PEMBeyond

PEMFC system and low-grade bioethanol processor unit development for back-up and off-grid power applications

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Authors: Paolo Fracas- Genport
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Summary

The aim of WP8.1 task is focused on the execution of a market analysis and to measure of the attractiveness of PEMBeyond technology solution proposed within the WP2,3,4,5,6.
During the first semester of the project, a market survey has been conducted in key market area (Italy, Finland, Israel) in order to identify a number of telecom tower installed, feature and dimension and costs of the power sources associated to telecom installations; additionally the market research has been extended worldwide searching on the web public market reports suitable with the scope of the task. The result of this preliminary analysis has been used to extend the identification of the size of the market globally.
The worldwide population and its growth trend have been utilized as key drivers to estimate the number of telecom tower in all the 267 countries of the 6 continents (Europe, Africa, Asia, North America, South America, Oceania). Public database with cost of fuel, cost of electric energy, cost of current VRLA batteries has been utilized to finally estimate with the support of the Techno-economical analysis tool (TEA Tool) the Market Size (Total Available Market) of energy cost for power generation and backup power in which PEMBeyond Technology can be competitively offered within a typical payback period (i.e. 3 year time).
The result described within this first document refers not only to the identification of the market size by country but also to the Served Available Market of PEMBeyond Fuel Cell System Technologies based on the target Capex costs as in the objective of the project (3.300 Euro/kWinstalled @>500 units & 5 kW).
The exercise of identification of Served Available Market will continue during the project execution based on the actual cost of the Bill of Materials for the components of PEMBeyond Fuel Cell System Technologies.

Confidentiality	PU

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Glossary

TEA	TECHNO-ECONOMICAL ANALYSIS
TAM	TOTAL AVAILABLE MARKET
SAM	SERVED AVAILABLE MARKET
MS	MARKET SHARE
CAPEX	CAPITAL EXPENDITURE
OPEX	OPERATIONAL EXPENDITURE
BTS	BASE TRANSCEIVER STATION
DG	DIESEL GENERATION
AL	LEAD ACID
RES	RENEWABLE ENERGY SYSTEM
BESS	BATTERY ENERGY STORAGE SYSTEM
O&M	OPERATIONAL & MAINTENANCE

1. Market Research Development

During the first phase of this task, it has been identified the market opportunity and the objectives of the market research and how to measures them. The primary objective has been to acquire an understanding of driving forces playing into the competitive arena (key relation among suppliers, users, substitutes technologies) and their impact and the actual status of the telecom tower market contest. A final subtask has been the design of the market research and backbone of the market database.

1.1 Objectives of Market Research

The scope of this research is to identify market opportunities for PEMBeyond technologies worldwide as backup power unit as well as generation power unit.

1.2 Market Measurement

Several variables have been identified and correlated in order to reach the objective of the workpackage. In this paragraph they will be detailed and explained while theirs correlation will be described in the “Report on techno-economical tool design” D.8.2. .

Market Size is the key variable used within the market research. The Market Size has been identified in term of *Total Available Market* (TAM); TAM has been defined as the total number of installation as well as in currency (Euro) without considering the effects of inflation/deflation (constant values). A second variable used to identify the market opportunities has been the size of the *Served Available Market* (SAM) with the by means of currency (Euro) without considering the effects of inflation/deflation (Constant values) as well as of units of telecom towers.

The SAM has been used to measure the amount of installed telecom tower worldwide in which PEMBeyond technologies can be offered, as their costs are lower then actual technologies. SAM has been defined as the total number of installation as well as in currency (Euro) without considering the effects of inflation/deflation (constant values).

The geographical area considered is worldwide. The values of TAM and SAM have been identified by worldwide in 267 countries, 6 continents (Europe, Africa, Asia, North America, South America, Oceania). In order to identify TAM values by countries, two "precursors" has been utilized. The first is: the total size of population (both sexes combined) by major area, region and country considering the "Instant Replacement Model" issued by United Nation (Revision 2012); this projection has been considered being an intermediate model of world growth population models proposed by UN. The second "precursor" utilized is the: *Ratio Population/Telecom Tower* that enables to convert the population into the units of installed telecom tower. The TAM in constant value of currency (Euro) has been measured in term of the *total cost of ownership* of the telecom's mix of installation in each country in the period of the lifetime.

Further additional technical and economical variables have been introduced to define a comprehensive model of actual installed mix of energy systems (grid-connected, off-grid) in each country and define the principal variables. The first group are technical variable as follow:

Lifetime of the installation of the telecom towers is used in order to calculate the overall costs of ownership in term of CAPEX as well as OPEX.

Average Power Loads is nominal average power of the typical telecom tower/BTS in each country. *Backup power loads* is nominal average of a back bridging power unit of the telecom tower/BTS in each country. This parameter as default has been considered as equal to the average back up power. *Backup runtime* is the average runtime to be fulfilled by a bridging power unit (typically an Lead-Acid or Lithium backup battery) It has been assumed an yearly energy outage. Therefore the bridging *Backup Energy* is the power requested during the backup runtime.

Fuel Efficiency as ratio of the electrical energy generated by a certain DG and chemical energy of the fuel and *Volumetric Energy Density as* the chemical energy in one litre of fuel has been both utilized to calculate the average *Cost of Energy of Fuel (Diesel vs Bioethanol)* consumed by the generator

A certain group of parameters has been utilized to modelling energy systems in different countries. The *Power Grid Factor* is the percentage of energy purchased by the utility to power the loads of the Telecom Towers, the *Power Local Generator Factor* is the percentage of energy produced by the DG or PEMBeyond Fuel Cell System in addition to the bridging unit. *Power Factor of RES-BESS systems* is considering a percentage of energy generated locally by a renewable energy system (RES) combined with a battery energy storage system (BESS). Therefore the generator runs if grid as well as the RES system are not available. Two energy systems scenarios per each country has been considered and measured. The *share of grid-on installation/ share of grid-off installation* is the parameter adopted to simulate a certain mix of energy systems.

Last part of parameters are economical:

Cost of Energy by grid is cost of energy purchased by the utility in each country.

A breakdown cost structure of the fuel by country has been introduced as follow. *Cost of Fuel* is the cost per litre of diesel used by a backup ICE generator. *Cost of Fuel Services* is the additional average cost for the transportation of the fuel to the telecom tower and other related services (local patrol services). This is the most relevant part of the fuel cost. The *Total cost of the Fuel* is therefore the sum of the above costs. In off-grid contests in which a DG operates 24/7 or not resilient power grids this is a relevant cost effecting the overall energy bill.

Capex cost of backup are the Average Capital Expenditure Costs of the bridging backup power units; the *Capex costs of Primary Generators* measures the Average Capital Expenditure Costs of DG or PEMBeyond Fuel Cell systems (procurement, installation, commissioning costs) as well as the *Capex of RES-BESS* measures the initial cost of the RES with battery storage system. Operating costs has been evaluated (*Opex of backup, Opex of Generators)* considering the yearly Operational (cost of the Fuel) and Maintenance cost for the generators during their lifetime. *Average years Replacements of generators* as well as *Average years Replacements backup bridging systems* has been identified and calculated. *Net presents Costs* is the total cost of ownership which includes all the initial capital cost (Capex) and the Operation and Maintenance Costs (Opex). Another complementary measured variable is the *Cost of Energy* which is a synthetic parameter that provides the Net Present Cost per unit of kWh utilized by the Telecom Tower during its lifetime.

TAM in constant currency, is therefore measured as overall Net presents Costs of all the installation in the country. *SAM in constant currency* is measured as a subset of TAM in which the Net presents Costs of the PEMBeyond Fuel Cell Systems are lower then actual Net presents Costs and the power generated by the PEMBeyond Fuel Cell Systems in higher or equal to the actual generated power. The *Market Share* to introduce PEMBeyond Fuel Cell Systems is calculated as ration between *SAM/* and *TAM.*

The Trend of TAM , SAM AND Market Share including *OPEX* as well excluding *OPEX* in the period 2014 – 2020 has been finally measured.

1.3 Market research methodology

In order to define typical energy systems scenarios as well validate the variables measured by the TEA tools several simulation has been conducted using Homer a commercial computer model that simplifies the task of designing hybrid renewable micro-grids, whether remote or attached to a larger grid. HOMER's optimization and sensitivity analysis algorithms has allowed to evaluate the economic and technical feasibility of typical scenarios and to compare variations in technology costs and energy resource availability combining PEMBeyond system with actual installed systems. A typical 5kW BTS load profile has been simulated also to evaluate data and information collected into the field.

Installation of Telecom Tower has been analysed collecting information into the field with interviews with local partners in Italy, Israel, Finland. Meeting followed by exchange of detailed information has been conducted in Italy with Linkem, Wind, Telecom Italia in Finland with TeliaSonera, in Israel with a partner active in installation of RES with telecoms in Africa and Middle East (Lightwind ltd).

They provided the number of installation and the present status, in their countries the operational requirements, the trend and criteria for investments and problem related to these installations. Detailed information about actual cost of fuels, batteries have been also provided by users.

These information has been integrated with several market studies in internet as mentioned in the attached bibliography. Cost of fuel in each country, cost of energy in each country thru public database has been searched and identified. Cost of ICE generators and cost of batteries, has been also identified in public market research (see bibliography).

The number of Telecom tower by energy identified in Italy, Finland, Us, India, China, Israel, the total units of installation by continent as well as the total number of units worldwide extrapolated by market reports has been utilized identify to calculated the *Ratio Population/Telecom Tower.* The same parameter has been extrapolated into the remaining countries having considered the development of the economy and political contest. A final calibration has been conducted to refine the result.

A further refine calibration of the *Ratio Population/Telecom Tower* by country will be conducted during the project considering historical data issued by UN within the Mobile-cellular telephone subscriptions reports.

2. Market Report

In this paragraph are introduced the key market ratio as result of the simulations conducted with TEA tools by continent. These results describe a market scenario in term of SAM and share of the market that can be addressed with PEMBeyond Fuel Cell System Technologies if target Capex costs are reached (3.300 Euro/kW$_{installed}$ @>500 units & 5 kW). A graphical representation of the trend of Market Size is showed in the figure 1.

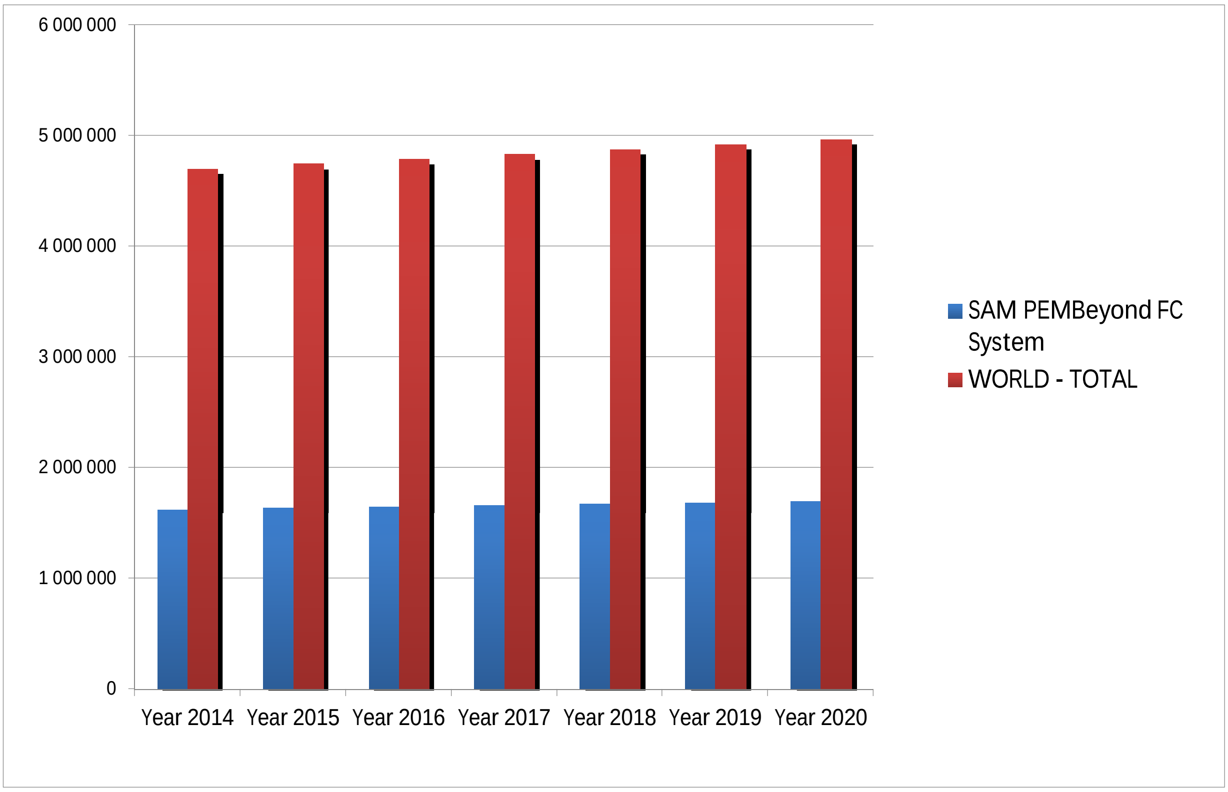

Fig.1 –Trend of the Served Available Market (based on the target PEMBeyond costs) and Total Available Market 2014-2020

Worldwide there are 4.700.000 telecom towers. As shown in fig. 2, the majority of installations is in Asia (52%), followed by Europe (17%), North America (15%), South America (12%), Africa (3%) and Oceania (1%).

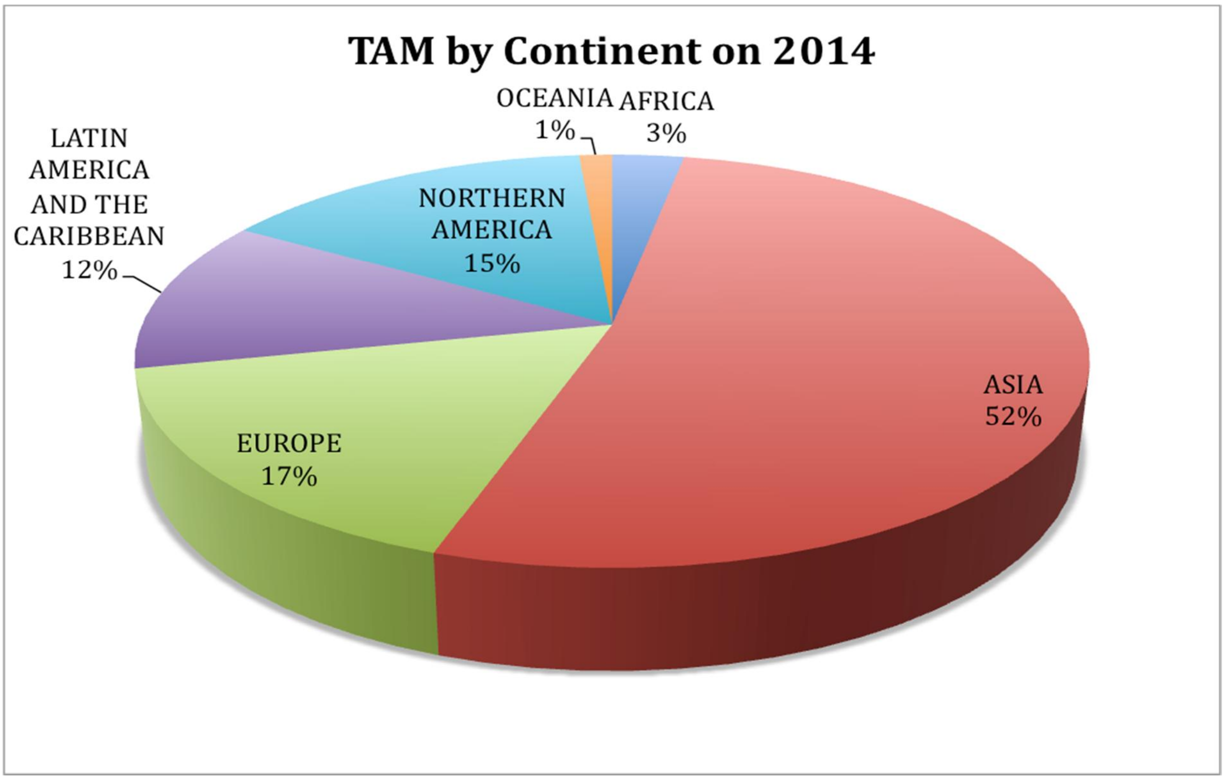

Fig.2 Total Available Market by Continent

However the most critical installations are placed in Africa due to the lack of grid infrastructure associated to a fast growing market for telecommunication services. PEMBeyond Fuel Cell Technology could play a fundamental role in the solution of power demand, avoiding relevant amount of environmental emissions as well as improve the reliability of the power supply integrated with Primary Renewable Energy Source (Solar and Wind Turbine) and Ion Lithium Battery Energy Storage systems.

In this report is presented the result of a “standard scenario” based on power unit with same size (5kW) for all countries. However, cost of fuels and cost of the electric energy of the grid and actual cost of the backup batteries are different as sourced by public databases.

Based on these assumption, we have deduced a potential market that can be approached by PEMBeyond Fuel Cell technology (Served Available Market), amounting 60% of the entire worldwide installations as shown in figure 3.

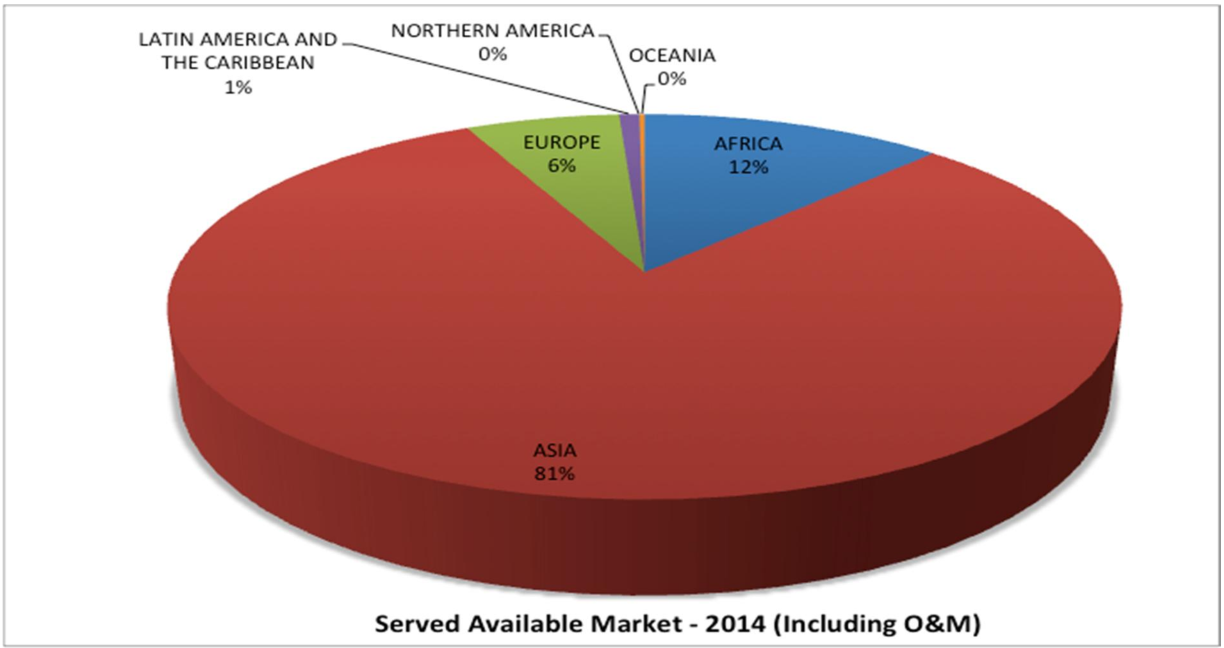

Fig.3 Served Available Market

The SAM has been used to measure the amount of installed telecom tower worldwide in which PEMBeyond technologies can be offered, as their costs are lower then actual technologies. SAM has been defined as the total number of installation as well as in currency (Euro) without considering the effects of inflation/deflation (constant values).PEMBeyond Energy Systems is almost competitive to reach the market demand in all the continents, as explained in Figure 4 , which compare Total Available Market to Served Available market.

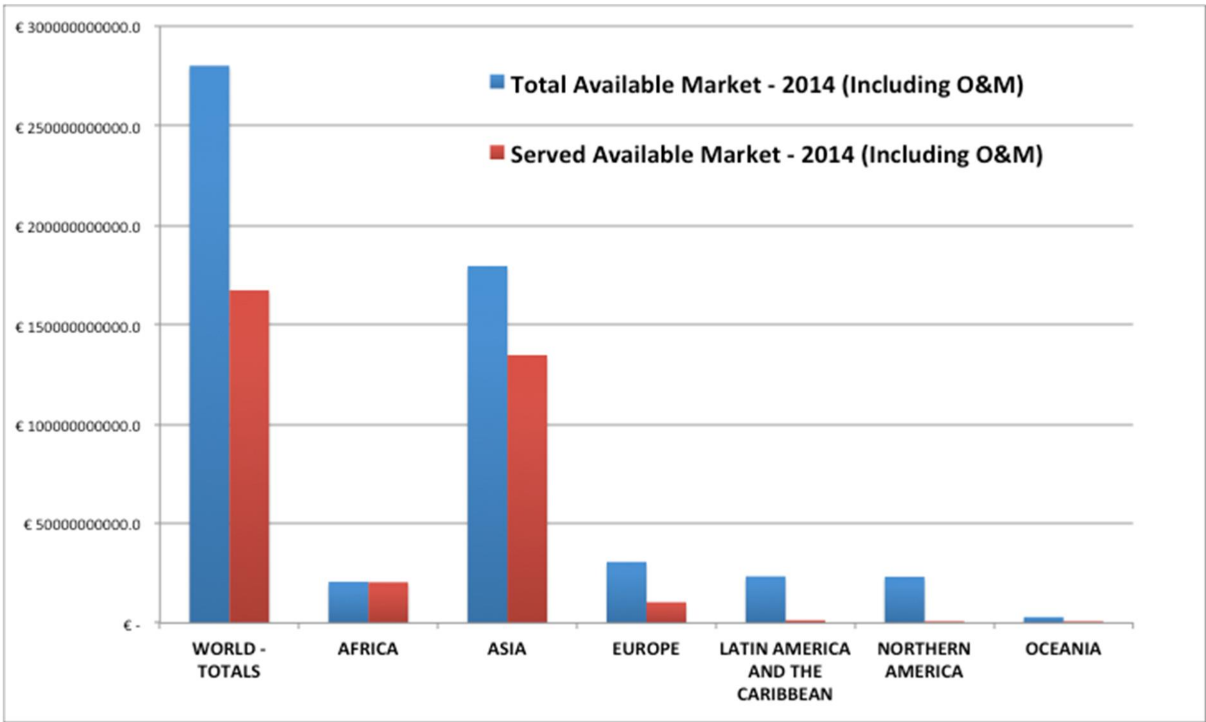

Fig.4 Comparison between TAM and SAM

The most favorable contest is where off-grid installations are more diffused, in Africa for example. In this continent the share of potential market is near 99% (of share) followed by Asia (75% of share) and Europe (34% of share).

Finally the figure below explains the actual Cost of Energy by continent with the power source configurations based on the combination of electric grid, diesel generators and Acid Lead battery.

These actual Cost of Energy are compared with the Pemebeyond Fuel Cell Technologies (green bar; 0,64 Euro/kWh) under the target costs scenario (3.300 Euro/$kW_{installed}$ @>500 units & 5 kW) which is below the worldwide average (0,71 Euro/kWh).

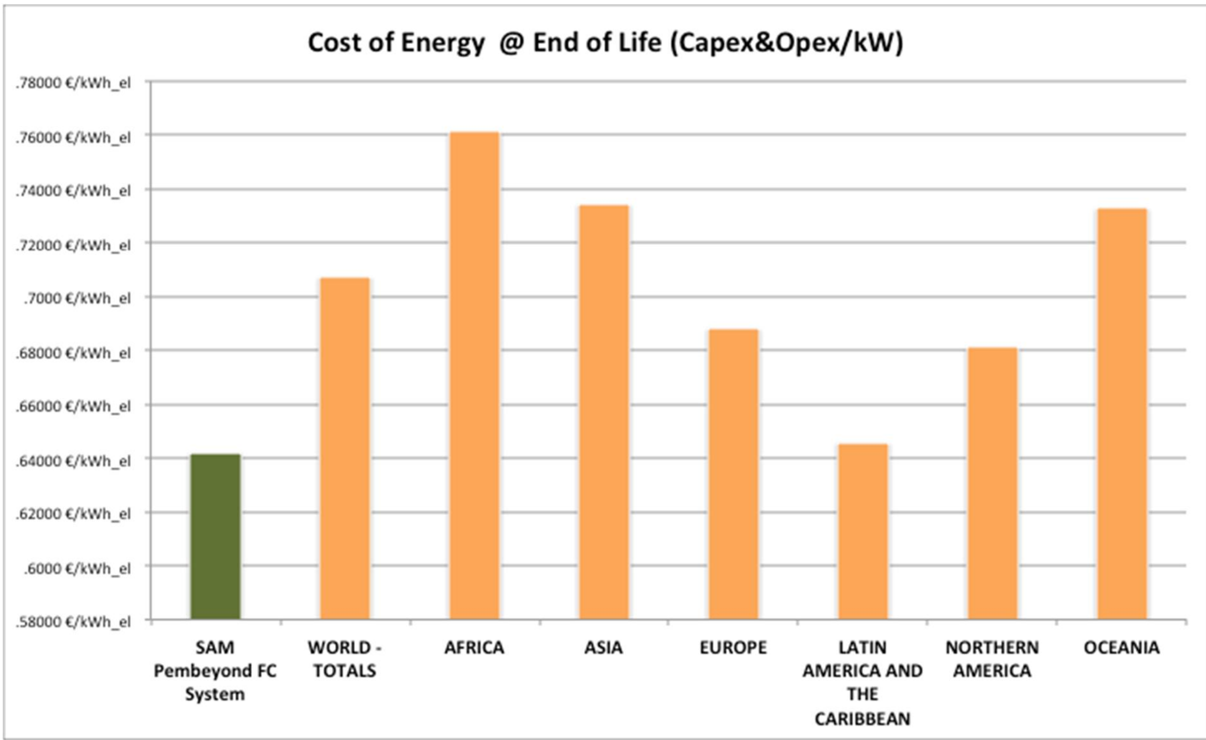

Fig.5 Cost of Energy a configuration based on the combination of electric grid, diesel generators and Acid Lead battery.

2.1 Energy System for Telecom Tower in Italy

There are almost 55.000 telecom towers in Italy owned by four major telecom companies to connect mobile devices connect to the Internet via cellular networks (3G and 4G/LTE networks) or Wi-Fi networks used in offices, factories, homes, and public spaces. Over the coming decade, network advances could include 5G cellular networks (the as yet unspecified next-generation standard), satellite services, and possibly long-range Wi-Fi. These technologies are increasing the number of BTS installation and demand of electric energy. The typical installation power range is 700 W up to 4 kW.

The majority of these installations are grid-connected, utilizing a VRLA battery bank as backup power unit. Some of them has a DG as primary backup power unit. There are 500 off-grid installation and all of these units utilizes a DG with a VRLA battery bank as bridging unit providing 2-4 hours of runtime. Several of these energy systems are older the 20 years and needs soon a replacement. It is expected the growth of installation due to the diffusion of LTE technology. Due to the high competitiveness arena and large investments on going, the Italian telecom companies has an high level of internal debt which causes high costs due to interests rates. Their energy bills due is one of the most relevant costs in the income statements. One of these companies has 120 Million of Euro yearly to power electric energy.

This contest is favorable for substitute energy technologies enabling the reduction of the Total Cost of Ownership in short term (a 3 years of payback is currently accepted) and a Capex cost of the installation competitive with current solutions.

Country	Company	Application (Backup /Aux)	Type of Power Source	End of Lifetime (site)	Nr. Of Site	Voltage	Power Loads	Backup Capacity	Battery Autonomy Vmin=43,2V
Italy	Linkem	Backup	VRLA	3 years	2.000	48,0 Vdc	0,7 kW	4 kWh	
Italy	Vodafone	Backup	VRLA	5 years	13.000	48,0 Vdc	3-4 kW		2 o 4 h
Italy	Telecom	Backup	VRLA	5 years	16.000	48,0 Vdc	3-4 kW		3 o 6 h
Italy	La3	Backup	VRLA		7.000	48,0 Vdc	3-4 kW		2 o 4 h
Italy	Wind	Backup	VRLA	5 years	14.000	48,0 Vdc	3-4 kW		2 o 4 h
Italy	Linkem	Off-grid power	VRLA		-				
Italy	Vodafone	Off-grid power	VRLA	5 years	150	48,0 Vdc	3-4 kW		2 o 4 h
Italy	Telecom	Off-grid power	VRLA	5 years	300	48,0 Vdc	3-4 kW		3 o 6 h
Italy	La3	Off-grid power	VRLA		50	48,0 Vdc	3-4 kW		2 o 4 h
Italy	Wind	Off-grid power	VRLA	5 years	50	48,0 Vdc	3-4 kW		2 o 4 h
					52.550				

The average cost for the actual installation of VRLA battery bank is 220 Euro/kWh (installed). Every 5 years these battery banks are usually replaced and they need a yearly maintenance to diagnostic and recharge.

In grid-connected energy systems (99% of installation in Italy), the estimated average NPC (Net Present Costs) in 3 years is 36.000 Euro (16.500 Euro O&M costs); the estimated cost of energy is 0,3 Euro/kWh.

In off-grid energy systems (1% of installation in Italy), the estimated average NPC (Net Present Costs) in 3 years is 138.000 Euro (92.000 Euro O&M costs); the estimated cost of energy is 1,1 Euro/kWh.

In off-grid contest PEMBeyond Fuel Cell systems (500 units / 1% of installation in Italy) the estimated average NPC (Net Present Costs) in 3 years is 126.000 Euro (77.000 Euro O&M costs); the estimated cost of energy is 1,0 Euro/kWh. Therefore could reach a 100% of market share.

2.2 Energy System for Telecom Tower in Europe

According to the result of a simulation based on the “ standard scenario “ (power size of the energy systems equivalent to 5kW of all the countries and 2 hours runtime of backup), the Telecom Tower units installed on 2014) in Europe are currently 776.000; the estimated units on 2020 amounts to 792.000.

The Total Available Market on 2014 amounts to 30 Billion of Euro (including Capex, O&M Costs of 3 years). The Potential Served Available Market amount to 10 Billion of Euro (including Capex, O&M Costs of 3 years) corresponding to the 34% of TAM.

The estimated NPC (Net Present Costs) concerning 3 years runtime, amounts to 90.400 Euro; the estimated average cost of energy is 0,69 Euro/kWh.

2.3 Energy System for Telecom Tower in Africa

Africa is one of the fastest growing regions in the world, with a forecast real GDP annual growth rate to 2017 of 5.5%. Over the next decade c.100M more people are expected to join the African middle class. African mobile telecoms have witnessed massive growth over the last decade; sub-scriptions CAGR reached 42% during 2006-08 and 21% 2009-11. This rapid uptake has been mainly driven by: mobile services being a core life enabler to all user segments, favourable macroeconomic factors flowing to higher consumption, licensing opportunities and improved regulatory environment.

Telecommunications growth Africa has positively impacted incomes across the continent: in Sub-Sahara Africa, mobile revenues reached $35bn in 2011 representing GDP contribution of approximately 3%.

According to the result of a simulation based on the “standard scenario“ (power size of the energy systems equivalent to 5kW of all the countries and 2 hours runtime of backup), the Telecom Tower units installed on 2014 in Africa are 135.000; the estimated units on 2020 amounts to 143.000.

The Total Available Market on 2014 amounts to 20,6 Billion of Euro (including Capex, O&M Costs of 3 years). The Potential Served Available Market amount to 20,4 Billion of Euro (including Capex, O&M Costs of 3 years) corresponding to the 99% of TAM.

The estimated NPC (Net Present Costs) concerning 3 years runtime, amounts to 100.012 Euro; the estimated average cost of energy is 0,76 Euro/kWh.

2.4 Energy System for Telecom Tower in Asia

Interrupted power supply, lack of power infrastructure and grid connectivity in many Asian countries has become major challenge for telecom operators to power their tower infrastructure. On account of these factors operators have to reply on alternatives to power their telecom sites. Presently, in many Asian countries, diesel generators and hybrid (diesel generators-batteries) powering solutions are primarily used. Growing subscriber base, increased competition, adoption and penetration of new technologies such as 3G and 4G is expected to put enormous pressure on operators to sustain service quality levels and expand their networks by keeping check over carbon emission levels. Spanning of network across Asian continent has considerably raised the demand for telecom tower power systems, which has spurred innovations and launch of green power solutions such as solar, wind, fuel cell, or others supported by either with battery or diesel back-up (predominantly by battery in most of the incidences).

According to 6Wresearch, Asia’s Telecom Tower Power Systems Market is projected to cross billion dollar mark by 2019, growing at a CAGR of 12.3% during 2014-19. Predominantly majority of the telecom towers in Asia are unreliable meaning partly supported by grid and partly by diesel power back-up.

The drivers for telecom power systems include growing mobile subscriber base, faster growth of urban population, inconsistent networked readiness index, and investments in telecom infrastructure. Latest trends in Asian telecom market are growing penetration of 3G and introduction of 4G in developed economies, passive infrastructure sharing, and adoption of green or energy efficient power solutions. Restraints in the market are identified as carbon emissions and high capital or associated costs.

Apart from India and China, high development activities in telecom sector are witnessed in South-Eastern region, especially in countries such as Laos, Vietnam, Myanmar, Cambodia, Indonesia and Philippines, due to growing mobile penetration, subscriber base, addition of telecom towers, improving economic conditions and urbanization trend. In South-Eastern countries, unreliable and off-grid telecom sites have increased significantly due to deployment of telecom towers in rural areas, which is driving the market for telecom tower power solutions in Asian region.

According to the simulation based on the “ standard scenario “ (power size of the energy systems equivalent to 5kW of all the countries and 2 hours runtime of backup), the Telecom Tower units installed on 2014 in Asia are 2.450.000; the estimated units on 2020 amounts to 2.622.000.

The Total Available Market on 2014 amounts to 179 Billion of Euro (including Capex, O&M Costs in the period 2014-2016). The Potential Served Available Market amounts to 134 Billion of Euro (including Capex, O&M Costs of 3 years) corresponding to the 75% of TAM.

The estimated NPC (Net Present Costs) concerning 3 years runtime, amounts to 96.484 Euro; the estimated average cost of energy is 0,76 Euro/kWh.

2.5 Energy System for Telecom Tower in South America

According to the simulation based on the “ standard scenario “ (power size of the energy systems equivalent to 5kW of all the countries and 2 hours runtime of backup), the Telecom Tower units installed on 2014 in Asia are 565.000; the estimated units on 2020 amounts to 600.500.

The Total Available Market on 2014 amounts to 23,4 Billion of Euro (including Capex, O&M Costs in the period 2014-2016). The Potential Served Available Market amounts to 1,35 Billion of Euro (including Capex, O&M Costs of 3 years) corresponding to the 6 % of TAM.

The estimated NPC (Net Present Costs) concerning 3 years runtime, amounts to 84.856 Euro; the estimated average cost of energy is 0,65 Euro/kWh.

2.6 Energy System for Telecom Tower in North America

According to the simulation based on the “ standard scenario “ (power size of the energy systems equivalent to 5kW of all the countries and 2 hours runtime of backup), the Telecom Tower units installed on 2014 in Asia are 706.946; the estimated units on 2020 amounts to 744.839.

The Total Available Market on 2014 amounts to 23,17 Billion of Euro (including Capex, O&M Costs in the period 2014-2016). The Potential Served Available Market amounts to 12,95 Million of Euro (including Capex, O&M Costs of 3 years) corresponding to the 0,1 % of TAM.

The estimated NPC (Net Present Costs) concerning 3 years runtime, amounts to 89.498 Euro; the estimated average cost of energy is 0,68 Euro/kWh.

2.7 Energy System for Telecom Tower in Oceania

According to the simulation based on the “ standard scenario “ (power size of the energy systems equivalent to 5kW of all the countries and 2 hours runtime of backup), the Telecom

Tower units installed on 2014 in Asia are 62.314; the estimated units on 2020 amounts to 67.237.The Total Available Market on 2014 amounts to 2, 9 Billion of Euro (including Capex, O&M Costs in the period 2014-2016). The Potential Served Available Market amounts to 0,35 Billion of Euro (including Capex, O&M Costs of 3 years) corresponding to the 12% of TAM.

The estimated NPC (Net Present Costs) concerning 3 years runtime, amounts to 96.289 Euro; the estimated average cost of energy is 0,73 Euro/kWh.

3. Conclusions

These first results highlight the value proposition of PEMBeyond Fuel Cell system Technology. We can in fact address a significant portion of the market (60% of Market size can be served) with a clean and safe power generation technology especially in emerging market area where Diesel Generators in combination with Acid Lead are currently predominant power solutions.

We have identified a huge amount of installation of telecom tower infrastructures worldwide. A relevant portion are located in developing countries in Africa and Asia where the electric grid is not completely available.

We have also found out that to tackle the demand of energy for Telecom Tower and its growth in next future (2020) a new approaches is necessary: cost of energy and reduction of environmental impacts should not be in contrast and PEMBeyond Fuel Cell Technology could be the choice to meet this challenge.

Therefore, Capex, Opex and efficiency are key factors to keep under control during the prosecution of project, due to the stringent requirements and the maturity of fuel cell technology.

The techno-economical analysis will be systematically conducted to validate the technologies' choice and verify their impact from an economical prospective in order to successfully fostering the diffusionof PEMBeyond technology.

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