DRAFT

Room Document: Baseline Efficiency Analysis of Fossil Fuel Power Plants

UNECE Group of Experts on Cleaner Electricity Production from Fossil Fuels

We Rely on Fossil Fuels

Electricity generation through the use of fossil fuels is a foundational pillar to modern society. Over two thirds of the world's electricity is supplied by fossil fuels with coal alone accounting for 42% of global electricity[1]. Electricity production has been built upon fossil fuels because they have historically been abundant and inexpensive. The power plant technologies needed to convert fossil fuels into electricity also has a history of being easy to construct without excessively high capital costs and have lent themselves to economies of scale[2]. Inexpensive fossil fuels and technology has created an electricity sector designed around these fuels where power plants have been constructed in locations where the energy-dense fossil fuels were readily available, delivered and were cheap and easy to handle[3]. The continued use of these fuels is expected in part because global supplies of abundant and inexpensive fossil fuels are estimated to last well into the future. At current production levels, proven coal reserves are estimated to last 118 more years and proven oil and gas reserves should last around 46 and 59 years respectively[4]. Overtime as electricity demand and production has grown, the use of fossil fuels have become deeper engrained into the energy foundation that modern societies are built upon.

Fossil Fuels Have Adverse Effects

Unfortunately there are drawbacks from continuing to use fossil fuels as a primary energy source. The combustion of fossil fuels releases carbon dioxide (CO_2) into the atmosphere and thus contributes to climate change. The CO_2 emissions from fossil fuel combustion for power generation is the single largest source of anthropogenic greenhouse gas (GHG) emissions[5]. These emissions make up 28% of the total CO_2 emissions from all sources[6]. More specifically, coal-fired power plants are the largest emitters of CO_2. Over the past 15 years, the rapid increase in capacity of coal-fired electricity generating stations has raised concerns about the surge in carbon emissions[7]. The current levels of carbon dioxide and other GHG emissions are exceeding the worst case scenarios outlined by climate experts. Still global emissions are increasing and are expected to continue increasing in the future[8]. The emissions from China and India are the world's first and third largest CO_2 emitters. Both nations have very large coal burning power sectors and their emissions have shown very strong growth in the past decade[9]. As a response to the raising level of emissions, there have been some calls in developed countries to completely abandon fossil fuels, especially coal, as a source of electricity. These calls make no economic sense for either the immediate or distant future because of the abundance of fossil fuel resources, their high energy content and relatively low cost that most economies depend on[10].

[1] World Coal Association 2011, via UNECE Energy Week 2011;IEA data, staff calculations http://www.unece.org/fileadmin/DAM/energy/se/pp/clep/ahge8/3_Opening_Budinsky_item_7.pdf
[2] UNECE (2013) *Mitigating Climate Change Through Investments in Fossil Fuel Technologies*, 8
[3] Ibid., pg14
[4] World Coal Association 2011, via UNECE Energy Week 2011;IEA data, staff calculations http://www.unece.org/fileadmin/DAM/energy/se/pp/clep/ahge8/3_Opening_Budinsky_item_7.pdf
[5] UNECE (2013) *Mitigating Climate Change Through Investments in Fossil Fuel Technologies*, 18
[6] Ibid., 18
[7] Ibid., 9
[8] UNECE Energy Week 2011
[9] UNECE (2013) *Mitigating Climate Change Through Investments in Fossil Fuel Technologies,* 65
[10] Ibid., 21

Improving Efficiency Can Mitigate These Problems

The most effective means of benefitting from continuing to use fossil fuel plants while reducing GHG emissions has proven to be increasing the energy efficiency of existing power plants. There is a direct, inverse correlation between running a fossil fuel fired power generator at higher efficiency and reducing the generator's CO_2 emissions. It can be assumed that for each 1 per cent increase in efficiency of a coal burning power plant there is a 2-3% reduction of CO_2 emissions[11]. This means that if all coal burning power plants were able to achieve a 1% efficiency increase, 0.23 $GtCO_2$ per year would be avoided. This amount equals the total emissions from the Netherlands and Denmark combined. Best practices at all plants would save 1.7 $GtCO_2$ per year.[12]

The Technology Exists

Improving energy efficiency has been a focus of intensive energy research over the past two decades[13]. As a result, there has been steady technological innovation towards increasing efficiency and reducing emissions from the power generation of fossil fuels, most notably from coal where most of the research has been focused[14]. Cleaner more efficient fossil fuel combustion technologies such as supercritical pulverized coal (SCPC) and ultra-supercritical pulverized coal (USCPC) steam generators are being increasingly introduced to electricity generation fleets in order to replace les efficient sub-critical generators[15]. China for example implemented a program in 2006 called "Large Substitute for Small" that removes smaller and older coal fired plants to replace them with newer and larger plants with advanced technology such as the SCPC and USCPC generators. China plans to add 525 GWs of new coal-burning power plants by 2020[16]. Other advanced technologies for power generation from fossil fuel plants are being developed that also offer higher efficiencies and lower carbon emissions. These include: Combined Cycle Gas Turbines (CCGT), Combined Heat and Power gas turbines (CHP), and Integrated Coal Gasification combined cycle plants (IGCC)[17].

Some Areas Still Using Old Technology

Since these technological advancements are a relatively new area of research, power plants older than a few decades are significantly far behind in the race to increase efficiency. Many countries with economies in transition still rely on power plants built with old and obsolete technology. It's often the case that power plants built prior to 1992 rely on coal for up to 80% of their electricity and were designed based on self-sufficiency energy policies that focus on the high availability and low costs of coal[18]. The construction of the power plants was followed by a serious economic contraction in the 1990s and then a lack of investment funds resulting in very little new building capacity in the region[19]. In Ukraine for example, nearly 47% of the total power generating fleet, or 75% of its thermal power capacity is more than 40 years old with a thermal power fleet that runs at an average load capacity of 31.5%[20].

Over the past few years, some countries have recognized their increasing energy demand and aging power plants. Mongolia, Kazakhstan and Uzbekistan have recently begun programs of modernization or of constructing new power plants but the average energy intensities in the countries with economies in transition are still significantly higher than most other countries. This situation suggests that future

[11] Ibid., 21
[12] EURACOAL, ECE/ENERGY/GE.5/2011/INF.1 -http://www.unece.org/fileadmin/DAM/energy/se/pp/clep/ahge8/4_RICKETTS.pdf
[13] UNECE (2013) *Mitigating Climate Change Through Investments in Fossil Fuel Technologies*, 21
[14] Ibid., 21
[15] Ibid., 65
[16] Ibid., 66
[17] Ibid., 21
[18] Ibid., 21, 65
[19] Ibid., 27
[20] Ibid., 28

investment in the energy sector will most likely go into energy conservation and increasing energy efficiency rather than into building new electricity generation capacity so there will most likely not be strong growth in the electricity sector expansion in the near future[21].

Technology Transfer

While there is pressure for developing countries to use these new technologies, adaptation can be difficult as the technology is expensive and requires engineering skills, materials, and equipment which are not available in most developing countries[22]. A means of diffusing low-carbon technology from developed to developing nations is therefore necessary and will be globally valuable to all nations considering the implications of climate change. The emission reduction potential of advanced fossil fuel power plant technologies has been recognized as an incentive to promote the transfer of energy efficient power plant technology to developing nations.

The international climate change negotiations conducted by the United Nations Framework Convention on Climate Change (UNFCCC) could act as a possible stage to enable this transfer. Access to advanced, low-carbon technologies was a considerable incentive for developing nations to support the UNFCCC during the convention's creation in 1992[23]. The Clean Development Mechanism (CDM) was created under the UNFCCC to promote sustainable development and reduce emissions has been a significant driver of more efficient power plant technology transfer[24]. Emission reduction permits can be issued to, then sold by developed nations in exchange for the reduced emissions in developing nations after transferring power plant technologies. The sale of the permits creates the necessary financial incentives to drive the technology transfer to upgrade obsolete, high-emitting power plants while achieving the dual goals of reducing emissions and supporting global development. Studies on technology transfer in CDM projects estimate that technology transfer has occurred in 36% - 46% of CDM projects[25]

The UNFCCC has extended the Kyoto Protocol and therefore the CDM until 2020 with hopes of drafting a successor document by 2015. There are possibilities that technology transfer will be included a post-Kyoto climate agreement. The first step in continuing the transfer of technology is to gather sufficient information on the current efficiencies of existing power plants. Any post-Kyoto agreement on reducing emissions will most likely require a detailed baseline measure of existing power plant efficiencies and emissions in order to properly measure how upgrades have improved both efficiency and emissions. Accurate baseline measurements will be exceptionally important if a emissions trading scheme is included as part post-Kyoto agreement from the UNFCCC after 2020.

[21] Ibid., 27
[22] Ibid., 6
[23] Sussex Energy Group (2010) *Low Carbon Technology Transfer: Lessons from India and China,* pg. 1
[24] Schneider, M., A. Holzer and V. Hoffmann (2008) *"Understanding the CDM's Contribution to Technology Transfer".* Energy Policy. 36:p 2936 Accessed via : Ecologic Institute (2010) Technology Transfer in the International Climate Negotiations.
[25] Data taken from: Ecologic Institute (2010) *Technology Transfer in the International Climate Negotiations* p34 with statistics based on the following:
-Haites, Erik, Maosheng Duan, and Stephen Seres (2006) "*Technology transfer by CDM projects*." Climate Policy 6, no. 3: pp. 327-344.
- Dechezleprêtre , Antoine, Matthieu Glachant, and Yann Ménière. (2007) "*The North-South Transfer of Climate-Friendly Technologies through the Clean Development Mechanism*." CERNA, Ecole des Mines de Paris. http://www.cerna.ensmp.fr/Documents/AD-MG-YM-ReportMDM.pdf
- de Coninck, H., F. Haake and N.H. van der Linden. (2007) "*Technology transfer in the Clean Development Mechanism*." Energy Research Centre of the Netherlands.

Room Document: Baseline Efficiency Analysis of Fossil Fuel Power Plants

UNECE Group of Experts on Cleaner Electricity Production from Fossil Fuels

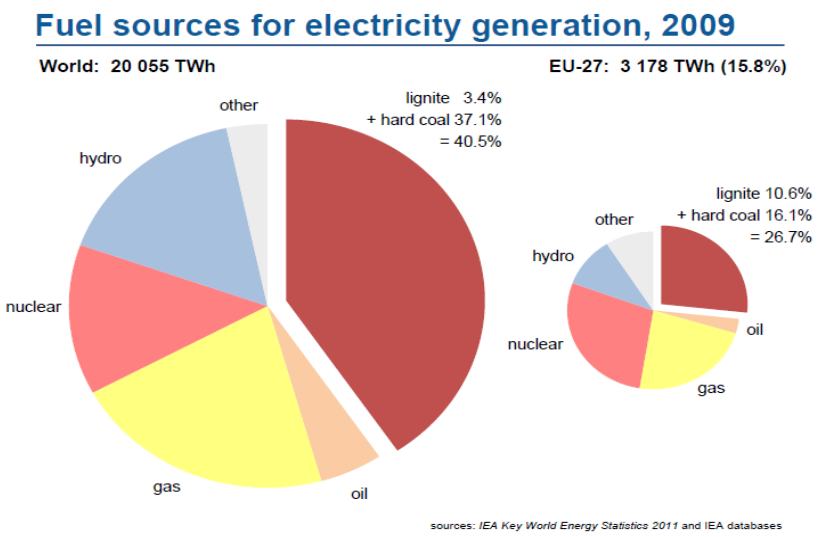
Why is the energy efficiency of fossil fuel power plants important?

1. We Rely on Fossil Fuels

Fossil fuels account for a significant portion of electricity production. Coal alone accounts for 42 percent of the world's electricity, with fossil fuels as a whole supplying over 2/3 of the world's electricity.

At current production levels, proven coal reserves are estimated to last 118 more years and proven oil and gas reserves should last around 46 and 59 years, respectively.

Source: World Coal Association 2011, via UNECE Energy Week 2011; IEA data, staff calculations
http://www.unece.org/fileadmin/DAM/energy/se/pp/clep/ahge8/3_Opening_Budinsky_item_7.pdf

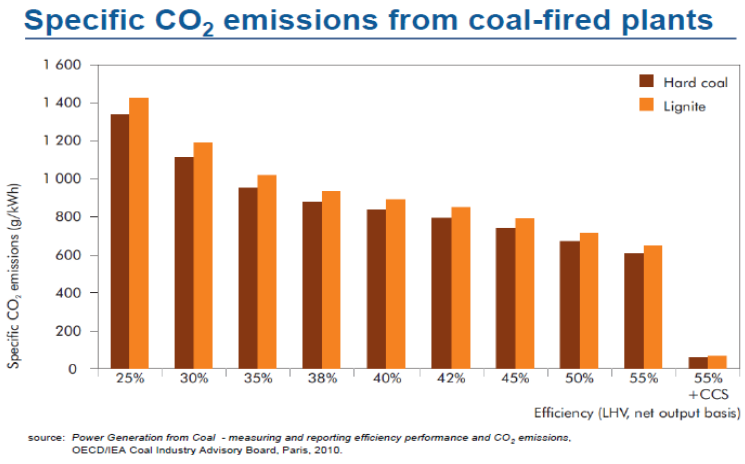


Source: EURACOAL, 2011
http://www.unece.org/fileadmin/DAM/energy/se/pp/clep/ahge8/4_RICKETTS.pdf

2. Fossil Fuels Have Adverse Effects

The burning of fossil fuels emits greenhouse gases into the atmosphere. As discussed in the UNECE Energy Week in November 2011, levels of greenhouse gases are exceeding worst case scenarios outlined by climate experts, and global emissions are increasing.

Source: UNECE Energy Week 2011
http://www.unece.org/fileadmin/DAM/energy/se/pp/clep/ahge8/3_Opening_Budinsky_item_7.pdf



U Source: EURACOAL, 2011
http://www.unece.org/fileadmin/DAM/energy/se/pp/clep/ahge8/4_RICKETTS.pdf

Countries heavily dependent on coal for electricity include:

South Africa	93%
Estonia	91%
Poland	90%
China	79%
Kazakhstan	70%
Serbia	70%
India	69%
Israel	63%
Czech Rep.	56%
Greece	55%
USA	45%
Germany	44%

Source: World Coal Association 2011, via UNECE Energy Week 2011; IEA data 2005-2011 averages

http://www.unece.org/fileadmin/DAM/energy/se/pp/clep/ahge8/3_Opening_Budinsky_item_7.pdf

Countries heavily dependent on natural gas for electricity include:

Turkmenistan	100%
Belarus	97%
Azerbaijan	81%
Uzbekistan	74%
Russian Fed.	49%
USA	29%
Germany	12%

Source: IEA, Based on 2012 data

3. Improving Efficiency Can Mitigate These Problems

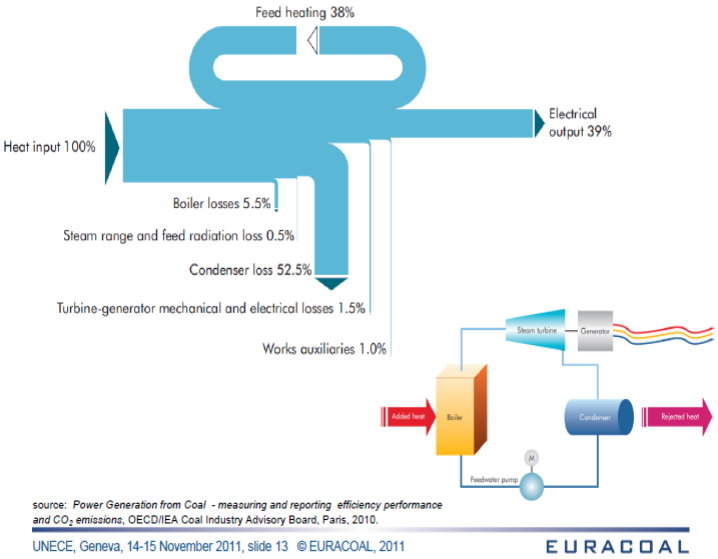
A one percentage point improvement in coal-fired power plant efficiency would save 0.23 $GtCO_2$ per year – the total CO_2 emissions from the Netherlands and Denmark. Best practices at all plants would save 1.7 $GtCO_2$ per year.

Yet some power plants still in operation today date back to the 1950s, with thermal efficiency ranges between 27 per cent and 35 per cent.

To address this, many European countries have set goals to increase the energy efficiency of coal-fired installations to over 40 per cent and the target of some of the latest projects is to achieve more than 50 percent efficiency by 2020.

Source: EURACOAL, ECE/ENERGY/GE.5/2011/INF.1
http://www.unece.org/fileadmin/DAM/energy/se/pp/clep/ahge8/4_RICKETTS.pdf

Example energy flows in a typical 500 MW subcritical pulverised coal-fired boiler



Source: EURACOAL, ECE/ENERGY/GE.5/2011/INF.1
http://www.unece.org/fileadmin/DAM/energy/se/pp/clep/ahge8/4_RICKETTS.pdf

How do we measure energy efficiency?

According to the World Bank, "Thermal efficiency (%) in power supply… is calculated by dividing gross electricity production from electricity and cogeneration plants by total inputs of fuels into those plants…. In the case of cogeneration plants, fuel inputs are allocated between electricity and heat production in proportion to their shares of the annual output."

$$E = \text{Energy efficiency } (E) = (P + H * s) / I$$

Where:

P	=	electricity production from public electricity plants and public CHP plants
H	=	useful heat output from public CHP plants
s^*	=	correction factor between heat and electricity, defined as the reduction in electricity production per unit of heat extracted
I	=	fuel input for public electricity plants and public CHP plants

* s depends on temperature of the heat extracted, and can be between 0.15 and 0.2. This analysis uses 0.175 with a sensitivity analysis in the appendix.

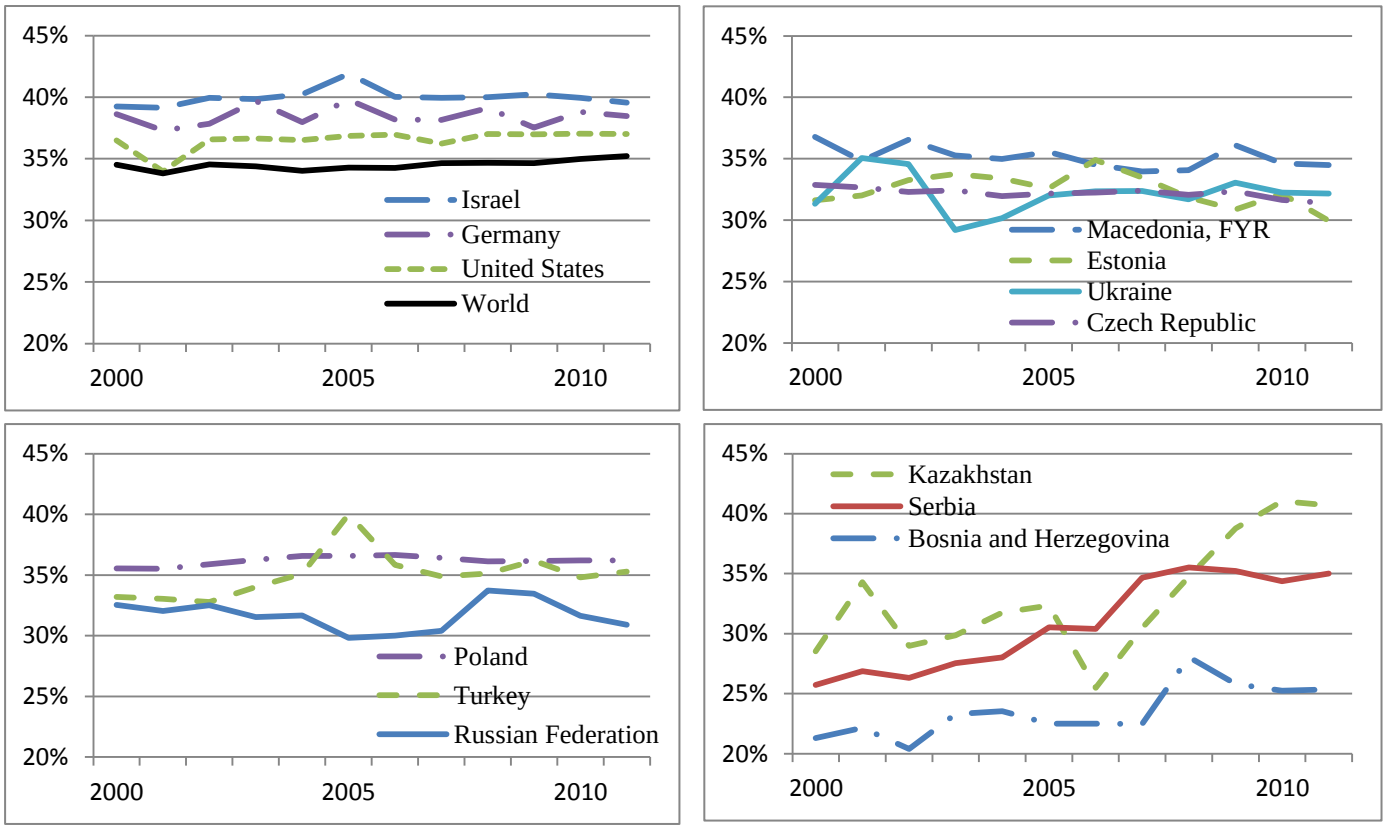
Source: IEA Information Paper: Energy Efficiency Indicators for Public Electricity Production from Fossil Fuels, 2008
http://www.iea.org/publications/freepublications/publication/En_Efficiency_Indicators.pdf

4. Trends in Coal Energy Efficiency

Coal: Worldwide efficiency of coal-fired power plants has remained relatively constant over the last 20 years, at around 35 percent efficiency, but some countries, such as Denmark, the Netherlands, and Norway, have achieved fleet averages of over 40 percent efficiency. Meanwhile, new and retrofitted plants have efficiency levels of up to 47 percent.

Source: IEA data, staff calculations

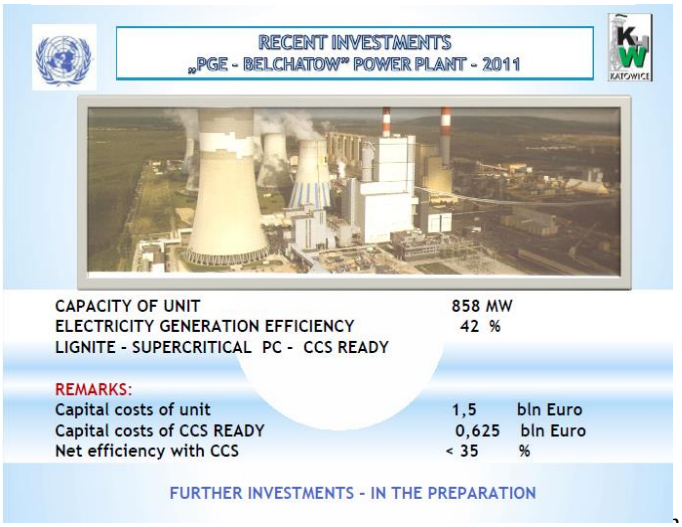
Evolution of Coal-Fired Power Plant



Source: IEA data, staff calculations

Newly Constructed Coal-Fired Power

Poland: PGE- Belchatow Power Plant



Source: Katowicki Holding Węglowy SA/ CEEp
http://www.unece.org/fileadmin/DAM/energy/se/pp/clep/ahge8/6_Poland_K

State-of-the-art coal-fired power plants

Canada Genessee 3	sub-bituminous coal	Genessee 3 supercritical once-through Benson type, two-pass, sliding pressure	41.4%
Japan Isogo New Unit 1	bituminous coal	Isogo New Unit 1 supercritical once-through, tower type, sliding pressure	42.0%
Germany Niederaussem K	lignite	Niederaussem K once-through supercritical tower type	43.7%
Denmark Nordjyllandsværket 3	international steam coals	Nordjyllandsværket 3 supercritical, Benson, tower type, tangential firing	47.0%
South Korea Younghung	international bituminous	Younghung supercritical once-through, tower type, sliding pressure	43.3%

from Fossil Fuels

Source: EURACOAL, ECE/ENERGY/GE.5/2011/INF.1
http://www.unece.org/fileadmin/DAM/energy/se/pp/clep/ahge8/4_RICKETTS.pdf

Refurbished Coal-Fired Power

Bulgaria: Maritza East 3 Power Plant

Czech Republic: Tusimice Project

- Increased capacity from 840 MW to 908 MW
- Rehabilitation and modernization program on all four lignite-fired units
- Improvement of efficiency from 30% to 35%
- 15-year lifetime extension
- Cost 700 million euros, of which 160 million euros were for environmental improvements
- Construction of two desulfurization units to reduce SO_2 emissions by over 94%; a new system for capturing dust from the boiler process; and a comprehensive water management system for reduction of fresh water consumption

Source: Enel Environmental Report 2010, Presentation 2011 http://www.unece.org/fileadmin/DAM/energy/se/pp/clep/ahge8/5_Enel_Geneva.pdf

- 4x200 MWe
- Enhancing net efficiency from 33% to 38%
- Lifetime extension till 2035
- CO_2 reduction from 1.1 to 1.0 tCO_2/MWh
- Installation of new once-through, double-pass boilers

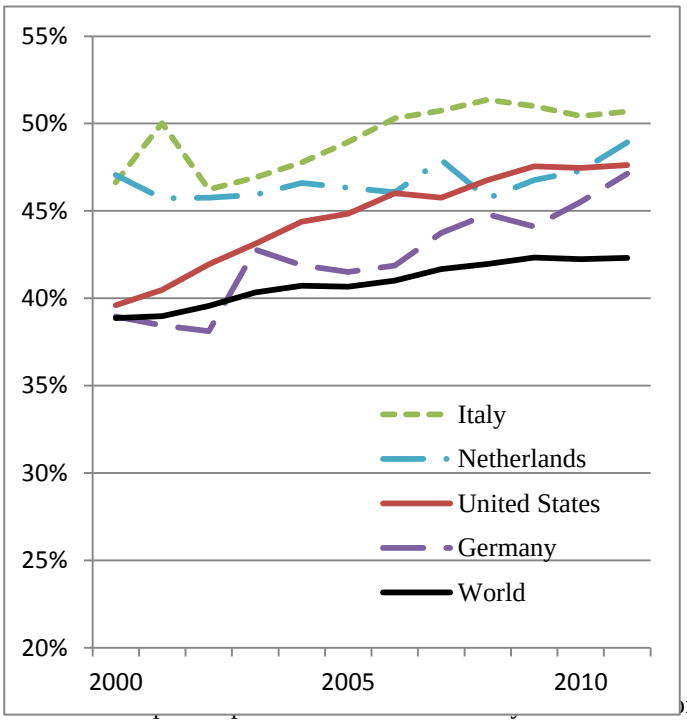
Source: Severoceske doly a.s., CEZ Group Presentation 2011; http://www.cez.cz/en/power-plants-and-environment/coal-fired-power-plants/cr/tusimice.html

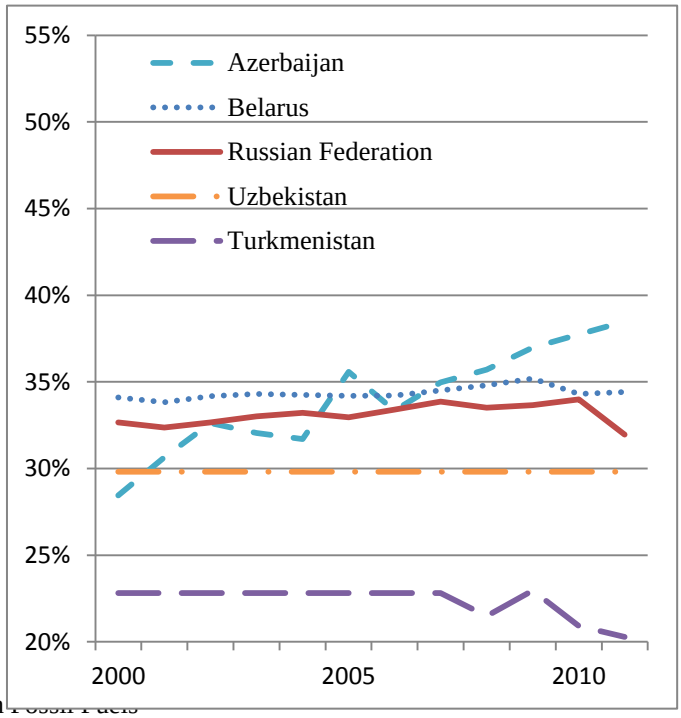
5. Trends in Natural Gas Energy Efficiency

Natural Gas: The average efficiency of worldwide gas-fired electricity generation has increased substantially over the last 20 years, from around 35 percent to 42 percent. Spain, Portugal, and Luxembourg have achieved national fleet efficiencies of over 50 percent.

Source: IEA data, staff calculations

Evolution of Natural Gas-Fired Power Plant Efficiency





Source: IEA data, staff calculations