

# Carbon and Energy Saving Financial Opportunities in the Industrial Compressed Air Sector

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**Abstract.** The transition towards a more sustainable energy scenario calls for both medium-to-long and short term interventions, with CO<sub>2</sub> reduction and fossil fuel saving as main goals for all the Countries in the World. Among all others, one way to support these efforts is the setting-up of immaterial markets able to regulate, in the form of purchase and sales quotas, CO<sub>2</sub> emissions avoided and fossil fuels not consumed. As a consequence, the upgrade of those sectors, characterized by high energy impact, is currently more than an option due to the related achievable financial advantage on the afore mentioned markets. Being responsible for about 10% electricity consumption in Industry, the compressed air sector is currently addressed as extremely appealing, when CO<sub>2</sub> emissions and burned fossil fuels saving are in question. In the paper, once a standard is defined for compressors performances, based on data from the Compressed Air and Gas Institute and PNEUROP, the achievable energy saving is evaluated along with the effect in terms of CO<sub>2</sub> emissions: with reference to those contexts in which mature intangible markets are established, an estimation of the financial benefit from savings sale on correspondent markets is possible, in terms of both avoided CO<sub>2</sub> and fossil fuels not burned. The approach adopted allows to extend the analysis results to every context of interest, by applying the appropriate emission factor to the datum on compressor specific consumption.

## 1. Introduction

The need for sustainable socio-economic models along with the awareness of the environmental risks related to present development paradigm are currently expressed in terms of fossil fuel consumption and CO<sub>2</sub> emissions reduction by policy makers of all World Countries. According to most recent data, up to 90% final energy uses are covered with fossil fuels, with equal shares for oil, coal and natural gas (i.e. per day, 86.7 million barrels, 10.6 million tons equivalent and 9.2 million barrels). Analysis prove that fossil fuels shortage is a short-to-mean term problem and fix a 53, 55 and 113 years-time horizon for oil, gas and coal exhaustibility, respectively. Based on current understanding, if atmospheric CO<sub>2</sub> concentration (currently stuck at 406 ppm) stabilizes at 450 ppm, a 2.1°C global warming has to be expected by 2100. In order not to overcome this threshold, an 80% reduction of current GHG emissions by 2100 has to be implemented and the massive renewable penetration in present market is left as the only viable option to be implemented in the medium-long term [1, 2, 3, 4].



These are the main reasons why, in almost all World Countries GHG - namely, CO<sub>2</sub> - emissions reduction, energy saving and energy generation from renewables by 2020 have been committed and environmental markets have been launched, on the idea that a financial value can be assigned to immaterial goods, such as avoided CO<sub>2</sub> emissions and fossil fuel saved: once these quantities are certified, quotas can be put on the market and a supply-demand dynamic applies, between “virtuous subjects” -either private or public- and those subject committed to reach emissions and/or energy saving targets. While far from ideal, as the price is not only fixed by a demand-to-supply balance, these markets allow to establish a technological standard and assign a financial value to energy virtuosity. On the same page, Carbon taxes and financial incentives to reward the adoption of high efficiency components have been established.

The compressed air sector (CAS) entirely relies on electrical energy: most recent data [5, 6] fix its impact in terms of electricity consumption at 10% industrial electricity consumption. By including the compressed air energy consumption in other sectors (i.e. residential and transports), this figure doubles, reaching 20% Industry electricity consumption [7, 8, 9]. 30-40% present energy consumption is commonly accepted as an estimation of the achievable electricity saving in the CAS [10, 11, 12, 13]. Once the datum on CO<sub>2</sub> emissions per kWh electricity is known, each context can be assigned with its corresponding quotas in terms of avoided CO<sub>2</sub> and fossil fuel saving.

The paper deals with the CAS Carbon dimension: after a brief overview on the compressed air electricity consumption for different Countries in the World, Carbon emissions associated to present market compressor technology are evaluated and presented as a function of delivered pressure and machine size (i.e. mass flow rate), based on data from the Compressed Air and Gas Institute (CAGI) and PNEUROP for the US and the EU market [14, 15]. The comparison among different machine types (e.g. screw and vanes) allows a quantitative estimation of the potential saving in existing compressors [15, 16]. Such a datum can be reversed in terms of CO<sub>2</sub> and fossil fuel credits, to be traded on environmental markets. Given the intrinsically diversified nature of intangible markets by Country and the different degrees of acceptance and applicability for fossil fuel and CO<sub>2</sub> saving interventions, dependently on their distance to target, the paper accounts for different scenarios, i.e. for different pricing mechanisms for both CO<sub>2</sub> quotas and energy saving. The reference is to the more mature markets toward which all others are orienting in terms of accounting and trading rules.

## 2. Overview of compressed air electricity consumption

World electricity consumption ranked at 18912 TWh in 2012, 13000 TWh (i.e. up to 70%) of which came from fossil fuels, i.e. oil, gas and coal [3]. Main use for electricity is in Industry and Buildings (either residential or commercial):

- among developed Countries, the US show the lowest share of electricity consumption in the industrial sector (23%), especially if compared to Europe (36%) and Australia (38%);
- in the US, the widest room for saving is in the building sector (72.3% overall consumption);
- absolute values prove that 48.0% Industry electricity consumption (i.e. 3843 TWh) comes from BRICS Countries; China alone represents a 72.7% of this share;
- the economic growth in BRICS Countries hinges on Industry, whose electricity consumption ranks at 68% (China), 60% (South Africa), 44% (Brazil), 46% (Russia) and 44% (India).

Projections on future energy consumption assume 2035 as the reference year: by then, they fix 450 ppmCO<sub>2</sub> as the limit atmospheric concentration and assume up to 40% global electricity consumption to come from BRICS Countries, with China share close to the sum of EU and the US. Hence, energy saving and CO<sub>2</sub> reduction technologies in Industry represent important options, to comply with environmental goals [3, 4].

Compressed air production accounts for a mean 10% overall Industry electricity consumption in developed Countries; when the compression needs from other sectors (e.g. portable tools, pneumatic heating, air conditioning, ventilation) sum up, the consumption doubles and ranks at 20% industrial electricity needs [5, 6, 7]. The transport sector is excluded, since there a direct conversion is done by

mechanical energy. Nonetheless, fuel saving and CO<sub>2</sub> emission reduction should account for the contribution from this sector as well. When evaluating the room for improvement related to electricity consumption in the CAS, it is worth observing that a decrease in the compressor-package absorption (i.e. compressor and electric motor) proportionally reflects on the overall energy consumption. The widest room for improvement is in leakages prevention (i.e. air waste reduction from present 20-40% level, due to both the compressor and the piping) and pressure level optimization (e.g. through filter replacement and proper piping design) [7, 8, 9]. Apart from the compressor technology, an interesting feature is the decrease in operating pressure levels, to combine with an upgrade of delivery and end-use systems: the compressor consumption roughly depends on the fourth square of the pressure ratio and the benefit of a 1 bar reduction from a given delivery pressure is expressed by Equation (1), with the adiabatic work as the reference:

$$S_{\beta,\%} = \left[ 1 - \frac{(\beta - 1)^{\frac{k-1}{k}} - 1}{\beta^{\frac{k-1}{k}} - 1} \right] \cdot 100 \quad (1)$$

A 1 bar reduction, from an 8 pressure ratio leads to a 10% saving. The higher the delivered pressure, the lower the benefit: at 15 bar delivery pressure, the 1 bar reduction leads to a 4% saving. A further beneficial effect associated to pressure reduction is in pipe losses reduction. When 13 bar is assumed as the starting pressure level (i.e. 6.34 kW/m<sup>3</sup>/min) the effect of a progressive pressure line decrease on the specific consumption can be seen as a percentage of the specific consumption at 13 bar: moving to 9 bar, a 20% saving is possible. Real absolute values for the specific energy consumption can be obtained by dividing the data by an overall global compressor efficiency [15]. As a rule of thumb, if both compressor and piping leaks are removed, the potential energy saving via compressor replacement can be doubled [5].

A study by the Authors [16] investigates the reduction in energy cost, via the improvement of present compressors technology (i.e. sliding vane rotary machines) and correlates it to the investment increase having the compressor size and type, the operating conditions and a 3 years payback time as parameters. At each efficiency increase the maximum acceptable investment increase grows from light to medium to heavy duty, due to the higher impact the energy cost has on the system financial management. The study accounts for air and water cooled machines as well and the analysis suggests that in big size machines a given performance improvement requires a higher investment in water than in air cooled compressors. The study also makes gives evidence that a further major variable affecting the investment feasibility is the discount factor purchaser can count on, particularly in presence of high financial investments, i.e. big size compressors and heavy duty applications.

### 3. Compressed air sector Carbon dimension

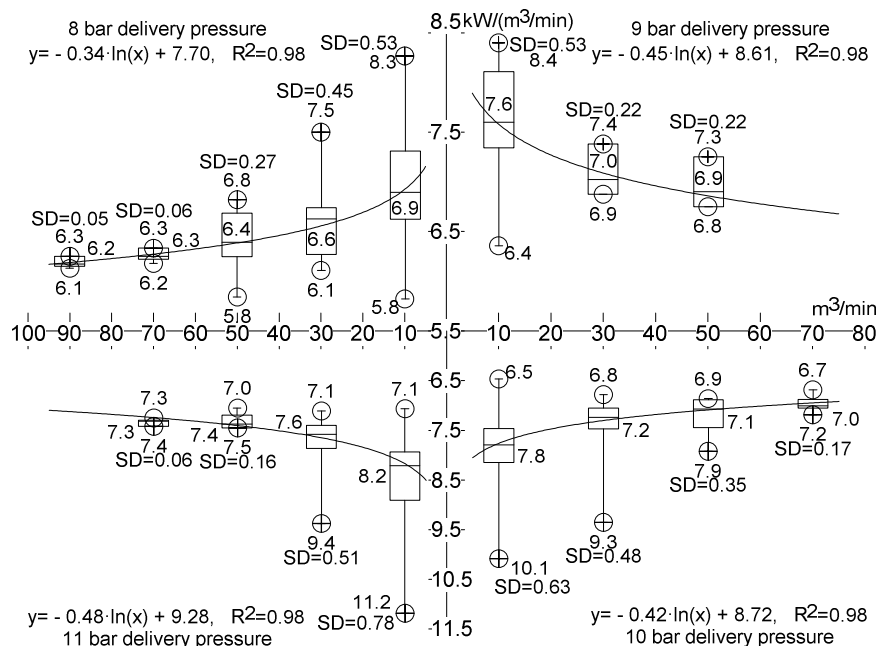
As a commodity, compressed air is an electricity user, hence values for emissions per kWh electricity allow a direct evaluation of its contribution to CO<sub>2</sub> emissions by Country. Dependently on the adopted energy mix and the reference value for power plants efficiency by context, a high spread among Countries should be expected among both EU States (e.g. Norway 0.01 kgCO<sub>2</sub>/kWh vs Greece 0.90 kgCO<sub>2</sub>/kWh) and different World Countries.

The average datum for Europe is 0.324 kgCO<sub>2</sub>/kWh; apart from Brazil (0.2 times the EU value) BRICS Countries have CO<sub>2</sub> emissions close to (see Russia, 0.9 times the EU value) or above the European datum: 3 times in India and South Africa, 2.3 times in China; specific emissions for Australia and US are 2.6 and 1.8 times those in the EU, respectively [17, 18, 19]. An assessment of compressors performances from many different manufacturers is presented in [15], based on CAGI data, gathered during a certification campaign in the US, and PNEUROP data for the EU. The results are in Figure 1: the volumetric flow rate is evaluated at 1 bar and 293.15 K and values for compressors power refer to unified delivery pressures, to enable a direct comparison among different machines.

Data, referring to air cooled compressors, are presented with no mention to the manufacturers' names and as a function of delivery pressure at rated flow rate and oil cooling medium (i.e. air or water) [14, 15]. Despite the fact that compressors processing high flow rates exhibit a lower scatter in performances among manufacturers if compared to lower-size machines, the great variability in compressors performances suggest that the technology is not aligned to the best standards. For 40-50 m<sup>3</sup>/min flow rates and below, 30-40% savings can be achieved by replacing the compressor unit.

Figure 2 reports the specific CO<sub>2</sub> emissions, with reference to the European context (324 gCO<sub>2</sub>/kWh), in terms of Carbon per cubic meter of compressed air (ccm). The coefficient of determination R<sup>2</sup> in the regression curves is a statistical measure of how well the regression model approximates ccm of existing machines (real data points). It can be observed that:

- ccm decreases with the flow rate. Specific emissions in air cooling machines, at 5, 20 and 50 m<sup>3</sup>/min flow rate are 0.041, 0.038 and 0.036 kgCO<sub>2</sub>/m<sup>3</sup>, whereas in water cooled machines they rank at 0.038, 0.036 and 0.035 kgCO<sub>2</sub>/m<sup>3</sup>, respectively;
- the higher power absorption by the pump for water circulation (water cooled machines) with respect to the fan (air cooled machines) leads to higher specific emissions;
- at 8 bar delivery pressure, air cooled machines have a high technological scatter among manufacturers, (e.g.: at 10 m<sup>3</sup>/min, a 0.065 kgCO<sub>2</sub>/m<sup>3</sup> scatter applies to a 0.036 kgCO<sub>2</sub>/m<sup>3</sup> standard), hence a wise compressor choice allows huge energy and emissions saving in this flow rate domain. Same goes with water cooled compressors, even if the scatter here is one order of magnitude lower than in air cooled; at higher flow rates, the ccm trend is asymptotic to lower values for both specific emissions and scatter (e.g.: 50 m<sup>3</sup>/min, 0.033 kgCO<sub>2</sub>/m<sup>3</sup> and 0.027 kgCO<sub>2</sub>/m<sup>3</sup>, respectively);
- the higher the delivery pressure, the higher the ccm difference among air and water cooled families, with a strong preference for water cooled machines; for a 9 bar pressure, the scatter further reduces, leading to a compressors population that is tightly distributed around the mean value: for a 30 m<sup>3</sup>/min flow rate, a 0.035 kgCO<sub>2</sub>/m<sup>3</sup>, with a 0.002 kgCO<sub>2</sub>/m<sup>3</sup> scatter is detected. For water cooled compressors, the scatter is negligible yet at 20 m<sup>3</sup>/min flow rate.



**Figure 1.** Market compressors (air cooled version) – Specific consumption vs flow rate [15]

It is worth observing that the chart can be referred to other contexts of interest, by simply scaling the numerical data in Figure 2 through the appropriate factor, as previously discussed. Thus the chart

provides the metric to read the trend in CO<sub>2</sub> emissions by machine size and type in the compressed air sector in any context of interest.

#### 4. Environmental markets – Carbon and energy saving trading

Presently, the European Emission Trading Scheme (EU-ETS) covers 45% of EU greenhouse gas emissions (roughly a 10-12% the whole emission scenario). The unit exchanged on this market is the ton of CO<sub>2</sub> (tCO<sub>2</sub>) avoided and it remained as unit for the others Carbon pricing instruments: covered installations are committed to surrender an allowance for each ton CO<sub>2</sub> they emit during the year. The allowances availability, combined with their tradability, creates a market price for allowances, that motivates committed emitters to choose between abatement options (investments) and purchasing on the market: 6-7 €/tCO<sub>2</sub> is the reference price at the moment, due to the abundance of credits, induced by the economic crisis. Nonetheless actors on the Carbon market have to face price variability for traded CO<sub>2</sub>, in both consolidated and newly established markets, dependently on whether fixed (e.g. Carbon taxes) or variable and market-sensitive (national and subnational ETS) fees apply [17, 20, 21, 22], which makes hard to predict Carbon price in both the long and the mean-to-short term [23, 24, 25]. An average 15 €/tCO<sub>2</sub> price can be considered, whilst in the eventuality of more stringent CO<sub>2</sub> commitments, 30-50 €/tCO<sub>2</sub> appears more realistic.

The same principle behind the Carbon market inspires the energy saving market, where fuel saving is exchanged and saving demand, coming from subjects that the law obliges to reach a target, is balanced by supply, provided by subjects who reached certified savings. The units exchanged are the Energy Saving Certificates (ESC), corresponding to a ton of oil equivalent (TOE) saved. When the analysis deals with the saving of electrical energy, the efficiency of the electric generation must be considered and kWh converted into TOE. A known datum is that inside the European context average electric generation efficiency changes, ranking from 30% (France and Sweden) to 46% (Luxembourg and Netherlands); an even higher spread on electric generation efficiency characterizes the worldwide scenario, adding further complexity to the analysis. The UK was the first Country to set up an Energy Savings Certificates scheme, with a cumulative actualized (i.e. accounting for saving devices obsolescence) 130 TWh mandatory saving for energy suppliers [28]. ESC trading in Italy, Great Britain and France, started in 2005, produced a trading unit -White Certificate (WhC)- soon expected to be implemented by other member States. 21 US States have energy efficiency targets, mandatory or voluntary [29]. New South Wales (Australia) ETS program is ready to be launched. Recently, India released a Climate Action Plan that encouraged the creation of a national market for ESCs and China also is debating on the scheme suitability [30]. A differentiation comes out between mature markets, benefitting from a consolidated structure and price dynamics – as in Italy – and new markets – as in UK, France, USA, China, Australia and India - whose full development and exploitation still requires time, but seems very promising, especially considering the growth in energy consumption in key sectors, as Industry and Residential, these Countries are expected to experience in the near future.

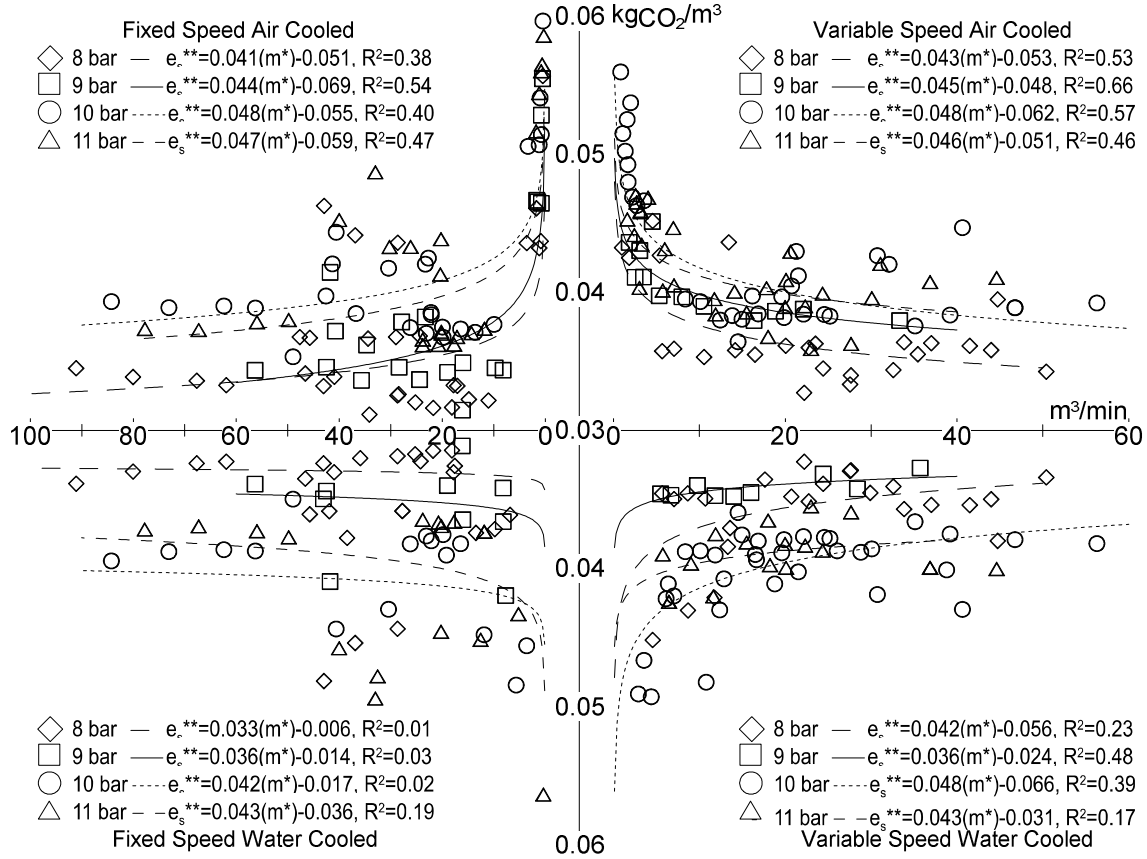
National commitments specificity, the need to match the period in which certificates are generated and spent along with the differences in Industry and energy standards among different Countries represent major limitations to the definition of a unified frame for national energy saving markets. The different sensibility to the themes of fossil fuel sources availability and CO<sub>2</sub> emissions increase further adds to this. The former is commonly perceived as a ‘questionable matter’, mostly due to the lack of a ready-to-use number on sources exhaustibility, whereas with CO<sub>2</sub>, the 450 ppm datum provides a clear quantitative indication on the room available for technology development for years to come and gives a better sense of what extent efforts should be pushed to, in order to prevent the overstepping of an assigned threshold. Thus a unitary development of environmental markets is hard to achieve.

In new markets (e.g. United Kingdom, France and Denmark), all savings are calculated and contributed to the first year and the number of certificates (NESC) is given by:

$$N_{ESC} = S \cdot L_{SPAN} \cdot \delta \quad (2)$$



in which  $S$  is the energy saving, calculated with respect to a baseline consumption,  $L_{SPAN}$  is the technical life for the application considered and  $\delta$  is the discount coefficient, accounting for technical aging, i.e. for the fact that the saving as declared at the beginning tends to decrease, as the time goes by [31]. These certificates are recognized at the same time the investment takes place.



**Figure 2.** Specific CO<sub>2</sub> emissions per unit mass compressed air in EU

In Italy, certificates are eligible only when energy is saved, i.e. the reward is provided at the same pace the energy savings happen [29]. Hence the uncertainty about the certificates value during years, due to market price fluctuations is the key for ESCs' market success [32] as in various comprehensive analysis [33, 34, 35, 36]. Equation (2) becomes:

$$N_{ESC} = k \cdot S \cdot \tau \quad (3)$$

in which,  $S$  is still the saving,  $k$  is a factor that converts thermal or electrical saving into TOE. Since certificates lifespan  $N_{l,s}$  (i.e. the 5 to 8 years period, during which the certificates are recognized) and the technology lifespan (i.e. the 15 to 20 years period, the saving lasts and after which technology becomes obsolete) are different, a discount factor,  $\tau$ , to redistribute the overall saving over the lifespan (i.e. to express the saving in the overall technological lifespan as a multiple of the first year saving), needs to be introduced [30, 31, 32]:

$$\tau = 1 + \frac{\sum_{j=1+N_{l,s}}^{N_{t,l}} (1 - \delta)^j}{N_{l,s}} \quad (4)$$

## 5. Energy and CO<sub>2</sub> emissions saving – Financial value assessment

A safe estimation of CAS related energy consumption on a European basis by PNEUROP, is 56 TWh, to which both screw and vanes compressors contribute, with 36.58 TWh and 19.17 TWh, for fixed and variable speed drive versions respectively, as in Figure 3 [6].

The compressor replacement, whose potential depends on the efficiency target for compressors and on the specific energy below which a compressor cannot be operated, represents an interesting option in the EU context. An in-depth investigation of market compressors specific consumption is in [15], where ISO 1217 testing conditions (i.e. 0°C and 1 bar) are considered: a 130 Wh/Nm<sup>3</sup> specific energy consumption is associated to 7 bar delivery pressure, with premium machines set at 85 Wh/Nm<sup>3</sup>. It has to be observed that these figures are nothing but a general datum, since compressors specific consumption depends on operating conditions, that can significantly vary among industrial applications. A by far more effective approach, when depicting machine replacement-based scenarios, is the one that assumes the compressor adiabatic isentropic efficiency as machine merit criterion. PNEUROP [6] sets a baseline curve for efficiency and foresees that a 0.7-2.1 TWh saving is possible by machine replacement, when fixed speed compressors are considered; the same figure for variable speed compressors is 0.3-1.2 TWh. An overall 1.0-3.3 TWh saving on compressors is thus achievable. When the whole compressed air chain underwent an upgrade process (e.g. compressor and piping leakage fix and pressure losses optimization), a further 2-7 TWh energy saving could be put on the market, for a cumulative 3-10.3 TWh saving. With reference to Italy, a 0.19 TOE/MWh electrical efficiency can be considered; with a 15 years lifespan, a 5 years financial lifespan, and a 0.02  $\delta$ ,  $\tau$  in Equation (4) is 2.65 and Equation (3) gives a 1.5-5.3 MTOE saving in the CAS. When an average 100 €/TOE price is assumed, this leads to a 150-530 M€, to split on 5 years financial lifespan.

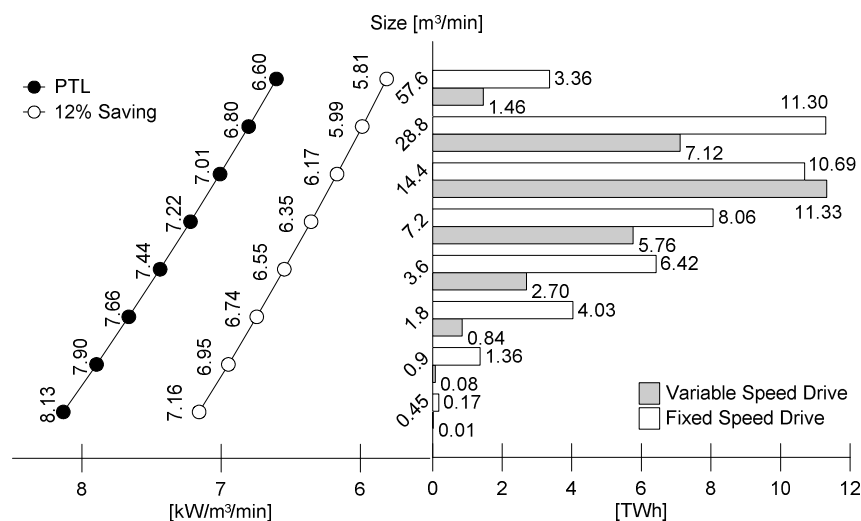
By accounting for the financial benefit associated with CO<sub>2</sub> trading on the European ETS market, 15-35 M€ (i.e. 15 €/tCO<sub>2</sub> and 1-2.5 MtCO<sub>2</sub> considered as average Carbon price and Carbon saving, respectively) add to the previous figure, leading to 165-565 M€ financial value. In a strict-commitment 50 €/tCO<sub>2</sub> scenario, the financial value of CAS-related Carbon credits and ESCs ranks at 200-655 M€.

A general datum can be provided, to allow a comparison among main immaterial markets, established at the present day, for the given 3-10.3 TWh saving scenario. A direct comparison with a different European context is possible by considering UK: a 18 €/MWh price applies to electricity saving, whereas the Carbon Price Floor fixes the Carbon quotas sale price at 15 €/tCO<sub>2</sub> [37]. Consequently, a 540-to-1854 M€ and a 204-to-700 M€ financial impact comes from energy saving certificates and CO<sub>2</sub> quotas selling, respectively: these two figures add up to a 750-to-2560 M€.

The pace of reform in China's electricity market is gathering speed, thus increasing competition and market awareness of large power users [38]. When a 38.4 €/MWh is considered as the reference, the financial revenue from electricity selling ranges between 1.2 and 4.0 billion Euro. As far as the trading of CO<sub>2</sub> quotas is concerned, the Beijing Pilot ETS can be safely assumed as the reference frame, in which a 9 €/tCO<sub>2</sub> price applies [17]; this leads to a minimum 189 M€ and a maximum 650 M€ revenue from CO<sub>2</sub> trading. The cumulative financial benefit of compressed air-related Carbon credits and ESCs ranks at 1.4 to 4.7 billion Euro.

Same considerations apply to Australia: apart from regionalism in price assignment [39], 17 €/MWh and 21 €/tCO<sub>2</sub> can be considered as reference prices for electricity saving and avoided CO<sub>2</sub> (according to the Carbon Pricing Mechanism, as in [17]), respectively. The correspondent market benefits are estimated in 500-1700 M€ and 532-1825 M€. The cumulative revenue is in the 1.0-3.5 billion Euro range.

In order to refer previous calculations to India a 39 €/MWh price for saved electricity [40] and a 100 €/tCO<sub>2</sub> sale price for CO<sub>2</sub> quotas on the market [17] are considered. Financial value for electricity saving ranges between 1.2 and 4.0 billion Euro, whereas a 2.9-9.8 billion Euro revenue is achievable by selling CO<sub>2</sub> quotas. The two of them add up to 4.1 to 14 billion Euro cumulative financial benefit on the market.



**Figure 3.** Cumulative electricity consumption – Present technological level (PTL) vs saving scenario [15]

In the US, each member State adopts its own paradigm in terms of immaterial market for both electricity saving and avoided Carbon emissions. Nonetheless, a general datum can be provided on the Carbon market, based on the Cap and Trade initiative, with a 8 €/tCO<sub>2</sub> Carbon price [17, 41]. Once an average 29 €/MWh electricity price is assumed [42], the financial impact on the market is estimated in 880-3015 M€ for electricity and 124-426 M€ for Carbon quotas sale, i.e. a cumulative 1.0-3.5 billion Euro. Such results call for a lobby action in the CAS and the achievable financial benefit encourages the adoption of a synergic activity to promote a new approach to compressed air production and delivery. One last datum can be given, that sums up all elements of the previous analysis: when the overall mean financial saving (430 M€) is referred to the overall electricity saving (4.5 TWh), the specific saving in the EU CAS turns out to be 10 c€/kWh.

The same approach applies to other contexts, even though due to the differences on both the NESC definition and numerical values for prices and discounting coefficient differences shall be expected on the value of specific saving in the CAS. In detail, 40 c€/kWh applies to UK, 70 c€/kWh to China; the value for Australia and US is 50 c€/kWh while it raises at 200 c€/kWh for India.

## 6. Conclusions

The compressed air industry entirely relies on the use of electrical energy, with shares ranging from few percentage points to values close to 20% overall industrial electricity needs. Given the present efficiency standards, a 25-50% saving is possible by fixing leakages in compressor and piping, optimizing pressure levels and replacing machines. Both CO<sub>2</sub> emissions and fossil fuels use are committed in almost all World Countries - on both a local (national and subnational) and global basis - and traded on immaterial markets assigning saved fossil fuel and avoided emissions with a price. The paper describes the Carbon dimension of present compressor technology and fixes CO<sub>2</sub> emissions per unit of compressed air delivered, based on CAGI and PNEUROP data for the US and EU context, respectively. The approach adopted allows to extend the results of the analysis to every context of interest, by applying the appropriate emission factor to the datum on compressor specific consumption. According to the PNEUROP analysis, 1-3.5 TWh can be saved through machine replacement in Europe, the overall saving almost doubles if leakages fixing and pressure level control take place. In terms of Carbon credits and fossil fuel saving, tradable quantities are 1-2.5 MtCO<sub>2</sub> and 1.5-5.3 MTOE, that refer to a 5 years financial timespan. This datum refers to the European context and based on projections for future trends in environmental markets, fixing 50 €/tCO<sub>2</sub> and 100 €/TOE as good approximations of applicable prices, it corresponds to a 430 M€ cumulative saving (mean value between 200 M€ and 655 M€). As a synthesis datum, the saving in the EU CAS can be



estimated in 10 c€/kWh. Such a datum is close to the net electricity cost in many Countries. Such an approach applies to all main Countries in the World and by providing a clear indication on both the mean value for cumulative saving and equivalent electricity cost in the CAS, it represents an effective tool to orient the decision making process. In the UK, a 1.7 billion Euro saving volume can be put on the market, corresponding to an average 40 c€/kWh. Same indicators for China are 3.0 billion Euro and 70 c€/kWh, whereas for Australia and USA they rank at 2.3 billion Euro and a 50 c€/kWh electricity cost. India has the greatest potential for saving, as 9.0 billion Euro saving can be achieved, corresponding to 200 c€/kWh electricity cost.

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