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Greenhouse Gas Emissions Calculations

Method:

Greenhouse gas emissions from the glass manufacturing industry are estimated based on the industry's usage of natural gas, electricity, and raw material. The methods for these estimations are discussed herein.

Greenhouse Gas Emissions from the Use of Natural Gas

The use of natural gas as fuel leads to direct emissions of carbon dioxide (CO₂), methane (CH₄), and Nitrous Oxide (N₂O). The amounts of natural gas usage and their corresponding greenhouse gas emissions for most of the glass manufacturing industry are obtained from the California Energy Commission (CEC) and are listed on Table 1. Once the amount of natural gas usage has been determined, the greenhouse gas emissions are calculated using emission factors. The emission factor used for CO₂ emissions is 0.005302 million metric tons of CO₂ equivalent (MMT CO₂e)/Million Therms. The emission factor used for CH₄ emissions is 2.1x10⁻⁶ MMT CO₂e/Million Therms. The emission factor used for N₂O is 3.1x10⁻⁶ MMT CO₂e/Million Therms. Since the emission factor for CH₄ and N₂O are several factor smaller than CO₂, we only used CO₂ for this calculation. To calculate total CO₂ emissions, we multiplied the natural gas usage by the emission factor. The results of these calculations are shown on Table 2.

Greenhouse Gas Emissions from the Use of Electricity

The use of electricity leads to indirect emissions of CO₂ and other greenhouse gases. The electricity used in the glass manufacturing was estimated based on the amount of production and the average use stated in reference 2. The estimates are shown on Table 1. Once the amount of electricity has been determined, the greenhouse gas emissions are calculated using an emission factor. For this estimate, only CO₂ emissions were calculated. To calculate the total CO₂ emissions, we multiplied the electricity usages by the emission factor of 804.5 lbs of CO₂/megawatt-hour (Mwh). This emission factor is the average value of the range obtained from reference 3. The results are shown on Table 2.

Greenhouse Gas Emissions from the Use of Raw Material

The use of Soda Ash (Na₂CO₃) and Limestone (CaCO₃) in glass melting operations leads to direct emissions of CO₂. Assuming the use of Soda Ash and Limestone are about the same across the container glass, fiberglass, and plate glass segments, the quantity used are estimated based on the amount of glass produced and the information given to ARB in Reference 4 and are shown on Table 1. This calculation was done together for the three segments of the glass industry where ARB had estimates of productions. Once the amount of Soda Ash and Limestone were calculated, CO₂ emissions associated with their use were calculated by multiplying the usage amount with an emission factor. The emission factor for Soda Ash is 0.4152 metric ton (MT) CO₂/MT Soda Ash processed (Ref. 4). The emission factor for Limestone is 0.4297 MT CO₂/MT Limestone processed (Ref.4). The results are shown on Table 2.

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Table 1. Greenhouse Gas Emissions Data

Production:	<u>1990 Container Glass</u> ~1,967,000 tons	<u>2006 Container Glass</u> ~1,434,500 tons	<u>Source</u> Ref 1
Natural Gas:	112 Million Therms	74 Million Therms	CEC
Electricity: (Factor Used ¹):	2,596,500 MMBtu 1.32 MMBtu/ton of product	1,893,500 MMBtu	Calc. Ref 2
Production:	<u>1990 Fiberglass²</u> ~231,700 tons	<u>2006 Fiberglass²</u> ~385,700 tons	<u>Source</u> Ref 1
Natural Gas: (Factor Used ¹):	16 Million Therms 7.06 MMBtu/ton of product	27 Million Therms Ref 2	Calc.
Electricity: (Factor Used ¹):	1,824,800 MMBtu 7.88 MMBtu/ton of product	3,037,600 MMBtu	Calc. Ref 2
Production: (Factor Used ¹):	<u>1990 Plate Glass</u> ~124,600 tons 13.64 MMBtu/ton of product	<u>2006 Plate Glass</u> ~154,000 tons	<u>Source</u> Calc. Ref 2
Natural Gas:	17 Million Therms	21 Million Therms	CEC
Electricity: (Factor Used ¹):	507,300 MMBtu 4.07 MMBtu/ton of product	626,600 MMBtu	Calc. Ref 2
<u>Raw Material</u>	<u>1990 (Container, Fiber, and Plate)</u>	<u>2006 (Container, Fiber, and Plate)</u>	<u>Source</u>
Soda Ash:	196,900 metric ton (MT)	167,300 MT	Ref 4
Limestone:	169,100 MT	143,700 MT	Ref 4
Production:	<u>1990 Others</u> TBD	<u>2006 Others</u> TBD	<u>Source</u> N/A
Natural Gas:	35 Million Therms	20 Million Therms	CEC
Electricity:	TBD	TBD	N/A
Raw material:	TBD	TBD	N/A

¹ Factor is estimated to be the average of range provided in reference.

² Fiberglass values are for insulation alone. Production of textile/reinforcement fibers are to be determined.

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Table 2. Summary of Calculated Carbon Dioxide Emissions³

	<u>1990 Container Glass</u>	<u>2006 Container Glass</u>
Natural Gas:	0.5913 MMT CO ₂	0.3945 MMT CO ₂
Electricity:	0.2777 MMT CO ₂	0.2025 MMT CO ₂
	<u>1990 Fiberglass²</u>	<u>2006 Fiberglass²</u>
Natural Gas:	0.0867 MMT CO ₂	0.1444 MMT CO ₂
Electricity:	0.1952 MMT CO ₂	0.3249 MMT CO ₂
	<u>1990 Plate Glass</u>	<u>2006 Plate Glass</u>
Natural Gas:	0.0913 MMT CO ₂	0.1115 MMT CO ₂
Electricity:	0.0543 MMT CO ₂	0.0670 MMT CO ₂
<u>Raw Material</u>	<u>1990 (Container, Fiber, and Plate)</u>	<u>2006 (Container, Fiber, and Plate)</u>
Soda Ash:	0.0818 MMT CO ₂	0.0695 MMT CO ₂
Limestone:	0.0744 MMT CO ₂	0.0632 MMT CO ₂
	<u>1990 Others</u>	<u>2006 Others</u>
Natural Gas:	0.1831 MMT CO ₂	0.1078 MMT CO ₂
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INDUSTRY TOTAL	1.640 MMT CO₂	1.491 MMT CO₂
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³ Results are shown for carbon dioxide only because the amount of the other greenhouse gases are small in comparison.

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References:

1. 2006 Glass Production and Cullet Used in California, CA Department of Conservation, November 2007
2. Energy Efficiency Improvement and Cost Saving Opportunities for the Glass Industry, Environmental Energy Technologies Division, August 2007
3. California Climate Action Registry General Reporting Protocol, Version 2.2, California Climate Action Registry, March 2007
4. E-mail from C. Philip Ross for the Glass Packaging Institute, October 11, 2007.