Potential and opportunities of renewable electricity in the Republic of Kazakhstan[1]

by Aleksey Cherednichenko, PhD[2]

1. Introduction

Kazakhstan is an economy in transition developing very rapidly. Proper choices in the power sector are very important to sustain this development.

The republic Kazakhstan has huge stocks of fossil resources. Presently eighty percent of electric, heating and combined heat and power plants use coal, which is the cheapest fuel. The national «Development program of the power sector of the Republic of Kazakhstan for the period till 2010, with prospect to 2015» [1], assumes that the demand for electricity doubles from 50 TWh to 101-106.5 in 2015, in order to cope with the economic development of the republic. In spite of the sharp increase of electricity prices – from 4.1 to 8.0 tenge[3]/kWh in 2007, and an expected increase to 11 tenge/kWh in February 2008 – the present huge power deficit is expected to persist.

The power expansion plans are focused basically on the use of local coals, and, first of all, the coal of the Ekibastuz deposits, which presently accounts for 60% of the total amount of coal consumed by the power sector. According to the national development program [1], the share of coal in the fuel structure of the power sector should be 74% in 2010 and 71% in 2015 - 71 %, remaining practically at the 1992 level (73,6 %). The Program does not specify the share of natural gas use in the power sector till 2015.

The important point to note is that the domestic power sector and most plants of the country have been constructed in the fifties of last century. Today they are depleted, obsolete and consume huge amount of fuels due to low efficiencies. According to the experts of the KazNiPiEnergoprom Institute, who carried out the framework development program [1], by 2012-2016 it will be necessary to refurbish all existing power plants of the country, whenever possible, and to build additional new capacities, also to replace the plants that have to be dismantled. It will be necessary to build power plants making use the best available technologies – natural gas combined cycles, integrated coal gasification and combined cycles, coal burning supercritical and ultra supercritical steam cycles – and increase the generation efficiency from 28% of today up to 40-50 %. This needs investment of about 3-5 billion US dollars for the period till 2012-2014 and up to 10-12 billion US dollars for the period till 2020) [3].

In the period 2004-2015 new capacities of the order of 3.3-3.5 GW have to be installed in the Republic Kazakhstan (in the Northern zone - 1800-1900 MW, in the Southern zone - 680 MW, in the western zone - 900 MW). Although the implementation should have started in 2004, practically nothing was implemented till 2007. In the longer term (2024) it is expected that the consumption of electricity will grow 1.4 times compared to 2015; the deficit of electricity is expected to reach 1.7-2 TWh in 2020, 3-4 TWh in 2024 [1].

[1] Special thanks to G. C. Tosato for his continuous suggestions and help.
[2] Cherednichenko Alexey Vladimirovich, PhD on Sciences, works at the "Kazakh Research Institute of Ecology and Climate», Department of Researches on Ozone and Climate, in Almaty. He is expert on Climate Change. E-mail: acherednichenko@network.kz; alexey@kniimosk.almaty.kz; telephone: +7.3272.2542265, mobile +7.83332164945.
[3] One US dollar bought 133 Kazakh tenge (2005), in November 2007 it buys 120.5 tenge.

2. Objective and methodology

This research aims at assessing the potential of, and the demand for, renewable energy sources for electric generation (RES) in the republic of Kazakhstan, in particular wind (WPS) and small hydropower plants.

The system analysis tool used in this research is the MARKAL model generator developed by the Implementing Agreement for a Program of Energy Technologies Systems Analysis of the International Energy Agency (IEA/ETSAP) [6].

The problem has been analyzed making use of the technical economic MARKAL – Kazakhstan model developed last year in the frame of an EC technical assistance TACIS project[4]. It represents the energy system of Kazakhstan from mining to end-uses, and its development from 2000 to 2040. In particular it represents the power sector of Kazakhstan with some detail.

With the help of the MARKAL – Kazakhstan model three main scenarios have been compiled and compared:

1. Base case scenario
2. Renewable scenario, and
3. Subsidy scenario.

Assumptions and main scenario results are briefly illustrated hereafter.

3. Description of the scenarios

3.1 Base case scenario

In the base case scenario the official Kazakh development plan for the country in general and the economic sectors has been used to project the demand for energy services. In the base case scenario GHG emissions are not constrained, fuel shares are practically free, new technologies are not bounded, and also the price of fuels remains at the 2004 level. In this base case the indications of the national plan were not forced in.

As shown in Figure 1, the growing demand for electric power is satisfied in 2020 by replacing the existing coal power plants with more efficient (40-45 %) coal technologies. The share of renewable power plants remains insignificant (Figure 2). Starting from 2016 only 1 GW of small hydropower station are used.[5]

In the base scenario the demand for electricity is covered by a 50% increase of coal fired power plants, to reach 22-23 GW in 2024. The share of natural gas power plants makes less than 3 %, or nearly 1GW. Nuclear power plants are not built. Hydropower plants remain at the existing level til 2012, afterward the capacity increases to about 1 GW.

[4] The MARKAL – Kazakhstan model has been developed in the frame of the TACIS project "Technical assistance to Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan with respect to their global climate change commitments", task 6 "Enhance Economic Modelling Capacity in Kazakhstan". It is now used by the "Kazak Research Institute Ecology and Climate".

[5] This is only 10% of the estimated potential – over 10 GW, with a potential average yearly productivity of 62 TWh. However this productivity is possible only if the existing small hydropower schemes, which have been built about 50 years ago, will be modernized [5].

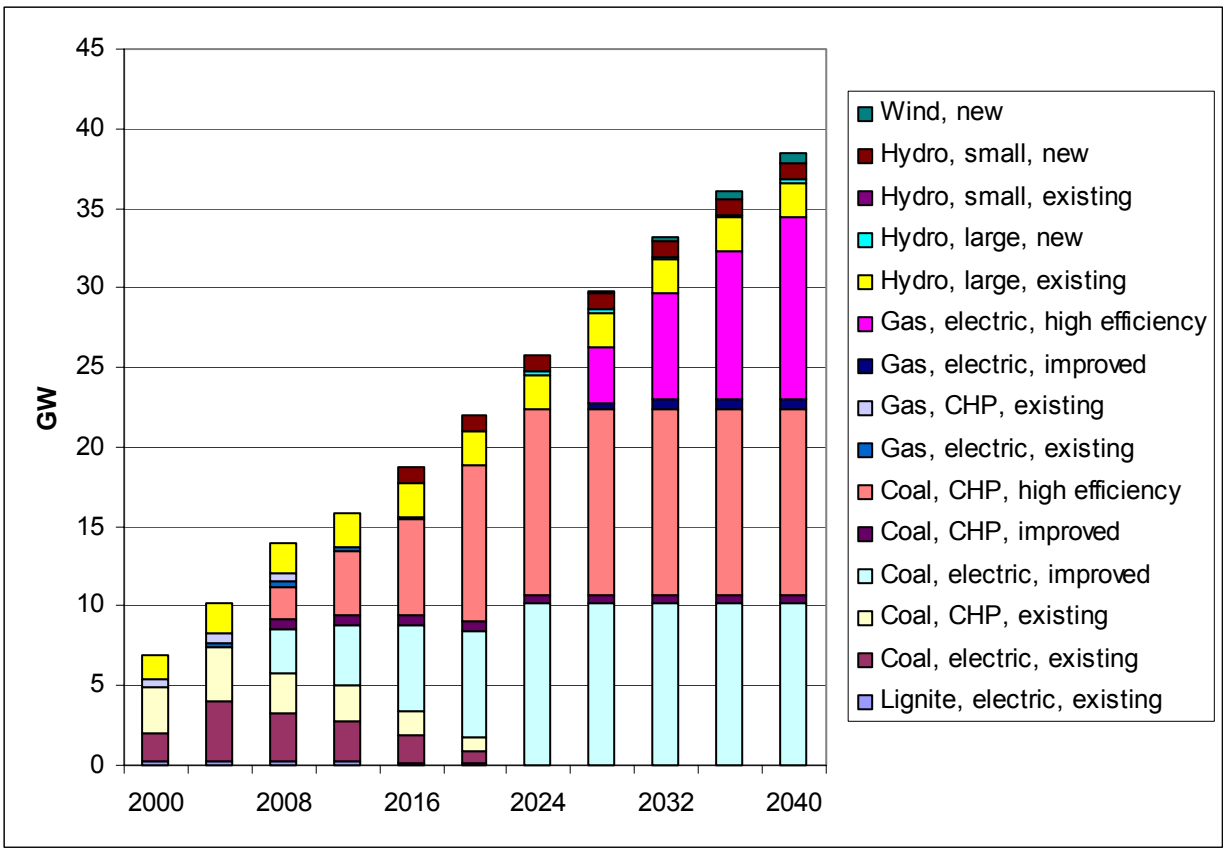

Figure 1: Time development of the electric capacities in Kazakhstan in the base case

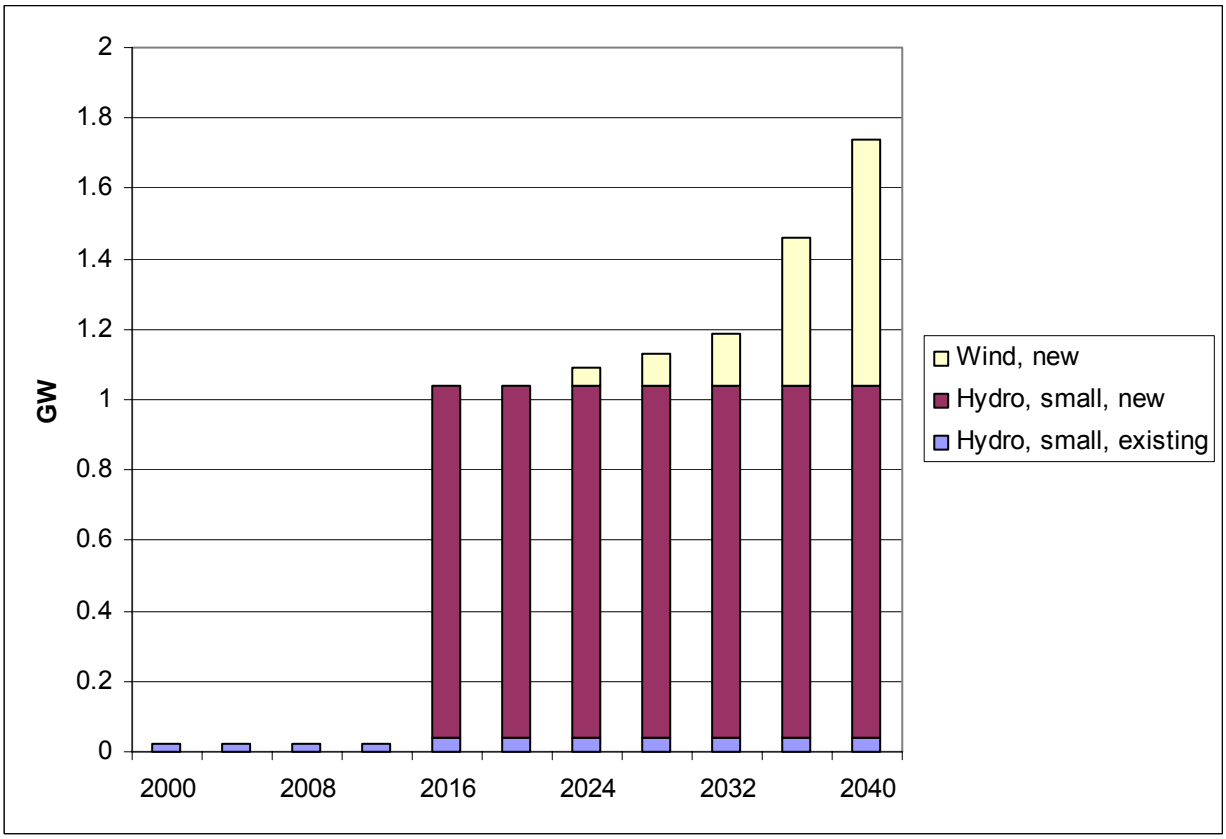

Figure 2: Contribution of new renewable energy sources in the base scenario in Kazakhstan

3.2 Renewable scenario

Presently Kazakhstan produces yearly only 0.36 TWh from small hydro, out of a potential of more than 8 TWh. At the same time the Republic has a huge potential of wind power. The preliminary assessment by experts of the institute "AlmatyHydroproject " shows that, at least in a number of regions of the Republic, the installation of 0.5-1 GW is possible. So, in the Djungar "gate" the construction of WPS with a generating capacity of more than 1GW seems possible, in the Shekel corridor up to 1 GW. The upgrade, and if necessary the expansion, of the electric grid would be an additional stimulus for the development and use of small hydro and wind.

But the use of RES is problematic at the present domestic conditions because the electricity generated by RES costs more than the electricity generated by coal or natural gas. The generation cost of coal and natural gas electricity ranges between 1.2 and 3.0 cents/kWh, while wind electricity in Kazakhstan could presently cost about 7-8 cents/kWh. Furthermore, the cost of transporting dispersed electricity to the consumers has to be added. Small hydro and wind power plants can be implemented only with an appropriate legal basis and economic incentives. What conditions make the exploitation of the small hydro and wind potential possible? It seems necessary to take policy actions in order to set standards and limits the coal and natural gas fired thermoelectric power plants, an upper limit to nuclear plants and to gradually increase the price of fossil fuel used for generation.

The following assumptions apply to the renewable scenario:

- An upper limit of 3-4 GW has been set to additional capacities of coal fired electric, thermal (for district heating) and combined heat and power plants (according to plans [1]) for the period till 2020-2024;
- In accordance to a recent statement of the Kazakh President Nazarbajev that at such high prices it is better to maximize exports [1], upper limits have been imposed to natural gas fired power plants: 1 GW to gas turbines and about 5GW to other high efficiency plants (half of the base case), where cheap associated gas is used near the oil fields;
- A fixed limit of 2 GW has been set to the total nuclear capacity, starting from 2024; and
- The 2000 natural gas price of 25 US dollars per thousand cubic meter (0.73 USD/GJ) has been first increased to 50-60 US dollars per thousand cubic meter (1.46-1.75 USD/GJ), which is the present cost of natural gas in KZ for thermoelectric heat and power plants, than further increased to reach the present international market value of 150-280 US dollars per thousand cubic meter (4.4-8.2 USD/GJ) in 2024-2028; also the price of coal for electric and thermal generation has been gradually increased from 0.25 USD/GJ to 0.6 USD/GJ in 2028, in order to follow the international markets.

As a result of these assumptions, the growing demand for electricity is satisfied by a different combination of power plants (see figure 3). Having limited the amount of new fossil and nuclear electric capacity, the system exploits all available hydro resources; afterwards, wind power plants enter the system (figure 4). In 2024 the installed capacity of RES reaches 3 GW.

The price increase of fossil resources has the effect of increasing the average efficiency of the electric, thermal and CHP plants (compare figure 5 with figure 3). In the 2008-2012 period, combined cycles, supercritical steam cycles and ultra supercritical steam cycles, integrated gasification coal combined cycle plants are built, for a total capacity of 4 GW. Another 2 GW are added in the period 2020-2024. In the year 2020 0.8 GW of wind power plants generate 1.74 TWh, about 1.5% of the total, in 2024 2 GW of WPS generate 4.2 TWh, covering about 3% of the demand.

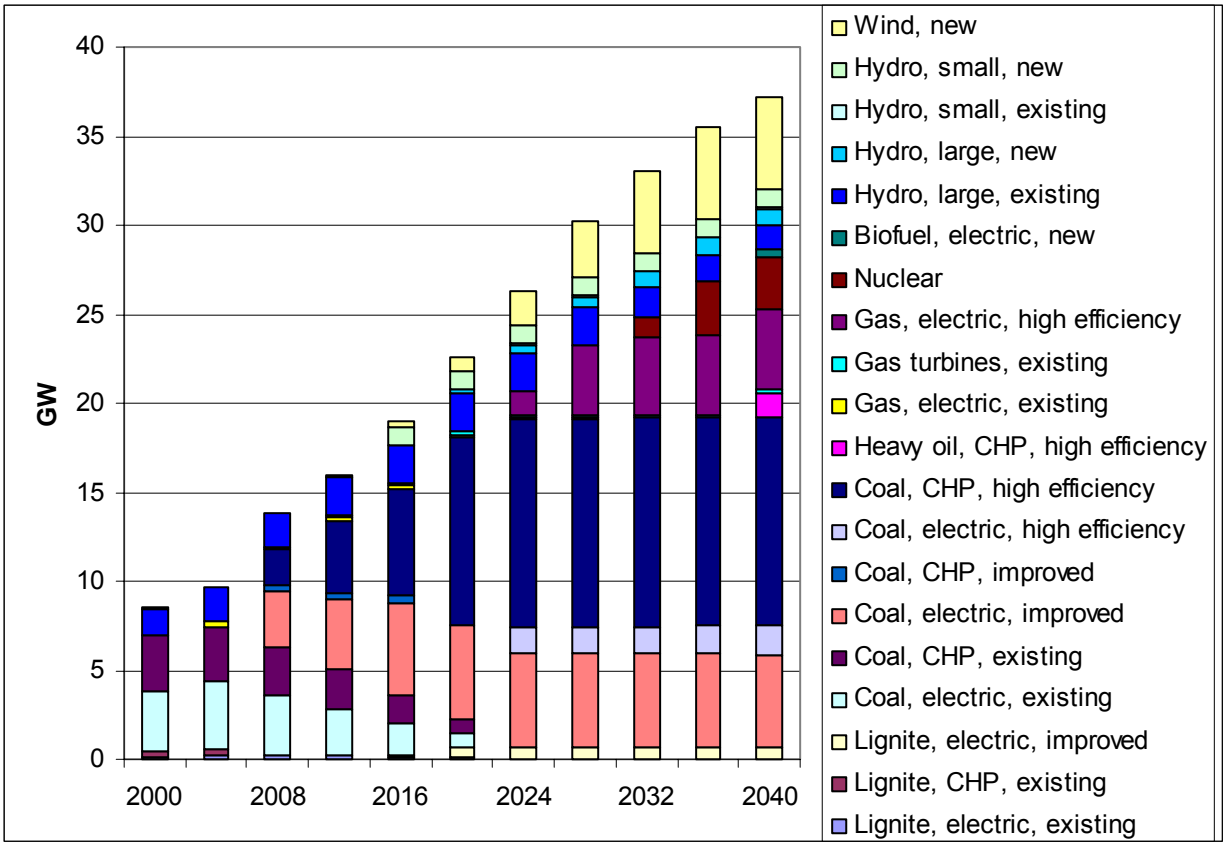

Figure 3: Time development of the electric capacities in Kazakhstan in the renewable scenario

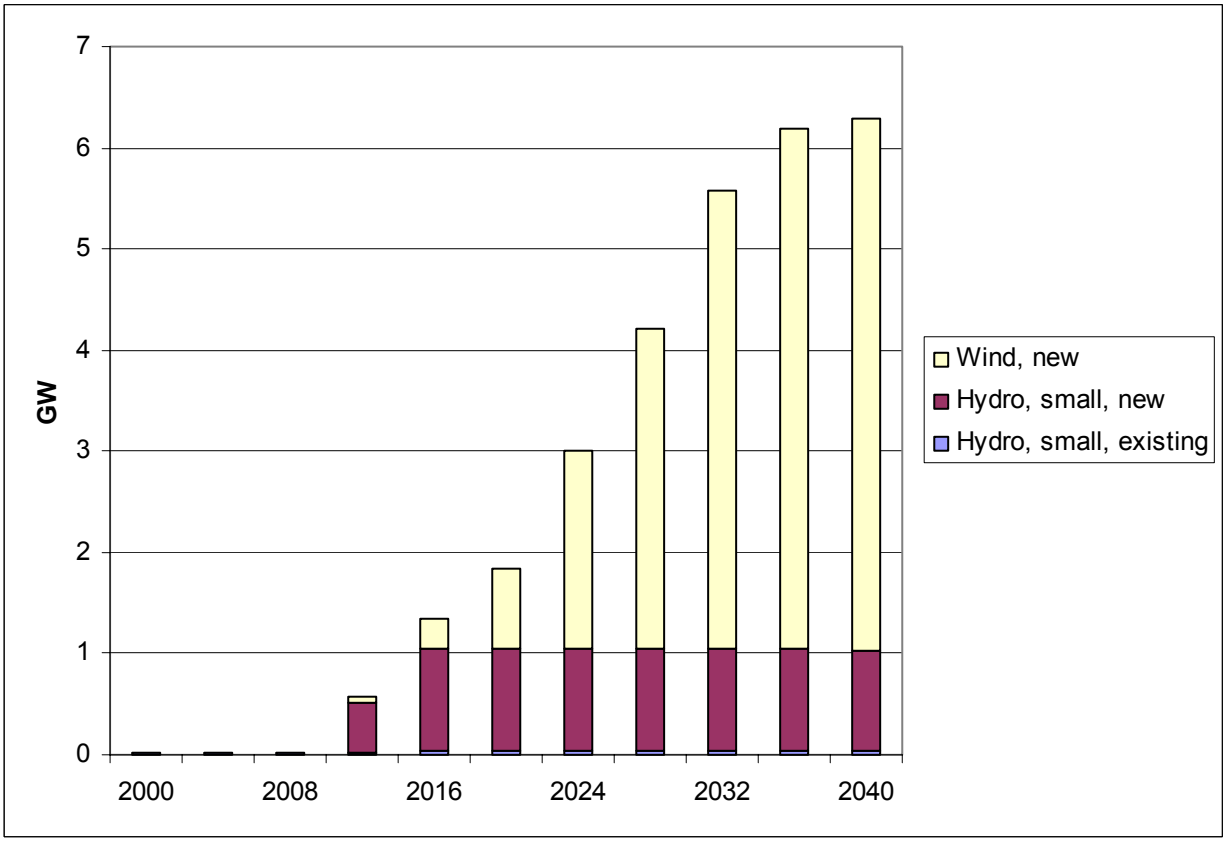

Figure 4: Contribution of new renewable energy sources in the renewable scenario in Kazakhstan

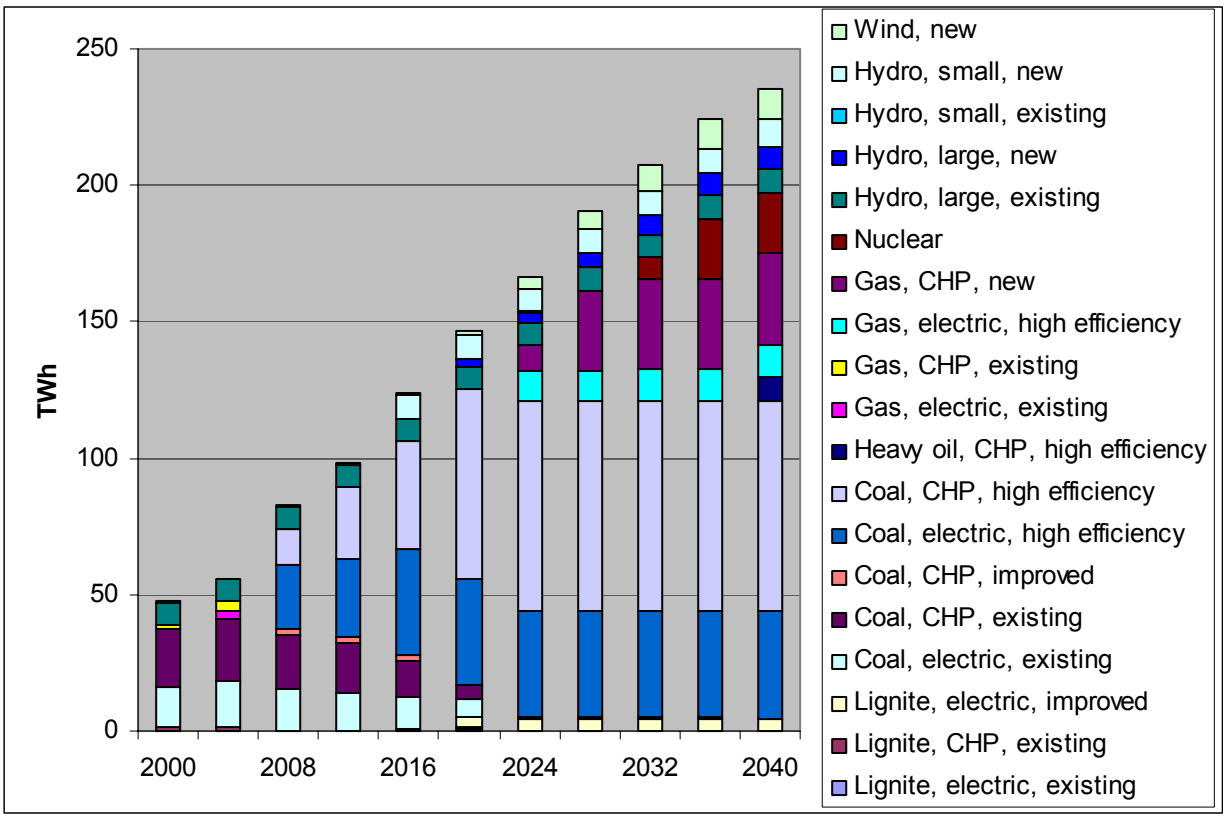

Figure 5: Electric generation by plant in the renewable scenario in Kazakhstan.

Although the capacity expansion plans are changing frequently, this scenario reflects more realistically the electric and heat generation structure planned in the medium term. This scenario shows as well a path towards the compliance with the limits imposed to Kazakhstan by the Kyoto protocol, if the Kazakh government decides to ratify it as an annex A country.

3.3 Subsidy scenarios

The problem with the renewable scenario is that wind power plants start to be installed only in 2016. Although available from 2008, the uptake is delayed and slow: 5 MW in 2016, 50 MW in 2020 and 2 GW only in 2024. What conditions make an earlier introduction of wind power plants possible? To explore the possibilities, subsidy scenarios have been built.

As shown in figure 6, the installation of wind power plants starts earlier if the wind electricity is subsidized with 3.2 US cents/kWh. In this case in 2016 wind power produces 0.58 TWh, which is about 0.5% of the total electric generation, up from 0.1% in the base case, in 2024 it covers 3% of the demand with 4.1 TWh. With a stronger subsidy of 5.8 US cents/kWh the systems starts building wind power plants event earlier, in 2008, and produces 0.23 TWh. In the period 2016-2020 the subsidy can be reduced to 1.2 US cents/kWh, without reduction of wind electricity generation. In this scenario wind power increases 10 fold form 2012 to 2020.

Subsidies can help developing wind power plants in Kazakhstan in the short term, when they are not yet competitive with the cheap domestic coal. However, the overall weight of wind subsidies on total investments on power plants in the coming decades is in the order of few percent points, and is

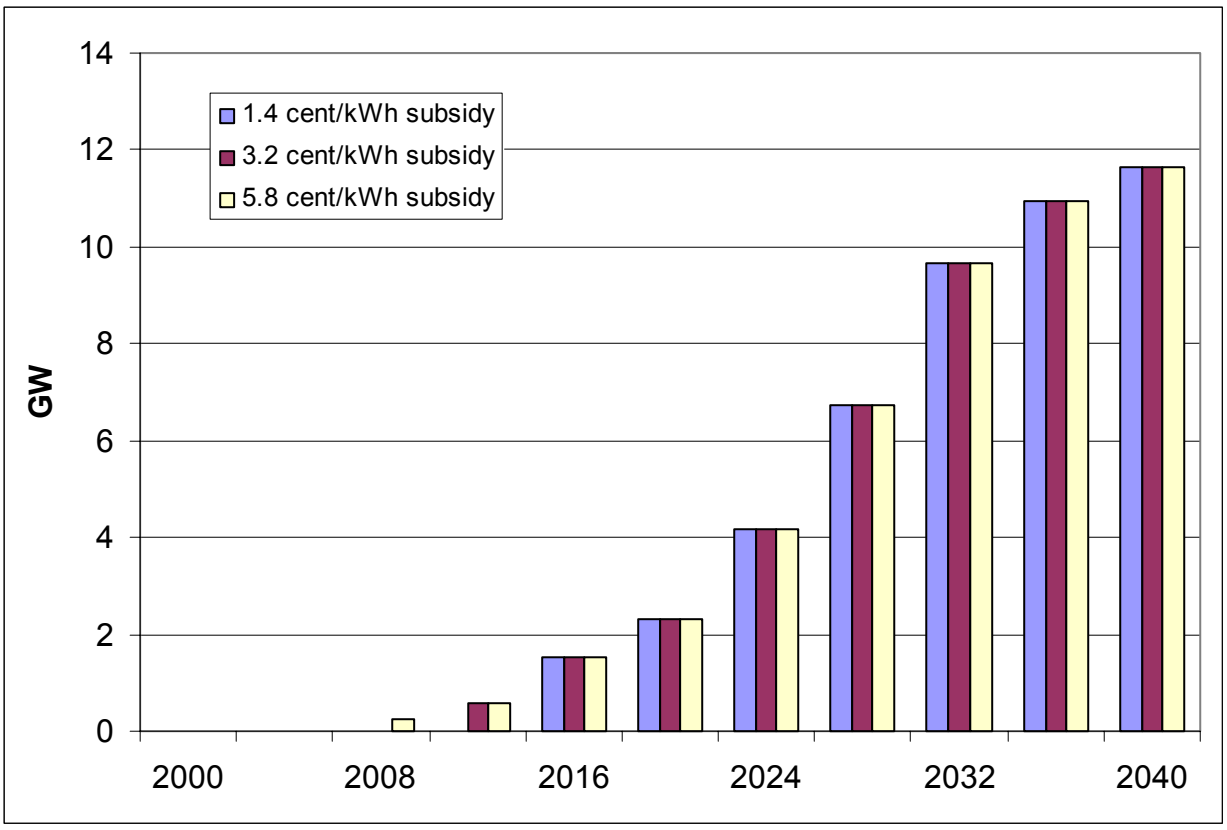

Figure 6: Effect of subsidies in the early development of wind power in Kazakhstan.

going to disappear in 2020, when wind electricity becomes competitive with fossil fuel fired power plants. More important than the subsidy is the gradual increase of fossil fuel prices for thermoelectric generation to international prices.

4. Comparison of the scenarios

Satisfying the same demand for electricity and heat through different mixes of power plants has important implications in the pattern of expenditures and in the profile of CO2 emissions.

4.1 Effect of subsidies on the cost of the power sector

The cost profile is shown in figure 7. In the base case the development of the electricity and heat generating systems in the next twenty years requires expenditures of the order of 1.5 – 2 billion US dollars every four years in the average. In the renewable scenario the expenditure jump to twice as much in the four year period around 2012. This is due mainly to the increase of fossil fuel prices and the need to build high efficiency plants, less to the construction of 0.5 GW of small hydro power plants.

The presence of subsidies for wind electricity increases the cost of the system slightly, about 40-55 million US dollars by 2008, up to about 100 million US dollars in 2016 – corresponding to 5% of total expenses. Due to higher investments on wind farms in the early years, the investments in 2020 are lower. Total investments on wind power plants between 2011 and 2022 are about 200 million USD. In the longer term the expenditure of the power sector is similar across scenarios.

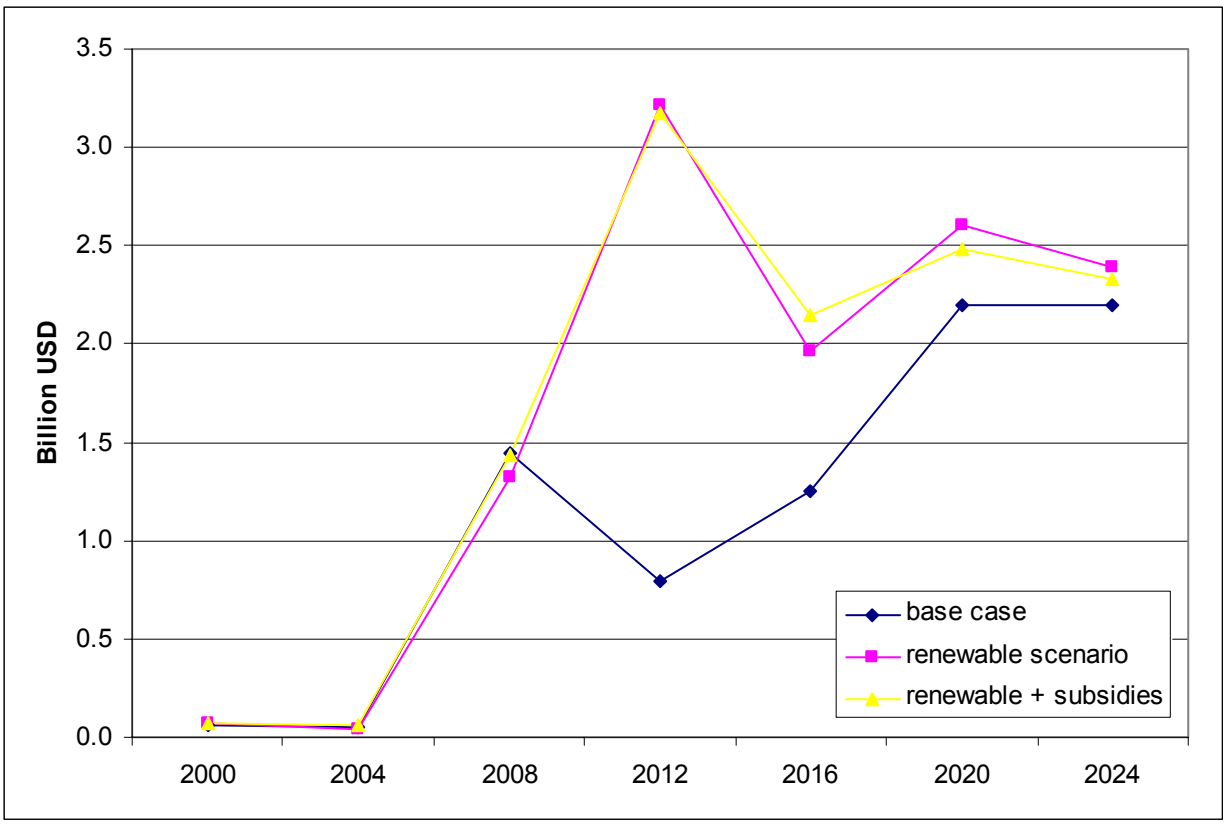

Figure 7: Costs profile of the Kazakh power sector by scenario

4.2 Effects on CO2 emissions

Moving from the base case scenario to the renewable scenario changes the structure of the Kazakh power sector and reduces CO2 emissions (figure 8) [5]. Different policies can reduce emissions and avoid that they follow the growth rate of the demand for electricity and heat. Increasing the price of fossil fuels for thermoelectric generation, without further constraints, has the effect of reducing CO2 emissions of about 20 MtCO2, about 15% of total in 2020-2024. Adding the constraints on technologies and fuels mentioned in the renewable scenario is capable of reducing CO2 emission of 40-50 MtCO2 in 2024 and of 70-80 in 2040. The generation of wind electricity contributes to the reduction with 3.5-4 MtCO2 in 2024 and up to 12-14 MtCO2 in 2040. In this scenario emissions are stabilised to the 1992 level till 2032.

5. Conclusion

This paper explores conditions that make the development of wind power plants possible in Kazakhstan in the next few decades. The growing demand for electricity and the abundant availability of windy sites offers very good conditions for the use of wind electricity. The development will depend appreciably on the change of energy prices and restrictions to the efficiency and input fuels of new power plants [7].

In particular it will be necessary to:

- Increase the price of natural gas from the present domestic value of 50-60 US dollars per thousand cubic meter (1.46-1.75 USD/GJ) to the present international market value of 150-280 US dollars per thousand cubic meter (4.4-8.2 USD/GJ) in 2024-2028; also the domestic price of coal has to approach international prices;

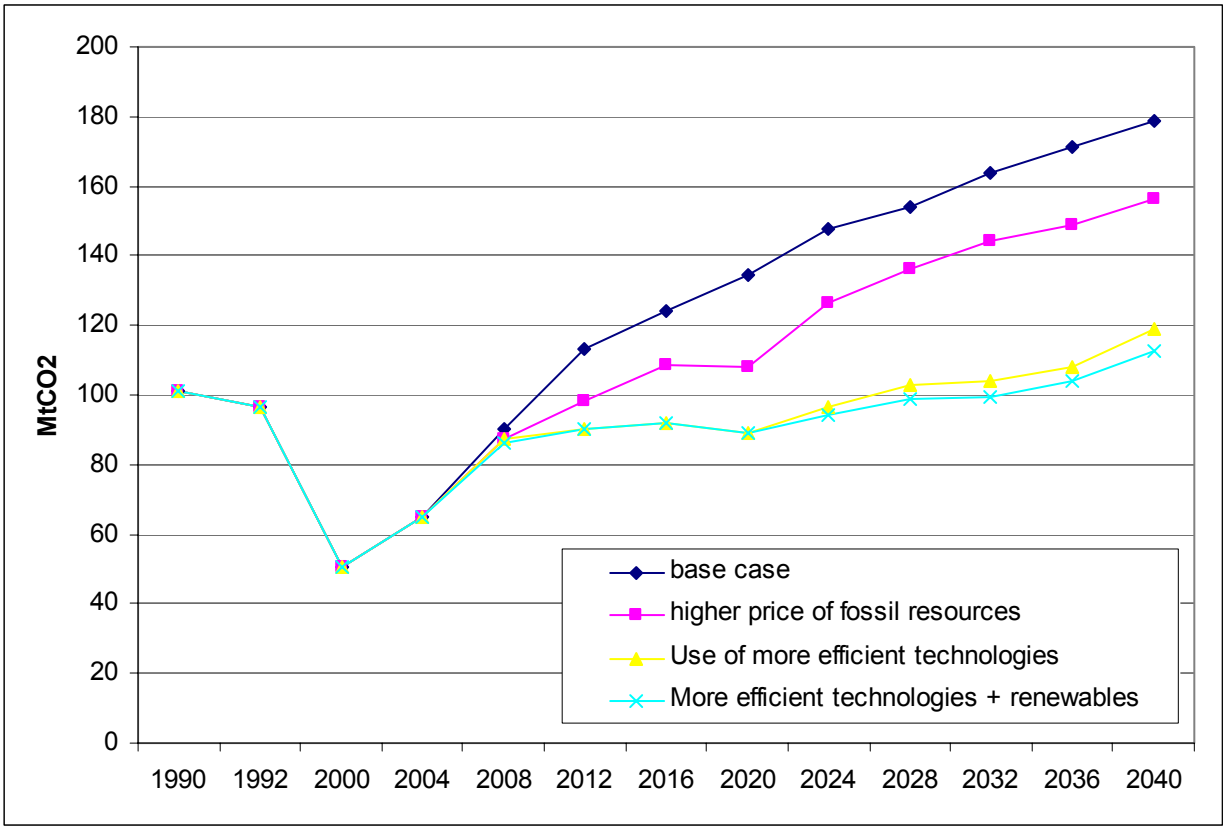

Figure 8: CO2 emissions of the Kazakh power sector by scenario *(early intervals are not proportional).*

- Limit the installed capacity of natural gas power plants in the period 2024-2040 to about 4.5 GW instead of about 12 GW as shown in the base case;
- Fix the capacity of nuclear power plants to 2 GW (zero in the base case); and
- Limit the market of new coal power plants to about 17 GW (instead of 23 in the base case).

At these conditions wind starts being used in 2016. In 2020 the installed capacity is 0.8 GW and generates about 1.7 TWh; in 2024, the installed capacity is 2 GW and generates about 4 TWh, i.e. 2.5% of the total. If the demand for electricity continues to grow, small hydro and wind can arrive to an installed capacity of 5.6 GW in 2028.

Wind can contribute to the generation of electricity before 2016 if wind electricity is subsidized. After 2020 wind electricity becomes competitive and subsidies are not necessary [7]. The total amount of subsidies is of the order of 50 million US dollars in the period 2010-2013, up to about 80 in the following period. The burden on total investments for plants is very low (2-4%), but essential for an early deployment of wind power plants.

The increased use of renewable energy sources for generating electricity, together with the general efficiency improvement of the fossil fuelled power plants to 40-45% result in an important reduction of CO2 emissions. The emissions from the power sector stabilize at the 1992 level till about 2030.

The main driver beyond these achievements appears to be the political will of substituting imports of electricity with domestic investments in more efficient technologies and renewable power plants.

6. References

1. «Development program of the power sector of the Republic of Kazakhstan for the period till 2010, with prospect to 2015», Institute «KazNIPIEnergoprom" (in Russian), 2003.

2. “MARKAL - An Energy-Environment-Economic Model for Sustainable Development”, Gary A. Goldstein, IRG; Amit Kanudia, KanORS Consulting Inc.; Richard Loulou, HALOA Inc.

3. The report « Improvement of potential of economic modelling in Kazakhstan », project SOFRECO, A.V.Cherednichenko, G.C. Tosato, G.Sergazina, R.Dolanbaeva; 2006; downloadable from http://www.sofreco.com/projets/c886/Reports.htm.

4. N. Nazarbaev's interview to the newspaper «El Pais», Spain 06.04.2007.

5. «Second National Communication of KZ», UNDP project, 2007 (in Russian).

6. “Documentation for the MARKAL Family of Models”, Richard Loulou, Gary Goldstein, Ken Noble, 2004, downloadable from www.etsap.org/documentation.

7. «Potential of use of renewable energy sources in the Republic of Kazakhstan (with use of model MARKAL)», (within the framework of the project on Development of the legislation on Renewable energies in Kazakhstan), UNDP project, Cherednichenko A.V., 2007 (in Russian).