KOSOVO CASE STUDY: LIGNITE COAL - ENERGY OF THE PAST, COALBED METHANE EXTRACTION - ENERGY OF THE FUTURE

Hoxha, B.B.*[1], Sweeney, K.[2], Kurti, H.[3], Dulaj, D.[4], Papa, A.[5]
[1] PetroFluids LLC – Houston, Texas, USA
[2] Fulbright Program – Prishtina, Kosova
[3] Environmental Statistics Agency of Kosova – Prishtina, Kosova
[4] United Nations Development Program – Prishtina, Kosova
[5] Exinn Technology – Tirana, Albania

ABSTRACT: Kosovo's largest energy asset, lignite coal, is also its primary detrimental reason to health and environmental issues. Ever since the Dardanian country declared independence in 2008, and even prior, Kosovo has experienced serious problems relating to air quality, municipal waste management, and water pollution. Lignite coal, is the dirtiest, and least efficient, out of all in the coal category. Subsequently, the 'unconventional resource' needs revitalization with new mining techniques, such as coalbed methane extraction (CBM) – enhanced or even CO_2 injection, coal gasification, syngas remediation etc. to produce the much-needed natural gas that fuels several industries in the country. The past decade has seen lignite rich countries such as USA, China, India, Canada, and Australia use such techniques successfully and the same energy model should be investigated in Kosovo.
Keywords: coal-bed methane extraction, coal seam gas, coal gasification, coal mining, alternative energy methods

1 INTRODUCTION

The most recent energy fallout experienced in 2015, globally affected the whole energy sector. Circumstantially, various countries have took measures to quickly adapt to alleviate the dependency on fossil fuels as a single, limited, energy source. Fig. 1 shows projection of energy consumption worldwide with renewable gaining the most growth (5% increase), coal essentially plateauing and decreasing, and large emphasis and support placed in production and development of natural gas (which should surpass coal by year 2030). The major consensus agrees that the current world reserves of coal are still bountiful and surpass any previously forecasted projections, but, recent global initiatives have pushed for diverting away from coal or re-utilizing it for more efficient and safer energy usage. The motivation is focused on clean, sustainable, energy diversification - considering the energy sector needs to adapt to overcome economic challenges influenced by geo-political and socio-economic factors. For this reason, and many more, many government agencies are developing energy programs that are prevalent in all types of circumstances (Hoxha et al.,2018a & Hoxha et al.,2018b). Additionally, the young republic of Kosova needs to follow suit and investigate different programs for revamping its coal lignite industry.

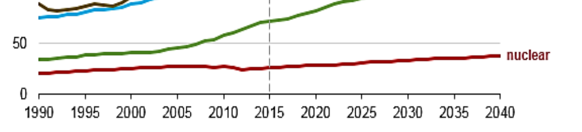

Figure 1: Projection of energy consumption, worldwide. Source- EIA 2016

2 COALBED METHANE

In the past few decades, CBM recovery and extraction has become an important source of energy in United States, Canada, Australia, and other countries. Since the late 1970's, the US has been the pioneer of investigating and exploring the means of producing natural gas from coal beds and determining its exploitation to become an economical and viable energy source (Flores, 1998 and Tim,2012). Ironically enough, this didn't always use to be the case. Historically, coal-bed gas has been considered a major coal-mine hazard since the early to mid 19th century. In fact miners, use to bring canaries with them into dangerous mines in order to help detect the hazardous gases that would seep into the mines. Due to modern technology, what use to be considered a nuisance hazardous by-product for mining coal, is now considered a primary target energy source. After USA and Canada, other countries with large reserves of coal are following suit. Australia has significantly developed its CBM extraction industry and uses the technique as a major method for natural gas production. China, Indonesia, and India have also followed suit. Considering China's major problem in coal dependency and pollution consequence, the Chinese government has redirected its focus in rehabilitating and reconstructing its coal mines to purpose coalbed methane mining and recovery. To date, just in the Qinshui Basin alone has seen over 4,000 producing wells (Qin et al.,2013 and Liu et al.,2018).

The interesting aspect for drilling in coal is that coal is both the source rock and the reservoir rock, categorizing it as an "un-conventional" reservoir. The coal is a microscopus solid with a very large surface area, giving it the capability to "sorb" large amounts of gas (sometimes more than 600 cubic ft/ton), specifically it can store more than 6-7 times in comparison to conventional rock. The methane gas in the coal compromises more than 90-95% of the total gas in the coal, and smaller amounts of gas consists of CO_2, nitrogen, hydrogen sulfide (see Fig.A1). Unlike other types of natural gas that is formed from conventional resources, the methane produced form the coal-beds contains minimal amounts of heavier gases such as NGL's (natural gas liquids or condensates) and only a small amount of gas is contained as “free gas” in fractures or cleats.

Coal-bed methane is distinct from a typical sandstone rock or other conventional gas reservoir, as the methane is stored within the coal matrix via a process called adsorption (see Fig.3). The methane is in a near-liquid state, stored inside the pores within the coal matrix. Additionally, the reservoir properties affecting extraction and production include porosity, adsorption capacity, cleat permeability, thickness of formation, initial reservoir pressure, density, initial gas-phase concentration, gas saturation, and water saturation. The methane gas will stay in a coalbed as long as the water table remains above the gas saturated coal and the gas can be released from the coalbed when cleat pressure is reduced by dewatering. Thus, some wells may never become economic if coal-wells can’t be properly dewatered.

Typically, CBM wells often produce lower gas rate production that conventional gas reservoirs. Table I, and Fig.2 depict the differences between a typical conventional gas well vs. a CBM gas well. A similar advantage that is worth mentioning is that, also, in CBM gas wells hydraulic fracturing can me used where O_2, steam, or even CO_2 can be injected to fracture and stimulate the well.

Table I: Comparison CBM well vs. Conventional well

	CBM Gas Reservoir	**Conventional Gas Reservoir**
Hydrocarbon Occurrence	Adsorbed to surface of coal	Inter-granular pore space of rock
Depth	Shallow < 1,000 m	Shallow to Deep (<7,000)
Pressure Regime	Sub-hydrostatic to hydrostatic	Typically, Hydrostatic
Methodology for Extraction	Dewatering & reducing pressure to allow gas “desorption”.	Pressure control
Gas & Water Production	Initial low & Gas & high water will gradual reverse and equilibrate.	Initial high gas & low water will reverse in exponential curve pattern.

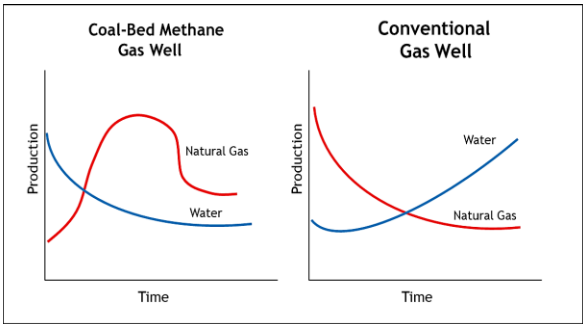

Figure 2: Diagram depciting difference in gas prodcution bwtween a CBM gas well vs. Conventional gas well. Source- Borrowed from Kuuskraa and Brandenberg, modified by Hoxha, 2018

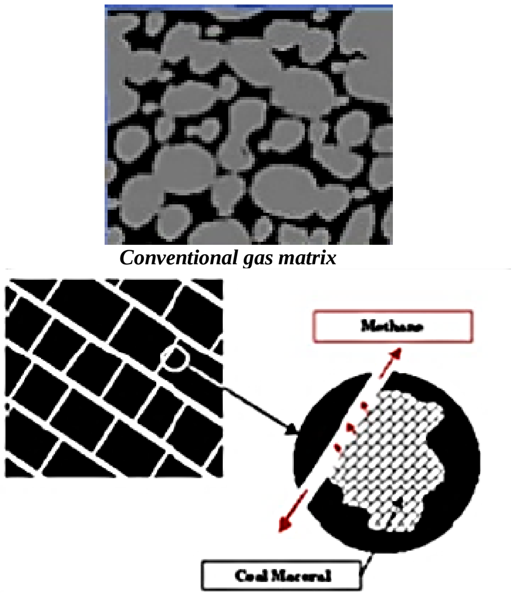

Figure 3: Difference in reservoir matrix between conventional and CBM gas wells

3 MINING IN KOSOVA

Kosova possesses the fifth largest global reserves (see Fig.4 and Fig.5) of lignite coal with approximately 14 billion tones and 20th in the world for production at 8.5 million metric tons/year (Kammen, 2012). The “dirty coal” produces more than 97% of electricity in Kosovo that is fueled by two old Soviet built (Kosova A and Kosova B) power plants located less than 10 kilometers from the center of the capital city of Prishtina. Burning the dirtiest form of coal in plants that desperately require renovation has a myriad of negative effects on the health of the local population, as well as the medical structure of Kosovo. Mentioned in the HEAL Report by Jensen (2016), it is estimated that the power plants create up to 352 € million per year in annual health costs, of which 169 € million falls on the population within the region. A 2012 report by the World Bank (Beer,2012), which quantified the health risks associated with air quality in Kosovo, determined that poor air quality causes 835 premature deaths in Prishtina per year. Jensen (2016) furthermore explains in more detail the serious implication associated, that as such of all pollutants emitted, the most damaging to health is particulate matter PM2.5. The author goes on to mention that the Kosova A and B are the largest emitters in Europe with a total of 7,500 tons of PM2.5 per year. Coupled with the fact that 6 of 7 Kosovo’s municipal landfills are considered Environmental “Hot Spots” by the Kosovo Environmental Protection Agency, Kosovo needs alternative energy strategies.

Kosovo has a had an active mining history for decades and is remarkably rich with various metallogeny resource that mainly compromise in lignite coal and other valuable mineral resources such as: zinc, lead, ferronickel, bauxite, magnesite, copper, gold, silver, chromium. Kosovo was historically a mining district for the former Yugoslavia (see Table AI and Table AII). Thus, it is no surprise that Kosovo is rich with such minerals to this day. In fact, most of the Balkans has been historically known to possess rich minerals.

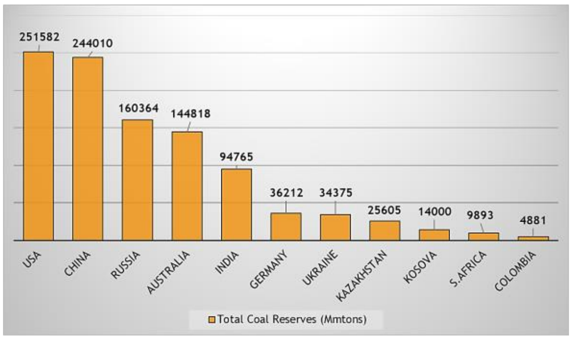

Figure 4: World coal reserves, as of 2016. Note - Kosovo, ranked top 10. Source- BP World Energy Report, June 2017

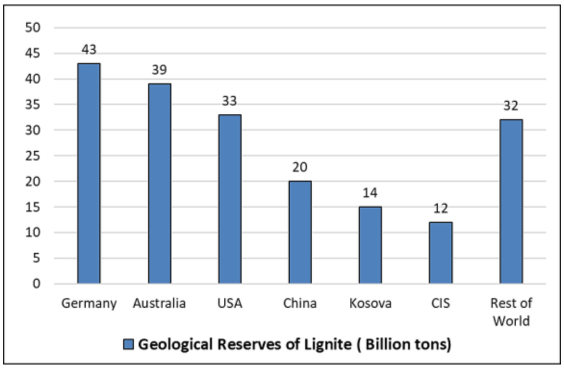

Figure 5: Geological reserves of lignite globally. Source – Qafleshi et al.,2013 & Bojaxhiu et al., 2009 and modified by Hoxha. Note - Kosovo, ranked top 5 in globally for lignite

Adjacent Albania also includes similar types of minerals, such as, magnesium ore, coal, bauxite, petroleum, bitumen, natural gas, iron ore, chromite, and nickel. In cooperation with Albania, Kosovo's energy sector has begun to incorporate collaboration initiatives with its sister country in order to utilize vast amount of unexploited mineral wealth and energy potentials. One example of cooperation is the power exchange program in which a newly build power transmission line of 400 kV recently connects the two countries. Albania's electrical power is mostly produced by hydropower plants (95-97%), while that of Kosovo comes chiefly from lignite coal (97%), making both highly dependent on one energy source. Both Albania and Kosovo suffer from power shortages due to insufficient output, old grids and theft. Thus, the power exchange has been designed to exchange energy to each other during shortages.

As of recently, Kosovo has received scrutiny from international regulatory agencies, and internal activist groups, on the use of its coal plants and the affect it has had on its populations health. In fact, plans to build a 3[d] plant (Kosova C) have been questioned and requests to perform additional feasibility studies are in effect. It has been proposed to the government agencies to explore new method for energy production and make use of its large lignite coal resources. One of which is what is considered coalbed methane extraction. Inherent within the alternative energy producing technique, the potential to utilize CBM extraction in Kosova supports a supposed assumption that could prove valid to the most basic case: to produce a more sustainable energy option form existing resources.

4 LIGNITE COAL RESERVES

The predominant form of coal in Kosova is lignite (see Fig.6 and Table II). The primary reserve basins belong to the upper Miocene with an age of about 9 million years. The coal seam thickness varies between 56 m and 70 m. The original overburden coverage shows a thickness of 60 m to 120 m (KEK report and Ministry of Energy report 2012-2013).

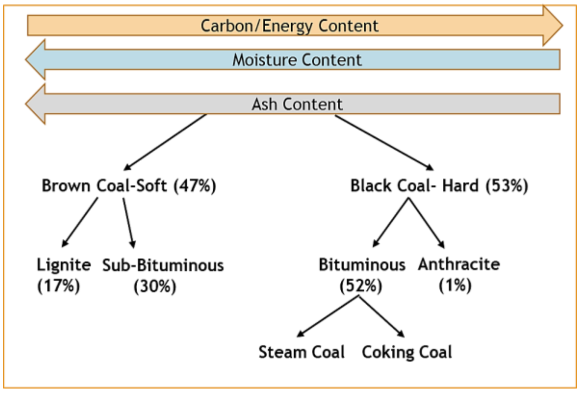

Figure 6: Schematic of different types of coals

Table II: Properties and characteristics of different types of coal

	% Carbon	% Moisture (%wt)	Calorific (KJ/Kg)	Energy Use
Peat	10-15%	> 50%	2,393	-
Lignite	<35 %	30 - 45 %	13,000 – 17,500	Electricity Generation
Sub-Bituminous	35 - 45%	20 - 30%	18,000 - 23,000	Industrial & Manufacture
Bituminous	45 - 86%	15 - 20%	23,000 – 35,000	Steel Plants
Anthracite	86 - 97%	≤ 15 %	≥ 35,000	Domestic & Industrial

The republic of Kosova has a total estimated geological reserve of approximately 14 billion tons (see Fig.7 and Table III) with 10-12 billion tons estimated as exploitable reserves. According to KEK report, as of 2016, it is estimated that over 400 million tons of lignite has been extracted from the Kosova basin alone.

Some typical characteristics of the lignite found in Kosovo include, an average stripping ratio for 1 ton of the coal is 1.7 m^3 top soil overburden, average deposits thickness of 40 m, and an average net calorific value (NCV) of 8,000 KJ/kg. Additionally, the average ash content is 12 - 20%, the average moisture content is 35 - 45%, and sulfur content of less than 1%. The concentration of lime is sufficient to absorb SO_x gas released while drilling thus desulfurization is not necessary. Total reserves with NCV above 8,400 KJ/kg are 29%, reserves between 7,700 – 8,4000 are 43% of the total reserves, and reserves with NCV value less than 7,700 account for 25% of the total reserves. The Klina reserves (0.9 billion tons) have proven to show some of the highest quality of coal with an NCV of 9,100 KJ/kg that could possibly equate to 206,822,088,000 m^3 of natural gas (Papa et al., 2014).

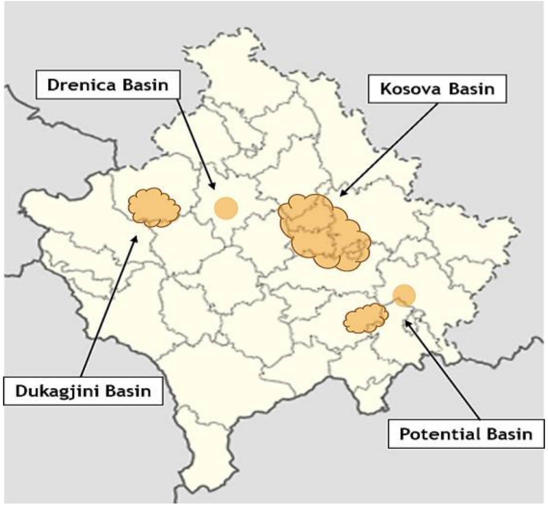

Figure 7: Geological lignite reserves. There are two major lignite basins: Kosova lignite basin and Dukagjini lignite basin, the smaller lignite basins are Drenica, Malishevë, Babush i Muhaxherëve and one potential lignite basin in southern part of Kosovo. Source-Kosovo ministry of energy, modified by Hoxha, 2018

Table III: Properties and characteristics of Lignite Basins and mines in Kosova

Mine/Basin	Moisture %	Sulfur %	Ash %	Calorific Value (KJ/kg)
Kusar				7,400
Tucep				7,197
Kosh				8,100
Shtupel				8,500
Grapc				8,600
Klina				9,046
Kijevë				4,890-8,025
Drenovc				7,953-9,209
Ponoshevc				6,907
Dukagjin Basin -Total	45%	<1%	22%	7,400 (Avg)
Klina Basin				9,046
Skenderaj & Drenica	32.5	1.6	25.6	7,850 (Avg.)
Bardh-Mirash (Kosova Basin)	<45%	<1%	18%	7,800
Sibovc (Kosova Basin)	<45%	<1%	18%	8,100

Kosova generates around 6000 GWh of electrical energy annually. Over 97% of this is produced by lignite-fired power-plants and less than 3% by hydro power (KEK Report, 2014). The lignite consumption in Kosovo is evidently dominated by the demand of the local thermal power plants. Average annual coal demand for electricity generation is 7.5 million tons, peaking at 10 million tons in 2015. Total lignite for the use for other purposes or consumers other than the power plants is estimated to 500,000 tons (see Fig. 8 and Fig. 9).

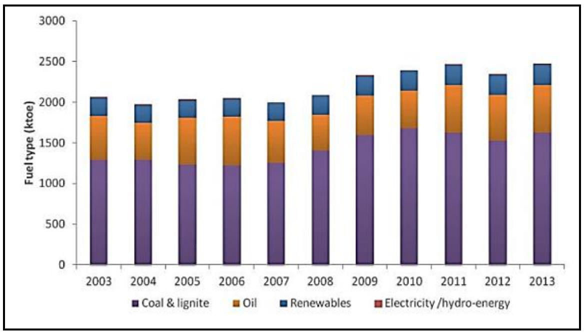

Figure 8: Energy consumption by fuel in Kosova. Source- European Environment Agency, 2015

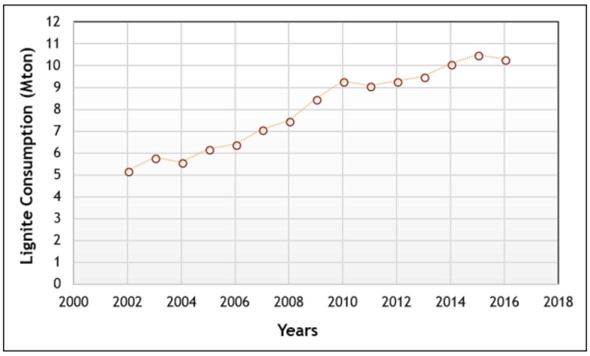

Figure 9: Lignite consumption in Kosovo in the past 17 years. Source- Qafleshi et al.,2013 & KEK report, 2016 and modified by Hoxha, 2018

5 FEASIBILITY STUDY

Coalbed methane production around the world, with USA and Canada leading the recovery, extraction and production process of CBM into natural gas has shown to be beneficial, profitable, and commercially viable if planned appropriately – specifically as a long-term solution. It is estimated that world CBM resources are around 100-260 Tm^3 with produciton at approximately 50 bcm/yr (see Table IV).

Table IV: Coalbed methane production around the world. Source - Mastalerz, 2014 & China united CBM corporation, modified by Hoxha, 2018. Note – most of the CBM resources and production are predictions and estimates based on geological surveys

Country	**CBM Resources (Tcf)**	**Production (bcf)**	**Key Basins**
Russia	<1,000	N/A	
USA	<1,000	250-300	San Juan
China	< 1,000	50	Qinshui
Australia	<700	140-150	Bowen, Surat
Canada	<500	200-210	Canada
Indonesia	< 400		
Poland	<300		
Germany	<100		
India	<70		
Kosovo	<40		Kosova & Dukagjini

There are two methods that are generally used for determining estimated recoverable methane gas, (1) boring on top of coal bed seam and extracting a core sample to perform petro-physics experimentation and (2) complex modeling and simulations based on geological survey. Critical geological parameters that are necessary for a coal-bed to be a viable candidate include, but are not limited to, thick laterally continuous coal seams, high in place coal reserves, suitable depth 100-300m, high gas content, and of course high permeability within the coal and the seams.

Recently, a report on the U.S.A geological survey predicted more than 1,000 trillion cubic feet (Tcf) of methane within the US where it is predicted that more than 200-300 Tcf are economically viable to produce (see Fig.A3). In Canada, it is estimated that approximately 500 trillion cubic feet of coal bed gas is available. In Kosova, experts and specialists alike, that have begun a preliminary investigation, are predicting a conservative number of 40- 50 Tcf. More than enough to sustain and profit the small south-eastern European nation.

It estimated that in order for extraction of the coal to be economically viable, it has to have high enough energy content (calorific value) to be worth the extraction cost. The most preferred coal form is Anthracite. It has been the general consensus among scientists that the minimum amount of calorific content for CBM extraction to be profitable is no less than 8,000-9,000 KJ/kg. Of course, other factors come into play in order to make the decision whether a coal basin is cost-efficient. Especially, operational costs. The average coal extraction costs for the Kosovo basin are assessed at 7.8-11 €/ton (KEK report, 2014). Granted, that the average costs of extraction represent dynamic categories which should practically be determined in the annual operational plans.

Although the republic of Kosova has the lowest and dirtiest type of the coal, Lignite, it's reserves constitute a fair amount above 8,000 KJ/kg, estimated at 35-40% of its total reserves. The question that must be asked is, with the operational costs that Kosova incurs to mine the coal, and with the current prices of natural gas in Europe, is it profitable to introduce this type of technology in Kosova? Maybe for the short-term it is not favorable, but the long-term decision needs to be assessed carefully– such as investing in a new energy source that will be reliable, abundant and cleaner. It needs to be considered that the government of Kosovo incurs hundreds of millions of euros annually due to health issues caused by the coal mining, and more so due to environmental impact. Thus, sophisticated economic models need to be utilized by the government of Kosova where they can partner up between public-private companies to investigate various options.

Other technical methods can also be investigated in order to determine the ability to commercially exploitable CBM reserves, and thus reduce operational costs. Such as including "Enhanced CBM Extraction" techniques where CO_2 is injected in to the well, and also the ability to drill multilateral horizontal wells for more efficient production (focus in China CBM wells).

Additionally, the government can follow other countries models by providing tax incentives for private companies to mine the coal in Kosova. It must be noted that momentarily only the state-owned company, KEK, operates in coal mining in Kosova. Furthermore, despite the high amount of coal mined, the energy sector is still very insufficient. Blackouts are common and irregular supply causes private sector losses of €300 million every year, according to the world bank. Thus, any project geared towards weaning Kosovo off lignite would be beneficial environmentally and economically. Most of these problems share similar solutions and could potentially be ameliorated if Kosovo were to be able to effectively implement the possibility to allow for CBM technology.

6 SUMMARY & CONCLUSIONS

Kosovo, eventually and essentially, seeks accession into the EU. This endeavor creates an incentive for better energy management/development in the country, where the industry is lagging way behind EU standards. The development of CBM extraction and recovery will help create new jobs, support innovation and boost competitiveness in the energy sector. Smarter use of resources is not only good for business but will also help protect the environment, preserve essential resources for current and future generations, and even create synergies for industries which most depend on it – power plants, manufacturing, industrial, and medical.

Additionally, some of the advantageous of CBM has over conventional use of coal include (1) the methane is a clean fuel in comparison to coal itself, (2) reduce greenhouse gases, (3) de-methanation increases mining safety, (4) does not affect significantly the physical and chemical properties of the coal. CBM gas can be used in power generation, auto-fuels, fertilizers, steel manufacturing, fuel for reactors in industries, and even residential and domestic electricity use.

Furthermore, if the planning is handled properly, Kosova could interact with its neighbors in a more productive way and possibly even export its excessive gas production into future gas pipelines that are being created across the Balkans. The Trans-Adriatic Pipeline is currently in its last construction phase in Albania, and it is projected that the Ionian-Adriatic Pipeline could begin construction after the completion of TAP in 2020, according to a report by Aslanov at the 2015 Albania Oil & Gas Summit. However, the gas pipeline that would link Kosovo to Albania (WBR), and eventually to western Europe, is still in the feasibility planning stage (see Fig.A2). But if constructed, would mean a vital access to transportation to either import or export natural gas into the country – a clean energy source that is much needed in the country.

7 ACKNOWELDGMENTS

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9 APPENDIX

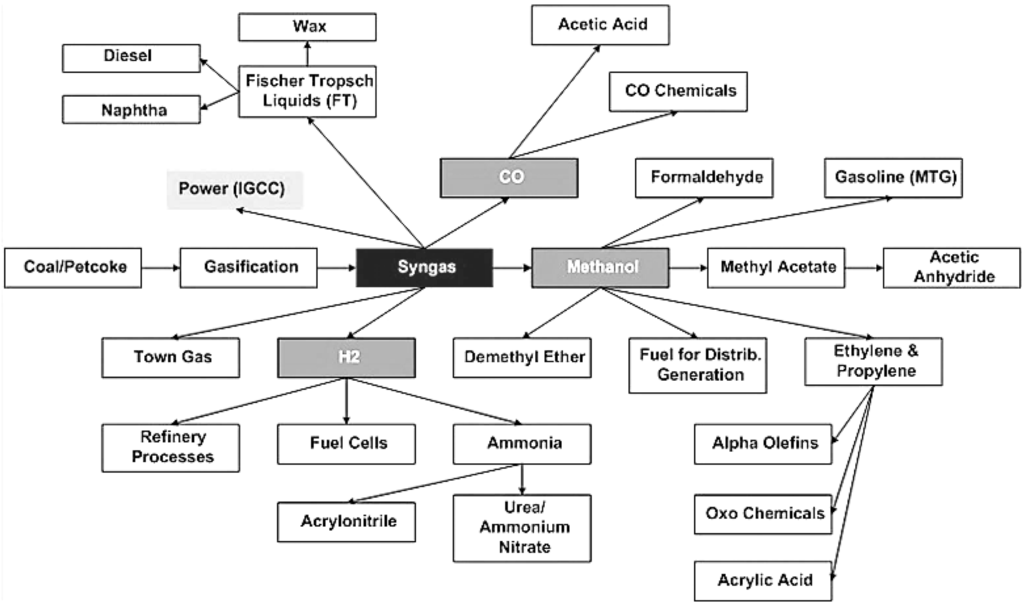

Figure A1: Schematic diagram displaying mechanisms of coal as a primary source for multiple use in energy refening

Figure A2: Gas pipeline projects in western Balkans. Source- Aslanov, 2015

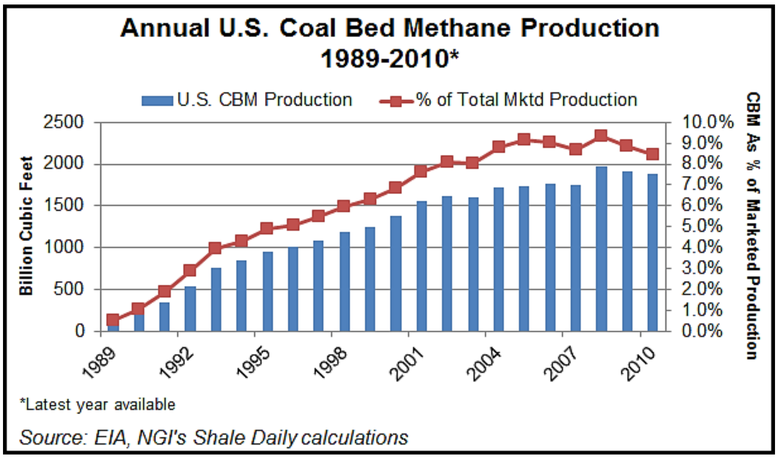

Figure A3: Annual US CBM extraction and production, where in 2008 it peaked with 10% of the market natural gas production reaching 2.4 Tcf production – mostly in the Rockies. Source- EIA report 2015

Table AI: Total mineral reserves/resources in the main source. Note- Trepca source is represented in adapted form in the table below. Santerg mine covers approximately 60% of the Trepca reserve. Artane, Hajvalia and Kishnica cover 27.4% of the Trepca reserve and Leposavic area mines covers 12.9%. Source- Report for the Mining strategy of the republic of Kosovo, 2013

MINE	Ore(t)	Pb (%)	Zn (%)	Ag (g/t)	Pb(t)	Zn(t)	Ag(kg)
Santerg	35,081,000	3.9	3.9	65	1,349,579	1,080,054	2,280,224
Gernac/BB/Gom	7,544,227	6.85	5.07	96.13	516,645	382,373	725,256
Artane/CB	16,037,227	4.67	6.52	89.91	749,354	1,045,444	1,441,879
Total	***58,662,569***	***4.5***	***4.3***	***75.8***	***2,615,578***	***2,508,321***	***4,447,359***

Note - The mineral-bearing region of Artane, Hajvalia, Badovc and Kishnica, including the surrounding sources, holds ore reserves of in total 16,037,342 tons, expressed in metal quantity in ore, the sources are home to 749,354 t lead, 1,045,444 t zinc and 1,441.879 kg silver. Total reserves in Kosovo for lead account to 2,066,000 tons, 1,317,000 tons for zinc, 2,600 tons of silver, 4,200 tons of bismuth, 1,655 tons of cadmium.

Table AII: Energy consumption & amount of energy in Kosovo, 2013. Source- report MZHE & Kosovo ministry of energy, 2015

	Energy Consumption (ktoe)	Energy Amount (ktoe)
Lignite	99.7	1624.3
Petroleum Products	774.9	586.8
Biomass	253.2	253.2
Biofuels	0	0
Electrical	411.9	11.5
Hydropower	-	11.2
Solar	1.3	1.3
Heat	7.6	-
Geothermal	0	-
Total	***1,348.6***	***2488.2***