GREENHOUSE GAS EMISSIONS FROM NEW ZEALAND GEOTHERMAL: POWER GENERATION AND INDUSTRIAL DIRECT USE

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ABSTRACT

Greenhouse gas emissions for geothermal power stations in New Zealand are reported annually under current regulations. The CO_2 and CH_4 emissions data are combined and reported as one CO_2-equivalent (CO_2e) emissions factor. In combination with the amount of steam used each year, and the MWh (net) of electricity generated that year, the overall geothermal emissions intensity for each power station can be calculated as gCO_2e/kWh(net). A recent study presented the emissions intensity for the 12 major geothermal power stations in New Zealand focusing on the calendar year 2018, with data back to 2010 for some stations. In this paper the emissions intensity is presented for the calendar year 2019, and compared with trends from previous years. In New Zealand the emissions intensity for geothermal power generation is on average an order of magnitude lower than for fossil fuels.

In most cases the geothermal emissions intensity numbers are calculated assuming that all of the CO_2 and CH_4 present in the steam entering the power station are released to the atmosphere during the power generation process. However in some geothermal plant designs a fraction of the gases are retained in the condensates, which are reinjected back into the reservoir. Accounting for the gases in the condensates results in a more accurate calculation of the actual emissions intensity. Another nuance of the emissions intensity for geothermal is that the numbers do not account for the benefits of geothermal fluids for direct use applications such as industrial process heat. Direct use projects utilise energy directly, as thermal energy, which is not accounted for in the emissions intensity data which only deals with electrical energy. Nevertheless the benefits of geothermal direct use are a very real, if invisible, part of the geothermal emissions intensity story, and examples are given.

1. INTRODUCTION

Electricity in New Zealand is majority renewable, mostly from hydro and geothermal, and also wind, biogas and solar PV. While none of these renewable energy sources are zero emissions (if all emissions over the lifecycle of the power stations are accounted for), the renewable sources all have much lower emissions intensity than fossil fuel sources (McLean and Richardson, 2019). Of the renewable sources, geothermal power stations have the highest operational emissions intensity. The source of the emissions of geothermal power stations is CO_2 and CH_4 which occur naturally underground in geothermal reservoirs, dissolved in reservoir fluid, are carried to the surface by production of geothermal fluids, and released during the power generation process.

The emissions from geothermal power stations in NZ are measured and reported annually under climate change legislation. This permits a detailed analysis of these emissions, which can be relatively variable, between different power stations, and also from year to year at the same station. A recent study focused on the emissions from 12 geothermal power stations in New Zealand, across the calendar year 2018 (McLean and Richardson, 2019). The data from geothermal power generation does not paint the full picture for geothermal in NZ, as it does not account for direct use. Geothermal developments also produce large volumes of fluid which are used for industrial process heat, and smaller direct-use applications. As this thermal energy is never converted into electrical energy, it is not reflected in the geothermal emissions intensity numbers, which are calculated as gCO_2e/kWh(net), where the kWh are net kilowatt hours of electrical energy.

With data now available from some newer stations, this study analyses data from 14 geothermal power stations for the calendar year 2019. Included for the first time is an accounting of emissions from some industrial direct use projects, which are a major and previously invisible benefit of geothermal to the emissions intensity story.

2.0 BACKGROUND

2.1 Geothermal power stations in NZ

There are 14 geothermal power stations and 2 direct use locations discussed in this paper, across 8 geothermal fields. With the exception of Ngawha geothermal field in Northland, these geothermal fields are located within the Taupo Volcanic Zone (TVZ) of the North Island of New Zealand, as indicated in Figure 1. Details of the power stations and direct use projects are given in Table 1, including owner/operator, commissioning date and the current rated electrical generation capacity (MWe) or thermal generation (MWth).

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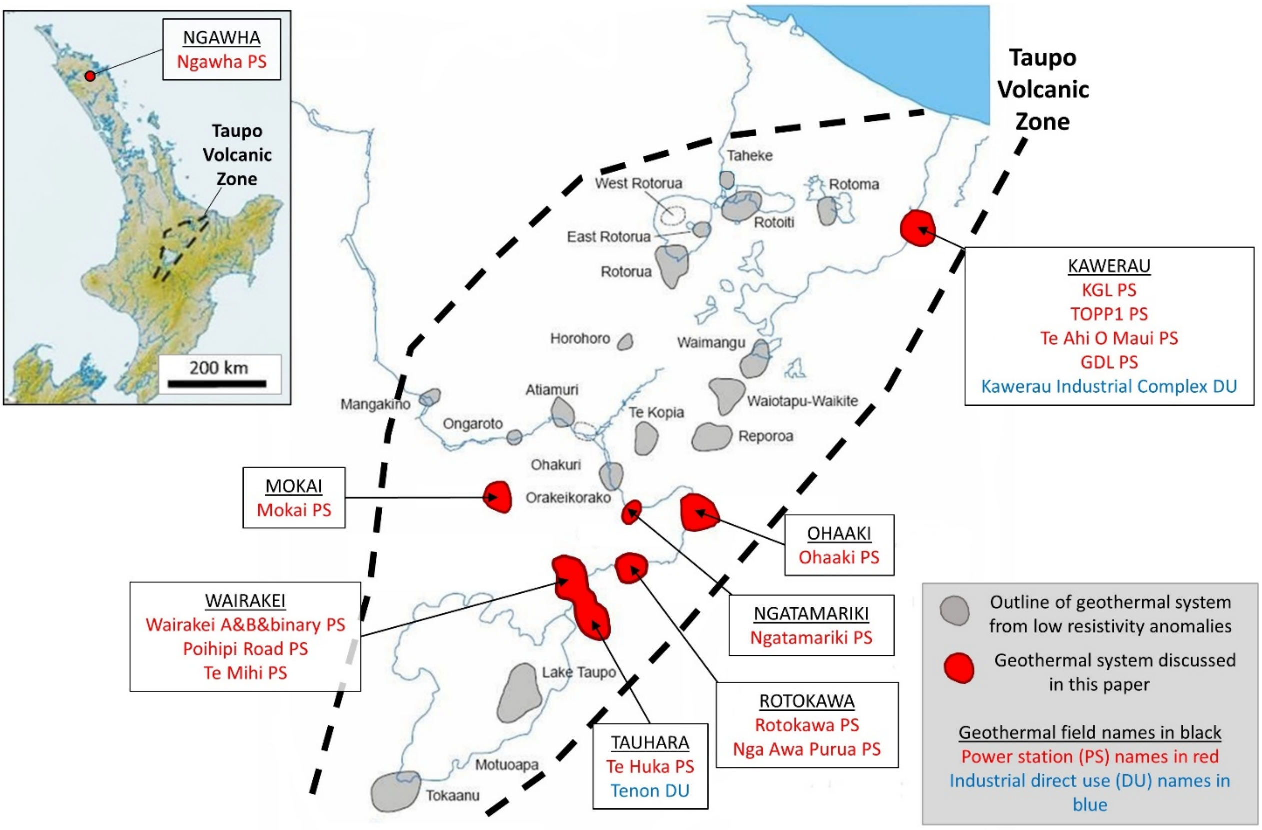

Figure 1: Location map of geothermal fields in New Zealand showing power stations and industrial direct use areas.

Table 1: Table with details of 14 power stations and 2 direct use projects shown in Figure 1.

Geothermal field	Power station or direct use project name	Owner/operator	Original commissioning date(s)	Current rated generation capacity
Wairakei	Wairakei A&B &binary	Contact	1958-1963, 2005 (binary)	132 MWe, 14 MWe
	Te Mihi	Contact	2014	166 MWe
	Poihipi	Contact	1997	50 MWe
Ohaaki	Ohaaki	Contact	1989	45 MWe
Tauhara	Te Huka	Contact	2010	28 MWe
	Tenon timber drying	Tenon Clearwood – process heat supplied by Contact	Converted from natural gas to geothermal in 2006	-
Rotokawa	Rotokawa	Mercury	1997, 2003	35 MWe
	Nga Awa Purua (NAP)	Mercury and Tauhara North No. 2 Trust	2010	140 MWe
Mokai	Mokai	Tuaropaki Power Company/ Mercury	1999, 2005, 2007	112 MWe
Ngatamariki	Ngatamariki	Mercury	2013	82 MWe
Kawerau	Kawerau (KGL)	Mercury	2008	107 MWe
	TOPP1	Ngati Tuwharetoa Geothermal Assets Ltd (NTGA)	2013	21 MWe
	Te Ahi O Maui (TAOM)	Eastland	2018	24 MWe
	GDL	Eastland	2008	8 MWe
	Kawerau Industrial Complex	Various users– process heat supplied by NTGA	Operational since 1950s	-
Ngawha	Ngawha (all plants)	Top Energy	1998, 2008	25 MWe

2.2 Operational vs lifecycle emissions

It is important to define terminology as there can be confusion between different types of emissions: operational emissions and lifecycle emissions. Operational emissions are those which are released during the operation of a pre-existing plant, such as emissions from combustion of coal, or emissions released from produced geothermal fluids. Some plant types have no operational emissions, such as solar plants where the conversion of sunlight to electricity produces no emissions (Figure 2).

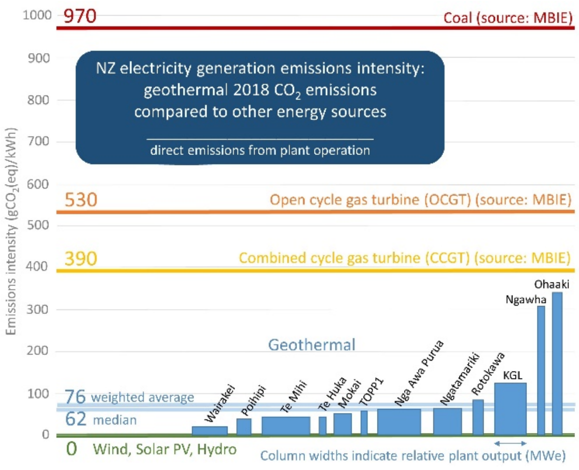

Figure 2: Comparison of operational emissions intensity for NZ electricity generation energy types from 2018 (McLean and Richardson, 2019).

Operational emissions do not tell the full story, as all types of plants have emissions associated with their materials and construction, to varying degrees. A full lifecycle analysis (LCA) is a non-trivial analysis which models the emissions over the expected lifespan of the plant, including emissions associated with materials and construction, operational emissions, and decommissioning. An LCA is by its very nature a model requiring numerous assumptions, and the lifecycle emissions modelled will depend very much on the expected life of the plant.

The Inter-governmental Panel on Climate Change (IPCC) reviewed LCAs for all energy types (IPCC, 2011). The data for the six energy types present in NZ are given in Table 2, including minimum and maximum, upper and lower quartiles (25^{th} and 75^{th} percentiles), and median (50^{th} percentile).

Table 2: Summary of lifecycle emissions for main NZ energy types (data from IPCC, 2011).

Energy type	Lifecycle emissions [gCO2e/kWh]				
	Min.	**25th**	**50th**	**75th**	**Max.**
Solar PV	5	29	**46**	80	217
Geothermal	6	20	**45**	57	79
Hydro	0	3	**4**	7	43
Wind	2	8	**12**	20	81
Gas	290	422	**469**	548	930
Coal	675	877	**1001**	1130	1689

These are shown graphically in Figure 3, which clearly shows the lifecycle emissions from renewable energy types (solar PV, geothermal, hydro and wind) dwarfed by lifecycle emissions from fossil fuels (gas and coal).

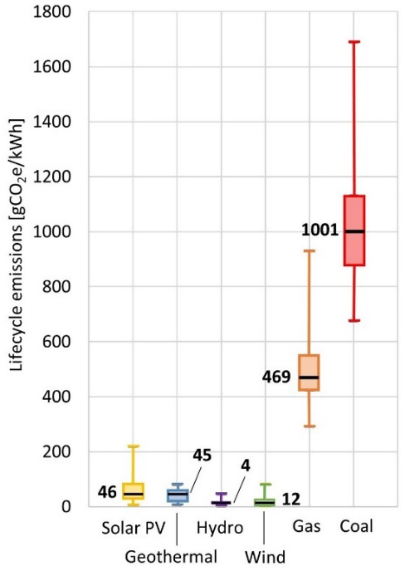

Figure 3: Box and whisker plots comparing lifecycle emissions between different energy types (see Table 2).

2.3 Factors affecting operational geothermal emissions intensity

Operational emissions from geothermal power stations are quite variable to a certain degree. Emissions can increase or decrease over time (Figure 4).

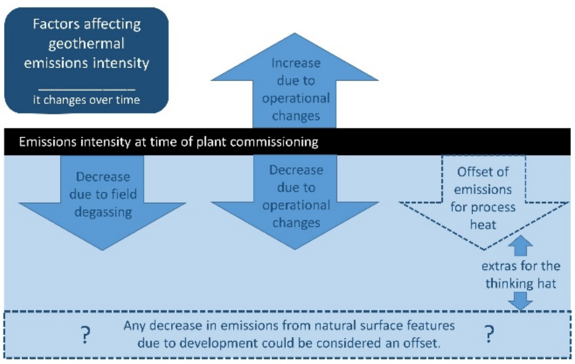

Figure 4: Schematic illustrating factors affecting geothermal emissions intensity.

There is a tendency for emissions to decrease due to degassing of the reservoir fluid over time. This is seen for example in the decline in emissions intensity of Rotokawa and NAP power stations over time, due to degassing of the Rotokawa geothermal field (Figure 5).

Emissions can either increase or decrease for a variety of operational reasons. A common reason is new wells being drilled, or well switching, as not all geothermal wells produce the same level of emissions. For example at Te Huka power station, changes in proportion of fluid coming from the two production wells results in both a drop and then a rise in emissions intensity (Figure 6).

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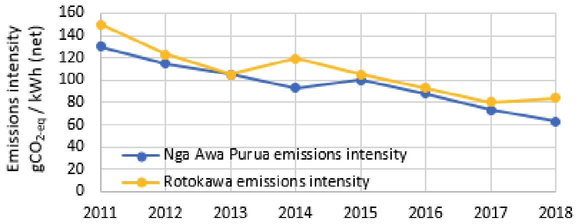

Figure 5: Example of emissions decreasing due to degassing of the Rotokawa geothermal field (McLean and Richardson, 2019).

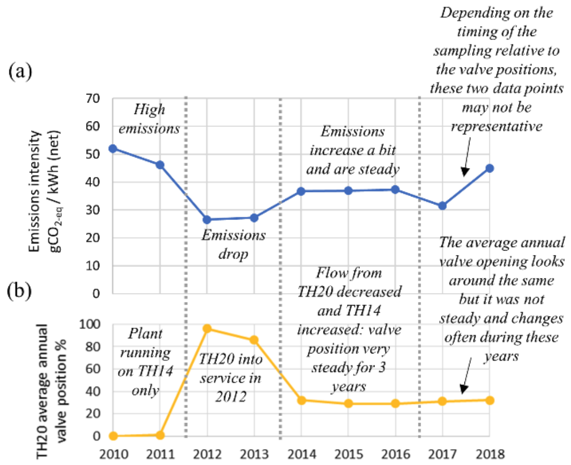

Figure 6: Te Huka power station (a) Emissions intensity; (b) TH20 valve position (McLean and Richardson, 2019).

Field degassing and operational changes are relatively easy to identify. Another important factor to consider for geothermal emissions intensity, which is more difficult to quantify, is that a by-product of geothermal electricity generation is large volumes of hot water, which can be used for direct use applications such as industrial process heat. Because the energy is never converted into electricity, this is not accounted for in the usual gCO_2e/kWh as the kWh is kilowatt hours of electricity energy. The potential offset of emissions by industrial process heat is explored in this paper.

2.4 Emissions reporting methodology

The methodology for measuring emissions under New Zealand's ETS regulations has been previously described (McLean and Richardson, 2019) and are summarised below.

The main Climate Change (Stationary Energy and Industrial Processes) Regulations 2009 (Schedule 2, Table 6), has allocated each station a default emissions factor (DF) which is the fraction of CO_2e present in the steam (tCO_2e/t steam). This emissions factor (EF) is multiplied by the total annual mass of steam (tonnes) to calculate the total annual mass of CO_2e (tonnes) (Equation 1).

$$mass\ CO_2(t) = EF\ (tCO_{2e}/t\ steam) \times mass\ steam\ (t) \qquad (1)$$

However, most geothermal power companies have applied for and been granted unique emissions factors (UEF) for their stations, under the Climate Change (Unique Emissions Factors) Regulations 2009 (Clauses 14-17). Reporting emissions under this regulation does require extensive testing of each steam supply, in order to measure the actual GHG emissions. Nevertheless, this approach is often preferred when the actual emission factor drops below the default emissions factor (DF).

Some power stations also take advantage of the provisions of Regulation 16, sub-clause 2, which allows an adjustment to be made to the UEF by accounting for CO_2 and CH_4 contained in condensates which are reinjected back into the geothermal field. Hence, the factor EF_R can be calculated using (Equation 2):

$$EF_R = mCO_2 + (mCH_4 \times 25) \qquad (2)$$

Where: EF_R is the emissions factor for the condensate being reinjected, expressed in tCO_2e/t condensate, and mCO_2 and mCH_4 are the mean mass fractions of CO_2 and CH_4 in the condensate.

Hence, the mass of CO_2e in each condensate stream is obtained by multiplying the factor EF_R by the tonnes of that stream, which is then subtracted from the mass of CO_2e calculated for the incoming steam supplies. The net emissions are still reported as a UEF, in terms of tCO_2e /t steam. Figure 7 illustrates this procedure for a typical power station.

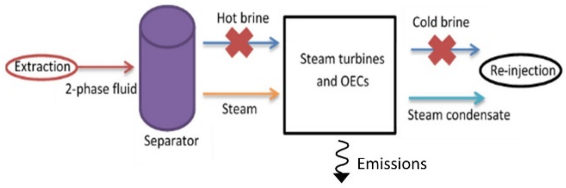

Figure 7: Schematic representation of the GHG mass flows into a geothermal station and their outflows as emissions or as gases reinjected in the condensate streams.

Emissions intensity (gCO_2e/kWh, which is the same as tCO_2e /GWh) is a measure of how much greenhouse gas is emitted per unit of electrical energy generated (Equation 3).

$$Emissions\ intensity = \frac{mass\ CO2e\ (g)}{energy\ (kWh\ net)} \qquad (3)$$

This metric is useful for comparison between different types of power stations, as it is independent of the fuel source.

3.0 POWER GENERATION EMISSIONS

3.1 Data for calendar year 2019

The emissions intensity for each of the 14 geothermal power stations in Table 1 is presented in Table 3, including the data from which emissions intensity is calculated. The MW-weighted average emissions intensity for calendar year 2019 is 73 gCO_2e/kWh. The median emissions intensity for 2019 is 60 gCO_2e/kWh, with a lower and upper quartile range of 44 – 85 gCO_2e/kWh.

Table 3: Geothermal power stations operational emissions intensity for 2019.

Power Station	Operated by	Geothermal Field	Emissions factor	Total mass of steam	Average generation	Emissions intensity	Annual emissions	Emissions rate
			t CO_2e/ t steam	t steam	MWe (net)	gCO_2e/ kWh(net)	t CO_2e	t CO_2e / day
Wairakei A&B&binary	Contact	Wairakei	0.0024	9,201,721	105	24	22,084	60
Te Mihi	Contact	Wairakei	0.0046	11,509,171	157	38	52,367	143
Poihipi	Contact	Wairakei	0.0049	3,070,059	42	41	15,043	41
Ohaaki	Contact	Ohaaki	0.0333	2,927,073	37	299	97,472	267
Te Huka	Contact	Tauhara	0.0078	1,233,832	22	51	9,624	26
Rotokawa	Mercury	Rotokawa	0.0137	1,720,821	30	88	23,575	65
Nga Awa Purua (NAP)	Mercury	Rotokawa	0.0089	7,431,208	128	59	66,138	181
Mokai	Mercury	Mokai	0.0046	5,360,957	92	30	24,500	67
Ngatamariki	Mercury	Ngatamariki	0.0111	4,042,308	84	61	44,870	123
Kawerau (KGL)	Mercury	Kawerau	0.0171	6,800,827	102	130	116,158	318
TOPP1	NTGA	Kawerau	0.0106	936,430	21	53	9,926	27
TAOM	Eastland	Kawerau	0.0139	1,035,031	22	75	14,387	39
GDL	Eastland	Kawerau	0.0155	231,376	6	70	3,586	10
Ngawha (all plants)	Top Energy	Ngawha	0.0827	730,660	22	312	60,389	165
					MW-weighted average	**73**	**Σ 560,119**	**Σ 1534**
					Median	**60**		
					25th percentile	**44**		
					75th percentile	**85**		

3.2 Trends over the past 5 years

The year 2014 was the last major change in generation capability in NZ with the commissioning of the 166 MW Te Mihi power station. Major additions such as this are effectively operational changes to the overall generation system, which can increase or decrease operational emissions. In the absence of such changes, then tendency of geothermal emissions to decline with time due to field degassing can be observed. Over the time period 2015 – 2019 no large power stations were commissioned or decommissioned. The overall geothermal emissions intensity over that time period is shown in Table 4 and Figure 8, which shows a decline in both the weighted average and median.

Table 4: Statistics on emissions intensity 2015–2019 (see Figure 8, data from McLean and Richardson, 2019).

Year	2015	2016	2017	2018	2019
# power plants	11	11	12	12	14
MW-weighted av	91	89	78	76	73
Minimum	15	15	24	21	24
25th percentile	32	36	32	45	44
Median	93	80	63	62	60
75th percentile	139	122	91	94	85
Maximum	376	463	375	341	312

The number of power stations for which data is available increased from 11 to 12 in 2017 with the inclusion of TOPP1, and increased again to 14 in 2019 with the inclusion of TAOM and GDL (see Table 1 for power stations details). The inclusion of these three power stations has negligible impact on the overall emissions intensity and trends, as the plants are small and their emissions intensities are quite mid-range. For example in 2019 the emissions intensities for TOPP1, TAOM and GDL are 53, 75 and 70 gCO_2e/kWh and the MW-weighted average is 73 gCO_2e/kWh.

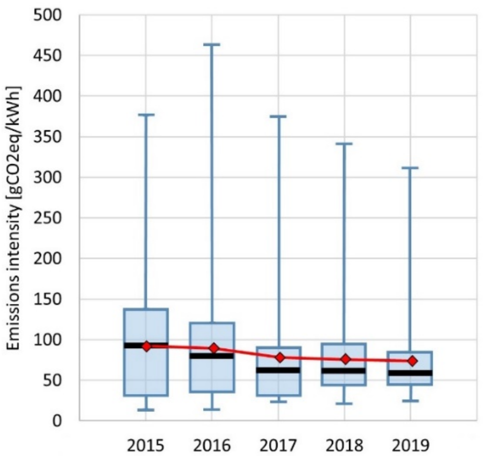

Figure 8: Box and whisker plots and MW-weighted average emissions intensity over the 5 years 2015 – 2019 (data from Table 4).

3.3 Example of accounting for CO_2e in condensate

Mercury's Ngatamariki station provides a recent example of a station which changed its UEF calculation method, to incorporate accounting for GHGs in the reinjected condensate streams (as allowed for in the regulations). Prior to 2019, no account was taken of these injected gases. This large binary station operates 4 identical 25 MW Ormat (OEC) units. Rather than directly measuring the gases in each of the 4 condensate streams (and summing), a mass balance approach has been used, as follows:

GHG emissions = GHGs in – GHGs reinjected

GHGs in = steam from Separator × conc. GHGs

GHGs reinjected =
(Brine + Condensate) flow to reinjection × conc. GHGs
- Brine flow from Separator × conc. GHG

Hence, Ngatamariki measures the GHG concentrations in the incoming brine stream and those in the outgoing (combined) brine + condensate stream, which is reinjected. Both the brine and reinjection flows are independently measured by separate flowmeters and the difference between these two measurements can be checked against the sum of the steam flows to each OEC.

Therefore, this mass balance method determines (by difference) the GHGs from all 4 condensate streams combined. This approach has produced more consistent results than by direct measurement of gases in the condensates themselves. It also involves fewer samples, since the 4 condensate streams would each require individual sampling (because the brine and condensate from each OEC are mixed separately, before being combined at the reinjection pumps).

The new UEF for Ngatamariki (0.0111 t CO_2e/t steam) was determined for the 2019 calendar year. If this UEF had been calculated without accounting for GHG reinjection it would have been 0.0127 t CO_2e/t steam; a difference of 13%.

For binary stations which condense geothermal steam at an elevated pressure, it can be worthwhile to measure and account for the reinjected CO_2e. This is due to the relatively high NCG partial pressures in their vaporisers, allowing higher levels of gases to dissolve in the condensates. However, for flash steam stations, with direct contact condensers, most of the CO_2 and CH_4 in the steam gets stripped out and vented to atmosphere through the gas extraction system. Therefore, the amount of CO_2e in the reinjected condensate is normally very low and accounting for it would have little impact on the UEF result.

4.0 DIRECT USE EMISSIONS

4.1 Overview

Examples of geothermal direct use emissions and displaced emissions are presented in this section to highlight the potential of geothermal direct use in decarbonising process heat in New Zealand.

Direct use of geothermal energy is the use of the geothermal steam and/or separated geothermal water as process heat. In New Zealand, geothermal energy is directly used as process heat for large industrial processes either as a primary supply or as a "cascade" use where the process uses geothermal fluids discharged from a previous process. The use of geothermal energy as process heat displaces fossil-based fuels required to generate the same amount of steam or hot water. In cascade systems with power generation as the previous process, the use of the discharge fluids as process heat would likely reduce the overall emissions intensity of the power plant and the cascade system, and further displace emissions from fossil-based fuels that would otherwise be used.

4.2 Kawerau Industrial Complex

The Kawerau Industrial Complex located in the Bay of Plenty is the largest and one of the longest-running industrial geothermal process heat users in the world. Since the 1950's, the complex has been home to a collection of pulp, paper, wood products, timber, and dairy processing industries that are supported by geothermal process heat supplied by Ngati Tuwharetoa Geothermal Assets Ltd. (NTGA) from the Kawerau Geothermal Field. The process heat supplied to the industrial complex, the annual emissions and the emissions intensity are shown in Table 5. Also in Table 5 is an estimate of the emissions that would be produced if Natural gas was being used as an energy source instead of geothermal.

Figure 9 compares the actual annual geothermal emissions from the Kawerau industrial complex with the emissions estimated if Natural gas was used. It can be seen that on average nearly 300,000 tonnes of CO_2e emissions are displaced every year by using geothermal energy at the Kawerau Industrial Complex (87% of potential emissions using natural gas).

When the thermal energy in Table 5 is converted from GJ to kWh(thermal), an emissions intensity can be calculated to compare to the values from electricity generation. The emissions intensity (thermal) is 25 gCO_2e/kWh(thermal) for all years in Table 5. The emissions intensity for electricity generation at Kawerau geothermal field are (from Table 3):

- KGL = 130 gCO_2e/kWh(net)
- TOPP1 = 53 gCO_2e/kWh(net)
- TAOM = 75 gCO_2e/kWh(net)
- GDL = 70 gCO_2e/kWh(net)

Table 5: Kawerau industrial complex geothermal direct use operational emissions for 2019 (see Figure 9).

Year	Total Mass of Steam	Emissions Factor	Total thermal energy supplied	Geothermal annual emissions	Emissions intensity	Estimated emissions using natural gas*	Displaced emissions
	t (tonnes)	tCO2e/t (2phase)	GJ	tCO2e	tCO2e/GJ	tCO2e	tCO2e
2013	2,003,852	0.0194	5552674	38,875	0.007	299,844	260,970
2014	2,220,571	0.0194	6153202	43,079	0.007	332,273	289,194
2015	2,267,534	0.0194	6283337	43,990	0.007	339,300	295,310
2016	2,398,825	0.0194	6647144	46,537	0.007	358,946	312,409
2017	2,412,647	0.0194	6685445	46,805	0.007	361,014	314,209
2018	2,279,785	0.0194	6317284	44,228	0.007	341,133	296,906
2019	2,279,994	0.0194	6317863	44,232	0.007	341,165	296,933

*Estimate based on an industrial Natural Gas emission of 54 kgCO_2e/GJ (MFE, 2019) replaced by geothermal process heat

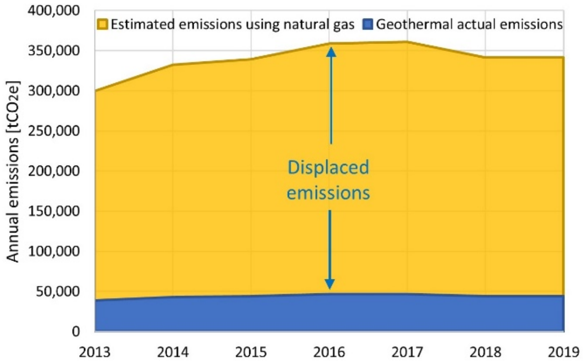

Figure 9: Kawerau industrial complex: comparison of actual annual geothermal emissions, and estimated emissions if natural gas was used as an energy source (data from Table 5).

The emissions intensity (thermal) at Kawerau geothermal field is much less than for electricity generation. This is expected as there is significant energy lost in the conversion of thermal energy to electrical energy. The worldwide average conversion efficiency for all types of geothermal power stations is only 12% (from thermal energy in the fluid coming out of the ground to net electrical energy out of the power station) (Zarrouk and Moon, 2014).

4.3 Tenon Timber Drying

The Tenon timber processing facility is located in Taupo, New Zealand, adjacent to the Tauhara geothermal field. The processing at Tenon includes the operations of timber drying kilns. These kilns were originally fueled with natural gas, prior to changing over to the use of geothermal fluid in 2006. Tenon receives two phase geothermal fluid from production facilities operated by Contact Energy in the Tauhara geothermal field. After heat is extracted from the fluid at Tenon, the fluid is cascaded to the nearby Nature's Flames pellet manufacturing facility, which commenced using geothermal fluid in 2019. At Nature's Flame additional heat is extracted from the fluid prior to reinjection into the Tauhara geothermal field.

The Tenon drying facility has the capacity to utilize up to 27MW of geothermal heat, and in 2019 utilised 396TJ of geothermal energy as shown in Table 6. From Table 6 and Figure 10 it can be seen that the use of geothermal energy at Tenon reduces CO2e emissions, on average by almost 20,000 tCO2e per year, compared to using natural gas (93% reduction compared to natural gas).

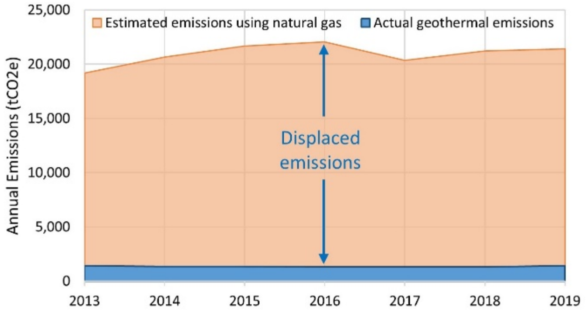

Figure 10: Tenon: comparison of actual annual geothermal emissions, and estimated emissions if natural gas was used as an energy source (data from Table 6).

The energy emissions intensity using geothermal energy at Tenon is significantly lower at 3.5kgCO_2e/GJ or 12.5 gCO_2e/kWh(thermal) than for power generation from the same geothermal field (51 gCO_2e/kWh(net) at Te Huka power station, Table 3). This is due to the lower conversion efficiency of thermal to electric energy as described in Section 4.2.

The additional use of the Tenon geothermal fluid at Nature's Flame, prior to reinjection (cascade use) will further reduce the emissions intensity of direct use geothermal at the Tauhara geothermal field. In this cascade use, the geothermal fluid from Tenon will be further processed at Nature's Flame to extract more energy from the fluid, with no increase in either fluid use or carbon dioxide emissions.

5.0 MBIE EMISSIONS DATA

New Zealand has a long history of utilisation of geothermal energy in direct use inductrial applications. However while the use of geothermal energy for electricity generation has increased significantly since 2008 (McLean and Richardson, 2019), this is not the case for direct use applications. New Zealand's use of geothermal energy for direct use applications is similar today to the 1990s, and has reduced from 2008 levels as shown in Figure 11. Direct use of geothermal energy is a relatively under-utilised resource with great potential to aid in New Zealand's emission reduction targets.

Table 6: Tenon Geothermal Energy use and associated carbon emissions 2013-2019.

Year	Total Mass of Steam	Emissions Factor	Total thermal energy supplied	Geothermal annual emissions	Emissions intensity	Estimated emissions using natural gas*	Displaced emissions
	t (tonnes)	tCO2e/t (2phase)	GJ	tCO2e	tCO2e/GJ	tCO2e	tCO2e
2013	1784010	0.0008	354976	1427	0.0040	19169	17741
2014	1663925	0.0008	382428	1331	0.0035	20651	19320
2015	1660547	0.0008	401329	1328	0.0033	21672	20343
2016	1644420	0.0008	408235	1316	0.0032	22045	20729
2017	1608487	0.0008	377222	1287	0.0034	20370	19083
2018	1627286	0.0008	393083	1302	0.0033	21226	19925
2019	1764021	0.0008	396453	1411	0.0036	21408	19997

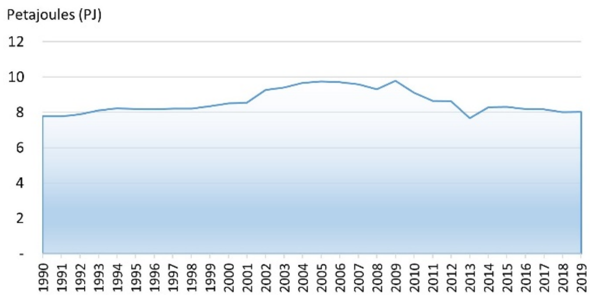

Figure 11: Geothermal direct use 1990-2019 (MBIE Renewables Statistics, 2020).

Geothermal energy is predominantly used for electricity generation in New Zealand as shown in Figure 12. Use of geothermal energy for direct use applications in New Zealand was approximately 8 PJ (equivalent to an average of ~254 MWt) in 2019. While geothermal energy use for electricity generation was approximately 186 PJ, resulting in ~7,393 GWh of electricity (or an average of 844 MWe).

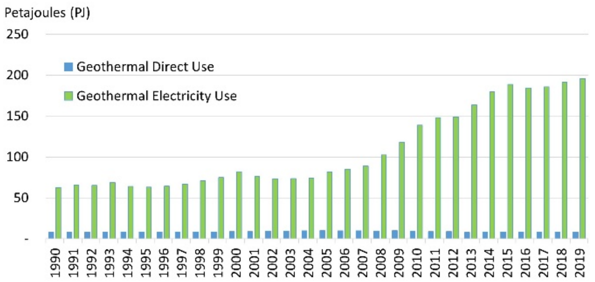

Figure 12: Geothermal energy use: direct use and electricity generation 1990-2019 (MBIE Renewables Statistics, 2020).

6.0 CONCLUSIONS

- For geothermal electricity generation the MW-weighted average emissions intensity from 14 power stations for the calendar year 2019 is 73 gCO_2e/kWh(net).
- This emissions intensity has been declining every year for the past 5 years from 91 gCO_2e/kWh in 2015.
- The provision in the UEF regulations to account for CO_2e reinjected back into the reservoir in condensate can make a significant difference in the case of binary power stations. At Ngatamariki this reduced the emissions factor of the power station by 13%.
- For geothermal industrial direct use at Kawerau Industrial Complex the emissions intensity is 7 $kgCO_2e/GJ$, while at Tenon the emissions intensity is 3.5 $kgCO_2e/GJ$.
- The emissions intensities for Kawerau and Tenon are equivalent to 25 and 12.5 gCO_2e/kWh respectively, where the kWh are thermal energy rather than electrical energy. This is significantly lower than the emissions intensity for electricity generation due to the low conversion efficiency of geothermal power plants.
- The use of geothermal energy at the Kawerau Industrial Complex and Tenon combined offsets around 320,000 tCO_2e per year on average (around 90%) as compared to the likely alternative energy source natural gas.
- Geothermal energy in New Zealand is predominantly used for power generation, with direct use utilising only a small proportion of the total geothermal energy used.
- There has been no growth in geothermal direct use since the 1990s and it has great potential to aid in the decarbonisation of New Zealand.

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