# COMPARISON OF IMPACT ON THE ENVIRONMENT BETWEEN THERMAL POWER PLANT AND PHOTOVOLTAIC POWER PLANT

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**Abstract:** Electricity generation can be done in conventional (or centralized) way (i.e. in large thermal power, plants fueled by solid, liquid and gaseous fuels, large hydropower plants and nuclear thermal power plants), or in dispersed way, which is defined as electricity production that is not centrally planned, is not managed by a dispatch center and is most often connected to the distribution network.

From the results for the pollution from emissions of gases from the Thermal Power Plant (TPP) - Bitola for 2012, the quantities of pollutants in specific values (kg/MWh) have been calculated, for the electricity generation from burning coal-lignite. These results are used for the calculation of the amount of emissions into the atmosphere and waste materials in the environment, from a fictitious (imagined) coal-lignite thermal power plant, with electricity production equal to the production of a real (existing) photovoltaic (PV) power plant with a capacity of 1 MW. The calculations are made for each year separately and in total for the period from 2013 to 2019.

It can be concluded that the production of "pure", or so-called "green electricity" in the future should be further emphasized by building photovoltaic power plants that directly use solar energy, together with other different types of renewable energy sources (RES), mainly wind energy. That is also in accordance with the Strategy for energy development of the Republic of North Macedonia until 2040 that envisages decommissioning of TPP – Bitola and strong growth of electricity generation from RES, mainly PV and wind energy.

**Key words**: PV plant, thermal power plant, electricity generation, environment impact

## 1. INTRODUCTION

Electricity generation can be done in conventional (or centralized) way (i.e. in large thermal power, plants fueled by solid, liquid and gaseous fuels, large hydropower plants and nuclear thermal power plants), or in dispersed way, which is defined as electricity production that is not centrally planned, is not managed by a dispatch center and is most often connected to the distribution network, [1].

North Macedonia relies predominantly on fossil fuels (low-grade lignite and gas) and hydropower, and is dependent on electricity imports. The total annual production of electricity in 2020 was 5127 GWh (Table 1), and another 3352 GWh was imported to satisfy the total domestic electricity demand, [2, 3].

Table 1. Electricity generation in North Macedonia for 2020 (in MWh)

| Fuel | Coal | Gas | Biogas | Hydro | Solar PV | Wind |
|---|---|---|---|---|---|---|
| GWh | 2509,86 | 1118,60 | 57,30 | 1287,47 | 37,11 | 116,88 |

The total installed electric power generation capacity in North Macedonia in 2020 was 2103,3 MW, which is for 14,8 MW greater than the installed capacity in 2019. Thermal power plants have

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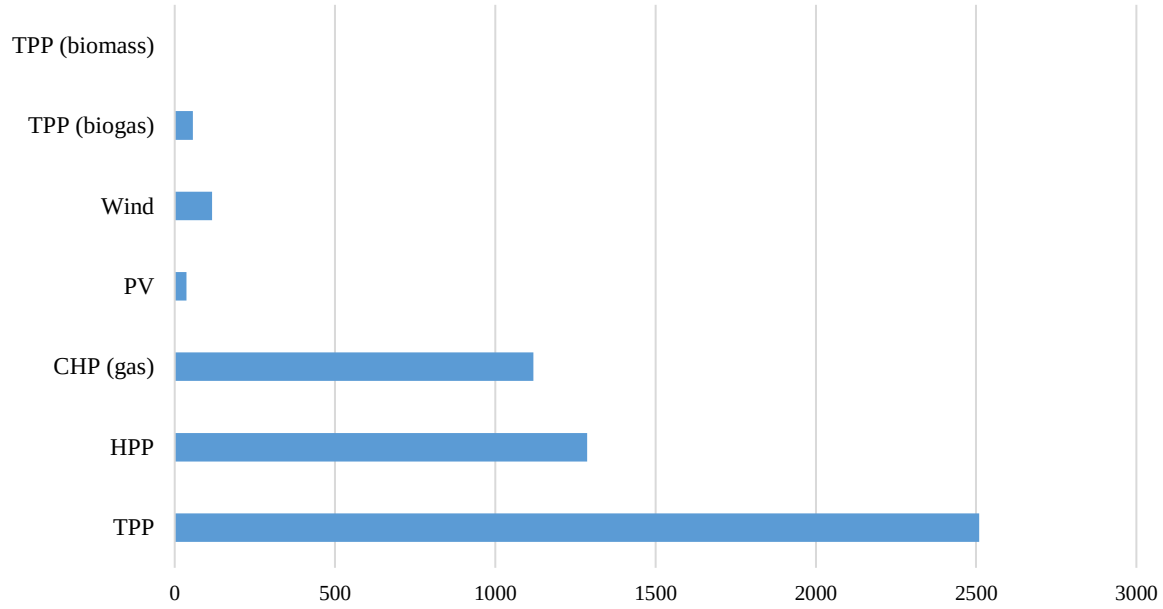
the largest share of the installed capacity with 49,16%, followed by hydroelectric power plants (HPP) with 33,52%, combined heat and power (CHP) plants with 13,66% and all the rest with 3,66%. Largest thermal power plant in the country is TPP Bitola, consisting of three blocks with total installed capacity of 699 MW (3x233 MW).

New 14,8 MW of electricity generation capacities were built in 2020, out of which 7 MW of PV plants and 7,8 MW of small HPP.

Figure 1 shows the percentage share of individual technologies used for electricity generation in 2020.




| | TPP | HPP | CHP (gas) | PV | Wind | TPP (biogas) | TPP (biomass) |
|---|---|---|---|---|---|---|---|
| GWh | 2510 | 1287 | 1119 | 37 | 117 | 57 | 0 |

**Figure 1. Share of individual technologies in the production of electricity in 2020 (in %)**

In January 2020 the government adopted the new Energy Development Strategy 2020-2040, [4] which elaborates three different scenarios: reference (business as usual), moderate transition and green (strong decarbonization) scenarios. The moderate transition and green scenarios both foresee coal phase-out in 2025 which makes it the first country in the Western Balkans to layout concrete options for a pre-2030 coal phase-out.

Even though, the final decision on which scenario will be implemented should have been made in 2020, it is still either not made or not declared in public. Considering that the strategy sees the green scenario as the least cost option it is likely that the country will move away from coal sooner rather than later, [5].

In the moderate transition and green scenarios in the Strategy, phase out of the PEK Bitola lignite-fired power plant in 2025 is also recommended. In the reference scenario investments for modernization and pollution control are given instead of phase out.

After 5 years stagnation of annual production of electricity from solar PV at around 23 GWh, in 2020 there was an increase in the electricity production to a level of 37 GWh. Several large projects are in different phases of development/construction (PV plant Oslomej-1 with 10 MW installed capacity should be operational by the end of this year) which will significantly increase installed capacity. An overview of installed PV capacity is given in Table 2.

Table 2. Installed PV capacity in the period 2016 - 2020

| Installed PV Capacity 2016 (MW) | Installed PV Capacity 2018 (MW) | Installed PV Capacity 2020 (MW) |
|---|---|---|
| 17 | 18,49 | 29,72 |

## 2. SPECIFIC POLUTTANTS EMISSIONS (PER MWh) FROM TPP

Climate change is a serious threat to the environment and people's health, wellbeing and quality of life, reducing access to natural resources and harming the economy and infrastructure. Greenhouse gases, as the most significant driver of observed climate change are attributable primarily to human activities. Worldwide, net emissions of greenhouse gases increased by 35% in the last three decades. The comparison between emissions of different gases based on a global warming potential concept is made with climate change indicators that characterize emissions of the gases, their concentrations in the atmosphere and the change over time, [6].

In the annual reports on the operation and production of the macedonian thermal power plants, the data on the quantities of harmful emissions of gases, nor on the quantities of waste ash, slag and wastewater are very rarely presented. There are no data regarding other released pollutants and substances, nor of the presence of radioactive materials, [7].

However, in the report on the operation of TPP Bitola in 2012 published on the website of JSC "Power plants of North Macedonia" (AD ESM), there are data on pollutant emissions in the air, consumption of coal, heavy oil (mazut) and waste dust, ash, slag and waste water, [8]. Pollutants emission in the atmospehere and release of waste materials in 2012 presented in Table 3 refer to total annual electricity production of 3971 GWh from TPP Bitola for the same year. Most of the results presented in the report [8] are measured by the company "Tehnolab" DOO – Skopje, specialised company for services in the area of environment protection and health and safety at work. Smaller part of the presented results are measured from the relevant departments of TPP Bitola.

The same table shows the calculated values of emissions into the atmosphere and waste materials, reduced in kg per produced MWh of electricity.

Table 3. Pollutant emissions and release of waste materials in 2012 for the production of 3971 GWh electricity in TPP Bitola

| No. | Component of emissions or waste | TPP Bitola total in tones | Reduced to kg/MWh |
|---|---|---|---|
| 1 | $SO_2$ (Sulphur dioxide) | 66891,81 | 16,8451 |
| 2 | CO (carbon monoxide) | 892,50 | 0,2248 |
| 3 | $N_yO_x$ (nitrogen oxides) | 16643,33 | 4,1912 |
| 4 | $CO_2$ (carbon dioxide) | 10448476,97 | 2631,1954 |
| 5 | Dust | 9256,92 | 2,3311 |
| 6* | Ash and Slag | 1547492,00 | 389,6983 |
| 7. | Coal | 6380251,00 | 1606,7114 |
| 8. | Heavy oil (mazut) | 20530,07 | 5,1700 |
| 9.** | Waste waters | 32819 m³ | $8{,}2647 \cdot 10^{-3}$ m³/MWh |

* from No. 1 to No. 6, measured by "Tehnolab" DOO – Skopje

** from No. 7 to No. 9, measured by TPP Bitola departments

Results reduced to specific values (kg/MWh) are very important because they will be used to calculate the amount of emissions into the atmosphere and waste materials in the environment, from a fictitious (imagined) lignite-fired thermal power plant, with electricity production equal to the production of a real (existing) photovoltaic power plant with a power of 1 MW, for the same time period.

Annual production of electricity from TPP Bitola for the period 2013-2019, in GWh is shown in Table 4.

Table 4. Annual electricity production of TPP Bitola for 2013-2019 (in GWh)

| TPP | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | Sum for 7 years | Annual average |
|---|---|---|---|---|---|---|---|---|---|
| Bitola 1 | 1245,70 | 851,10 | 804,70 | 546,30 | 842,90 | 885,00 | 1066,90 | **6242,60** | 891,80 |
| Bitola 2 | 1009,90 | 1207,60 | 1110,80 | 913,00 | 1219,60 | 782,40 | 945,50 | **7188,80** | 1026,97 |
| Bitola 3 | 1314,10 | 1258,20 | 1070,80 | 1213,10 | 1013,60 | 877,90 | 1138,70 | **7886,40** | 1126,63 |
| **TOTAL:** | **3569,70** | **3316,90** | **2986,30** | **2672,40** | **3076,10** | **2545,30** | **3151,10** | **21317,80** | **3045,40** |
| **AVERAGE:** | **1189,90** | **1105,63** | **995,43** | **890,80** | **1025,37** | **848,43** | **1050,37** | **7105,93** | **1015,13** |

## 3. COMPARISON OF AVERAGE ANNUAL EMISSION FROM TPP AND PV PLANT WITH IDENTICAL ELECTRICITY PRODUCTION

Table 5 shows the production of electricity for the period from 2013 to 2019 for the photovoltaic power plant with a capacity of 1 MWp installed in the village Egri, Bitola municipality, [9]. Values for every month, total annual as well as average produced electricity from PV plant are given in this table. Total annual electricity production as well as sum production for the observed seven year period is also shown in the same table. Because the electricity produced by the PV plant in Egri is "green energy", emissions and waste materials released in the environment have zero values. In order to emphasize the environment protection and the most environment friendly (cleanest) way of electricity production, emisions of pollutants and waste materials shown in Table 6 have values of zero.

Table 5. Electricity production of PV plant with installed capacity of 1 MW, located in the village of Egri, Bitola, for the period 2013 – 2019 (in MWh)

| Month → year ↓ | | Jan I | Feb II | Mar III | Apr IV | May V | June VI | July VII | Aug VIII | Sep IX | Oct X | Noe XI | Dec XII | Total annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2013 | 67,410 | 69,714 | 113,742 | 162,550 | 166,632 | 170,848 | 182,248 | 170,028 | 155,354 | 130,910 | 63,574 | 71,788 | **1524,798** |
| 2 | 2014 | 42,578 | 97,210 | 127,100 | 126,510 | 162,074 | 166,878 | 182,408 | 180,208 | 126,510 | 98,740 | 71,194 | 44,154 | **1425,564** |
| 3 | 2015 | 78,462 | 93,904 | 92,074 | 155,272 | 160,524 | 164,390 | 190,078 | 173,112 | 128,950 | 105,256 | 101,970 | 81,384 | **1525.376** |
| 4 | 2016 | 79,040 | 89,910 | 126,066 | 160,246 | 156,850 | 163,354 | 183,456 | 171,642 | 129,840 | 109,216 | 72,388 | 88,320 | **1530,328** |
| 5 | 2017 | 58,262 | 87,698 | 136,506 | 158,184 | 164,484 | 167,846 | 179,942 | 176,426 | 136,318 | 143,808 | 76,736 | 79,122 | **1565,332** |
| 6 | 2018 | 80,270 | 66,274 | 115,354 | 158,956 | 157,880 | 140,752 | 173,970 | 164,076 | 150,818 | 124,090 | 71,824 | 76,532 | **1480,796** |
| 7 | 2019 | 51,314 | 101,152 | 157,292 | 146,750 | 148,418 | 166,884 | 181,486 | 181,646 | 152,506 | 135,550 | 62,712 | 44,154 | **1529,864** |
| **Total** | | 457,336 | 605,862 | 868,134 | 1068,468 | 1116,862 | 1140,952 | 1273,588 | 1217,138 | 980,296 | 847,570 | 520,398 | 485,454 | 10582,058 |
| **Average** | | 65,334 | 86,552 | 124,019 | 152,638 | 159,552 | 162,993 | 181,941 | 173,877 | 140,042 | 121,081 | 74,343 | 69,351 | 1511,723 |

For the production of electricity from a fictitious thermal power plant burning lignite, equal to the production from the solar power plant of 1 MW, individually for each year of the considered seven-year period, Table 7 shows the emissions of gases and waste materials. Using the data from Table 4, for specific values kg/MWh (for the existing TPP Bitola), for each year and totally for the whole period, for equally produced electricity in GWh, we have calculated the values of generated sulphur dioxide ($SO_2$), carbon monoxide (CO), carbon dioxide ($CO_2$), nitrogen oxides ($NO_x$), dust, ash and slag. These values, together with used amount of lignite and heavy oil for electricity production from fictitious TPP are also presented in Table 7.

Emissions of gases released into the atmosphere and waste materials released into the environment, refer to the combustion of coal-lignite with an average energy value of 6503,6 kJ/kg.

Table 6. Total production of electricity in a photovoltaic plant (PV) with a capacity of 1 MW for the period from 2013 to 2019 in GWh and total emissions, pollution and waste

| PV plant | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | Sum for 7 years | Average per year |
|---|---|---|---|---|---|---|---|---|---|
| Net el. production [GWh] | 1,524789 | 1,425564 | 1,525376 | 1,530328 | 1,565332 | 1,480796 | 1,529864 | 10,582049 | 1,511721 |
| $SO_2$ [t] | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| CO [t] | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| $No_x$ [t] | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| $CO_2$ [t] | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Dust [t] | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Ash and slug [t] | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Coal [t] | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Heavy oil [t] | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |
| Waste water [$m^3$] | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 | 0,0 |

Table 7. Production of electricity in fictitious TPP coal (burning lignite with 6503,6 kJ/kg), equal to the production of 1 MWp PV plant for period 2013 - 2019 and total emissions of waste materials

| **TPP electricity production = PV plant electricity** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** | **Sum for 7 years** | **Annual average** |
|---|---|---|---|---|---|---|---|---|---|
| Net el. production [GWh] | 1,525 | 1,426 | 1,525 | 1,530 | 1,565 | 1,481 | 1,530 | 10,582 | 1,512 |
| $SO_2$ [t] | 25,7 | 24,0 | 25,7 | 25,8 | 26,4 | 24,9 | 25,8 | 178,3 | 25,5 |
| CO [t] | 0,3 | 0,3 | 0,3 | 0,3 | 0,4 | 0,3 | 0,3 | 2,4 | 0,3 |
| $No_x$ [t] | 6,4 | 6,0 | 6,4 | 6,4 | 6,6 | 6,2 | 6,4 | 44,4 | 6,3 |
| $CO_2$ [t] | 4012 | 3751 | 4014 | 4027 | 4119 | 3896 | 4025 | 27843 | 3978 |
| Dust [t] | 3,6 | 3,3 | 3,6 | 3,6 | 3,6 | 3,5 | 3,6 | 24,7 | 3,5 |
| Ash and slug [t] | 594,2 | 555,5 | 594,4 | 596,4 | 610,0 | 577,1 | 596,2 | 4123,8 | 589,1 |
| Coal [t] | 2450 | 2291 | 2451 | 2459 | 2515 | 2379 | 2458 | 17002 | 2429 |
| Heavy oil (mazut) [t] | 7,9 | 7,4 | 7,9 | 7,9 | 8,1 | 7,7 | 7,9 | 54,7 | 7,8 |
| **Waste water [m³]** | 12,6 | 11,8 | 12,6 | 12,6 | 12,9 | 12,2 | 12,6 | 87,5 | 12,5 |

## 4. CONCLUSION

From the results for the pollution from emissions of gases from the Thermal Power Plant (TPP) - Bitola for 2012, the quantities of pollutants in specific values (kg/MWh) have been calculated, for the electricity generation from burning coal-lignite. These results are used for the calculation of the amount of emissions into the atmosphere and waste materials in the environment, from a fictitious (imagined) coal-lignite thermal power plant, with electricity production equal to the production of a real (existing) photovoltaic (PV) power plant with a capacity of 1 MW. The calculations are made for each year separately and in total for the period from 2013 to 2019.

Analyzing the obtained results, it is obvious that the pollution of the environment and the production of greenhouse gases from the coal-fired thermal power plants is very high. On the other hand, the production of electricity in photovoltaic power plants is not accompanied by any emissions of gases or waste materials.

It can be concluded that the production of “pure”, or so-called "green electricity" in the future should be further emphasized by building photovoltaic power plants that directly use solar energy, together with other different types of renewable energy sources (RES), mainly wind energy. That is also in accordance with the Strategy for energy development of the Republic of North Macedonia until 2040 that envisages decommissioning of TPP – Bitola and strong growth of electricity generation from RES, mainly PV and wind energy (up to 1400 MW of new PV capacities and up to 750 MW of wind turbines until 2040).

This can by further encouraged and justified having in mind the recent surge in electricity prices in Europe, reaching values of more than 250 EUR/MWh in average [10] and recent increase in prices for $CO_2$ under the EU emission trading scheme (EU-ETS) from around 20 EUR/t$CO_2$ up to around 60 EUR/t$CO_2$ (price for 25.10.2021 is 58,27 EUR/t$CO_2$) [11] and the latest European Commission (EC) report on North Macedonia, chapter 15 – Energy [12], with reference to not meeting the target for production of energy from RES (the share in 2018 was 18,12%, while the target for 2020 is 23%).

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