# Adapting Gas-Power Generation to New Role in Low-Carbon Energy Systems

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- Enel Presentation
- Generation Shift & Market in Europe
- Enel Approach to Gas Plant Upgrade
- Cost & Business Impact

# Enel Research at a glance

**~160 Researchers**
**3 Research Centers**
**2 Research Stations**
**2 Chemical Laboratories**
**40 Patents**

**Cooperation with major universities in Europe and USA**

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# Gas-Power Generation role in the electricity scenario
## Feedbacks from Washington Workshop

Several challenges and opportunities need attention in the coming years:

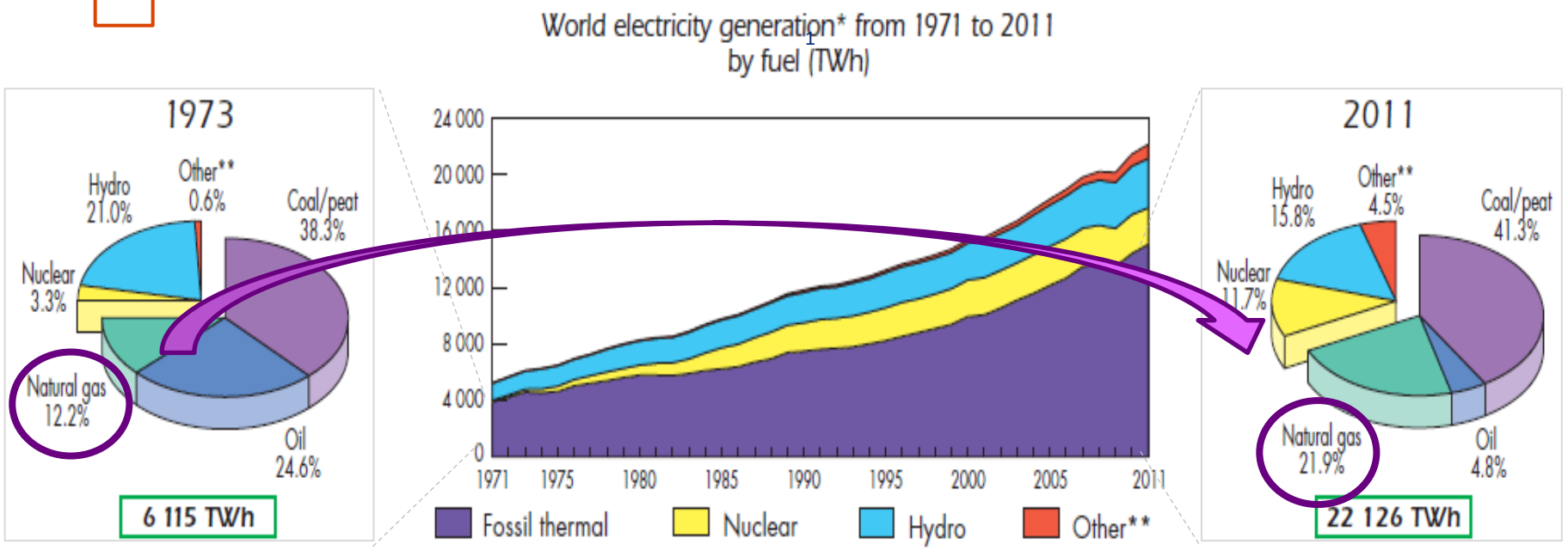
- **Bulk power system** issues but also **distributed domain**.
- Ensure **long-term capacity adequacy of generation, transmission and gas pipelines.**
- **Gas generation as complementary to the integration of variable renewables** on electricity grids
- Multi-disciplinary nature of the issues:
  - **Policy and regulation** issues applicable in the short term,
  - **Model and tool development** in the medium term
  - **Technology development** in a longer term **.**
- **Divergences in developments** between North America, Europe and Asia.

**Three high priority areas** were highlighted:

- **Capacity markets that encourage flexible capacity** of gas-power generation.
- **International markets**, Cross border (national, regional) transmission and gas pipes.
- **Adaptability on the demand side** e.g. multi-fuel devices that can use electricity and/or gas etc

# Gas-Power Generation role in the electricity scenario

## Global trend of power generation by source



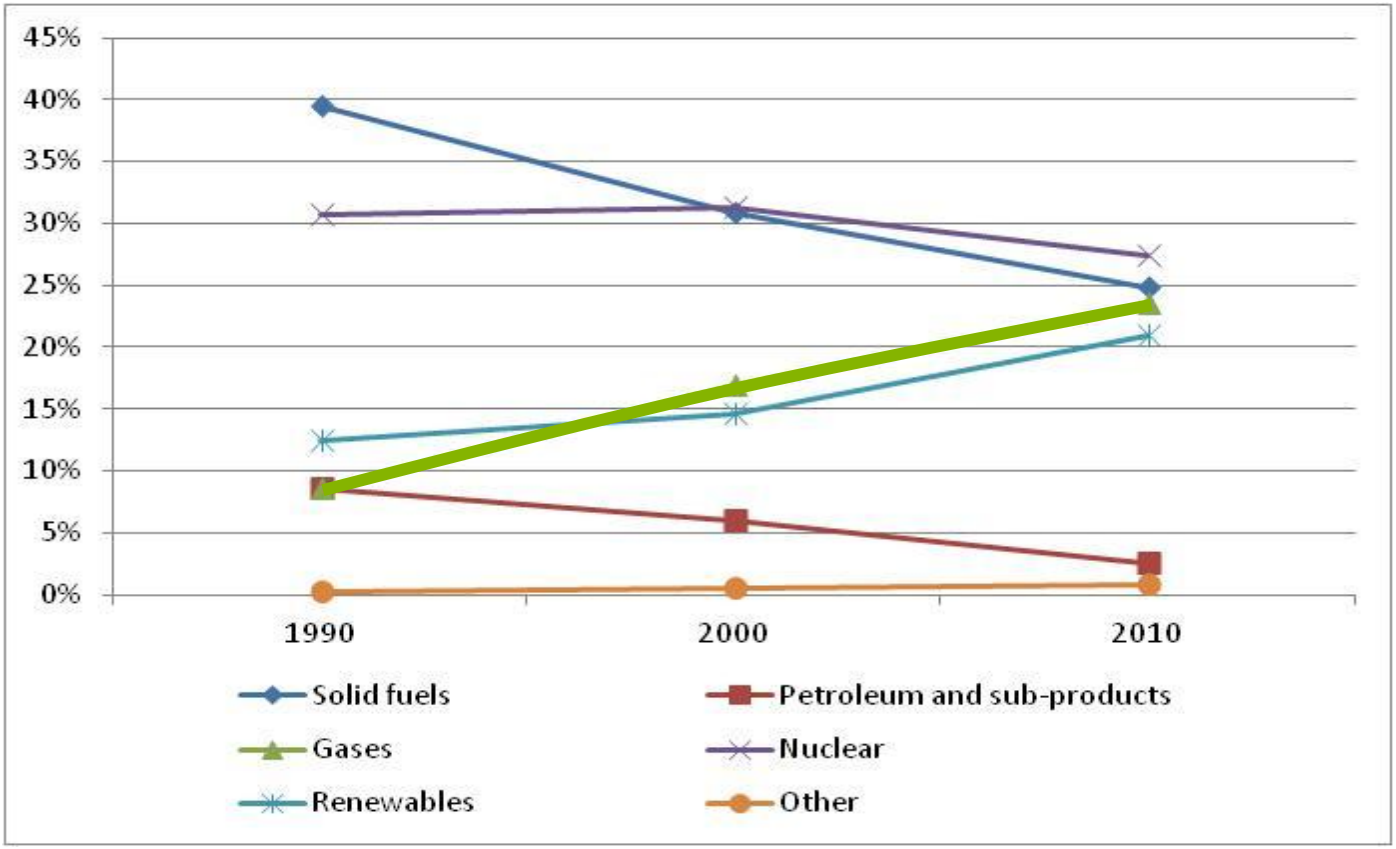

1 – From "*Key World Energy STATISTICS", IEA 2013*

- 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**
- Contraction of **oil** is **mainly compensated** by **increase of gas generation**

# Gas-Power generation role in the electricity scenario

## EU power generation structure evolution

EU-27 electricity generation (1990-2000-2010)



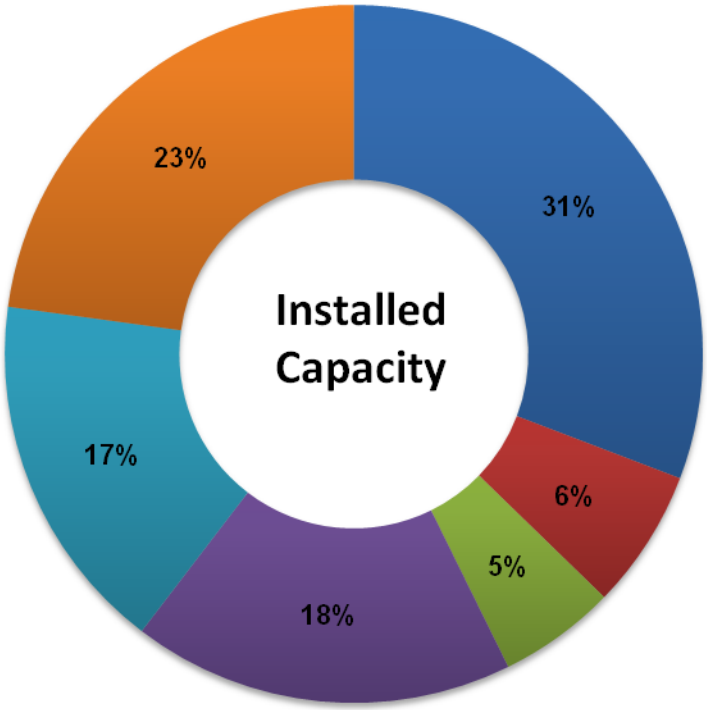

Note: Hydro is considered within RES

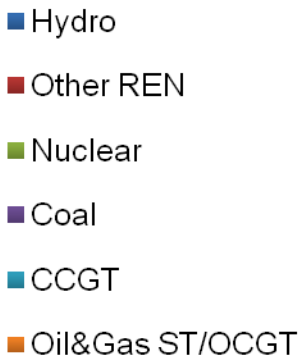
*Source: Market Observatory for Energy, June 2012*

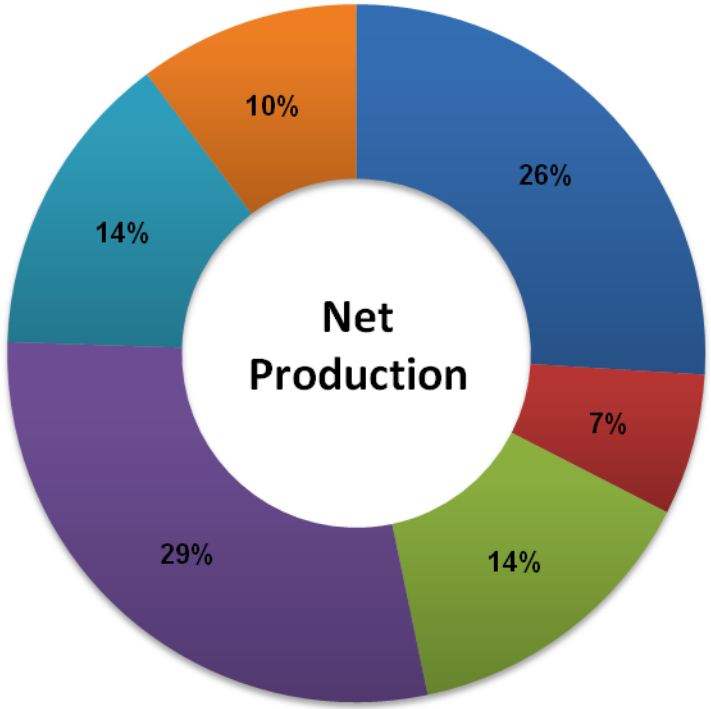
# Gas-Power generation role in the electricity scenario

## The Enel Generation Portfolio

**ENEL GROUP - YEAR 2013**




**98.916 MW**

**286 TWh**

*Source: ENEL*

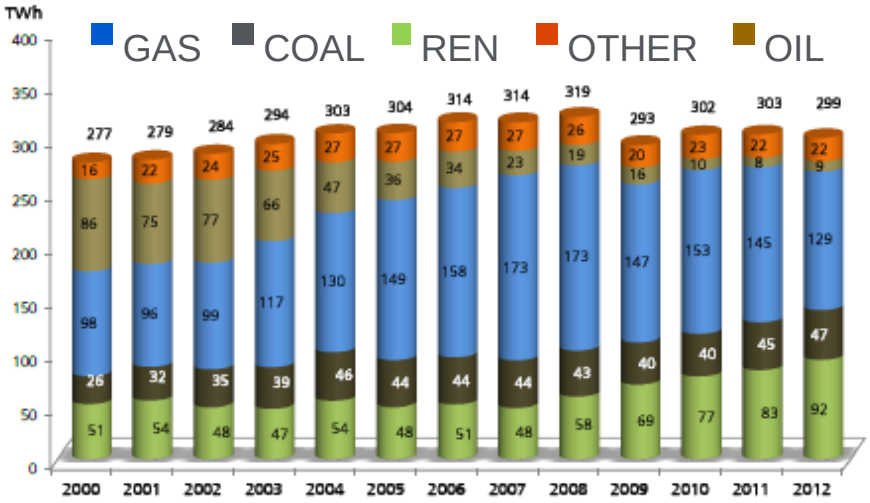
# Gas-Power generation role in the electricity scenario

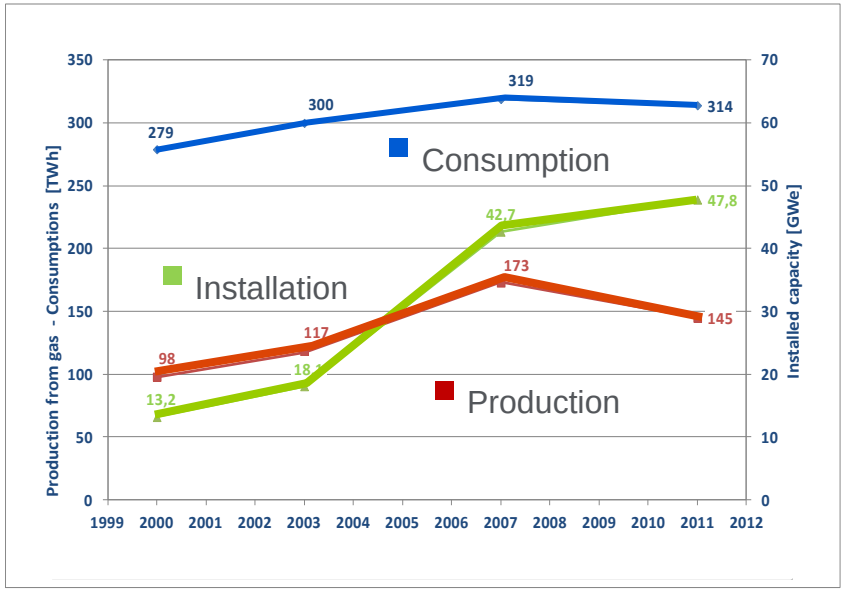
## Pulverized coal vs gas turbine combined cycle plants

| | | USC PC | CCGT |
|---|---|---|---|
| **Investment cost[1]** | $/kW | **~2100** | **~1050** |
| **O&M variable cost[1]** | $/MWh | **~18** | **~61** |
| | | | |
| **NOx emission[2]** | mg/Nmc | **100÷200** | **30÷50** |
| **Particulate emission[2]** | mg/Nmc | **15÷30** | **-** |
| | | | |
| **Efficiency[1]** | % | **40÷45** | **55÷60** |
| | | | |
| **Land requirement[4]** | $m^2$/MW | **2000÷4000** | **400÷600** |
| | | | |
| **Warm start-up time[3]** | h | **4÷5** | **0,5÷1,5** |

1 - Source: Projected Costs of Generating Electricity, INTERNATIONAL ENERGY AGENCY, 2010
2 - Typical value of advanced european plants
3- Source: “Summary Report on Coal Plant Dynamic Performance Capability”, Jimmy Lindsay and Ken Dragoon”, Renewable Northwest Project, August 16, 2010
4- Source: “Report on land requirement of thermal power stations”, Government of India, Central Electricity Authority, 2007

# Italian power generation sector
## Evolution of the generation mix and market




- Disappearance of oil generation
- Strong increase in REN
- Slight decrease in gas

- In the period 2007-2011 installed gas capacity increased
- In the last years an important reduction in gas production has occurred and this trend is not changing

*Source: GSE 2012 report*

# Spanish power generation sector
## Evolution of the generation mix and market

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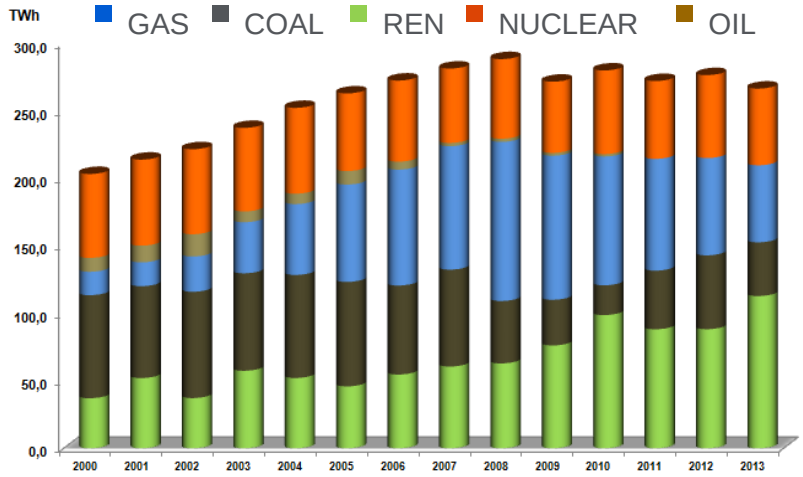
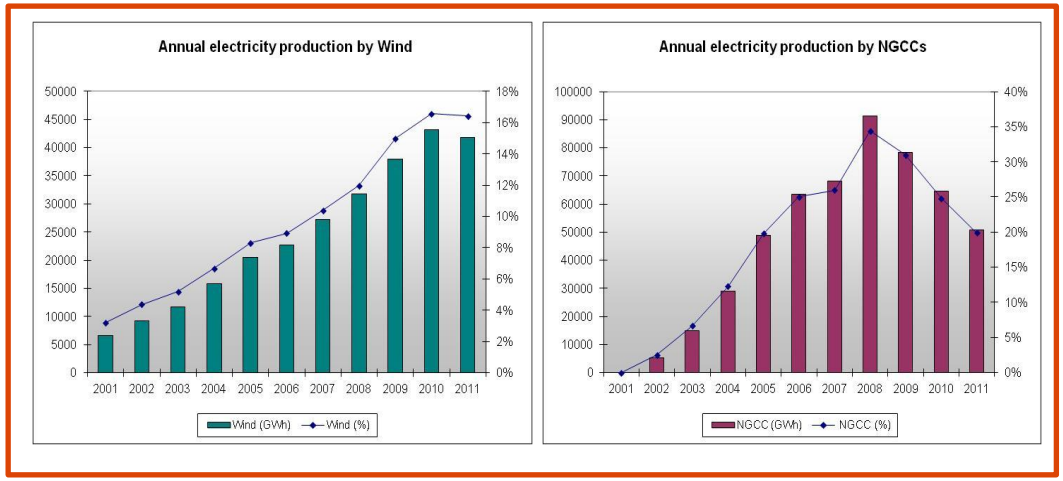



Annual production: wind vs CCGT




- Strong reduction of coal generation
- Reduction of nuclear generation
- Increase in gas and renewable generation

- Strong increase of wind installations in the last decade leaded to CCGT production reduction
- CCGT fleet used to compensate wind production variations

*Source: Market Observatory for Energy, June 2012 & REE Espana*

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# Gas-Power generation role in the electricity scenario

## Technology Drivers to increase Plant competiveness

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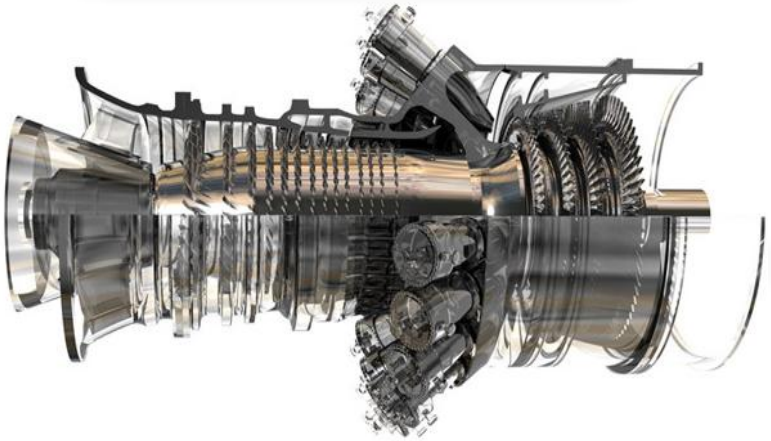
**Plant competitiveness**

**Efficiency increase**



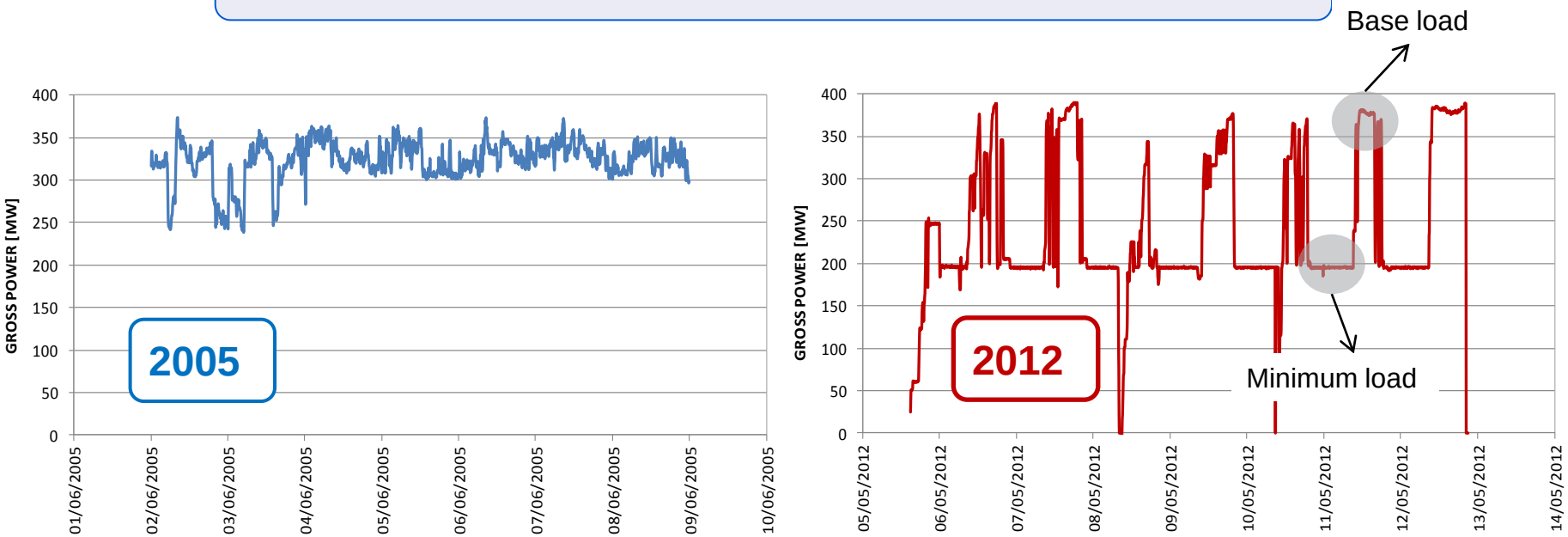
**Emission reduction**

**Operation flexibility improvement**

# Flexibility & Efficiency of Gas-Power Generation

## The new role of GTCCs: the Enel's case

**Typical weekly trend of combined cycle power (Italian PPs)**




- Increased number of startup / shut down cycles
- Reduced operation at base load
- Operation at minimum environmental load during nights

# Flexibility & Efficiency of Gas-Power Generation

## A mature solution for intermittency management

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- **Maturity level** of available solutions ranges from Small scale prototype level to Demonstration system level, depending on the component / intervention level.

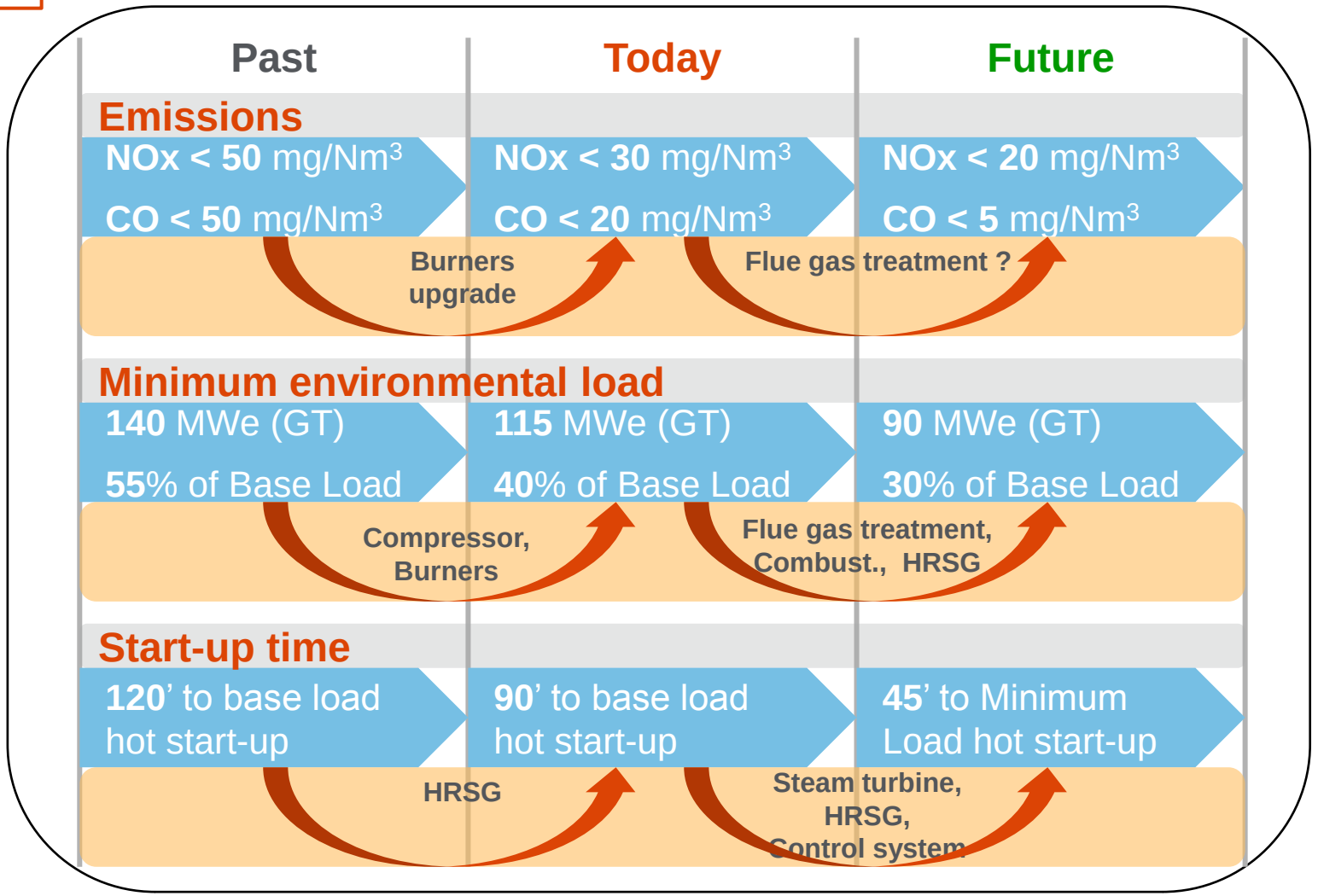
| | Coal | CCGT |
|---|---|---|
| MEL (% of Base Load) | 33-40 | 35-40 |
| Ramp Rate (%of Base Load/ min | 3-5 | 5-10 |
| Net Efficiency (%) | 40-45 | 55-60 |
| Warm Start-up Time (min) | 240-300 | 30-90 |

- **Areas of improvement include:**
  - > **Minimum Environmental Load (MEL(*)) Reduction**: next generation CCGT power plants are expected to reduce their MEL up to 20% and 30% respectively;
  - > **Start-up time reduction**: towards daily startup;
  - > **Ramp rate increase** to follow fluctuating renewable generation;
  - > **Startup cost reduction**;
  - > **Fuel-flexible GTs**: combustor development targeted to reach the same NOx emissions as natural gas with alternative fuel (bio-gas, hydrogen, ..).



(*): the plant minimum load at which environmental limits are respected

# Operation flexibility improvement
## Enel's Italian CCGT fleet upgrading






(*): HRSG Heat Recovery Steam Generator

# Operation flexibility improvement

## Advanced diagnostic tools for lifetime monitoring&management

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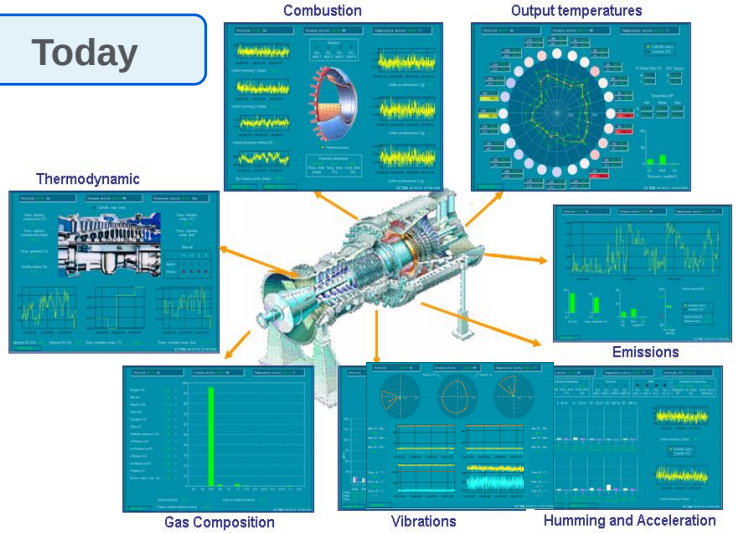
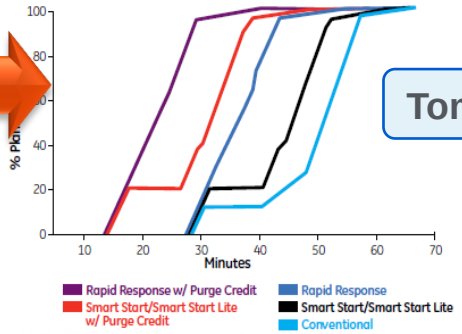
**GTDS: Enel's Gas Turbine Diagnostic Systems**

**Today**




- **15 GT power plants** monitored
- Supporting the operation through statistics rules **for anomaly prediction and analysis**

**Lifetime monitoring & management**




**Tomorrow**

- **Life & maintenance models**: tracking history of each GT component
- **On-line lifetime calculation**
- Choosing **start-up curve for optimizing lifetime and/or market request**

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# Flexibility of Gas-Power Generation
## Potential and Constraints

**Potential of untapped flexibility in Large Generation assets**

- **In 2012** (IEA 2012) CCGT power plants produced about 4500 TWh (worldwide), accounting for **20%** (renewable 7%, hydrogen and biofuels excluded) of the total production.
- **In 2050** (IEA "4 degrees scenario") CCGT power plants are expected to produce about 10000 TWh (worldwide), accounting for **22%** (renewable 18%, hydrogen and bio-fuels excluded).
- **Low NOx hydrogen fueled gas turbines** are expected to be introduced to the market by 2025 **to provide temporal decoupling of electricity supply and demand**

**Constraints/ Drivers for implementation**

- **Uncertainties in future regulatory scenario** of renewable generation (government subsidiaries and compensation devices development) **interferes with investment decisions** about the machinery development.
- **Gas price** can **strongly affect the convenience to invest** in coal plant development rather than **in CCGT**.

# Flexibility of Gas-Power Generation
## Technology and Cost

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### Technology evolution

- **GT combustor development** for reducing MEL of CCGT and to maintain competitiveness of open cycle gas turbines;
- **Improve part-load efficiency** of CCGT plants;
- **Advanced diagnostic systems** for monitoring the lifetime machinery consumption;
- **Advanced Control Systems** for optimizing transient operation and start-up;
- **Low-NOx combustors and new TBC materials** development for hydrogen and bio-fuel fed gas turbines.

### Cost Evolution

- **Increasing the flexibility** of existing gas power plants would **require not negligible investments,** with new equipment/component installations and replacements in many cases and improvement of existing R&C systems. A moderate cost increase with respect to traditional plants would be required in case of new builds.
- **Flexible operation will lead toward higher operation and maintenance costs.**
- **Increased part load efficiency will help reducing additional operational costs**.
- **Advanced monitoring & diagnostic tools** for on-line monitoring of the lifetime of critical components **will significant contribute to keep these costs under control**.



*(*) TBC: Thermal Barriers & Coatings*

# Flexibility of Gas-Power Generation
## Business Impact

- **In the current scenario**, in which renewable production systems benefit of dispatch priority, **thermal plants undergo discontinuous operation**. Typical number of starts per year in Italy ranges between 50 and 100 for GTs and is costantly increasing. GTCC yearly operating hours are below 1500 in many cases.
- **The return to business** of an investment aimed at increasing flexibility (fast start-up, higher load ramps, reduced minimum load) **could lead to significantly increase margin** from selling electricity in a strongly fluctuating market.
- On the contrary**, if the regulatory scenario will** force distributed generation systems to **reduce their load fluctuations and increase their predictivity**, a more stable but lower production could be required to thermoelectric plants. In this case, **a retrofit**, able to reduce the minimum load, **could be economically convenient** and can determine the convenience to keep a power plant alive or shut it down.
- **In this uncertain market energy scenario**, strongly affected by regulatory elements, **it is difficult to imagine that new players can be attracted to install and run large fossil plants in the near future.**

# Flexibility of Gas-Power Generation
## Development Roadmap

- From an electric utility perspective, the increase of flexibility of thermoelectric plants requires the **implementation of advanced predictive diagnostic tools able to on-line manage the plant life consumption and optimize the operation and maintenance plans**.

- In other words**, an utility has to be able to decide if a rapid start-up and shut-down is convenient or not**, considering in details the impact on the increase of maintenance costs.

- R&D efforts have to be addressed **to increase productivity of models** able to on-line assess the residual lifetime of critical components.

- Moreover, **more advanced regulation & control system are needed** - especially for coal plants - **to identify the best set point conditions in rapid load transients.**.

# Thank you for Your Attention