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# Analysis of Time Dependent Valuation of Emission Factors from the Electricity Sector

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## 1. Introduction

In recent years, energy consumption and associated Greenhouse Gas (GHG) emissions and their potential effects on the global climate change have been increasing. Climate change and global warming has been the subject of intensive investigation provincially, nationally, and internationally for a number of years. While the complexity of the global climate change remains difficult to predict, it is important to develop a system to measure the amount of GHG released into the environment. Thus, the purpose of this chapter is to demonstrate how several methods can accurately estimate the true GHG emission reduction potential from renewable technologies and help achieve the goals set out by the Kyoto Protocol - reducing fuel consumption and related GHG emissions, promoting decentralization of electricity supply, and encouraging the use of renewable energy technologies.

There are several methods in estimating emission factors from facilities: direct measurement, mass balance, and engineering estimates. Direct measurement involves continuous emission monitoring throughout a given period. Mass balance methods involve the application of conservation equations to a facility, process, or piece of equipment. Emissions are determined from input/output differences as well as from the accumulation and depletion of substances. The engineering method involves the use of engineering principles and knowledge of chemical and physical processes (EnvCan, 2006). In Guler (2008) the method used to estimate emission factors considers only the total amount of fuel and electricity produced from power plants. The previous methodology does not take into consideration the offset cyclical relationship, daily and yearly, between electricity generated by renewable technologies. It should be noted that none of the methods mentioned above include seasonal/daily adjustments to annual emission factors. Specifically, the proposed research would include analyzing existing methods in calculating emission factors and attempt to estimate new emission factors based on the hourly electricity demand for the Province of Ontario.

In this Chapter, several GHG emission factor methodology was discussed and compared to newly developed monthly emission factors in order to realize the true $CO_2$ reduction potential for small scale renewable energy technologies. The hourly greenhouse gas emission factors based on hour-by-hour demand of electricity in Ontario, and the average Greenhouse Gas Intensity Factor ($GHGIF_A$) are estimated by creating a series of emission factors and their corresponding profiles that can be easily incorporated into simulation software (Gordon & Fung, 2009). The use of regionally specific climate-modeled factors, such as those identified, allowed for a more accurate representation of the benefits associated with GHG reducing technologies, such as photovoltaic, wind, etc. This chapter will demonstrate that using Time Dependent Valuation (TDV) emission factors provide an upper limit while using hourly emission factors provide a lower limit. These factors based on hour-by-hour electricity demand data for the Province of Ontario will provide renewable technology researchers with the tools necessary to make informative decisions concerning the selection of renewable technologies.

## 2. Traditional methodologies to estimate GHG emission factors from the electricity generation sector

There are two main methods to estimate pollutant and GHG emission Factors from the electricity generation sector: 1) direct measurement or 2) estimation. Direct measurement is considered to be the most accurate since it uses real-time data from the generation sector. However, these data are not readily available and historically, GHG emissions have been estimated from fossil fuel and process-related activities. Estimation is the method used by several countries when preparing their national GHG inventories (ICPP, 1997). In the past, GHG emissions from the electricity generation sector were calculated using the Average GHG Intensity Factor ($GHGIF_A$) (Guler et al., 2008). The $GHGIF_A$ is the amount of GHG emissions per kWh electricity produced. This method assumes that the reduction in electricity demand is uniformly distributed amongst all types of electricity generation. For example, the $GHGIF_A$ estimated in 1993 was 136 g/kWh for the Province of Ontario. Table 1 shows the $GHGIF_A$ values for the years 2004, 2005, and 2006 for the Province of Ontario from the electricity generation sector (EnvCan, 2006).

| **Annual $GHGIF_A$ (g of $CO_2$/kWh)** | | |
|---|---|---|
| **2004** | **2005** | **2006** |
| 200 | 221 | 189 |

Table 1. Annual Emission Factors

The combustion of fossil fuels produces several major greenhouse gases. The amount of emissions from $CO_2$, $CH_4$, $SO_2$, NO, and $N_2O$ varies from one fuel to another, and they are calculated using emission factors. These emission factors are commonly expressed in tons of $CO_2$ per MWh or grams per kWh of electricity produced (Gordon & Fung, 2009).

## 3. Accuracy of GHG emission factors

It is necessary to develop methodology to accurately estimate GHG emissions from the electricity generation sector in order to facilitate the implementation of awareness programmes and renewable technologies which are supported with information on current energy usage. It should be noted that the time of use of electricity is related to GHG emissions generated throughout the day (MacCracken, 2006). Therefore, prior to implementing these programmes and renewable technologies, it is necessary to have an accurate model for emission and electricity estimation.

The Province of Ontario has a very unique mix of electricity production technologies. Hydro and nuclear technologies are generally considered to be base load power (IESO, 2006), since they both operate at constant load and fossil generating plants are typically used to handle fluctuations in electricity demand throughout the day. The $GHGIF_A$ estimate is based on the generation mix for the Province of Ontario (nuclear, hydro, coal, etc.) and is not adequate to account for most of the GHG emissions from the electricity generation sector, which mainly come from fossil generating stations. Therefore, in order to estimate and phase out fossil completely, a different emission factor needs to be developed. In response to this, a second intensity factor ($GHGIF_M$) was developed. The $GHGIF_M$ intensity factor was calculated by dividing the net fossil fuel plant electricity production by the total equivalent $CO_2$ emissions. The value estimated for 1993 was 903.7 t/GWh (Guler et al., 2008). This emission factor assumes that all electricity consumption is provided by fossil plants. This would be beneficial if trying to replace all fossil plants with renewable technologies. However, both of the methodologies neglect to show hourly changes in emission factors.

## 4. GHG emission factor methodologies

Renewable technologies (solar and wind) have become an accepted form of generating electricity and heat in the Province of Ontario. There are many advantages in using solar and wind energy such as taking advantage of an abundant source of free energy (sun and wind), as well as being an effective method in reducing GHG emissions. However, the electricity produced by a renewable technology, such as a photovoltaic (PV), or micro-wind turbine and the availability of solar and wind energy, changes throughout the day. Therefore, an hourly GHG emission factor is needed to truly understand the impact that renewable technologies have on emissions since there is a divergence between when electricity can be generated and when it is required.

Some of these renewable technologies that are being used in the residential and commercial sectors include photovoltaic, micro-wind turbines, ground source heat pumps, and advance solar thermal technologies. Continuous improvement of these technolgies have promoted the development of hybrid homes. The combination of several of these technologies together will result in end-use energy savings and GHG emission reductions. However, prior to implementing any of these technologies, it is necessary to have an accurate estimation of the true reduction potential of GHG emission factors in order to have a clear understanding of the saving potentials associated with renewable technologies.

Currently, Environment Canada uses fuel consumption data from the electricity sector in order to estimate emissions. However, this method can be simplistic and time consuming as well as difficult to use due to the unavailability of certain types of data. Moreover, this method only provides an annual average emission factor which does not reflect the cyclic behaviour of emission factors throughout the day. In 2005, Time Dependent Valuation (TDV) was introduced as a viable method to provide the aformentioned data (MacCracken, 2006). This method was adopted by California as an energy efficient standard for residential and non-residential buildings. Time dependent valuation views energy demand differently depending on the time of use (MacCracken, 2006). California has been able to determine the societal impacts of time of use energy consumption. As a result, this method of analysis would allow for a more accurate representation of the potential reduction of GHGs by using renewable technologies.

This following sections will discuss existing emission factor methodolgy and introduce monthly TDV emission factor methodology.

### 4.1 Hourly GHG emission factors

Different emission factors have been developed in the past: hourly, seasonal, and seasonal time dependent emission factors (Gordon & Fung, 2009). This chapter will introduce monthly TDV emission factors and compare them to existing emission factors. GHG emissions from the electricity generation industry have been calculated using the Average GHG Intensity Factor ($GHGIF_A$) (Guler et al., 2008). This value represents the amount of GHG emissions produced as a result of generating one kWh of electricity. The $GHGIF_A$ for 2004, 2005, and 2006 were estimated using the methodology mentioned above in conjunction with the electricity output information from Gordon & Fung (2009). It should be noted that the emission factor for $CO_2$ does not take into consideration $CH_4$ and $N_2O$ since these are considered to represent negligible amounts in comparison to $CO_2$, $SO_2$, and NO (Gordon & Fung, 2009). This section will only focus on $CO_2$ emissions since the majority of pollutants are in this form and the purpose of this chapter is to demonstrate emission factor methodology.

The GHG emissions due to coal fired and natural gas plants were determined using Equation 1 (Gordon & Fung, 2009).

$$HCO_2 = (HECOAL)(i) + (HEOTHER)(j) \tag{1}$$

Where,

$HCO_2$ = Hourly $CO_2$ production (kg)

HECOAL = Hourly Electricity generated by Coal plants

HEOTHER = Hourly Electricity generated by Other (natural gas, etc.)

i = $CO_2$ emission factor (OPG, 2006)

j = Environment Canada natural gas emission factor (Environment Canada, 2006)

Currently, there is a hourly greenhouse gas emission factor ($NHGHGIF_A$) model which is based on the hour-by-hour demand of electricity in Ontario from nuclear, fossil, hydro, natural gas and wind (Gordon & Fung, 2009). The $NHGHGIF_A$ was calculated by dividing the hour-by-hour emissions from $CO_2$ by the hour-by-hour total electricity generated from the different sources (Gordon & Fung, 2009). It should be noted that the new greenhouse gas intensity factor ($NGHGIF_A$) was estimated by taking the average of the hourly emission factors for each season. The $NGHGIF_A$ was determined using Equations 2 and 3 (Gordon & Fung, 2009).

$$NHGHGIF_A = \frac{HCO_2}{HEGTOTAL} \tag{2}$$

$$NGHGIF_A = \sum_{i=1}^{8760} \frac{NHGHGIF_{Ai}}{8760} \tag{3}$$

Where,

$NHGHGIF_A$= New Hourly Greenhouse Gas Intensity Factor ($g\ CO_2/kWh$)

$NGHGIF_A$ = New Greenhouse Gas Intensity Factor ($g\ CO_2/kWh$)

$HCO_2$ = Hourly $CO_2$ production (g)

HEGTOTAL= Hourly Electricity Generated Total (kWh)

i = hour

The values obtained for the $NGHGIF_A$ were compared for the years 2004, 2005, and 2006 (Gordon & Fung, 2009).

### 4.2 Seasonal time dependent valuation emission factors

Currently, there are several TDV profiles (annual and seasonal) for greenhouse gases for the Province of Ontario in the public domain (Gordon & Fung, 2009). As discussed in Gordon & Fung (2009), the hourly GHG emissions data has been compiled to developed different types (annual and seasonal) of emission factors. The latter has shown that emission factors vary with electricity demand (MacCracken, 2006). It has also been observed that shape and magnitude of GHGIF profiles varies with time of day, year, climate, and geographical location (Gordon & Fung, 2009). Hourly emission data does exist from the power generating sector, but is not publicly available. Therefore, rather than using a single annual GHGIF value for the entire year, seasonal GHGIF profiles based on the electricity demand for the Province of Ontario were developed by Gordon & Fung (2009).

The approach detailed below was used in order to provide a better method to properly estimate greenhouse gases within the Province of Ontario. Hourly electricity consumption data from the IESO and hourly GHG emission factors estimated in the previous section were used to determine Seasonal TDV emission factor profiles for the years 2004, 2005, and 2006. These profiles were calculated using Equation 4 (Gordon & Fung, 2009).

$$\text{Seasonal TDV NGHGIF}_A = \frac{\sum_{i=1}^{N} \text{NGHGIF}_A(h_j)}{N} \quad (4)$$

Where,

Seasonal TDV $NGHGIF_A$ = Seasonal Time Dependent Valuation New Greenhouse Gas Intensity Factor (g $CO_2$ /kWh)

$N$ = number of days in the season

$i$ = day number

j = hour number

The hourly and averaged values obtained for the seasonal TDV $NGHGIF_A$ were compared for the years 2004, 2005, and 2006.

### 4.3 Monthly time dependent valuation emission factors

Currently, there are several TDV profiles (annual and seasonal) for greenhouse gases for the Province of Ontario in the public domain (Gordon & Fung, 2009). However, monthly GHG emission factors are not available. Therefore, this section will provide renewable technology professionals with monthly TDV profiles for estimating emissions.

The approach detailed below was used in order to provide a better method to properly estimate greenhouse gases within the Province of Ontario. Hourly electricity consumption data from the IESO and hourly GHG emission factors estimated in Section 4.1 were used to determine monthly TDV NGHGIF profiles for the years 2004, 2005, and 2006. These profiles were calculated using Equation 5 for each hour in a day.

$$\text{Monthly TDV NGHGIF}_A = \frac{\sum_{i=1}^{N} \text{NGHGIF}_A(h_j)}{N} \quad (5)$$

Where,
Monthly TDV $NGHGIF_A$ = Monthly Time Dependent Valuation New Greenhouse Gas Intensity Factor (g $CO_2$ /kWh)

N = number of days in the month
i = day number
j = hour number

The hourly and average values obtained for the monthly TDV $NGHGIF_A$ were compared for the years 2004, 2005, and 2006.

## 5. Test case scenario

The following test case provides an example on how the different GHG emission factors can be used to demonstrate the cyclic behaviour of emission factors througout the day, month, season, and year. In addtion, the test cases also show the beneficial attributes associated with renewable technologies.
Transient System Simulation Tool (TRANSYS) building energy simulation software can be used to perform highly complex thermal analysis, HVAC analysis and electrical power flow simulations.
Tse et al. (2008) performed simulations, using TRANSYS, which included the use of PV on the computational model for a townhouse that would be built in the Annex area in Toronto.
TRANSYS was used to simulate and help optimize the performance of the home, as well as the different systems that would be implemented. The systems that were analyzed consist of a solar domestic hot water system, a photovoltaic system (6.25 kW), and a ground source heat pump. Hourly annual simulations were run to demonstrate the potential electricity contribution and emission savings from PV. This data has been utilized in combination with the hourly, seasonal and monthly TDV emission factors discussed in the previous sections to estimate the reduction potential of GHG emissions by the use of PV technology.

## 6. Results

### 6.1 Hourly GHG emission factors

The results for the $NGHGIF_A$ for the years 2004, 2005, and 2006 are shown in Table 2 (Gordon & Fung, 2009).

| Season | $NGHGIF_A$ (g of $CO_2$/kWh) | | |
|---|---|---|---|
| | **2004** | **2005** | **2006** |
| Annual | 208 | 221 | 189 |
| Winter | 248 | 231 | 196 |
| Spring | 164 | 205 | 164 |
| Summer | 174 | 241 | 214 |
| Fall | 244 | 205 | 190 |

Table 2. Hourly annual and seasonal average GHG emission factors

Table 2 shows a large variance between emission factors throughout the year and from year to year. Clearly, the use of hourly data is necessary to accurately estimate the GHG reduction potential from renewable technologies.

### 6.2 Annual time dependent valuation emission factors

Table A-1 in Appendix A shows the annual TDV emission factors (Gordon & Fung, 2009). It can be observed that emissions throughout the day vary considerably. It should be noted that the maximum TDV values for the years 2004, 2005, and 2006 occurred at 1 p.m.

Table 3 shows the annual average TDV GHG emission factors. These values were obtained by using the annual TDV GHG emission factors in Table A-1 in Appendix A.

| | $NGHGIF_A$ (g of $CO_2$/kWh) | | |
|---|---|---|---|
| | **2004** | **2005** | **2006** |
| Annual | 224.2 | 237.3 | 207.2 |

Table 3. Annual average TDV GHG emission factors

### 6.3 Seasonal time dependent valuation emission factors

Seasonal TDV emission factors were also developed for the years 2004, 2005, and 2006 (Gordon & Fung, 2009) as shown in Table 4. Table A-2 and A-3 in Appendix A show the seasonal TDV emission factor profiles for 2004, 2005, and 2006. The following can be observed from Table 4:

- For the year 2004 – the highest emission factors were in the fall (afternoons) and winter (early mornings).
- For the years 2005 and 2006 the highest emission factor was observed in the summer.

| **Season** | $NGHGIF_A$ (g of $CO_2$/kWh) | | |
|---|---|---|---|
| | **2004** | **2005** | **2006** |
| Winter | 264.7 | 246.4 | 213.4 |
| Spring | 182.0 | 221.5 | 179.9 |
| Summer | 190.1 | 256.6 | 229.5 |
| Fall | 259.8 | 224.8 | 206.1 |

Table 4. seasonal average TDV GHG emission factors

### 6.4 Monthly time dependent valuation emission factors

Monthly TDV emission factors were developed for the years 2004, 2005, and 2006 as shown in Table 5. Table A-4 in Appendix A shows the monthly TDV emission factor profiles for 2004, 2005, and 2006. The following can be observed from Table 4:

- For the year 2004 – the highest and lowest emission factor was observed in January and May, respectively.
- For the year 2005 – the highest and lowest emission factor was observed in August and May, respectively.
- For the year 2005 – the highest and lowest emission factor was observed in July and April, respectively.

This section discussed the different types of existing and new GHG emission factors for the years 2004, 2005, and 2006. The hourly emission factor proved to be the most accurate and monthly TDV were more accurate than using the seasonal average value.

However, it is the user's responsability to select the appropiate emission factor depending on the type of analysis conducted. In certain cases it might be more practical to employ seasonal, time dependent valuation (seasonal or monthly), or annual average emission factors to estimate $CO_2$ emissions without sacrificing much accuracy.

| Season | $NGHGIF_A$ (g of $CO_2$/kWh) | | |
|---|---|---|---|
| | 2004 | 2005 | 2006 |
| January | 284.3 | 242.2 | 215.1 |
| February | 259.3 | 228.9 | 198.8 |
| March | 214.5 | 230.4 | 180.8 |
| April | 171.3 | 209.6 | 125.5 |
| May | 144.0 | 183.2 | 164.8 |
| June | 156.0 | 238.7 | 216.9 |
| July | 166.4 | 236.8 | 233.9 |
| August | 179.4 | 245.4 | 205.3 |
| September | 210.9 | 222.1 | 188.0 |
| October | 265.0 | 206.0 | 193.6 |
| November | 242.4 | 192.9 | 191.1 |
| December | 199.9 | 214.3 | 155.4 |

Table 5. Monthly TDV average GHG emission factors

### 6.5 Test case study

The electricity generated by the PV simulations performed for 2005 is illustrated in Figure 1 (Tse et al., 2008). It can be observed that PV electricity generation was the highest during the summer.

Table 6 shows the total electric power generated by PV for year 2005 using the test case townhouse located in the Annex part of Toronto (Tse et al., 2008).

| Photovoltaic |
|---|
| Electricity Generated (kWh) |
| 7767 |

Table 6. Total electricity generated by PV for test case study

Figure 1 shows the total monthly electric power generated by the PV system for the year 2005. Electricity generation was the highest during July and throughout the summer.

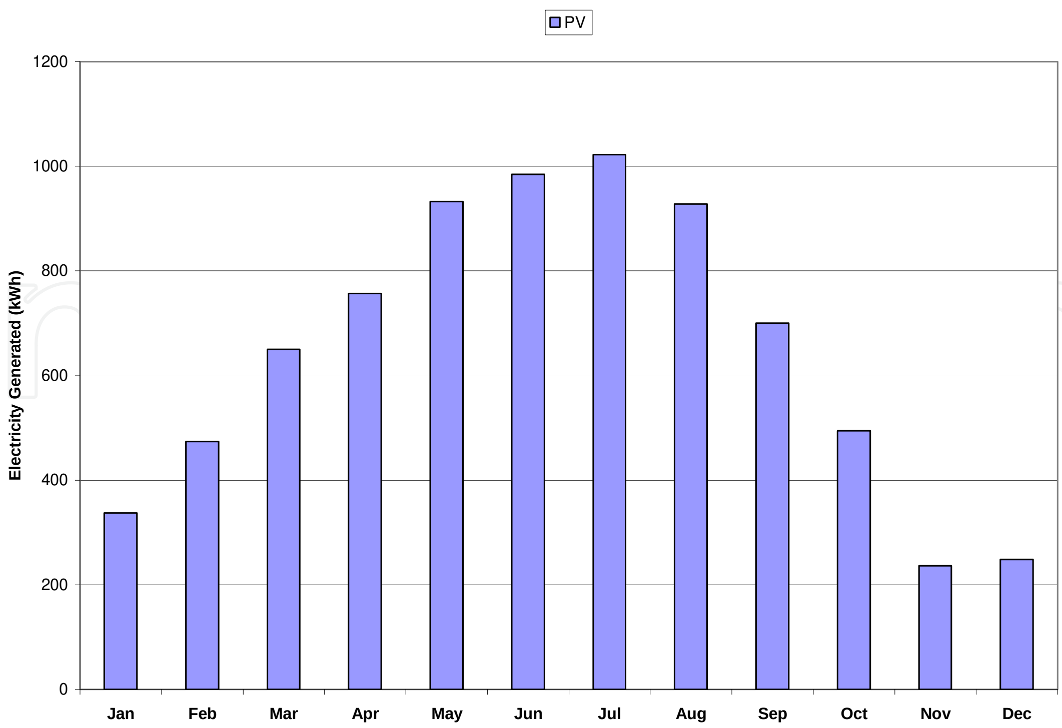


Fig. 1. Monthly electricity generated by PV for test-case study

In order to calculate the $CO_2$ emission reduction potential by PV, the hourly electricity data was multiplied by the different emission factors as defined in Equations 6, 7, 8, 9 (Gordon & Fung, 2009), and 10.

$$GHG_{el,HNGHGIF_A} = \sum \left[ \left( Generated_{el,hourly} \right) \left( NHGHGIF_A \right) \right] \tag{6}$$

Where,
$GHG_{el,HNGHGIF_A}$ = Annual GHG emission reduction using the new hourly emission factor (g of $CO_2$)
$Generated_{el,hourly}$ = Hourly electricity generated by renewable technology for test case house (kWh)
$NHGHGIF_A$ = New Hourly Greenhouse Gas Intensity Factor (g $CO_2$/kWh)

$$GHG_{el,SANGHGIF_A} = \sum \left[ \left( Generated_{el,hourly} \right) \left( SANGHGIF_A \right) \right] \tag{7}$$

Where,
$GHG_{el,SANGHGIF_A}$ = Annual GHG emission reductions using the seasonal average emission factor (g of $CO_2$)
$Generated_{el,hourly}$ = Hourly electricity generated by renewable technology for test case house (kWh)
$SANGHGIF_A$ = Seasonal Average New Greenhouse Gas Intensity Factor (g $CO_2$/kWh)

$$GHG_{el,AANGHGIF_A} = \sum \left[ \left( Generated_{el,hourly} \right) \left( AANGHGIF_A \right) \right] \tag{8}$$

Where,
$GHG_{el,AANGHGIF_A}$ = Annual GHG emission reductions using the annual average emission factor (g of $CO_2$)
$Generated_{el,hourly}$ = Hourly electricity generated by renewable technology for test case house (kWh)
$AANGHGIF_A$ = Annual Average New Greenhouse Gas Intensity Factor (g $CO_2$/kWh)

$$GHG_{el,TDVNGHGIF_A} = \sum\left[\left(Generated_{el,hourly}\right)\left(TDVNGHGIF_A\right)\right] \quad (9)$$

Where,
$GHG_{el,TDVNGHGIF_A}$ = Annual GHG emission reductions using the seasonal time dependent valuation new greenhouse gas intensity factor (g $CO_2$/kWh)
$Generated_{el,hourly}$ = Hourly electricity generated by renewable technology for test case house (kWh)
$TDVNGHGIF_A$ = Seasonal Time Dependent Valuation New Greenhouse Gas Intensity Factor (g $CO_2$/kWh)

$$GHG_{el,TDVNGHGIF_A} = \sum\left[\left(Generated_{el,hourly}\right)\left(TDVNGHGIF_A\right)\right] \quad (10)$$

Where,
$GHG_{el,TDVNGHGIF_A}$ = Annual GHG emission reductions using the monthly time dependent valuation new greenhouse gas intensity factor (g $CO_2$/kWh)
$Generated_{el,hourly}$ = Hourly electricity generated by renewable technology for test case house (kWh)
$TDVNGHGIF_A$ = Monthly Time Dependent Valuation New Greenhouse Gas Intensity Factor (g $CO_2$/kWh)
Table 7 summarizes the total emission reduction results from PV by using the different emission factors. The upper and lower limits of $CO_2$ reductions were obtained by using the seasonal TDV and annual average emission factors, respectively. It should be noted that the new monthly TDV emission factors resulted in an emission reduction potential very close to that of using hourly emission factors.

| **Emission Factor Type** | **Emission Reduction Potential (kg of $CO_2$)** | **% Difference** |
|---|---|---|
| Hourly | 1856 | |
| Seasonal Average | 1727 | -6.97 |
| Annual Average | 1716 | -7.54 |
| Seasonal TDV | 1974 | 6.36 |
| Monthly TDV | 1854 | -0.12 |

Table 7. Emission reduction potential comparison for test case study

The total monthly emission reduction potential by PV is shown in Figure 2. During June and July the emission reductions were the highest and in November, the lowest.

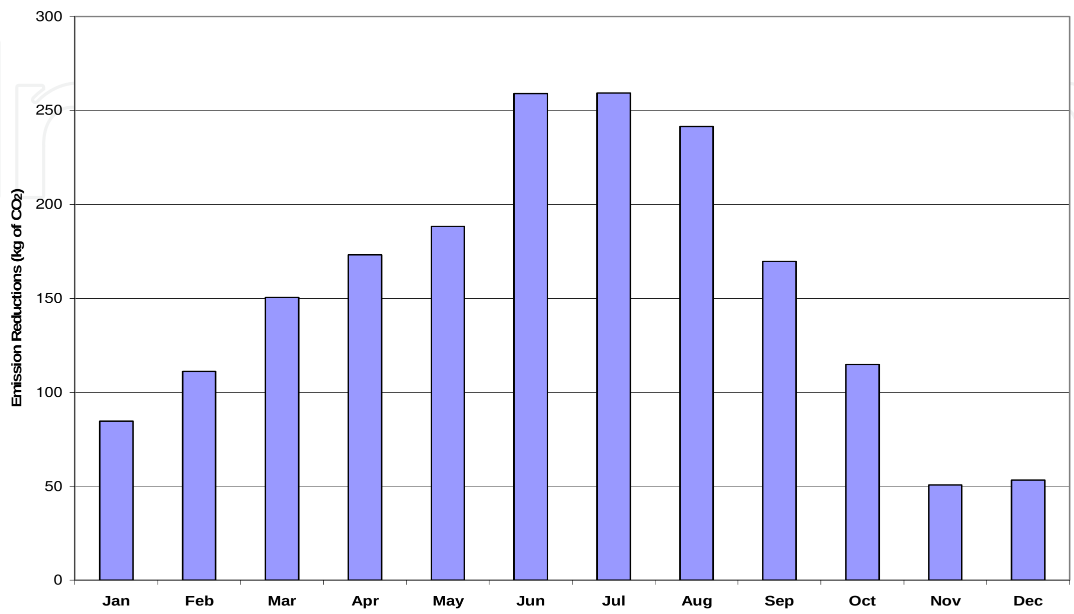


Fig. 2. Monthly emission reductions for PV test case study

## 7. Conclusion

Several emission factors were developed for the years 2004, 2005, and 2006. The hourly emission factor proved to be the most accurate. In addition, depending on the type of analysis conducted it might be practical but not as accurate to employ seasonal, time dependent valuation, or annual averages emission factors to estimate $CO_2$ emissions. It was observed that TDV and seasonal average emission factors were more accurate than using the annual average value. It should also be mentioned, that monthly TDV emission factors proved to be as accurate as using hourly values. The use of hourly emission factors to accurately estimate the potential reduction of renewable technologies should be incorporated in all renewable technology assesments.

## 8. Recommendations

This chapter discussed the use of hourly, seasonal, monthly and annual emission factors in order to demonstrate the daily fluctuations from the electricity generation sector. In the future, peak, weekly and marginal emission factors could be developed in order to increase the accuracy of emission estimations. In addition, emission factors could be updated every year in order to allign with current renewable technology analysis models and electricity generation mix.

## 9. Appendix A

| Annual | | | |
|---|---|---|---|
| TDV NGHGIF$_A$ (g of $CO_2$/kWh) | | | |
| **Hour** | **2004** | **2005** | **2006** |
| **1** | 185.9 | 219.7 | 181.2 |
| **2** | 179.2 | 213.3 | 170.5 |
| **3** | 173.6 | 206.2 | 161.5 |
| **4** | 171.6 | 203.9 | 159.4 |
| **5** | 177.1 | 209.1 | 167.9 |
| **6** | 192.5 | 216.8 | 178.3 |
| **7** | 210.7 | 223.7 | 191.5 |
| **8** | 227.8 | 236.7 | 209.1 |
| **9** | 237.0 | 244.2 | 218.3 |
| **10** | 243.6 | 248.5 | 223.1 |
| **11** | 248.1 | 251.5 | 227.3 |
| **12** | 251.1 | 253.6 | 229.5 |
| **13** | 253.0 | 255.6 | 229.9 |
| **14** | 252.0 | 255.2 | 228.7 |
| **15** | 249.7 | 252.9 | 225.4 |
| **16** | 248.4 | 249.3 | 223.3 |
| **17** | 247.8 | 248.3 | 223.7 |
| **18** | 246.5 | 249.6 | 224.9 |
| **19** | 244.3 | 248.6 | 225.5 |
| **20** | 246.6 | 249.0 | 228.1 |
| **21** | 246.9 | 252.1 | 228.0 |
| **22** | 236.4 | 247.3 | 219.5 |
| **23** | 215.2 | 235.0 | 207.0 |
| **24** | 195.0 | 226.0 | 191.4 |

Table A-1. Annual TDV emission factor comparison for 2004-2006

| Winter | | | | Spring | | | |
|---|---|---|---|---|---|---|---|
| TDV NGHGIF$_A$ (g of CO2/kWh) | | | | TDV NGHGIF$_A$ (g of CO2/kWh) | | | |
| **Hour** | **2004** | **2005** | **2006** | **Hour** | **2004** | **2005** | **2006** |
| **1** | 254.9 | 241.8 | 200.7 | **1** | 133.3 | 192.3 | 147.0 |
| **2** | 254.8 | 234.8 | 191.4 | **2** | 129.1 | 188.5 | 138.9 |
| **3** | 252.9 | 229.3 | 183.1 | **3** | 126.6 | 180.0 | 132.9 |
| **4** | 250.9 | 226.8 | 179.8 | **4** | 125.6 | 179.0 | 130.8 |
| **5** | 252.4 | 227.5 | 183.8 | **5** | 130.7 | 186.8 | 140.2 |
| **6** | 255.3 | 231.9 | 186.5 | **6** | 148.2 | 201.2 | 153.0 |
| **7** | 258.8 | 234.7 | 196.6 | **7** | 171.0 | 213.2 | 171.3 |
| **8** | 262.5 | 240.9 | 208.5 | **8** | 192.4 | 228.5 | 189.7 |
| **9** | 265.6 | 247.1 | 216.3 | **9** | 203.0 | 234.2 | 194.5 |
| **10** | 266.8 | 250.5 | 219.7 | **10** | 208.7 | 237.0 | 198.7 |
| **11** | 268.8 | 253.1 | 225.7 | **11** | 213.2 | 239.8 | 202.8 |
| **12** | 270.9 | 254.8 | 228.5 | **12** | 214.8 | 241.8 | 204.5 |
| **13** | 272.8 | 256.5 | 229.0 | **13** | 215.5 | 244.3 | 204.4 |
| **14** | 272.8 | 256.5 | 227.8 | **14** | 215.2 | 244.1 | 203.4 |
| **15** | 271.3 | 252.8 | 224.8 | **15** | 212.3 | 242.0 | 201.3 |
| **16** | 268.8 | 246.5 | 219.2 | **16** | 212.4 | 240.8 | 200.7 |
| **17** | 268.6 | 244.9 | 218.8 | **17** | 212.4 | 240.5 | 201.1 |
| **18** | 270.9 | 250.3 | 224.4 | **18** | 205.0 | 234.4 | 195.9 |
| **19** | 274.6 | 257.5 | 233.3 | **19** | 198.5 | 224.8 | 190.5 |
| **20** | 273.4 | 258.5 | 235.3 | **20** | 204.2 | 228.6 | 198.7 |
| **21** | 273.3 | 260.1 | 234.2 | **21** | 206.5 | 238.3 | 203.1 |
| **22** | 271.4 | 259.2 | 229.1 | **22** | 190.3 | 231.9 | 187.3 |
| **23** | 265.4 | 253.5 | 217.6 | **23** | 161.5 | 218.2 | 170.4 |
| **24** | 255.3 | 243.3 | 207.8 | **24** | 138.8 | 206.0 | 155.6 |

Table A-2. Seasonal TDV GHG Emission Factors for Winter and Spring

| Summer | | | | Fall | | | |
|---|---|---|---|---|---|---|---|
| TDV NGHGIFA (g of CO2/kWh) | | | | TDV NGHGIFA (g of CO2/kWh) | | | |
| **Hour** | **2004** | **2005** | **2006** | **Hour** | **2004** | **2005** | **2006** |
| **1** | 129.4 | 244.9 | 199.8 | **1** | 226.1 | 199.9 | 177.2 |
| **2** | 119.8 | 236.6 | 186.5 | **2** | 213.2 | 193.4 | 165.1 |
| **3** | 112.5 | 227.6 | 175.2 | **3** | 202.5 | 187.9 | 154.8 |
| **4** | 109.9 | 224.1 | 173.2 | **4** | 200.2 | 185.7 | 153.8 |
| **5** | 114.3 | 225.6 | 181.9 | **5** | 210.9 | 196.5 | 165.8 |
| **6** | 134.7 | 229.1 | 189.5 | **6** | 231.7 | 205.0 | 184.0 |
| **7** | 159.5 | 232.4 | 202.1 | **7** | 253.4 | 214.3 | 196.0 |
| **8** | 187.5 | 251.1 | 227.3 | **8** | 268.7 | 226.4 | 211.0 |
| **9** | 205.0 | 262.4 | 243.1 | **9** | 274.5 | 233.2 | 219.4 |
| **10** | 220.1 | 268.1 | 250.7 | **10** | 278.8 | 238.4 | 223.4 |
| **11** | 228.3 | 270.4 | 254.0 | **11** | 282.2 | 242.6 | 226.6 |
| **12** | 234.5 | 273.4 | 256.3 | **12** | 284.2 | 244.4 | 228.5 |
| **13** | 237.8 | 276.7 | 256.3 | **13** | 285.7 | 245.0 | 230.0 |
| **14** | 236.6 | 276.4 | 254.6 | **14** | 283.5 | 243.8 | 229.1 |
| **15** | 234.1 | 275.3 | 251.0 | **15** | 281.3 | 241.3 | 224.5 |
| **16** | 234.7 | 273.5 | 251.3 | **16** | 277.4 | 236.3 | 221.8 |
| **17** | 234.4 | 272.4 | 252.9 | **17** | 275.9 | 235.4 | 221.8 |
| **18** | 228.5 | 272.1 | 252.0 | **18** | 281.7 | 241.4 | 227.3 |
| **19** | 218.7 | 267.5 | 248.3 | **19** | 285.5 | 244.4 | 229.8 |
| **20** | 223.3 | 267.3 | 251.3 | **20** | 285.4 | 241.8 | 227.1 |
| **21** | 226.3 | 269.8 | 252.6 | **21** | 281.5 | 240.2 | 222.2 |
| **22** | 209.7 | 264.3 | 245.7 | **22** | 274.0 | 233.9 | 216.1 |
| **23** | 176.2 | 249.8 | 236.9 | **23** | 257.9 | 218.4 | 202.9 |
| **24** | 146.7 | 248.7 | 214.9 | **24** | 239.2 | 206.1 | 187.5 |

Table A-3. Seasonal TDV GHG Emission Factors for Summer and Fall

| January | | | | February | | | |
|---|---|---|---|---|---|---|---|
| TDV NGHGIF$_A$ (g of CO2/kWh) | | | | TDV NGHGIF$_A$ (g of CO2/kWh) | | | |
| **Hour** | **2004** | **2005** | **2006** | **Hour** | **2004** | **2005** | **2006** |
| **1** | 282.1 | 229.9 | 195.4 | **1** | 254.4 | 221.2 | 183.0 |
| **2** | 288.0 | 226.7 | 184.4 | **2** | 251.0 | 210.6 | 174.1 |
| **3** | 286.6 | 224.6 | 174.3 | **3** | 248.6 | 203.0 | 168.0 |
| **4** | 285.0 | 221.4 | 169.0 | **4** | 245.2 | 201.2 | 165.5 |
| **5** | 283.9 | 221.2 | 172.5 | **5** | 252.0 | 203.9 | 169.8 |
| **6** | 283.1 | 222.6 | 177.0 | **6** | 256.5 | 212.1 | 173.6 |
| **7** | 279.3 | 223.0 | 190.0 | **7** | 258.5 | 220.0 | 184.0 |
| **8** | 278.0 | 231.9 | 210.2 | **8** | 260.3 | 228.9 | 196.5 |
| **9** | 280.2 | 241.9 | 221.7 | **9** | 263.7 | 234.0 | 203.7 |
| **10** | 280.1 | 244.0 | 222.7 | **10** | 264.0 | 236.1 | 207.3 |
| **11** | 280.5 | 248.4 | 228.0 | **11** | 264.7 | 238.4 | 214.9 |
| **12** | 282.2 | 251.1 | 232.1 | **12** | 264.6 | 238.5 | 216.3 |
| **13** | 285.4 | 253.7 | 233.7 | **13** | 266.6 | 241.0 | 215.2 |
| **14** | 286.5 | 256.6 | 235.2 | **14** | 268.1 | 239.9 | 213.4 |
| **15** | 287.0 | 251.7 | 233.9 | **15** | 265.6 | 236.0 | 209.5 |
| **16** | 285.8 | 246.0 | 224.5 | **16** | 260.5 | 230.3 | 206.3 |
| **17** | 283.3 | 245.4 | 224.5 | **17** | 258.3 | 228.4 | 205.0 |
| **18** | 284.5 | 251.8 | 233.5 | **18** | 257.9 | 231.6 | 205.4 |
| **19** | 289.6 | 258.7 | 244.5 | **19** | 262.6 | 240.9 | 219.0 |
| **20** | 287.5 | 257.2 | 241.6 | **20** | 264.6 | 246.0 | 223.2 |
| **21** | 287.9 | 258.7 | 240.7 | **21** | 265.2 | 246.5 | 220.7 |
| **22** | 287.7 | 256.9 | 236.7 | **22** | 264.2 | 244.6 | 213.9 |
| **23** | 286.4 | 249.9 | 227.9 | **23** | 257.5 | 238.6 | 195.6 |
| **24** | 281.4 | 238.9 | 208.7 | **24** | 248.1 | 222.3 | 187.1 |
| March | | | | April | | | |
| TDV NGHGIF$_A$ (g of CO2/kWh) | | | | TDV NGHGIF$_A$ (g of CO2/kWh) | | | |
| **Hour** | **2004** | **2005** | **2006** | **Hour** | **2004** | **2005** | **2006** |
| **1** | 191.2 | 228.4 | 172.8 | **1** | 116.9 | 177.5 | 79.7 |
| **2** | 189.0 | 223.7 | 164.0 | **2** | 115.1 | 175.7 | 74.9 |
| **3** | 187.4 | 217.9 | 153.9 | **3** | 114.6 | 167.2 | 73.7 |
| **4** | 185.6 | 215.7 | 150.9 | **4** | 115.6 | 167.9 | 76.1 |
| **5** | 184.9 | 218.5 | 155.3 | **5** | 124.2 | 176.9 | 82.3 |
| **6** | 192.3 | 225.1 | 158.6 | **6** | 147.0 | 197.9 | 99.0 |
| **7** | 205.3 | 227.6 | 170.8 | **7** | 168.2 | 207.5 | 121.3 |
| **8** | 218.1 | 227.8 | 179.1 | **8** | 188.0 | 219.8 | 138.7 |
| **9** | 224.8 | 233.2 | 185.2 | **9** | 196.1 | 224.8 | 144.1 |
| **10** | 225.1 | 235.3 | 188.7 | **10** | 201.3 | 229.1 | 151.5 |
| **11** | 227.2 | 236.3 | 192.2 | **11** | 204.2 | 230.6 | 155.4 |
| **12** | 230.4 | 239.7 | 193.6 | **12** | 204.1 | 230.7 | 157.4 |
| **13** | 230.2 | 241.5 | 194.1 | **13** | 204.5 | 232.4 | 155.7 |
| **14** | 231.8 | 240.3 | 193.4 | **14** | 203.8 | 230.9 | 153.3 |
| **15** | 229.0 | 237.5 | 193.2 | **15** | 201.8 | 229.9 | 149.3 |
| **16** | 228.5 | 233.3 | 189.2 | **16** | 199.9 | 231.1 | 148.0 |
| **17** | 228.2 | 231.5 | 187.9 | **17** | 197.9 | 229.9 | 146.4 |
| **18** | 225.8 | 229.9 | 185.2 | **18** | 189.2 | 221.8 | 139.5 |
| **19** | 225.4 | 226.2 | 183.8 | **19** | 183.2 | 211.1 | 134.5 |
| **20** | 228.9 | 229.9 | 196.4 | **20** | 196.0 | 219.0 | 150.9 |
| **21** | 229.1 | 232.8 | 198.1 | **21** | 198.1 | 227.1 | 155.8 |
| **22** | 223.2 | 235.2 | 193.4 | **22** | 176.1 | 213.8 | 129.5 |
| **23** | 210.3 | 232.1 | 182.6 | **23** | 145.9 | 197.9 | 105.1 |
| **24** | 195.7 | 230.3 | 176.9 | **24** | 120.4 | 180.0 | 89.4 |

Table A-4. Monthly TDV GHG Emission Factors for the years 2004, 2005, and 2006

| May | | | | June | | | |
|---|---|---|---|---|---|---|---|
| TDV NGHGIF$_A$ (g of CO2/kWh) | | | | TDV NGHGIF$_A$ (g of CO2/kWh) | | | |
| **Hour** | **2004** | **2005** | **2006** | **Hour** | **2004** | **2005** | **2006** |
| **1** | 87.4 | 147.5 | 129.1 | **1** | 106.4 | 215.9 | 194.7 |
| **2** | 80.3 | 143.0 | 123.9 | **2** | 102.3 | 208.1 | 181.1 |
| **3** | 78.8 | 134.0 | 117.5 | **3** | 94.5 | 197.4 | 169.5 |
| **4** | 78.1 | 135.9 | 115.5 | **4** | 91.3 | 191.1 | 161.9 |
| **5** | 83.8 | 146.6 | 130.6 | **5** | 93.5 | 194.7 | 168.9 |
| **6** | 101.9 | 163.8 | 142.3 | **6** | 110.6 | 199.7 | 180.1 |
| **7** | 132.0 | 175.9 | 158.1 | **7** | 134.9 | 216.6 | 201.0 |
| **8** | 156.6 | 192.7 | 176.8 | **8** | 158.2 | 241.7 | 223.1 |
| **9** | 168.1 | 197.1 | 180.4 | **9** | 173.1 | 251.5 | 227.5 |
| **10** | 175.3 | 199.1 | 181.8 | **10** | 184.3 | 254.4 | 231.6 |
| **11** | 180.8 | 202.9 | 185.2 | **11** | 190.5 | 257.7 | 235.8 |
| **12** | 180.9 | 206.4 | 187.3 | **12** | 196.1 | 259.4 | 238.7 |
| **13** | 182.1 | 209.0 | 188.0 | **13** | 198.2 | 261.1 | 239.0 |
| **14** | 181.4 | 209.4 | 186.4 | **14** | 196.9 | 259.9 | 238.7 |
| **15** | 178.7 | 208.2 | 184.2 | **15** | 193.6 | 257.3 | 237.1 |
| **16** | 180.7 | 204.4 | 184.5 | **16** | 194.3 | 256.6 | 239.2 |
| **17** | 180.8 | 203.6 | 187.1 | **17** | 193.9 | 256.6 | 241.7 |
| **18** | 172.8 | 194.8 | 182.7 | **18** | 184.6 | 255.1 | 236.1 |
| **19** | 164.8 | 185.5 | 178.2 | **19** | 175.6 | 250.0 | 230.5 |
| **20** | 168.1 | 187.8 | 183.1 | **20** | 174.7 | 251.1 | 232.1 |
| **21** | 170.5 | 201.4 | 186.0 | **21** | 177.6 | 259.1 | 236.3 |
| **22** | 152.0 | 196.7 | 171.9 | **22** | 169.5 | 256.3 | 230.5 |
| **23** | 120.8 | 181.8 | 154.6 | **23** | 137.7 | 241.7 | 224.1 |
| **24** | 99.5 | 169.5 | 140.5 | **24** | 112.9 | 236.3 | 206.5 |
| **July** | | | | **August** | | | |
| TDV NGHGIF$_A$ (g of CO2/kWh) | | | | TDV NGHGIF$_A$ (g of CO2/kWh) | | | |
| **Hour** | **2004** | **2005** | **2006** | **Hour** | **2004** | **2005** | **2006** |
| **1** | 108.1 | 227.5 | 213.4 | **1** | 123.7 | 236.7 | 174.9 |
| **2** | 98.2 | 216.4 | 200.6 | **2** | 113.7 | 230.3 | 158.5 |
| **3** | 92.8 | 207.3 | 188.6 | **3** | 106.1 | 220.2 | 146.9 |
| **4** | 91.4 | 203.8 | 183.7 | **4** | 101.6 | 217.2 | 145.7 |
| **5** | 96.7 | 203.2 | 187.5 | **5** | 103.7 | 219.0 | 156.9 |
| **6** | 111.3 | 202.4 | 186.1 | **6** | 125.3 | 221.8 | 163.9 |
| **7** | 131.4 | 204.0 | 197.0 | **7** | 146.6 | 221.5 | 173.8 |
| **8** | 157.4 | 228.6 | 225.1 | **8** | 177.9 | 239.2 | 201.5 |
| **9** | 175.8 | 244.3 | 243.1 | **9** | 195.5 | 247.5 | 218.4 |
| **10** | 191.4 | 251.0 | 252.4 | **10** | 209.2 | 253.8 | 227.6 |
| **11** | 201.6 | 251.0 | 257.0 | **11** | 216.3 | 257.3 | 230.3 |
| **12** | 207.4 | 251.8 | 260.0 | **12** | 223.2 | 260.5 | 232.7 |
| **13** | 212.0 | 255.7 | 260.3 | **13** | 226.9 | 264.1 | 233.5 |
| **14** | 210.6 | 257.2 | 258.8 | **14** | 225.4 | 264.1 | 233.3 |
| **15** | 209.1 | 256.2 | 255.6 | **15** | 221.9 | 262.0 | 229.2 |
| **16** | 209.0 | 255.5 | 252.3 | **16** | 220.4 | 260.7 | 230.7 |
| **17** | 210.3 | 255.5 | 252.5 | **17** | 218.8 | 259.2 | 233.2 |
| **18** | 205.7 | 254.5 | 253.6 | **18** | 212.3 | 260.5 | 232.2 |
| **19** | 196.0 | 251.2 | 250.3 | **19** | 201.2 | 255.7 | 228.8 |
| **20** | 194.1 | 246.3 | 249.4 | **20** | 208.6 | 254.6 | 228.7 |
| **21** | 199.4 | 248.3 | 253.0 | **21** | 219.5 | 261.2 | 232.5 |
| **22** | 193.5 | 248.7 | 252.8 | **22** | 201.8 | 251.8 | 220.6 |
| **23** | 159.8 | 235.0 | 248.2 | **23** | 167.3 | 232.4 | 209.7 |
| **24** | 130.3 | 228.5 | 232.4 | **24** | 139.1 | 238.0 | 184.5 |

Table A-4. (Continued)

| September | | | | October | | | |
|---|---|---|---|---|---|---|---|
| TDV NGHGIF$_A$ (g of CO2/kWh) | | | | TDV NGHGIF$_A$ (g of CO2/kWh) | | | |
| **Hour** | **2004** | **2005** | **2006** | **Hour** | **2004** | **2005** | **2006** |
| **1** | 137.1 | 195.8 | 138.8 | **1** | 207.5 | 159.8 | 144.3 |
| **2** | 125.9 | 190.5 | 127.7 | **2** | 192.9 | 149.6 | 136.0 |
| **3** | 116.4 | 184.4 | 118.3 | **3** | 182.2 | 142.8 | 127.4 |
| **4** | 117.4 | 182.9 | 120.8 | **4** | 185.0 | 143.9 | 131.5 |
| **5** | 129.8 | 191.0 | 138.8 | **5** | 205.8 | 165.5 | 154.0 |
| **6** | 162.9 | 202.9 | 164.1 | **6** | 241.3 | 187.5 | 175.2 |
| **7** | 199.0 | 212.5 | 183.0 | **7** | 274.1 | 203.7 | 189.4 |
| **8** | 221.9 | 224.8 | 201.7 | **8** | 290.1 | 216.6 | 203.0 |
| **9** | 229.7 | 232.4 | 215.0 | **9** | 290.6 | 223.7 | 210.3 |
| **10** | 243.3 | 234.8 | 220.1 | **10** | 295.2 | 228.1 | 217.1 |
| **11** | 250.6 | 238.4 | 222.1 | **11** | 298.7 | 232.1 | 221.7 |
| **12** | 255.9 | 243.5 | 222.5 | **12** | 300.3 | 235.1 | 223.1 |
| **13** | 257.0 | 245.6 | 222.0 | **13** | 303.1 | 234.4 | 222.5 |
| **14** | 257.5 | 244.6 | 216.8 | **14** | 300.9 | 234.1 | 222.2 |
| **15** | 255.8 | 245.0 | 212.9 | **15** | 296.7 | 233.6 | 220.3 |
| **16** | 259.2 | 240.4 | 213.7 | **16** | 295.3 | 235.0 | 220.9 |
| **17** | 260.5 | 239.0 | 214.2 | **17** | 294.9 | 233.9 | 219.1 |
| **18** | 255.1 | 237.1 | 211.0 | **18** | 291.3 | 228.6 | 215.3 |
| **19** | 248.3 | 231.7 | 209.0 | **19** | 294.0 | 228.9 | 219.0 |
| **20** | 261.5 | 238.1 | 217.9 | **20** | 293.6 | 228.3 | 217.4 |
| **21** | 251.5 | 235.1 | 209.2 | **21** | 286.7 | 224.2 | 209.9 |
| **22** | 221.1 | 222.8 | 191.9 | **22** | 271.9 | 213.5 | 199.9 |
| **23** | 187.7 | 212.2 | 172.8 | **23** | 244.6 | 189.7 | 185.0 |
| **24** | 157.7 | 203.8 | 148.7 | **24** | 222.8 | 170.9 | 161.4 |
| **November** | | | | **December** | | | |
| TDV NGHGIF$_A$ (g of CO2/kWh) | | | | TDV NGHGIF$_A$ (g of CO2/kWh) | | | |
| **Hour** | **2004** | **2005** | **2006** | **Hour** | **2004** | **2005** | **2006** |
| **1** | 232.7 | 175.2 | 176.0 | **1** | 192.7 | 218.3 | 141.8 |
| **2** | 218.2 | 166.8 | 159.5 | **2** | 180.7 | 214.3 | 130.9 |
| **3** | 205.8 | 160.7 | 148.2 | **3** | 171.5 | 210.8 | 122.6 |
| **4** | 197.8 | 153.9 | 144.6 | **4** | 163.7 | 208.8 | 116.8 |
| **5** | 200.6 | 156.0 | 148.3 | **5** | 164.8 | 213.3 | 118.3 |
| **6** | 210.4 | 159.0 | 164.2 | **6** | 170.8 | 206.7 | 127.0 |
| **7** | 223.4 | 172.8 | 173.6 | **7** | 180.8 | 199.6 | 134.5 |
| **8** | 238.6 | 191.3 | 192.1 | **8** | 192.4 | 200.4 | 147.1 |
| **9** | 248.8 | 197.9 | 201.4 | **9** | 201.9 | 207.1 | 156.3 |
| **10** | 252.4 | 207.0 | 204.8 | **10** | 208.0 | 211.3 | 159.1 |
| **11** | 254.8 | 213.3 | 207.8 | **11** | 211.7 | 215.8 | 163.8 |
| **12** | 256.8 | 213.3 | 209.3 | **12** | 213.7 | 218.4 | 170.2 |
| **13** | 258.7 | 214.5 | 211.9 | **13** | 214.8 | 219.7 | 171.9 |
| **14** | 254.7 | 211.9 | 211.4 | **14** | 214.5 | 217.7 | 170.6 |
| **15** | 257.0 | 206.6 | 205.6 | **15** | 209.7 | 213.7 | 164.5 |
| **16** | 250.2 | 196.6 | 200.8 | **16** | 199.6 | 207.3 | 160.3 |
| **17** | 246.3 | 197.0 | 199.9 | **17** | 197.7 | 206.4 | 164.8 |
| **18** | 260.6 | 212.3 | 211.2 | **18** | 215.9 | 224.2 | 183.6 |
| **19** | 266.6 | 219.4 | 213.0 | **19** | 222.8 | 227.2 | 185.3 |
| **20** | 264.3 | 213.1 | 209.3 | **20** | 219.7 | 221.3 | 179.5 |
| **21** | 262.9 | 212.8 | 207.3 | **21** | 220.4 | 222.5 | 176.9 |
| **22** | 261.6 | 207.6 | 204.4 | **22** | 219.5 | 223.0 | 174.9 |
| **23** | 255.0 | 191.3 | 195.4 | **23** | 213.2 | 218.2 | 161.8 |
| **24** | 239.7 | 179.4 | 187.5 | **24** | 197.0 | 216.9 | 148.0 |

Table A-4. (Continued)

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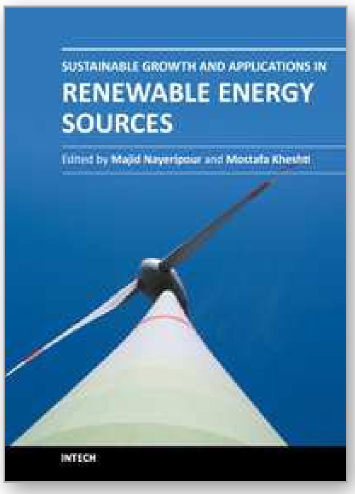


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Worldwide attention to environmental issues combined with the energy crisis force us to reduce greenhouse emissions and increase the usage of renewable energy sources as a solution to providing an efficient environment. This book addresses the current issues of sustainable growth and applications in renewable energy sources. The fifteen chapters of the book have been divided into two sections to organize the information accessible to readers. The book provides a variety of material, for instance on policies aiming at the promotion of sustainable development and implementation aspects of RES.