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The ISO 50001 Impact Estimator Tool (IET 50001 V1.1.4) - User Guide and Introduction to the ISO 50001 Impacts Methodology

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Energy Technologies Area

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Disclaimer

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1 Introduction to the IET 50001 Tool and this Document

ISO 50001-Energy management systems – Requirements with guidance for use, is an internationally developed standard that provides organizations with a flexible framework for implementing an energy management system (EnMS) with the goal of continual energy performance improvement. The ISO 50001 standard was first published in 2011 and has since seen growth in the number of certificates issued around the world, primarily in the industrial (agriculture, manufacturing, and mining) and service (commercial) sectors. Policy makers in many regions and countries are looking to or are already using ISO 50001 as a basis for energy efficiency, carbon reduction, and other energy performance improvement schemes.

The Impact Estimator Tool 50001 (IET 50001 Tool) is a computational model developed to assist researchers and policy makers determine the potential impact of ISO 50001 implementation in the industrial and service (commercial) sectors for a given region or country. The IET 50001 Tool is based upon a methodology initially developed by the Lawrence Berkeley National Laboratory that has been improved upon and vetted by a group of international researchers. By using a commonly accepted and transparent methodology, users of the IET 50001 Tool can easily and clearly communicate the potential impact of ISO 50001 for a region or country.

This document is written in support of the Impact Estimator Tool 50001 Version 1.1.4. It contains:

1. A step-by-step user guide to the IET 50001 Tool and
2. A detailed description of the ISO 50001 impacts methodology, which is employed by the IET 50001 Tool.

2 IET 50001 Step-by-Step User Guide

2.1 IET 50001 Worksheets

The IET 50001 Tool contains five worksheets within the Microsoft Excel workbook. The five worksheets are:

1. INTRO
2. IET50001
3. INDUSTRIAL
4. SERVICE
5. INFORMATION

The INTRO worksheet contains basic information about the tool and its purpose. There are no inputs or results on this worksheet.

The IET50001, INDUSTRIAL, and SERVICE worksheets all contain inputs to the tool. Inputs on the INDUSTRIAL and SERVICE worksheets are optional. The IET50001 worksheet contains required inputs. Additionally, the IET50001 worksheet contains all results from the tool.

The INFORMATION worksheet lists default values, units, sources, and notes for various inputs used throughout the tool.

2.2 Industrial and Service Sector Definitions

IET 50001 analyzes industrial and service sectors separately and users can define parameters unique to each sector. Industrial and service sectors are defined by International Energy Agency's Energy Technology Perspective (IEA, 2015) as:

The **service sector** includes activities related to trade, finance, real estate, public administration, health, food and lodging, education and commercial services. This is sometimes also referred to as the commercial and public service sector.

The **industrial sector** includes the manufacturing and construction industries. Key industry sectors include iron and steel, chemical and petrochemical, non-metallic minerals, and pulp and paper. Use by industries for the transformation of energy into another form or for the production of fuels is excluded and reported separately under other energy sector. Consumption of fuels for the transport of goods is reported as part of the transport sector.

2.3 IET 50001 Tool Inputs and Results

Inputs cells for the IET 50001 Tool are found on the IET50001, INDUSTRIAL, and SERVICE worksheets. All input cells are pre-populated with default values. In some instances, equations or other data from the IET 50001 Tool are set as default values. All default values can be overwritten. In the case that default values are generated by equations, overwriting the cells will delete the equation previously used.

Users should progress through the IET 50001 Tool carefully as changes to any input will change results. This section details the input cells and describes what information is being requested by the tool. Additionally, information regarding the default values and their sources are provided.

Results are found on the IET50001 worksheet. Result values update automatically when input cell values are changed.

2.3.1 IET 50001 Tool Color Coding

Throughout the IET 50001 Tool, each cell is color coded so it is easy to distinguish "Default Input", "Calculated or Fixed Parameter", and "Tool Output". The color-coding scheme is shown in Figure 1.

Default Input	User can overwrite these values with data for the country or region of interest.
Calculated Data or Fixed Parameter	Includes formulas and cannot be changed.
Tool Output	**Important results.**

Figure 1: Key for using the tool. "Default Input", "Calculated Data or Fixed Parameter", and "Tool Output" values are color-coded to improve user friendliness and ease of use.

2.3.2 IET50001 Worksheet

The IET50001 worksheet is divided into two main sections:

- Inputs
- Results

The inputs section contains three steps:

- Step 1: Key Parameters and Variables
- Step 2: Energy Consumption by Source
- Step 3: Delivered Energy[1] Consumption by Sector

The results section contains three subsections:

- Numerical Results
- Graphical Results
- Detail to Support the Results

The subsequent sections of this document describe the inputs steps and output subsections.

[1] Energy arriving at the boundary (ies) of an organization.

2.3.2.1 Key Parameters and Variables

In this step, the user defines basic input parameters and variables that the IET 50001 Tool will use to calculate results. Figure 2 is a screen shot of these parameters and variables. Users should only update the parameters in light blue cells. Default values in light blue boxes are based on relevant global data and should be revised by the user if region or country specific information is available.

Parameter	Value	Units
Current Year (Used for $ Cost NPV)	2015	Year
Start Year (Min = 2011)	2011	Year
End Year (Max = 2050)	2030	Year
Adoption Period	19	[Years]
Passenger Vehicle Equivalent CO2 Emissions	4.75	[tCO2/Passenger Vehicle/Year]
Energy Savings Attributable to ISO 50001	5.00%	[%/year]
Continual Savings Improvement	1.00%	[%/year]
Annual Interest Rate	1.83%	[%/year]
Offsite Electricity Generation Multiplier	3.01	[1]
Offsite Steam Generation Multiplier	1.43	[1]

	Industrial Uptake	Service Uptake	Units
ISO 50001 Uptake in 2011 (L0)	0.00%	0.00%	[%]
ISO 50001 Uptake in 2030 (L)	50.0%	50.0%	[%]
k (function steepness)	0.30	0.65	[1]
#of years before PMG	14	9	[Years]
t-PMG	2025	2020	Year

Figure 2: Screenshot of the Key Parameters and Variables section of the IET50001 worksheet.

Details about the parameters listed in the table above are provided below:

Current Year is the year in which this tool is being used. This information is used to discount the dollar value of the cost savings to present value dollars.

DEFAULT VALUE: 2015, the year this manual was first drafted.

Start Year is the desired year in which the adoption of ISO 50001 EnMS has started. The Start Year value should not precede 2011; the year ISO 50001 was first published.

DEFAULT VALUE: 2011, the year in which ISO 50001 was first published.

End Year is the final year of interest for which energy, energy cost, and CO_2 emission savings are calculated. For the purposes of the IET 50001 Tool, the End Year cannot be greater than 2050. The selection of end year can either be determined by the user's interest or based on data availability.

> DEFAULT VALUE: 2030, five years beyond the U.S. National Determined Contribution target year.

Adoption Period is the duration, through which ISO 50001 is implemented. This value is automatically calculated based on the start and end years.

Passenger Vehicle Equivalent CO2 Emissions is based on weighted average of combined fuel economy and vehicle miles traveled of U.S. cars and light trucks in the year 2011.

> DEFAULT VALUE: 4.75 tons of annual CO2 emissions per passenger vehicle based on U.S. Environmental Protection Agency's data (U.S. EPA, 2016).[2]

Energy Savings Attributable to ISO 50001 is the percentage of energy savings resulting from the first year a given quantity of energy consumption is under the management of an ISO 50001 energy management system.

> DEFAULT VALUE: 5%, the minimum improvement level required of facilities earning Silver level certification under the U.S. Department of Energy Superior Energy Performance (SEP) program. Industrial and service facilities certified to SEP have achieved an average energy performance improvement of 10% per certification cycle with a range of energy performance improvement percentages of 5.6% - 41.9% per certification cycle (U.S. DOE, 2016). SEP certification requires third party certification of ISO 50001 and verification of meeting a minimum energy performance improvement percentage. The greater than 5% achievement of an average SEP facility points to the conservative nature of the default value.

> EXAMPLE: Assume 5% Energy Savings Attributable to ISO 50001.

> Year 1: 100.00 units of energy under EnMS, 5.00 units of energy saved, 95.00 units of energy consumed in subsequent years.

Continual Savings Improvement is the percent of additional energy savings for the energy consumption that became under management in the previous year(s).

> DEFAULT VALUE: 1%, the minimum improvement level required of facilities earning Silver level certification under the U.S. Department of

[2] 260,350,940 passenger vehicles in the US emitted 1,236,666,965 metric tons of CO2 in 2014.

Energy Superior Energy Performance program for continual energy performance improvement.

EXAMPLE: Assumes 5% Energy Savings Attributable to ISO 50001 and 1% Continual Savings Improvement values.

Year 1: 100.00 units of energy under EnMS, 5.00 units of energy saved, 95.00 units of energy consumed in subsequent years.
Year 2: 95.00 units of energy under EnMS, 0.95 units of energy saved, 94.05 units of energy consumed in subsequent years.
Year 3: 94.05 units of energy under EnMS, 0.94 units of energy saved, 93.11 units of energy consumed in subsequent years.
Year 4: 93.11 units of energy under EnMS, 0.93 units of energy saved, 92.18 units of energy consumed in subsequent years.

Annual Interest Rate is used for inflation adjustment and discounts annual cost savings in the future and brings them to the present year.

DEFAULT VALUE: 1.83%, based on a U.S. treasury bond's 10-year yield in 2016 (U.S. Treasury, 2016).

Offsite Electricity Generation Multiplier is used to convert delivered electricity savings to primary basis.

DEFAULT VALUE: 3.01, based on reported 66.8% generation, transmission, and distribution losses (U.S. DOE, Energy Information Administration, 2012).[3]

Offsite Steam Generation Multiplier is used to convert delivered steam savings to primary basis.

DEFAULT VALUE: 1.43, calculated assuming 20% boiler efficiency and 10% losses during transmission (U.S. DOE, 2010).

ISO 50001 Uptake in L_0 and L (where L_0 = Start Year and L = End Year) is the percentage of energy consumption predicted to be under the management of an ISO 50001 EnMS in year L_0 and L. Values for industrial and service sectors are entered separately. The choice of 0% and 50% uptake for L_0 and L respectively, is designed to illustrate the potential impact of ISO 50001 EnMS on global energy consumption and

[3] Similar results are achieved (66.2% conversion losses and an offsite electricity generation multiplier of 2.96) using data from International Energy Information Agency's, Energy Technology Perspective 2015 will results in similar results. But to maintain consistency within our data sources, EIA data is used for default values.

emissions, although actual uptake is uncertain in the absence of globally consistent policy drivers.

DEFAULT VALUES: Full market penetration.

Industrial L0 = 0%,
Industrial L = 50%,
Service L0 = 0%,
Service L = 50%

k **(Function Steepness)** is the steepness of a logistic function used to model a non-linear ISO 50001 EnMS adoption. The logistic function and its parameters that are used to model the adoption rate are further explained in the methodology section of this document (Section 3.3.1.1).

DEFAULT VALUE: 0.30 for industrial and 0.65 for service sectors, based upon analysis of historic global uptake of ISO 14001.

Number of Years before the Point of Maximum Growth (t_{PMG}-t_i) is the number of years between the standard's introduction and the point of maximum growth (PMG). PMG is where the logistic function used to model a non-linear ISO 50001 EnMS adoption changes its inflection.

DEFAULT VALUE: 14 years for industrial and 9 years for service sectors, based upon analysis of historic uptake of global ISO 14001.

Point of Maximum Growth (t_{PMG}) is the year at which the function growth rate starts to decay which results in a change of the function's inflection. This value is calculated automatically based on the "Start Year" and the "Number of Years Before PMG".

2.4 Delivered Energy Consumption by Sector

The IET 50001 Tool uses the breakdown of energy sources consumed by the region or country being modeled as inputs when determining energy, cost, and CO_2 savings.

The table shown in Figure 3 below can be filled in directly on the IET50001 worksheet or will be auto populated if the INDUSTRIAL and SERVICE worksheets are utilized. Users are recommended to use the INDUSTRAIL and SERVICE worksheets if detailed energy consumption, electricity generation mix, CO_2 emissions, and price data are available. Details about the INDUSTRIAL and SERVICE worksheets are explained in Section 2.7.2.2.

If granular data is not available for use in the INDUSTRIAL and SERVICE worksheets, users should provide high-level information in the Energy Consumption By Source table and not fill out the INDUSTRIAL and SERVICE worksheets.

	Industrial				Service			
	Fraction	Energy Consumption	Price of Energy	Emissions	Fraction	Energy Consumption	Price of Energy	Emissions
Delivered Energy	[%]	[EJ]	[$US/TJ]	[tCO2/TJ]	[%]	[EJ]	[$US/TJ]	[tCO2/TJ]
Electricity	25%	29	$19,838	160	52%	16	$28,150	159
Natural Gas	18%	21	$4,995	50	24%	7.4	$7,677	50
Coal (Industrial)	36%	42	$3,033	90	0.0%	0.0	$3,033	90
Biomass and Waste	6.5%	7.6	$3,779	81	2.9%	0.9	$3,779	81
Coke and Breeze (Metallurgical Coal)	0.0%	0.0	$5,213	108	4.2%	1.3	$5,213	108
Distillate Fuel Oils (Oil Products)	11%	13	$24,909	70	12%	3.7	$25,875	70
Residual Fuel Oils	0.0%	0.0	$18,956	70	0.0%	0.0	$20,947	70
LPG (and NGL)	0.0%	0.0	$13,374	58	0.0%	0.0	$13,374	58
Steam and Hot Water (Imported to facilities)	4.6%	5.5	$5,327	84	4.5%	1.4	$5,099	84
Total	100%	118.1			100%	30.7		
Blended Delivered Cost | Emission			$10,070	96.90			$20,250	114.59
Blended Primary Cost | Emission			$6,743	69.53			$10,332	57.73

Figure 3: Screenshot of the Energy Consumption by Source section of the IET50001 worksheet.

DEFAULT VALUES:

The magnitude of energy consumption and subsequently the fraction of each energy source consumed are 2012 values reported by the International Energy Agency's (IEA, 2015).[4]

Default energy prices are in 2013 dollars and come from various data sources including U.S. Department of Energy (U.S. DOE, 2015), U.S. DOE's Manufacturing Energy Consumption Survey (MECS) (U.S. DOE, 2010), and U.S. DOE's Commercial Buildings Energy Consumption Survey (U.S. DOE, 2003).

Default emission factors as reported by the U.S. Environmental Protection Agency (U.S. EPA, 2014).

2.5 End Use Energy Consumption by Sector

The IET 50001 Tool uses data supplied by the user to linearly interpolate estimated energy consumption values for the industrial and service sectors for all years being modeled. At least two years of (site or delivered) end use energy consumption data must be provided for the IET 50001 Tool to function.

As seen in Figure 4, up to 12 historic or projected energy consumption values can be input in the table (If needed, more can be added by simply inserting new rows). Users must input the year corresponding to any energy consumption value provided. The Industrial & Service (I&S) column represents the sum of industrial and service sector energy consumptions.

The IET 50001 Tool uses this data and fits a linear line to the data for the industrial and service sectors separately. A third line is fit for the industrial and service energy

[4] Energy consumption data can be visualized and also downloaded from IEA's website: http://www.iea.org/etp/explore/

consumption data in aggregate. The IET 50001 Tool uses these linear fits and interpolates to solve for the energy consumption for any given year.

> DEFAULT VALUES: Three years of historical (2007, 2010, and 2011) as well as four years of projected (2020, 2030, 2040, and 2050) energy consumption data for the industrial and service sectors as reported by the International Energy Agency (IEA, 2015).

STEP 3: DELIVERED ENERGY CONSUMPTION BY SECTOR

Year	Delivered Energy Consumption by Sector [EJ]		
	Industrial	Service	I&S
2007	126	33.5	160
2010	134	35.4	169
2011	136	36.0	173
2020	160	41.8	202
2030	185	48	233
2040	204	55	260
2050	222	63	285
			0
			0
			0
			0
			0

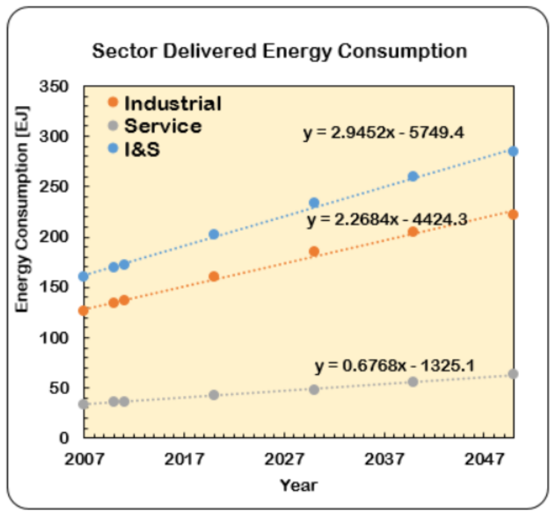

Figure 4: Screenshot of the Sector Energy Consumption section of the IET50001 worksheet.

2.6 Numerical Results

Users can type in the year of interest that falls within the modeled period and the Numerical Results section will provide specific results for that given year. As seen in Figure 5, the year 2030 has been put into the table and the IET 50001 Tool presents results related to that year. Results include annual and cumulative energy, cost, and CO_2 savings for the industrial and service sectors independently and in aggregate. A contextual value of equivalent number of passenger vehicles is available only for annual results.

Year	Sector	Total Annual Savings				Cumulative Savings		
		Primary Energy [EJ]	Cost [2015 $US B]	Emissions [MtCO2]	Passenger Vehicles [Million]	Primary Energy [EJ]	Cost [2015 $US B]	Emissions [MtCO2]
2030	Industrial	10.37	$ 53.3	721	152	63.3	$ 349.9	4,399
	Service	5.47	$ 43.1	316	67	41.61	$ 354.7	2,402
	Total (I&S)	15.85	$ 96	1,037	218	104.9	$ 704.6	6,801

Figure 5: Screenshot of the Numerical Results section of the IET50001 worksheet.

2.7 Graphical Results

The IET 50001 Tool provides a set of graphical results that span from the Start Year to the End Year. Figures are provided for the industrial and service sectors independently and in aggregate. Graphs of annual energy and CO_2 savings, cumulative energy savings and cumulative CO_2 savings are presented. Figure 6 shows a screen shot of the graphical results.

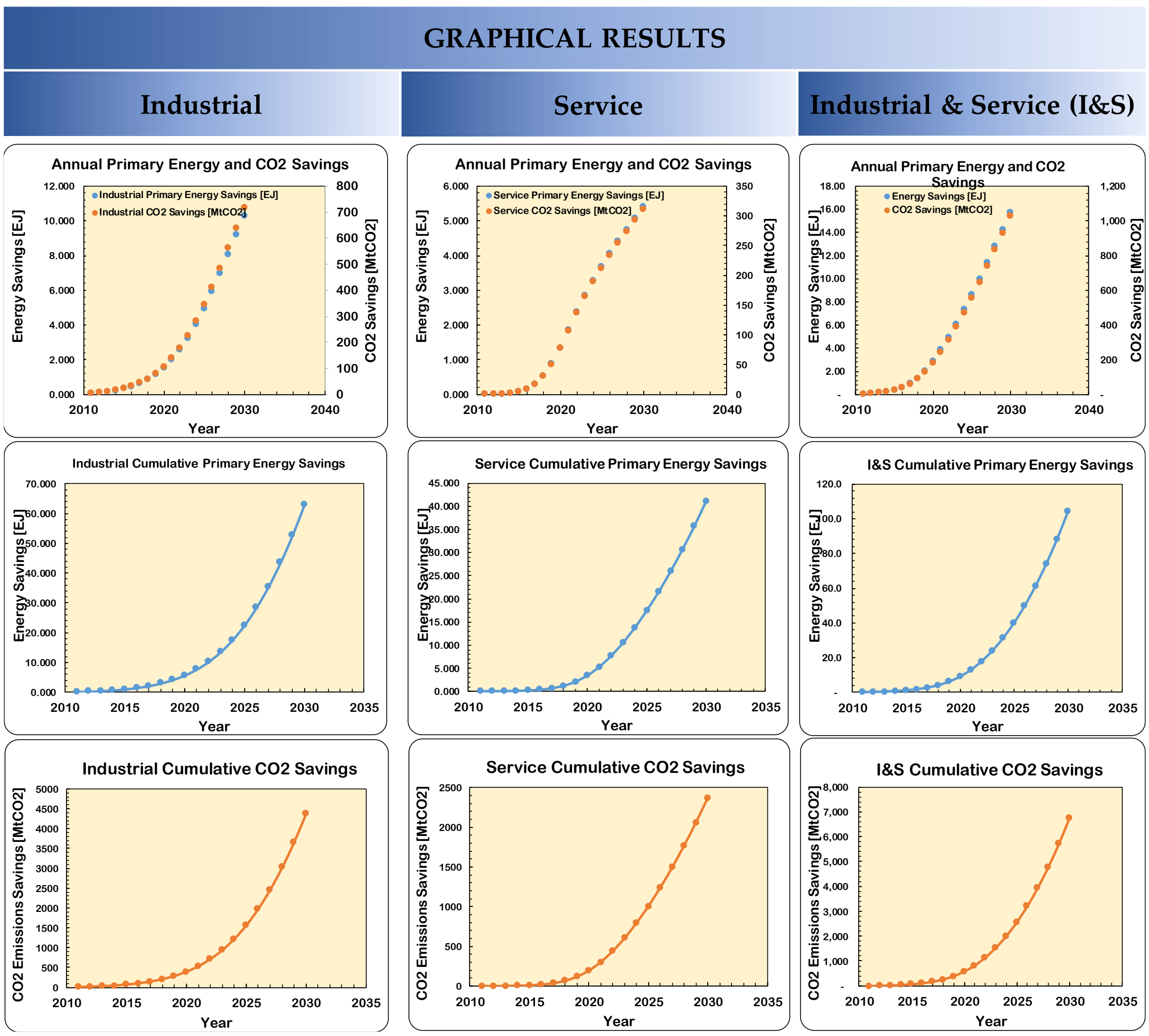

Figure 6: Screenshot of the Graphical Results section of the IET50001 worksheet.

2.7.1.1 Detail to Support the Results

The Detail to Support the Results section of the IET 50001 Tool provides supporting details for all savings calculated. This exhaustive output section adapts itself to match the duration for which the IET 50001 Tool is operated (i.e. Start Year to End Year).

Results provided in the Detail To Support The Results section include:

- Energy Consumption
- Adjusted Energy Consumption
- I&S ISO 50001 Uptake
- New Consumption Under ISO 50001
- Industrial Delivered Energy Savings
- Service Delivered Energy Savings
- Industrial Primary Energy Savings
- Service Primary Energy Savings
- Industrial CO2 Savings
- Service CO2 Savings
- CO2 # of Passenger Vehicle Equivalent
- Industrial Cost Savings
- Service Cost Savings
- I&S Total Annual Energy, CO2, and Cost Savings
- I&S Cumulative Energy, CO2, and Cost Savings

2.7.2 Industrial and Service Worksheets

The structure of the INDUSTRIAL and SERVICE worksheets is identical. These worksheets contain two main sections:

- Summary of Energy Consumption by Source
- Detailed Breakdown of Energy Consumption by Source Table

2.7.2.1 Summary of Energy Consumption by Source

The Summary of Energy Consumption by Source provides an overview of the breakdown of energy sources in the Industrial or Service sector. These high level breakdowns center on fuel, electricity, and steam and hot water that have been delivered to a facility, not on a primary energy basis. The values in this summary table are populated by entering data in the following table where detailed breakdown of energy consumption by source is defined (The detailed breakdown of energy consumption by source table is discussed in section 2.7.2.2). The IET 50001 Tool then aggregates the detailed breakdown into the summary table shown in Figure 7.

SUMMARY OF ENERGY CONSUMPTION BY SOURCE:

Energy Source	Fraction (%)	Consumption (EJ)	Emissions (tCO2/TJ)	Price ($US/TJ)
US Industrial Sector	100%	118	96.9	$ 10,069.84
Fuel	70.8%	84	76.0	$ 6,993.82
Electricity*	24.6%	29	159.8	$ 19,837.81
Steam and Hot Water*	4.6%	5	83.6	$ 5,326.73

Figure 7: Screenshot of the Summary of Energy Consumption by Source section of the INDUSTRIAL worksheet (SERVICE worksheet section is similar except for default values).

2.7.2.2 Detailed breakdown of energy consumption by source table

The detailed breakdown of energy consumption by source table provides users the ability to input granulated data regarding the energy sources consumed by the industrial and service sectors.

As shown in Figure 8, energy consumption data are broken down to three main categories of energy sources calculated on a delivered/site basis. Each main energy consumption category is further broken down to improve accuracy and allows users to better define energy consumption, CO_2 emissions, and energy prices. Energy sources that are indented and have cells shaded a lighter color will aggregate up to the energy source listed above them in a darker shaded cell.

	Source	Fraction (%)	Consumption (EJ)	Emissions (tCO2/TJ)	Price ($US/TJ)	Energy Cons
FUEL	Natural Gas	25%	21.00	50.3	$ 4,995.00	[1]
	Coal (Industrial Coal)	50.2%	42.000	89.7	$ 3,033.02	[1]
	Biomass and Waste	9%	7.64	80.5	$ 3,778.63	[1]
	Pulping/Black Liquor	-	-	89.5	$ 4,748.57	-
	Wood Byproducts	-	-	88.9	$ 2,426.41	-
	Still Gas (waste gases and byproducts)	-	-	63.2	$ 4,160.92	-
	Coke and Breeze (Metallurgical Coal)	0.0%	0.000	107.7	$ 5,213.00	[1]
	Distillate Fuel Oils	15.5%	13.000	70.2	$ 24,908.65	[1]
	No. 1	-	-	69.4	-	-
	No. 2	-	-	70.1	-	-
	No. 4	-	-	71.1	-	-
	Residual Fuel Oil	0.00%	0.000	70.2	$ 18,956.36	[1]
	No. 5	-	-	69.1	-	-
	No. 6	-	-	71.2	-	-
	LPG (and NGL)	0.00%	0.000	58.5	$ 13,373.71	[1]
ELECTRICITY	Coal	42%	12.047	90.5	$ 19,837.81	[1],[1
	Natural Gas	22%	6.320	50.3	$ 19,837.81	[1],[1
	Petroleum	5%	1.382	72.4	$ 19,837.81	[1],[1
	Distillate Fuel Oil (Average No. 1, 2, 4)	-		66.6	$ 19,837.81	-
	Residual Fuel Oil No. 6	-		71.2	$ 19,837.81	-
	Petroleum Coke	-		97.1	$ 19,837.81	-
	Jet Fuel	-		68.5	$ 19,837.81	-
	Kerosene	-		71.3	$ 19,837.81	-
	Propane	-		59.6	$ 19,837.81	-
	Nuclear	11%	3.161	0.0	$ 19,837.81	[1],[1
	Hydropower	16%	4.698	0.0	$ 19,837.81	[1],[1
	Wind	2%	0.696	0.0	$ 19,837.81	[1],[1
	Biomass	1%	0.406	77.1	$ 19,837.81	[1],[1
	Wood and Wood-derived Fuels	-		88.9	$ 19,837.81	-
	Landfill Gas	-		49.4	$ 19,837.81	-
	Municipal Solid Waste	-		86.0	$ 19,837.81	-
	Agricultural Byproducts	-		112.0	$ 19,837.81	-
	Other Biomass Gases	-		49.4	$ 19,837.81	-
	Other Gases	0%	0.000	104.6	$ 19,837.81	[1],[1
	Geothermal	0%	0.087	0.0	$ 19,837.81	[1],[1
	Solar	1%	0.203	0.0	$ 19,837.81	[1],[1
HEAT	Commercial Heat (Imported to facilities)	100%	5.48	83.6	$ 5,326.73	[1]

Figure 8: Screenshot of the detailed breakdown of energy consumption by source section of the INDUSTRIAL worksheet (SERVICE worksheet section similar except for default values).

Fuel is defined as the sum of purchased fuel, fuel transferred into the plant boundary, and byproduct fuel (from non-fuel sources) produced and consumed onsite. The **electricity** generation mix is made up of coal, natural gas, nuclear, hydropower, biomass, other gases, petroleum, geothermal, and solar. These categories have been selected based upon the data provided by the U.S. Department of Energy, International Energy Agency[5], Energy Information Agency Electricity Monthly Update.[6] **Steam and hot water** includes the quantity of each of these energy sources imported to facilities and not generated onsite.

[5] Energy Technology Perspectives 2015 and Key World Statistics 2015.

[6] U.S. DOE. Energy Information Administration: Monthly Energy Review January 2016. Table 7.2b Electricity Net Generation.

Energy Consumption is the amount of delivered energy consumed by the industrial and service sectors at a country, regional, or global level. While the fraction of energy consumption by source will change over time, for the purposes of this tool an assumption is made that these fractions will remain constant.

DEFAULT VALUES: The magnitude of energy consumption and subsequently the fraction of each energy source consumed are 2012 values reported by the International Energy Agency's (IEA, 2015).[7]

Emission Factors are reported in units of carbon dioxide equivalent and are used to estimate emissions from consumption of energy sources.

DEFAULT VALUES: Default emission factors as reported by the U.S. Environmental Protection Agency (U.S. EPA, 2014). CO_2 emissions from combustion of biomass and waste is accounted for and is a straight average of the emission factors of pulping liquor, black liquor, wood byproducts, and still gas. Emissions from electricity is a weighted average of emissions from the generation mix assuming a site to source multiplier of 3.01 to account for losses in generation, transmission, and distribution. The Industrial and Service tabs automatically calculate the CO_2 emission intensity associated with consumption of electricity based on the generation mix defined by the user. As a point of reference, the global emission intensity of producing and distributing one unit of electricity is 169 tCO_2/TJ as reported by de la Rue du Can, et. al. (de la Rue du Can, Price, & Zwickel, 2015).

Price of Energy by sector and source in 2013 dollars.

DEFAULT VALUES:

Prices of Coal, Electricity, Natural Gas, and Oil Products[8] are U.S. specific prices reported by the U.S. Department of Energy (U.S. DOE, 2015). The price of coal used for the service sector is the average price of the metallurgical coal for all users. The price of electricity is assumed to be constant regardless of the generation mix.

The main components of Biomass and Waste are pulping liquor, black liquor, wood byproducts, and still gas (waste gases and byproducts) as defined by the U.S. DOE's Manufacturing Energy Consumption Survey (MECS). The default value for the price of Biomass and Waste for both industrial and service sectors is the straight average of those components as reported by MECS 2010. (U.S. DOE, 2010)

Price of commercial heat for the industrial sector (typically steam) is from MECS 2010 (U.S. DOE, 2010), and for the service sector (typically hot water) is from

[7] Energy consumption data can be visualized and also downloaded from IEA's website: http://www.iea.org/etp/explore/
8 Oil Products are referred to Distillate Fuel Oil in the Annual Energy Outlook document.

U.S. DOE's Commercial Buildings Energy Consumption Survey (U.S. DOE, 2003).

Users should note that the color-coding system used in previous cells does not directly apply to the table shown in Figure 8. The color-coding system does apply to the text in this table, light blue text indicates cells that are user inputs and black text indicates cells that are calculated or are outputs. The references listed on the right hand side of the table are linked to the INFORMATION worksheet. The user must update these manually on both the INDUSTRIAL or SERVICE and INFORMATION worksheets if the reference is changed.

3 ISO 50001 Impacts Methodology

3.1 Introduction

A methodology to determine the impact that industrial and service (commercial) sector ISO 50001 implementation has on a regional, country, or global scale has been developed by researchers at the Lawrence Berkeley National Laboratory with input from members of the Energy Management Working Group of the Clean Energy Ministerial. Members of the ISO 50001 Impacts Research Network, a collaboration of global researchers, have refined the methodology.

The methodology takes user-supplied inputs to determine the amount of energy under the management of an ISO 50001 certified energy management system (EnMS) and the savings that result from management of that energy. Savings determined with the methodology include energy, energy cost, and CO_2 emission savings.

The ISO 50001 Impacts Estimator Tool (IET 50001 Tool) is a software embodiment of the ISO 50001 impacts methodology.

As with any methodology, ensuring that data inputs and assumptions related to ISO 50001 adoption rate and future energy consumption are of high quality and well-founded is critical to obtaining a meaningful result. Making systematic changes to the methodology input data provides the ability to understand the range of potential impacts that would result from different policy scenarios as well as determine the sensitivity of results to input changes.

3.2 Nomenclature

ATPEC	Adjusted Total Projected Energy Consumption
CES	Cumulative Energy Savings
CIES	Continual Improvement of Energy Savings
CO_2	Carbon Dioxide
CSI%	Continual Savings Improvement Percentage
ECUM	Energy Consumption Under Management
k	Steepness of the logistic function (function growth rate)
L	Logistic function maximum value (upper asymptote)
L_0	Logistic function initial value (lower asymptote)
NAES	New Annual Energy Savings
PVE	Passenger Vehicle Equivalent (CO_2 emissions per passenger vehicle)
PV	Present Value
R	Interest rate based on a 10 year US treasury bond yield rate
$t_{current}$	Present year to which the annual savings are being discounted to
t_i	The year at which the cost savings are observed
t_{PMG}	Point of Maximum Growth

TAES	Total Annual Energy Savings
TNAES	Total New Annual Energy Savings
TPEC	Total Projected Energy Consumption

3.3 ISO 50001 Impacts Methodology Inputs

3.3.1 ISO 50001 Uptake Function (ECUM)

The ISO 50001 impacts methodology calculates savings due to ISO 50001 on the energy consumption for which it has been applied. This is done in recognition that of the total amount of industrial and service sector energy consumption, some fraction will be under the management of an ISO 50001 EnMS. This fraction may change year to year. The ISO 50001 uptake methodology does not consider the number of ISO 50001 certificates issued or number of facilities covered by those certificates, as these metrics do not convey any quantification of the amount of sector wide energy under the management of an ISO 50001 EnMS.

To determine the fraction of energy consumption under the management of an ISO 50001 EnMS, the ISO 50001 uptake methodology assumes that the uptake of ISO 50001 increases non-linearly over an adoption period. The methodology assumes the adoption rate grows exponentially and then decays exponentially past a mid-point year. This results in each year of the adoption period being assigned an individual ISO 50001-uptake percentage. This assumption is based upon historic evidence of ISO 9001 and ISO 14001 globally and in individual countries.

A logistic function is used to model this non-linear uptake of ISO 50001. The shape of the logistic function is illustrated in Figure 9 and detailed in Equation 1.

Equation 1 $$\mathbf{f}(\mathbf{t}) = \boldsymbol{L_0} + \frac{\boldsymbol{L - L_0}}{\mathbf{1} + \boldsymbol{e}^{-\boldsymbol{k}(\boldsymbol{t} - \boldsymbol{t_{PMG}})}}$$

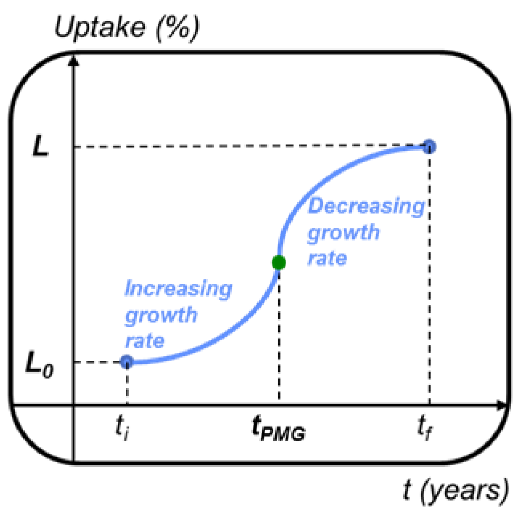

Figure 9: Standard logistic function

Where:

L_0 is the initial year uptake value of ISO 50001 for the time period of interest,
L is the final year uptake value of ISO 50001 for the time period of interest,
t_{PMG} is the point of maximum growth in the time period of interest, and
k is a factor to adjust the rate of uptake (function growth rate).

The process of determining values for the coefficients used in the logistic function are described in the following subsections.

3.3.1.1 Determining t_m and k

The coefficients t_m and k are determined by fitting a historical ISO 14001, or another ISO management system certificate data for the country or region being modeled. This is a similar approach previously used in the literature to model diffusion of innovation and other international standards such as ISO 9000 and ISO 14000 (Viadiu, Fa, & Saizarbitoria, 2006). These historic certification data are plotted and Excel's solver is used to determine t_m and k.

EXAMPLE USING Global DATA: Figure 10 shows plots of the number of historic ISO 14001 certificates issued for industrial and service sectors each year since the standard was published. The best-fit line using the logistic function equation is also plotted for each sector. This serves as a first fitting of the logistic function coefficients. Table 1 summarizes the resulting function parameters and the corresponding R^2 values resulting from the first round of iteration.

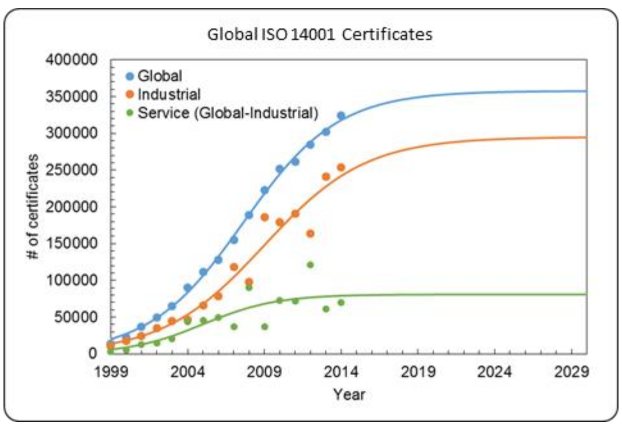

Figure 10: First iteration for determining t_m and k

Table 1: Function parameters (1st iteration)

ISO 14001	Industrial	Service	Global (I&S)
L_0 [No. of Certificates]	0	0	0
L [No. of Certificates]	294,984	80,848	357,710
t_{PMG} [Years]	14	10	13
k [1]	0.30	0.42	0.33
R^2	0.95	0.71	1.00

Historic data are evaluated for non-routine events such as economic downturns as well as the absence of data. Based upon these events, select historic data points are removed to refine the coefficient determination.

> EAMPLE USING GLOBAL DATA: Historic global data of ISO 14001 certification include data from world economic crash of 2008. Data points taken beyond the year 2006 are omitted when calculating revised values for t_m and k. Figure 11 shows the resulting historic data points and the refined logistic curve based using refined coefficients. Table 2 summarizes the resulting function parameters and the corresponding R^2 values resulting from the second round of iteration.

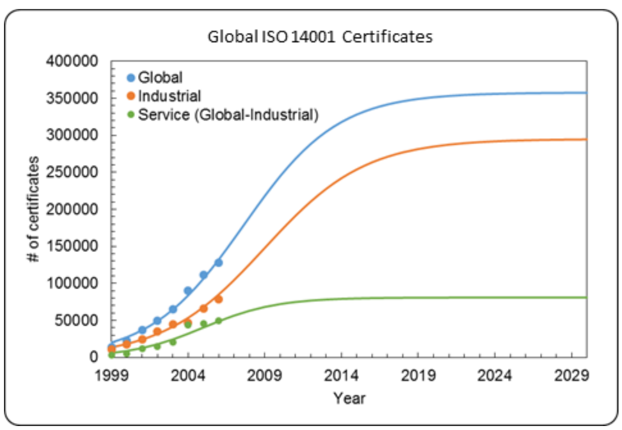

Figure 11: Second iteration for determining t_m and k values

Table 2: Function parameters (2nd iteration)

ISO 14001	Industrial	Service	Global (I&S)
L_0 [No. of Certificates]	0	0	0
L [No. of Certificates]	294,984	80,848	357,710
t_{PMG} [Years]	14	9	12
k [1]	0.30	0.65	0.37
R^2	0.97	0.95	0.99

3.3.1.2 Determining L_0 and L

The selection of L_0 and L establishes the starting and final values of the logistic function. When establishing t_{PMG} and k, units for L_0 and L are the number of ISO 14001 certificates issued. The number of certificates issued for these standards, or even ISO 50001, does not convey any information regarding the quantity of energy consumption under the management of an ISO 50001 EnMS. When being used to determine the impact of ISO 50001, the ISO 50001 impact methodology requires that L_0 and L have units of percentage of energy consumption under the management of an ISO 50001 EnMS as a function of total projected energy consumption (TPEC).

An appropriate value for L_0 may be 0% if 2011, the year ISO 50001 was first published, is selected as the start year.

The selection of a value for L may be based on a number of factors, which should be documented to maintain the transparent nature of the methodology and its use. L_0 is set to 0% as very few ISO 50001 certificates were issued in 2011. For both the industrial and service sectors, values for L were selected to be 50%. Figure 12 shows energy and CO_2 emission savings (in annual and cumulative basis) as a function of uptake in the year 2030. 50% uptake (indicated by dashed lines), was picked since it is a moderate assumption of what the global adoption of ISO 50001 EnMS might be in the future.

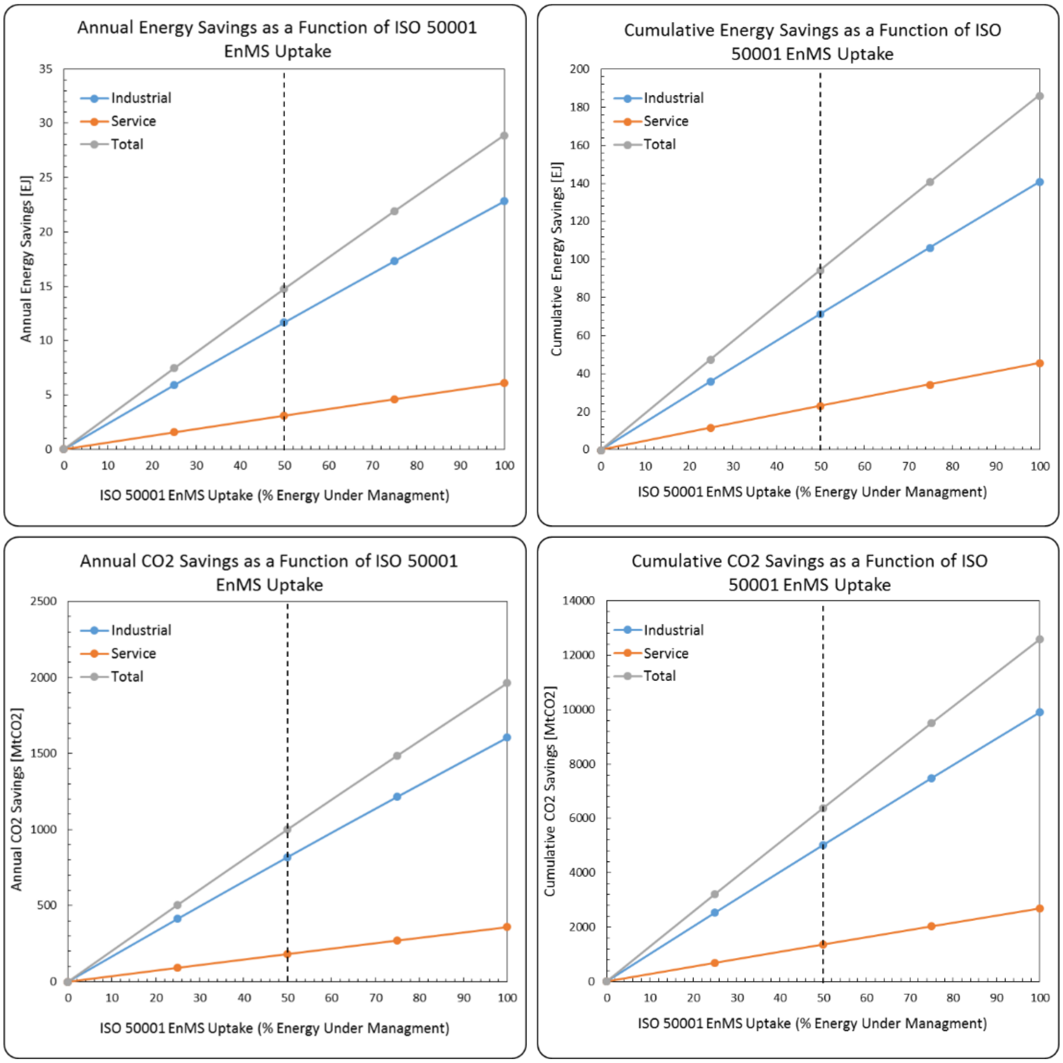

Figure 12: Energy and CO2 Savings as a Function of ISO 50001 EnMS Uptake in the Year 2030.

3.3.1.3 Finalized Logistic Curve

Having determined L_0, L, t_{PMG}, and k values, the uptake of ISO 50001 expressed as percent Energy Consumption Under Management (ECUM) can be calculated for each year during the adoption period using Equation 1. Figure 13 graphically presents the annual percentage ECUM values for the industrial and service sectors based upon Global data. The “S” shape of the logistic function is clearly evident.

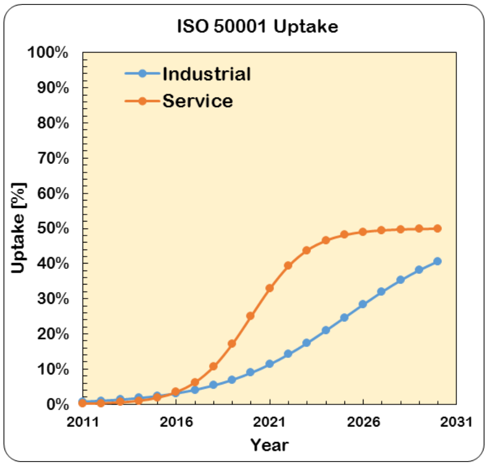

Figure 13: Uptake curve for industrial and service sectors (50% target uptake by 2030)

3.4 ISO 50001 Impacts Methodology Calculations

3.4.1 Energy Savings

The ISO 50001 Impacts Methodology separately determines two types of energy savings from ISO 50001: savings that result from the first year energy comes under the management of an ISO 50001 EnMS, and additional energy savings in subsequent years resulting from the continual improvement foundation of ISO 50001. Continual improvement energy savings are calculated for energy consumption that has already come under the management of an ISO 50001 EnMS in previous years.

Energy savings should be calculated on a primary energy basis to reflect savings within the region of interest. If projected energy consumption values used as inputs are on a delivered energy basis, they should be converted to primary energy consumption.

3.4.1.1 Start Year (t = 0) Annual Energy Savings

Before calculating annual energy savings for the initial year (t = 0), initial year ECUM must be established by taking the product of initial year Total Projected Energy Consumption (TPEC) and initial year ISO 50001 uptake percentage for both the industrial and service sectors (Equation 2).

Equation 2 $$\mathrm{ECUM}_0 = \mathrm{TPEC}_0 \times \mathrm{ISO\ 50001\ uptake\ \%}_0$$

New annual energy savings (NAES) attributable to ISO 50001 is then calculated (Equation 3) as the product of industrial and service sector ECUM and the percentage of energy savings attributable to ISO 50001.

Equation 3 $$\mathrm{NAES}_t = \mathrm{ECUM}_t \times \mathrm{\%\ of\ ES\ attributable\ to\ ISO\ 50001}$$

Because this year is the first year of impact from ISO 50001, continual improvement in energy savings from previous years is not a consideration; therefore, Total New Annual Energy Savings (TNAES) for the first year equals the NAES. However, this will be a consideration in energy savings estimates for subsequent years.

3.4.1.2 Calculating Energy Savings for Subsequent Years

TPEC values are commonly available from government or other reports. These values typically do not include adjustment for the impact ISO 50001 will have on energy consumption.

Adjusted total projected energy consumption (ATPEC) is calculated for years after the initial year by subtracting energy savings from the previous year from the current year unadjusted TPEC value estimates as shown in Equation 4.

Equation 4 $$\mathrm{ATPEC}_t = \mathrm{TPEC}_t - \sum_{n=1}^{t-1} \mathrm{TNAES}_n$$

The ATPEC for a given year is then used along with the ISO 50001 uptake % for that same year to calculate ECUM per Equation 5.

Equation 5 $$\mathrm{ECUM}_t = \mathrm{ATPEC}_t \times (\text{ISO 50001 uptake }\%_t - \text{ ISO 50001 uptake }\%_{t-1})$$

Figure 14 graphically represent relationship between TPEC, ECUM, and NAES for years one and two.

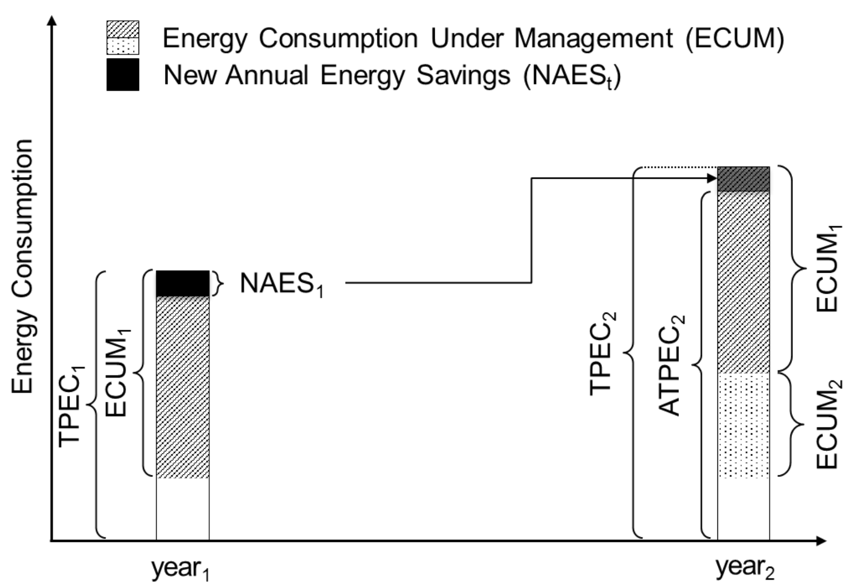

Figure 14: Total Projected Energy Consumption and Adjusted Total Projected Energy Consumption

Continual improvement of energy performance is a foundation of ISO 50001. The ISO 50001 Impacts Methodology takes this into account by calculating continual improvement energy savings (CIES) for years subsequent to the initial year. To account for continual energy performance improvement, energy consumption that comes under the management of an ISO 50001 EnMS each year must be accounted for separately. Equation 6 details how Continual Improvement Energy Savings (CIES) is calculated.

Equation 6 $$\mathrm{CIES}_t = \mathrm{CSI\%} \times \left(\sum_{n=1}^{t-1} \mathrm{ECUM}_n - \sum_{n=1}^{t-1} \mathrm{NAES}_n - \sum_{n=1}^{t-1} \mathrm{CIES}_n\right)$$

TNAES for a given year after the initial year is calculated as the product of current year ECUM and the percentage of energy savings attributable to ISO 50001 plus CIES for the current year (Equation 7).

Equation 7 $$\mathrm{TNAES}_t = \mathrm{ECUM}_t \times \text{\% of ES attributable to ISO 50001} + \mathrm{CIES}_t$$

Figure 15 illustrates the relationship of multiple years ECUM, NAES, and TAES. Figure 16 illustrates NAES for the first two years, showing how CIES from the year one ECUM is included in determining year two NAES.

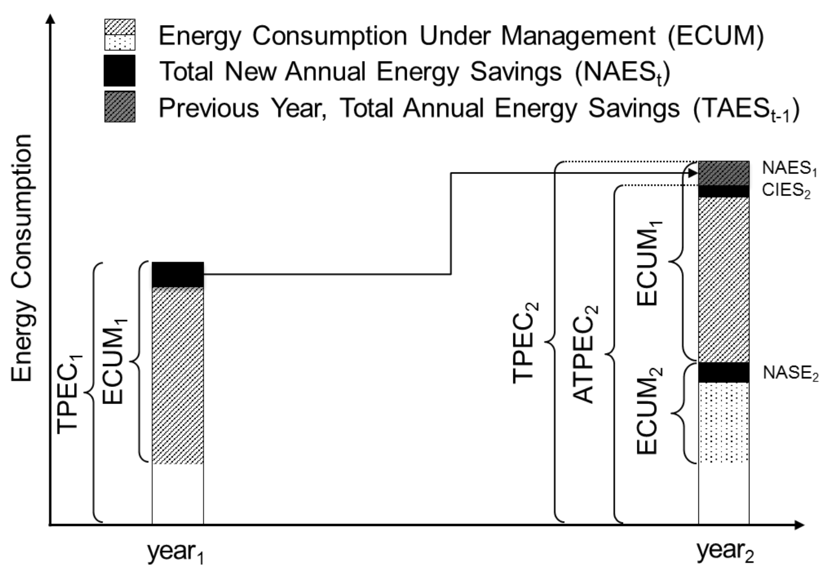

Figure 15: Graphical representation of the Continual Improvement of Energy Savings for Years 1 and 2

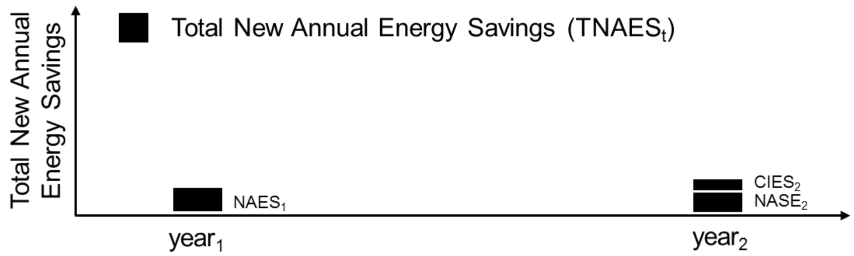

Figure 16: Graphical representation of the New Annual Energy Savings for Years 1 and 2

3.4.1.3 Total Annual Energy Savings

For each year, the total annual energy savings (TAES) is calculated as the summation of each year's NAES (Equation 8). TAES is also graphically represented in Figure 17.

Equation 8 $$\mathrm{TAES}_t = \sum_{n=1}^{t} \mathrm{TNAES}_n$$

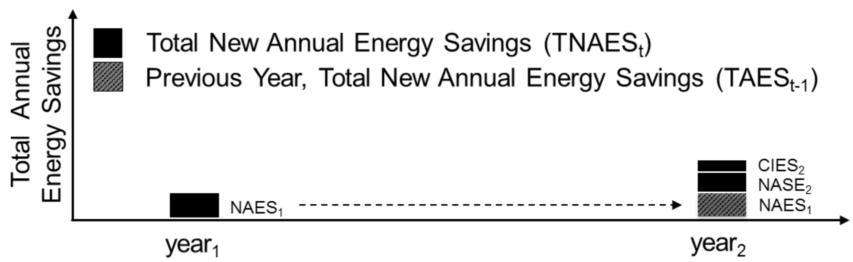

Figure 17: Graphical representation of the Total Annual Energy Savings for Years 1 and 2

3.4.1.4 Cumulative Energy Savings

Finally, the cumulative energy savings (CES) is calculated as shown in Equation 9.

Equation 9 $$\mathrm{CES}_t = \sum_{n=1}^{t} \mathrm{TAES}_n$$

3.4.2 CO_2 emission savings

3.4.2.1 Absolute CO_2 Emission Savings

CO_2 emissions savings for a given year of the adoption period are calculated as the product of TAES and a CO_2 emissions rate (Equation 10). CO2 emission rates are typically reported on a delivered basis, such as metric tons of CO2 per kWh consumed. For energy types that typically do not include a primary to delivered multiplier, such as natural gas or diesel fuel, this issue will not be of concern. However, for energy types that do commonly include primary to delivered multipliers such as delivered electricity and steam, care should be taken to ensure that the energy savings, which are calculated on a delivered energy basis, are multiplied by a delivered energy basis CO_2 emissions rate.

Equation 10 $$\text{Annual } CO_2 \text{ emission savings}_t = \text{TAES}_t \times CO_2 \text{ emission rate}$$

3.4.2.2 Passenger Vehicle Equivalent of CO_2 Emission Savings

A passenger vehicle equivalent of CO_2 emission savings for a given year is calculated to provide context to the CO_2 savings. This calculation is performed as the product of the calculated CO_2 emission savings for the adoption period year and the passenger vehicle equivalent CO_2 emissions value (Equation 11). The output of this calculation is the equivalent number of passenger vehicles taken off the road as compared to the CO_2 emission savings from ISO 50001.

Equation 11 $$\text{Annual PVE of } CO_2 \text{ emission savings}_t = \frac{CO_2 \text{ emission savings}_t}{\text{PVE } CO_2 \text{ emissions}}$$

3.4.3 Cost Savings

Energy cost savings are calculated for the current year as well as adjusted for inflation to account for the present value of the energy cost.

3.4.3.1 Current Year Cost Savings

Cost savings for a given year are calculated as the product of NAES for the given year and a blended energy cost value. The blended energy cost value is the average of the energy costs for each energy source weighted by its share of total energy consumption. The cost savings for each year is then discounted to present value. Equation 12 can be used to determine present value of annual cost savings.

Equation 12 $$\text{Cost savings}_i = \text{NAES}_i \times \text{blended energy cost}$$

3.4.3.2 Present Value of Cost Savings

The cost savings for each year can be discounted to present value. Equation 13 can be used to determine present value of annual cost savings:

Equation 13 $$\text{PV} = \frac{\text{Annual Cost Saving for year } i}{(1+r)^{(t_i - t_{current})}}$$

3.4.4 Cumulative Savings from Individual Adoption Period Years

Energy, energy cost, and CO_2 emission savings calculated for individual adoption period years can be accumulated to reflect savings over time. Number of passenger vehicle equivalent CO_2 emissions cannot be aggregated. Cumulative savings are calculated as the summation of savings for each year of the adoption period.

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