FINDING THE BALANCE BETWEEN THE ENERGY SECCURITY AND ENVIRONMENTAL PROTECTION IN SERBIA

by

***Masa Z BUKUROV*[a*], *Milun J BABIC*[b] *and* *Blazo LJUBICIC*[c]**

[a]Faculty of Technical Sciences, Novi Sad, Serbia, Trg Dositeja Obradovica 6
[b]Faculty of Mechanical Engineering, Kragujevac, Serbia
[c]Koch Heat Transfer, Houston, TX, USA

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Abstract
There are very few issues that are as important to our collective future as energy. Like everyone else, Serbia has its stake in reducing energy price, enhancing the security of energy supply, and reducing emissions, including greenhouse gas (GHG) emissions associated with fossil fuels. In the years to come Serbian economy is expected to grow and industry to search and explore the potential of using cleaner alternative fuels. There is a lot that could be done to conserve energy and to reduce environmental footprint. But the most important thing that could be done to enable Serbian industry to reduce emissions is the implementation of a modernized Power Generation system. At the same time the reality can't be neither sugarcoated nor ignored and alternatives to fossil fuel will succeed only if they are economically feasible for suppliers and users alike. New technologies currently under development should be considered to allow Serbia the use of energy resources in a more efficient ways and with better protection of the environment. If successfully deployed, the development of alternative, renewable fuels will allow Serbian energy sector to effectively decouple its growth from GHG emissions. This paper explore opportunities and the potential of alternative fuels for increasing competition in energy supply, for reducing emissions and in Serbia while decreasing dependence on imported energy.

Key words: *energy, clean coal technologies, coal-water fuel, CO2 capture, natural gas, renewables, biomass*

1. Introduction

In the continuing world energy crisis of the 21st century, the story doesn't end with this year's sub-$100 oil and sub-5 $/GJ natural gas prices. Hydrocarbons are still most essential in supplying global energy needs and will be at least through 2030, [1]. Why oil and gas will still be No. 1? Ethanol requires taking 1.6 liters of the energy equivalent of gasoline to make 1 liter of ethanol, it involves making a subsidized fuel from a subsidized crop. Wind power makes natural gas yet more essential for base-load power supply. Solar power is expensive, unreliable and won't reduce demand for natural gas, and to increase the use of hydropower, "more mountains should be built" [2].

The structure of the Serbian energy sector reflects all of the flaws of global market. Oil and gas remain the primary energy sources, supplying 70% of Serbian energy demand 40 years ago, and supplying 70% today. To protect its national interests, reduce dependency on imported oil, preserve local capital, and assure the overall health and welfare of the local population, (including enhancing the standard of living), sound environmental practices and the responsible use of energy, (both carbonaceous and non-carbonaceous), are carefully considered by each and every country, [3, 4], and Serbia is certainly not an exception.

2. Global Market

The global energy consultancy PFC Energy publishes every year the top 50 energy companies of the world for 2009 based on market cap.

Two year ago, (2008), five of the top six positions on the PFC Energy 50 were occupied by ExxonMobil, Royal Dutch Shell, Chevron, BP, and TOTAL. At that time, ExxonMobil had reclaimed its long-standing leadership of the PFC Energy 50 list from PetroChina. Last year, PetroChina tops the list with a market capitalization of $353.1 billion, 9% larger than ExxonMobil's $323.7 billion. Number four ranked Petrobras listed a value of $199.2 billion, larger than either Royal Dutch Shell or BP.

In the past twelve months, the combined value of the list's nine traded national oil companies (NOCs) rose by 66%. During the same period, the six super-majors – ExxonMobil, Shell, BP, Chevron, Total, and ConocoPhillips increased their combined value by less than 1%, while OECD-based integrated companies gained only 6% in value, [5].

PFC Energy called 2009 a "turnaround year" for countries as well as companies. Russian companies, last year's worst performers, posted a combined 88% value gain. The value of the Chinese companies grew 52% [3]. The transformation of the oil-and-gas industry continuous and many long-term trends were underway before the financial crisis has reasserted them. The key message from the Global Market to Serbian Energy Sector is that investors see more potential in companies with growing end-user markets and preferential access to resources, and they have soured on the refining business in mature markets. To attract capital Serbia will have to work hard on both, end-users market and resources.

Although there is plenty of coal, there are several reasons why in the foreseeable future Serbia cannot meet its energy demand only with coal, [4, 6]. The first is clear: environmental; even if the cleanest coal technology were adopted, even if all dirty coal plants were replaced, and even if Serbia could be adding new coal-fired power plants, coal still cannot replace oil because virtually no oil is used for power generation and nothing but oil is used for transportation. Therefore, introducing Clean Coal Technologies, and diversifying the energy sources of the future, is the most realistic propositions and Serbia's only real hope.

3. Clean Coal Technologies

Developed nations cannot expect Serbia and other developing nations to surrender their drive towards improved living standards by imposing restrictions on the use of coal, which is the world's most abundant and lowest cost energy resource available from a number of secure suppliers around the globe. In addition many developing nations like Serbia have large reserves of coal, often low-rank, [7, 8]. Consequently the most important thing Serbia can do is to help limit harmful emissions, especially SOx, NOx, and particulates from coal and assist its industry in deploying clean coal technologies, [9].

1.1. LRC into a low-rank coal-water fuel (LRCWF)

One technology that will be particularly valuable in upgrading low-rank coals, eliminating fugitive dust emissions, reducing acid gas emissions, improving transportability, and producing a low-cost alternative to oil, is the technology to convert LRC into a low-rank coal-water fuel (LRCWF). Beginning of 1990s Z. Bukurov, W. Willson, and B. Ljubicic, published number of articles related to the use of this technology for the underwater coal excavation at Kovin mine [10, 11, 12].

1.1.1. Hydrothermal treatment Technology

Hydrothermal treatment (HT) technology is the most effective way to upgrade low-rank coals (LRCs). HT is a non-evaporative, moderate temperature and pressure process that upgrades LRC continuously in aqueous slurry to effect a permanent reduction in the inherent moisture. Following HT, LRCs can be concentrated into commercial coal-water fuels with energy contents rivaling those produced from more costly bituminous coals without the use of expensive proprietary additives. HT preserves the preferred combustion characteristics of LRCs and yields a fuel that has superior ignition performance, better carbon burnout and no agglomerating tendencies in comparison to bituminous CWFs. Production of premium LRCWFs was first demonstrated in a pilot plant at the US Department of Energy (DOE) Grand Forks Energy & Environmental Research Center, (EERC) with a number of LRCs from around the world, including.

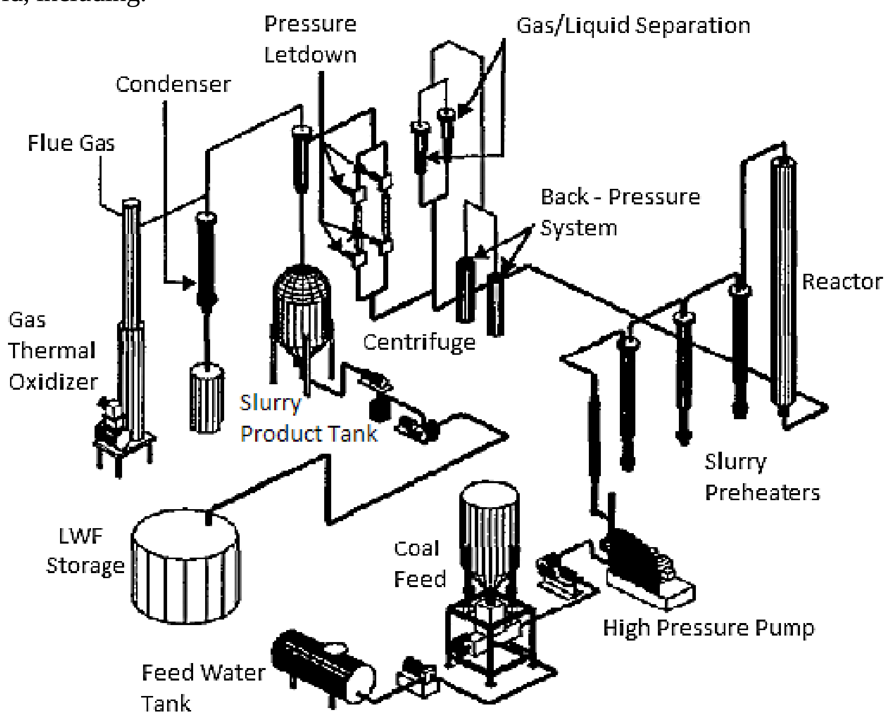

Fig. 1 EERC 7.5-tpd HWD pilot plant [13]

Figure 1 [13] is a process flow diagram of 7.5 tons/day pilot LRCWF production facility. The process was independently validated in pilot plants in Australia and Japan, and is ready for a commercial scale demonstration.

Via HT Upgraded LRC coal was concentrated up to 60% in a LRCWF with an energy density of nearly 16.7 MJ/kg. Tests demonstrated excellent combustion characteristics with over 99.8% carbon burnout, minimal boiler tube fouling, and SOx emissions well below the minimum required for environmental compliance, [10, 11].

1.1.2. Coal-Water Fuel Production

Of all the low-rank coal drying technologies assessed, [14], the most promising is hydrothermal treatment. The HT process is particularly effective for producing a concentrated LRCWF suitable for many liquid fuel applications. Production of a liquid fuel with its inherent benefits also eliminates the stability problems that have plagued all other low-rank coal drying processes designed to produce a dried low-rank coal that can be safely handled and transported.

HT is an advanced technology, featuring moderate temperature/pressure, non-evaporative drying, which irreversibly removes much of the inherent moisture from low-rank coal. Hydrothermal treatment allows LRCWFs to be produced with solids content rivaling those obtained for bituminous coal-water fuels, without the uses of costly additives. LRCWFs are non-hazardous, easily transportable liquid fuels that avoid all the stability problems of dust generation and spontaneous combustion associated with low-rank coals.

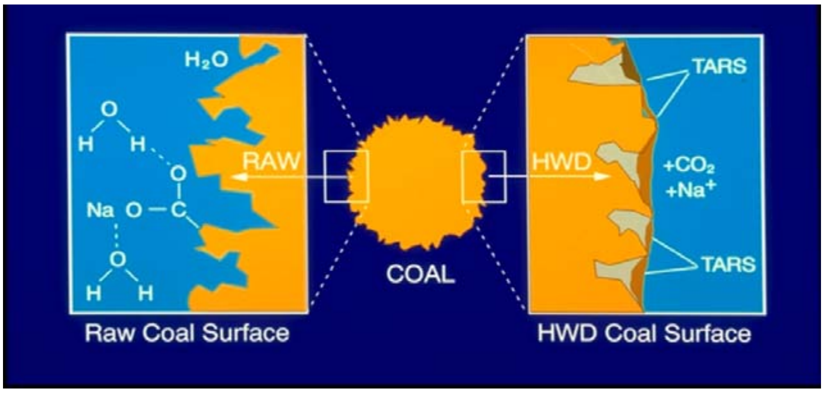

Fig.2 Hydrothermal Treatment (HT) - Permanent Moisture Reduction in LRCs (color image see on our web site)

LRCWF is produced by treating slurry of pulverized low-rank coal at temperatures to 300 ^{o}C and the corresponding saturated steam pressure in water, hence the name hydrothermal treatment. Figure 2 shows an artist’s rendition of what occurs during HT. HT is similar in many respects to pressure cooking, and the process retains most of the desirable characteristics of low-rank coal. Sufficient residence time at reaction conditions is provided in a reactor to ensure that the interior of the largest particle reaches the desired temperature. Due to differences in thermal expansion between coal and water, upon heating some water expands out of the coal. Carbon dioxide is also released which drives additional water from the coal. De-volatilized waxes and oils, being hydrophobic (water hating), are retained on the coal surface in the pressurized aqueous environment, giving a uniform wax distribution which upon cooling seal most of the micro-pores and minimize water re-absorption. The changes thought to occur during hydrothermal treatment are depicted in fig. 2. By retaining most of the volatile matter in the form of waxes, the high reactivity of low-rank coals, as well as most of the energy value, is preserved. Following HT, the system pressure is reduced and excess water is removed, leaving a LRCWF with typically 60% dry solids.

As opposed to some of their bituminous counterparts, no LRCWFs produced to date, regardless of PSD, have shown any tendency towards dilatant (tending to solidify when stirred or agitated), shear thickening behavior. Consequently, the higher the shearing force applied, the lower the viscosity, which accounts for their ease of atomization. Therefore, generally no stability enhancing or viscosity breaking additives are used for LRCWFs. Instead, stirring and/or recirculation are used to maintain a constant feed in LRCWF storage and feed tanks. Typically the only additive recommended for LRCWFs is a biocide to prevent biological growth in fuel that is to be stored for some period of time before use.

In the left side of fig. 2 is presented microscopic view of raw low-rank coal (LRC) particle: Water fills macro and micro pores of the raw coal particle. Water is also bound to the coal particle via hydrogen bonding to the oxygen containing sites in the LRC and via electrostatic bonding to between oxygen in water and cat ions (mineral matter) that are bonded to the LRC. This water is called inherent moisture, as opposed to surface moisture and explains why some LRCs containing over 50% moisture appear dry. Most Alaskan LRCs are sub bituminous coal and have inherent or equilibrium moisture values of 25-30%. The high inherent moisture in LRCs increase shipping costs, i.e., a 100-car unit train shipping Alaskan LRC is actually shipping 25 cars of water and only 75 cars of dry coal. This has relegated most LRCs to be used for mine-mouth or nearby power plants where the electricity is transported.

In the right side of fig. 2 is presented microscopic view of hydrothermally treated LRC particle: Hydrothermal treatment involves heating LRC to coal specific temperatures in an aqueous phase maintained by pressures above the saturated steam pressure (typically around 285 ^{o}C and 10MPa), somewhat analogous to pressure cooking. Water expands and is expelled from most of the pores when much of the oxygen in LRC is released as CO_2 during heating. This eliminates most of the pore bound moisture and that held by the LRC's oxygen functionalities. When CO_2 is lost, cat ions are also released into the water phase eliminating the inherent water associated with LRC cat ions. However, a key to permanent moisture removal is the evolution of some of the LRC volatile matter as waxy substances upon heating. Waxy material, being hydrophobic is retained on the LRC in the pressurized aqueous environment. Upon cooling it seals most of the micro-pores and limits moisture re-absorption. Following hydrothermal treatment there is a net increase in the energy content of the dry LRC since most of the volatile matter is retained and LRC carbon lost as CO_2 has already been oxidized.

4. CO2 Capture Technologies

Energy independence may be jeopardized if coal continues to be demonized in our eagerness to discourage any source of energy that emits CO_2s' market. The Serbian's most significant source of electric energy close to 70 percent may then be idled. Wind and solar power plants, even at a mandated penetration of 20 percent or more, only produce electricity about 30 % of the time, [15]. At these penetration levels, they could not possibly replace the need for base load generation, such as coal-fired power.

Carbon sequestration is a way to reduce greenhouse gas emissions. It complements two other major approaches for greenhouse gas reduction, namely improving energy efficiency and increasing use of non-compatible with the large energy production and delivery infrastructure now in place. All three approaches will need to make significant contributions if

Serbia is to meet the objective of the United Nations Framework Convention on Climate Change, which is the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

There are two primary types of carbon sequestration. First type, described here, focuses on carbon dioxide capture and storage, where carbon dioxide is captured at its source (e.g., power plants, industrial processes) and subsequently stored in non-atmospheric reservoirs (e.g., depleted oil and gas reservoirs, un-mineable coal seams, deep saline formations, deep ocean, etc.). The other type of carbon sequestration focuses on enhancing natural processes to increase the removal of carbon from the atmosphere (e.g., forestation).

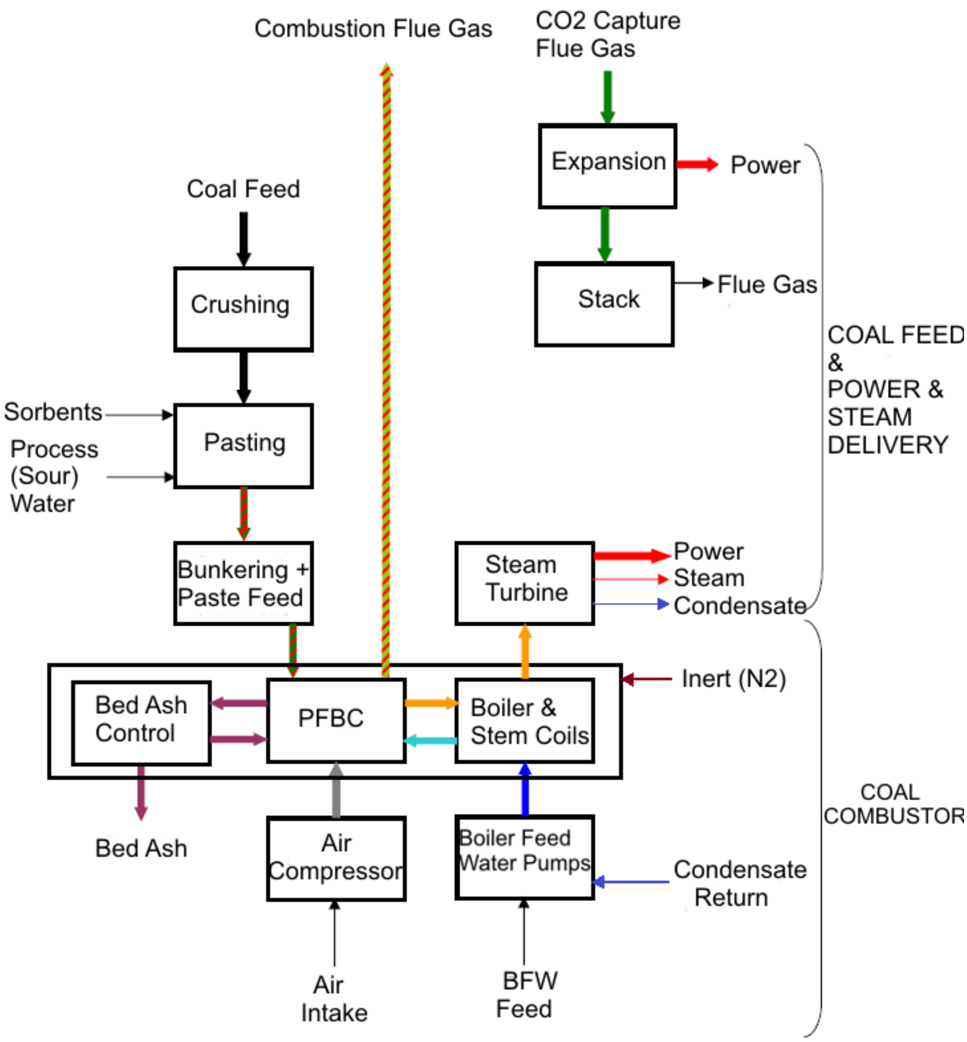

Fig. 3 Sargas Main process diagram (color image see on our web site)

A unique CO_2 capture test technology is being developed by Norwegian clean energy company “Sargas,” and promising results achieved at Scandinavian power group Fortum plant, Värtaverket in Stockholm. In the period from November 2007 to February 2008 Sargas and Fortum tested this Ultra Low Emissions technology, (Main process diagram shown in fig. 3 above, [16]. This pressurized solution consistently captured over 95 % of the CO_2 content of the exhaust gas for the whole test period.

The main features of this technology are:

- Capture of CO_2 in flue gas from a pressurized, combustor/boiler,
- Long residence time, low oxygen,
- High CO_2 partial pressure,
- Reduced volume flow of flue gas to be purified,
- Circumventing many challenges encountered by other CO_2 capture technologies,
- Cost-efficient, compact and proven technology capture process,
- Repowering inefficient older installations, and
- Capture-ready building.

Technology was developed in cooperation with, amongst others, the Swedish Royal Institute of Technology (KTH), Massachusetts Institute of Technology (MIT) and Siemens. The Institute for Energy Technology (IFE) at Kjeller has assisted with the control of methods and results. A scaled-down capture component has been built at Værtan, beside one of the plant's large coal-fired boilers. Exhaust gas has then been ducted under pressure from the boiler into this cleansing column, which uses similar technology to that used worldwide in applications that include ammonia production. This pressurized solution consistently captured over 95 % of the CO_2 content of the exhaust gas for the whole test period.

Through the Värtaverket project Sargas proved that their pressurized, post-combustion, pre expansion, technology is technically sound and commercially competitive. Comparison of the alternatives cost of electricity for a base 400 MW for different coal technologies is shown in fig. 4.

Sargas's process is based on standard industrial components working together in a new way. This means that coal power plants technology with CO_2 capture is not only technically feasible but also commercially justifiable. Coal is an inexpensive fuel for power generation and in many parts of the world will continue to have a central role in the foreseeable future.

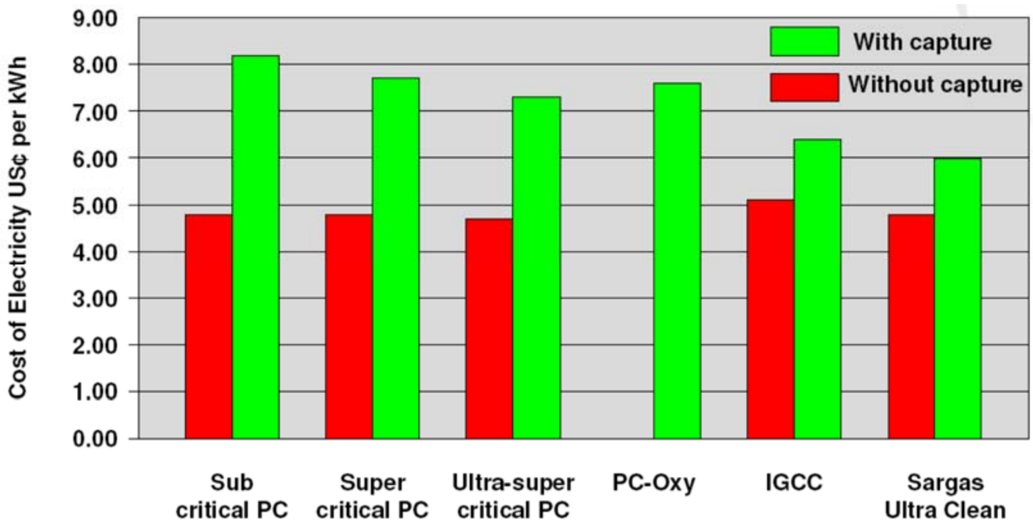

Fig.4 Cost of Electricity for 400 MW Unit (color image see on our web site)

5. Natural Gas

There are three primary reasons for worldwide low growth in gas demand. First, relatively high CO_2 price levels are needed for coal-fired electricity generation to be physically displaced by gas-fired generation. Under a cap and trade program, given the political constraints on regional impacts of energy price increases, such price levels most likely will not be reached in the next decade. Second, the development of renewable electricity generation resources tends to reduce natural gas demand in some regions by backing out gas-fired generation on the margin. As a result, consumers may end up paying more for energy and CO_2 emission reductions than would have occurred if natural gas were to be used more heavily. Third, non-electric gas usage is likely to stay flat due to continuing growth in conservation and energy efficiency programs and the price response to carbon, [17].

On the other hand Serbia is taking somewhat different approach. According to Serbian Energy Development Strategy it is predicted to increase natural gas consumption from 14% in 2007 to 18% until 2015 [6]. This requires finishing of underground storage capacity, as well as construction of distributive pipelines on the whole territory of Serbia.

6. Renewables

It is always interesting to look all the walls built between renewable energy camps and traditional energy camps. The renewable camp finds traditional energy old, outdated and dangerous. The traditional energy advocates find renewable energy expensive and impractical.

But there are good arguments on both sides. Renewables have great potential, but there are still issues (storage, intermittence, cost, maintenance, investment). Conventional energy is currently practical, but offers a future with severe imperfections (climate change, global warming, loss of fuel source, reliance on unstable economies for fuel). In the end, there is no simple way to disband traditional energy and convert it entirely into renewables overnight.

Recently adopted European Regulation on Measures of Incentives for the Production of Electricity Using Renewable Energy and Combined Production of Electricity and Thermal Energy has opened long waited bases to produce energy from renewable, [18]. From available renewable energy resources Serbia will most likely turn to biomass. Although solar energy is significant, it is not likely that it will start to be used to a greater extent. However if one out of five households, (in 2002 there were 2.5 million households in Serbia), installs a solar collector of 4 m^2, it would generate about 1750 GWh of heating energy annually. This would for the most part replace the use of electrical energy and partially the energy of fossil fuels s used for running water heating. This would also reduce carbon-dioxide emission for about 2.3 million tons per year.

Small water power plants are energy generating installations with the power of up to 10 MW and they fall into the category of “privileged energy producers.” By utilizing the total potentials of small water power plants it would be possible to produce about 4.7% of total electricity production in Serbia (34,400 GWh in 2006) and about 15% of current production of electricity in water power plants (10,900 GWh/annually). The wind power in Serbia is estimated at about 1300 MW. However, for the proper estimate and validation of the wind power economics, more data are needed. In addition, the potential of geothermal energy of the existing hot water springs is estimated at about 216 MWt, which equals the power obtained from about 180,000 tons of oil. This is mostly the low temperature energy which cannot be used for electrical energy production through the application of traditional technologies. [4]

1.2. Biomass

Biomass gasification technology has been studied and developed over the past 50 years and continues to have global appeal due to the growing interest in clean, renewable energy. Hundreds of biomass gasifiers are in operation with a majority being small-scale plants in Asia and Europe providing heat or electricity to farms and small industries, [19, 20]. In the United States, most biomass gasification installations have been small-scale plants, although some large-scale operations have been announced. It should be noted that cultivation, transportation and conversion to Bio-fuel is not CO_2 neutral and it is water intensive and in most parts of the world water is a critical issue.

Regardless, sooner-or-later, the world, (Serbian industry should too), is going to start using all the biomass, waste, or grown for the purpose to make syngas for production of gasoline/diesel.

6.1.1. Biomass in Serbia [4]

It is well known that Serbia has a substantial biomass potential estimated at 2.7 million tons of oil equivalent (toe). About 40 percent of the RES potential is in using biomass, of which 1.0 Mtoe is wood biomass potential (tree felling and wood biomass remnants during primary and/or industrial treatment), and over 1.4 Mtoe is agricultural biomass (remains of agriculture and farming cultures, including liquid manure). Animal husbandry based biomass energy potential suitable for the production of biogas is estimated at 42.000 toes. Studies also indicate that there is a measurable potential for rapeseed, sunflower and soya based biodiesel production. Despite of all initiatives, advocates and producers in Serbia will have to continue to push hard forward with the development of different types of biofuels. The first generation of biofuels made from crops is developed to reduce use of fossil fuels and combat global warming. Now, we need to develop a second generation biofuels which will move away from competition with food and animal feed. However, production of biofuels based on biomass is not likely to expand as rapidly as first generation was introduced. The production process is much more complex and we cannot expect we will get a second generation biofuels in a short while. Still, low-grade biomass could play a large part in heat production to help Serbia reach its objectives in achieving high percentage of renewable energy in its final energy consumption.

7. Conclusions

In the future mix of Serbian energy sector alternative forms of energy, such as biofuels, wind, and solar power, will play a growing role in satisfying higher demand, but so will fossil fuels, including oil, gas, and particularly clean coal technologies. Indeed, all forms of energy, as well as greater efficiency, will be needed to support Serbia’s developing economy. Number of technologies is being developed, few of them are reviewed in this paper, and most are tested on a commercial scale. But though Serbia should do everything sensible to promote alternative energy, there's no point trying to do everything possible. Today, it is not possible to talk about any energy related technology without being politically correct, economically sound, and environmentally friendly. There are financial, political, and technical pressures as well as time constraints that will force tough choices; solutions will need to achieve the biggest emissions reductions for the least money in the shortest time. The capital requirements are large, investments are delicate, there are number of choices, and they are all difficult. However, without a major change in energy policy, dependence on oil and gas means that Serbia will continue to send million of dollars of our hard-currency needed for the development of alternative forms of energy across its borders. Coal in the Serbian energy mix will be mostly for electricity generation. In that respect, it will have to compete with other primary sources of electricity, mostly renewable (including biomass). Though burning coal is considered one of the most polluting ways to generate energy, the industry has already created clean technology once. Emissions of sulfur dioxide, particulate matter, and nitrogen oxides have decreased dramatically since the 1970s. It is not only possible to do it again, it is essential, because coal provides such a large part of the Serbian energy mix, it's unlikely that a new cleaner technology will come along to replace it.

8. Acknowledgement

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9. References:

[1] BP Amoco Statistical Review of World Energy, 2009.
[2] Solar power: Areva buys solar company Ausra, PennEnergy, March 2, 2010
[3] Economides, M.J. and Oligney, R., The Color of Oil: The History, the Money and the Politics of the World's Biggest Business, Energy Industry Books, USA 2009.
[4] Ministry of Mining and Energy of Republic of Serbia, http://www.mre.gov.rs/
[5] Energy Users News, February 2010
[6] Provincial Secretariat for Energy and Mineral Resources, Republic of Serbia, Autonomous Province of Vojvodina, Implementation Program of the Energy Development Strategy of the Republic of Serbia in the AP Vojvodina (2007-2012), Novi Sad, 2009
[7] Coal Outlook Supplement, May 20, 2007.
[8] Population Division of the Department of Economic and Social Affairs of the United Nations Secretariat, World Population Prospects: The 2004 Revision and World Urbanization Prospects: The 2003 Revision, 12 February 2006, http://esa.un.org/unpp
[9] The Clean Use of Coal, A technology Review, ISBN 92-64-12657-0.
[10] Ljubicic, B., Bukurov, Z., Anderson, C., Cvijanovic, P., Stajner, K., Project "Kovin" – Economics of Upgrading Low Rank Coal, 12th International Conference on Slurry Handling, Hydrotransport 12, Brugge, Belgium, September 28-30, 1993.
[11] Ljubicic, B., Bukurov, Z., Stajner, K., The "Kovin" Trial lignite Dredge Mine, 19th International Technical Conference on Coal Utilization and Fuel Systems, Clearwater, FL, USA, March 21-24, 1994.
[12] Ljubicic, B., Bukurov, Z., Stajner, K., Coal Dredging Efficiency – The underwater Mining Experience at Kovin Coal Mine, 13th International Conference on Slurry Handling, Hydrotransport 13, Johannesburg, South Africa, September 3-5, 1996.
[13] USDEO Topical Report: 94-EERC-02-7: "Preparation and Combustion of Yugoslavian Lignite-Water Fuel", March 1994.
[14] Energy Deskbook, US Department of Energy, DOE/IR05114-1.
[15] "The World Factbook." CIA, 09 February 2006, Online: www.cia.gov/.
[16] Private communication with Herman de Mayer, Director of Technology, Sargas
[17] Emissions forecasts from IEA, 2008.
[18] The EU SET Plan and European Industrial Initiatives Raffaele Liberali, DG Research, Director of Directorate K– Energy, European Biofuels Technology Platform 2nd Plenary Meeting, January 22nd, 2009
[19] Schmitz, B., Riesgo, J., Biofuels & Biorefinery research and demonstration activities of the European Commission: update on recent developments, DG Research, DG Transport and Energy, European Biofuels Technology Platform 2nd Plenary Meeting, January 22nd, 2009
[20] Panoutsou, C., Availability of sustainable biomass feed-stocks for biofuels: update on key issues, EBTP, European Biofuels Technology Platform 2nd Plenary Meeting, January 22nd, 2009

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