NET ZERO ENERGY APPROACHES FOR INDUSTRIAL MICROGRIDS

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Objectives

- Address the concept of net zero energy to assist in the study and development of future microgrids for buildings with annual zero energy consumption.

- Overview the most common definition approaches available for zero energy buildings and propose a definition for zero energy microgrids based on these definitions.

- Address the importance of net metering structures in zero energy buildings and their possible integration into microgrid systems.

- Evaluate whether five distinct industrial and commercial buildings can achieve annual zero energy by deploying on-site renewable sources within their site boundary through a case study.
Building Sector

The building sector is a major contributor to the global energy consumption and carbon emissions, accounting for 40% of total primary energy consumption. Minimizing the energy consumption and carbon footprint buildings has become essential to meet environmental goals and reduce the use of fossil fuels for power generation.

This can be achieved through:

✓ Energy efficiency measures to decrease building energy consumption.
✓ On-site renewable sources to avoid imported energy from conventional energy sources.

The integration of microgrids also plays an important role in the building sector, being an important asset to help mitigate the environmental impact from the use of fossil fuels.
What is a Microgrid?

A microgrid is seen as a small distribution grid integrated with microgeneration units, storage units and controllable loads serving economic, technical and environmental aims. In addition, it should be able to operate in both grid-connected and islanded mode.

Microgrids may constitute a great opportunity towards achieving net zero energy in efficient buildings.
What is a Microgrid?

A microgrid is connected to the public grid at the point of common coupling (PCC), enabling active interaction with the distribution system operator (DSO).

- During grid-connected operation mode, the microgrid is connected to the public power grid at the point of common coupling (PCC).
- During islanded operation mode, the microgrid is disconnected from the public power grid and operates autonomously to supply the critical loads.
Zero Energy Buildings

“A zero-energy building (ZEB) is an energy efficient building where, on a source energy basis, the actual annual delivered energy is less than or equal to the on-site renewable exported energy.” – Common definition according to the U.S. Department of Energy
Zero Energy Buildings

In other words, ZEBs are energy efficient buildings connected to the public grid and make use of the on-site renewable energy systems located within the site boundary to reduce the imported energy from the grid.

- **Delivered energy**

  The delivered energy is any type of primary or secondary energy imported from the utility grid and consumed by the building to fulfil energy and thermal needs, including electricity, natural gas, fuel oil, propane, wood, coal, hot water and chilled water.

- **Exported energy**

  The exported energy is any excess renewable energy produced by on-site renewable sources that can be exported to the utility grid.

- **Site boundary**

  The site boundary can be larger than the building footprint and it is the only area available to deploy renewable energy sources (RES) for on-site energy production.
Zero Energy Buildings

There are other definition approaches that are strongly dependent on the project goals and interests such as the amount of energy accounted for at the source or at the site, as well as energy costs and environmental concerns associated with the use of fossil fuels.

<table>
<thead>
<tr>
<th></th>
<th>Easier to implement</th>
<th>Easier to achieve</th>
<th>Equates fuel types</th>
<th>Conversion factors</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Site ZEB:</strong> Produces at least as much annual energy as it uses, when accounted for at the site.</td>
<td>✓</td>
<td>✗</td>
<td>✗</td>
<td>✗</td>
</tr>
<tr>
<td><strong>Source ZEB:</strong> Produces at least as much annual energy as it uses, when accounted for at the source.</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Cost ZEB:</strong> Cost paid for the exported annual energy is at least equal to the cost paid for the imported energy.</td>
<td>✓</td>
<td>✗</td>
<td>✓</td>
<td>✗</td>
</tr>
<tr>
<td><strong>Emission ZEB:</strong> Produces at least as much annual energy from emission-free renewable sources as it uses from other sources.</td>
<td>✗</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Zero Energy Buildings

In order to achieve net zero energy, a building should:

1st

Supply-side

Implement energy efficiency measures to reduce on-site energy consumption.

2nd

On-site Supply

Use on-site renewable sources located inside of the building footprint and site boundary.

3rd

Off-site Supply

Purchase and use off-site renewable sources imported or collected from outside of the site boundary.
Zero Energy Buildings

Some energy efficiency measures for industrial buildings to reduce the energy consumed in specific industrial processes.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Energy efficiency measures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulp and paper</td>
<td>Use of recycled pulp and heat recovered from bleaching plants effluents and thermo-mechanical pulping plants; use of pulping aids to increase pulping yield; optimization of water removal during forming and pressing stages</td>
</tr>
<tr>
<td>Iron and steel</td>
<td>Insulation of reheat furnaces to reduce heat losses; use of gas recovered from blast furnaces and basic oxygen furnaces; adoption of foamy slag practices in electric arc furnaces</td>
</tr>
<tr>
<td>Non-metallic minerals</td>
<td>Reduction of air leaks and improvement of insulations in the glass production; use of heat recovered from furnaces; reduction of heat losses in kiln shells; optimization of grate coolers in the cement production</td>
</tr>
<tr>
<td>Non-ferrous metals</td>
<td>Adjustment of air to fuel ratios to improve furnace combustion; use of recycled aluminium and exhaust gas recovered from furnaces; increase of oxygen concentration in the combustion air during the smelting process</td>
</tr>
<tr>
<td>Chemical and pharmaceutical</td>
<td>Improvement of air filtration quality and efficiency in clean rooms; reduction of volumetric flow rate in fume hoods; optimization of the distillation column operation</td>
</tr>
<tr>
<td>Petroleum refineries</td>
<td>Optimization of flares to reduce losses; recovery of hydrocarbons from blow-down systems; insulation of heated product storage tanks; mitigation of fouling in the crude distillation process</td>
</tr>
<tr>
<td>Food and beverage</td>
<td>Implementation of multiple stage drying processes; use of heat and hold techniques in the blanching process; use of vapour recompression and membrane filtration for water removal</td>
</tr>
</tbody>
</table>
Zero Energy Buildings

Why are microgrids important to achieve net zero energy in buildings?

Because microgrids significantly increase the reliability and quality of the power supplied to the loads without disturbances and interruptions.

In particular, microgrids can:

✓ Provide a safe integration of several renewable energy sources and distributed generation units into the building sector.
✓ Enable control and coordination of the available resources, allowing building owners to correctly manage their energy consumption and increase overall building efficiency.
✓ Contribute to a significant reduction in energy costs, which is particularly important in cost ZEBs.
Zero Energy Buildings

NET ZERO ENERGY MICROGRIDS!

According to the literature, an off-grid or standalone ZEB is defined as: “a building that does not require a connection to the grid, meaning it can autonomously supply itself with energy, as it has enough capacity to store energy for use during nighttime”.

Therefore, both net ZEB and standalone ZEB definitions can be applied in order to establish a definition for zero energy microgrids.

Taking this into consideration, a zero energy microgrid can be defined as:

- A microgrid that produces at least as much annual renewable energy from distributed energy resources as it imports from the public grid during grid-connected operation and has enough capacity to produce and store renewable energy for use during islanded operation.
Net Metering

Net metering is a billing system that credits customers for the excess electricity fed into the utility grid. It consists of a bi-directional meter that measures the balance between electricity imported from the utility grid and excess electricity produced by the customer.

This allows the customer to take advantage of the credits gained and import electricity from the utility grid during periods when local generation is at a minimum.
Net Metering

Net metering policies vary by region and country, which may denote how much the credits are worth and how long the customer can retain them.

- Cost ZEBs require a net metering agreement that allows the customers to be credited at avoided generation rates, in which customers are credited for their excess electricity according to the costs saved by the utility company for not having to generate this electricity. In general, small producers are credited at full retail rate for any excess electricity they feed into the grid.

What about microgrids?

Even though microgrids are well suited for net metering programs, they are often excluded from most policies because only a single customer is eligible for net metering and microgrids usually involve multiple customers.
Net Metering

However, in the United States...

- The state of Pennsylvania allows net metering in renewable installations up to 5 MW for microgrids.

- The state of Connecticut applies virtual net metering that allows each municipal customer to host up to 5 non-municipal accounts in critical facilities connected to a microgrid.

- In virtual net metering, the credits are applied to the utility account instead of the customer account. This overcomes problems regarding distributed generation in buildings with multiple occupants.

- Because microgrids can also integrate distributed generation considered non-renewable, net metering can only be applied in microgrids containing exclusively renewable sources and clean generators based on biogas or biomass. In addition, electricity cannot be credited by the utility if it is provided by energy storage devices charged with imported electricity from the utility grid.
## Net Metering Policies in Europe (2019)

<table>
<thead>
<tr>
<th>Country</th>
<th>Eligible capacity</th>
<th>Solar</th>
<th>Wind</th>
<th>Hydro</th>
<th>Geothermal</th>
<th>Biogas</th>
<th>Biomass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albania</td>
<td>Up to 500 kW</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belgium</td>
<td>Up to 10 kW</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Cyprus</td>
<td>Up to 40 MW (aggregate capacity)</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Denmark</td>
<td>Up to 50 kW</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Greece</td>
<td>Up to 20 kW</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hungary</td>
<td>Up to 50 kVA</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Italy</td>
<td>Up to 500 kW</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Latvia</td>
<td>Up to 3*16A</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Lithuania</td>
<td>Up to 100 kW (legal persons)</td>
<td>✓</td>
<td></td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Moldova</td>
<td>Up to 200 kW</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Netherlands</td>
<td>Up to 3*80A</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Source Energy Conversion

There are many definition approaches for ZEBs available in the literature, the most common ones being:

- **Site ZEB → Accounts for energy at the site**
  (no conversion factors used)

- **Source ZEB → Accounts for energy at the source**
  (uses source energy conversion factors in kWh_{primary}/kWh)

- **Cost ZEB → Accounts for energy and fuel costs**
  (uses energy and fuel prices in €/kWh or $/kWh)

- **Emission ZEB → Accounts for carbon emissions**
  (uses emission factors in kg_{CO2}/kWh)

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Focus of this work
Source Energy Conversion

All the delivered and exported on-site energy is converted to source energy by multiplying each energy type by the respective source energy conversion factor. This ensures that no specific building is credited or penalized for the relative efficiency of its energy provider.

The source energy conversion considers the energy consumed during extraction, processing and transport of primary fuels, as well as any energy losses during thermal combustion, transmission and distribution.
## Source Energy Conversion Factors

<table>
<thead>
<tr>
<th>Country</th>
<th>Electricity</th>
<th>Natural gas</th>
<th>Fuel oil</th>
<th>Propane</th>
<th>Wood</th>
<th>Coal</th>
<th>Hot water</th>
<th>Chilled water</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>3.14</td>
<td>1.05</td>
<td>1.01</td>
<td>1.01</td>
<td>1.00</td>
<td>1.00</td>
<td>1.20</td>
<td>1.00</td>
</tr>
<tr>
<td>Canada</td>
<td>2.05</td>
<td>1.02</td>
<td>1.01</td>
<td>1.03</td>
<td>1.00</td>
<td>1.00</td>
<td>1.20</td>
<td>0.71</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>3.07</td>
<td>1.22</td>
<td>1.10</td>
<td>1.09</td>
<td>1.04</td>
<td>1.00</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Portugal</td>
<td>2.50</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Spain</td>
<td>2.11</td>
<td>1.07</td>
<td>1.12</td>
<td>1.05</td>
<td>1.25</td>
<td>1.14</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>France</td>
<td>2.58</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Germany</td>
<td>3.00</td>
<td>1.10</td>
<td>1.10</td>
<td>1.10</td>
<td>1.20</td>
<td>1.10</td>
<td>0.70</td>
<td>---</td>
</tr>
<tr>
<td>Denmark</td>
<td>2.50</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.80</td>
<td>---</td>
</tr>
<tr>
<td>Poland</td>
<td>3.00</td>
<td>1.10</td>
<td>1.10</td>
<td>1.10</td>
<td>0.20</td>
<td>1.10</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Switzerland</td>
<td>2.97</td>
<td>1.15</td>
<td>1.24</td>
<td>1.15</td>
<td>1.06</td>
<td>1.66</td>
<td>0.80</td>
<td>---</td>
</tr>
<tr>
<td>Italy</td>
<td>2.42</td>
<td>1.05</td>
<td>1.07</td>
<td>1.05</td>
<td>1.00</td>
<td>1.10</td>
<td>1.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Finland</td>
<td>1.70</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.50</td>
<td>1.00</td>
<td>0.70</td>
<td>0.40</td>
</tr>
</tbody>
</table>
Weighting System

The weighting system converts the physical measured units of different energy types into a uniform metric to allow comparison and compensation among each other.

- **Symmetric weighting (L=G)** → Same conversion factors for both weighted demand and weighted supply quantities.
- **Asymmetric weighting (L≠G)** → Different conversion factors for weighted demand and weighted supply.

In static weighting systems, the conversion factors do not vary over the year. In quasi-static or dynamic weighting systems, the conversion factors change on a monthly or hourly basis.
Weighting System

The energy balance is determined from the balance between delivered and exported on-site renewable energy or between load and generation. The weighted demand is the sum of all delivered energy to the building and the weighted supply is the sum of all exported energy, both determined by summing each energy type multiplied by the respective source energy conversion factor.

\[
E_{\text{balance}} = W_{\text{demand}} - W_{\text{supply}} = \sum_i \left( E_{\text{del},i} \times r_{\text{del},i} \right) - \sum_i \left( E_{\text{exp},i} \times r_{\text{exp},i} \right)
\]

where \( E_{\text{del},i} \) and \( E_{\text{exp},i} \) are the delivered energy and exported on-site renewable energy for an energy type \( i \), respectively. And \( r_{\text{del},i} \) and \( r_{\text{exp},i} \) are the source energy conversion factor for the delivered and exported energy type \( i \), respectively.

Buildings can be defined as ZEB if their annual energy balance is less than or equal to zero \( (E_{\text{balance}} \leq 0) \).
Case Study

The enterprises under study include a flour mill, a quarry, an abrasives production plant, a yarn mill and a hypermarket. This study uses an optimization algorithm to determine the number of photovoltaic (PV) panels and wind turbines (WT) necessary to achieve annual net zero energy and at the same time minimize the implementation cost.

<table>
<thead>
<tr>
<th>Solar irradiance (kWh/m²)</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>Jul</th>
<th>Aug</th>
<th>Sep</th>
<th>Oct</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air temperature (°C)</td>
<td>9.3</td>
<td>10.3</td>
<td>13</td>
<td>14.6</td>
<td>17.9</td>
<td>22.2</td>
<td>24.5</td>
<td>23.8</td>
<td>21.5</td>
<td>17.4</td>
<td>13.3</td>
<td>10.9</td>
</tr>
<tr>
<td>Wind speed (m/s)</td>
<td>4.9</td>
<td>5.2</td>
<td>5.1</td>
<td>5</td>
<td>4.7</td>
<td>4.4</td>
<td>4.5</td>
<td>4.5</td>
<td>4.1</td>
<td>4.3</td>
<td>4.7</td>
<td>5.1</td>
</tr>
</tbody>
</table>

The algorithm was developed using the function “linprog” in Matlab which allows finding the optimal solution for a problem defined by inequality constraints, equality constraints and boundaries.
The objective function for this problem is given by:

\[
\min \quad n_{pv} \times C_{pv} + n_{wt} \times C_{wt} + P_{grid} \times C
\]

where \(n_{pv}\) and \(n_{wt}\) are the number of PV modules and WTs needed to be installed, \(C_{pv}\) and \(C_{wt}\) are their respective cost, and \(P_{grid}\) is the amount of power imported from the grid which is associated to a high cost value \(C\).

The algorithm is forced to prioritize the lower cost of PV panels and WTs, thus avoiding power imported from the grid.

Subjected to:

\[
\begin{align*}
P_{Gpv} \times n_{pv} & \geq 0 & A_{pv} \times n_{pv} & \leq A_{Tpv} \\
P_{Gwt} \times n_{wt} & \geq 0 & A_{wt} \times n_{wt} & \leq A_{Twt} \\
P_{grid} & \geq 0 & P_{grid} & \leq P_{load}
\end{align*}
\]

where \(P_{Gpv}\) and \(P_{Gwt}\) are the amount of power from a PV module and WT, which along with \(P_{grid}\) need to be greater than or equal to zero. \(A_{pv}\) and \(A_{wt}\) are the areas of each PV panel and WT, which cannot be lower than zero or exceed the maximum amount of area available for deploying PV panels and WTs, denoted by \(A_{Tpv}\) and \(A_{Twt}\) respectively. The amount of power imported from the grid cannot exceed the amount of power consumed by the building, denoted by \(P_{load}\).
Case Study

And restricted to the zero energy balance formula given by:

\[
\frac{P_{\text{load}}}{\text{Demand}} - \frac{(P_{\text{Gpv}} \times n_{\text{pv}} + P_{\text{Gwt}} \times n_{\text{wt}} + P_{\text{grid}})}{\text{Supply}} = 0
\]

This allows the objective function to determine the number of PV modules and WTs according to the zero energy balance, where supply equals demand.

- The algorithm was used for each building with the input data and the technical specifications for PV panels and WTs in order to evaluate whether these industrial and commercial buildings can achieve annual net zero energy by deploying on-site renewable sources within their site boundary.
## Case Study

The results obtained for each enterprise are listed in the table below.

<table>
<thead>
<tr>
<th></th>
<th>Demand (kWh/y)</th>
<th>Area for PV / WT (m²)</th>
<th>Number of PV / WT units</th>
<th>Estimated cost of PV / WT (€)</th>
<th>Generated energy (kWh/y)</th>
<th>Imported energy (kWh/y)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flour mill</td>
<td>1689504</td>
<td>3200* / 1125</td>
<td>794.57 / 3.58</td>
<td>516472 / 30044</td>
<td>918141</td>
<td>771363</td>
</tr>
<tr>
<td>Quarry</td>
<td>253109</td>
<td>900* / 1500</td>
<td>223.47 / 4.77</td>
<td>145258 / 40059</td>
<td>301893</td>
<td>29038</td>
</tr>
<tr>
<td>Abrasives</td>
<td>1188783</td>
<td>3360* / 1200*</td>
<td>834.30 / 3.82</td>
<td>542296 / 32047</td>
<td>964740</td>
<td>329422</td>
</tr>
<tr>
<td>Yarn mill</td>
<td>1271467</td>
<td>825* / 330</td>
<td>204.85 / 1.05</td>
<td>133153 / 8813</td>
<td>238183</td>
<td>1043145</td>
</tr>
<tr>
<td>Hypermarket</td>
<td>3499328</td>
<td>4925** / 6500*</td>
<td>1222.9 / 20.69</td>
<td>794883 / 173590</td>
<td>1589001</td>
<td>1910327</td>
</tr>
</tbody>
</table>

* Rooftop installation / ** Parking lot installation
Case Study

[Bar chart with categories: Flour mill, Quarry, Abrasives, Yarn mill, Hypermarket. Categories show energy consumption in GWh and types of energy: Electricity, Gas/LPG, Generation.]
Case Study

The annual energy balance for each building was then determined using different symmetric, asymmetric and asymmetric opposite (O) weighting systems.

- **Symmetric weights** \( L=G \)
- **Asymmetric weights** \( L<G \) / \( L>G \) (O)

**DL No. 118/2013 (Dispatch No. 15793-D/2013)**
**Regulations EN 15603 & DIN V 18599**

<table>
<thead>
<tr>
<th></th>
<th>Symmetric</th>
<th>EN 15603 Asymmetric</th>
<th>DIN V 18599 Asymmetric</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Asymmetric L&lt;G</td>
<td>Asymmetric L&gt;G (O)</td>
<td>Asymmetric L&lt;G</td>
</tr>
<tr>
<td>Flour mill</td>
<td>1421556</td>
<td>1664532.07</td>
<td>2050388.55</td>
</tr>
<tr>
<td>Quarry</td>
<td>-133349.5</td>
<td>-218019.11</td>
<td>-124959.58</td>
</tr>
<tr>
<td>Abrasives</td>
<td>114321</td>
<td>10489.24</td>
<td>326065.68</td>
</tr>
<tr>
<td>Yarn mill</td>
<td>2297130</td>
<td>2864539.05</td>
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Case Study

![Graph showing energy consumption in different categories: DIN Asymmetric (O), EN Asymmetric, DIN Asymmetric, and EN Asymmetric (O). The categories are color-coded as follows: Flour mill (red), Quarry (green), Abrasives (yellow), Yarn mill (purple), Hypermarket (blue), and Zero energy (dashed line).]
Case Study

The results previously presented show that:

1. Only the quarry can achieve net zero energy when using symmetric, EN asymmetric, EN asymmetric opposite (O), and DIN asymmetric opposite (O) weighting. This is mainly due to nature of this enterprise, which has sufficient open space available for the deployment of on-site renewable sources to offset its annual energy demand.

2. Both the quarry and the abrasives manufacturing plant achieved annual net zero energy when using DIN asymmetric weighting. This weighting system is aimed at promoting RES technology diffusion in buildings, favouring the exported on-site renewable energy over delivered energy.

3. Most of the enterprises are far from achieving annual net zero energy when considering EN asymmetric opposite (O) and DIN asymmetric opposite (O) weighting, apart from the quarry. Asymmetric opposite (O) weighting is aimed at promoting self-consumption from on-site renewable sources in buildings, penalizing the delivered energy to the building.
Conclusions

❑ The integration of microgrids constitutes a great opportunity towards achieving zero energy in efficient buildings due to the benefits they provide.

❑ Achieving zero energy in industrial and commercial buildings may not be possible without implementing energy efficiency measures or alternatively by storing excess energy generated from on-site renewable sources.

❑ A net metering structure is suggested to help buildings achieve annual zero energy, since it is not economically viable to store electricity for long time periods due to the high cost of energy storage systems.

❑ The various weighting options available in the regulations have a significant impact in the building energy balance and an asymmetric weighting system facilitates achieving annual net zero energy if generation is weighted higher than load, promoting RES technology diffusion in the building sector.

❑ The subject addressed is in desperate need of standardization and common understanding of its concept. More efforts and developments should be made towards the environmental impact of energy intensive buildings and enhancement of future microgrids.
INDuGRID Project

The work presented here was part of the task 2.2 of the R&D project “INDuGRID - Efficient Energy Management in Industrial Microgrids with High Penetration of PV Technology”, which ended in 2019 and involved institutions from four countries, including Portugal, Spain, Argentina and Peru.

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- **IPT (Portugal)**, funded by FCT
  Mário Gomes, mgomes@ipt.pt

- **UNSJ (Argentina)**, funded by MINCyT
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- **WAIRA (Peru)**, funded by CONCYTEC
  Franco Canziani Amico, franco@waira.com.pe
The main objective of this R&D project was the introduction of innovative solutions to the improvement of energy efficiency in industrial environments using intelligent electrical microgrids with high penetration of PV technology. This main goal was divided into four distinct objectives.

**O1) To design architectures of electrical microgrids for small and medium size industries.**
(Tasks 1.1 – 1.4)

**O2) To develop protocols for efficient energy management in industrial microgrids.**
(Tasks 2.1 – 2.4)

**O3) To develop tools to operate industrial microgrids autonomously.**
(Tasks 3.1 – 3.4)

**O4) To introduce innovative tools for improving the power quality in industrial microgrids.**
(Tasks 4.1 – 4.5)

INDuGRID Project

**T1.1** Evaluating architectures of industrial microgrids ← IPT
T1.2 Integration of PV systems in industrial microgrids
T1.3 Dimensioning of the energy storage systems
T1.4 Design of communication and metering infrastructures

(2017)

- Conference papers: 2
- Journal publications: 2
- Technical reports: 1
- Master theses: 1
- Seminars: 1

**T2.1** Design of the energy management system
**T2.2** Protocols for guaranteeing zero net energy industries ← IPT
T2.3 Actions to reduce the impact of disturbances
T2.4 Proof of concepts by tests in the experimental set-up

(2018)

- Conference papers: 3
- Journal publications: 2
- Technical reports: 1
- Master theses: 0
- Seminars: 1

**T3.1** Autonomously operation of industrial microgrids
**T3.2** Evaluating management strategies in autonomous operation
**T3.3** Cooperation between cluster of autonomous microgrids ← IPT
T3.4 Proof of concepts by tests in the experimental setup

(2019)

- Conference papers: 2
- Journal publications: 1
- Technical reports: 1
- Master theses: 1
- Seminars: 1

**T4.1** Development of voltage regulation algorithms
T4.2 Reduction of steady-state voltage imbalances
T4.3 Voltage support during grid faults
T4.4 Reduction of voltage and current harmonics
T4.5 Proof of concepts by tests in the experimental set-up
INDuGRID Project

IPT group: Mário Gomes, Paulo Coelho, José Fernandes, Filipe Bandeiras and Eduardo Pinheiro

Project duration: 36 months (01/09/2016 – 31/08/2019)

WORK DEVELOPED

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THANK YOU
FOR YOUR ATTENTION