# Life-Cycle Impact Assessment & Environmental Life Cycle Declarations

## Environmental Accountability Tools for the Energy Sector, Based on ISO-14044 and ASTM E06.71.10

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# UNEP Life-Cycle Impact Assessment Initiative

## Goals:

- Convert the guidance standard of ISO 14044 into a finalized set of LCIA impact indicators.
- Use this indicator set to establish protocols for an international LCIA-based environmental accounting system.
- Present this environmental accounting system for adoption by the international community, starting with OECD.

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# Environmental Life Cycle Declaration (consistent with ISO-14025)

Environmental Life Cycle Declarations are prepared for each new supply option or upgrade to an existing system under consideration. This declaration contains the following information:

- Identifies the regional power grid which serves as the LCIA baseline for comparison
- Describes key design aspects of the new supply option or design upgrade
- Provides a graphic environmental impact profile of the new supply option or design upgrade
- Summarizes key advantages and trade-offs

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# Regional Grid LCIA Baselines

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

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# Scope of LCIA

- extraction and processing of fuel resources (fossil, biomass, nuclear)

- transport of fuel resources

- construction of power plant

- operation of power plant

- distribution of electricity to users

- decommissioning of power plant and continued treatment of waste (nuclear, fly ash)

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# LCIA Modeling

Identify the impact category and justify the category based upon biophysical event

Model the biophysical pathway of the impact using stressor-effects network modeling.

Characterize the spatial, temporal and intensity of the impact category

Select the impact indicator using a node along the stressor-effects network that has the strongest link to both the stressor and impact endpoint.

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# Established LCIA Impact Indicators Natural Resources

- Depletion of Non-Renewable Energy Resources
- Depletion of Water Resources
- Depletion of Wood Resources
- Depletion of Strategic Metals
- Depletion of Terrestrial Habitats
- Depletion of Riparian Habitats
- Depletion of Riverine Habitats
- Depletion of Lake Habitats
- Depletion of Key Species (e.g., T & E species)

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# LCIA Stressor-Effects Modeling
# Selection of the Node 2 Indicator

**Depletion of Habitats**

**Node 2 Indicator: Depletion of habitats (hectares)**

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# LCIA Impact Indicators Emissions and Wastes

- Cumulative Greenhouse Gas Loading
- Oceanic Acidification Loading
- Regional Acidification Loading
- Neurotoxic  Chemical Loading
- Eco-Toxic Chemical Loading
- Systemic Chemical Loading
- Pulmonary Chemical Exposures
- Ground Level Ozone Exposures
- PM 2.5 Exposures
- Hazardous and Radioactive Waste Risks

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# LCIA Stressor Effects Modeling Node 3 Indicator

## Regional Acidification

QuickTime™ and a

**Node 3 Indicator: Acidification Loading = % Wet deposition of strong acid emissions in areas of exceedance of critical load**

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# Node 2 Indicator: Cumulative-Greenhouse Gas Loading (2040)

**Node 2 Indicator: Cumulative Greenhouse Gas Loading (2040)**

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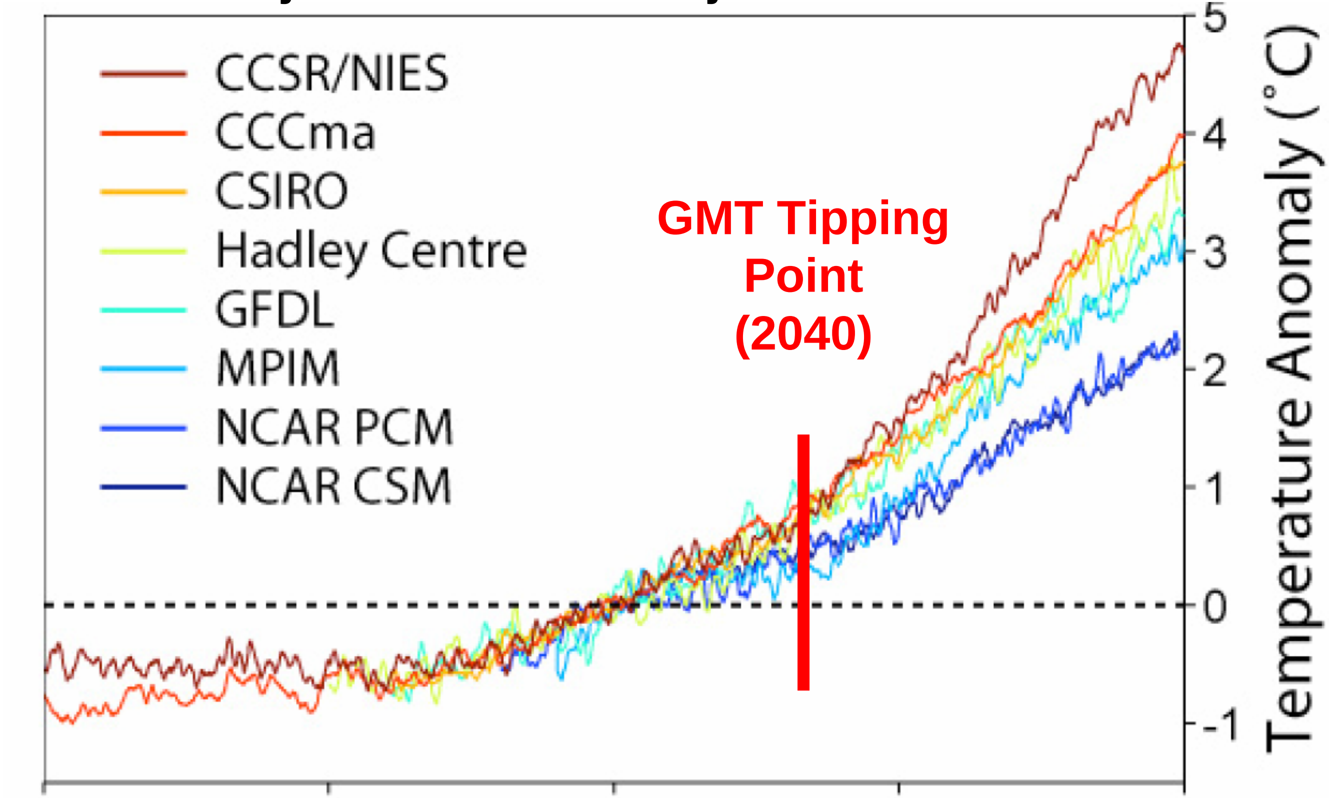
# Node 4 Global Mean Temperature Increases and 2040 Tipping Point

**Major GMT Model Projections**




**These projections indicate that it is 10x more effective to reduce Cumulative Greenhouse Gas Loadings before 2040**

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# Nodes 2,3,4   Cumulative GHG loading linkage to the 2040 GMT Tipping Point

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are needed to see this picture.

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TIFF (LZW) decompressor
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GMT
Tipping
Point

Increases in the **Cumulative Greenhouse Gas Emissions** are leading to the 2040 GMT tipping point

… because increases in the **C-GHG Emissions** is thermal driver linked to increases in global radiative forcing

… which then leads to the increase in GMT.

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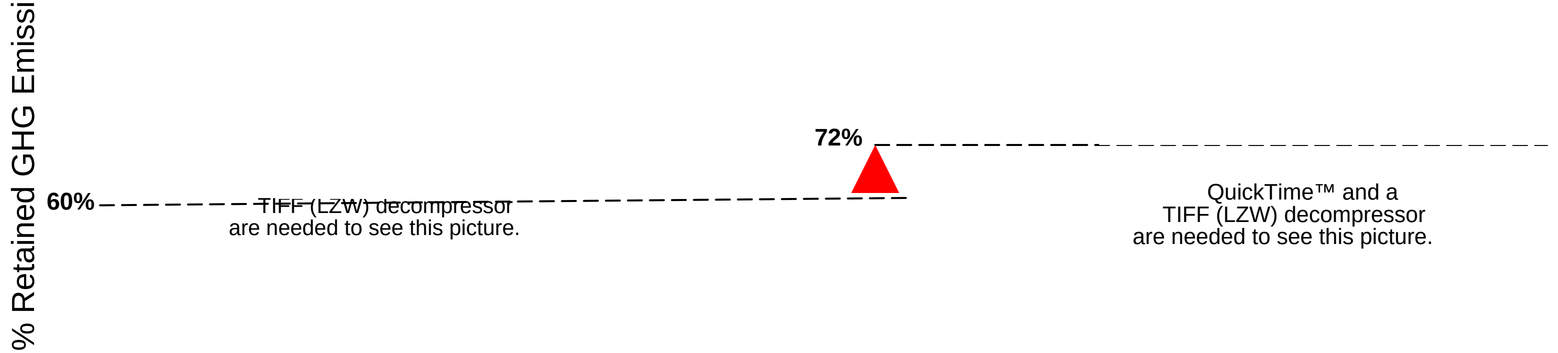
# Cumulative GHG Loading-2040

**60% Annual GHG Emissions (2007) still retained in atmosphere in 2040**

**72% Annual GHG Emissions (2015) still retained in atmosphere in 2040**




**C-GHG loading (2007-2040) = $\sum$ (% Annual Retained GHG Emissions)**

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# Environmental Life-Cycle Declarations of Western Power

## Regional Grid Baseline: WECC

| | | |
|---|---|---|
| Coal | 247,013 GWh | 32.5% |
| Hydro | 188,382 GWh | 28.3% |
| Gas | 155,672 GWh | 23.3% |
| Nuclear | 74,164 GWh | 11.1% |
| Oil | 1,917 GWh | 0.3% |
| Renewable | 30,490 GWh | 4.6% |
| | | |
| Total | 847,640 GWh | 100.0% |

## Nutrition Facts

Serving Size 1 cup (236ml)
Servings Per Container 1

Amount Per Serving

| | |
|---|---|
| **Calories** 80 | Calories from Fat 0 |
| | % Daily Value* |
| **Total Fat** 0g | 0% |
| Saturated Fat 0g | 0% |
| *Trans* Fat 0g | |
| **Cholesterol** Less than 5mg | 0% |
| **Sodium** 120mg | 5% |
| **Total Carbohydrate** 11g | 4% |
| Dietary Fiber 0g | 0% |
| Sugars 11g | |
| **Protein** 9g | 17% |

Vitamin A 10% • Vitamin C 4%
Calcium 30% • Iron 0% • Vitamin D 25%

*Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

# Environmental Impact Profile*

Mt. Shasta Biomass Power Station

Impact Levels Per 1000 Gwh

| **Depletion of Natural Resources** | **Impact Levels** |
|---|---|
| Non-Renewable Energy | 12,000 barrels of oil |
| Water | -- |
| Strategic Metals | -- |
| Terrestrial Habitats | 14,000 hectares |
| Wetland Habitats | 1,200 hectares |
| Lake Habitats | -- |
| River Habitats | -- |
| Key Species | 50 % loss |
| **Impacts from Emission Loadings** | |
| Cumulative Greenhouse Gases | 12,000,000 tons $CO_2$ |
| Oceanic Acidification | 149,000 tons $CO_2$ |
| Acid Rain | 96 tons $SO_2$ |
| Smog | 33,000 exposures |
| Soot (PM 2.5) | 87,000 exposures |
| Neurotoxicity | -- |
| Systemic Chemical Toxicity | -- |
| Eco-Toxicity | 106 kg TCDD |
| **Risks from Hazardous Wastes** | |
| Radioactive Wastes | -- |

*** Based Upon Life-Cycle Impact Assessment**

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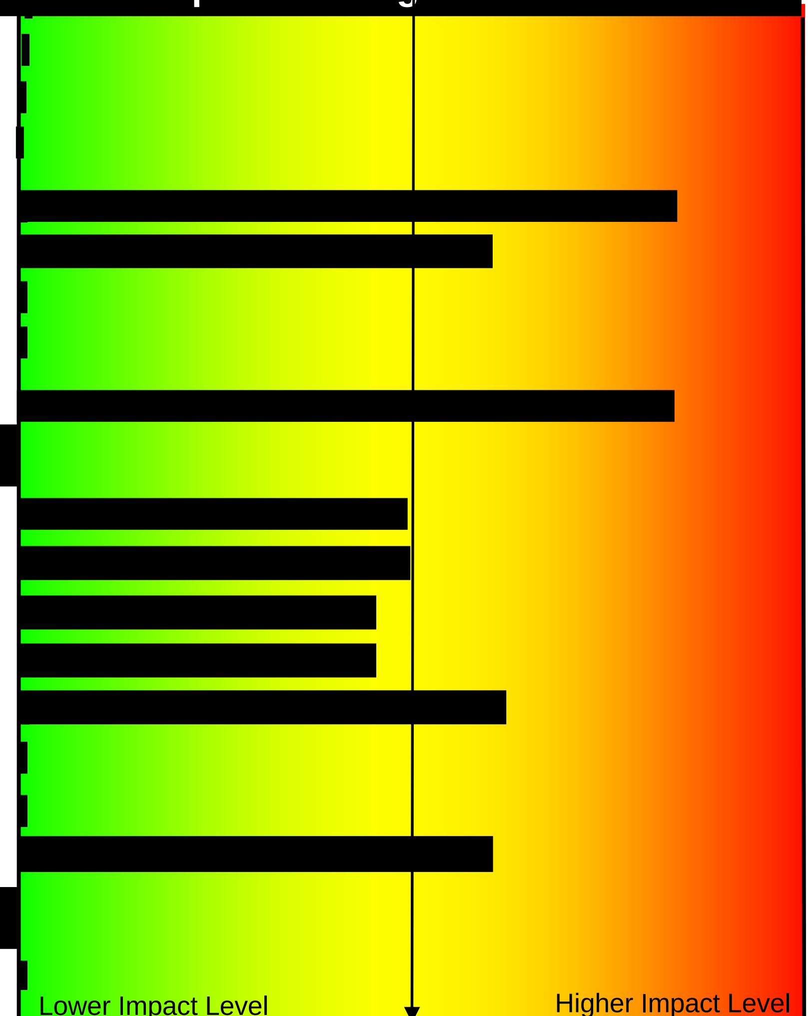
# Environmental Impact Profile*

Mt. Shasta Woody Biomass Plant

Impact Levels per 1000 Gwh

| Depletion of Natural Resources | Impact Levels |
|---|---|
| Non-Renewable Energy | 12,000 barrels oil |
| Water | -- |
| Strategic Metals | |
| Terrestrial Habitats | 14,000 hectares |
| Wetland Habitats | 1,200 hectares |
| Lake Habitats | -- |
| River Habitats | -- |
| Key Species | 50 % loss |
| **Impacts from Emission Loadings** | |
| Cumulative Greenhouse Gases | 12,000,000 tons $CO_2$ |
| Oceanic Acidification | 149,000 tons $CO_2$ |
| Acid Rain | 96 tons $SO_2$ |
| Smog | 33,000l exposures |
| Soot (PM 2.5) | 87,000 exposures |
| Neurotoxicity | -- |
| Systemic Chemical Toxicity | -- |
| Eco-Toxicity | 106 kg TCDD |
| **Risks from Hazardous Wastes** | |
| Radioactive Wastes | -- |

Compared to Regional Grid




Average Impact level of Regional Grid

* Based Upon Life-Cycle Impact Assessment

QuickTime™ and a
TIFF (LZW) decompressor
are needed to see this picture.

## *Key LCIA Findings and Environmental Trade-offs*

- Habitat disruption from forestry operations at least 2 orders of magnitude greater than other power technologies on an equivalent power production basis (100,000 ha per 50 MW capacity for woody biomass systems).
- Regional emissions related to human health are exposing surrounding populations above threshold levels.
- Acidifying gas emissions deposit in areas of known exceedance of critical loading with the dispersion area of the plant.
- Reduced carbon storage/ha due to removal of fuel loading to control fire danger led to reduction in net sequestration rate.
- Wood chip piles at biomass operations were found to biodigest during storage, resulting in significant methane releases. These results were found to cancel 40% of the total GHG sequestration potential alone.

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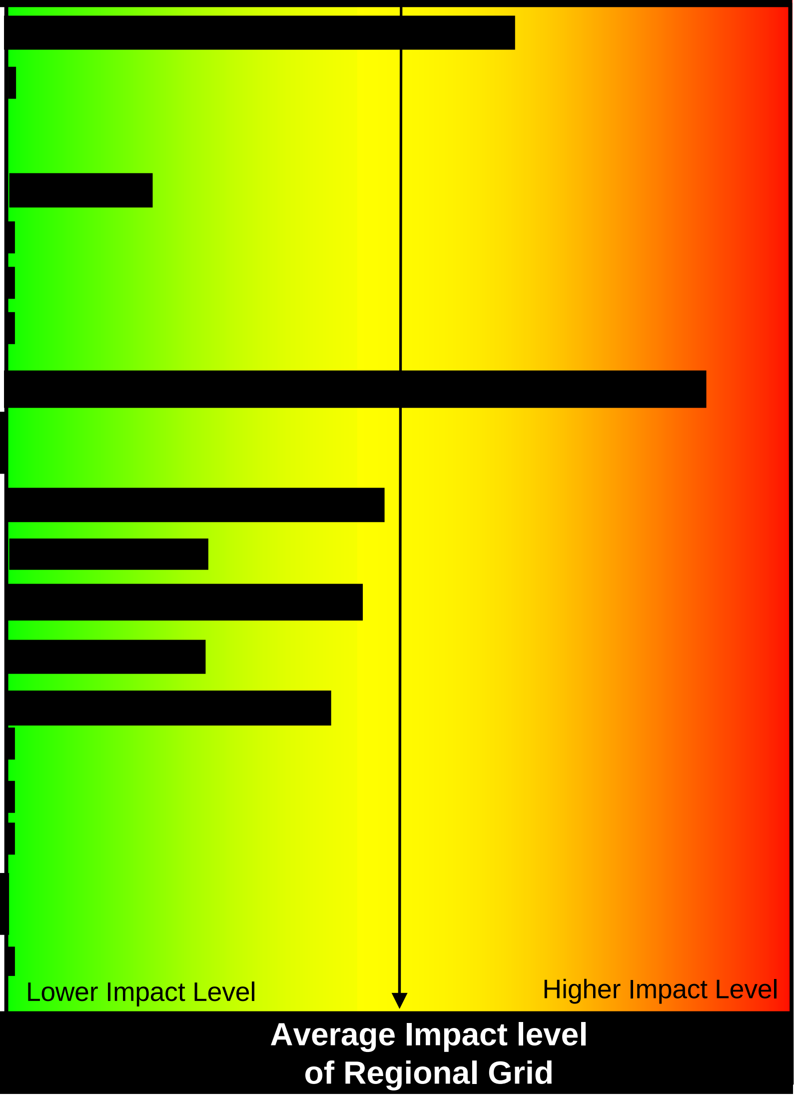
# Environmental Impact Profile*

Altamont Wind Power Station/Natural Gas LVRT
Impact Levels Per 1000 Gwh

| Depletion of Natural Resources | Impact Levels |
|---|---|
| Non-Renewable Energy | 6,800,000 eq. GJ oil |
| Water | -- |
| Strategic Metals | |
| Terrestrial Habitats | 200 hectares |
| Wetland Habitats | -- |
| Lake Habitats | -- |
| River Habitats | -- |
| Key Species | 60% |
| **Impacts from Emission Loadings** | |
| Cumulative Greenhouse Gases | 17,960,000 tons $CO_2$ |
| Oceanic Acidification | 29,000 tons $CO_2$ |
| Acid Rain | 29 tons $SO_x$ |
| Smog | 5,000 annual exposure |
| Soot (PM 2.5) | 3,000 annual exposures |
| Neurotoxicity | -- |
| Systemic Chemical Toxicity | -- |
| Eco-Toxicity | -- |
| **Risks from Hazardous Wastes** | |
| Radioactive Wastes | -- |

**Compared to Regional Grid**




* Based Upon Life-Cycle Impact Assessment

# Potential LCIA Concerns from Expansion of Western Wind Power

- Major wind developments are being linked to SCGT natural gas/hydro as backup power to compensate for intermittency. The additional wind deployment will have the tendency to lower the efficiency of the natural gas fleet back to SCGT (35-40%) from deployment of NGCC (58-60%).

- The visual and direct disruption of habitats from both towers as well as ROW are estimated to be from 600,000 to 1,900,000 hectares (both visual and direct) within the WECC for planned projects up through 2025.

- Even with extensive EIAs in place continuing loss of key species (birds, bats) have been reported from new wind projects.

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## Key LCIA Findings

This NGCC plant has negligible impact levels for 11 out of the 19 impact categories.

This NGCC plant has three environmental trade-offs

- Non renewable energy resource depletion
- Cumulative greenhouse gas loading C-GHG loading
- Oceanic Acidification

LNG sourcing increases both the C-GHG loading and Oceanic Acidification trade-offs due to methane emissions at the natural gas well heads in Iran, Russia and other major LNG countries.

It has been estimated by NASA (2007) that 400 million tons of GHG emissions are escaping annually.

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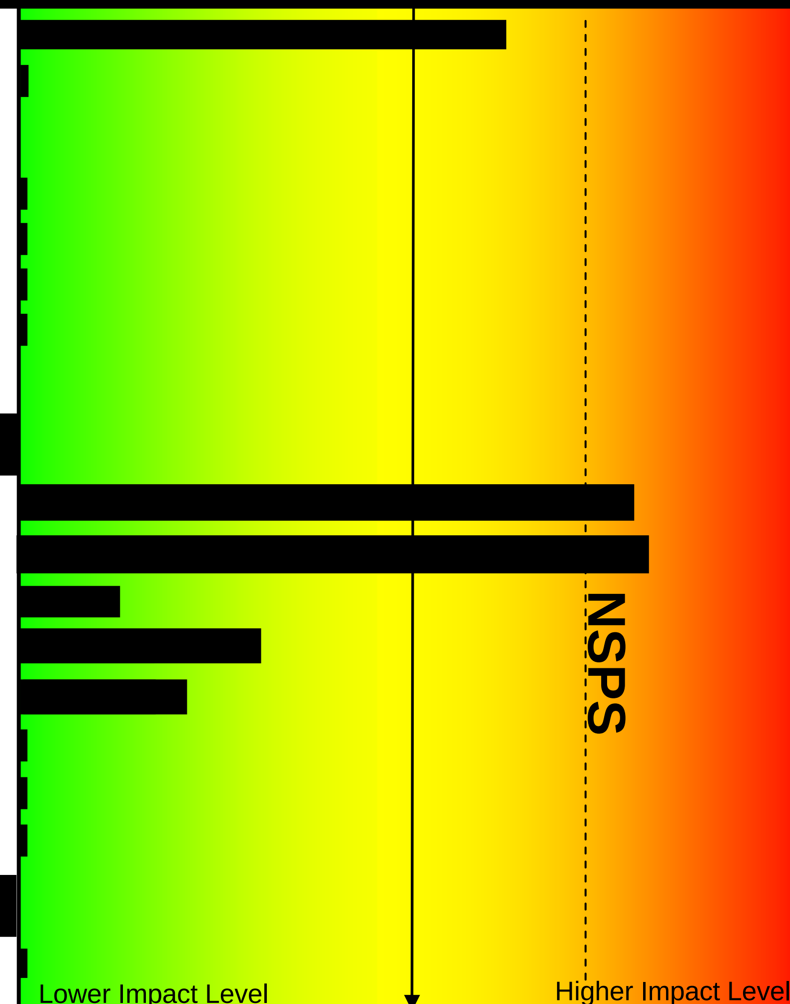
# Environmental Impact Profile*

NGCC Power Station (40% LNG)

Impact Levels Per 1000 Gwh

| Depletion of Natural Resources | Impact Levels |
|---|---|
| Non-Renewable Energy | 9,000,000 eq. GJ oil |
| Water | -- |
| Strategic Metals | |
| Terrestrial Habitats | 14 hectares |
| Wetland Habitats | -- |
| Lake Habitats | -- |
| River Habitats | -- |
| Key Species | -- |
| **Impacts from Emission Loadings** | |
| Cumulative Greenhouse Gases | 700,000 eq. tons $CO_2$ |
| Oceanic Acidification | 350,000 tons $CO_2$ |
| Acid Rain | 25 eq. tons $SO_2$ |
| Smog | 3,000 annual exposures |
| Soot (PM 2.5) | 6,000 annual exposures |
| Neurotoxicity | -- |
| Systemic Chemical Toxicity | -- |
| Eco-Toxicity | -- |
| **Risks from Hazardous Wastes** | |
| Radioactive Wastes | -- |

**Compared to Regional Grid**




**Average Impact level (Regional Grid)**

* Based Upon Life-Cycle Impact Assessment

# Canadian Power LCIA Studies

## Saskpower Project

- Developed comprehensive Provincial Power Baseline
- Environmental Life Cycle Declarations for all new supply options for the 2013 and 2017 investment periods.
- Developed environmental designs for new power technologies
- Conducted peer review LCIA study to support all Declarations

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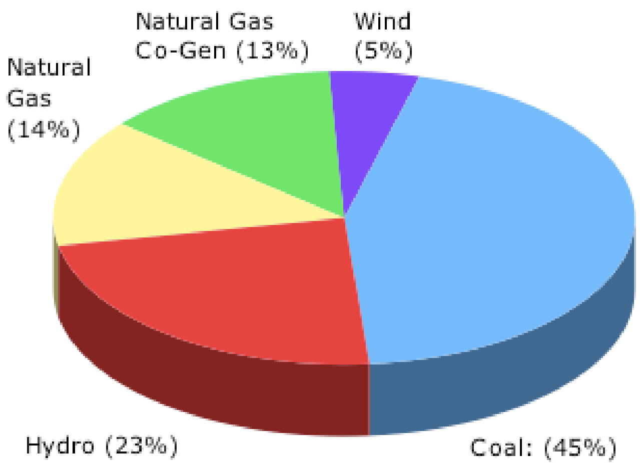
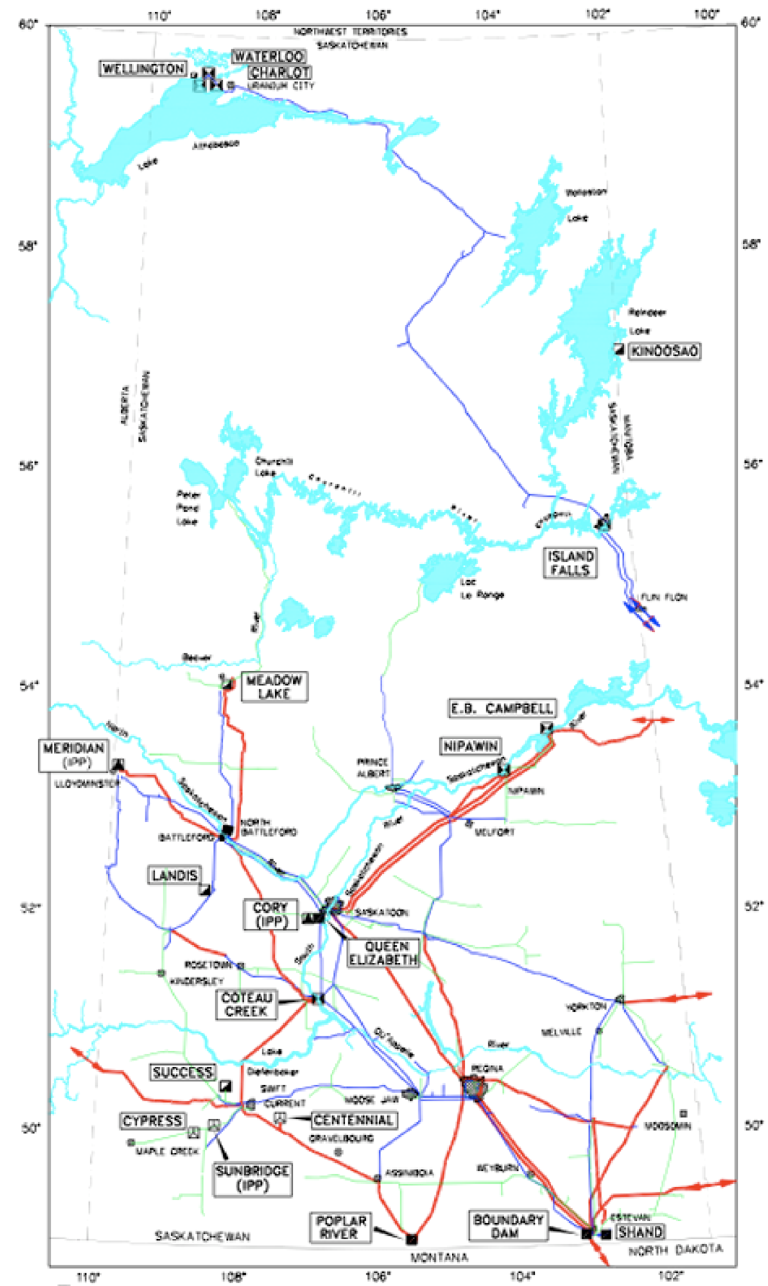
# Saskatchewan Power Baseline




Net power generation: 20,386 GWh

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# New Supply Options Under Consideration

| | |
|---|---|
| 1.) High Efficiency SCGT | 2040 GWh (annual) |
| 2.) Repower Older Natural Gas Unit | 2380 GWh |
| 3.) Advance Coal (CC, Oxyfuel) | 2230 GWh |
| 4.) Compliant Coal | 2230 GWh |
| 5.) Petcoke Gasification(CC, Poly) | 2,540 GWh |
| 6.) Hybrid Wind/SCGT Natural Gas | 1,590 GWh |
| 7.) Hybrid Wind/Oxyfuel Coal (CC, Poly) | 5,000 GWh<br>270,000 tons $H_2$ |

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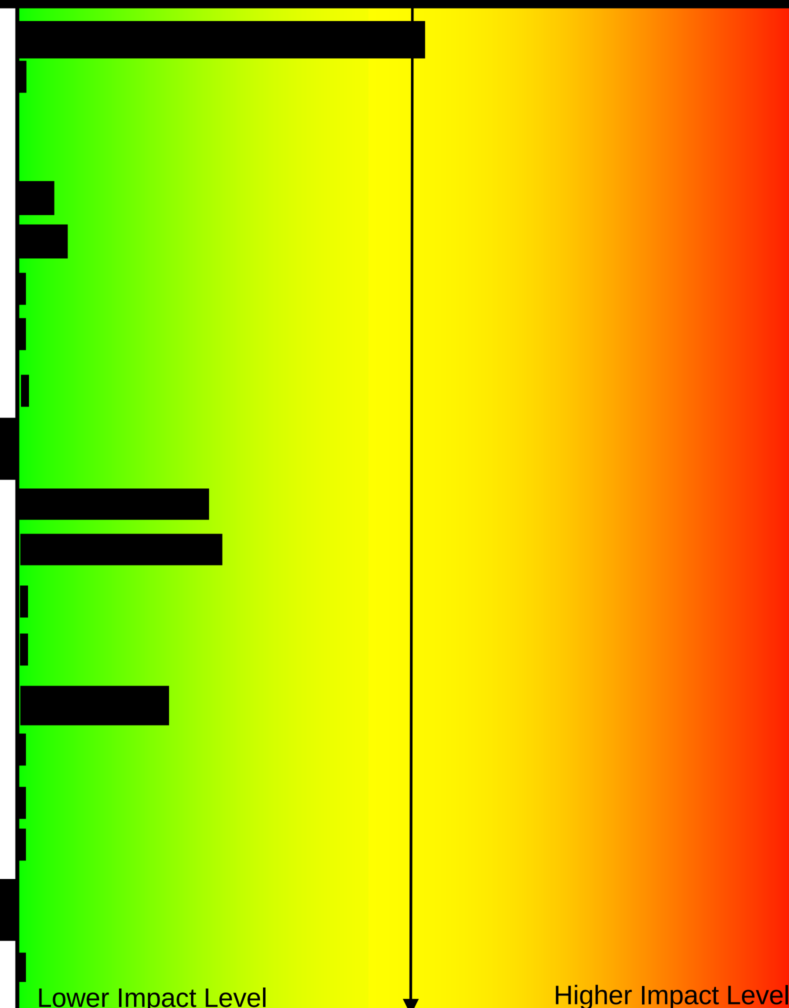
# Environmental Impact Profile

## New Supply Option 2017

## CC-OxyFuel Coal

| Resources Depletion | Oxy-Fuel Coal Impacts* | Compared to Regional Grid |
|---|---|---|
| Non-Renewable Energy | -- | |
| Water | -- | |
| Strategic Metals | | |
| Terrestrial Habitats | -- | |
| Wetland Habitats | -- | |
| Lake Habitats | -- | |
| River Habitats | -- | |
| Key Species | -- | |
| **Impacts from Emissions** | | |
| Cumulative Greenhouse Gases | -- | |
| Oceanic Acidification | -- | |
| Acid Rain | -- | |
| Smog | -- | |
| Soot (PM 2.5) | -- | |
| Neurotoxicity | -- | |
| Systemic Chemical Toxicity | -- | |
| Eco-Toxicity | | |
| **Risks from Wastes** | | |
| Radioactive Wastes | -- | |




Average Impact level (Regional Grid)

* Per 1,000 GWh electricity production

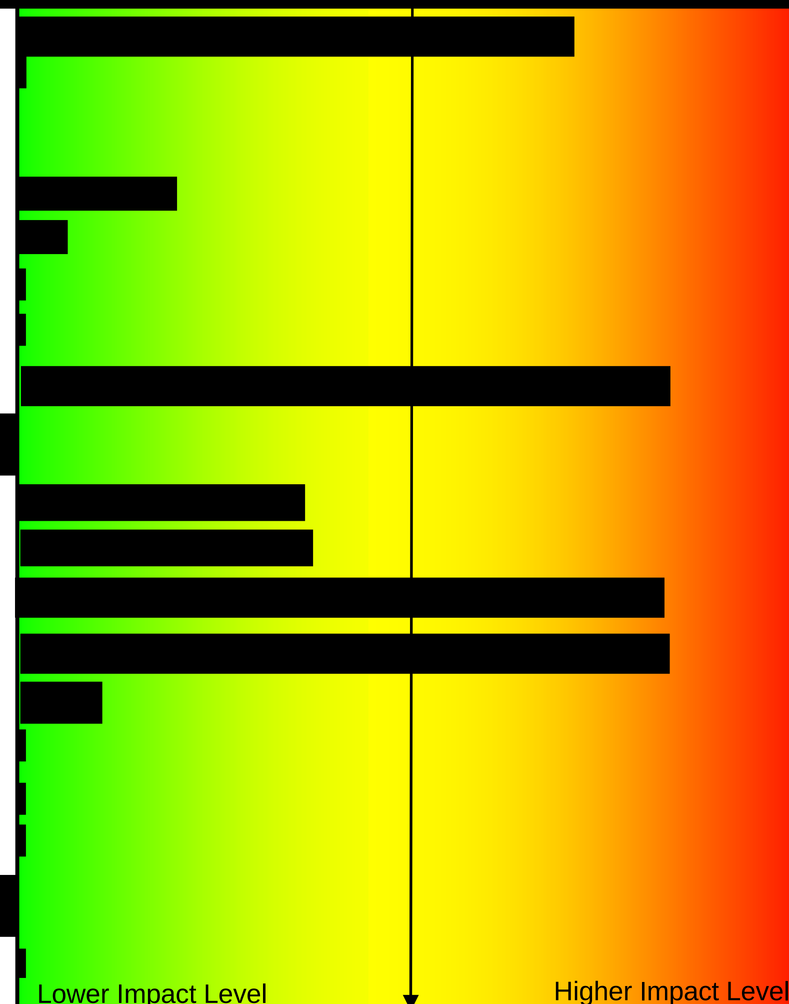
# Environmental Impact Profile

## New Supply Option 2018

## CC- Pet-Coke /Gasification Plant (Polygeneration)

| Resources Depletion | PC Gasification Impacts |
|---|---|
| Non-Renewable Energy | -- |
| Water | -- |
| Strategic Metals | |
| Terrestrial Habitats | -- |
| Wetland Habitats | -- |
| Lake Habitats | -- |
| River Habitats | -- |
| Key Species | -- |
| **Impacts from Emissions** | |
| Cumulative Greenhouse Gases | -- |
| Oceanic Acidification | -- |
| Acid Rain | -- |
| Smog | -- |
| Soot (PM 2.5) | -- |
| Neurotoxicity | -- |
| Systemic Chemical Toxicity | -- |
| Eco-Toxicity | |
| **Risks from Wastes** | |
| Radioactive Wastes | -- |

PC Gasification Compared Grid Average




Average Impact level (Regional Grid)

* Per 1,000 GWh electricity production

# New Poly Hybrid Design

## Integrating Wind with
## Coal Power Generation Technologies

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are needed to see this picture.

# Key Design Elements

2000 MW Wind Development

- 500 MW high capacity factor wind electricity (> 5000 hrs/yr)
- 1500 MW higher variable wind for hydrogen/oxygen production

300 MW OxyFuel Coal

- Carbon Capture
- Oxygen from wind electrolysis eliminates the need for the air separation and increasing total electricity production by 20%
- 99%+ pure oxygen eliminates any issues concerning NOx

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are needed to see this picture.

Low Capacity Factor Wind
Hydrogen/Oxygen Production

High Capacity Factor Wind Electricity

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TIFF (LZW) decompressor
are needed to see this picture.

# Key Environmental Advantages

The only power system to date to achieve virtually impact free status

It would allow Saskatchewan province from being the highest per capita C-GHG loading in Canada to become the lowest per capita province within 20 years.

The deployment is sufficient scale to allow the retirement of all of older coal units as well as the inefficient SCGT peaker units.

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are needed to see this picture.

# LCIA Provides Strategic Information

## Cumulative GHG Loading (C-GHG)

# Projected C-GHG Loadings (2040)
## 11 Western States

| | |
|---|---|
| WECC Electricity (BAU) | **19 billion tonnes** |
| Western 11 States (BAU) | **85 billion tonnes** |
| Global Increase (Most Likely) | **1,800 billion tonnes*** |
| **Current Global** | **6,600 billion tonnes** |

**85 billion tonnes will add enough radiative forcing to increase GMT by as much as 0.09 $^{o}$C by 2040.**

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# C-GHG Load Reduction (LR):
# AB-32 2020 Goals for Electric Power

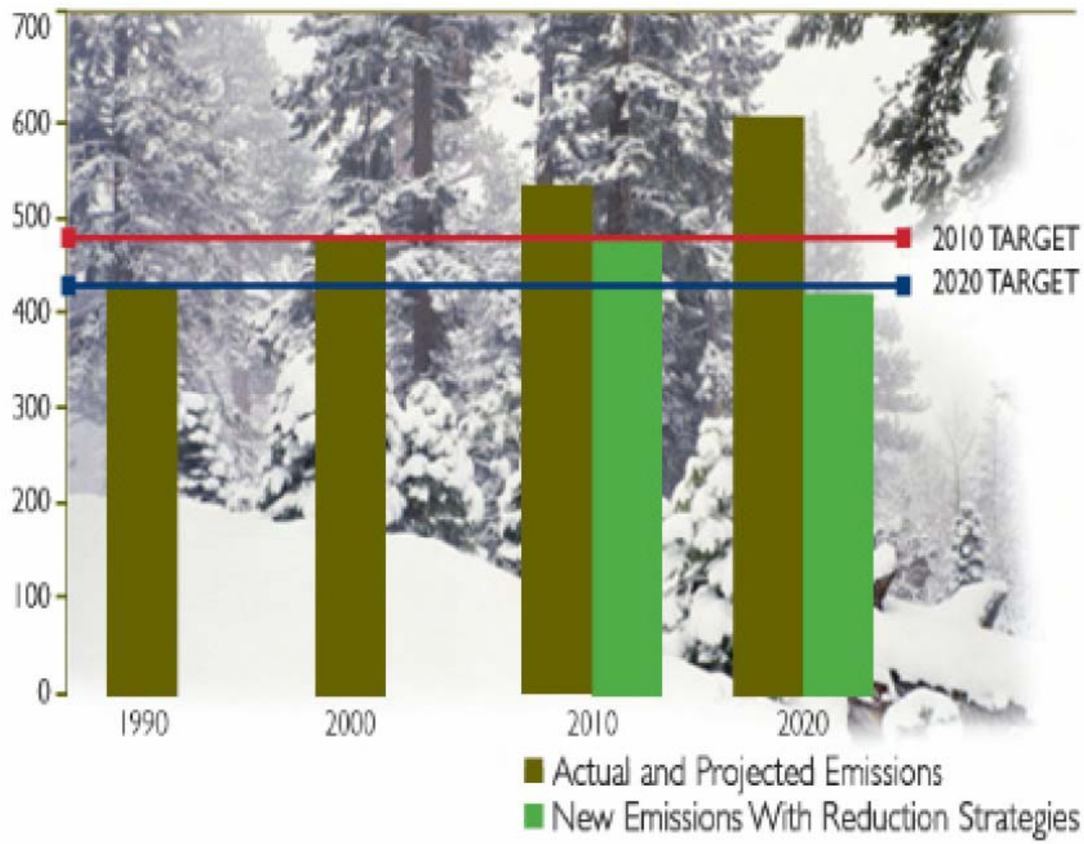


**Figure ES-2**

California Climate Change Emissions and Targets After Implementing Emission Reduction Strategies

**Projected C-GHG Load Reduction = 780 million tons**

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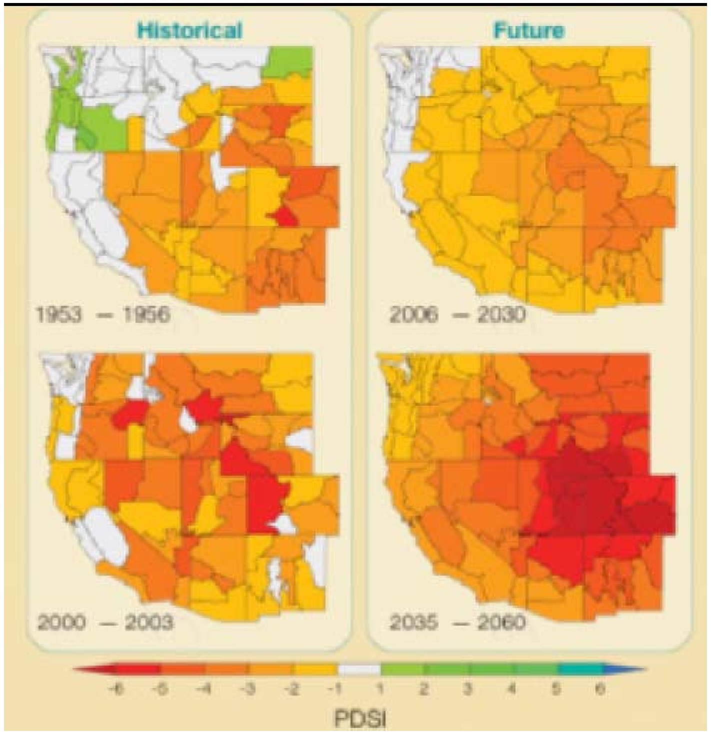
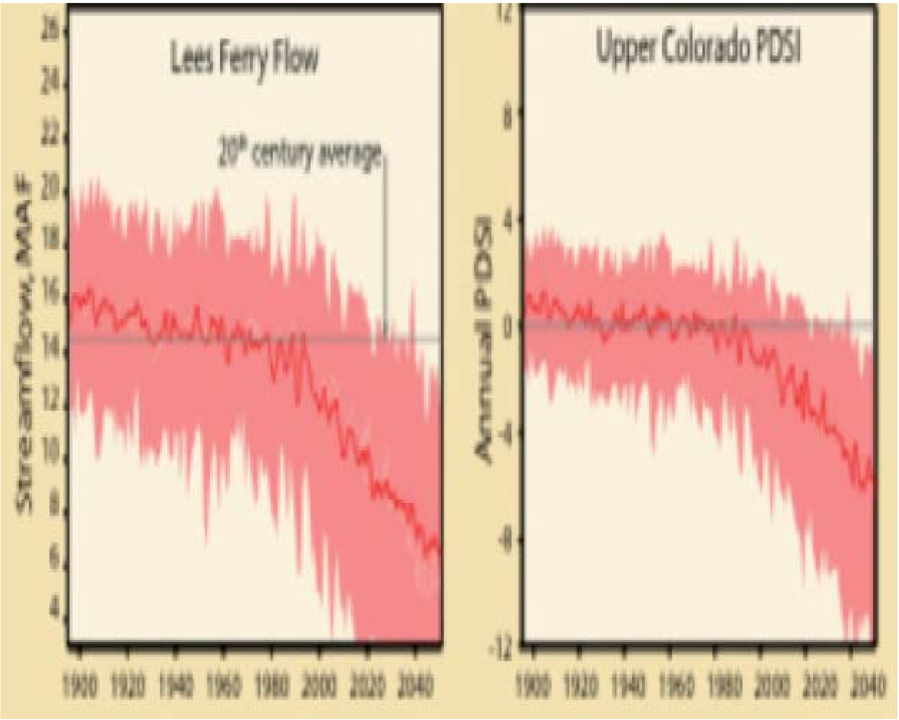
# Potential Increase in C-GHG Loading from Loss of Colorado River Hydropower




**Net Increase C-GHG Loading from Make up Thermal Units (70%NGCC/30% Advanced Coal)= 316,000,000 tonnes**

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# C-GHG Load Reduction Potential from Conversion to Toyota Prius Fleet

**Modeling the conversion to Prius hybrid fleet (55 mpg)**

- **5,000,000 units deployed by 2020**
- **15,000 miles/year**
- **Replacing 22 mpg standard vehicle**

**C-GHG Load Reduction Potential**

**550 million tons**

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# Potential Deployment by 2020-25 C-GHG Load Reductions

| | |
|---|---|
| Reducing projected increase global airline fleet by 20% | **20 billion tons** |
| Maximizing Carbon Storage of US farming soils | **8 billion tons** |
| Incremental Upgrading the Existing US Coal Fleet | **33 billion tons** |
| AB 32 2020 Mandates | **<3 billion tons** |
| WGA 2025 Goals (includes AB 32 2020) | **7 billion tons** |
| Western Deployment of Solar, Wind, Geothermal (2025) | **< 1 billion tons** |
| Deployment of Nuclear | **TBD** |

**Still looking for the other heavy hitters……….**

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