEC_{D,j}$
Data unit:	kWh
Description:	Intended electricity consumption of device i during time interval j in each year of the crediting period
Equations	Equation 2
Source of data:	Carbon advisory service
Description of measurement methods and procedures to be applied:	Electricity consumption can be monitored by the device company using sensor technology on the device. There are two methods for this: 1. Direct kWh measurement: Some device companies use sensor technology to directly measure KWh of actual

	electricity consumption at each time step. 2. Device run-time measurement: Some device companies use sensor technology to measure only device run times (i.e., for each time step, the device records only that it was drawing full power, not drawing power, or drawing some fraction of full power). This is then multiplied by the company's estimate of the device's full power draw to estimate KWh per time step. Project proponents can use either direct kWh measurement or device run-time measurement. Option 1, *Direct Expression of Intended Electricity Consumption.* Option 2, *Modeling of Intended Electricity Consumption* allows the project proponent to undertake a sample of total devices, using meters or data loggers that can measure the exact output of each device within the project boundary. These meters/loggers will be on a statistically significant number of devices, in accordance with the CDM sampling guidance. The carbon advisory service will receive this data and, on an annual basis, use that data to extrapolate to the entire population of devices.
Frequency of monitoring/recording:	Continuous (Option 1) or annual sampling surveys (Option 2)
QA/QC procedures to be applied:	Option 1: When devices are directly monitored, the meter or data logger will be included in the database of each device, and the project proponent must demonstrate that the meter/logger has been calibrated and maintained according to manufacturer specifications. Option 2: The project proponent must follow the CDM *Guidelines for sampling and surveys for CDM project activities and programme of activities*. VVBs can use that guidance as a way to validate the robustness of the sampling plan. Project proponents are particularly advised to review Section 8 of that document, "Recommended evaluation criteria for DOE validation", which outlines the criteria that the VVB will use when assessing the quality of the sampling plan.
Purpose of data:	Calculation of baseline emissions
Calculation method:	Calculated by the carbon advisory service with all entries entered into an auditable spreadsheet.
Comments:	Each variable should be recorded once per time step (e.g., once per 5-minute period). Given an amount of electricity consumed, the device's consumption pattern without time-shifting is defined and does not vary by more than 5%. In other words, if a device shifts 10 kWh of usage within a usage cycle, the kWh actually consumed in the project scenario for that cycle should be within 5% of the 10 kWh that the device would have consumed in the

	baseline. The carbon advisory service needs to be able to know how much electricity would have been consumed (intended) and how much actually was used. In most cases, it can be assumed that 10 kWh shifted within a usage cycle would still require 10 kWh during Time B. But if that's not the case, the level of consumption in the project scenario cannot be more than 5% different from the baseline scenario.

Data / Parameter:	$AEC_{D,i}$
Data unit:	kWh
Description:	Actual electricity consumption of device i during time interval j in each year of the crediting period.
Equations	Equation 3
Source of data:	Carbon advisory service
Description of measurement methods and procedures to be applied:	Electricity consumption can be monitored by the device company, using sensor technology on the device itself. There are two methods for this: 1. Some device companies use sensor technology to directly measure KWh of actual electricity consumption at each time step. 2. Some device companies use sensor technology to measure only device run times (i.e., for each time step, the device records only that it was drawing full power, not drawing power, or drawing some fraction of full power). This is then multiplied by the company's estimate of the device's full power draw to estimate KWh per time step. For Option 1, the project proponent will use one of these methods. Option 2 allows the project proponent to undertake a sample of total devices, using meters or data loggers that can measure the exact output of each device within the project boundary. These meters/loggers will be on a statistically significant number of devices, in accordance with the CDM sampling guidance. The carbon advisory service will receive this data and, on an annual basis, use that data to extrapolate to the entire population of devices.
Frequency of monitoring/recording:	Continuous (Option 1) or annual sampling surveys (Option 2)
QA/QC procedures to be applied:	Option 1: When devices are directly monitored, the meter or data logger will be included in the database of each device, and the project proponent must demonstrate that the meter/logger has been calibrated and maintained according to manufacturer specifications. Option 2: The project proponent must follow the CDM *Guidelines for sampling and surveys for CDM project activities and*

	programme of activities. VVBs can use that guidance as a way to validate the robustness of the sampling plan. Project proponents are particularly advised to review Section 8 of that document, "Recommended evaluation criteria for DOE validation", which outlines the criteria that the VVB will use when assessing the quality of the sampling plan.
Purpose of data:	Calculation of project emissions
Calculation method:	Will be calculated by the carbon advisory service with all entries entered into a spreadsheet that can be viewed by the VVB at verification.
Comments:	Each variable should be recorded once per time step (e.g., once per 5-minute period). Given an amount of electricity consumed, the device's consumption pattern without time-shifting is defined and does not vary by more than 5%. In other words, if a device shifts 10 kWh of usage within a usage cycle, the kWh actually consumed in the project scenario for that cycle should be within 5% of the 10 kWh that the device would have consumed in the baseline. The carbon advisory service needs to be able to know how much electricity would have been consumed (intended) and how much actually was used. In most cases, it can be assumed that 10 kWh shifted within a usage cycle would still require 10 kWh during Time B. But if that's not the case, the level of consumption in the project scenario cannot be more than 5% different from the baseline scenario.

Data / Parameter	$OM_{PS,y}$ and $OM_{BL,y}$
Data unit	tCO2/MWH
Description	
Equations	2 and 3
Source of data	Carbon advisory service
Description of measurement methods and procedures to be applied	The Operating margin is continuously monitored in each time step by the carbon advisory service using the techniques described in the Baseline Emissions section.
Frequency of monitoring/recording	Data must be monitored continuously and recorded on at least a daily basis.
QA/QC procedures to be applied	The VVB can review the data and methods used to collect the operating margin data from the carbon advisory service.
Purpose of data	Calculation of baseline and project emissions
Comments	Each variable must be recorded once per time step, e.g., once per 5-minute period. Note: in cases where the data and methods

	used to provide the operating margin is proprietary, the VVBs may confidentially review the data and validate the output of the carbon advisory service without providing that data publicly, such as in a verification report.

9.3 Description of the Monitoring Plan

All data collected as part of monitoring must be archived electronically and kept at least for two years after the end of the last project crediting period.QA/QC procedures should include, but are not limited to:

- Data gathering, input and handling measures;
- Input data checked for typical errors, including inconsistent physical units, unit conversion errors,
- Typographical errors caused by data transcription from one document to another, and missing data for specific time periods or physical units;
- Input time series data checked for large unexpected variations (e.g., orders of magnitude) that could indicate input errors;
- All electronic files to use version control to ensure consistency;
- Physical protection of monitoring equipment;
- Physical protection of records of monitored data (e.g., hard copy and electronic records);
- Input data units checked and documented;
- All sources of data, assumptions and emission factors documented.

10. REFERENCES

None

APPENDIX A: ACTIVITY METHOD

Applicability Conditions

The applicability conditions of this methodology are designed to exclude project activities that can be implemented without the incentives provided by the carbon market. Listed below are the key applicability conditions and, in italics, their relevance in terms of preventing non-eligible projects from being approved under the VCS Program:

- The project activity involves the use of a carbon advisory service to shift the electricity usage of a device (or system of devices) that draws electricity from an electrical grid: *The applicability criteria should help ensure similarity in key areas, regardless of where the project may be implemented. For example, the requirement that the project activity involve a device that draws electricity from the grid can be considered uniform regardless of socio-economic or climatic conditions, grid emission factors and energy prices.*

- Project activities must use a carbon advisory service to shift the electricity usage of devices from times of high carbon intensity to periods of lower carbon intensity: *As indicated in the positive list, virtually no devices – EV chargers, HVAC equipment, lighting, water heaters or any other device whose activity can be regulated – are connected to a carbon advisory service. The fact that one of the criterion requires the use of a carbon advisory service, which meets very specific requirements, would indicate that the generation of carbon credits is an important factor in implementing the project. By focusing purely on "carbon optimization" as opposed to economic optimization, most projects that use software to shift the electricity usage would not be eligible under this methodology.*

- The project activity uses a carbon advisory service that has enough information available to determine (or estimate with a high degree of confidence) the operating margin (OM) of the grid from which the relevant device (or system of devices) draws power. The carbon advisory service must either use a direct API setup between it and the grid or use a regression model that complies with Section 4.1.6 of the *VCS Standard, v3.7*. The carbon advisory service must also be able to facilitate the issuance of signals to advise devices to shift their electricity consumption in time based on the OM. *The steps to use a carbon advisory service that meets these conditions are not insignificant. Project developers must be willing to go through these steps, which will filter out more "business-as-usual" projects, such as demand response (see below). In fact, there would be no reason to comply with the VCS Standard unless carbon credits were a significant consideration.*

- This methodology is not applicable when factors other than marginal carbon intensity (e.g., demand response based on electricity cost) is utilized by the project activity to determine the timing of electricity consumption: *Making more common types of activities, such as demand response, ineligible further helps differentiate the proposed project activity as something that is truly not common practice. In addition, demand response programs do have an economic benefit (incentive payments, lower energy bills), whereas focusing only on marginal carbon intensity typically does not provide an economic benefit to the end-user, thus making the project less likely to happen without carbon finance*.

Positive List

This methodology specifies a positive list for additionality based on activity penetration of the applicable project activity, per Section 4.6.9(1) of the *VCS Standard, v3.7*. The analysis below demonstrates that the level of activity penetration for time-shifting electricity consumption to times when less carbon-intensive electricity is generated on the electrical grid is significantly less than 5 percent.

The positive list for activities established under this methodology is based on a demonstration that the project activities have achieved a low level of penetration relative to their maximum adoption potential, in accordance with VCS requirements. This activity penetration level is estimated using the following equation:

$$APy = OAy / MAPy$$

Where:

APy = Activity penetration of the project activity in year y (percentage)

OAy = Observed adoption of the project activity in year y (e.g., total number of instances installed at a given date in year y, or amount of energy supplied in year y)

MAPy = Maximum adoption potential of the project activity in year y (e.g., total number of instances that potentially could have been installed at a given date in year y, or the amount of energy that potentially could have been supplied in year y)

The following analysis estimates the global penetration level, current as of 2018, for the project activity.

As of the writing of this methodology, there is no large-scale commercial application of a carbon advisory service or automated emission reductions program. While there are many demand response activities, these are all focused on reducing cost and the level of peak demand, which may or may not have anything to do with emissions reductions. In fact, there are few companies that have a precise methodology to determine the emissions intensity of the grid in real time. As a result, it can be stated that zero percent of appliances, whether it be EV chargers, HVAC equipment, lighting, water heaters or any other device whose activity can be regulated, are connected to a carbon advisory service.

Further evidence of the lack of commercial activity for this project type can be found in different sources. In a recent article, *Electric Vehicles Are Getting Marginally Better in a Big Way*, the writer referred to Watt Time's partnership with eMotorWerks as "the game-changer."[2] This partnership will analyze the electricity grid in real time, allowing EV chargers to activate when there are more renewables on the grid. A similar article describes another charger that would be the first to charge with the carbon intensity of the grid in

[2] https://blog.ucsusa.org/rachael-nealer/average-vs-marginal-electric-emissions-802

mind, "*JuiceBox Green 40 is the first electric vehicle charging solution (or EVSE) that helps an EV driver to spite greenhouse gas emissions by charging when electricity is greenest*."[3]

Because this project activity is a completely new field with few if any fully commercial technologies, the methodology uses an activity method for demonstrating additionality, with this technology as the basis for a positive list. The project activity has not reached commercial scale. The one company known to be able to qualify as a carbon advisory service (WattTime) has only a few partnerships that to date, which currently affect around 450 devices, a tiny fraction of the total potential. These efforts are considered pilot-scale in the view of WattTimes's partners. Thus, the "total number of instances installed at a given date in year y" is zero, and thus OA can be considered to be zero.

Despite the lack of deployment, this type of project has been commercially available for three years prior to the writing of this methodology. WattTime first developed its technology in January of 2014. WattTime had rolled out a pilot and was actively looking for customers for the first version of its product, and in 2014, some electric vehicles were already charging using the WattTime feed. It took some time for WattTime to identify its first customer, but WattTime provided its service first to Electric Motorwerks. WattTime was ready to deliver the technology, and sent Emotorwerks the first contract proposal at the end of 2014.

MAP is considered based on a number of factors, including resource availability, technological capacity, implementation potential, market access, customer acceptance and other factors. In this case, given that the product is essentially software, and the marginal costs of deploying software are extremely low. There are no particular restraints like resource availability or market access. Thus, for the purposes of this methodology, MAP can be considered the entire market for each type of device that the carbon advisory service can control (see Table 3 below). Because the Observed Activity is essentially zero, and the adoption potential is in the billions of devices, this project activity is considered additional and thus eligible assuming project proponents can meet all of the methodology's other applicability conditions.

[3] https://cleantechnica.com/2015/07/07/greenest-ev-charging-solution-on-market-just-released/

Table 3: Global Population of Devices

Devices	Devices/year	Total Devices
Washing Machines, residential		840,000,000[4]
Fridges & Freezers, residential		1,400,000,000[5]
Personal Computers		2,000,000,000[6]
Personal Computers	270,000,000[7]	2,832,520,000[8]
Smartphones	1,495,000,000[9]	3,279,760,000[10]
Tablets	168,000,000[11]	1,004,000,000[12]
Air Conditioners, Residential		408,300,000[13]
Air Conditioners, Commercial		187,000,000[14]
Electric Car Chargers, Private		1,257,000[15]
Electric Car Chargers, Public, Slow Charger		161,802[16]
Total	**1,933,000,000**	**11,952,998,802**

4
http://www.bigee.net/media/filer_public/2013/03/28/bigee_domestic_washing_machines_worldwide_potential_20130328.pdf

5
http://www.bigee.net/media/filer_public/2012/12/04/bigee_doc_2_refrigerators_freezers_worldwide_potential_20121130.pdf

6 http://www.worldometers.info/computers/

7 https://www.gartner.com/newsroom/id/3568420

8 http://www.pewglobal.org/2015/03/19/internet-seen-as-positive-influence-on-education-but-negative-influence-on-morality-in-emerging-and-developing-nations/technology-report-15/

9 https://www.gartner.com/newsroom/id/3609817

10 http://www.businessinsider.com/how-many-people-own-smartphones-around-the-world-2016-2

11 https://www.gartner.com/newsroom/id/3560517

12 https://www.emarketer.com/Article/Global-Tablet-Audience-Total-1-Billion-This-Year/1012451

13 https://ies.lbl.gov/sites/all/files/lbnl-1003671.pdf

14 https://ies.lbl.gov/sites/all/files/lbnl-1003671.pdf

15 https://www.iea.org/publications/freepublications/publication/Global_EV_Outlook_2016.pdf

16 https://www.iea.org/publications/freepublications/publication/Global_EV_Outlook_2016.pdf

The project activity has not been commercially available for three years. As required in the *VCS Standard, v3.7*, Step 3 (barriers test) of the CDM *Tool for the Demonstration and Assessment of Additionality* must be completed to demonstrate that the project activity faces barriers to its uptake. The key barriers (technical and investment) of this project activity are as follows:

- There is a lack of infrastructure for implementation and logistics for maintenance of the technology. To effectively select to use power during times of less carbon-intensive marginal emissions, it is necessary for devices to understand in real time:

  1) The real-time carbon intensity of the grid (measured in CO2e/MWh)
  2) The carbon intensity of the grid in context of the baseline scenario (whether carbon intensity is relatively high or low for this time period on this grid)
  3) The expected carbon intensity of the grid in the future. A forward-looking projection that assesses whether the grid is likely to get more or less carbon-intensive in the coming hours is needed to effectively select less carbon-intensive times to consume power.
  4) In many cases the above information must be combined into a device specific control signal that tells a device, based on information provided by that device (i.e., the current temperature in a building), whether that device should use power now, or wait for later.

  The infrastructure for devices to understand 2-4 above does not exist anywhere in the world except for a few pilots based on early infrastructure developed by WattTime with grant financing. The proposed project activity requires this infrastructure, which must also be extremely reliable. This infrastructure does not currently exist, and at least in the case of WattTime, cannot exist without the possibility of carbon finance, to develop and maintain it. WattTime has had success obtaining support from partners interested in voluntary carbon reductions to support development of the technology. However, these partners state that their inability to generate carbon credits to recognize their voluntary actions is a key barrier to implementing the carbon advisory service.

- The focus on the environmental benefits of time switching electricity usage and not the economic benefits (e.g., demand response) results in little or no financial advantage to the end-user of the technology, representing an investment barrier. It is difficult for any party, including the carbon advisory service, to raise financing, obtain a loan or seek an investor because of these circumstances. This presents a barrier to implementation and scaling. To date, WattTime has primarily been supported by grant financing, providing further evidence of investment barriers for a carbon advisory service.

Sub-Step 3b of the CDM *Tool for the Demonstration and Assessment of Additionality* requires that the identified barriers do not prevent the implementation at least one of the alternatives. The continuation of the status quo (i.e., no modifications to the device or system are made to time-shift electricity consumption) is not affected by the lack of infrastructure and financing present for the project activity.

APPENDIX B: SAMPLE DATA SET

This data set shows how time-shifted charging an electric vehicle would affect total electricity consumption and emissions. For the purposes of a project verification, such a data set would typically be presented in a spreadsheet and made available for a VVB to spot check.

Fleet size	1	vehicle
Baseline emissions	36	pounds CO_2
Project emissions	32	pounds CO_2
Net savings	4	pounds CO_2
Baseline electricity use	24.2	kWh
Actual electricity use	24.2	kWh

Raw data (note: only sampling of data shown for sake of brevity):

Timestamp	**Intended energy use (kWh)**	**Actual energy use (kWh)**	**Operating margin (CO2/kWh)**
2015-04-28 23:00:00+00:00	0.55	0.55	1.298
2015-04-28 23:05:00+00:00	0.55	0.55	1.298
2015-04-28 23:10:00+00:00	0.55	0.55	1.298
2015-04-28 23:15:00+00:00	0.55	0.55	1.298
2015-04-28 23:20:00+00:00	0.55	0.55	1.303
2015-04-28 23:25:00+00:00	0.55	0	1.518
2015-04-28 23:30:00+00:00	0.55	0	1.518
2015-04-28 23:35:00+00:00	0.55	0	1.518
2015-04-28 23:40:00+00:00	0.55	0.55	1.298
2015-04-28 23:45:00+00:00	0.55	0	1.404
2015-04-28 23:50:00+00:00	0.55	0.55	1.332
2015-04-28 23:55:00+00:00	0.55	0.55	1.322
2015-04-29 00:00:00+00:00	0.55	0.55	1.332
2015-04-29 00:05:00+00:00	0.55	0	1.427
2015-04-29 00:10:00+00:00	0.55	0	1.427
2015-04-29 00:15:00+00:00	0.55	0	1.518
2015-04-29 00:20:00+00:00	0.55	0	1.516
2015-04-29 00:25:00+00:00	0.55	0	1.565

2015-04-29 00:30:00+00:00	0.55	0	1.565
2015-04-29 00:35:00+00:00	0.55	0.55	1.516
2015-04-29 00:40:00+00:00	0.55	0	1.517
2015-04-29 00:45:00+00:00	0.55	0	1.545
2015-04-29 00:50:00+00:00	0.55	0	1.559
2015-04-29 00:55:00+00:00	0.55	0	1.545
2015-04-29 01:00:00+00:00	0.55	0	1.545
2015-04-29 01:05:00+00:00	0.55	0	1.545
2015-04-29 01:10:00+00:00	0.55	0	1.545
2015-04-29 01:15:00+00:00	0.55	0	1.545
2015-04-29 01:20:00+00:00	0.55	0.55	1.517
2015-04-29 01:25:00+00:00	0.55	0	1.565
2015-04-29 01:30:00+00:00	0.55	0	1.565
2015-04-29 01:35:00+00:00	0.55	0	1.545
2015-04-29 01:40:00+00:00	0.55	0	1.545
2015-04-29 01:45:00+00:00	0.55	0	1.545
2015-04-29 01:50:00+00:00	0.55	0	1.545
2015-04-29 01:55:00+00:00	0.55	0	1.545
2015-04-29 02:00:00+00:00	0.55	0	1.545
2015-04-29 02:05:00+00:00	0.55	0	1.545
2015-04-29 02:10:00+00:00	0.55	0	1.545
2015-04-29 02:15:00+00:00	0.55	0	1.545
2015-04-29 02:20:00+00:00	0.55	0	1.565
2015-04-29 02:25:00+00:00	0.55	0	1.565
2015-04-29 02:30:00+00:00	0.55	0	1.559
2015-04-29 02:35:00+00:00	0.55	0	1.545
2015-04-29 02:40:00+00:00	0	0	1.545
2015-04-29 02:45:00+00:00	0	0	1.545
2015-04-29 02:50:00+00:00	0	0	1.545
2015-04-29 02:55:00+00:00	0	0	1.559
2015-04-29 03:00:00+00:00	0	0	1.545
2015-04-29 03:05:00+00:00	0	0	1.559
2015-04-29 03:10:00+00:00	0	0	1.516
2015-04-29 03:15:00+00:00	0	0	1.517
2015-04-29 03:20:00+00:00	0	0	1.559
2015-04-29 03:25:00+00:00	0	0	1.565