



FEDERAL TRANSIT ADMINISTRATION

Transit Greenhouse Gas Emissions Estimator: User Guide

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1 Introduction

The Transit Greenhouse Gas (GHG) Emissions Estimator is a spreadsheet tool that allows users to estimate the partial lifecycle GHG emissions generated from the construction, operations, and maintenance phases of projects across select transit modes. Users input general information about a project, and the tool calculates annual GHG emissions by project phase. Total annual GHG emissions for a transit project is the sum of amortized construction emissions,¹ annual maintenance emissions, and annual operations emissions, minus annual displaced emissions.

Section 2 provides detailed instructions on how to use the tool. Sections 3 and 4 provide information on the GHG emissions factors, data source, and assumptions used in the tool.

The tool was developed in connection with the Greenhouse Gas Emissions from Transit Projects Programmatic Assessment. Although the tool lacks the precision that may be attainable by using more complex emission models or route-specific ridership estimates, it provides a resource to generate coarse but informative estimates of greenhouse gas emissions for a broad range of transit projects. In no case is the use of this tool mandatory, and transit agencies should work with Federal Transit Administration (FTA) Regions to determine whether to conduct project-specific analyses of GHG emissions and the best approach for doing so.

2 How to Use the Estimator

The tool utilizes macros. When opening the tool, be sure to click “Enable Content” when prompted to do so in order to ensure the tool runs properly.

Step 1: Enter Construction Inputs

The tool asks user to enter information associated with constructing a transit project (Figure 1). If this information is not applicable to the project, click “Move to Transit Operations” to proceed.

FIGURE 1: CONSTRUCTION INPUTS SCREEN

The screenshot shows the 'CONSTRUCTION INFORMATION' screen. At the top right is a button labeled 'Move to Transit Operations'. Below this, there are three input fields: 'Structured Parking Spots' (0), 'Lot Parking Spots' (0), and 'Trees Removed' (0). A horizontal line separates this from the main input section. On the left is a 'Transit Mode' dropdown menu. To its right are two groups of input fields: 'Miles of Track/Alignment' with sub-fields for Underground (0), Elevated (0), At-Grade (0), and Catenary (0); and 'Number of Stations' with sub-fields for Underground (0), Elevated (0), and At-Grade (0). On the far right are two buttons: 'Add Construction to Calculation' (green) and 'Remove Marked Entries' (red). Below these is a table labeled 'ALREADY ADDED:'.

ALREADY ADDED:	Transit Mode	Miles of Track/Alignment				Number of Stations			
		Underground	Elevated	At-Grade	Catenary	Underground	Elevated	At-Grade	Mark for Deletion with 'X'
	Light Rail	1	3	11	0	0	0	16	

- Input the following information:
 - **Structured Parking Spots:** Enter the total number of structured (garage) parking spaces that will be constructed for the project.

¹ Total construction related GHG emissions are amortized over a 50-year period, which corresponds to the minimum useful lifespan of facilities, per FTA Circular 5010.

- **Lot Parking Spots:** Enter the total number of surface lot parking spaces that will be constructed for the project.
- **Trees removed:** Enter the total number of trees that will be removed as a result of construction the transit project.

If the project does not involve any additional construction click the “Move to Transit Operations” buttons. If the project involves construction of track, pavement, and/or transit stations proceed to the following steps.

- **Select Transit Mode:** From the pull down menu, select the type of transit mode being constructed
 - Heavy Rail
 - Commuter Rail
 - Light Rail
 - Streetcar
 - Bus Rapid Transit (BRT): New lane miles: Choose this when constructing of a new dedicated lane or right-of-way
 - BRT: Converted lane miles: Choose this when converting or upgrading an existing facility
- **Enter the miles of track by alignment type:** Enter the number of miles of track (or lane-miles for BRT projects) that will be constructed. Enter number of miles by alignment: above ground, below-ground, or at-grade.
- **Enter the miles of catenary:** Enter the number of miles of catenary overhead wire that will be constructed for the project. If the project does not use a catenary system then leave the cell black or enter zero.
- **Enter the number of stations by alignment types:** Enter the number of stations that will be constructed for the project. Enter number of stations by type: above ground, below-ground, or at-grade.
- Once all the construction inputs associated with the selected transit mode have been entered click the “Add Construction to Calculation” button.
- If a project includes infrastructure related to another type of transit mode, users can select another transit mode from the drop down menu and enter the associated construction inputs. Click the “Add Construction to Calculation” button once finished.
- Users can delete information previously entered by entering an “X” in the appropriate cell in the “Already Added” section, then clicking the “Remove Marked Entries” button.
- Once all construction related inputs associated with the transit project have been added click the “Move to Transit Operations” button at the top to move to the next data input screen.

Step 2: Enter Transit Operations Inputs

The tool asks user to enter information associated with operations of the new transit project (Figure 2). If this information is not applicable to the project, click “Move to Displaced Emissions” to proceed.

FIGURE 2: TRANSIT OPERATIONS INPUTS SCREEN

- Input the following information:
 - **Select a Transit Mode:** From the pull down menu, select the type of transit mode that will operate as part of the transit project
 - Heavy Rail
 - Light Rail
 - Streetcar
 - Commuter Rail
 - Bus/DR Bus
 - Vanpool
 - School bus
 - Sedan/Auto
 - **Select Fuel Source:** From the drop down menu, select the type of fuel that the transit vehicle will use to operate. Notes regarding fuel source:
 - Heavy rail, light rail, and streetcar have electric as the only fuel source option.
 - The tool does not include all vehicle fuels for buses, demand response vehicles, and vanpools. For example, buses operating with gasoline, liquefied propane gas, ethanol, kerosene, and hydrogen are not included in the tool because data for the emissions associated with these fuel types were not readily available.
 - For electric fuel source, users will also need to select an eGRID subregion from the corresponding drop down menu. The tool allows the user to choose the “US Mix” region from the EPA’s eGRID2012, which represents the average electricity generation mix for the country, or an eGRID subregion, which reflects more region-specific electricity generation. Refer to the map of eGRID subregions to identify the applicable subregion or refer to the [eGRID subregion finder tool](#) to look up the subregion by zip code.
 - **Enter annual vehicle miles traveled (VMT):** Enter in the annual VMT for the selected transit mode.
- Click “Add VMT to Calculation” Button. The transit operations data entered will appear in the “Already Added” area.

- Continue to add transit operation inputs as needed to account for all transit operations associated with the transit project.
- Users can delete information previously entered by entering an “X” in the appropriate cell in the “Already Added” section, then clicking the “Remove Marked Entries” button.
- Once all transit operations related inputs have been added click the “Move to Displaced Emissions” button at the top to move to the next data input screen.

Step 3: Enter Displaced Emissions Inputs

The tool asks user to enter information associated with transit and personal vehicle VMT that is displaced due to the new transit project (Figure 3). If this information is not applicable to the project, click “Move to Facility Operations” to proceed.

FIGURE 3: DISPLACED EMISSIONS INPUT SCREEN

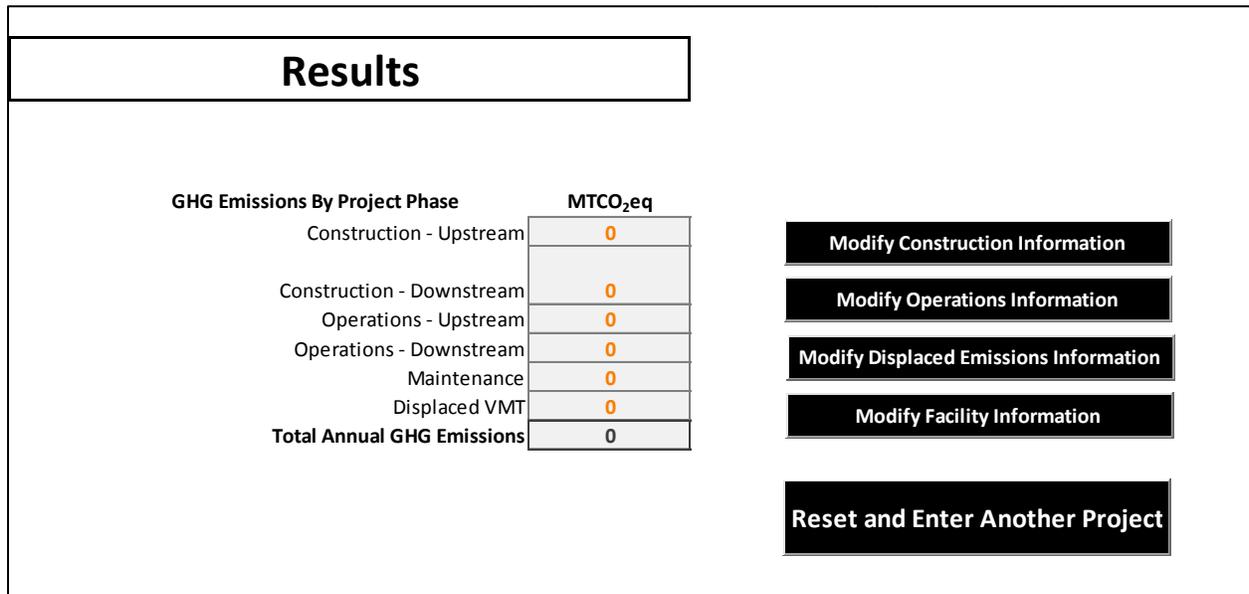
- Input the following information:
 - **Select a Mode:** From the pull down menu, select the type of mode that will have VMT displaced due to the transit project:
 - Heavy Rail
 - Light Rail
 - Streetcar
 - Commuter Rail
 - Bus/DR Bus
 - Vanpool
 - School bus
 - Sedan/Auto
 - **Select Fuel Source:** From the drop down menu, select the type of fuel that the vehicle will use to operate. Notes regarding fuel source:
 - Heavy rail, light rail, and streetcar have electric as the only fuel source option.
 - The tool does not include all vehicle fuels for buses, demand response vehicles, and vanpools. For example, buses operating with gasoline, liquefied propane gas, ethanol, kerosene, and hydrogen are not included in the tool because data for the emissions associated with these fuel types were not readily available.

- **Select Building Type:** From the pull down menu, select the type of facility that will be constructed as part of the transit project:
 - Station
 - Maintenance/Storage Facility
- **Enter Square Footage:** Enter the square footage of the facility.
- Click the “Add Facility to Calculation” button. The facility operations data entered will appear in the “Already Added” area.
- Continue to add facility operations inputs as needed to account for all new facilities constructed as part of the transit project.
- Users can delete information previously entered by entering an “X” in the appropriate cell in the “Already Added” section, then clicking the “Remove Marked Entries” button.
- Once all facility operations inputs have been added click the “Calculate Emissions” button at the top to move to the Results screen.

Step 5: View Results

The tool presents the total annual GHG emissions generated by the transit project in metric tons of CO₂ equivalent (MTCO₂eq) by project phase and by upstream and downstream emissions (Figure 5).

FIGURE 5: RESULTS SCREEN



3 Emission Factors

The Tool uses the GHG emission factors in Table 1 to calculate the GHG emissions estimates by transit mode for the construction, maintenance, and operations phases of transit project development. See the Data Sources section for details on the data resources used to develop the emissions factors used in the Tool.

TABLE 1: GHG EMISSION FACTORS USED IN THE TOOL

HEAVY RAIL	Phase	Source	Upstream	Downstream	MTCO ₂ eq		
	Const.	Track Mile	Underground	111,262	5,085	/mi	
			Elevated	3,223	717	/mi	
			At Grade	580	362	/mi	
	Const.	Catenary		3,161	-	/mi	
			Station	Underground	143,384	1,640	/facility
				Elevated	133,694	1,135	/facility
	At Grade	81,764		457	/facility		
	Maint.	Track Mile		-	5	/mi/yr	
			Vehicle		-	0.0003	/mi/yr
Ops.	Vehicle	Electric	0.0030	-	/veh-mile		
		Station		-	0.0117	/sq-ft/yr	
			Maint/Storage Fac.	Electricity	-	0.0121	/sq-ft/yr
		Heat	-	0.0018	/sq-ft/yr		

COMMUTER RAIL	Phase	Source	Upstream	Downstream	MTCO ₂ eq		
	Const.	Track Mile	Underground	111,262	5,085	/mi	
			Elevated	3,223	717	/mi	
			At Grade	580	362	/mi	
			Conv./Upgraded	-	-	/mi	
	Const.	Catenary		3,161	-	/mi	
			Station	Underground	143,384	1,640	/facility
				Elevated	133,694	1,135	/facility
	At Grade	81,764		457	/facility		
	Maint.	Track Mile		-	5	/mi/yr	
Vehicle				-	0.0010	/mi/yr	
Ops.	Vehicle	Electric	0.0029	-	/veh-mile		
		Diesel	0.0109	0.0029	/veh-mile		
		Station		-	0.0117	/sq-ft/yr	
Maint/Storage Fac.	Electricity		-	0.0121	/sq-ft/yr		
		Heat	-	0.0018	/sq-ft/yr		

LIGHT RAIL AND STREETCAR	Phase	Source	Upstream	Downstream	MTCO ₂ eq		
	Const.	Track Mile	Underground	111,262	5,085	/mi	
			Elevated	2,905	310	/mi	
			At Grade	310	109	/mi	
			Conv./Upgraded	310	74	/mi	
	Const.	Catenary		3,161	-	/mi	
			Station	Underground	35,760	615	/facility
				Elevated	57,560	301	/facility
	At Grade	2,527		9	/facility		
	Maint.	Track Mile		-	5	/mi/yr	
Vehicle				-	0.000012	/mi/yr	
Ops.	Vehicle	Electric	0.0043	-	/veh-mile		
		Station		-	0.0117	/sq-ft/yr	
			Maint/Storage Fac.	Electricity	-	0.0121	/sq-ft/yr
		Heat	-	0.0018	/sq-ft/yr		

BUS/BUS RAPID TRANSIT	Phase	Source	Upstream	Downstream	MTCO ₂ eq	
	Const.	New BRT Lane/ROW		248	197	/mi
			Conv./Upgraded Lane/ROW	158	70	/mi
			Trolleybus Catenary	902	-	/mi
			Station	2,527	9	/facility
	Maint.	Pavement, BRT		-	3	/mi/yr
			Vehicle		-	0.00005
	Ops.	Vehicle	Electric	0.0017	0.0000	/veh-mile
			Diesel	0.0005	0.0027	/veh-mile
			Biodiesel	0.0001	0.0022	/veh-mile
LNG			0.0007	0.0026	/veh-mile	
Station		CNG		0.0008	0.0026	/veh-mile
			Electricity	-	0.0117	/sq-ft/yr
		Heat		-	0.0017	/sq-ft/yr
			Maint/Storage Facility	Electricity	-	0.0152
		Heat	-	0.0010	/sq-ft/yr	

DR, VANPOOL, DISPLACED AUTOS	Phase	Source	Upstream	Downstream	MTCO ₂ eq		
	Const.	Vanpool	Diesel	0.0002	0.0011	/mi	
			Gas	0.0002	0.0010	/mi	
			Ethanol	-0.0001	0.0013	/mi	
	Ops.	Sedan/Auto	Gas, Ethanol	0.0001	0.0003	/mi	
			CNG, LPG	0.0001	0.0003	/mi	
			H (gaseous)	0.0005	-	/mi	
			HEV	0.0001	0.0002	/mi	
		School Bus	Bio/Diesel		0.0000	0.0003	/mi
				Diesel	0.0003	0.0015	/mi
Biodiesel				0.0001	0.0012	/mi	
			LPG	0.0003	0.0015	/mi	
Demand Response Bus	CNG		0.0004	0.0014	/mi		
		Diesel	0.0005	0.0027	/mi		
Response Bus	Biodiesel		0.0001	0.0022	/mi		
		CNG	0.0008	0.0026	/mi		

PARKING	Phase	Source	Upstream	Downstream	MTCO ₂ eq	
	Const.	Lot		1	-	/space
			Garage	5	-	/space
	Ops.	Lot		-	0.0001	/space/yr
Garage			-	0.0001	/space/yr	

CARBON STORAGE		Upstream	Downstream	MTCO ₂ eq
C Sequestration Loss Due to Tree Removal		-	0.8368	/tree/yr

4 Data Sources

Construction Related Emission Factors

In the construction phase of a transit project, upstream emissions are the emissions associated with the extraction, transport, and production of the materials used in the construction of the facilities (e.g., asphalt, concrete, base stone, and steel). Downstream construction emissions are tailpipe emissions resulting from the operation of construction vehicles and equipment. The primary data sources for construction-related greenhouse gas emissions factors in the Estimator Tool are the Federal Highway Administration's (FHWA) Infrastructure Carbon Estimator (ICE) and research by Hanson *et al* (2014). FHWA's ICE is a spreadsheet tool that estimates the lifecycle energy and greenhouse gas emissions from the construction and maintenance of transportation facilities. ICE's lifecycle emissions include those resulting from the operation of construction vehicle and equipment and the embodied energy and emissions associated with the extraction, transport, and production of the materials (i.e. asphalt, concrete, base stone, and steel) used in the construction of the transportation facilities. The information in ICE is based on a nationwide database of construction bid documents, data collected from State Departments of Transportation, and consultation with transportation engineers and lifecycle analysis experts. ICE use emission factors from the Pavement Lifecycle Assessment Tool (PaLATE). Hanson *et al* provides a technique to assess the greenhouse gas emissions associated with the construction of commuter rail projects, with focus given to the lifecycle emissions associated with materials used to construct track, catenary systems, station platforms, parking facilities, and tunnels and bridges.

Emission factors for the construction of structure (garage) and surface parking on a per-space basis are based on data from FHWA's ICE. ICE's parking emissions include those from the operation of construction vehicle and equipment, and the embodied energy and emissions associated with the extraction, transportation, and production of the materials (i.e. (asphalt and base course stone) required to construct parking facilities.

Maintenance Related Emission Factors

Maintenance phase greenhouse gas emissions are all considered downstream emissions. The Estimator Tool uses greenhouse gas emission factors for maintenance of track/lane-miles and transit vehicles. The greenhouse gas emission factors for track/lane-mile maintenance are based on FHWA's ICE. The ICE tool accounts for direct emissions associated with routine maintenance activities such as snow removal and vegetation management, among other activities. The ICE tool used data from the Los Angeles County Metropolitan Transportation Authority and the NTD to estimate total fuel use for rail-related maintenance activities.

The Tool's greenhouse gas emission factors for vehicle maintenance are based on research by Chester (2008), which calculated the greenhouse gas emissions for vehicle maintenance for buses and rail. Greenhouse gas emission rates for bus vehicle maintenance are based on a 40-foot bus. Greenhouse gas emission rates for rail vehicle maintenance, which includes routine maintenance (standard upkeep and inspection), cleaning, and flooring replacement, are based on four types of vehicles: Bay Area Rapid Transit heavy rail trains, Caltrain commuter rail trains, Muni light rail trains, and the Massachusetts Bay Transit Authority's (MBTA's) Green Line light rail trains. The emissions factors used in the tool for light rail vehicle maintenance are based on an average of the Muni and MBTA light rail vehicle estimates.

Vehicle Operations Related Emission Factors

The Tool uses upstream and downstream greenhouse gas emissions factors for the operation of road- and rail-based transit vehicles across a range of fuel sources. During the operations phase, upstream emissions are associated with the extraction, production, and transportation of the vehicle fuel; downstream emissions are the tailpipe emissions resulting from the operation of a transit vehicle. Emissions factors for road-based vehicles, including buses, were derived from Argonne National Laboratory's Greenhouse Gases, Regulated Emissions, and Energy use in Transportation (GREET) Model, 2015 release.

The Tool's downstream emissions factors for road vehicle operations represent GREET's default "pump-to-wheels"² emissions factors for the 2015 simulation year. The Tool's upstream emissions (well-to-pump)³ figures for road vehicle operations were derived by subtracting GREET's pump-to-wheels emissions factors from GREET's "well-to-wheels" emissions factors:

$$\text{Upstream vehicle operations emissions} = \text{GREET well-to-wheels} - \text{GREET pump-to-wheels}$$

The tool uses the following GREET vehicle types (right of colon) to calculate emissions for the vehicle types available in the tool (left of colon):

- *Electric bus*: Heavy-Duty, Transit Bus, Electric Vehicle, U.S. mix
- *Diesel bus*: Heavy-Duty, Transit Bus, Compression-ignition direct-injection (CIDI) diesel
- *Biodiesel bus*: Heavy-Duty, Transit Bus, CIDI biodiesel
- *Liquefied natural gas (LNG) bus*: Heavy-Duty, Transit Bus, Spark-ignition (SI) Vehicle LNG
- *Compressed natural gas (CNG) bus*: Heavy-Duty, Transit Bus, SI Vehicle CNG
- *Demand response bus*: Use same as buses above
- *Vanpool diesel*: Light Heavy-Duty Vocational Vehicles with diesel as baseline
- *Vanpool gas*: Medium Heavy-Duty gasoline as baseline
- *Vanpool ethanol*: Light Heavy Duty, diesel baseline; ethanol as fuel
- *All Sedan/Autos*: Spark-ignition internal combustion engine vehicles, except for biodiesel, which is CIDI internal combustion engine vehicle
- *School bus diesel*: Heavy-Duty, School Bus, CIDI diesel
- *School bus biodiesel*: Heavy-Duty, School Bus, CIDI biodiesel
- *School bus Liquefied petroleum gas (LPG)*: Heavy-Duty, School Bus, SI Vehicle LPG
- *School bus CNG*: Heavy-Duty, School Bus, SI Vehicle CNG

The tool uses emissions factors for each rail mode's electric vehicle operations based on energy consumption rates derived from energy use and transit VMT data reported in the NTD and electricity emission rates from the EPA's Emissions & Generation Resource Integrated Database (eGRID) 2012, as follows:

$$(1) \text{ Total 2010–2014 rail mode electricity use} / \text{Total 2010–2014 rail mode VMT} = \text{kilowatt-hours (kWh)/VMT rail mode}$$

$$(2) \text{ kWh/VMT rail mode} * \text{eGRID2012 annual total output emission rates}^4$$

² Pump-to-wheel emissions are the operational emissions associated with the vehicle technology (i.e., tail pipe emissions and the energy efficiency of the vehicle).

³ Well-to-pump emissions are those associated with producing the fuel used in the vehicle.

⁴ eGRID annual total output emission rates are available at: www.epa.gov/sites/production/files/2015-10/documents/egrid2012_summarytables_0.pdf. Last accessed 9/16/16.

Commuter rail consumes both diesel and electricity; however, NTD does not report VMT by diesel and electricity separately. The VMT of 4 of 24 commuter rail systems nationwide for which NTD has data reported are powered all electrically. For electrically-powered commuter rail, VMT and kWh data from NTD 2014 for the four all-electric commuter rail systems were used to calculate the energy consumption information used in the Tool's commuter rail electric operations factors.

Facility Operations Related Emission Factors

The emissions factors for maintenance and storage facilities used in the Tool are based on annual electricity and heating usage data from seven transit agencies; the estimates for greenhouse gas emissions from station electricity are based on data from two subway stations. The project team aggregated the information and estimated the average annual electricity and heating fuel usage per square foot by facility type.⁵ The aggregate average annual electricity data (kWh) and heat data, provided in gallons of heating oil, therms of natural gas, and cubic feet of natural gas, were converted to greenhouse gas emissions using the following conversion factors:

- 1 kWh electricity = 0.000689551 MTCO₂ (per EPA)⁶*
- 0.01010 MCF natural gas = 1 kWh electricity⁷*
- 1 therm = 29.3001 kWh electricity*
- 1 gallon residual fuel oil (#6 oil) = 43.9 kWh electricity⁸*

Carbon Storage Emission Factors

The Tool uses emissions factor for the annual, per-tree carbon sequestration⁹ loss due to tree removal. The project team referred to data from the U.S. Department of Agriculture (USDA) (Novak and Crane (2002) and Zhao and Sander (2015)). The researchers have estimated the per-tree carbon storage of an urban tree in the U.S. based on data from various American cities. Understanding sequestration rates depend on tree species and diameter, among other factors. The USDA has estimated the volume of carbon sequestered for every one metric ton of carbon stored annually. The emission factor for tree lost that is used in the Tool was derived as follows:

- (1) 0.22801 MT C stored per urban tree based on data from 11 American cities (Novak and Crane; Zhao and Sander)*
- (2) For every 1 MT C stored annually, approximately 3.67 MTCO₂ are sequestered per year (USDA)*
- (3) 0.22801 MT C stored * 3.67 MTCO₂ sequestered per year = 0.8368 MTCO₂ sequestered/tree/year*

⁵ Though cubic footage is the preferred unit of measurement for building size, the project team was limited to the available square footage information.

⁶ CO₂ only

⁷ Energy Information Administration: www.eia.gov/tools/faqs/faq.cfm?id=667&t=8

⁸ www.think-energy.net/energy_units.htm

⁹ Carbon sequestration describes the process by which carbon is removed from the atmosphere and stored in carbon sinks such as oceans, forests, or soils.