A New Age for coal with Carbon Capture and Storage(CCS)

*Organized by SCI's Science and Enetrprise and Process Engineering Groups*

# From clean coal power plants to the zero emissions power plants: 10 years of experiences of ENEL

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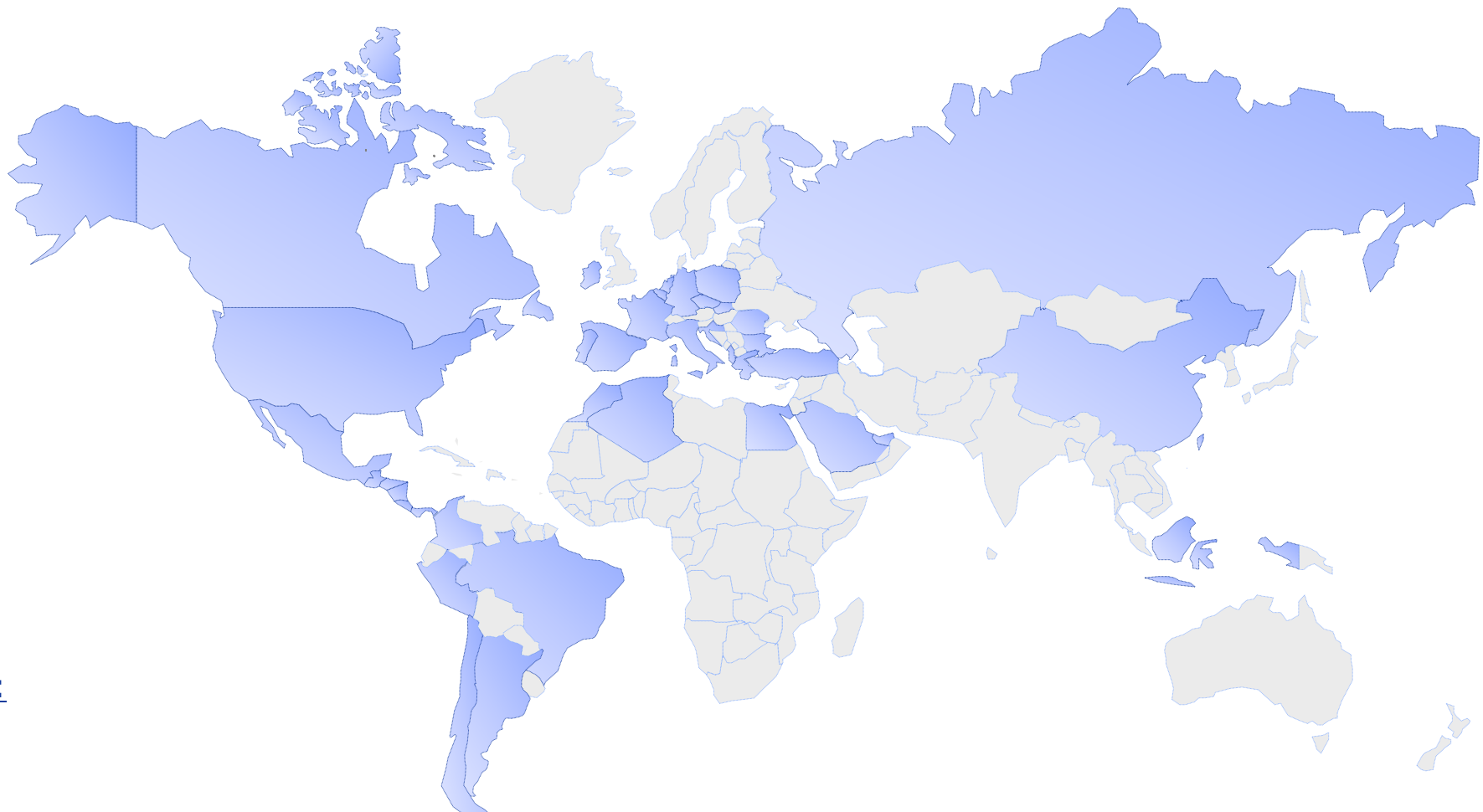
# Outline

- Enel's profile
- Enel's fuel  mix
- Sulcis : Circulating Fluidized Bed Combustor
- Torrevaldaliga : coal power plant
- Improvement of efficiency and emissions of  power plants fleet
- ENEL Group: Initiatives on CCS towards zero emissions
- Results in emissions reduction by power plants
- Final remarks

**Use:** Public

# Enel today

## An international, integrated energy operator



Presence in:
**40 countries**

Installed capacity:
**97.839 MW**

Annual output:
**295,7 TWh**

EBITDA:
**16,7 bln €**

Customers:
**60,5 million**

Employees:
**73.702**

CAPEX 2013-2017:
**€27 billion**

Data updated @ 31/12/2012

**1st utility in Italy, 2nd largest in Europe by installed capacity**
**Present throughout the entire electricity and natural gas value chain**

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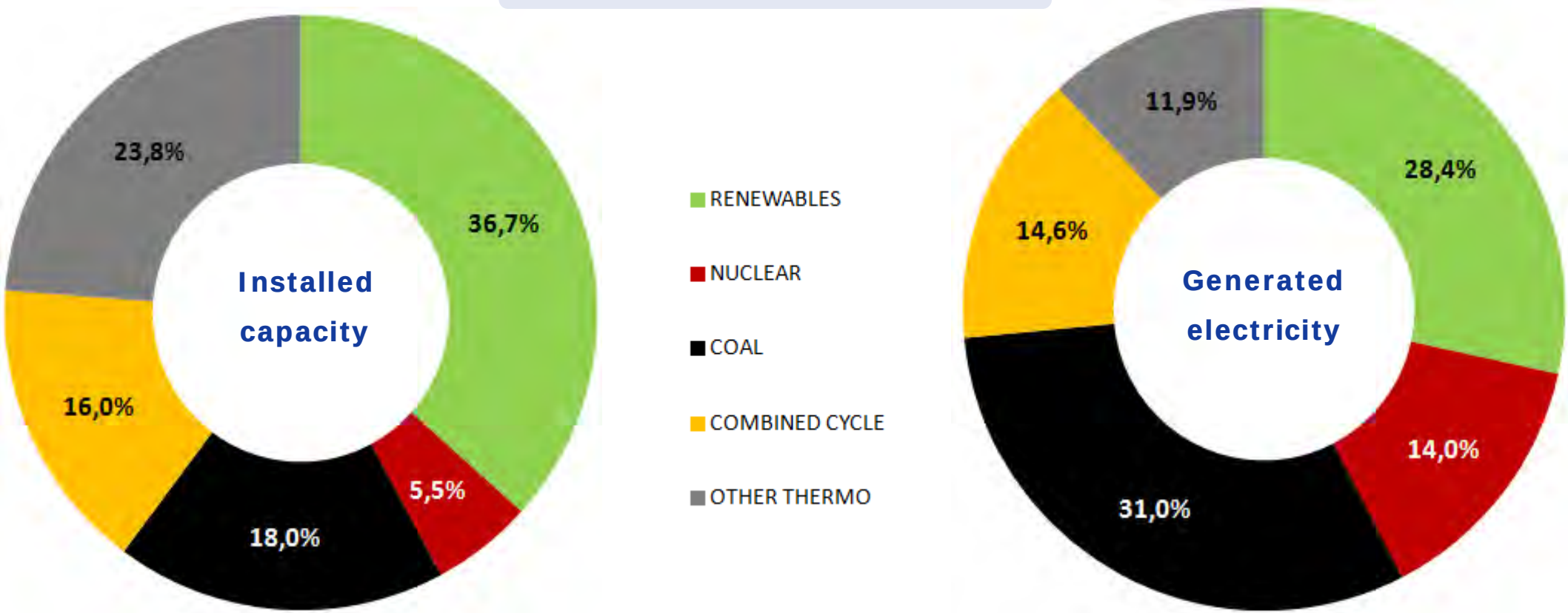
# Enel today

## An international, integrated energy operator

**ENEL GROUP - YEAR 2012**




**97.839 MW**

**296 TWh**

**Although the importance of renewable energies is increasing both in terms of installed capacity and generated energy, conventional generation will continue to play a key role at least in the next decades**

# Power generation systems retrofit

## Sulcis 2 CFB on old coal unit (240 MW)


Main project data

- Gross power output (MWe) 350
- Net efficiency 40%
- SH Steam temperature 565°C
- RH Steam temperature 580°C
- Fuel (20% sulcis(♣) 80% south african coal)
- Emission SO2/NOx/Particulate 200(✪)/200/30 (mg/Nm3)
- Ashes to coal mine
- Biomass co-firing system since 2007 (8÷15 %)

- **1° start-up** **July 4th 2005**
- **Commercial operation** **May 2006**

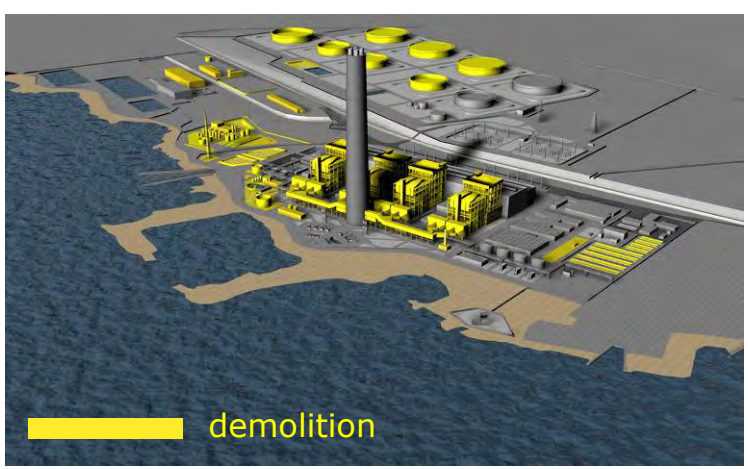
(♣) Sulcis coal: 6% S - 17% ash –38% volatile

(✪) $SO_2$ = 200 mg/Nm$^3$ with 0% of sulcis coal - 400 mg/Nm$^3$ with 20% of sulcis coal

# Torrevaldaliga Nord power plant: Enel's best practice

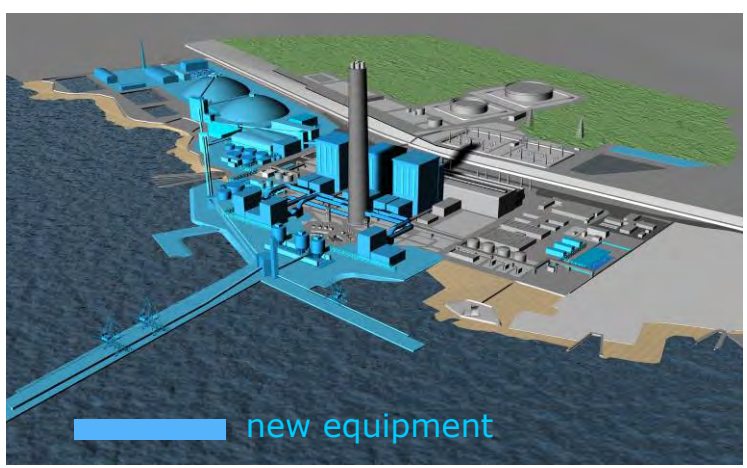
## HIGH EFFICIENCY POWER PLANT

| | |
|---|---|
| • Net efficiency | ~ 45 % |
| • Superheater steam outlet temperature | 604 °C |
| • Reheater steam outlet temperature | 612 °C |
| • Feedwater and condensate preheater station | 7 |
| • Condenser Back pressure | 0.042 bar |




**Yesterday: 4 fuel oil units, 2640 MW**

Units shut-down in 2006




**Today: 3 coal units, 1980 MW**

Commercial operation:

- Unit 4 January 2008
- Unit 3 August 2008
- Unit 2 August 2010



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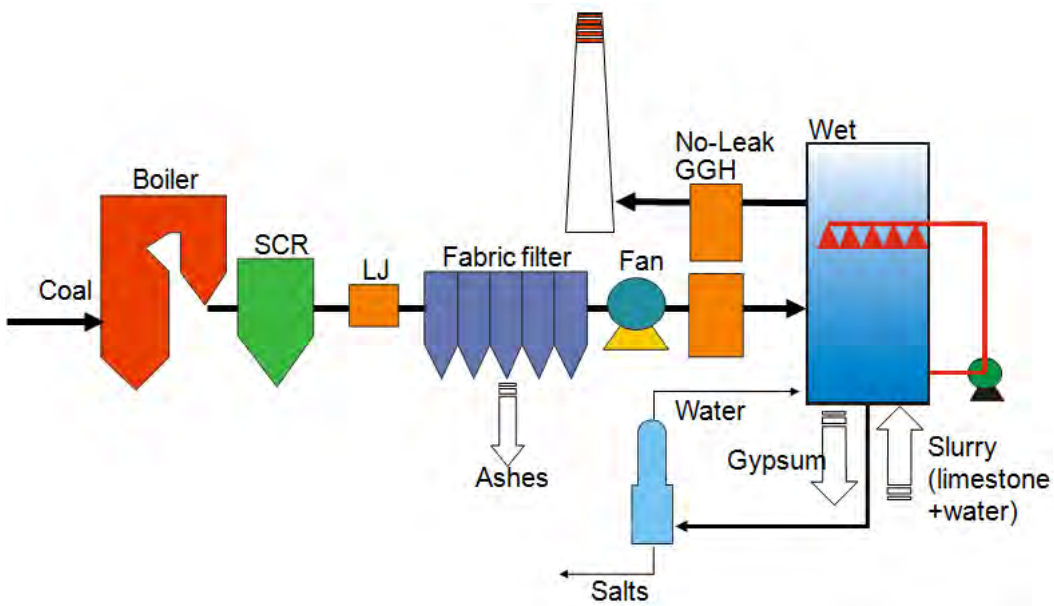
# Torrevaldaliga coal power plant

## Emission control technology state-of-the art

### LOW EMISSION FLUE GAS TREATMENT LINE




### NOx

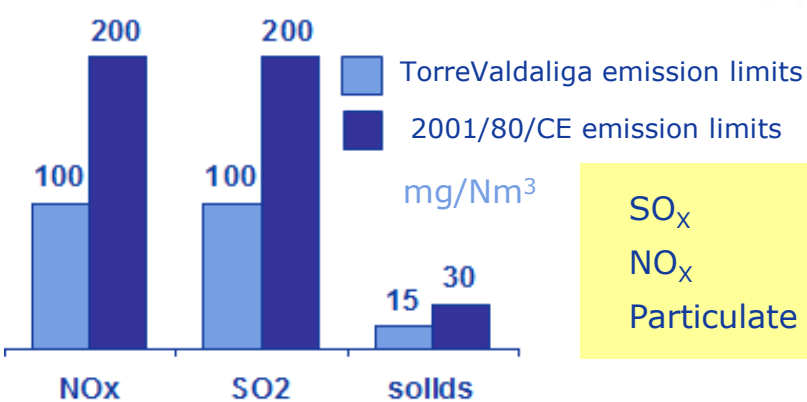
- Advanced combustion system
- High dust Selective Catalytic Reduction (SCR)
- Urea to ammonia Plant (Ammogen)

### Particulate

- Fabric Filter
- Particulate removal efficiency > 99%

### SOx

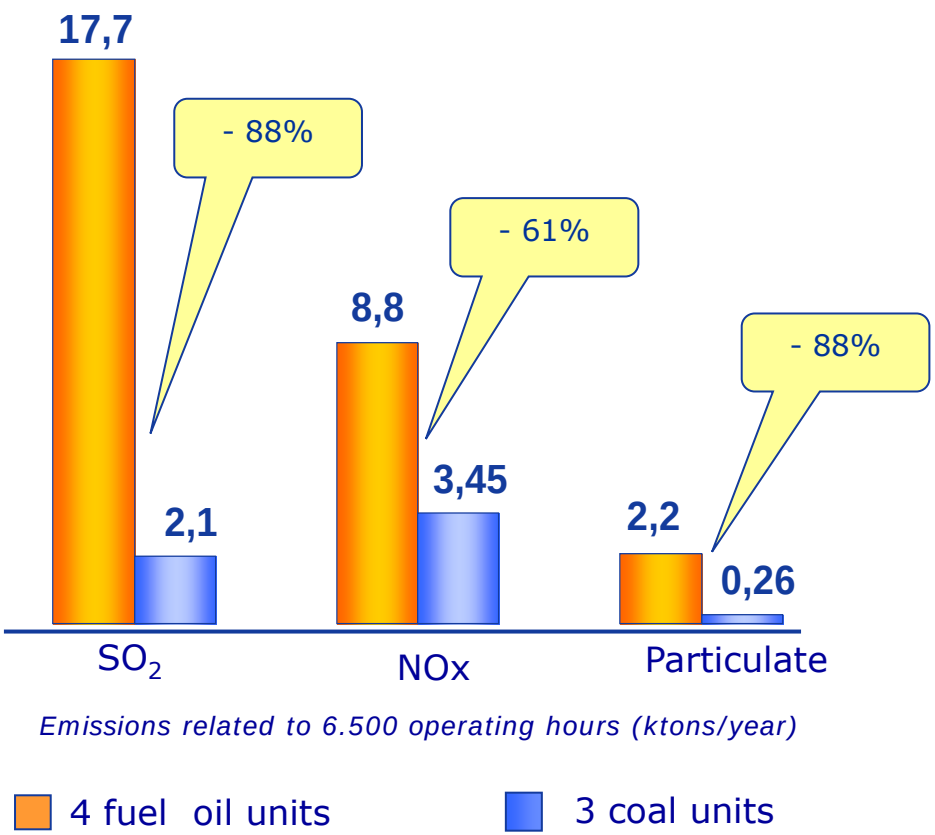
- Gas - Gas Heater (GGH) zero-leakeage
- Wet Flue Gas DeSOx (FGD) limestone-gypsum
- SOx removal efficiency > 97%




| | |
|---|---|
| $SO_X$ | ≤ 100 mg/Nm³ on hourly basis and 2100 t/y (~ 50 mg/Nm³ in base load) |
| $NO_X$ | ≤ 100 mg/Nm³ on hourly basis and 3450 t/y (~ 85 mg/Nm³ in base load) |
| Particulate | ≤ 15 mg/Nm³ on hourly basis and 260 t/y (~ 6 mg/Nm³ in base load) |

# Torrevaldaliga coal power plant

## Emission control technology state-of-the art

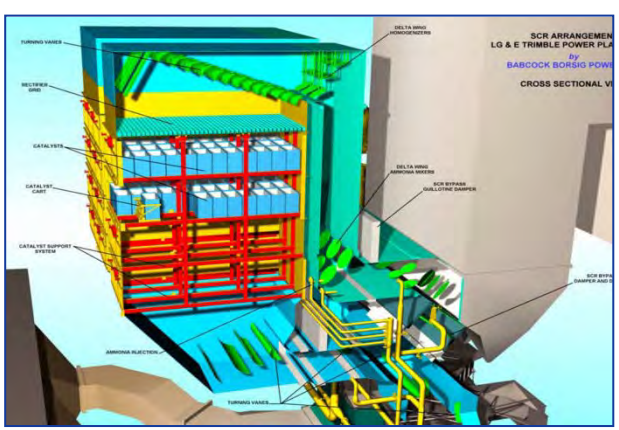




# Improving efficiency and emissions of coal units

## Retrofit of the Brindisi Sud power plant

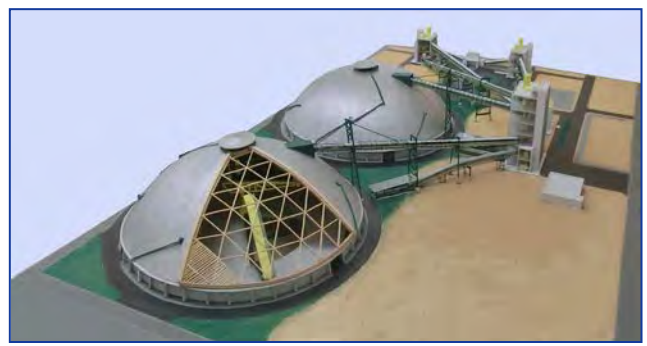
Mill upgrading



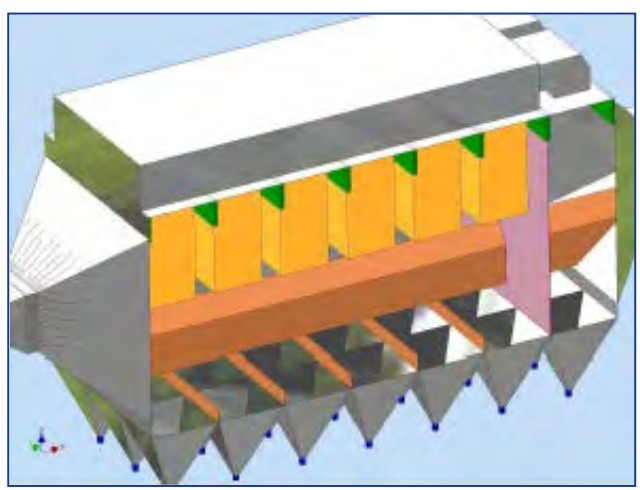
SCR revamping

**Brindisi Sud PP**
**4 x 660 MWe PC units**

- Opposite fired boilers
- Low-NOx burners + OFA
- Supercritical, once through
- SH outlet temperature 538°C
- RH outlet temperature 540°C



New coal dome erection



ESP to Fabric Filter conversion

# Improving efficiency and emissions of coal units

## Fabric filters today running in Enel's Italian fleet

| Plant | Capacity (MWe) | FF type | Installation | Supplier | Year | Bag Lenght [m] | Comp. | Emissions guarantees [mg/Nm3] (°) | Expected FF Emiss. in Operation [mg/Nm3] |
|---|---|---|---|---|---|---|---|---|---|
| Fusina 1&2 | 2 x 160 | PJ, HP/LV | Conversion | TMK | 1999 | 8,5 | 2 | <30 | <15 |
| Genova 6 | 160 | PJ, HP/LV | Conversion | TMK | 2003 | 9 | 4 | <30 | <15 |
| Sulcis 2 (*) | 340 | PJ, HP/LV | New (**) | Aster | 2005 | 8,5 | 16 | <25 | <15 |
| Torrevald. 1÷3 | 3 x 660 | PJ, HP/LV | New (**) | TMK | 2005 | 8 | 16 | <10 | <9 |
| Brindisi S.# 3&4 | 2 x 660 | PJ, HP/LV | Conversion | TMK | 2010-12 | 8 | 4 | <20 | <10 |
| (*) CFB Boiler | (**) Over the old ESP foundations | | | (°) hourly basis | | | | | |

- "Conversion" means "transformation" from an electrostatic precipitator to a fabric filter by using the existing casing.
- Acronyms: PJ pulse jet; HP/LV high pressure low volume type; TMK Termokimik spa Torrevald.: Torrevaldaliga North power plant.



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# Improving efficiency and emissions of coal units

## Fabric filters today running in Russia and South America

Reftinskaya Power Plant (RUS)

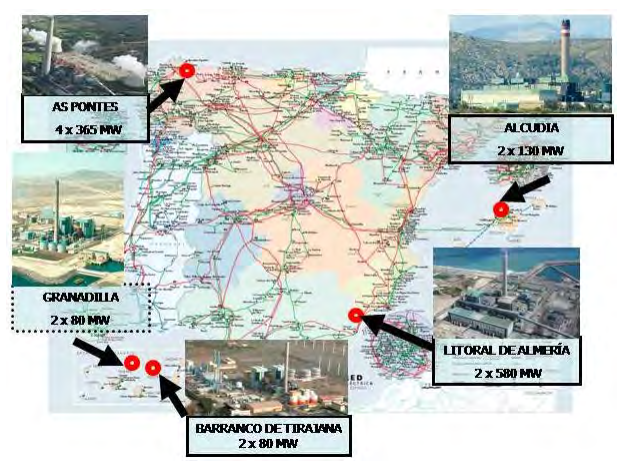
| Plant | Country | Capacity (MWe) | FF type | Installation | Supplier | Year | Bag Lenght [m] | Comp. | Emissions guarantees [mg/Nm3] | Expected FF Emiss. in Operation [mg/Nm3] |
|---|---|---|---|---|---|---|---|---|---|---|
| BOCAMINA II | Chile | 350 | PJ, HP/LV | New | Slavex | 2012 | 6,5 | 20 | <30 | <15 |
| Reftinskaya 5 | Russia | 300 | PJ, IP/IV | Conversion | ALSTOM | 2013 | 8 | 4 | <50 | <20 |
| Reftinskaya 7 | Russia | 500 | PJ, HP/LV | Conversion | Clyde Bergmann | 2014 (°) | 8,5 | 16 | <50 | <20 |
| Reftinskaya 4 | Russia | 300 | PJ, IP/IV | Conversion | ALSTOM | 2015 (°) | 8 | 4 | <50 | <20 |

(°) Expected date / schedule to be confirmed.

**Filters in Russia** will be **particularly challenging** in terms of operation and maintenance **considering the very high dust content of the coals (up to 40%)**

# Other coal retrofit projects under evaluation

| PLANT | FUEL | LOCATION | RETROFIT TARGET |
|---|---|---|---|
| **Novaky** (2x110MWe) | Lignite | Slovacchia | NOx reduction |
| **Litoral** (2x580MWe) | Bituminous coal | Spain | NOx reduction |
| **Alcudia** (2x130MWe) | Antracite | Spain | NOx reduction |
| **As Pontes** (4x365MWe) | Bituminous coal | Spain | NOx reduction |


**More than 3000MWe coal fired units under evaluation**

# ENEL Group: R&D towards zero emissions plants

## Carbon Capture & Storage :Experiences matured

ENEL Group, since 2006, decided to take the lead in the development of CCS technologies in coal fired plants .

ENEL Group has developed several projects and pursues the development knowledge of technology options for CCS:

- Post-combustion CCS technology ( pilot scale and power units feasibility)
- Oxy-Coal combustion atmospheric technology: ( projects in Italy and Spain)
- Oxy -Coal combustion pressurized (Pilot project in Italy)
- Pre-combustion CCS technology :Electric Power from Hydrogen
- Algae cultivation facility to trap combustion gases: Pilot in Spain
- calcium carbonate looping pilot plant 1.7 Mw (Spain )
- Pre-Feasibility study for application of post combustion capture technologies to coal fired plant in China (SINO-ITALY agreement)

# CCS: Post-combustion Carbon Capture technology

## CO2 capture pilot plant

**Operation: since June 2010**

# CCS: Post-combustion Carbon Capture technology

## CO2 capture pilot plant :R&D activities

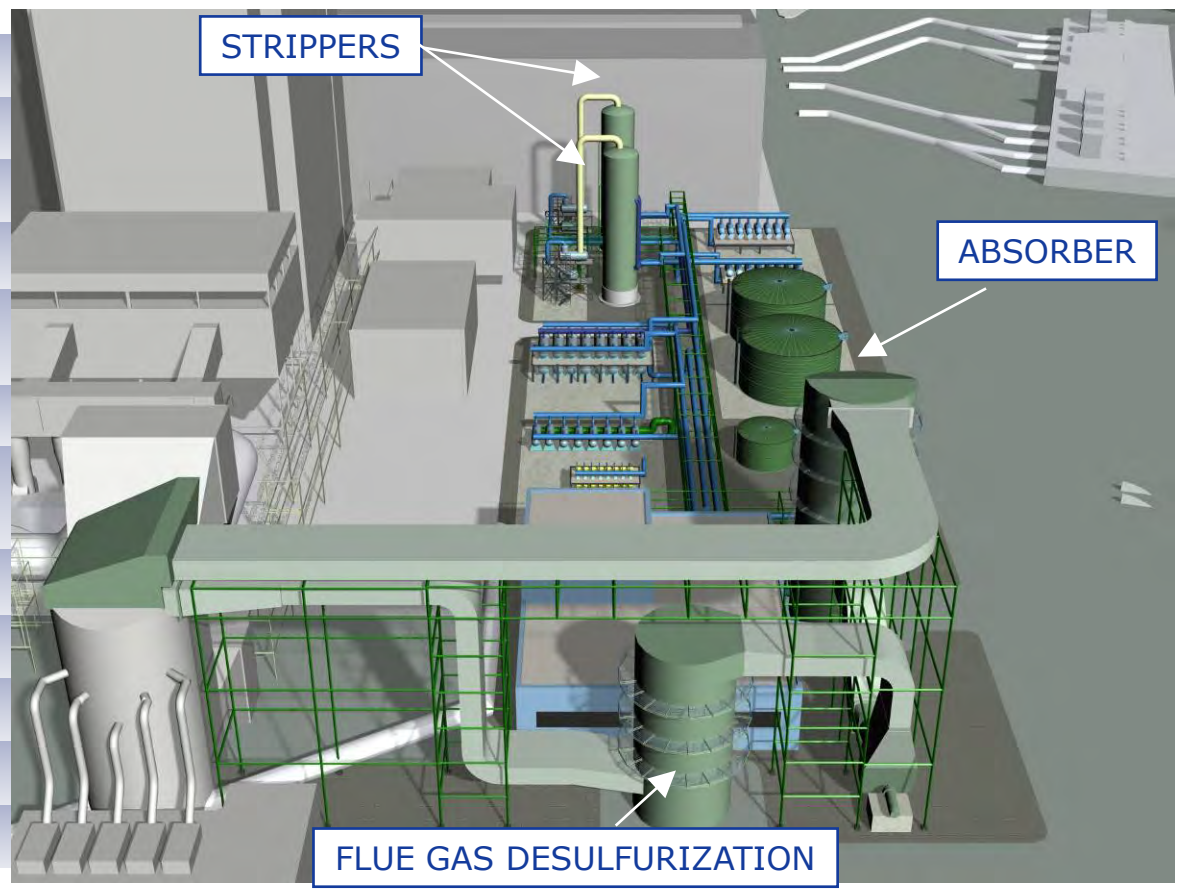
- Operational experience with base solvent (MEA 20%- 30%+ inhibitors)
  - Assessment of the MEA absorption technology: (reliability, environmental impact, power consumption and capture performance)
  - Definition of operating procedures
  - Cost evaluation at different operating conditions for retrofit application.
  - Flue gas composition: CO2 stream and emissions

- Testing of advanced solvents and inhibitors
  - An experimental program to test some advanced solvents and inhibitors has been set up with the aim to reduce power consumption, limit solvent degradation and improve environmental performances.
  - The pilot plant is flexible enough to allow the test of different kind of innovative liquid solvents. Enel is available to discuss with developers the terms for testing them.

# CCS: Post-combustion Carbon Capture technology

## Large scale CCS : Porto Tolle feasibility study

| | |
|---|---|
| Type of Project | **Retrofit** |
| Power generation | **660 MWe** |
| Primary fuel | **Bituminous coal** |
| Secondary fuel | **Biomass** |
| Power Generation Tech | **USC-PC** |
| % of flue gas treated | **40 %** |
| $CO_2$ Capture Tech | **Post Combustion Capture with Amine** |
| Stored $CO_2$ | **1.000.000 ton $CO_2$ / y** |
| $CO_2$ Capture rate | **90 %** |
| $CO_2$ Storage solution | **Deep saline aquifer** |
| Storage location | **North Adriatic Sea** |
| $CO_2$ value chain | **Pure storage** |

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# CCS: Post-combustion Carbon Capture technology

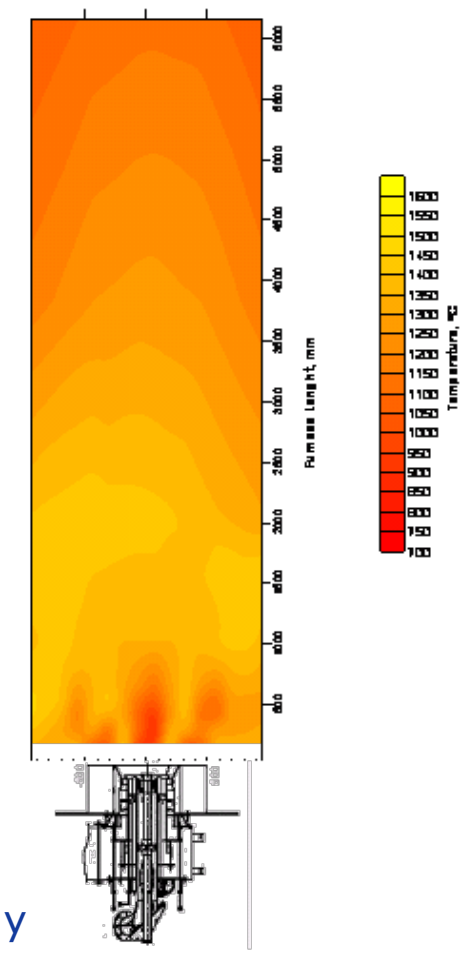
## MOST-IMELS –ENEL Cooperation Agreement CCS - CHINA Phase 1

| Power Station Feature |
|---|
| Power Plant : TONG CHUAN |
| Unit Capacity: 2X600MW |
| Construction Year: 2007-2008 |
| Total Capacity: 1200MWe |
| Power plant surface |
| Fuel : SHAANXI Coal |
| Cycle efficiency 92.5% |
| •Max load: 637 MWe |
| Steam Generator: sub-critical |
| Steam rate: 2070(T/h) |
| Steam Pressure(Max): 16.67Mpa |
| Steam temperature 538 °C |
| Steam Turbine: 3 Stages |
| Condenser: Air cool |

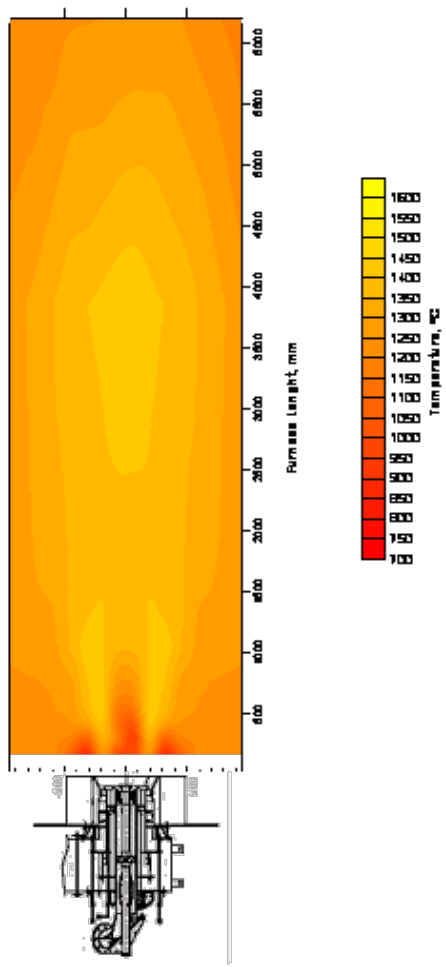
# Oxy-Coal combustion atmospheric technology

## Livorno 3 MW combustion facility

- 3 MW combustion test facility at Enel's Livorno labs was modified to oxygen operation
- Oxy-coal atmospheric combustion tests were successfully performed with different flue gas recirculation ratios
- Results of the first experimental campaigns provided elements about feasibility of retrofit and combustion technology



Baseline air



O2-Coal 61% R

# Oxy -Coal combustion pressurized

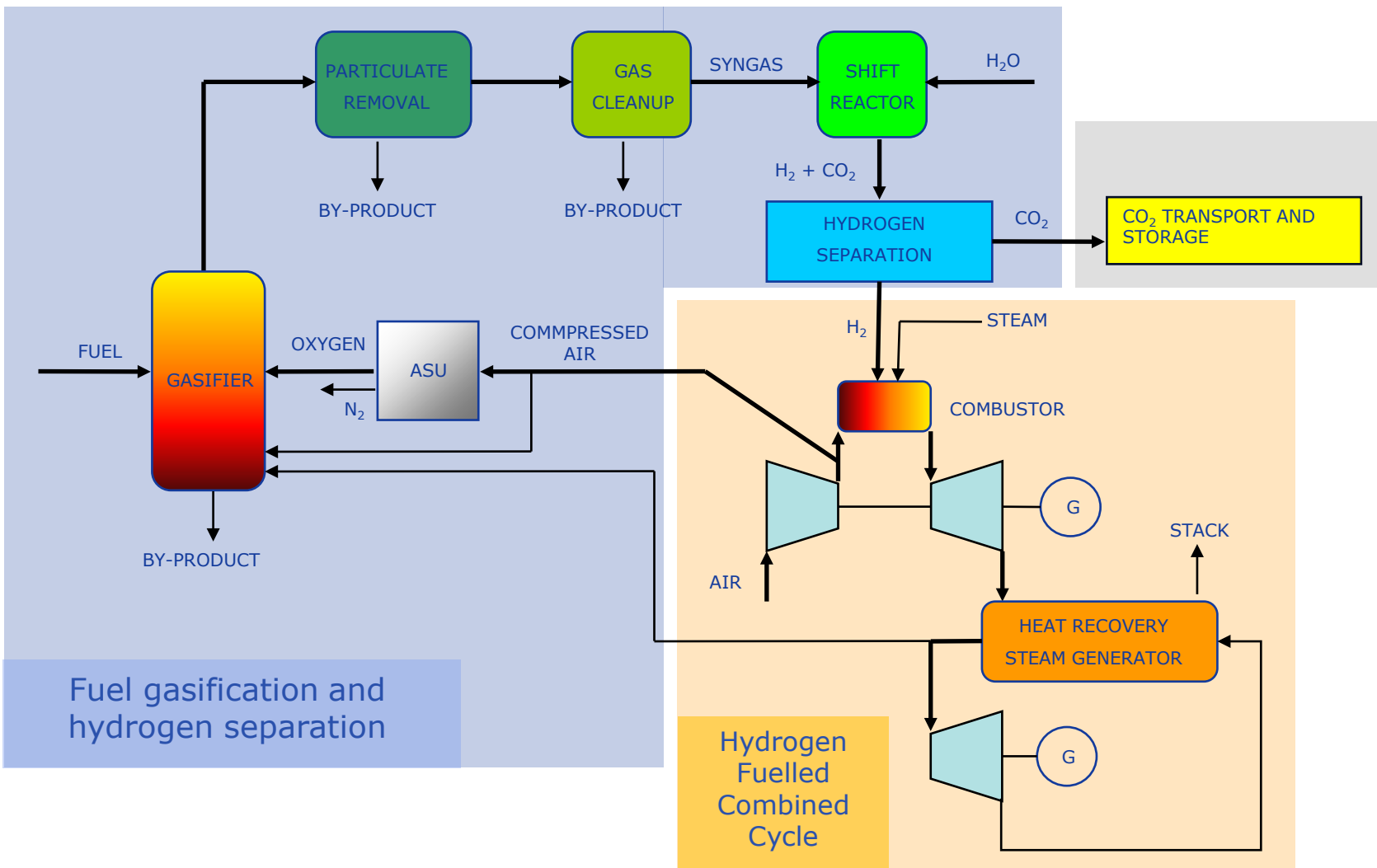
## An italian technology option for zero-emissions plants

- The combustion process: coal combustion with oxygen under pressurized conditions
- Project objective: development and demonstration on industrial scale a patented pressurized coal-combustion process with the purpose to make it possible CO2 capture and storage with energy penalties lower than those of other CCS technology options
- Timing: started on 2006
- Status : Feasibility study and costing for a Zero Emission the demo plant completed

ITEA:5 MW facility

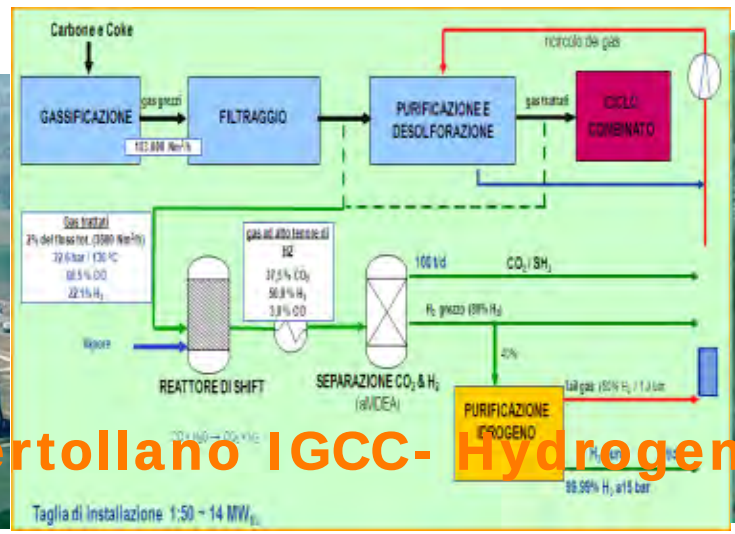
# Pre-Combustion Carbon Capture Technology

## Power from Hydrogen: Zero Emission IGCC



# Pre-Combustion Carbon Capture Technology

## R&D on IGCC-CCS (Puertollano+Fusina)




Puertollano IGCC- Hydrogen –CO2

Fusina : Hydrogen fuelled Turbine

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# ENEL strategy implementation

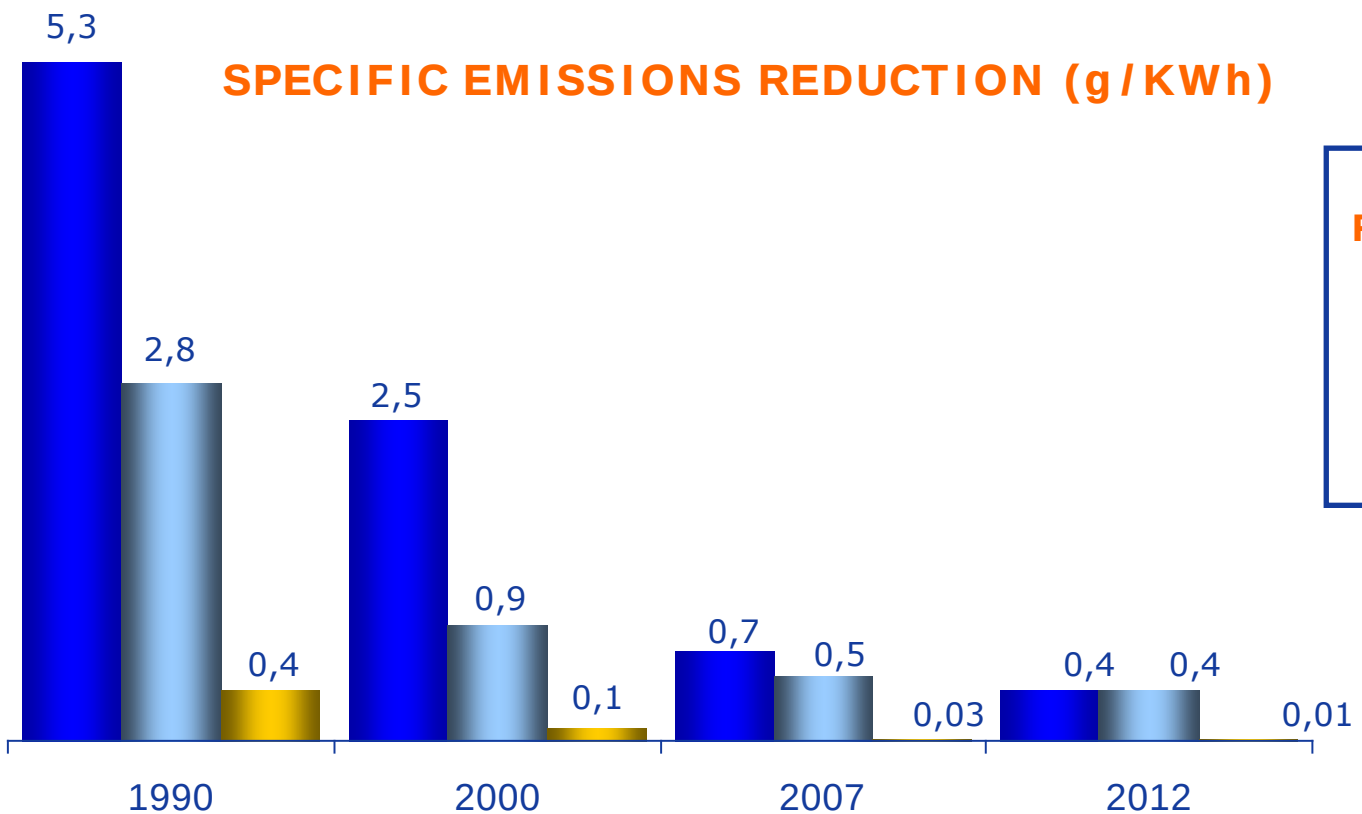
## A continuously growing commitment

**Financial commitment for the environmental protection (M€)**


Source: ENEL environmental report 2012

# Results of ENEL strategy implementation

## Emission reduction from 1990 to 2012 – Italian fleet

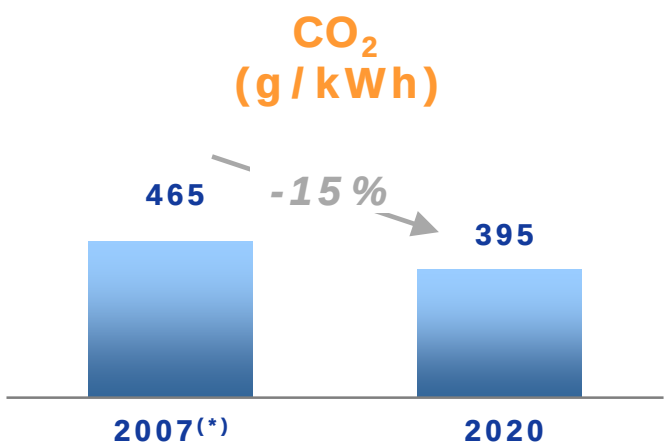


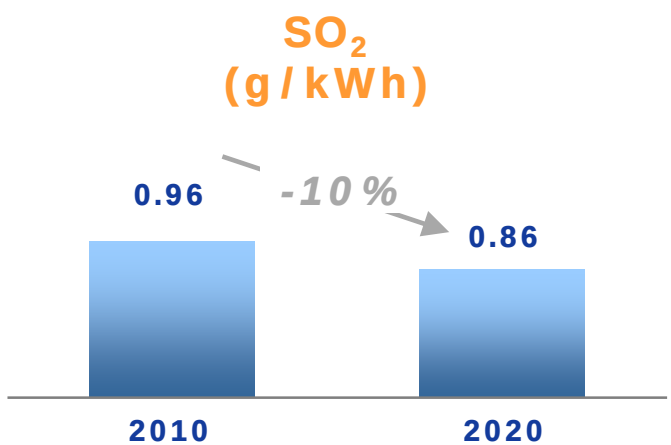

**ABSOLUTE EMISSIONS REDUCTION 2000-2012 (%)**

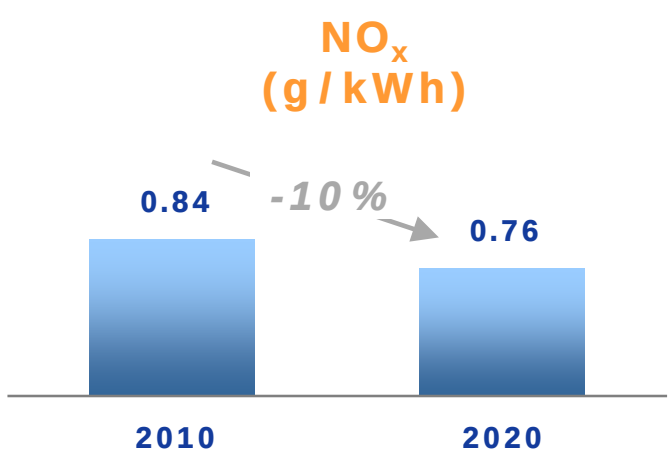
- $SO_2$ **- 92%**
- $NO_x$ **- 86%**
- **DUST** **- 98%**

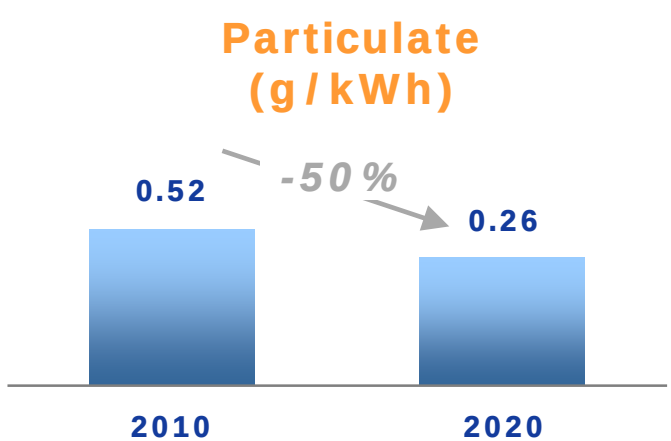
# Trend on reducing emissions

## Future targets




* Target set in 2007 being the year before Emission Trading System Phase II (2008-2012)

# Final remarks

- ENEL is strongly committed to reduce emissions from fossil fuel power plants pursuing a strategy based on:
  - High efficiency technologies
  - Low NOx combustion systems coupled with SCR (only for coal)
  - FF progressively replacing ESP in coal plants
  - Operational excellence
  - R&D support to improve O&M processes and select BAT
  - Continuous financial commitment
  - R&D towards zero emissions
- The strategy implementation leaded to a massive emission reduction in the last years (-92% $SO_2$, -86% NOx -98% dust in Italy from 1990 to 2012)
- New projects will be launched in Countries where ENEL operates for further reducing the environmental impact of thermoelectric power plants
- ENEL is available to share lesson learnt and to support whom interested to the best practice on fossil fuel power plants



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# THE REAL REVOLUTION

# IS NOT TO CHANGE THE WORLD

RATHER THAN CHANGING THE PLANET,
WE HAVE ALWAYS PREFERRED TO CHANGE OURSELVES

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