COGENERATION AND CLEAN DEVELOPMENT MECHANISM

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Abstract*. Argentine presents nowadays little investment in generation power plants. Two thermoelectrical ones will enter in operation soon, but this will not solve the increasing industrial energetic demand. Other solutions must be found in order to avoid an energetic crisis. The argentine industrial sector has a high thermal demand, ten times higher as the electrical one. This sector presents a high cogeneration potential, theoretically 3.8 GW, which represents a 36.5 % contribution to the central distribution system Cogeneration systems have to be considered as capital intensive projects subject to the effects of the economy of scale. This implies that the industry must look forward to make a high inversion. Nevertheless these systems imply thermal and electrical generation with high reduction of Greenhouse effect gases, that is to say reduction of carbon oxides emission, due to the fact of combustible diminution. Therefore a way to it make this possible is to apply for a certificate of emissions reduction. Since the investment profitability for cogeneration system implementation can be elevated in large facilities with gas turbines and heat recovery boiler, and thermal vector do not present a large scale of transport distribution and has to be provide in situ, thermal demand centers are proposed as a way to solve this. The objective of this paper is to review restrictions of cogeneration systems installation and to discuss them in function of the financial credit for reduction of greenhouse gases emissions by using the Clean Development Mechanism.*

Keywords*: clean development mechanism CDM, cogeneration potential, certified emissions reduction CER.*

1. INTRODUCTION

Argentine presents nowadays little investment in generation power plants. Two thermoelectrical ones will enter in operation soon, but this will not solve the increasing industrial energetic demand. Other solutions must be found in order to avoid an energetic crisis. Nevertheless, a way to contribute to energetic generation is the installation of cogeneration systems, using the potential that industries can offer. The argentine industrial sector has a high thermal demand, ten times higher as the electrical one. Therefore cogeneration can represent an option to generate both energetic demands, giving a way to solve the well known energetic crisis. This sector presents a high cogeneration potential, theoretically 3.8 GW, which represents about 36.5 % contribution to the central distribution system. Countries as Holland or Denmark make use of this possibility, providing a contribution of 40%. Cogeneration systems have to be considered as capital intensive projects subject to the effects of the economy of scale. This implies that the industry must look forward to make a high inversion. Nevertheless these systems imply thermal and electrical generation with high reduction of Greenhouse effect gases, that is to say reduction of carbon oxides emission, due to the fact of combustible diminution. Therefore a way to it make this possible is to apply for a certificate of emissions reduction CER. Since the investment profitability for cogeneration system implementation can be elevated in large facilities with gas turbines TG and heat recovery generator HRSG, and thermal vector do not present a large scale of transport distribution, being provided in situ, thermal demand centers are proposed as a way to solve this. Several factors must be taken into account in case of installation of a cogeneration system, such as: heat demand constancy, electricity sale rates, and regulation rules, among others. The objective of this paper is to review the legal and financial restrictions of cogeneration systems installation and to discuss them in function of the financial credit for reduction of greenhouse gases emissions by using the Clean Development Mechanism, CDM.

Greenhouse effect emissions evolution represents the best way to point out national government compromise with the surroundings. Kyoto Protocol looks forward to stabilize Greenhouse effect gas emission concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Developed countries have now an opportunity to take the lead in combating climate change and its adverse known effects. Therefore, CDM represents a cooperative action between developed and developing countries.

2. ARGENTINE ENERGETIC CONSUME

Figure 1 shows the argentine energetic consume of different sectors, residential, commercial - public and industry in kTEPs (TEP equivalent petroleum tons) during the period 1970-2003, with a significant increase in both residential and industrial sectors, having the latter through all the period the higher energetic consume.

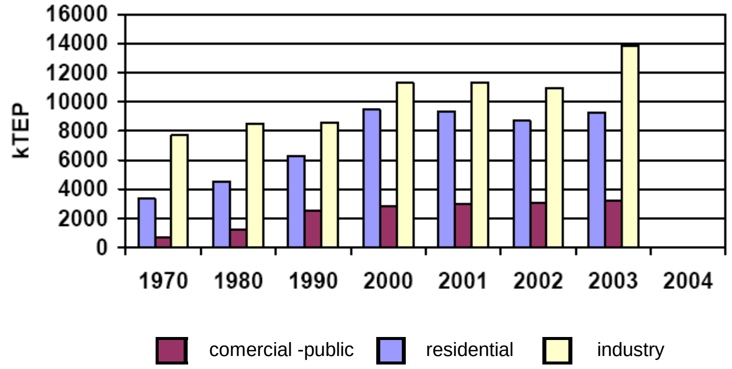

Figure 1. Energetic consume in Argentine during the period 1970-2003.
(Fushimi & Sosa, 2005)

Figure 2 shows the annual sector participation to final energetic consume during 2003, discriminating between the residential, commercial, agriculture, transportation, industry and non-energetic ones. The industrial sector with 13818 from a total of 43403 TEPs, is nowadays the greater energy demanding sector, 33%, being Transportation in the second place with 25%.

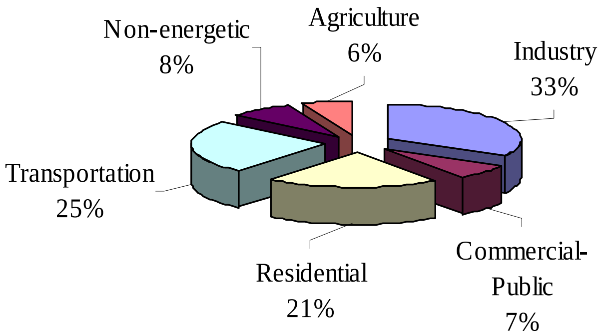

Figure 2. Energetic final consume of different argentine sectors in 2003.
(Fushimi & Sosa, 2005)

In Argentine the industrial sector has high natural gas availability, being its thermal consume about ten times higher as its electrical consume. From a thermodynamical point of view, this indicates that this sector has the capacity to cogenerate electricity with a production higher as its consume, being in conditions to supply energy to the central energetic system.

Argentine presents nowadays little investment in generation power plants. Two thermoelectrical ones will enter in operation soon, but this will not solve the increasing industrial energetic demand. Figure 3 shows the natural gas demand of the industrial sector in the period January-1999 till March 2005, in 10^3 cubic meters of 9300 kcal higher heat capacity HHC, (Fushimi and Sosa, 2005). Looking forward to a rational use of primary resources, this natural gas consume could be used in cogeneration systems, so as to generate both, thermal and electricity energetic vectors. The integration of power and heat processes in a cogeneration system brings significant improvements in the rational use of fossil resources with a reduction of surroundings impact, since it reduces carbon oxides emission, due to the fact of combustible diminution. Argentine has little development of cogeneration systems due to the fact that electricity is cheap. Nowadays the energetic industrial demand is increasing, and solutions must be found in order to avoid an energetic crisis.

Cogeneration systems reduce Greenhouse effect emissions, GEIs, being in the place to apply for financial credit for reduction of greenhouse gases emissions through the Clean Development Mechanism.

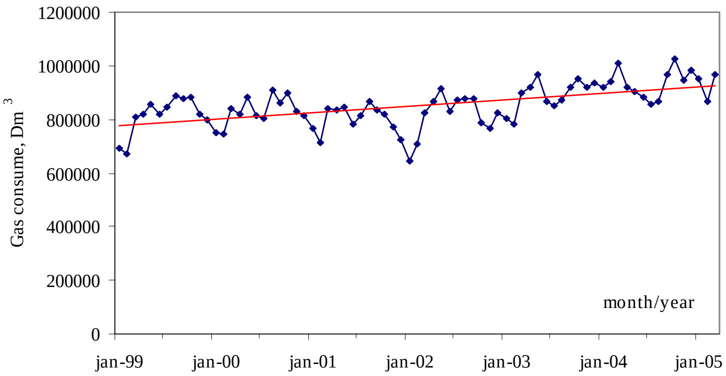

Figure 3. Natural gas consume of the industrial sector during the period 1999-2005. (Fushimi & Sosa, 2005)

3. COGENERATION POTENTIAL OF INDUSTRIAL SECTOR IN ARGENTINE

Cogeneration represents an efficient way to use rationally primary resources and to reduce combustible consumes. Considering natural gas consume, the theoretical thermodynamical cogeneration potential can be calculated. Average monthly consume is about 851503 Dm^3/month, that represents 11150 MW power in terms of LHC, lower heat capacity.

Figure 4 indicates the higher, medium and lower values of the final natural gas consume in MW of different industries during 2004.

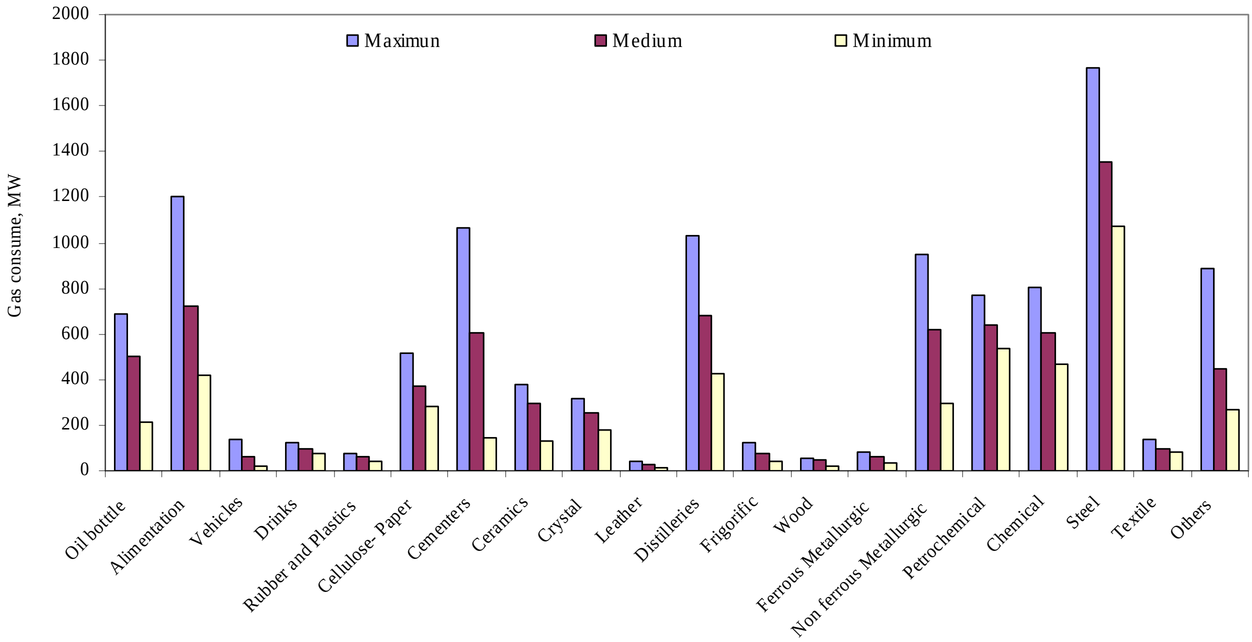

Figure 4. Natural gas consume for different industrial sectors. (Fushimi & Sosa, 2005)

The technology of the cogeneration system defines the energetic coefficient Sk as the relation between electricity and heat. The amount of electricity that the cogeneration system will generate depends on the thermal demand of the involved industry and on the selected technology to be apply, that is to say on Sk. Considering a value of 70%, Fig.5 indicates the maximum, mediums and minimum amounts of electricity to be generate from natural gas consumes of the different industries.

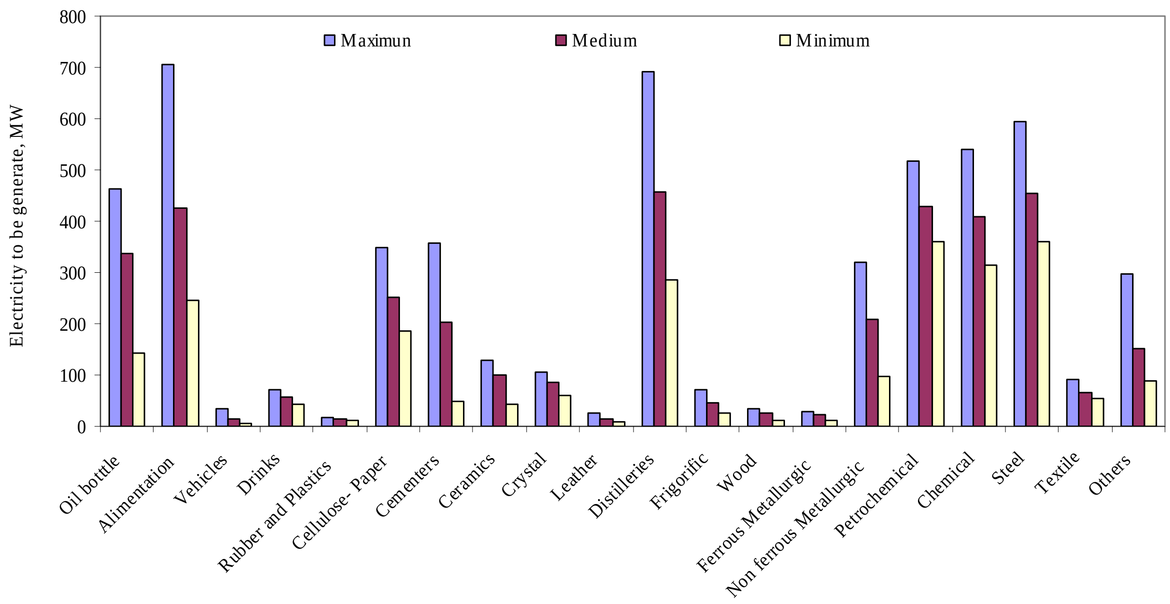

Figure 5. Maximum, medium and minimum consumes and electricity to be generate.
(Fushimi & Sosa, 2005)

Considering that the thermal demand of the industrial sector is about 95% of total gas consume, only a fraction of this value will be in the place to offer technical conditions for the installation of a cogeneration system. Supposing a value of 50%, the theoretical cogeneration potential of the argentine industrial sector will be between 2.4 – 5.4 GW, with an average value of 3.8 GW, Tab. 1.

Table 1. Cogeneration potential of the argentine industry.
(Fushimi & Sosa, 2005)

Consume			Electricity to be generate		
maximum	medium	minimum	maximum	medium	minimum
MW	MW	MW	MW	MW	MW
11146	7627	4738	5442	3771	2401

Considering a monthly average generation of 7500 GWh of the argentine Electrical Market Wholesaler, Mercado Eléctrico Mayorista MEM, the average theoretical potential contribution of the industrial sector could be 2715 GWh, increasing in average the total generation in 36 %. The cogeneration of the industry sector would contribute with a 27 % of increase to the central system, Tab. 2.

Table 2. Effect of the cogeneration in the monthly average generation.
(Fushimi & Sosa, 2005)

	maximum	medium	minimum
Power, MW	5442	3771	2401
Monthly generation, GWh	3918	2715	1729
% Cogeneration	52%	36%	23%
Average monthly potential generation in GWh	11418	10215	9229
Cogeneration contribution	34	27	19

The potential contribution of the industrial sector to the central system could be up to 34 %, depending on minimum, average or maximum value consumes. Developed countries such as Holland and Denmark present a cogeneration contribution of 40 % other higher.

The feasibility of implementation of cogeneration systems depends widely on regulation and legislation. In the actual argentine normative, a Cogenerator is considered as an actor whose only purpose is the sale of both energetic vectors, thermal and electrical, but must not be involved in obtaining of a product. Besides the Autogenerator is considered as an actor that generates its own electrical demand. Actually our legislation do not take into account the fact that a industry can generate excess electricity so as to supply its own electrical demand, being in the place to be sell the rest to the central system. This is nowadays been revised, it is expected that sooner the industries will be able to produce energy in excess and sell it to the main system according to future regulations, Energy Plus.

4. GREENHOUSE GAS EMISSIONS

Kyoto Protocol looks forward to impulse activities in order to minimize worldwide global reduction of Greenhouse Gas (GHG) emissions through the creation of a international market of certified emission reductions, CER. The Parties included in Annex I by 2008-2012 have to reduce their GHG emissions by an average of 5% below their 1990 levels. For many countries, such as the EU, European Union, member states, this corresponds to 15% below their expected GHG emissions in 2008 and implies domestic action in accordance with national circumstances, looking forward to reduce emissions towards achievement of ultimate objective of the Kyoto Protocol Convention. EU introduced quotas in six key industries, energy, steel, cement, glass, brick making, and paper/cardboard.

A certified emission reduction, CER, is a unit equal to one metric tone of carbon dioxide equivalent, calculated using global warming potentials. Table 3 shows the CDM statistics indicating the CDM projects and the expected CERs until the end of 2012, assuming that all activities deliver simultaneously their expected annual average emission reductions and that there is no renewal of crediting periods.

Table 3. CDM statistics.
(UNFCCC, 2007)

	Annual Average CERs	Expected CERs until end of 2012
CDM project pipeline: > 1600	N/A	> 1900000000
632 registered	135248774	> 870000000
77 requesting registration	12559146	> 80000000

Though the average emissions reduction is 5%, the case of Spain as a member of the EU is important, since this country has increased carbon dioxide emissions (CO_2) in 42% in the period 1990-2002, from 227 millions tones in 1990 (baseline year) to 323.5 millions tons in 2002, Tab. 4.

Table 4. Total and carbon dioxide emissions (CO_2) in Spain (1990 and 2002).
(Nieto & Santamaría, 2003)

Emissions	Period		Relative increase 1990
	1990	2002	
Total	287.6	400.2	38%
CO_2	227.1	323.5	42%
	79%	81%	

Considering that the carbon dioxide emissions represent 79% of total emissions in year 1990, this implies an 80.85% increase of the total GEI emissions in Spain, Tab. 4. This relative increase is higher as the adopted 15% maximum in the period 2008-2012, according to EU adopted rules. To the baseline corresponds the total emissions of CO_2, CH_4, N_2O in 1990 and the emissions of PFCs, HFCs and SF6 in 1995.

Table 5. Total carbon dioxide emissions (CO_2) in Spain (1990-2002).
(Nieto & Santamaría, 2003)

Year	CO_2 equivalent emissions (millions tons)	
	Total	Index
Baseline	289.85	100
1990	287.61	99
2002	400,156	139
Kyoto limit	333.33	115

In 2002 the energetic sector and transportation were the main responsible for the emissions with a 78% of total GEI value, that is to say this represents an 43% increase relative to baseline. If actual conditions remain unchanged until

2012, dioxide carbon emissions will increase the index up to 154. This means that Spain must be in the place to purchase yearly CERs about 113 millions tons equivalent, Tab. 6.

Table 6. Emissions prognostics for Spain in 2012.
(Economy Department, Spain, 2003)

	Equivalent CO_2 emissions (million tons)	
	Total	Index
Kyoto limit	333.33	115
2012	446.37	154
Expected CERs in 2008-2012	113042	

Spain looks forward to invest in emission reducing projects in order of 250 millions euro, nevertheless this will not supply its demand, taking into account the future GEI emissions prognostics and the national cap on the emissions. Spain as well as other EU countries are potentially buyers of CERs, generated in developing countries such as Brazil other Argentine. Table 7 shows the predicted average annual reduction of several Latin-American countries, ranking Brazil in the first place. Countries as Brazil other Argentine are therefore potentially CDM developers.

Table 7. Average Annual Reductions.
(UNFCCC, 2007)

Country	Average Annual Reductions	Country	Average Annual Reductions
Brazil	16271186	Ecuador	435088
Argentine	3230112	Colombia	414205
Chile	3034361	Bolivia	82680
Peru	747724	Total	24215356

4.1 CERTIFIED GREENHOUSE EMISSIONS

Figure 6 presents the price evolution of Certified Greenhouse Emissions Reduction, CER. The highest values about 30 euros/ton CO_2 are found in June/2005 and February/2006. From this time the price decreases, having actually values below 5 euros/ton CO_2.

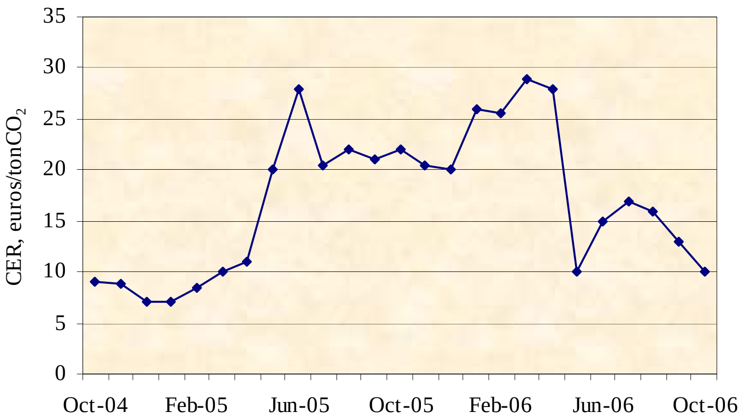

Figure 6. CER price evolution in the period from October/2004 to October /2006.
(UNFCCC, 2007)

In this year CER prices are must lower, being actually below 2 euros/ton CO_2. It is expected that this will change if the first Protocol commitment period 2008-2012 is extended till 2020.

5. DISCUSSION

In order to analyze the feasibility of the possibility of cogeneration systems in the argentine sector, a gas turbine + heat recovery steam generator TG + HRSG model was proposed, considering TG units available in the international market in the range 22 - 130 MW. The CER price was considered in the range 0 - 24 U$S / ton CO_2, for the following three systems:

a) Gas turbine LM 2500 PE (22.8 MW)
b) Gas turbine V 64.3ª (67.7 MW)
c) Gas turbine PG 9171 E (126.01 MW)

Table 8 presents specific cost, conventional gas consume and resource mitigation for the three selected gas turbine TG+HSRG cogeneration systems.

Table 8. Gas Turbine data.
(GTW Handbook, 2004-2005)

		Specific Cost	Conventional consume MW		Resource mitigation	
Gas turbine	MW	U$S/kW	Electricity	Vapor	%	MM m^3/year
LM 2500 PE	23	402	64.6	28.9	33.7	25.8
V64 3.A	68	219	191.8	98.9	33.6	80.0
PG 9171 E	126	150	357.3	181.7	30.8	135.8

Figure 7 shows the sensibility of the proponed cogeneration system with the price of the certified emissions reduction CER, ranking from -5% to 20%. Taking into account the evolution, Fig. 6, from 30 euros/ton CO_2 in June/2006 to 5 euros/ton CO_2 in October/2006, below 2 euros/ton at present, seems that the implementation was much feasible last year as is nowadays.

The smallest unit, LM 2500 PE, gives the lowest values, ranking from -2% al 8%. This implies that for the actual CER prices, this Project is not economically feasible.

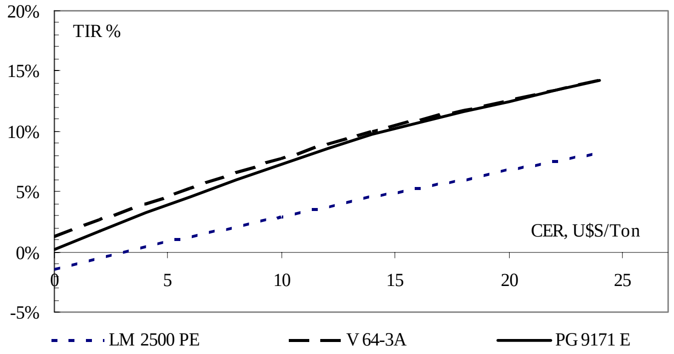

Figure 7. Sensibility of cogeneration Project with the CER price for three alternatives of cogeneration system. (Sosa & Fushimi, 2006)

The biggest unit PG 9171 E implies an investment of 150 U$S/kW, its specific cost is about 2.6 times lower as the small one and 1.4 as the intermediate unit V64-3.A. The resource mitigation follows this tendency, showing values up to 135.8 MM m^3/year. Cogeneration TG+HRSG systems with nominal power 22- 130 MW show TIR values up to 15%, if CER prices are higher as 20 U$S/ton CO_2.

The economical feasibility of these projects seams to be attractive for large scale systems, taking into account the present CER prices. Nevertheless if the evolution is positive and returns to values of June/2005 and February/2006 the small scale project have a chance.

6. CONCLUSIONS

The argentine industry presents an attractive cogeneration potential, having the capacity to increase up to 34% the actual electrical power generation of the central system. Alimentation, distilleries, chemical, steel and metallurgical industries have potential higher as 300 MW.

Cogenerated energy could be injected in the central system according to future regulations, Energy Plus.

The implementation of cogeneration systems depends widely on CER prices. Taking into account the evolution, from 30 euros/ton CO_2 in June/2006 to 5 euros/ton CO_2 in October/2006, below 2 euros/ton at present, shows that the implementation was much feasible last year as is nowadays. An increase to the former values is expected if the first commitment period 2008-2012 of the Protocol is extended till 2020.

The European Union EU as well as other developed countries will purchase credits directly from another party. Particularly Spain will have to achieve about 113.042 millions ton equivalent CO_2 emissions. Countries as Brazil other Argentine are potentially CDM developers.

Cogeneration TG+HRSG systems with nominal power 22- 130 MW show TIR values up to 15% if CER prices are higher as 20 U$S/ton CO_2. Considering actual CER prices, the smallest unit LM 2500 PE presents negative TIR values. Gas turbine systems with V64 3.A and PG 9171 E gives place to higher resource mitigation percentages.

Bigger scale cogeneration systems have an opportunity taken into account the present CER prices.

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