EURO Course
SUSTAINABILITY ASSESSMENT OF NATURAL GAS SYSTEMS

ENVIRONMENTAL ASPECTS OF NATURAL GAS STRATEGY

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http://powerlab.fsb.hr/neven/lectures/EurocourseEnvironment.pdf

AIM

To present the environmental consequences of energy strategy envisaging increased natural gas consumption and introduce methods for assessing the mitigation effects of those strategies

CONTENTS

1. Introducing Kyoto Protocol and other environmental legislation objectives
2. Outlining the environmental impact of conversion to natural gas
3. Introducing increased energy efficiency technologies enabled by the use of natural gas
4. Presentation of the case of introduction of natural gas in Portugal and the consequences to greenhouse gases (GHG) and other emissions
5. Outlining the potential for GHG emission avoidance by use of natural gas in Europe

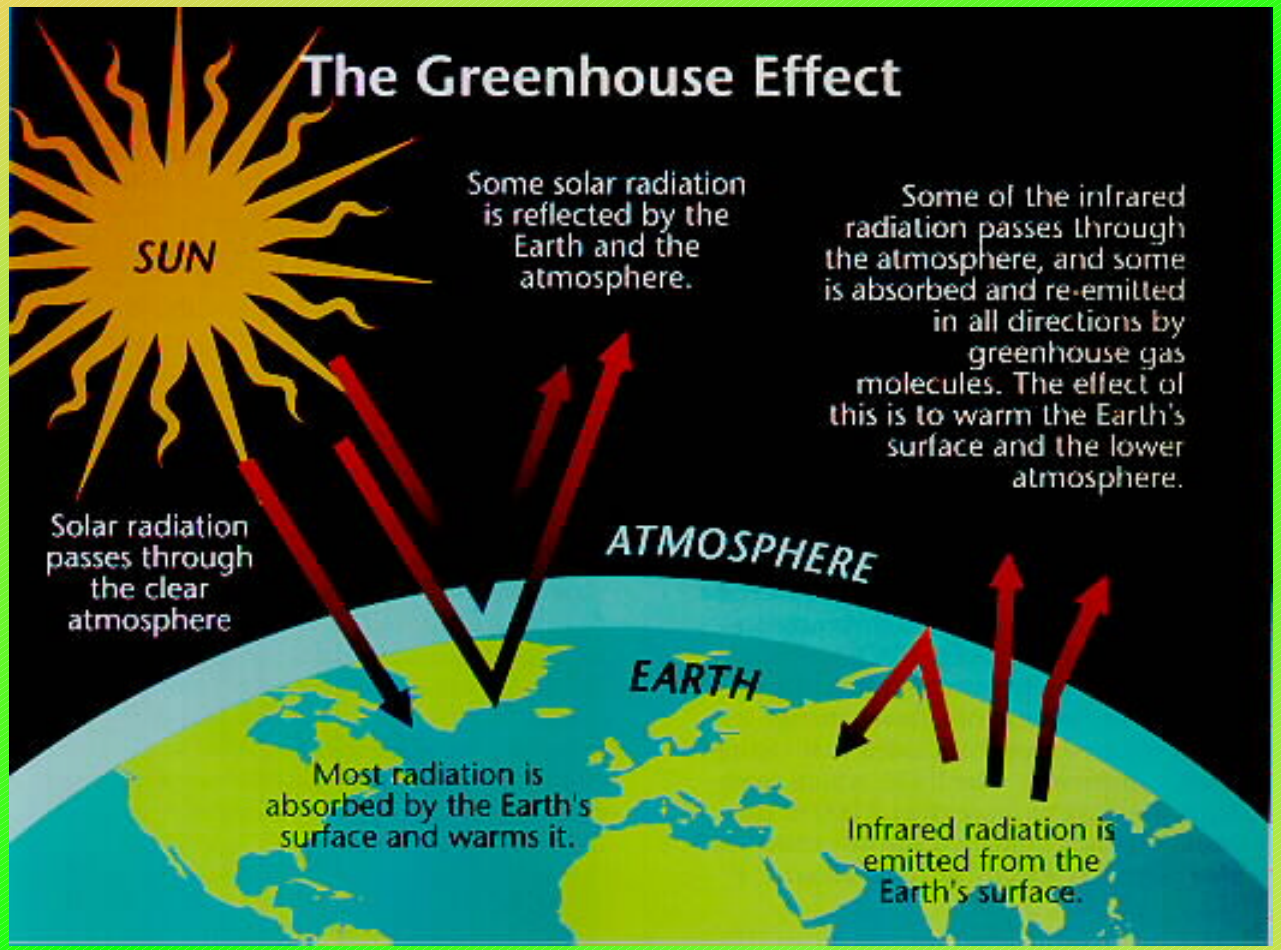
1 .Introducing Kyoto Protocol and other environmental legislation objectives

THE CONVENTION ON CLIMATE CHANGE

UN Framework Convention on Climate Change

- signed by 182 countries
- mitigation of climate change by reducing anthropogenic greenhouse gases (GHG) emission
- Greenhouse effect?

THE GREENHOUSE EFFECT

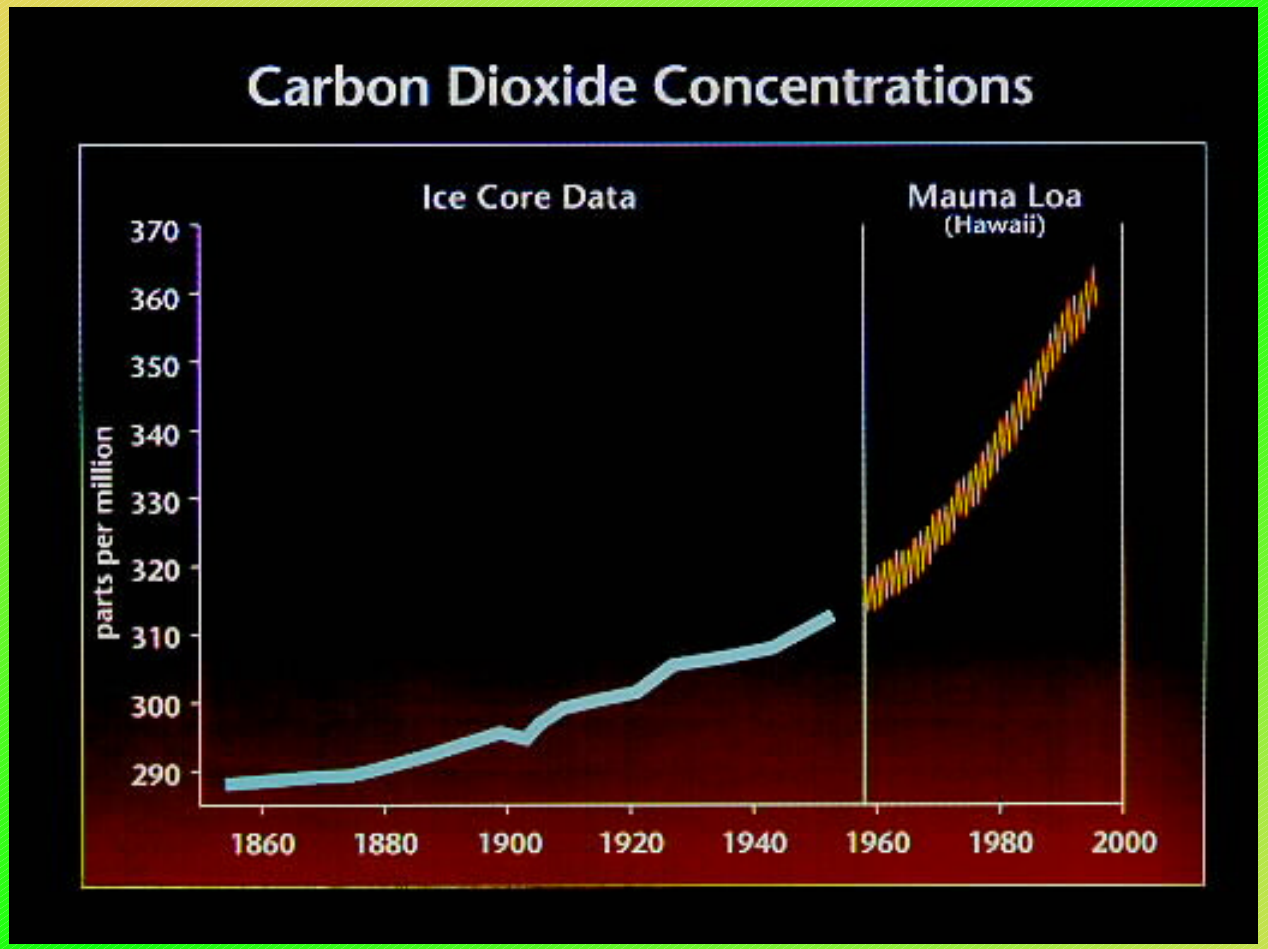


Greenhouse gases:

- CO_2
- CH_4
- N_2O
- HFC, PFC, SF_6

- **Of importance to Natural Gas are CO_2 and CH_4**
- Without GH effect 30° lower temperature

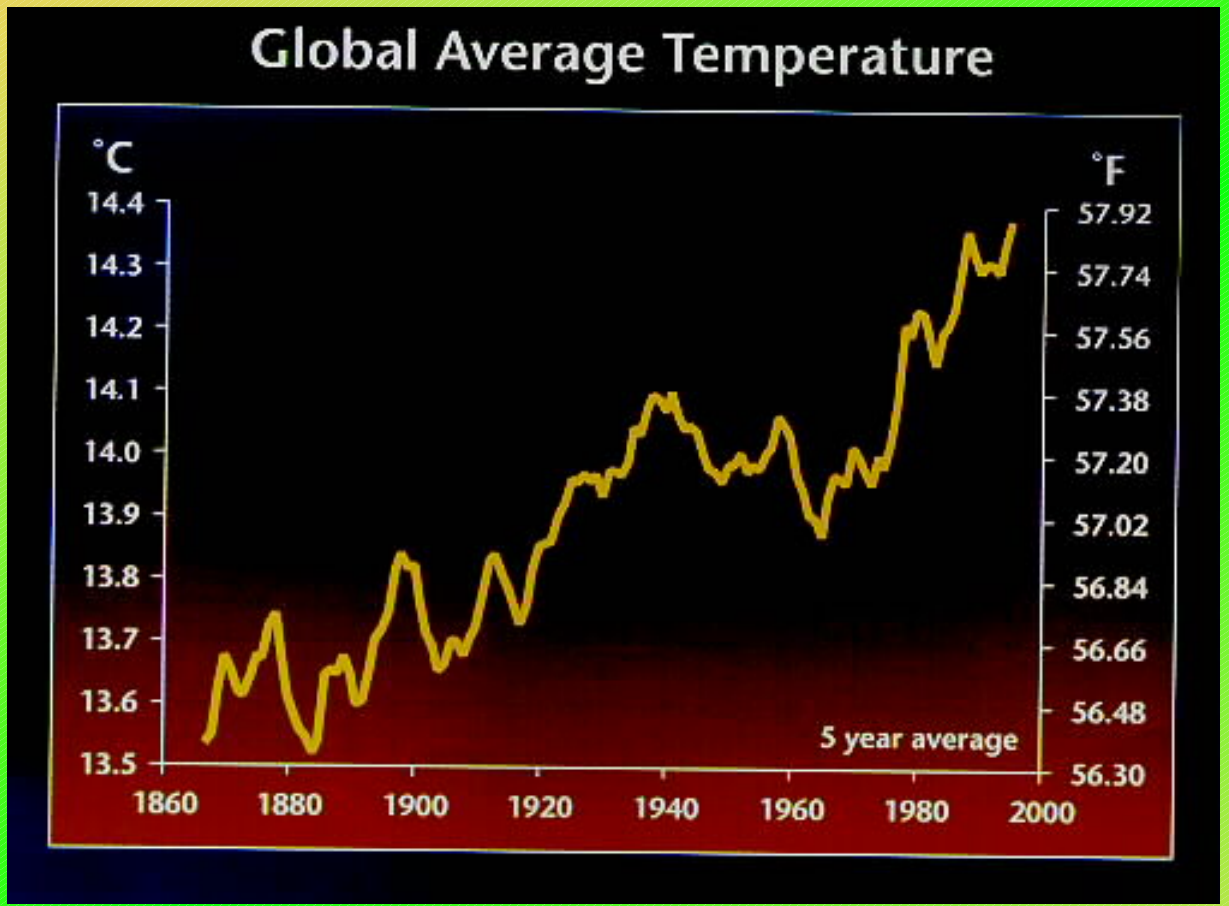
THE GREENHOUSE EFFECT



CO_2 concentrations

- Measured since 1960
- From ice caps since 1860
- Facts

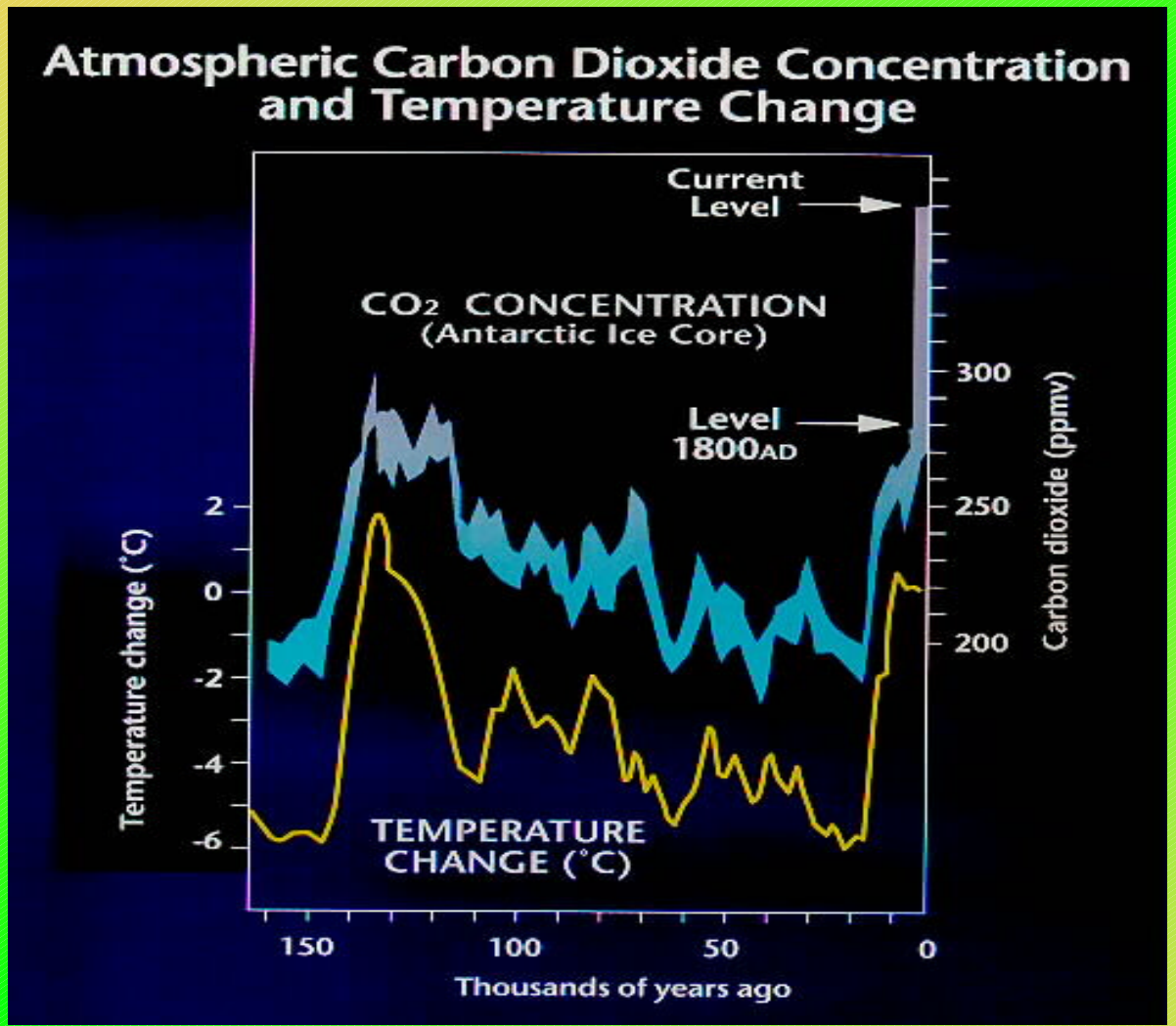
THE GREENHOUSE EFFECT



Temperatures

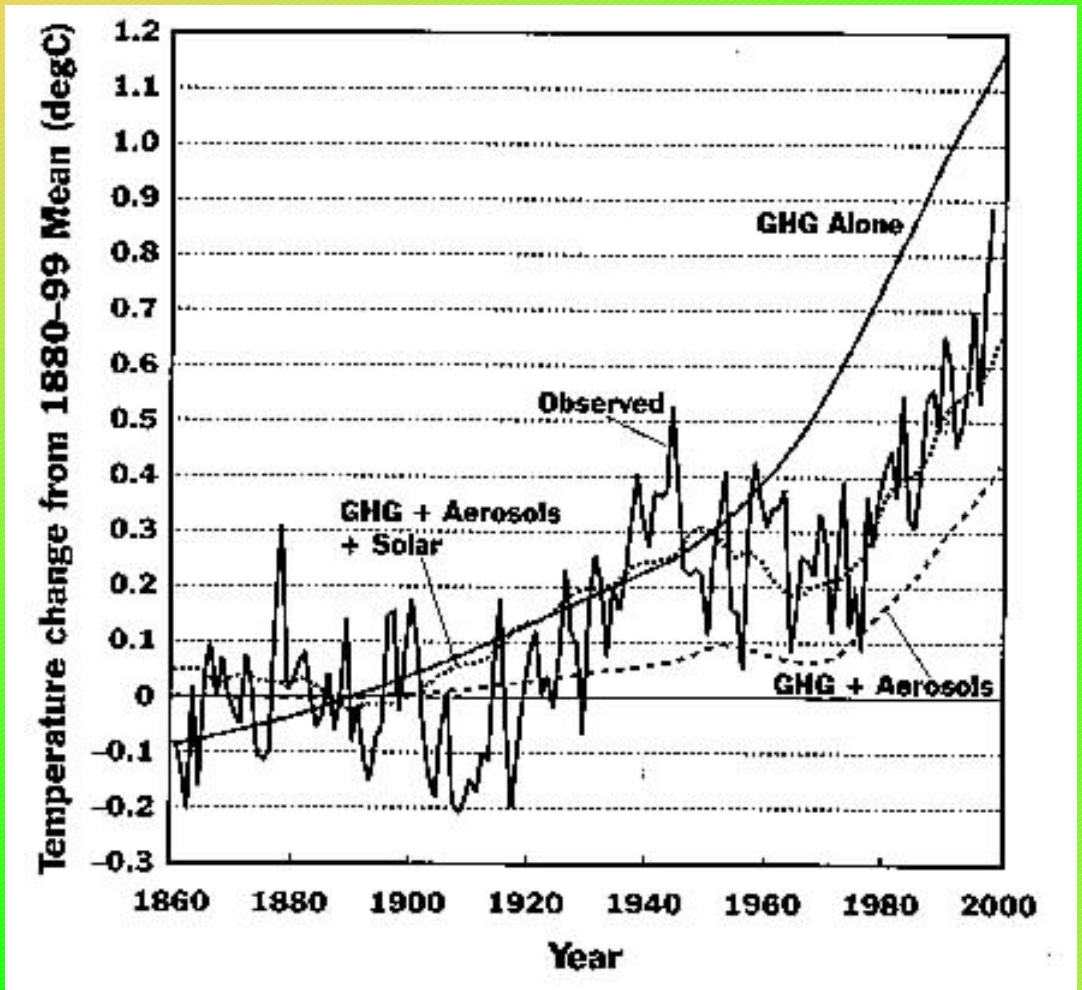
- The averaging problem
- Facts

THE GREENHOUSE EFFECT



Correlation of CO_2 concentrations and temperatures

THE GREENHOUSE EFFECT



Is it anthropogenic? Is it really correlated?

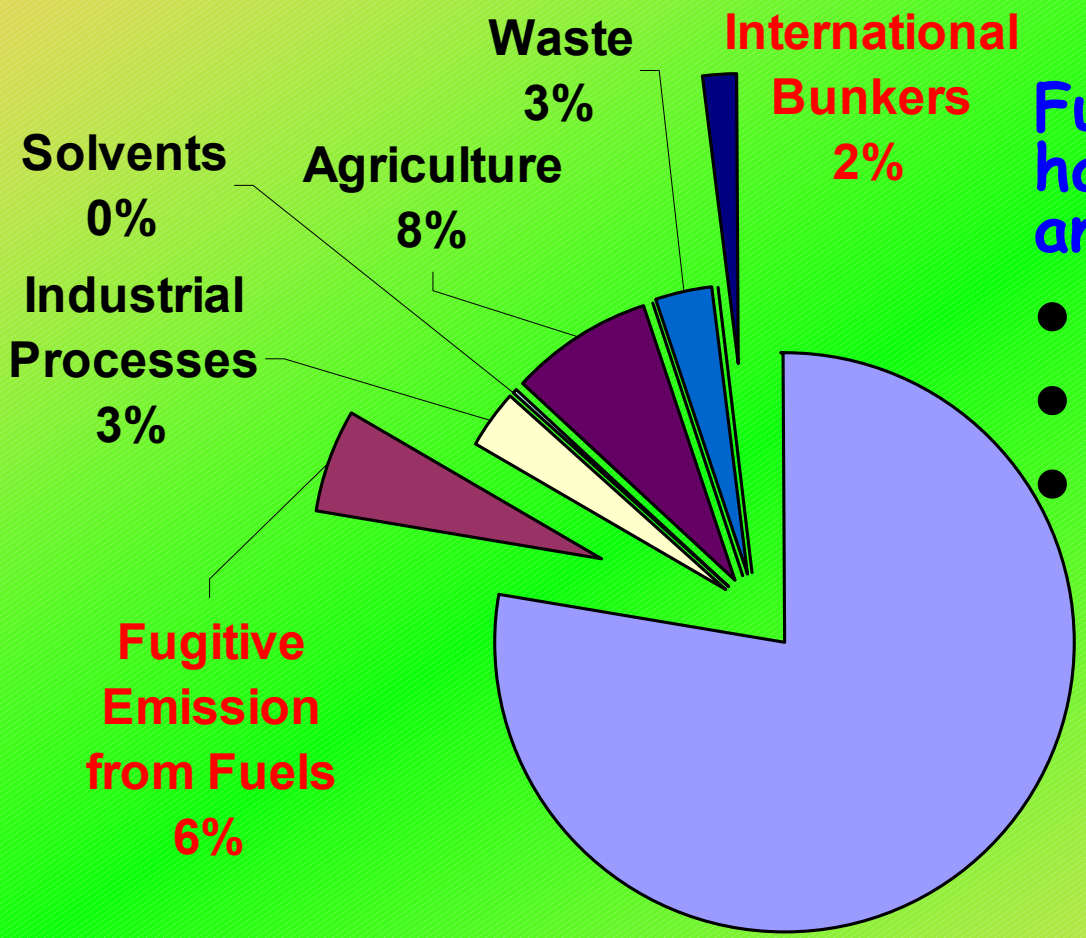
- If we can predict it then we understand the mechanism
- GHG models have to include Aerosols and Solar forcing

THE KYOTO PROTOCOL

Kyoto Protocol to the Convention in 1997:

- Reduction in GHG emissions in 38 developed countries and economies in transition (so called Annex B to KP)
- 5% reduction from the 1990 levels by the first budget period in 2008-2012
- Signed by 84 countries and ratified by 43 as October 2001
- Romania is the only Annex B country that ratified KP
- The Protocol will enter into force when 55 Parties to the Convention, incorporating Parties included in Annex I which accounted in total for at least 55% of the total carbon dioxide emissions for 1990 of the Parties included in Annex I, have ratified KP

THE GHG EMISSION



Fuel Combustion and Fuel handling major sources of anthopogenic GHG:

- Coal
- Oil
- Natural Gas

Source: www.unfccc.de
Gases: CO_2, CH_4, N_2O
Global Warming Potential

EUROPEAN CLIMATE CHANGE PROGRAMME (ECCP)

- ECCP was established in June 2000 to help identify the most environmentally and cost effective additional measures enabling the EU to meet its target under the Kyoto Protocol, namely an 8% reduction in GHG from 1990 levels by 2008-2012.
- ECCP has been set as a multi-stakeholder consultative process focussed on energy, transport, industry, research and agriculture and the issue of ET within the EU.

Source: http://europa.eu.int/comm/environment/climat/eccp.htm

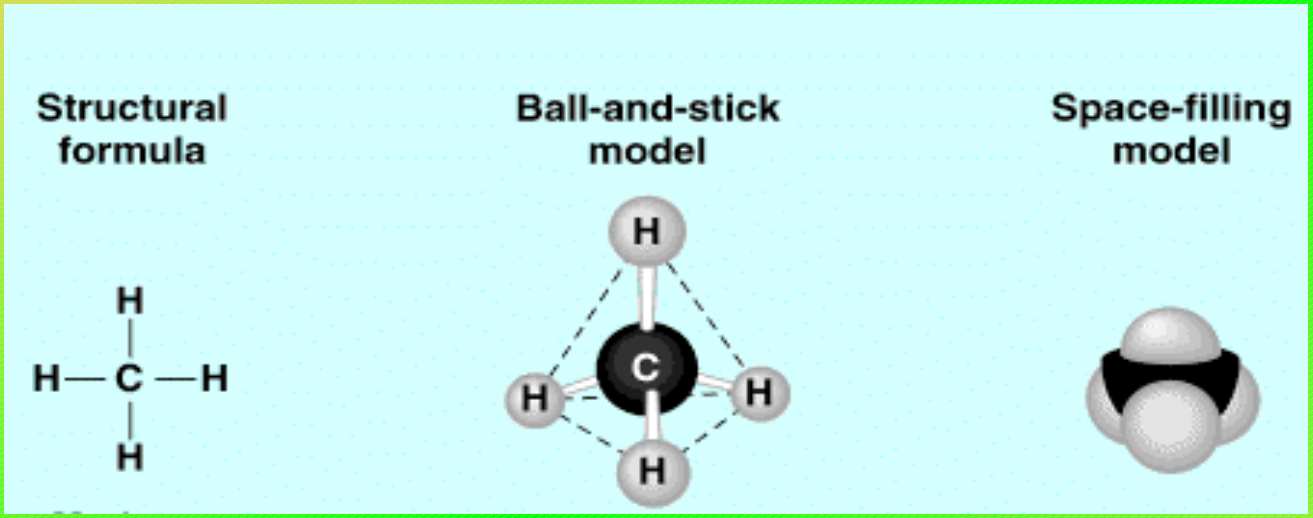
EUROPEAN CLIMATE CHANGE PROGRAMME (ECCP)

- ECCP investigated more than 40 measures and could identify cost-effective options totalling 664-765 MtCO2eq.
- ECCP Report was presented on July 2-3, 2001, in Brussels - the Report classifies the measures in 3 different categories, to allow a better indication of the short-term potential of cost-effective measures at the EU level:
  - measures at an advance stage of preparation - 8 measures representing an estimated 240 MtCO2eq cost-effective emission reduction potential;
  - measures in the pipeline - 11 measures with an estimated cost-effective emission reduction potential of about 140 MtCO2eq;
  - measures needing further work - 22 measures.

2.Outlining the environmental impact of conversion to natural gas

NATURAL GAS CHEMISTRY

What makes natural gas environmentally friendly?



Natural Gas is mainly methane

75%-98%
94% average for US Natural Gas

- Methane has the highest hydrogen/carbon weight ratio for all hydrocarbons
- 25% hydrogen – lowest CO2 emissions for the same energy output
- Low sulphure, particles, etc.

NATURAL GAS EMISSION FACTORS

IPCC methodology – emission factors

	Oil	Natural Gas	Coal
GgC/PJ	20.0	15.3	25.8
GgCO2/PJ	73.3	56.1	94.6

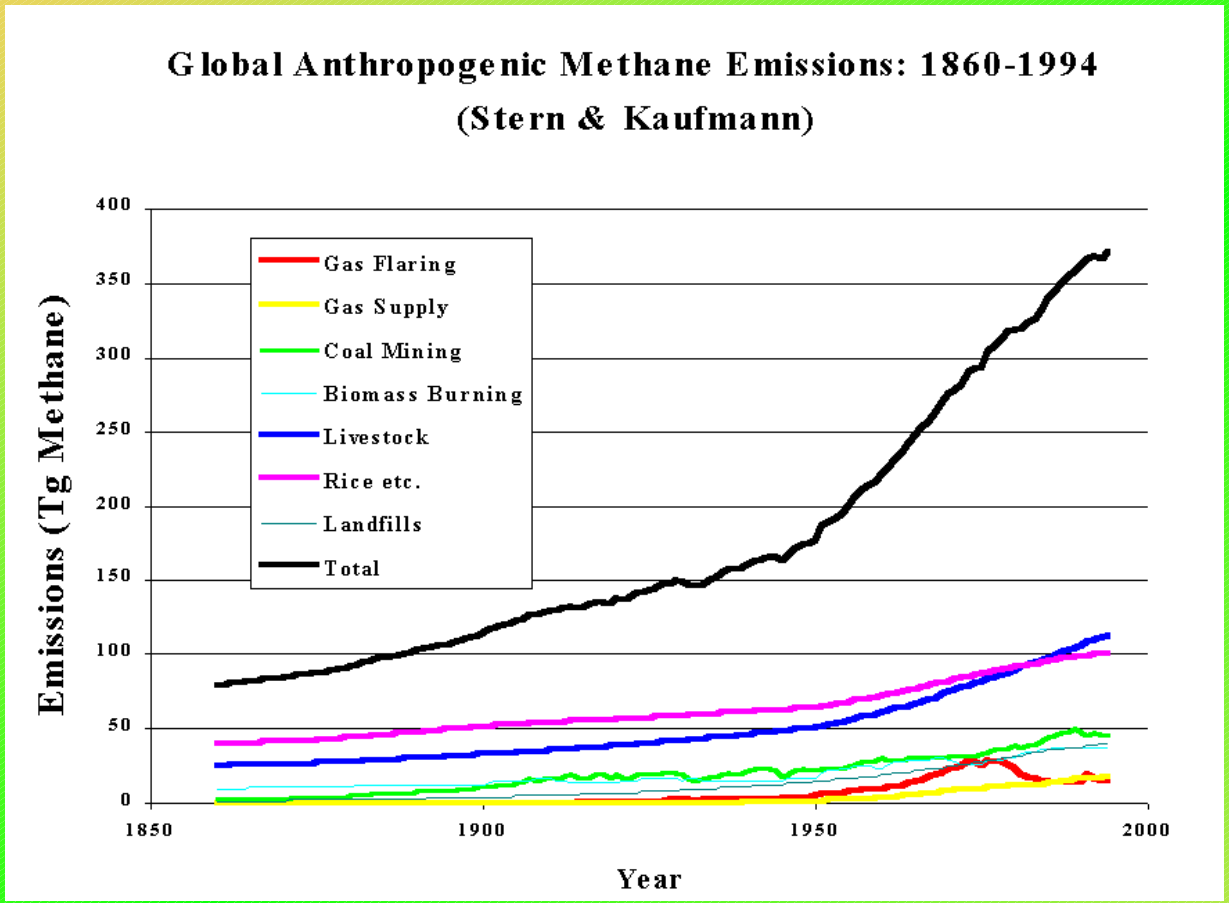
1 Gg = 1000 t; 1 Mtoe = 42 PJ

Source: http://www.unep.ch/ipcc/index.html

Natural Gas versus oil/coal

- 77% emission compared to oil
- 59% emission compared to coal

METHANE EMISSIONS



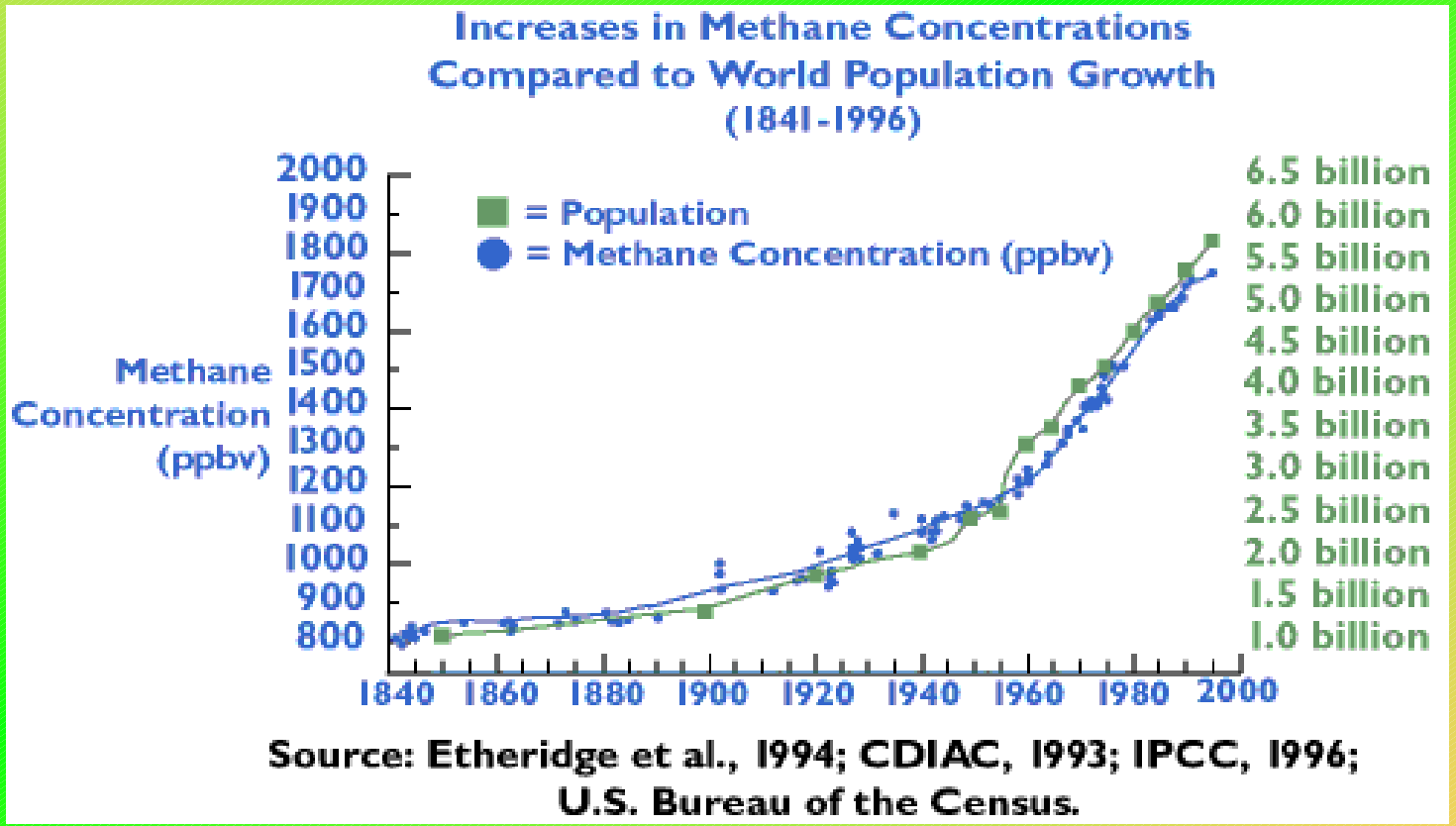
Source: http://cdiac.esd.ornl.gov/trends/meth/ch4.htm

Methane emissions

- 6% of total greenhouse effect
- 21 higher Global Warming Potential than CO_2
- Only small part comes from Natural Gas handling

METHANE EMISSIONS

Methane concentration well correlated to world population – sign of anthropogenic nature



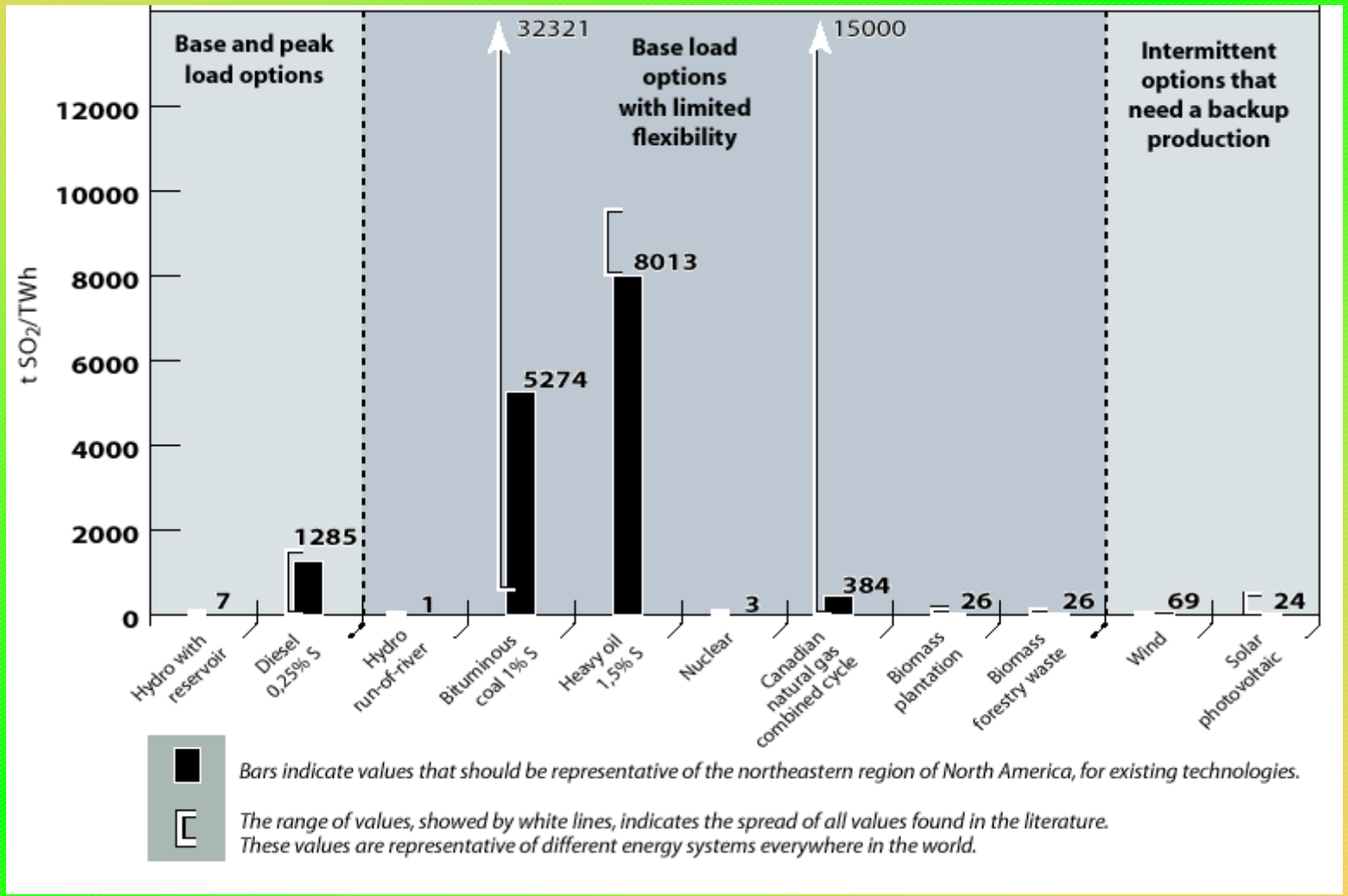
NATURAL GAS EMISSIONS

Natural gas combustion results in

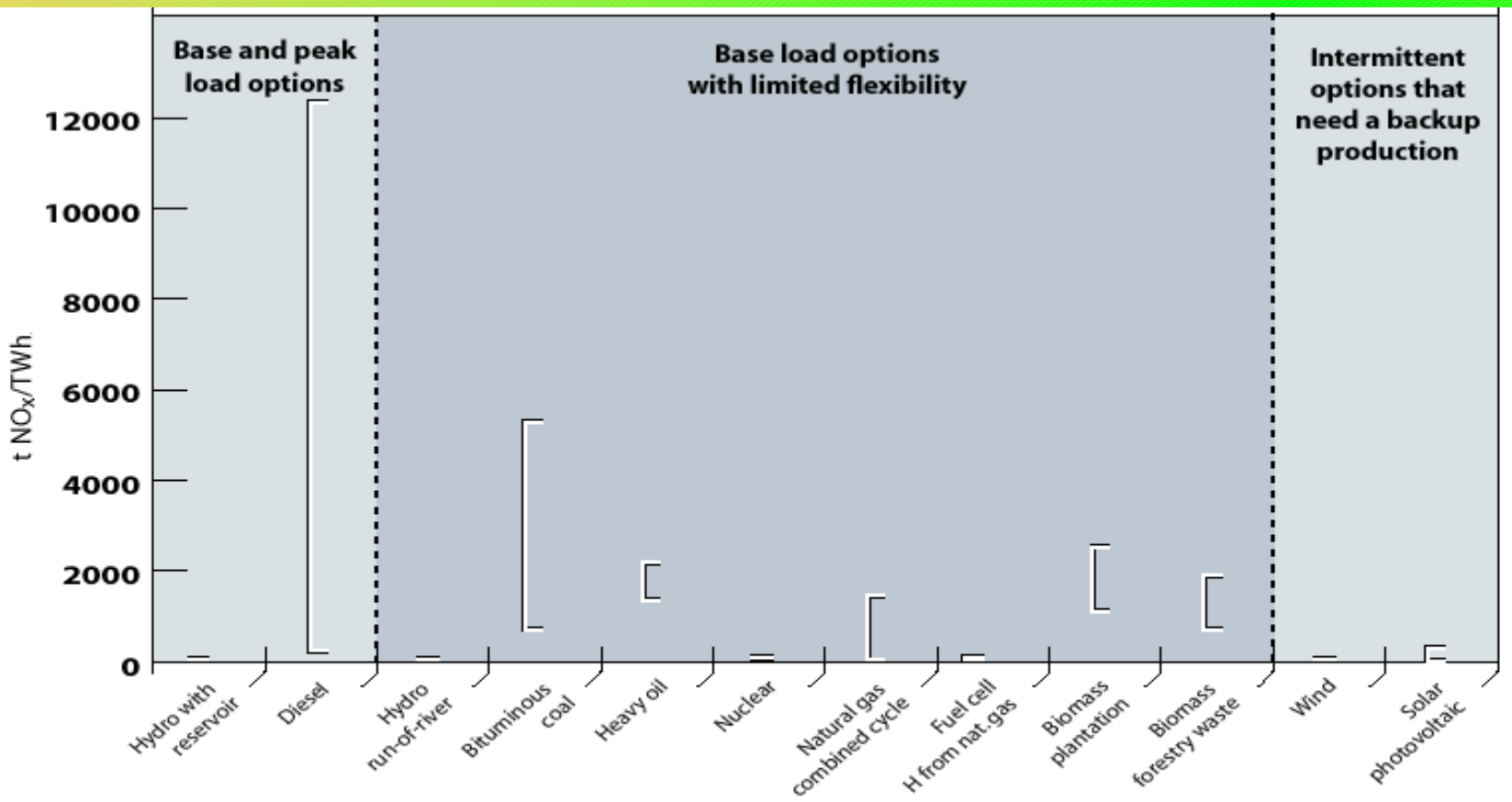
- Virtually no emissions of SO_2
- Virtually no emissions of particles
- lower emissions of CO
- lower emissions of reactive hydrocarbons
- Up to 95% lower emissions of NO_x
- Up to 70% lower emissions of CO_2

than combustion of other fossil fuels.

NATURAL GAS SO_2 EMISSIONS

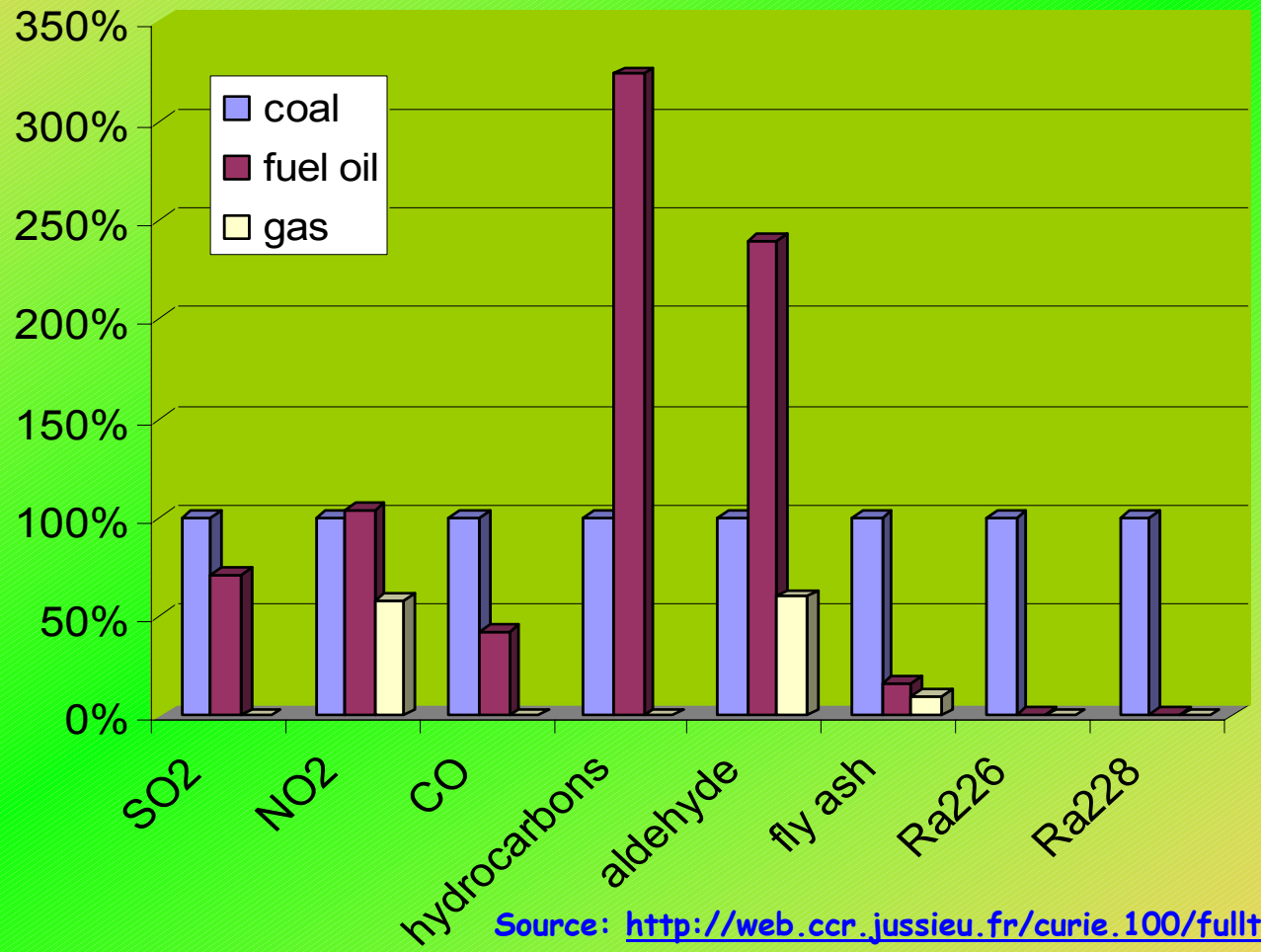


NATURAL GAS NO_x EMISSIONS



White lines represent the range of values found in the literature. These values are representative of different energy systems and combustion technologies everywhere in the world.

NATURAL GAS EMISSIONS



Source: http://web.ccr.jussieu.fr/curie.100/fulltext/chmielewski.htm

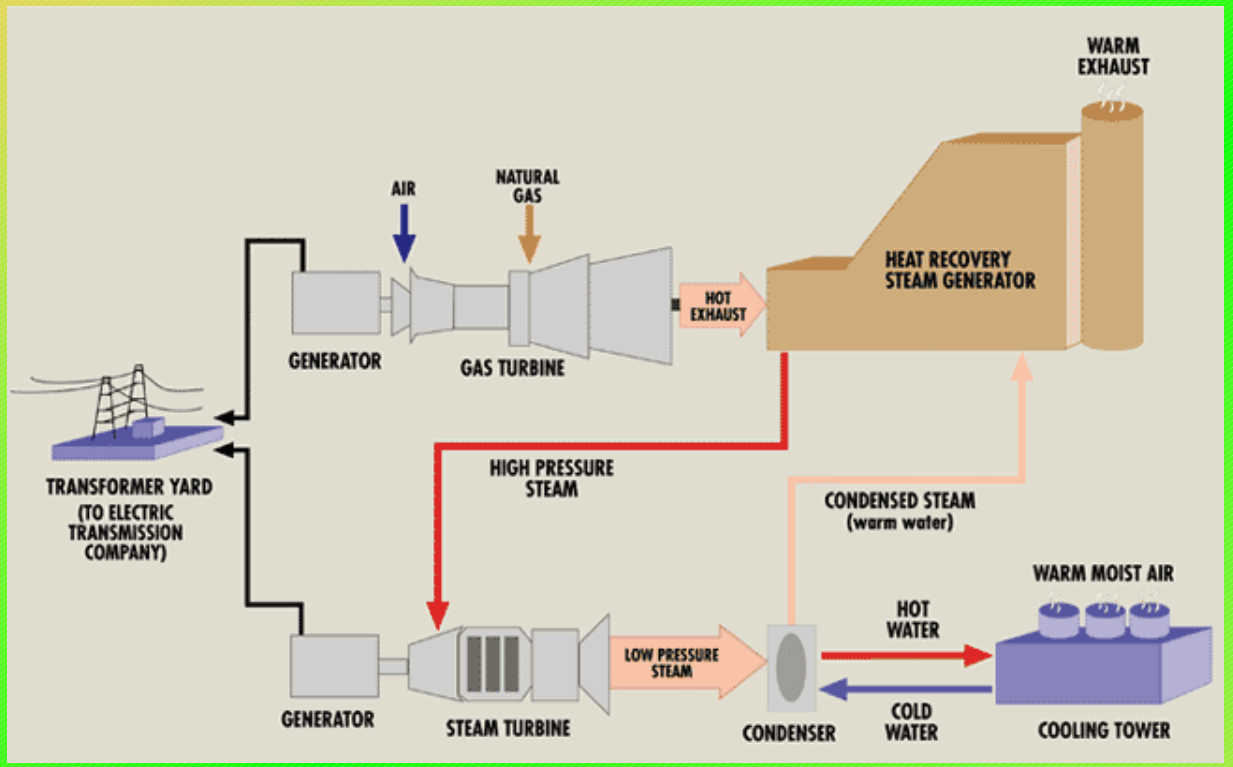
3.Introducing increased energy efficiency technologies enabled by the use of natural gas

ENERGY EFFICIENT TECHNOLOGIES

Natural Gas brings technologies that increase the efficient use of energy

- Power production – combined cycle
- Final consumption – space and water heating
- It is always more environmentally efficient to produce heat directly from natural gas (or any fossil fuel) than from electricity
- The ideal would be combined cycle plus combined heat and power production at the location of heat consumption – distributed power

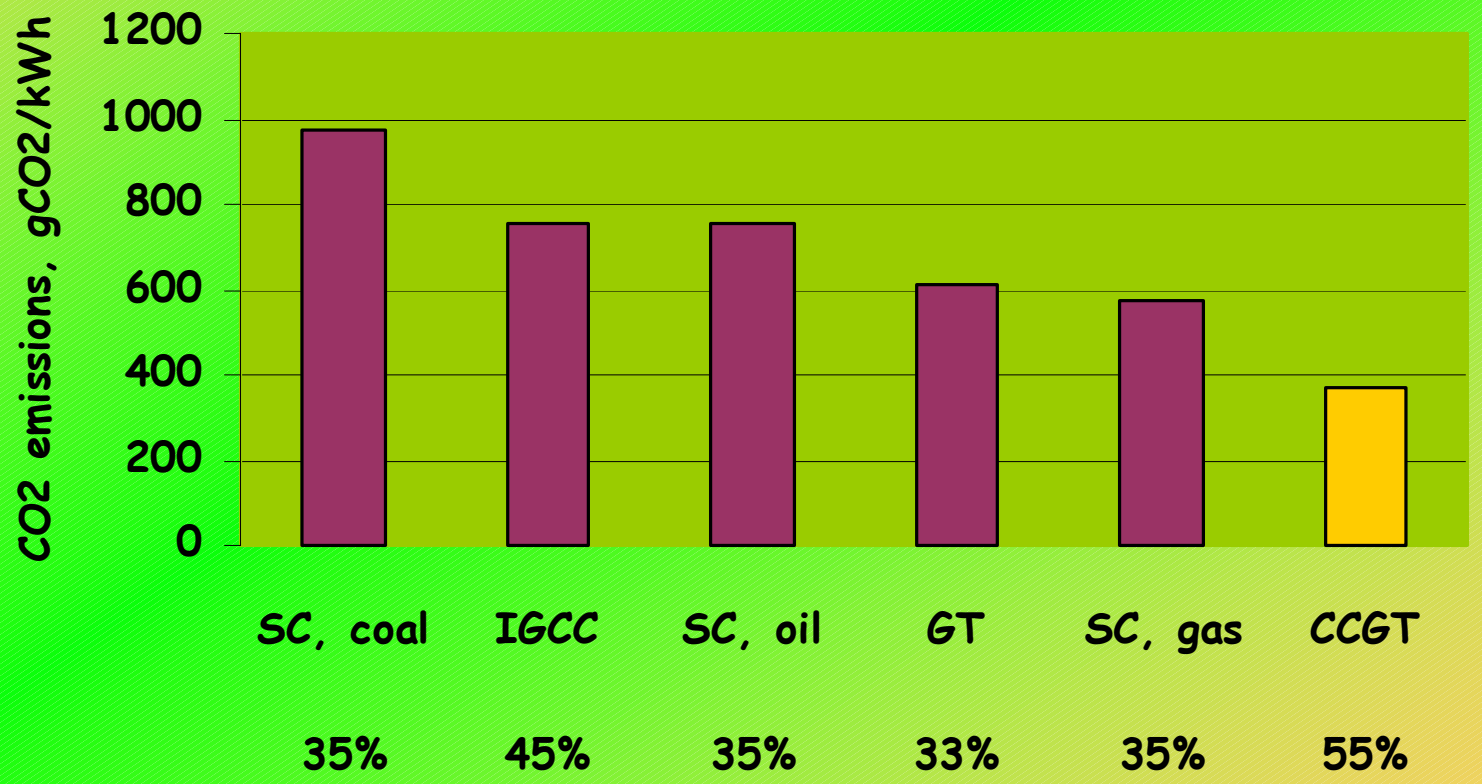
COMBINED CYCLE



- Combined Cycle gas fired power plant reaches efficiency of 55%
- Steam Cycle coal/oil fired 28%-40%
- Higher efficiency – lower emissions per kWh

COMBINED CYCLE

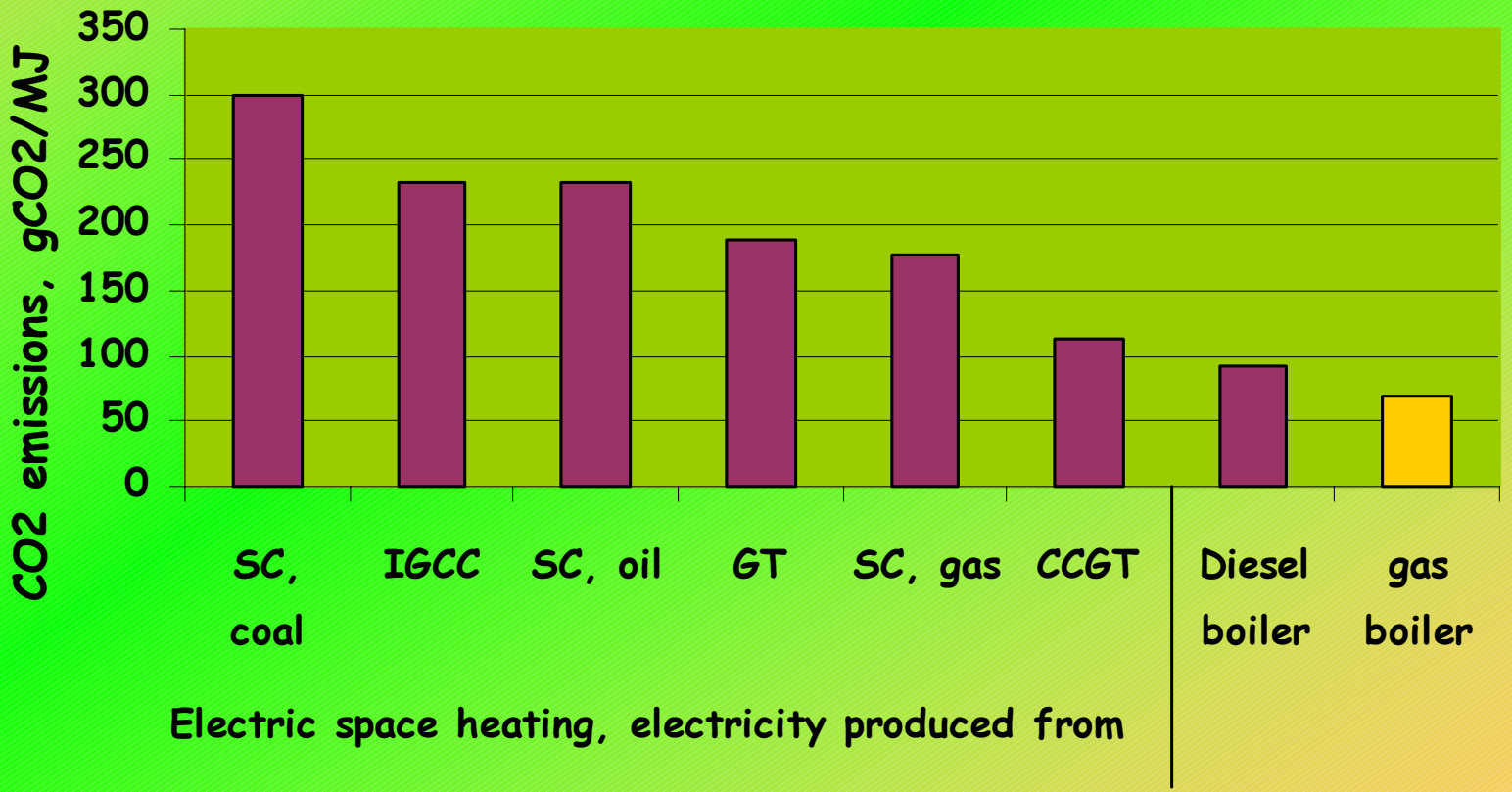
Comparison of CO2 emissions per kWh for different power production technologies



HEATING

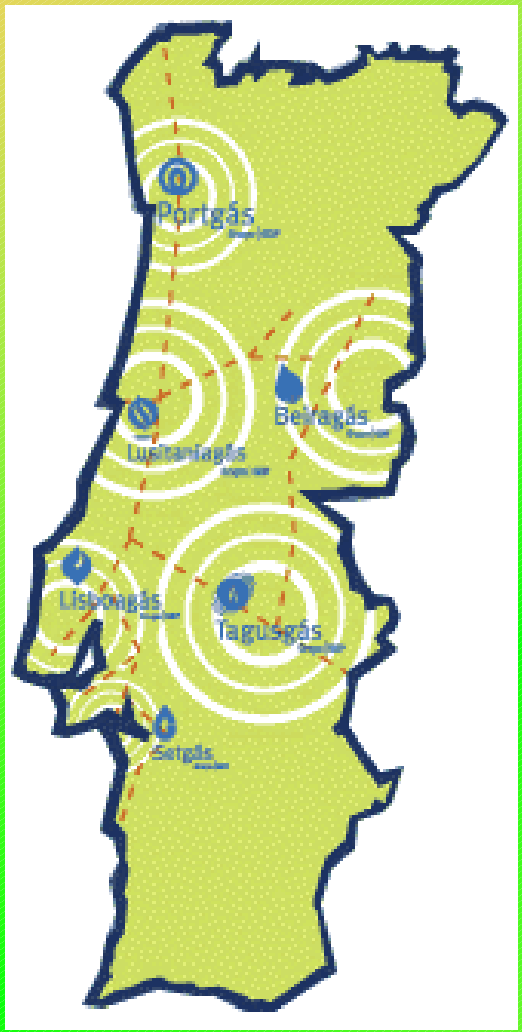
Why it is more environmentally friendly to use natural gas for heating applications than electricity?

- higher efficiency on the path from primary to final energy



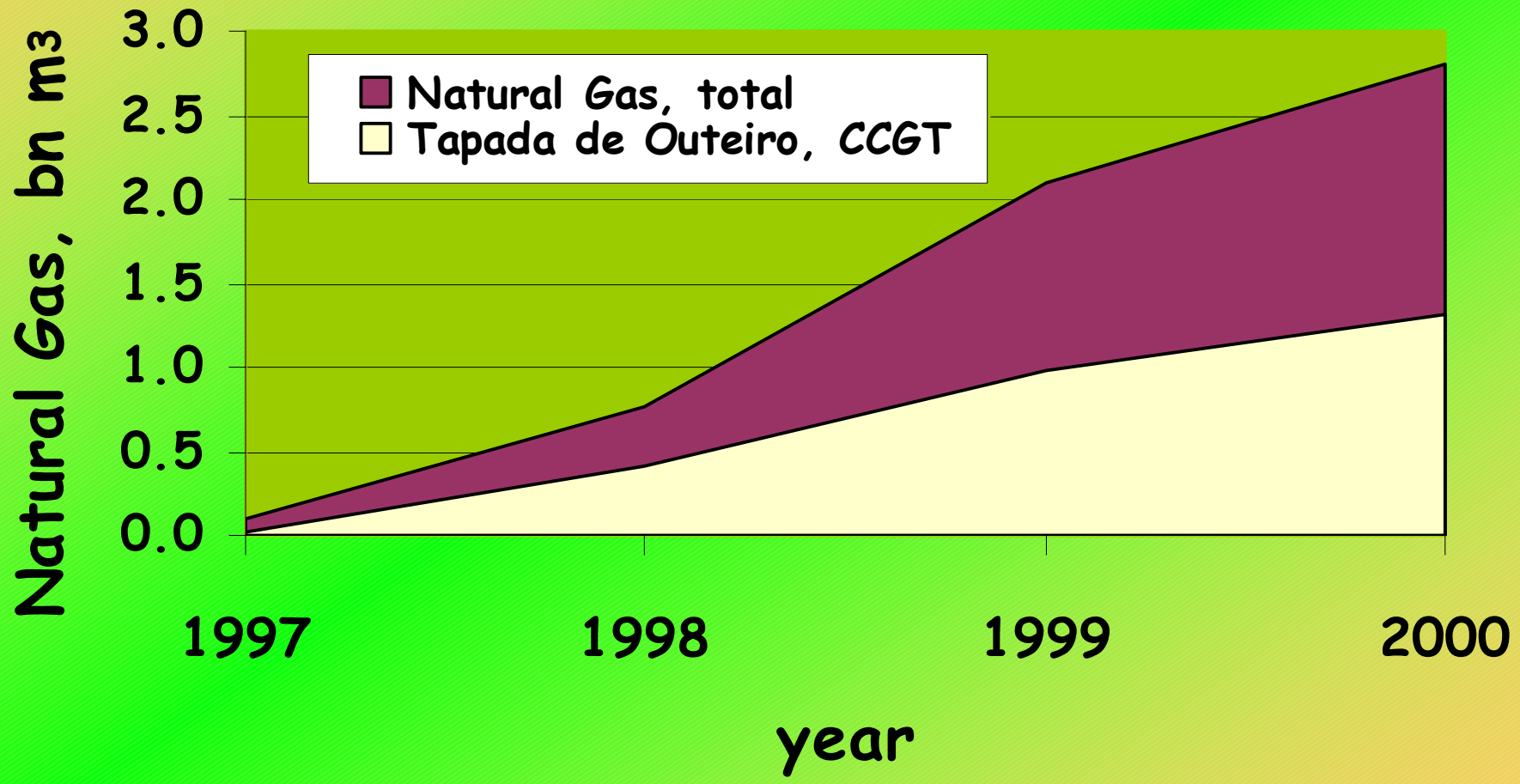
4. Presentation of the case of introduction of natural gas in Portugal and the consequences to greenhouse gases (GHG) and other emissions

NATURAL GAS COMES TO PORTUGAL

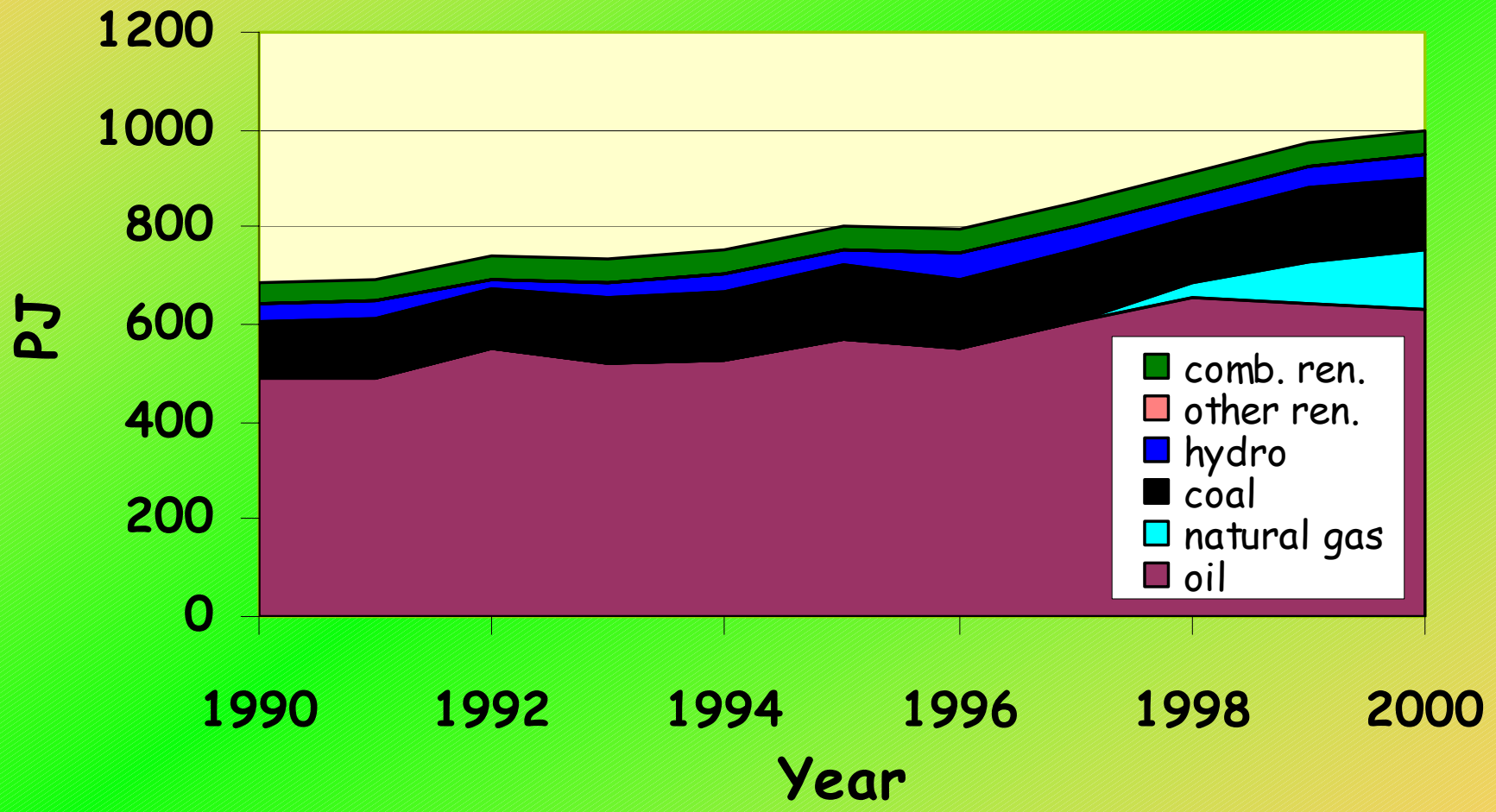


- The first, southern, gas pipeline link to Spain in 1997 (Algerian gas)
- The second, nothern, link in 1998
- LNG terminal in 2003
- Turbogás: 3x330 MW CCGT in Tapada de Outeiro (near Porto)
- Conversion of customers of city gas, piped propane, etc.
- Gassification of main cities and towns

NATURAL GAS COMES TO PORTUGAL



NATURAL GAS COMES TO PORTUGAL



Primary energy per fuel, 1990-2000

NATURAL GAS: AVOIDED EMISSIONS

Model

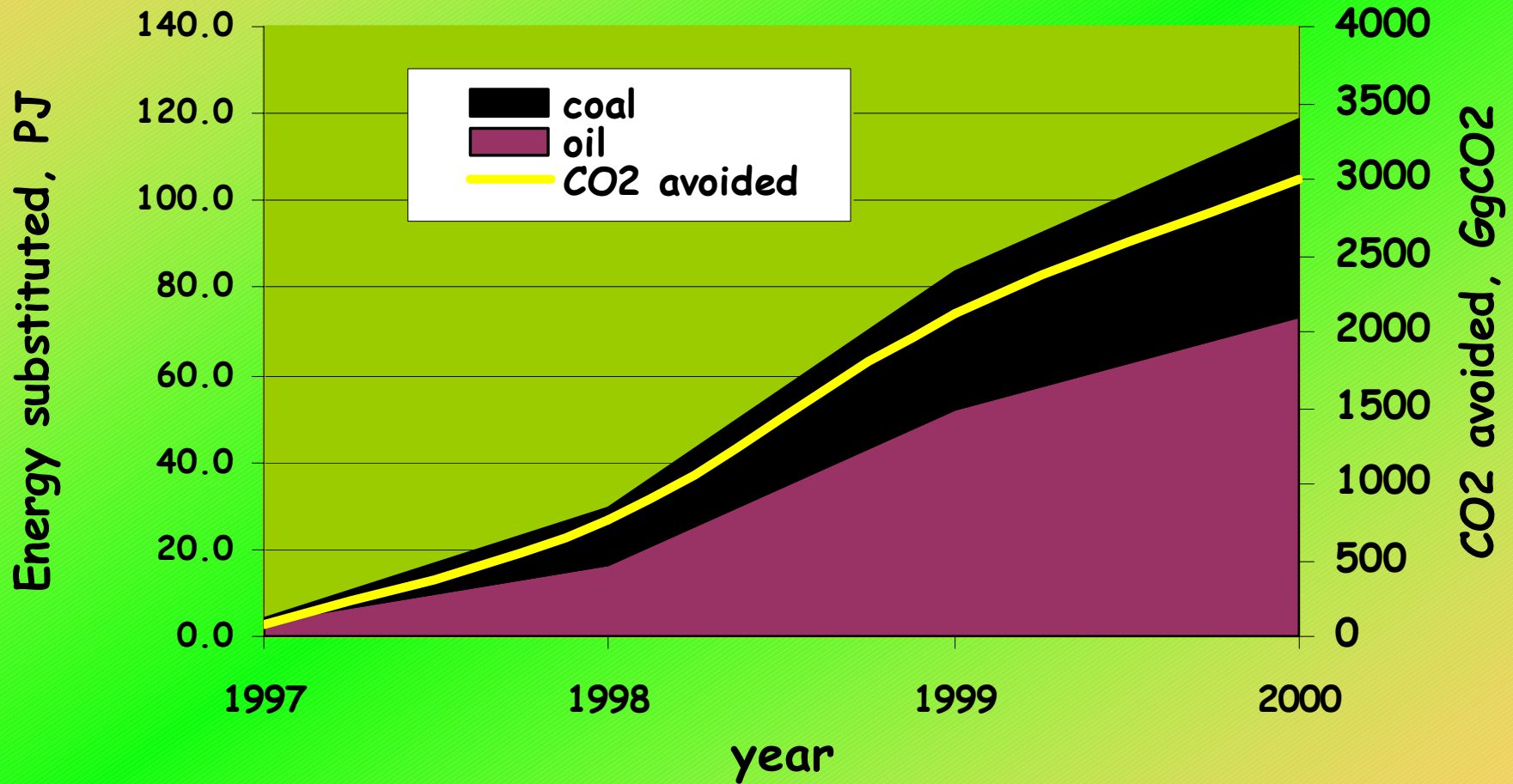
- GHG emissions avoided by introduction of natural gas
- CO_2 from fuel combustion the most important mechanism
- Other GHG sources can be neglected for the first estimate
- Hypothesis: introduction of Natural Gas will not change the demand for final energy
- Emission reduction mechanisms:
  - Fuel substitution
  - Increased efficiency
    - Combined Cycle
    - Substituting electricity by Natural Gas for space and water heating

NATURAL GAS: AVOIDED EMISSIONS

Fuel substitution

1. Hypothesis: without Natural Gas the needed electricity would be produced mainly from coal (80%)
   - No big hydro potential left
   - Commercial potential of renewables still negligible
   - Oil fired base power production not viable
   - Nuclear not an option in Portugal currently
   - Electricity import was not an option until 2001
2. Hypothesis: the rest of Natural Gas is substituting oil in primary energy (city gas, propane, butane, Diesel, etc., peak power production)
3. Hypothesis: the substitution of other fuels is negligible

NATURAL GAS: AVOIDED EMISSIONS



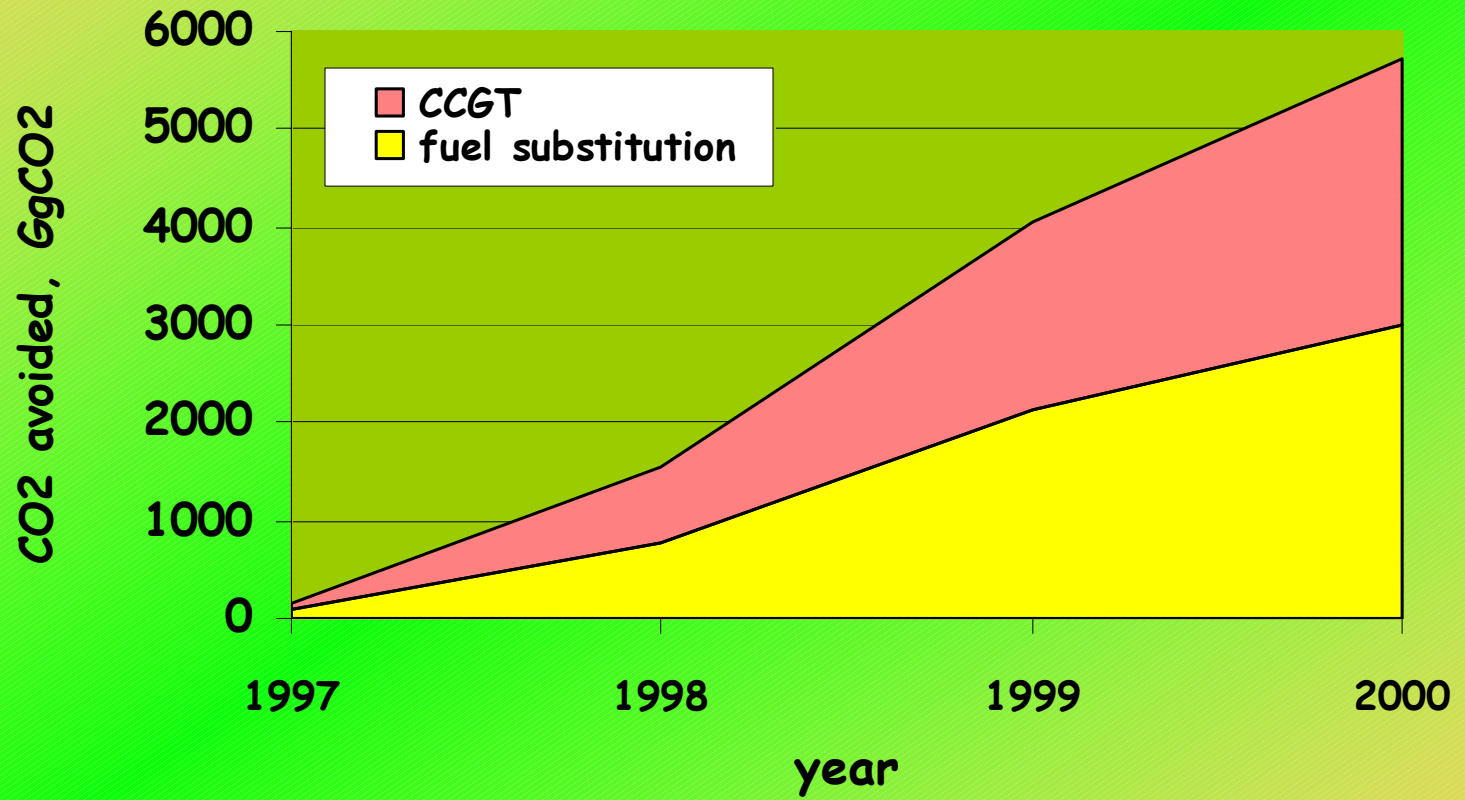
Around 5% of total CO_2 emissions in Portugal avoided due to fuel substitution

NATURAL GAS: AVOIDED EMISSIONS

Increased efficiency

- Combined Cycle
  - Tapada de Outeiro CCGT efficiency = 55%
  - Replacing coal/oil fired steam cycle, efficiency = 35%-40%
  - Around 5% more CO2 avoided due to higher efficiency of CCGT

NATURAL GAS: AVOIDED EMISSIONS



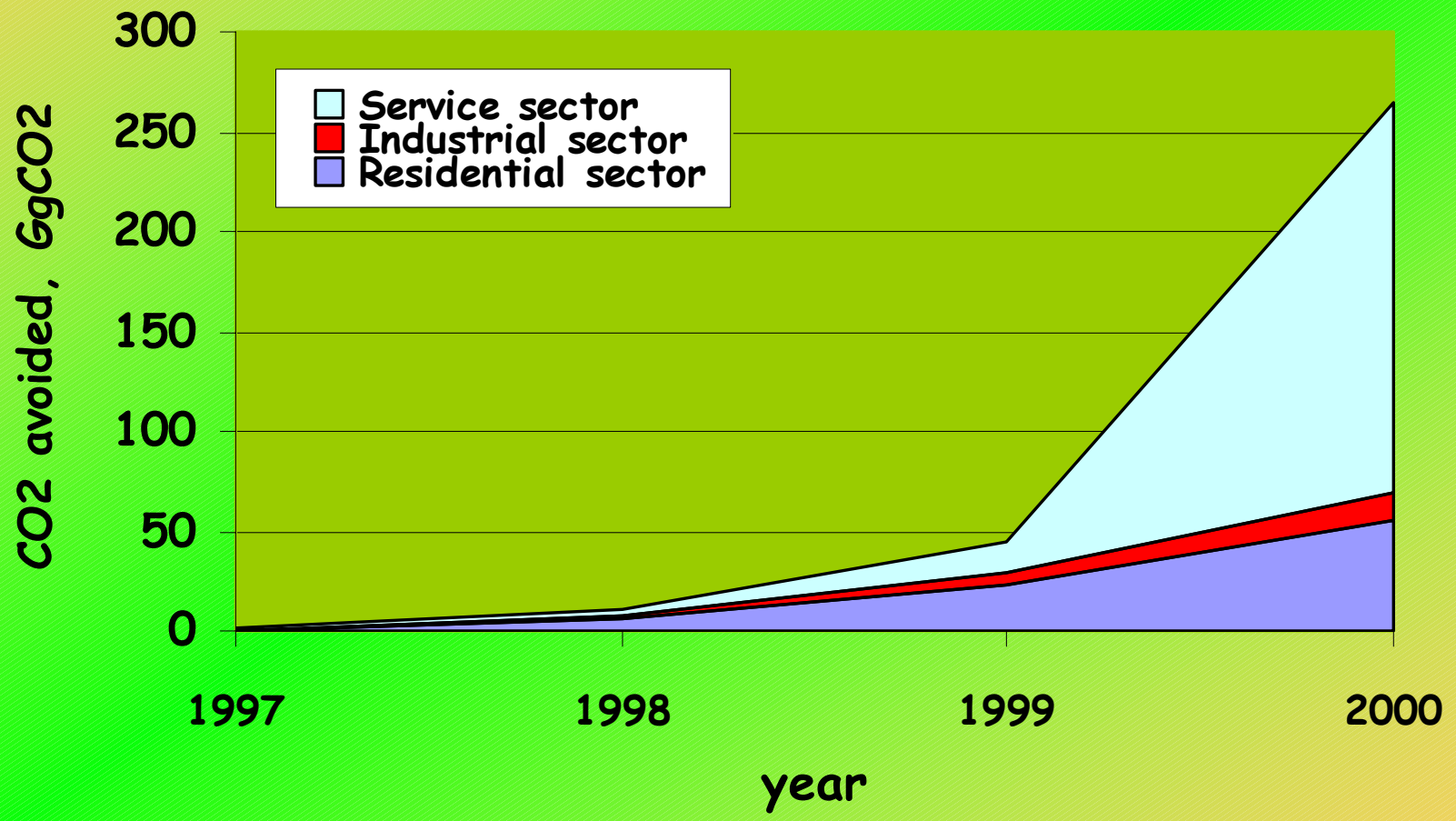
Increased efficiency: around 5% more CO2 avoided due to higher efficiency of CCGT

NATURAL GAS: AVOIDED EMISSIONS

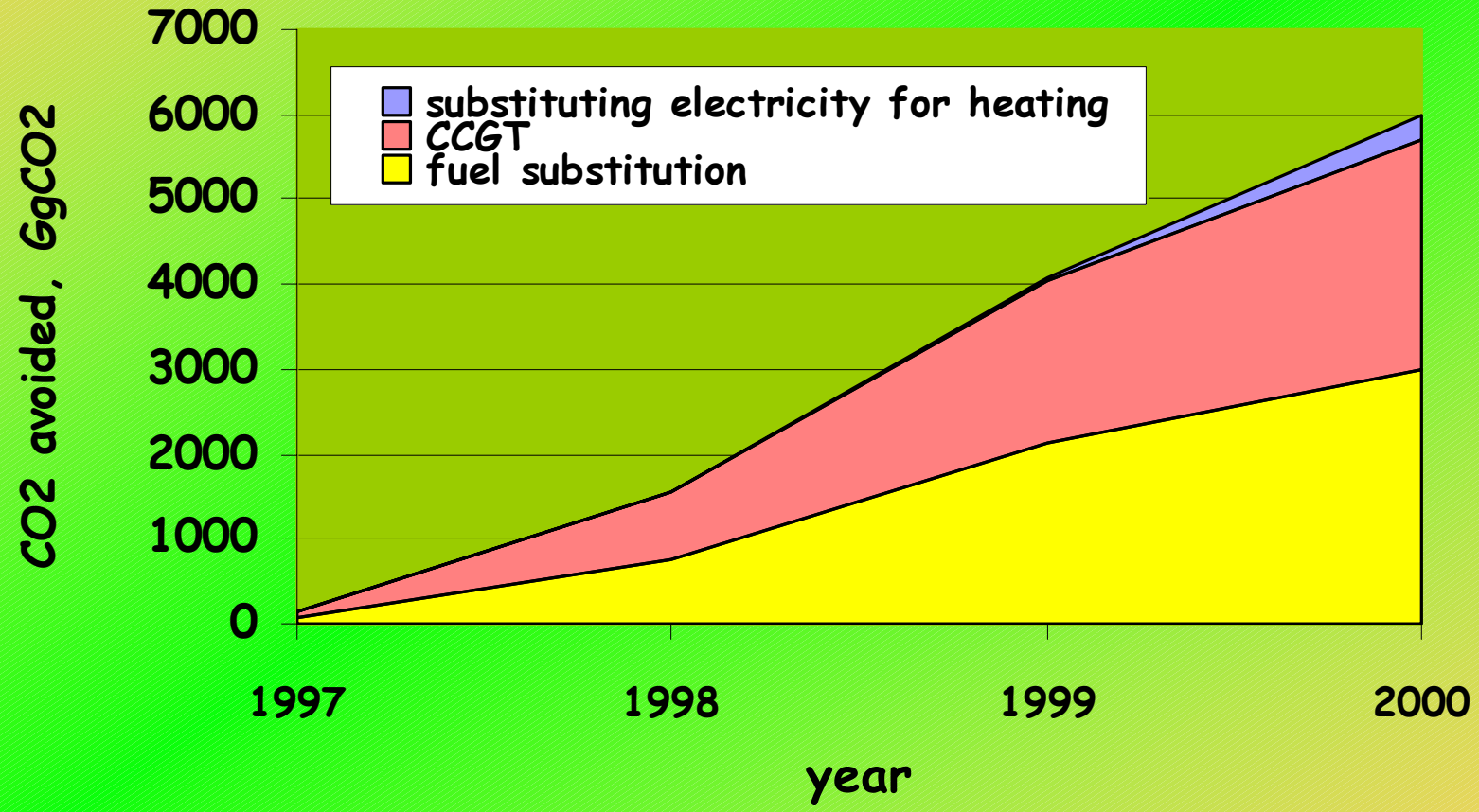
Increased efficiency

- Substituting electricity by Natural Gas for space and water heating
  - Hypothesis: the new (not those converted from piped gas) gas customers will substitute a part of their electricity used for space, water and process heating by natural gas
  - Residential sector survey: 86% of new gas is substituting electricity space and water heating
  - Service sector estimate: 50% of new gas is substituting electricity space, water and process heating
  - Industrial sector estimate: 5% of new gas is substituting electricity space, water and process heating

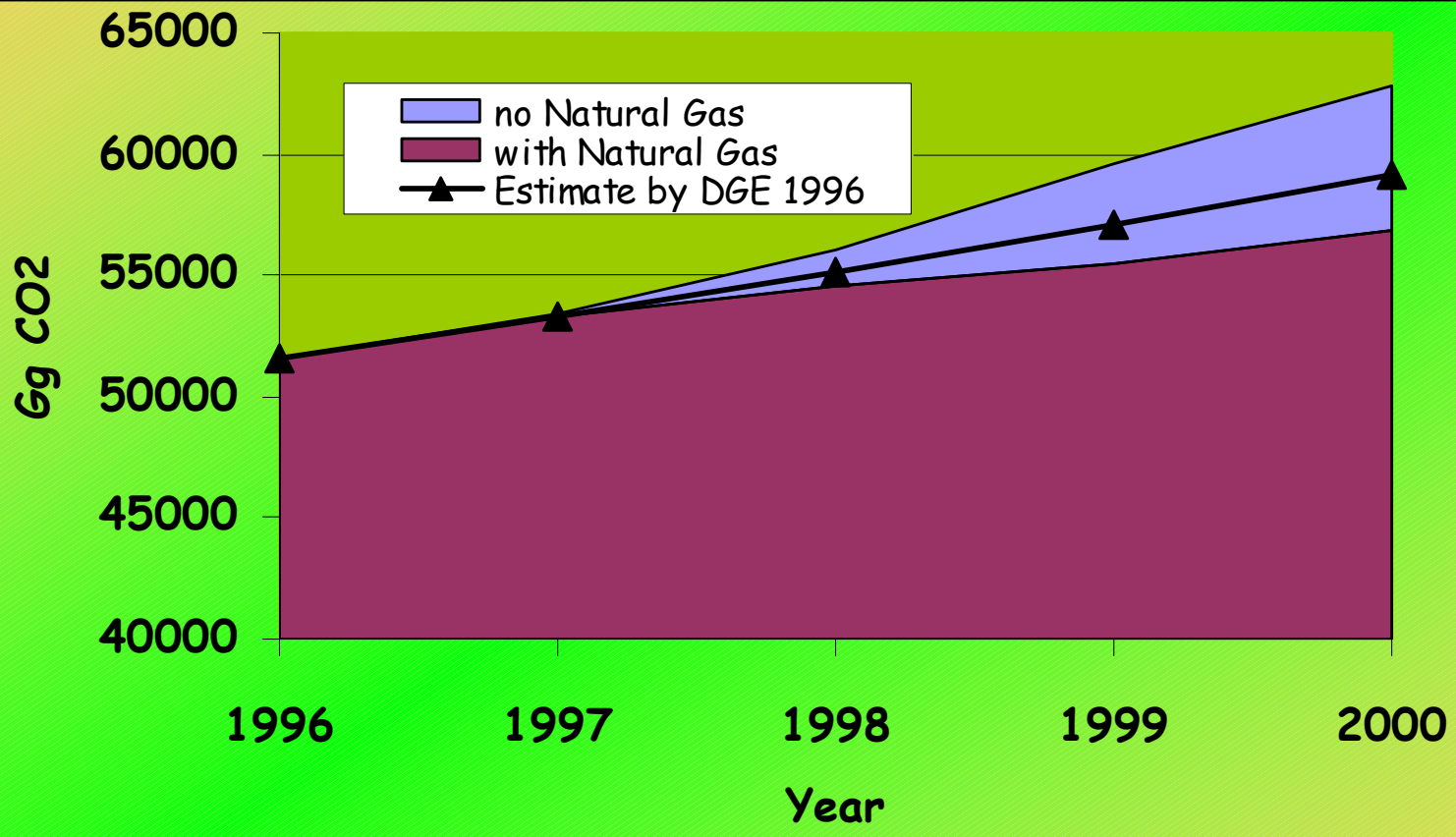
NATURAL GAS: AVOIDED EMISSIONS



NATURAL GAS: AVOIDED EMISSIONS



NATURAL GAS: AVOIDED EMISSIONS



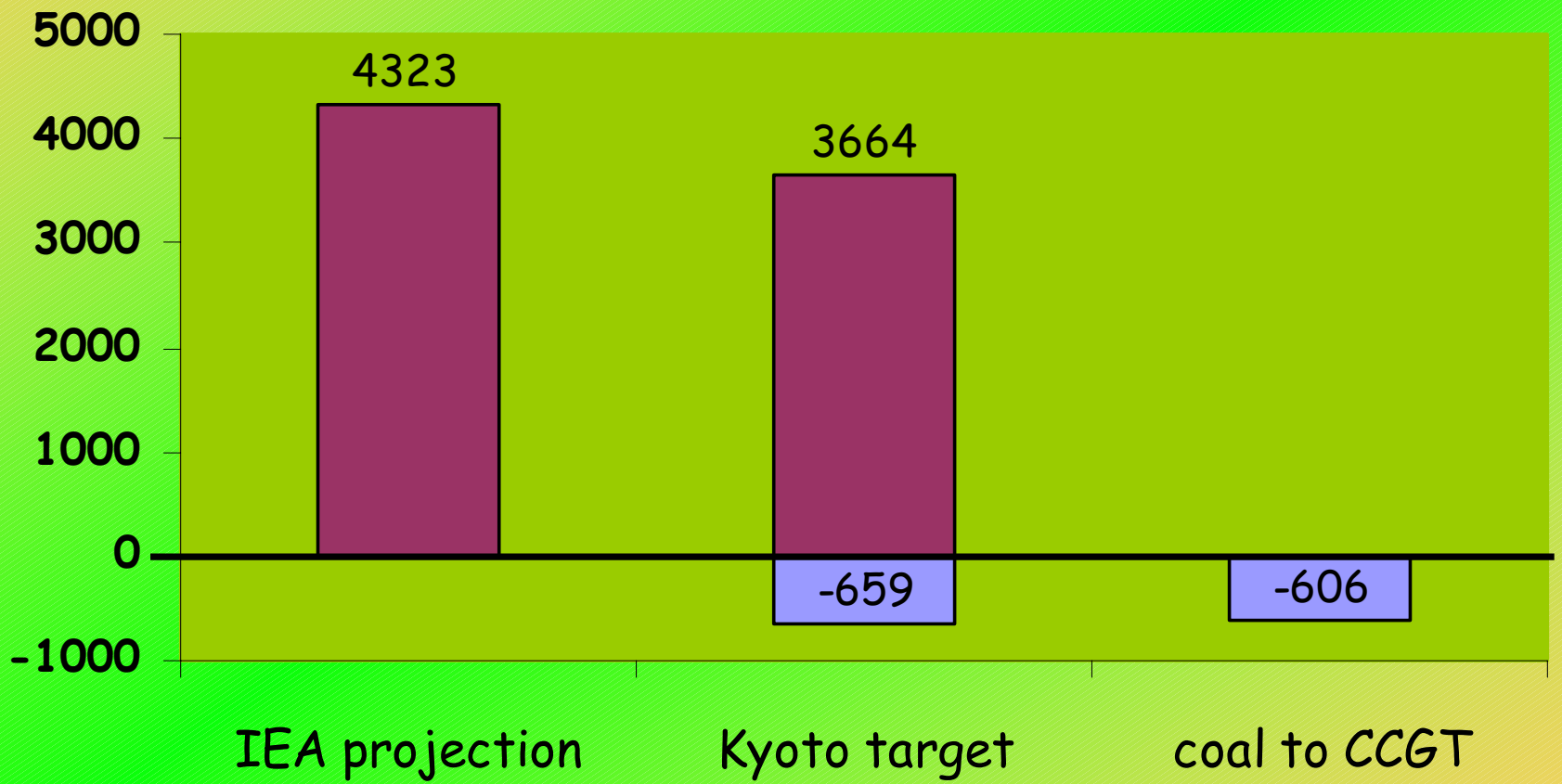
The influence of the introduction of Natural Gas to Portugal – increased final energy consumption due to higher Natural Gas comfort or due to unexpectedly high economic growth

5.Outlining the potential for GHG emission avoidance by use of natural gas in Europe

NG GHG MITIGATION POTENTIAL

- Most of new power generating will be CCGT
- The potential of replacing coal in power generating would be nearly enough to satisfy Kyoto targets
- OECD Europe Kyoto target = 3664 $MtCO_2$
- IEA projections for 2010 = 4323 $MtCO_2$
- Gap = 659 $MtCO_2$
- OECD Europe = 1000 TWh of electricity from coal
- Coal power = 973 $MtCO_2$
- CCGT = 367 $MtCO_2$
- Difference coal to CCGT = 606 $MtCO_2$
- High cost of investment and higher cost of gas

NG GHG MITIGATION POTENTIAL



Conclusions

CONCLUSIONS

- Natural gas is the most economically viable way of reducing GHG emissions in the short-medium term
- There are limits to its potential:
  - Price increase due to increased demand
  - It is only a temporary stay, since it is also a fossil fuel
  - Distributed application depends on piping – very slow penetration
- It will be the main fuel in power generation in Europe in the first two decades of XXI century
- Do not use electrical space and water heating if you have an alternative

This presentation is available in pdf format at:
http://powerlab.fsb.hr/neven/lectures/EurocourseEnvironment.pdf