METRICS

This document describes the metrics used in the RenewIT. Moreover, the methodology used to calculate them also is explained. For more information about the metrics developed and used in the framework of the RenewIT project, download the Deliverable D3.1 Metrics for Net Zero Energy Data Centres.

ENERGY USE

NON-RENEWABLE PRIMARY ENERGY CONSUMPTION

The non-renewable primary energy ($Pe_{DC,nren}$) means energy from non-renewable sources which has not undergone any conversion or transformation process. The conversion from delivered energy (e_{del}) to the amount of non-renewable primary energy required is done through the non-renewable primary energy weighting factors ($w_{del,nren}$).

$$Pe_{DC,nren} = \left[\left(e_{del,el} \cdot w_{del,nren,el}\right) + \left(e_{del,fuel} \cdot w_{del,nren.fuel}\right) + \left(e_{del,Dheat} \cdot w_{del,nren,Dheat}\right) + \left(e_{del,DCool} \cdot w_{del,nren,DCool}\right)\right] - \left[\left(e_{exp,el} \cdot w_{exp,nren,el}\right) + \left(e_{exp,heat} \cdot w_{exp,nren,heat}\right)\right]$$

$e_{del,i}$ = energy delivered by energy carrier i

$w_{del,nren,i}$ = non-renewable weighting (or conversion factor) of energy delivered by source i

$e_{exp,i}$ = energy exported from energy carrier i

$w_{exp,nren,i}$ = non-renewable weighting (or conversion factor) of energy exported by source i

where*:*

el = electricity

$fuel$ = natural gas, biogas or biomass

$Dheat$ = district heating

$DCool$ = district cooling

heat = heat

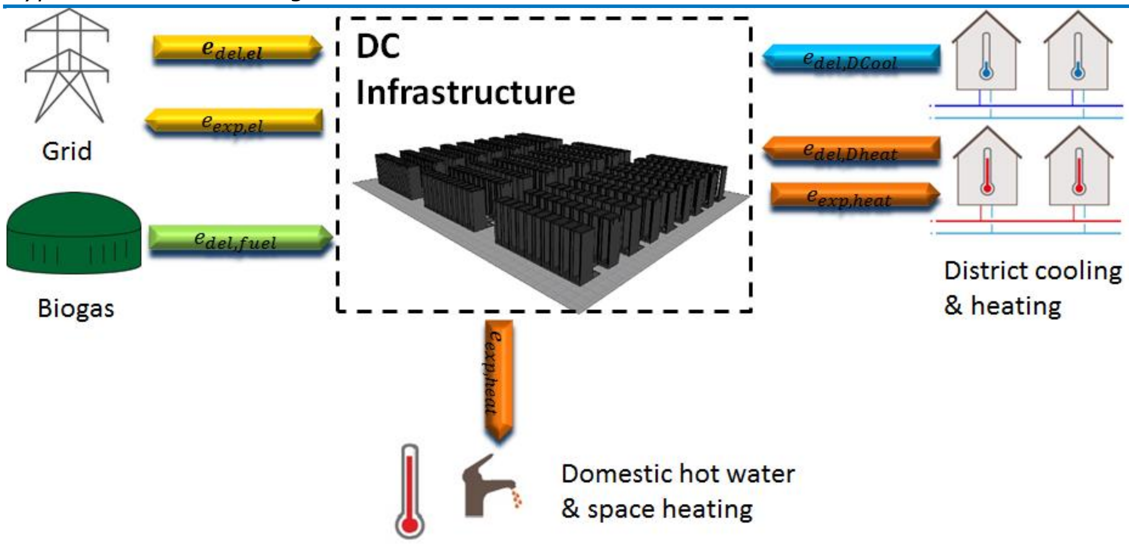

Figure 1 Delivered and exported energy fluxes of the Data Centre.

The non-renewable primary energy is expressed in [MWh_{PE}/year]. The result given is for one year.

NON-RENEWABLE PRIMARY ENERGY CONSUMPTION PER KILOWATT IT

The non-renewable primary energy per kilowatt IT ($Pe_{DC,nren,IT}$) is the normalized annual consumption of non-renewable primary energy by the total IT power capacity of the installation.

$$Pe_{DC,nren,IT} = \frac{Pe_{DC,nren}}{(P_{IT,inst} \cdot IT_{safety,margin})}$$

$P_{IT,inst} = maximum\ expected\ IT\ power\ consumption$

$IT_{safety,margin} = IT\ oversizing\ safety\ margin$

The non-renewable primary energy per kilowatt IT is expressed in [MWh_{PE}/kW_{IT}·year]. The result given is for one year.

ECONOMIC FIGURES

TOTAL COST OF OWNERSHIP (TCO)

The total cost of ownership (TCO) is the addition of the initial investment costs ($CAPEX$), the operational expenditures ($OPEX$), the residual value of components (RV) and the replacement cost (REC). The TCO is used to assess the true total costs of building, owning, and operating their Data Centre physical facilities during a certain amount of years. In the RenewIT Tool the maximum assessment period (T) is equal to the system life span (T_n) which is 15 years; therefore the cost of replacement of the components is neglected in the economics calculations.

$$TCO\ (T) = CAPEX + OPEX(T) + RV(T) + REC(T)$$

$CAPEX = initial\ investment\ costs$

$OPEX(T) = \ operational\ expenditures\ at\ the\ end\ of\ the\ assesment\ \ period\ T$

$RV(T) = residual\ value\ of\ the\ system\ at\ the\ end\ of\ the\ assessment\ \ period\ T$

$REC(T) = replacement\ cost\ of\ the\ system\ at\ the\ end\ of\ the\ assessment\ \ period\ T$

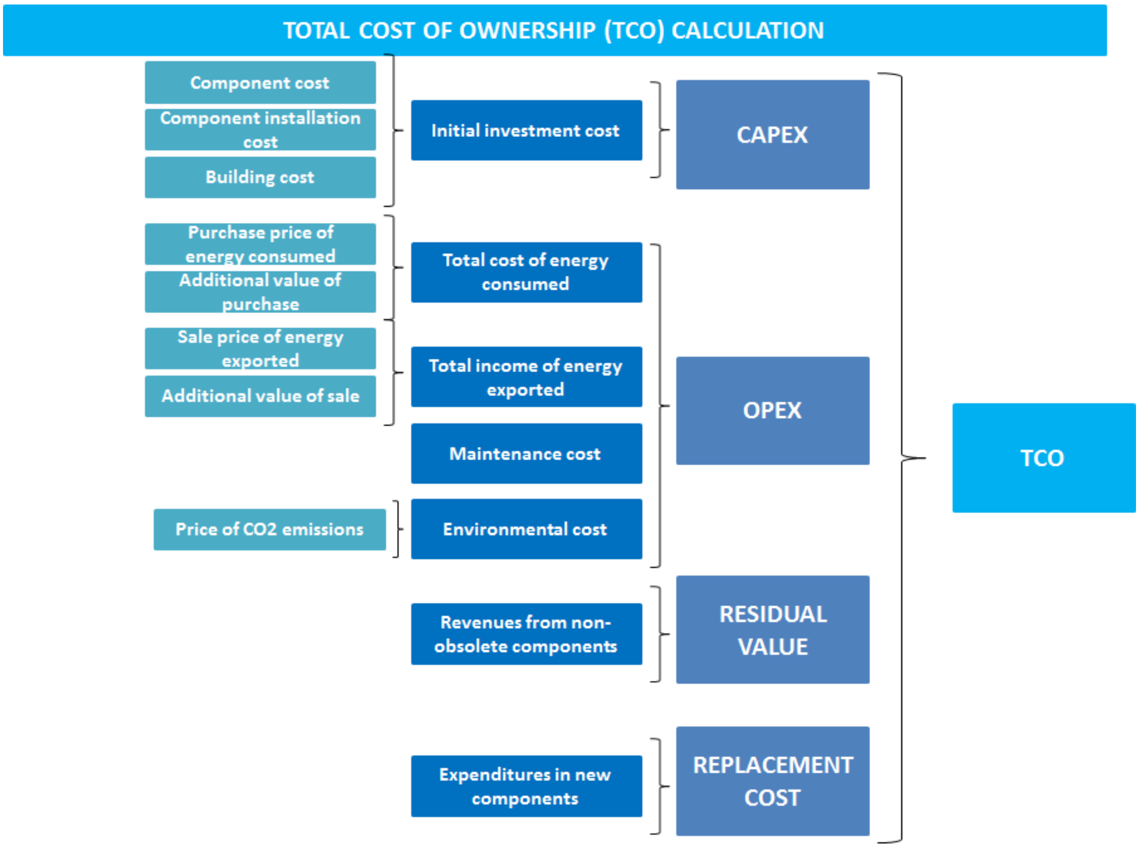

Figure 2 Diagram about the economic fluxes for the economic evaluation of an energy system.

The total cost of ownership is expressed in [Thousands of €]. The number of years considered for the calculation of the total cost of ownership depends on the assessment period defined.

CAPITAL EXPENDITURE (CAPEX)

This is the amount of money used to acquire assets or improve the useful life of existing assets. In general terms, CAPEX include purchasing (CC_j) and installation costs (CI_j) of cooling and power components, construction costs of the Data Centre (CC_{DC}) and any investment realized to improve or enlarge the Data Centre facility. The cost of the servers is not included in the economic evaluation.

$$CAPEX = \sum_{j=1}^{NC} CC_j + CI_j + CC_{DC}$$

$NC = number\ of\ components$

$CC_j = investment\ cost\ of\ component\ j$

$CI_j = installation\ cost\ of\ component\ j$

$CC_{DC} = construction\ cost\ of\ the\ Data\ Centre, mainly\ building\ cost.$

The capital expenditure is expressed in [Thousands of €]

OPERATIONAL EXPENDITURE (OPEX)

Operational expenditure (OPEX) is the ongoing costs for running a product, business or system. In the case of Data Centres, OPEX includes: energy costs ($OPEX_{EC}(T)$) (electricity costs and/or other energy carrier costs), maintenance costs ($OPEX_{CM}(T)$) and environmental costs[1] ($OPEX_{CO_2}(T)$). The energy costs should be calculated for each energy carrier and prices can be temporary dependent. All the costs are subjected to the discount, inflation, market and evolution rates of the prices. The evolution rates used for the energy source considered in the RenewIT tool are listed in Table 1. The values assumed for the rest of rates are shown in Table 2.

$$OPEX(T) = OPEX_{EC}(T) + OPEX_{CM}(T) + OPEX_{CO_2}(T)$$

$OPEX_{EC}(T) = energy\ costs\ at\ the\ end\ of\ the\ assessment\ period\ T$

$OPEX_{CM}(T) = components\ maintenance\ cost\ at\ the\ end\ of\ the\ assessment\ period\ T$

$OPEX_{CO_2}(T) = environmental\ costs\ at\ the\ end\ of\ the\ assessment\ period\ T$

where:

$$OPEX_{EC}(T) = \sum_{i=1}^{NES} [\sum_{t=1}^{T} (e_{del,i}(t) \cdot w_{del,€,i}(t) - e_{exp,i}(t) \cdot w_{exp,€,i}(t))] \cdot RDE(T)_i + ADC_i + ADC2_i$$

$NES = number\ of\ energy\ sources$

$e_{del,i}(t)$ = *energy delivered by energy carrier i, at year t*

$w_{del,€,i}(t)$ = *purchase price of energy provided by the energy carrier i, at year t*

$e_{exp,i}(t)$ = *energy exported from energy carrier i, at year t*

$w_{exp,€,i}(t)$ = *sell price of energy exported by the energy carrier i, at year t.*

$ADC_i = additional\ cost, if\ any, of\ energy\ carrier\ i, for\ instance\ connection\ cost$

[1] The RenewIT tool gives the possibility to the user to choose to include or not the environmental costs.

$ADC2_i = second\ additional\ cost, if\ any, of\ energy\ carrier\ i, for\ instance\ fixed\ terms$

$RDE(T)_i = discount\ rate\ t\ the\ end\ of\ the\ assessment\ period\ T, of\ energy\ carrier\ i$

where:

$$RDE(T)_i = \sum_{t=1}^{T} \frac{1}{(1 + \frac{RRE_i}{100})^t}$$

$$RRE_i = \frac{R - RX_i}{1 + (\frac{RX_i}{100})}$$

$RRE_i = real\ interest\ rate\ of\ energy\ carrier\ i$

$R = market\ interest\ rate$

$RX_i = evolution\ rate\ of\ energy\ carrier\ i$

Table 1 Evolution rates of the energy sources considered in the RenewIT tool.

Energy source	Evolution rate (%)
Biogas	2.8
District heating	2.8
District cooling	2.8
Electricity	2.8
CO_2	5
H_2O	3

$$OPEX_{CM}(T) = \left[\sum_{t=1}^{T}\sum_{j=1}^{NC} CM_j\,(t)\right] \cdot RD(T)$$

$CM_j(t) = maintenance\ cost\ of\ component\ j, at\ year\ t$

$RD(T) = discount\ rate\ at\ the\ end\ of\ the\ assessment\ period\ T$

where:

$$RD(T) = \sum_{t=1}^{T} \frac{1}{(1 + \frac{RR}{100})^t}$$

$$RR = \frac{R - RI}{1 + (\frac{RI}{100})}$$

$RR = real\ interest\ rate$

$RI = inflation\ rate$

Table 2 Value of the rates used for the economic evaluation.

Rate	%
R	5
RI	2
RR	2.94
RD (at t=1)	0.97

$$OPEX_{CO_2}(T) = \sum_{i=1}^{NES}[\sum_{t=1}^{T}(EM_{CO_2,i}(t) \cdot w_{€,CO_2}(t))] \cdot RDE(T)_{CO_2}$$

$EM_{CO_2,i}(t) = CO_2\ emissions\ of\ energy\ carrier\ i, at\ year\ t$

$w_{€,CO_2}(t) = price\ of\ CO_2\ emissions, at\ year\ t$

$RDE(T)_{CO_2} = CO_2\ emissions\ discount\ rate\ at\ the\ end\ of\ the\ assesment\ period\ T$

The operational expenditure is expressed in [Thousands of €]. The number of years considered for the calculation of the operational expenditures depends on the assessment period defined.

Residual value of components (RV)

The assessment period defines the timeframe used to perform the economic evaluation of the system. This value will not only affect the OPEX of the system, taking more or less consumption (energy used per year) into account for the evaluation. It will also affect the TCO, due to the fact that components have a certain life span during which the providers ensure their correct functionality. Therefore, depending on the life span (T_n) of the components and the assessment period (T) some residual value of the components (RV) are still present. Being the residual value the future value of a good in terms of absolute value in monetary terms. The procedure followed to compute the residual value of components is based on the methodology defined by the European Norm EN 15459:2008[2].

$$RV(T) = (\sum_{j=1}^{NC} CC_j) \cdot (\frac{T - T_n}{T_n}) \cdot RD(T)$$

$NC = number\ of\ components$

$CC_j = investment\ cost\ of\ component\ j$

$T = assessment\ period$

$T_n = system\ lifespan$

[2] CEN, 2008, Energy performance of buildings – Economic evaluation procedure for energy systems in buildings, EN 15459:2008, European Committee for Standardization.

$RD(T) = discount\ rate\ at\ the\ end\ of\ the\ assessment\ period\ T$

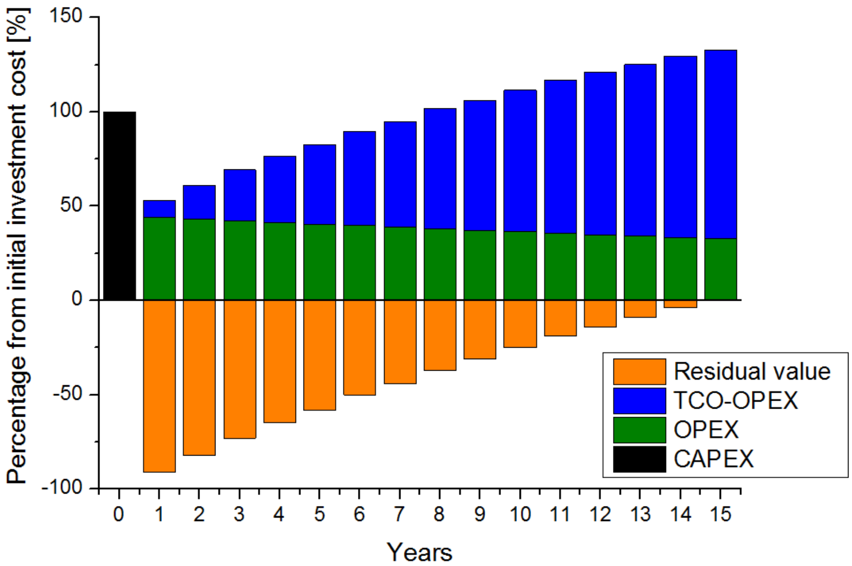

Figure 3 Evolution of the Data Centre TCO

CAPITAL EXPENDITURE PER KILOWATT IT (CAPEX PER KILOWATT IT)

The capital expenditures are normalized by the total IT power capacity of the Data Centre, indicating the investment that have to be done for each kilowatt IT that is installed. The investment costs of a traditional Data Centre, in average values of € per unit of IT power, is 10.784 €/kW_{IT}.

$$CAPEX_{IT} = \frac{CAPEX}{(\,P_{IT,inst} \cdot \ IT_{safety,margin})}$$

$OPEX(T)_{DC} = \ operational\ expenditures\ of\ Data\ Centre\ at\ year\ T$

$T = assessment\ period$

$P_{IT,inst} = maximum\ expected\ IT\ power\ consumption$

$IT_{safety,margin} = IT\ oversizing\ safety\ margin$

The capital expenditure per kilowatt IT is expressed in [€/kW_{IT}]

OPERATIONAL EXPENDITURES PER KILOWATT IT (OPEX)

The annual operational expenditures are normalized by the total IT power capacity of the Data Centre, indicating the cost of process each kilowatt IT in our facility.

$$OPEX_{IT,year} = \frac{(\frac{OPEX(T)}{T})}{(\,P_{IT,inst} \cdot \ IT_{safety,margin})}$$

$OPEX(T) = \ operational\ expenditures\ of\ Data\ Centre\ at\ year\ T$

$T = assessment\ period$

$P_{IT,inst} = maximum\ expected\ IT\ power\ consumption$

$IT_{safety,margin} = IT\ oversizing\ safety\ margin$

The annual operational expenditure per kilowatt IT is expressed in [€/kW$_{IT}$·year]. The result given is for one year.

Capacity Analysis

Space capacity credit ($CC_{IT,m2}$)

The space capacity credit (CC_{IT,m^2}) measures the occupied space in the whitespace and is calculated as the relation between the Data Centre whitespace area and the surface used by the racks.

$$CC_{IT,m^2} = (1 - \frac{Actual\ whitespace\ m^2 occupied}{Design\ whitespace\ m^2}) \cdot 100$$

The space capacity credit is expressed in [%]

IT installed capacity credit ($CC_{IT,inst}$)

The IT installed capacity credit ($CC_{IT,inst}$) defines the unused IT capacity and it is calculated as the relation between the IT peak power consumption of the system (P_{IT}) and the maximum IT peak power that the Data Centre is sized ($P_{IT,inst}$).

$$CC_{IT,inst} = (1 - \frac{P_{IT}}{P_{IT,inst}}) \cdot 100$$

$P_{IT} = IT\ peak\ power\ consumption$

$P_{IT,inst} = maximum\ expected\ IT\ power\ consumption$

The IT installed capacity credit is expressed in [%]

Total facility installed capacity credit ($CC_{FAC,INST}$)

The total facility installed capacity credit ($CC_{fac,inst}$) defines the available electric capacity of the facility. It is calculated as the ratio between the facility peak power consumption (P_{fac}) and the maximum facility peak power that the installation can handle ($P_{fac,inst}$).

$$CC_{fac,inst} = (1 - \frac{P_{fac}}{P_{fac,inst}}) \cdot 100$$

$P_{fac} = facility\ peak\ power\ consumption$

$P_{fac,inst} = installed\ total\ facility\ power\ capacity$

The total facility installed capacity credit is expressed in [%]

ENERGY EFFICIENCY AND RENEWABLE ENERGY

POWER USAGE EFFECTIVENESS (PUE)

The power usage effectiveness (PUE) is calculated as the total primary energy consumption of the Data Centre ($Pe_{DC,tot}$) divided by the total primary energy delivered to the IT equipment ($Pe_{DC,tot,IT}$). PUE is a metric to identify how efficient the electricity is used from the Data Centre control to the IT equipment, so it gives the relation of the extra amount of energy consumed in order to keep the servers working properly. PUE is defined in coherence with the standard ISO-IEC 30134-2 Information Technology – Data Centres – Key Performance Indicators – Part2: Power Usage Effectiveness (PUE), using the following general formulation.

$$PUE = \frac{Pe_{DC,tot}}{Pe_{DC,tot,IT}} = \frac{\sum_i e_{del,i} \cdot w_{del,tot,i} - \sum_i e_{exp,el} \cdot w_{del,tot,el} + e_{ren,i} \cdot w_{del,tot,i}}{e_{del,IT} \cdot w_{tot,IT}}$$

where

$$w_{tot,IT} = \frac{Primary\ energy\ to\ prodcue\ electricity + Purchased\ electricity}{All\ electricity\ at\ site}$$

$$w_{tot,IT} = \frac{e_{del,i} \cdot w_{del,tot,i} + e_{grid} \cdot w_{del,tot,el}}{e_{del,i} + e_{grid}}$$

$e_{del,i}$ = *energy delivered by energy carrier i*

$w_{del,tot,i}$ = *total weighting (or conversion factor) of energy delivered by source i*

$e_{exp,el}$ = *exported electrical energy*

$w_{exp,tot,el}$ = *total weighting (or conversion factor) of the exported electrical energy*

$e_{ren,i} = renewable\ energy\ delivered\ by\ energy\ carrier\ i$

$e_{del,IT} = delivered\ energy\ to\ the\ IT\ servers\ of\ the\ Data\ Centre$

$w_{tot,IT}$[3] $= total\ weighting\ (or\ conversion\ factor)\ for\ the\ delivered\ energy\ to\ the\ IT\ servers$

The power usage effectiveness is a dimensionless metric.

COOLING SEASONAL PERFORMANCE FACTOR (SPF)

The cooling seasonal performance metric (SPF) calculates the relation between the cooling energy produced ($Q_{cool,DC}$) and the amount of electrical

[3] In case of use more energy sources than the electricity from the grid otherwise $w_{tot,IT} = w_{del,tot,el}$

energy consumed to produce it (P_{el}), showing the efficiency of the cooling system.

$$SPF = \frac{\sum_i Q_{cool,DC,i}}{\sum_i P_{el,i}}$$

$Q_{cool,DC,i} = heat\ removed\ from\ the\ Data\ Centre\ by\ component\ i$

$P_{el,i} = electrical\ power\ consumed\ by\ component\ i$

The cooling seasonal performance factor is a dimensionless metric.

RENEWABLE ENERGY RATIO (RER)

The renewable energy ratio (RER_{EP}) is the metric that allows calculating the share of renewable energy use in a Data Centre. The renewable energy ratio is calculated relative to all energy use in the Data Centre, in terms of total primary energy. The RenewIT tool is also taking into account the percentage of renewable energy that the national electricity grid has.

$$RER_{EP} = \frac{\sum_i e_{ren,i} + \sum_i[(w_{del,tot,i} - w_{del,nren,i}) \cdot e_{del,i}]}{\sum_i e_{ren,i} + \sum_i[(w_{del,tot,i} \cdot e_{del,i}) - \sum_i[(w_{exp,tot,i} \cdot e_{exp,i})}$$

$e_{del,i}$ = energy delivered by energy carrier i

$w_{del,tot,i}$ = total weighting (or conversion factor) of energy delivered by source i

$w_{del,nren,i}$ = non-renewable weighting (or conversion factor) of energy delivered by source i

$e_{exp,i}$ = energy exported from energy carrier i

$w_{exp,tot,i}$ = total weighting (or conversion factor) of energy delivered by source i

$e_{ren,i} = renewable\ energy\ delivered\ to\ the\ Data\ Centre\ by\ energy\ carrier\ i$

The renewable energy ratio is expressed in [%].

PRIMARY ENERGY SAVINGS

FRACTIONAL ENERGY SAVINGS (F_{SAVEP})

The fractional energy savings ($fsav_{EP}$) shows the savings achieved on the non-renewable primary energy consumption by a technical solution ($PE^{sol}_{DC,nren}$), and the energy efficiency measures taken, compared to a reference case or legacy Data Centre ($PE^{ref}_{DC,nren}$).

$$fsav_{EP} = \frac{PE^{ref}_{DC,nren} - PE^{sol}_{DC,nren}}{PE^{ref}_{DC,nren}} \cdot 100 = \left(1 - \frac{PE^{sol}_{DC,nren}}{PE^{ref}_{DC,nren}}\right) \cdot 100$$

where:

$PE_{DC,nren}^{ref}$ = *non renewable primary energy consumption of the reference case*

$PE_{DC,nren}^{sol}$ = *non renewable primary energy consumption of the solution case*

The fractional energy savings are expressed in [%].The result given is for one year.

Number of equivalent houses consumption

This indicator shows the equivalent residential houses that can be energetically satisfied with the savings achieved on the non-renewable primary energy consumption by a technical solution, and a set of energy efficiency measures, respect to a reference Data Centre. The average energy consumption of a European (EU) household has been assumed 16282 kWh/dwelling, based on the report of Odyssee[4].

$$Number\ of\ houses = \frac{PE_{DC,nren}^{ref} - PE_{DC,nren}^{sol}}{PE_{House}}$$

$PE_{DC,nren}^{ref}$ = *non renewable primary energy consumption of the reference case*

$PE_{DC,nren}^{sol}$ = *non renewable primary energy consumption of the solution case*

PE_{House} = *average non renewable primary energy consumption of a EU household*

The number of equivalent houses consumption is expressed in [Houses]. The result given is for one year.

Total cost of ownership Savings

Fractional economic savings (fsavTCO)

The fractional economic savings ($fsav_{TCO}$) shows the savings achieved on the total cost of ownership by a technical solution (TCO_{sol}), and the energy efficiency measures taken, compared to a reference case or legacy Data Centre (TCO_{ref}).

$$fsav_{TCO} = \left(1 - \frac{TCO_{sol}}{TCO_{ref}}\right) \cdot 100$$

TCO_{sol} = *total cost of ownership of the solution case*

TCO_{ref} = *total cost of ownership of the reference case*

[4] Odyssee, May 2015, "Energy Efficiency Trends for households in the EU".

The fractional economic savings are expressed in [%].The percentage of TCO savings depends on the number of years taken into account for the economic evaluation. Where the number of years is defined by the assessment period selected.

Annual savings in operating expenditure per kilowatt IT ($OPEX_{,kWIT,\ year}$)

This value shows the annual reduction in the operational expenditures ($OPEX_{savings}$) achieved by the concept ($OPEX_{IT,year,sol}$), and the energy efficiency measures taken, compared to a reference case ($OPEX_{IT,year,ref}$). The value is normalized by the total IT power capacity of the facility given the ratio of euros saved for each kilowatt of IT installed.

$$OPEX_{savings} = OPEX_{IT,year,sol} - OPEX_{IT,year,ref}$$

$OPEX_{IT,year,sol} = normalized\ annual\ operational\ expenditures\ of\ the\ solution\ case$

$OPEX_{IT,year,ref} = normalized\ annual\ operational\ expenditures\ of\ the\ reference\ case$

The savings in operational expenditures are expressed in [€/kW_{IT}·year]. The result given is for one year.

Payback Period

It is defined as the length of time, usually expressed in years, needed for an investment's net cash receipts to cover completely the initial outlay expended in acquiring the investment.

$$Payback\ period = \frac{Total\ Investment}{Annual\ Cash\ Inflows} = \frac{(TCO_{sol} - TCO_{ref})}{(OPEX_{ref,year} - OPEX_{sol,year})}$$

$TCO_{sol} = total\ cost\ of\ ownership\ of\ the\ solution\ case$

$TCO_{ref} = total\ cost\ of\ ownership\ of\ the\ reference\ case$

$OPEX_{ref,year} = annual\ operational\ expenditures\ of\ the\ reference\ case$

$OPEX_{sol,year} = annual\ operational\ expenditures\ of\ the\ solution\ case$

The payback period is expressed in [years]

CO_2 Emissions Savings

This metric measure the annual savings achieved on the CO_2 emissions ($CO_{2},_{savings}$) by the technical solution ($EM_{CO_2}^{sol}$), and advanced concepts applied, compared to a reference case ($EM_{CO_2}^{ref}$). The weighting factor used are the CO_2 emission coefficient (w_{CO_2}) which is the quantity of CO_2 emitted to the atmosphere per unit of energy, for a given energy carrier.

$$CO_{2,savings} = EM_{CO_2}^{ref} - EM_{CO_2}^{sol}$$

where:

$$EM_{CO_2}^{DC} = \sum_i e_{del,i} \cdot w_{del,CO_2,i} + \sum_i e_{exp,i} \cdot w_{exp,CO_2,i}$$

$EM_{CO_2}^{DC} = CO_2$ *emissions of a Data Centre*

$e_{del,i}$ *= energy delivered by energy carrier i*

$w_{del,CO_2,i}$ *=* CO_2 *emission weighting (or conversion factor) of energy delivered by source i*

$e_{exp,i}$ *= energy exported from energy carrier i*

$w_{exp,CO_2,i}$ *=* CO_2 *emission weighting (or conversion factor) of energy exported by source i*

The CO_2 emissions savings are expressed in [tCO_2/year]. The result given is for one year.

Annual free cooling hours

Annual hours applying free cooling strategy with the selected Data Centre configuration.

The annual free cooling hours is expressed in [hours/year][5]

Net import energy

The net import electrical energy ($ne_{imp,el}$) is the difference between the annual delivered ($e_{del,el}$) and exported ($e_{exp,el}$) electrical energy. Therefore measure the annual quantity of electrical energy that is subtracted from the grid.

$$ne_{imp,el} = e_{del,el} - e_{exp,el}$$

$e_{del,el}$ *= delivered electrical energy*

$e_{exp,el}$ *= exported electrical energy*

The net energy import is expressed in [MWh/year]. The result given is for one year.

[5] The total number of hours in a year is 8760 hours