The Ecological Footprint of Sandia National Labs

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National Nuclear Security Administration

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An Overview of the Ecological Footprint Concept

- A measure of human demand on nature
- Compares consumption of natural resources with the Earth's regeneration capacity
- Estimates the land area required to support the resource consumption, greenhouse gas (GHG) emissions, and waste generation of a population

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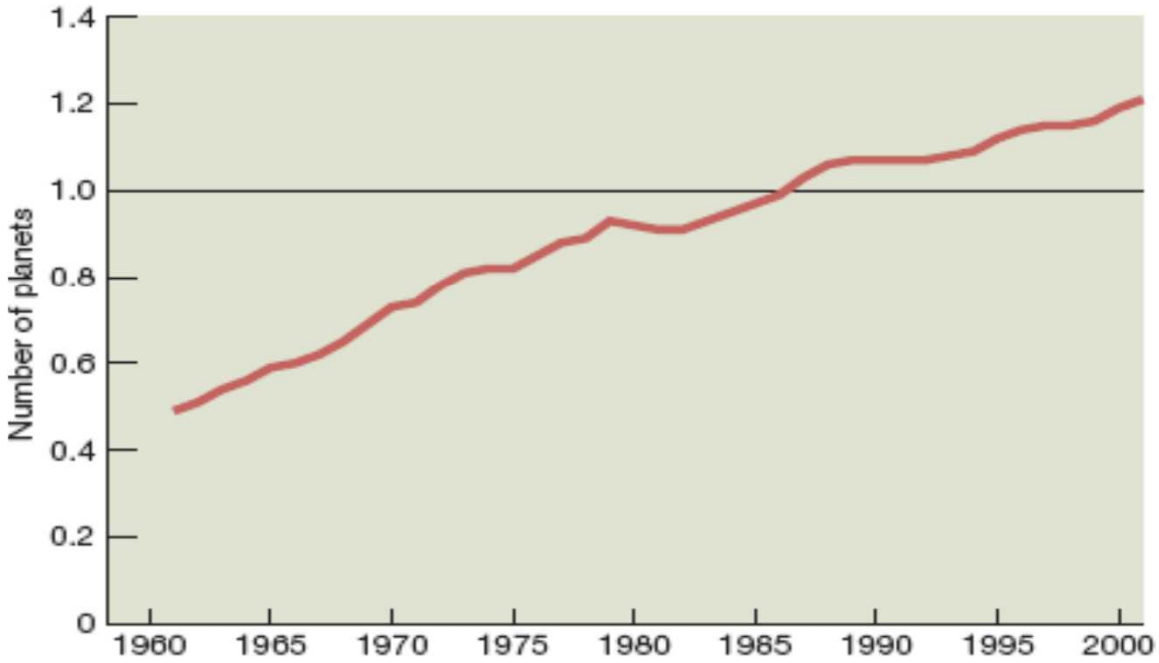
Why Measure Ecological Footprints?

According to the Living Planet Report, Humanity has exceeded the carrying capacity of the Earth in the 1980s, and has been incurring an ecological deficit ever since.

Fig. 2: **HUMANITY'S ECOLOGICAL FOOTPRINT,** 1961–2001



Source: WWF Living Planet Report 2004

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Generic Ecological Footprint Models

The Average American's Ecological Footprint

Source: http://www.myfootprint.org

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Project Goals

- Develop a baseline Ecological Footprint Model (EFM) specific to SNL/NM for FY05 to quantify environmental impact and resource consumption
- Integrate the EFM as a tool for supporting projects and missions at SNL/NM
- Illustrate areas of concern and success related to the application of the EFM

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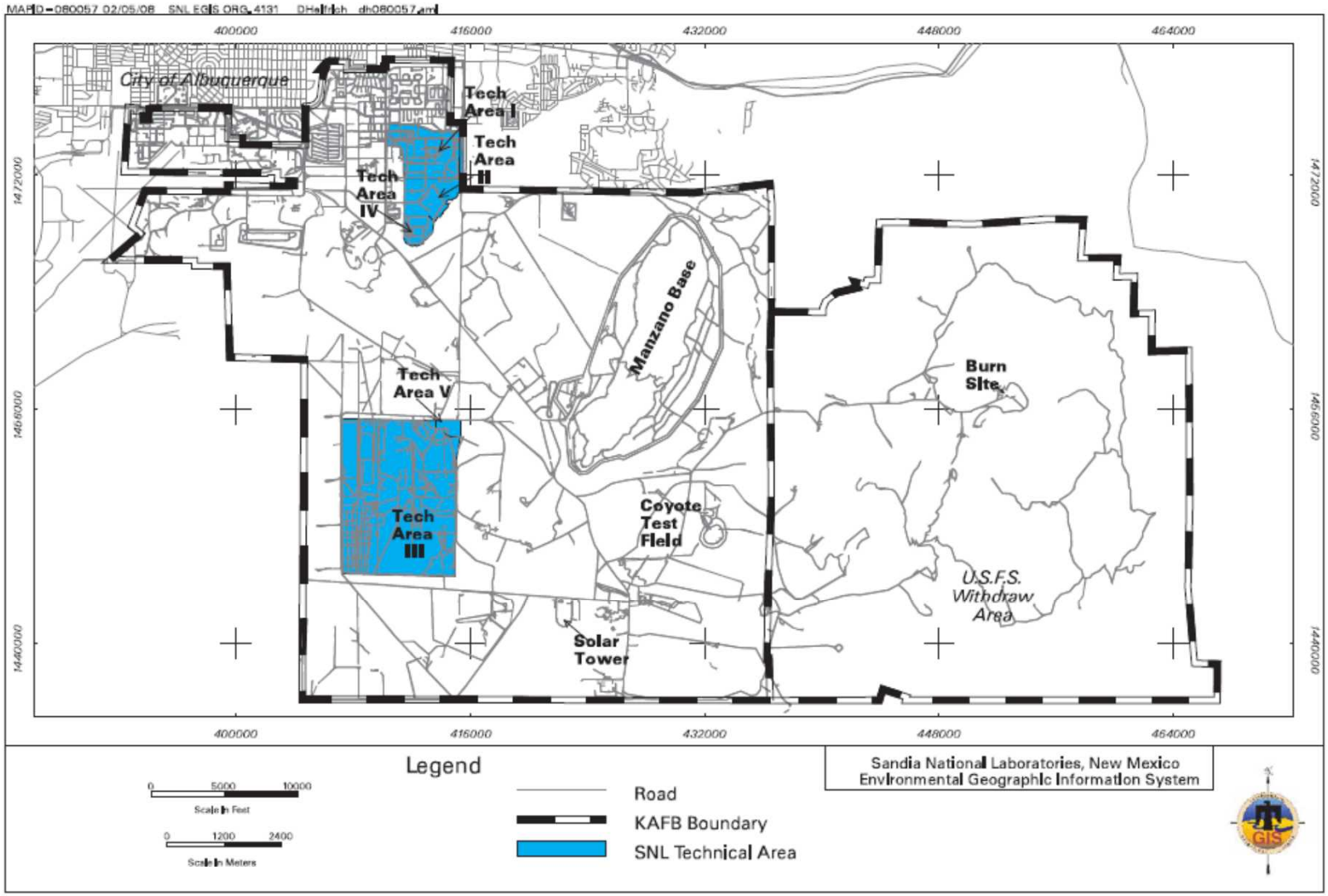
Geographical Boundaries



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General SNL/NM Site Statistics

- 8,600 acres of total landholdings
  - 5,600 acres of DOE property
  - 3,000 acres of US Air Force property
- 10,600 staff
- Over 700 government-owned buildings
- 5.4 million gross ft^2 of building space

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Analysis Methodology

- Determine the categories that contribute to the ecological footprint
- Develop calculation methods specific to each category
- Cross reference findings with known ecological footprint models

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Primary Footprint Categories

1. Energy
2. Transportation
3. Waste
4. Land
5. Water

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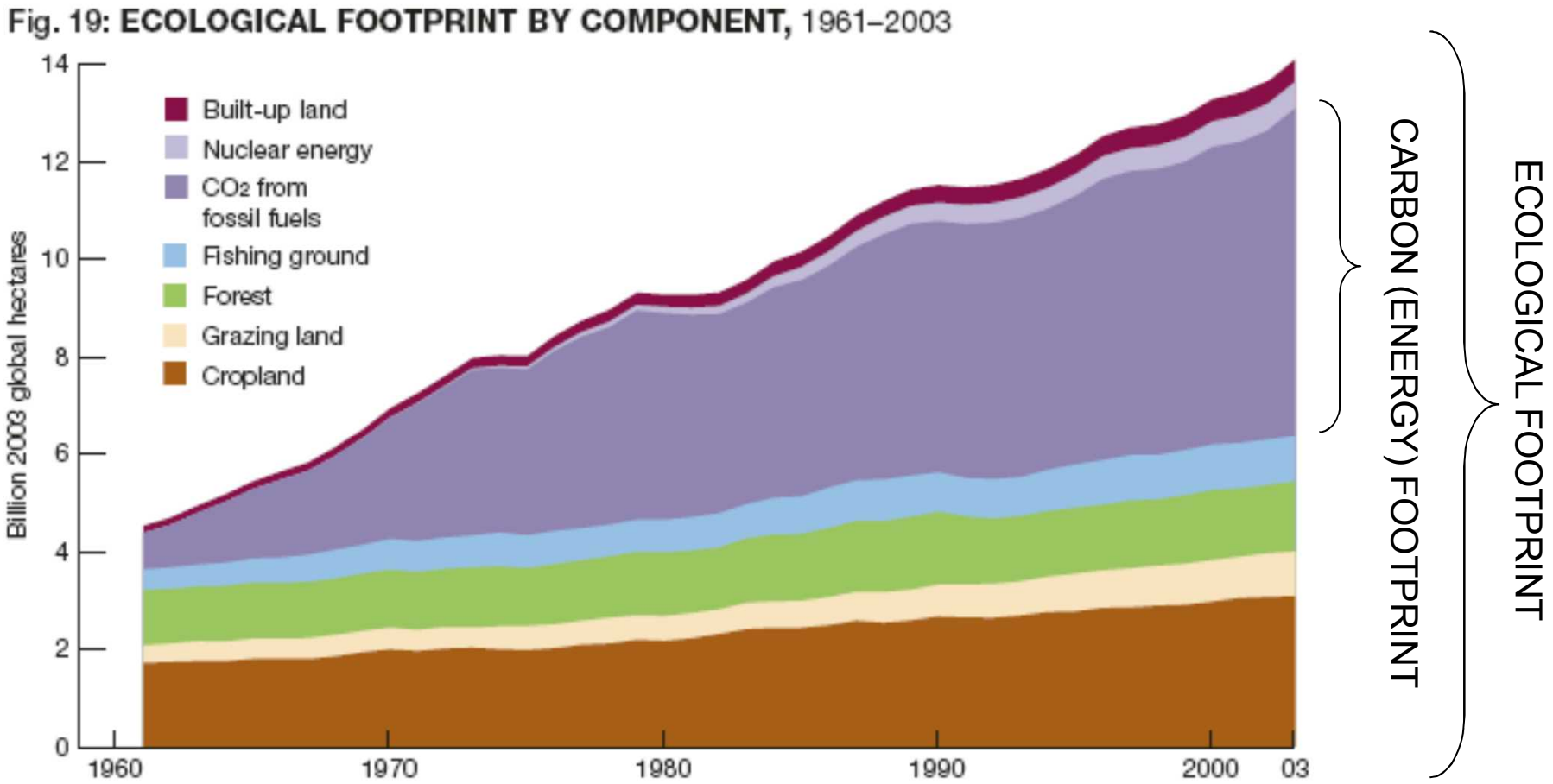
Types of Footprints



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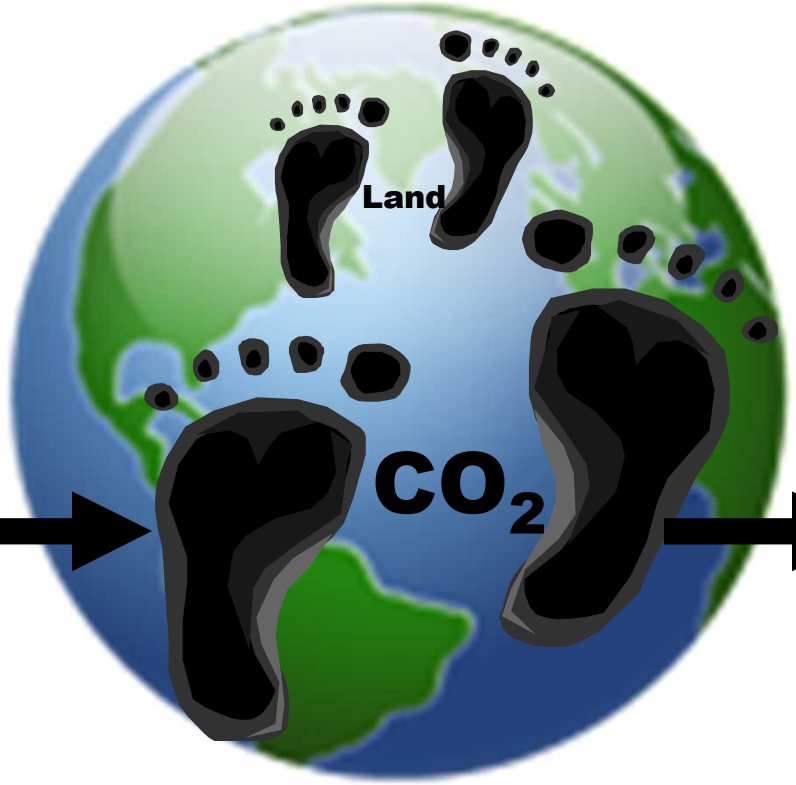
SNL/NM's Ecological Footprint Contributions



Inputs:
- Energy
- Transportation
- Waste

Outputs:
- CO_2
- CH_4 x 23 GWP
- N_2O x 296 GWP

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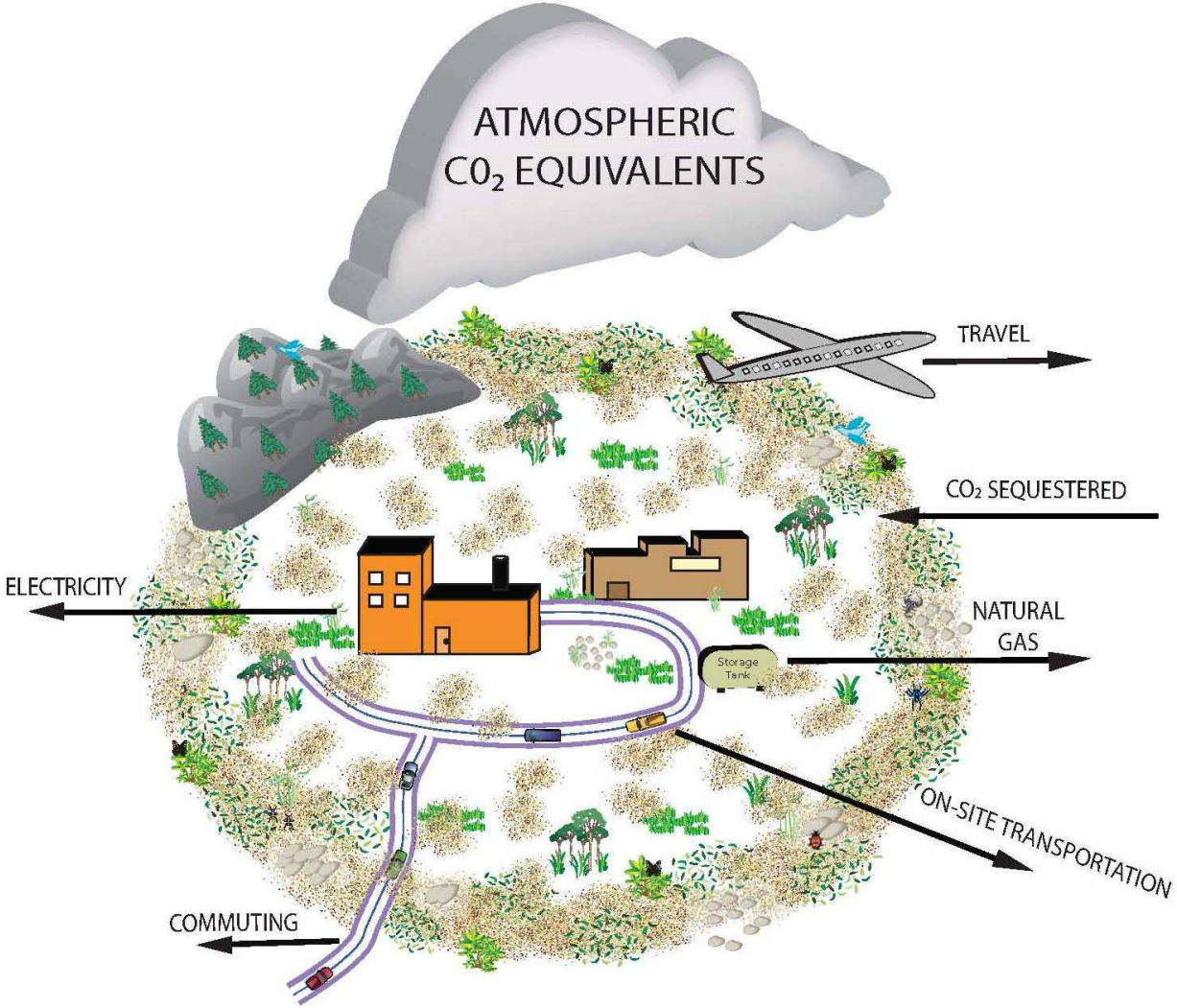
Sandia's Ecological Footprint



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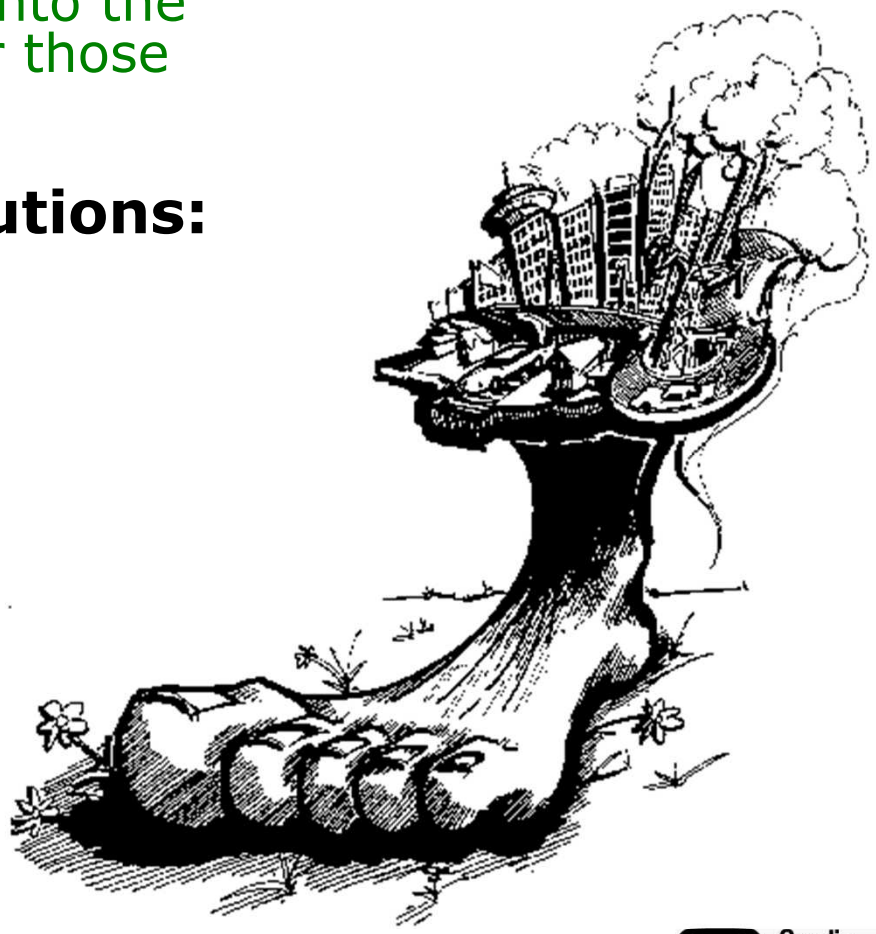
The Carbon Footprint Model

Calculate carbon dioxide equivalent (CO_2E) emissions and convert into the land area required to sequester those emissions

Carbon Footprint Contributions:

- ***Energy Use***
  - **Coal-fired Electricity**
  - **Hydroelectricity**
  - **Biomass Electricity**
  - **Natural Gas**
- ***Transportation***
  - **Employee Commuting**
  - **Fleet Vehicles**
  - **Air Travel**
  - **Rental Cars**
- ***Waste***
  - **Waste Transportation**
  - **Landfill GHG Emissions**



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Carbon Footprint Methodology

1. *Determine Total CO_2E Emissions*: *Determine* CO_2 *Sequestration* Most industrial processes have associated GHG emissions which can be calculated based on fuel-specific multipliers.

2. *Area in Global Hectares (**gha**):* The world's average forest has an absorption capacity of 0.192 hectares per metric ton of CO_2 per year. Since not all land is as productive as a forest, we multiply by an equivalence factor of 1.17gha/ha to compensate for bio-productive inequalities.

3. *Express Findings in Local Hectares (**lha**)*: We have estimated that the local New Mexican landscape has an absorption capacity of 1.89 local hectares per metric ton of CO_2 per year. Since this value is specific to the local landscape, an equivalence factor is not needed.

CO_2E = Carbon dioxide equivalent (includes N2O and CH4 based on their corresponding global warming potentials
gha = global hectare (1 ha of the Earth's average bioproductive land)
lha = local hectare (1 ha of the average bioproductive land on the SNL/NM campus)
1ha = 2.47 acres = 107,639 ft^2

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Carbon Footprint Energy Calculation

Example: Grid Electricity Carbon Footprint

a) FY05 Grid Electricity Consumption: $\frac{MWh}{year}$

b) NM Grid CO_2 Emissions Factor: $2{,}054\frac{lbs\ CO_2}{MWh}$

c) NM Grid N_2O Emissions Factor: $4.4\frac{lbs\ N_2O}{MWh}$

d) N_2O Global Warming Potential: $296\frac{lbsCO_2E}{lbsN_2O}$

e) NM Grid CH_4 Emissions Factor: $0.0131\frac{lbsCH_4}{MWh}$

f) CH_4 Global Warming Potential: $23\frac{lbsCO_2}{lbsCH_4}$

$$\left(\frac{MWh}{year}\right)\left(2{,}054\frac{lbsCO_2}{MWh}+4.4\frac{lbsN_2O}{MWh}(296)+0.0131\frac{lbsCH_4}{MWh}(23)\right)=357{,}900\,tonneCO_2$$

CO_2E = Carbon dioxide equivalent (includes N2O and CH4 based on their corresponding global warming potentials

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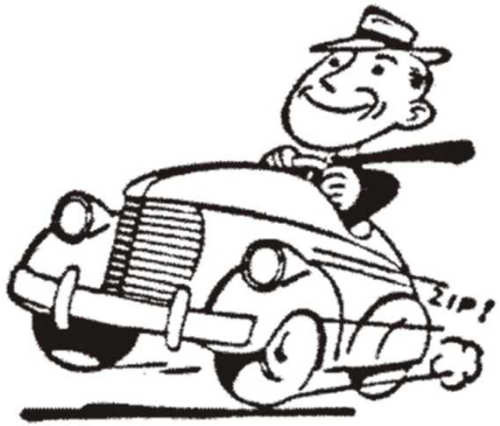
Carbon Footprint Transportation Calculation

Example: Commuter Carbon Footprint



a) # Employees Driving to Work Daily: *commuters*

b) Average Round Trip Commute: $\frac{miles}{commuter}$

c) Average Fuel Economy: $\frac{miles}{gallon}$

d) Gasoline CO_2 Emission Factor: $19.54\frac{lbsCO_2}{gallon}$

e) Gasoline CH_4 Emission Factor: $\frac{gCH_4}{mile}$

f) CH_4 Global Warming Potential: $23\frac{lbsCO_2}{lbsCH_4}$

g) Gasoline N_2O Emission Factor: $\frac{gN_2O}{mile}$

h) N_2O Global Warming Potential: $296\frac{lbsCO_2E}{lbsN_2O}$

$$(commuters)\left(\frac{miles}{commuter}\right)\left(\left(\frac{gallon}{miles}\right)\left(19.54\frac{lbsCO_2}{gallon}\right)+\left(\frac{gCH_4}{mile}\right)(23)+\left(\frac{gN_2O}{mile}\right)(296)\right)=22{,}810\,tonneCO_2E$$

CO_2E = Carbon dioxide equivalent (includes N2O and CH4 based on their corresponding global warming potentials

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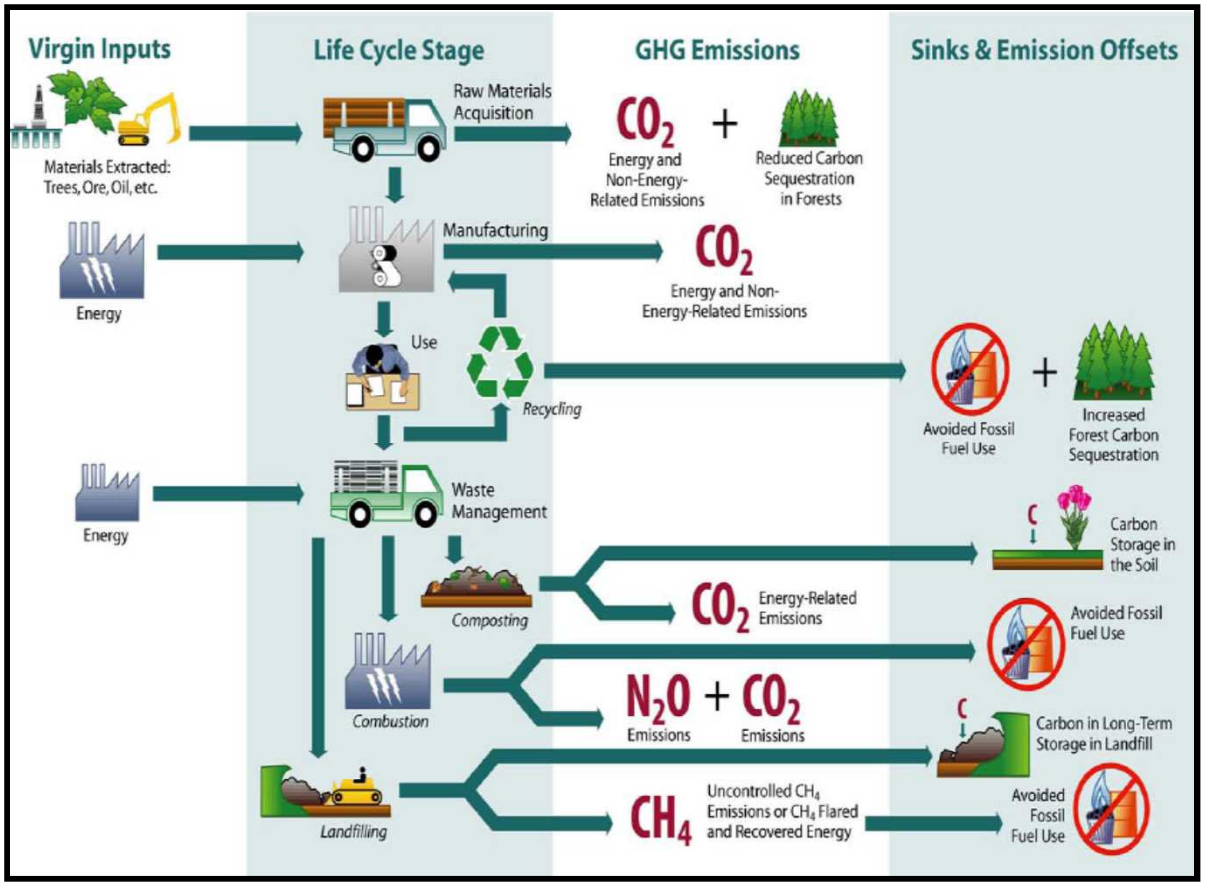
Carbon Footprint Model Waste Calculation

WARM Captures:

- GHG emissions
- Sinks
- Emission offsets



EPA's Waste Reduction Model Material Life Cycle

Source: http://www.epa.gov/climatechange/wycd/waste/downloads/chapter1.pdf

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WARM Results

Recycling helps reduce GHG emissions.

Commodity	Tons Recycled	Tons Landfilled	Total MTCO2E
Aluminum Cans	2	-	24
Steel Cans	5	-	8
Corrugated Cardboard	263	-	818
Phonebooks	4	-	10
Dimensional Lumber	257	-	630
Mixed Paper, Office	152	-	518
Mixed Metals	1,150	-	6,046
Mixed Plastics	5	-	7
Mixed Recyclables	280	-	816
Mixed MSW	NA	10,015	1,910
Carpet	3	-	20
Personal Computers	26	-	58
Concrete	3,773	-	29
Tires	5	-	8
		Total	10,902

Output data from WARM

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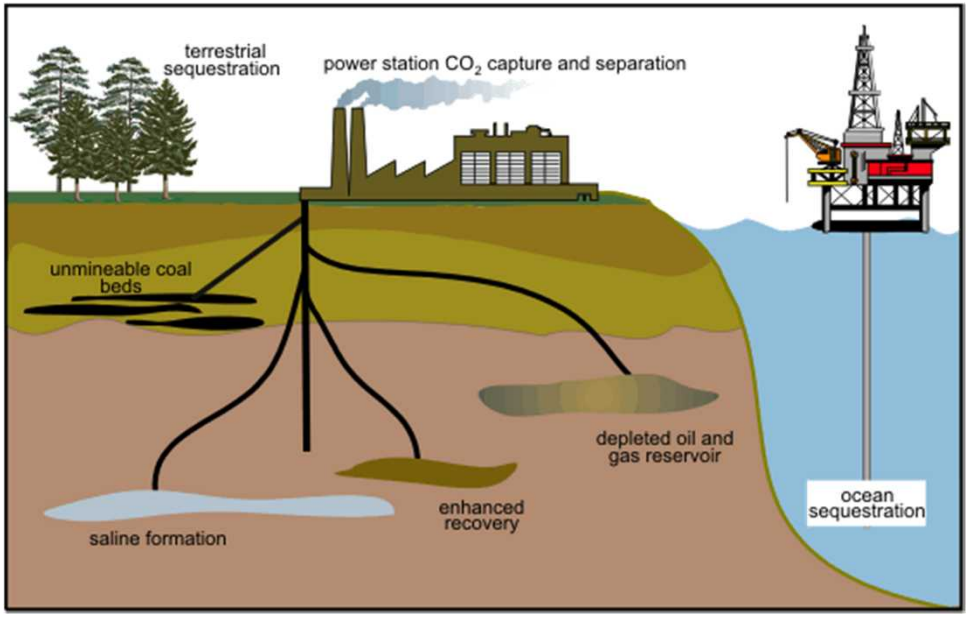
Global Hectares – The Details

$$(tonneCO_2E)\left(0.192\frac{ha}{tonneCO_2}\right)\left(1.17\frac{gha}{ha}\right)=gha$$

a) Total CO_2E Emissions: $tonneCO_2E$

b) Average Forest Absorption Capacity: $0.192\frac{ha}{tonneCO_2}$

c) Equivalence factor: $1.17\frac{gha}{ha}$



The world's average forest has an absorption capacity of 0.192 hectares per metric ton of CO_2 per year. Since not all land is as productive as a forest, we multiply by an equivalence factor of 1.17gha/ha to compensate for bio-productive inequalities.

CO_2E = Carbon dioxide equivalent (includes N2O and CH4 based on their corresponding global warming potentials
gha = global hectare (1 ha of the Earth's average bioproductive land)
1ha = 2.47 acres = 107,639 ft^2

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Local Hectares – The Details

- The SNL/NM landscape consists Pinyon-Juniper woodlands and desert grasslands.
- Carbon sequestration potential for desert grasslands, along with aboveground net primary production of Pinyon-Juniper woodlands and desert grassland, were used to estimate carbon sequestration potential for Pinyon-Juniper woodlands.

Calculation of Pinyon-Juniper Sequestration Ratio:

a. NM Rangeland Grass/Legume Sequestration Ratio: $0.13 \frac{tonneC}{ha}$
b. Desert Grassland Aboveground Net Primary Production: 0.95 Mg C/ha/yr
c. Average Pinyon-Juniper Aboveground Net Primary Production: 1.0 Mg C/ha/yr

$$\left(\frac{0.13 \frac{tonneC}{ha}}{0.95 \frac{Mg.C}{ha.yr}} \right) = \left(\frac{x \frac{tonneC}{ha}}{1.0 \frac{Mg.C}{ha.yr}} \right) \qquad x = 0.14 \frac{tonneC}{ha}$$

lha = local hectare (1 ha of the average bioproductive land on the SNL/NM campus)
1ha = 2.47 acres = 107,639 ft^2

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Local Hectare - Continued

- **Carbon sequestration was converted into CO_2 sequestration potentials, which were multiplied by the percentages of corresponding vegetation types to yield an average CO_2 sequestration potential for the local landscape.**

a. Atomic Mass of C: 12.01 g/mol
b. Atomic Mass of CO_2: 44.01 g/mol
c. Percentage of Grassland-Legume: 74%
d. Percentage of Pinyon-Juniper Woodlands: 26%

$$\approx \left(0.13\frac{tonneC}{ha}\times 74\% + 0.14\frac{tonneC}{ha}\times 26\%\right)\left(\frac{44.01\frac{g}{mol}CO_2}{12.01\frac{g}{mol}C}\right)$$

$$\approx 0.53\frac{tonneCO_2}{lha} \approx 1.88\frac{lha}{tonneCO_2}$$

lha = local hectare (1 ha of the average bioproductive land on the SNL/NM campus)
1ha = 2.47 acres = 107,639 ft^2

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Carbon Footprint Results

Category	*gha*	*lha*
Energy	80,050	669,910
Commuting	7,740	62,420
Natural Gas	6,620	55,390
Airline Travel	4,360	36,500
Waste emissions	2,460	20,580
Rental Cars	840	7,000
Fleet	650	5,410
Carbon Footprint	102,720	857,210

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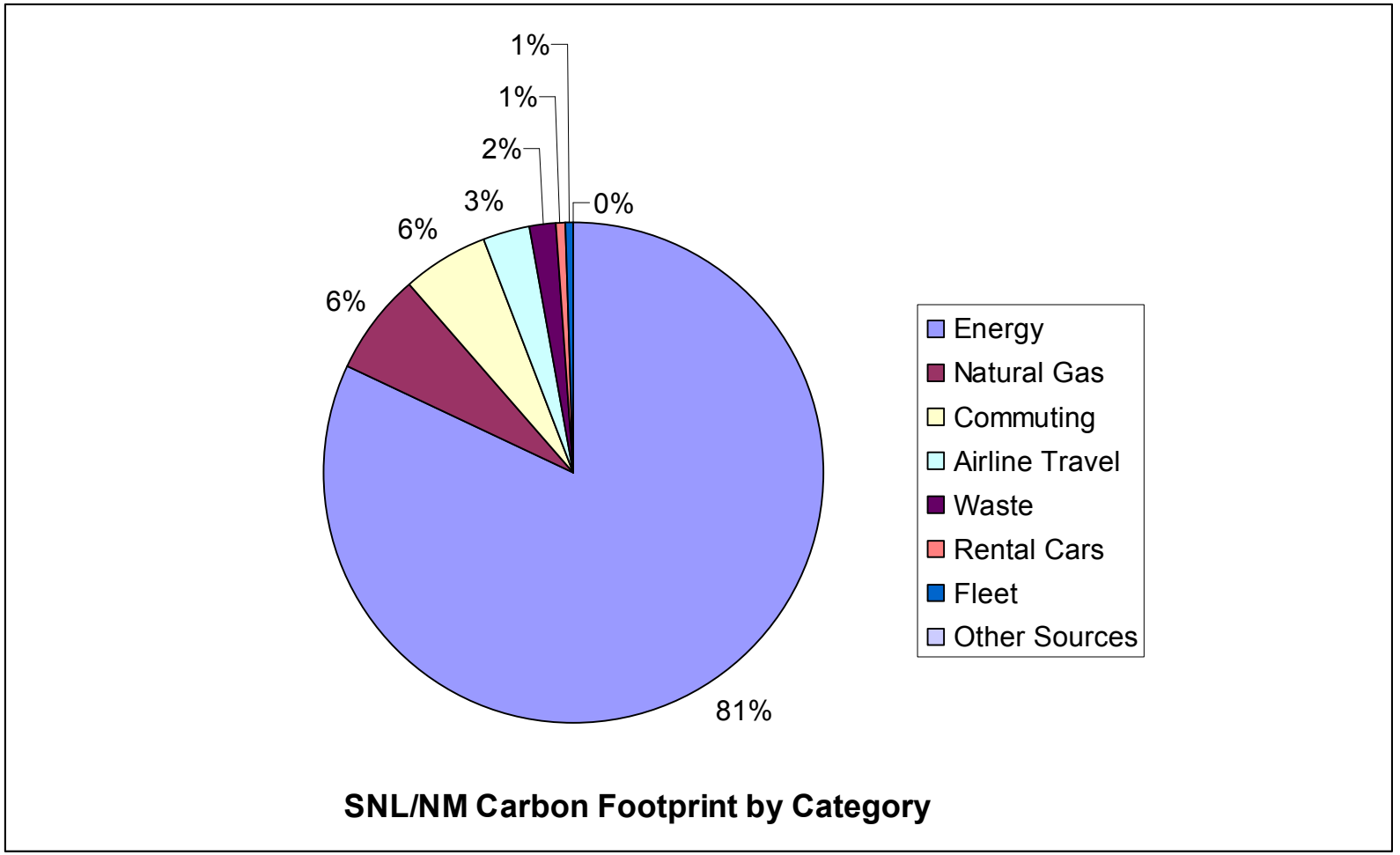
Carbon Footprint Results



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Land Use Footprint

Components of Land Use:

- Land area owned/operated by SNL/NM: 3,470 *lha*
- SNL/NM DOE owned land area: 1,190 *lha*
- Total developed area: 350 *lha*

lha = local hectare (1 ha of the average bioproductive land on the SNL/NM campus)
1ha = 2.47 acres = 107,639 ft^2

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Ecological Footprint Results

Carbon Footprint + Land Use Footprint = Total Ecological Footprint

$$102{,}720\,gha + 40\,gha = 102{,}760\,gha$$

$$857{,}210\,lha + 350\,lha = 857{,}560\,lha$$

Total Landholdings – Ecological Footprint = Ecological Deficit

$$3{,}470\,lha - 857{,}560\,lha = -854{,}090\,lha$$

lha = local hectare (1 ha of the average bioproductive land on the SNL/NM campus)
1ha = 2.47 acres = 107,639 ft^2

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Water Use Footprint

Water Footprint Components:

- FY05 water consumption by SNL/NM
- Comparison of consumption by the City of Albuquerque and other large water users

Regional Water Comparison

a) SNL water use FY05: 406 million gallons
b) Intel Corporation: 880 million gallons
c) University of New Mexico: 482 million gallons
d) City of Albuquerque: 32.8 billion gallons

SNL/NM is responsible for 1.17% of the total water usage in Albuquerque.

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Water Footprint Results

SNL Water Use per Building Square Foot
a) SNL water use: 406 million gallons
b) SNL square footage: 6 million ft^2

$$\frac{406 million.gallons}{6.5 million ft^2} = 67 \frac{gal}{ft^2}$$

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SNL/NM FY05 Baseline Ecological Footprint Results

- CO_2E emissions make up most of the ecological footprint
- Energy use is the largest component of the footprint
- The ecological footprint in *lha* units is much larger than that in *gha* units
- Land use is a small contribution to the ecological footprint
- Water use is not directly related to the ecological footprint, but should be considered an important environmental impact

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Conclusions

Benefits	Shortcomings
Allows for the standardization of various impacts, both direct and indirect	Lack of available data
Includes the impact of waste assimilation	Although this analysis includes a "water footprint," this resource cannot be normalized to footprint units
Yields a quantifiable measure of environmental impact	Contamination from pollutants, and their impact on bioproductivity, is not included in the model
Potentially a significant asset to emerging carbon markets	Does not account for biodiversity
Potentially the environmental/sustainability complement to economic state indicator models (GDP and RPI)	Although the analysis accounts for CH_4 and N_2O emissions, sequestration only applies to CO_2

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Path Forward

- Transportation study
- Increased R&D regarding renewable energy
- Management focus group, Remaking Sandia, to set goals and obtain support and resources
- Energy Reduction Initiatives
  - Retro-commissioning
  - Load reduction efforts (i.e. Lights out campaign)
  - Energy projects

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