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Global Impact Estimation of ISO 50001 Energy Management System for Industrial and Service Sectors

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Energy Technologies Area

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DISCLAIMER

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1 Introduction

A methodology has been developed to determine the impacts of ISO 50001 Energy Management System (EnMS) at a region or country level. The impacts of ISO 50001 EnMS include energy, CO_2 emissions, and cost savings. This internationally recognized and transparent methodology has been embodied in a user friendly Microsoft Excel® based tool called ISO 50001 Impact Estimator Tool (IET 50001). However, the tool inputs are critical in order to get accurate and defensible results. This report is intended to document the data sources used and assumptions made to calculate the global impact of ISO 50001 EnMS reported below:

> "Broad implementation of ISO 50001 across service and industrial sectors globally (50% global uptake by the year 2030) could drive cumulative [*delivered*] energy savings of approximately 64 exajoules [105 exajoules of *primary* energy] by 2030, saving over $700 billion in energy costs and avoiding 6,500 Mt of CO2 emissions. The projected annual emissions savings in the year 2030 are equivalent to removing 212 million passenger vehicles from the road [by the year 2030]" (The White House, 2016)

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

3 Key Input Parameters

The following parameters are critical in order to run the IET 50001. This section introduces these key input parameters and provides references from where they were obtained. If no references were used, assumptions are documented for transparency.

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.

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 (19 years in this case).

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 Environmental Protection Agency data (U.S. EPA, 2016).[1]

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.

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

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 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).[2]

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 steam transmission and distribution (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. L_0 is set to 0%, assuming that there is no energy consumption under the management of an ISO 50001 EnMS in the year 2011 (standard's introduction year). The uptake after 19 years (years 2030) is

[2] Using data from International Energy Information Agency's, Energy Technology Perspective 2015 will results in a similar value (66.2% conversion losses and an offsite electricity generation multiplier of 2.96).For consistency, EIA data is used as default.

assumed to be 50%. Meaning that 50% of all industrial and service energy consumption is under the management of an ISO 50001 EnMS. Figure 1 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. 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 emissions, although actual uptake is uncertain in the absence of globally consistent policy drivers.

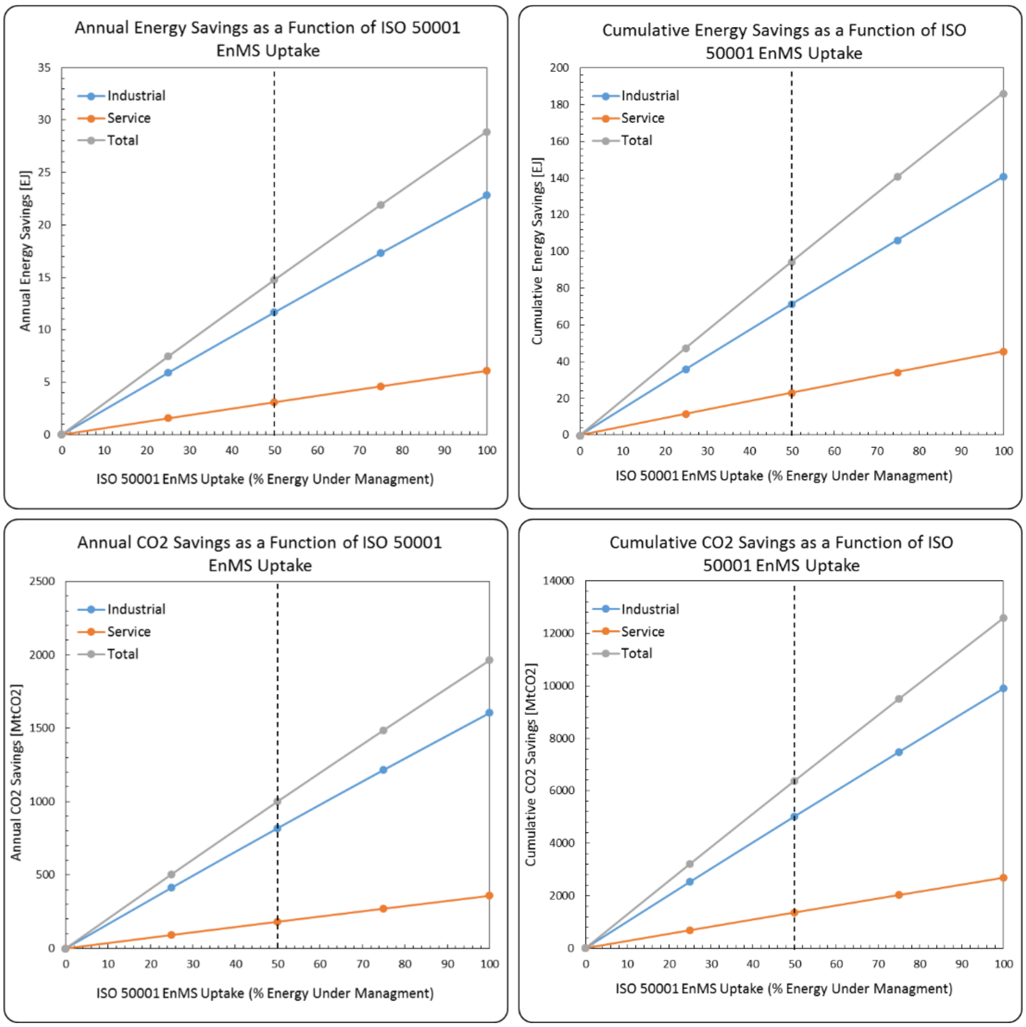

Figure 1: Energy and CO2 Savings as a Function of ISO 50001 EnMS Uptake in the Year 2030.

DEFAULT VALUES: Full market penetration.

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

ISO 50001 Uptake is modeled using a logistic function. Equation 1 is used in the IET 50001 to come up with the annual ISO 50001 EnMS uptake. Figure 2 represents a generic logistic function. Appendix A has more information on how coefficients of the logistic function were determined using historical ISO 14001 data.

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

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).

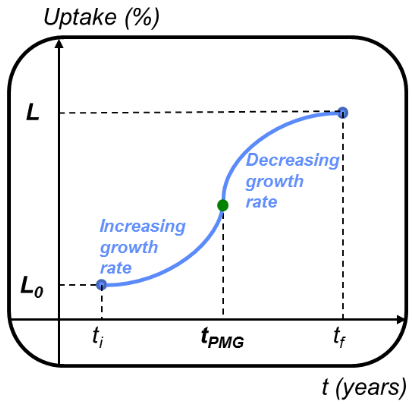

Figure 2: Generic Logistic Function Representation

k **(Function Steepness/Growth Rate)** is the steepness of a logistic function used to model a non-linear ISO 50001 EnMS adoption.

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".

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. Data sources used to populate Figure 3 are further explained in this section.

	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	24.6%	29.00	$19,838	159.8	52.4%	16.10	$28,150	159.8
Natural Gas	17.8%	21.00	$4,995	50.3	24.0%	7.38	$7,677	50.3
Coal (Industrial)	35.6%	42.00	$3,033	89.7	0.0%	0.00	$3,033	89.7
Biomass and Waste	6.5%	7.64	$3,779	80.5	2.9%	0.89	$3,779	80.5
Coke and Breeze (Metallurgical Coal)	0.0%	0.00	$5,213	107.7	4.2%	1.30	$5,213	107.7
Distillate Fuel Oils (Oil Products)	11.0%	13.00	$24,909	70.2	12.0%	3.68	$25,875	70.2
Residual Fuel Oils	0.0%	0.00	$18,956	70.2	0.0%	0.00	$20,947	70.2
LPG (and NGL)	0.0%	0.00	$13,374	58.5	0.0%	0.00	$13,374	58.5
Steam and Hot Water (Imported to facilities)	4.6%	5.48	$5,327	83.6	4.5%	1.38	$5,099	83.6
Total Energy, Blended Cost, & Emissions	100%	118.12	$10,070	96.90	100%	30.73	$20,250	114.86

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

Energy Consumption is the amount of delivered energy consumed by the industrial and service sectors globally. 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).[3]

Price of Energy by sector and source in 2013 dollar.

> DEFAULT VALUES:
>
> Prices of Coal, Electricity, Natural Gas, and Oil Products[4] 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. The default value for the price of Biomass

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

[4] Oil Products are referred to Distillate Fuel Oil in the Annual Energy Outlook document.

and Waste for both industrial and service sectors is the straight average of those components as reported by MECS. (U.S. DOE, 2010)

Price of commercial heat for the industrial sector (typically steam) is obtained from MECS (U.S. DOE, 2010), and for the service sector (typically hot water) is obtained from Commercial Buildings Energy Consumption Survey (CBECS) (U.S. DOE, 2003).

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[5]. The global emissions intensity of producing and distributing one unit of electricity is calculated by using the electricity generation mix reported by the IEA (IEA, 2015). The calculated number assuming a 3.01 electricity generation multipliers comes out to be <u>160 tCO_2/TJ</u> which is in close agreement with the value of <u>169 tCO_2/TJ</u> as reported by Lawrence Berkeley National Laboratory's (LBNL) Energy Analysis and Environmental Impacts Division (de la Rue du Can, Price, & Zwickel, 2015).

5 Delivered 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 the years of interest.

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

6 Results

By using the data discussed in sections 3 through 5 and the impact estimation methodology, energy, cost, and CO_2 emission savings are calculated for the year 2030 assuming 50% uptake by industrial and service sectors. Figure 4 presents results estimated for impact of ISO 50001 EnMS globally in the year 2030. 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 in an annual basis.

[5] Typically CO_2 emissions from biomass fuel combustion (also known as biogenic CO_2) are not included in the total GHG emission factor because the uptake of CO_2 during biomass growth results in zero net emissions over time (U.S. DOE, 2010)

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	$ 53.9	680.9	143	63.26	$ 352.0	4,130.1
	Service	5.47	$ 43.5	324.1	68	41.61	$ 350.0	2,409.2
	Total (I&S)	15.85	$ 97.4	1,004.9	212	104.87	$ 702.0	6,539.3

Figure 4: Screenshot of the Numerical Results section of the IET50001 worksheet

Appendix A

Parameters for the logistic function are determined using historical ISO 14001 data (ISO, 2015). Figure 5 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 the first iteration 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.

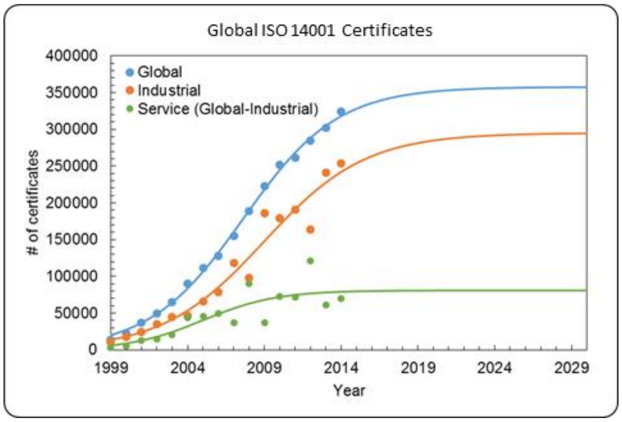

Figure 5: First iteration for determining tm and k

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. Historic global data of ISO 14001 certification include data from world economic crash of 2008; therefore, data points taken beyond the year 2006 are omitted when calculating revised values for t_m and k. Figure 6 shows the resulting historic data points and the second iteration of the logistic curve. Table 2 summarizes the resulting function parameters and the corresponding R^2 values resulting from the second round of iteration.

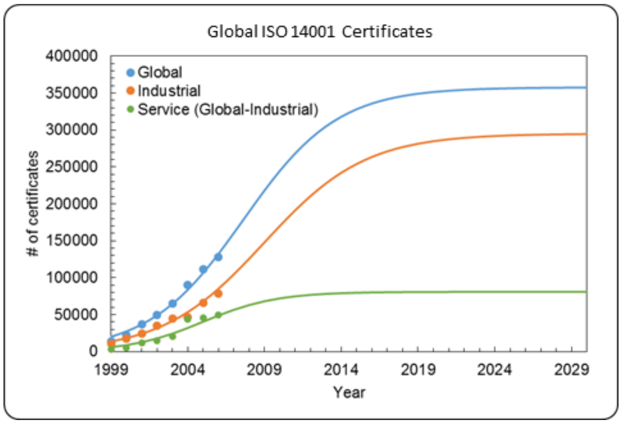

Figure 6: Second iteration for determining t_m and k values

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

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