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A cradle to gate life cycle assessment of Turkish lignite used for electricity generation with site-specific data

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ABSTRACT

Coal, a major source for electricity generation in many regions, is expected to keep its position among global energy sources in the next two decades. There are significant life cycle impacts of coal used for electricity generation such as heavy metal emissions and acidification. Impacts related to the combustion phase have so far been the focus of attention and are better documented than other phases of the life cycle. Relatively less attention has been paid to impacts of mining and coal preparation processes at mining sites due to generation of large quantities of wastewater, particulate matter and heavy metal emissions, and the use of heavy machinery which is energy-intensive. To this date, there are only a few studies specifically addressing impacts associated with the mining and coal preparation phases in the open literature. To further advance our understanding of the scale of impacts during these phases, this paper presents a life cycle assessment of lignite from extraction phase to the delivery to the power plant based on analysis of high quality data from twelve lignite mining sites that serve major lignite power plants in Turkey. For impacts on land use, four indicators which include erosion resistance, mechanical filtration, groundwater replenishment loss and biotic production, are estimated. Following life cycle impact assessment, two environmental performance improvement alternatives that can be easily implemented in mining sites are evaluated to quantify the potential degree of improvement. These alternatives include dewatering of the slurry waste and recovery of coal, and using biodiesel mixed fuel and watering roads to reduce dust formation. The analyses show that 40% improvement can be realized for ecotoxicity potential to water category through simple changes in mining practices.

1. Introduction

Due to global distribution of vast amounts of coal reserves, coal price stability, public opposition to nuclear energy and its high capital cost, and deployment barriers of renewable energy sources; coal is an attractive option for electricity generation. According to the International Energy Outlook 2013 report, in 2010 coal-fired electricity generation accounted for 40% of overall worldwide electricity generation and in 2040, its share is predicted to remain high at 36% (EIA, 2013).

Approximately a quarter of electricity in Turkey is generated at coal-fired power plants, and this has been the case for almost a decade. As of 2013, 44% of electricity was generated at imported natural gas-fueled power plants, 25% at hydro power plants, 14% at imported hard coal fueled power plants, 13% at local lignite fueled power plants, and remaining 4% was generated at geothermal and wind power plants. The installed capacity of the lignite fueled power plants was 8086 MW in 2013. With the discovery of new lignite reserves between 2005 and 2009, which doubled the previous lignite reserve estimate for Turkey, 15 more lignite-fueled power plants with a total installed capacity of 16,600 MW are expected to be built in the near future (EUAS, 2013). Fig. 1 shows the locations of the current and planned lignite-fueled power plants in Turkey, and Table 1 presents the installed capacities of the current and planned lignite-fueled power plants.

In Turkey, the majority of coal basins are of tectonically disturbed nature and have a lot of folding and faulting. Hence, application of modern mining methods is restricted. Due to low

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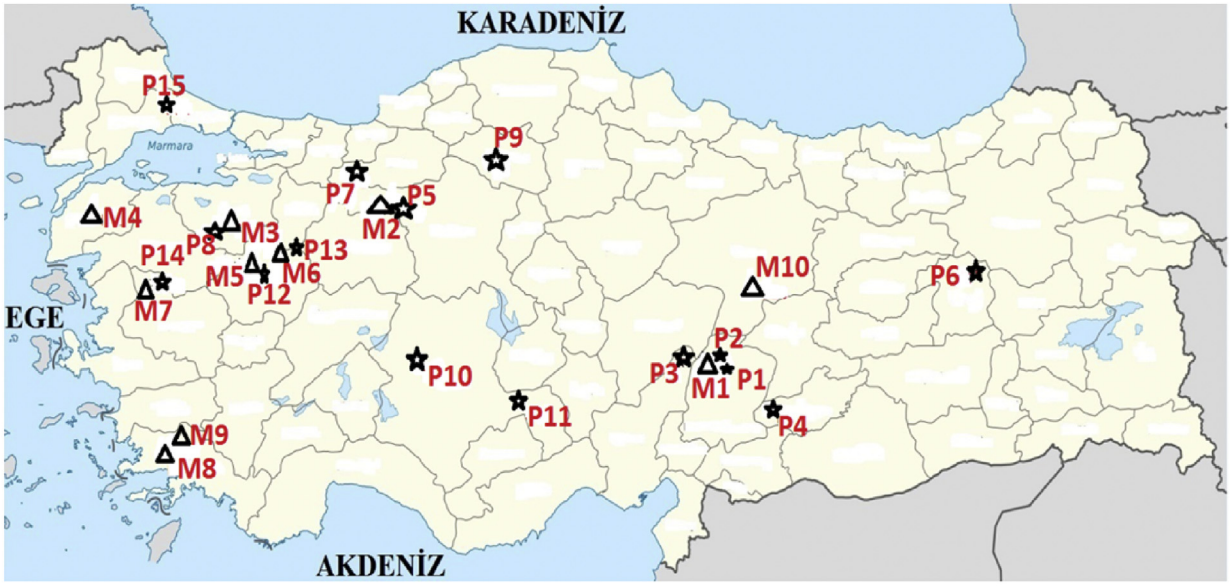

Note: The legend ★ represents planned power plants and ▲ represents current power plants.

Fig. 1. Locations of current (2013) and planned lignite-fueled power plants (DEKTMK, 2013).

Table 1
Locations and installed capacities of current (2013) and planned power plants (DEKTMK, 2013) (M and P represent current and planned power plants, respectively).

#	Location	Current installed capacity of power plants (MW)		Planned installed capacity of power plants (MW)		Total installed capacity (current + planned) (MW)
1	Afsin-Elbistan A-B	M1	2800	P1	7200	10,000
2	Afsin-Elbistan		–	P2	1250	1250
3	Adana-Tufanbeyli		–	P3	600	600
4	Adiyaman-Golbasi		–	P4	150	150
5	Ankara-Cayirhan	M2	620	P5	500	1120
6	Bingol-Karliova		–	P6	150	150
7	Bolu-Goynuk		–	P7	270	270
8	Bursa-Orhaneli, Keles-Davutlar	M3	210	P8	270	480
9	Canakkale-Can	M4	320		–	320
10	Cankiri-Orta		–	P9	135	135
11	Konya-Ilgin		–	P10	500	500
12	Konya-Karapinar		–	P11	3900	3900
13	Kutahya-Tuncbilek	M5	365	P12	300	665
14	Kutahya-Seyitomer	M6	600	P13	150	750
15	Manisa-Soma	M7	1034	P14	1050	2084
16	Mugla-Yenikoy-Kemerkoy	M8	1050		–	1050
17	Mugla-Yatagan	M9	630		–	630
18	Tekirdag-Saray		–	P15	175	175
19	Sivas-Kangal	M10	457		–	457
	Total Capacity (MW)		**8086**		**16,600**	**24,686**

stripping ratio[1] values, coal seams located at shallow depth conditions were produced by surface mining methods. Both open-pit and strip (also named as open cast) mining methods are applied depending on seam inclination, depth below surface and topographical conditions. In open-pit mines, the overburden is loosened by means of blasting operations as the presence of strong rock mass above the coal seam may inhibit mechanical excavation. Overburden rock fragmented by means of mechanical excavation and/or blasting is loaded and hauled to waste dumps either by means of excavator/trucks or conveyor belts. Then the lignite is extracted by hydraulic and electrical excavators and heavy trucks. In the case of strip mining method mechanical excavation methods are mainly applied. The overburden removal is carried out by using draglines or Bucket Wheel Excavators (BWE) in open cast mines. The overburden is not transported to waste dumps located outside of the excavation area, instead overburden is just moved to adjacent strip where the coal is exploited, directly by a dragline. The region where the coal has been extracted is used as the dump area.

In the case of underground mining, depending on seam and surrounding strata characteristics, various forms of longwall mining methods are applied. Longwall mining method is a well-recognized mining method. The coal is produced from a

[1] Volume of overburden (or waste material) required to be handled in order to extract a certain volume of ore.