Life Cycle Assessment (LCA) of Poplar Plantations

Global warming potential and energy consumption in the US PNW

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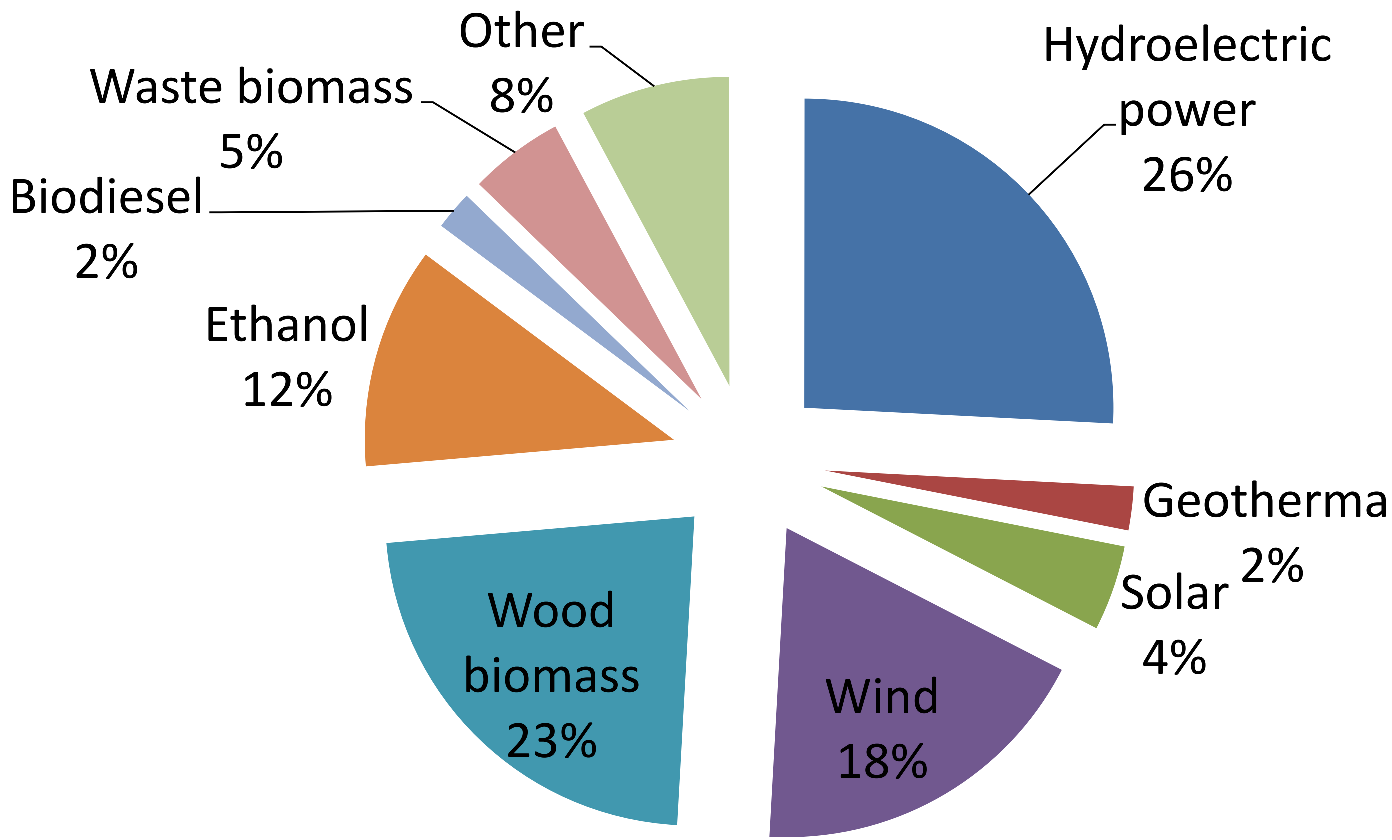
Western Forest Graduate Research Symposium, April 28th, 2015

Outline

- Demand and sources of energy
- Biomass and growing requirements
- Case studies
- LCA tool/ Databases/LCIA methodology
- GWP and energy consumption
- Main findings

U.S. Renewable energy consumption 2014

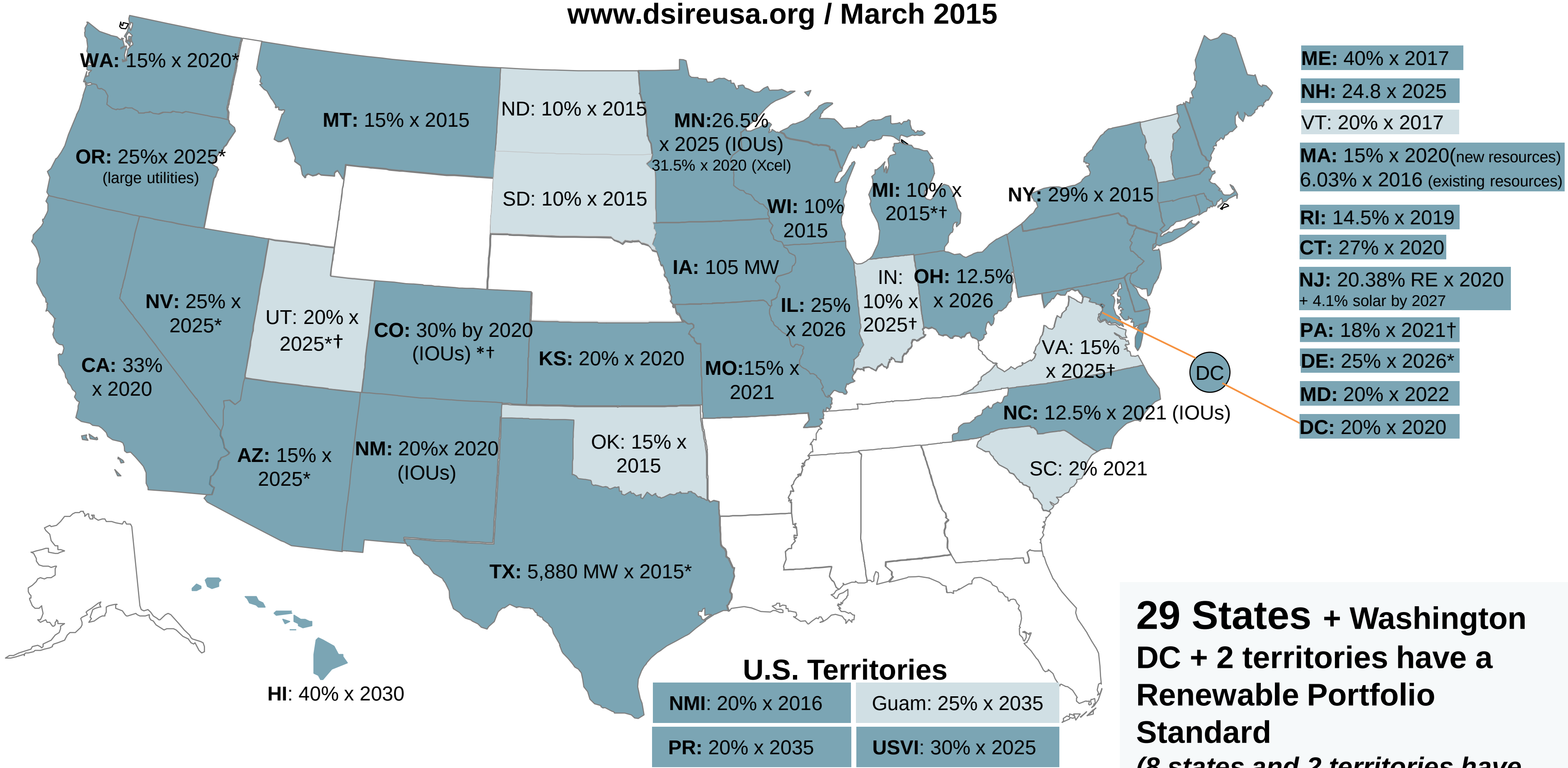


Total: 10.08 ExaJoule
42% from biomass

http://www.eia.gov/forecasts/steo/tables/?tableNumber=24#

Renewable Portfolio Standard Policies

www.dsireusa.org / March 2015



29 States + Washington DC + 2 territories have a Renewable Portfolio Standard

(8 states and 2 territories have renewable portfolio goals)

- Renewable portfolio standard
- Renewable portfolio goal

* Extra credit for solar or customer-sited renewables

† Includes non-renewable alternative resources

Biomass

- Poplar
- SRWC and lumber plantations

- Goal: Compare GWP and energy consumption of poplar biomass sites

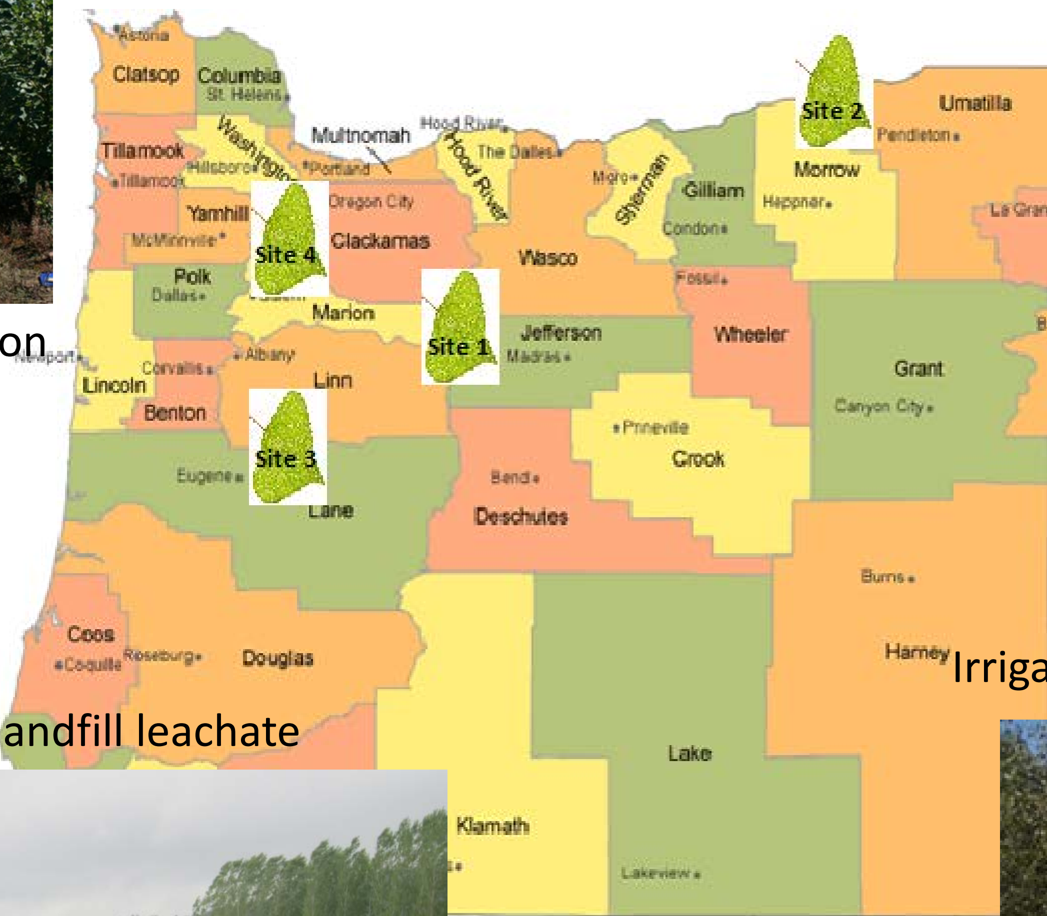
- Scope: From cutting production to biomass (cradle-to-gate)

- Functional unit: 1 BDmT

Sites

Without irrigation

Irrigation with river water

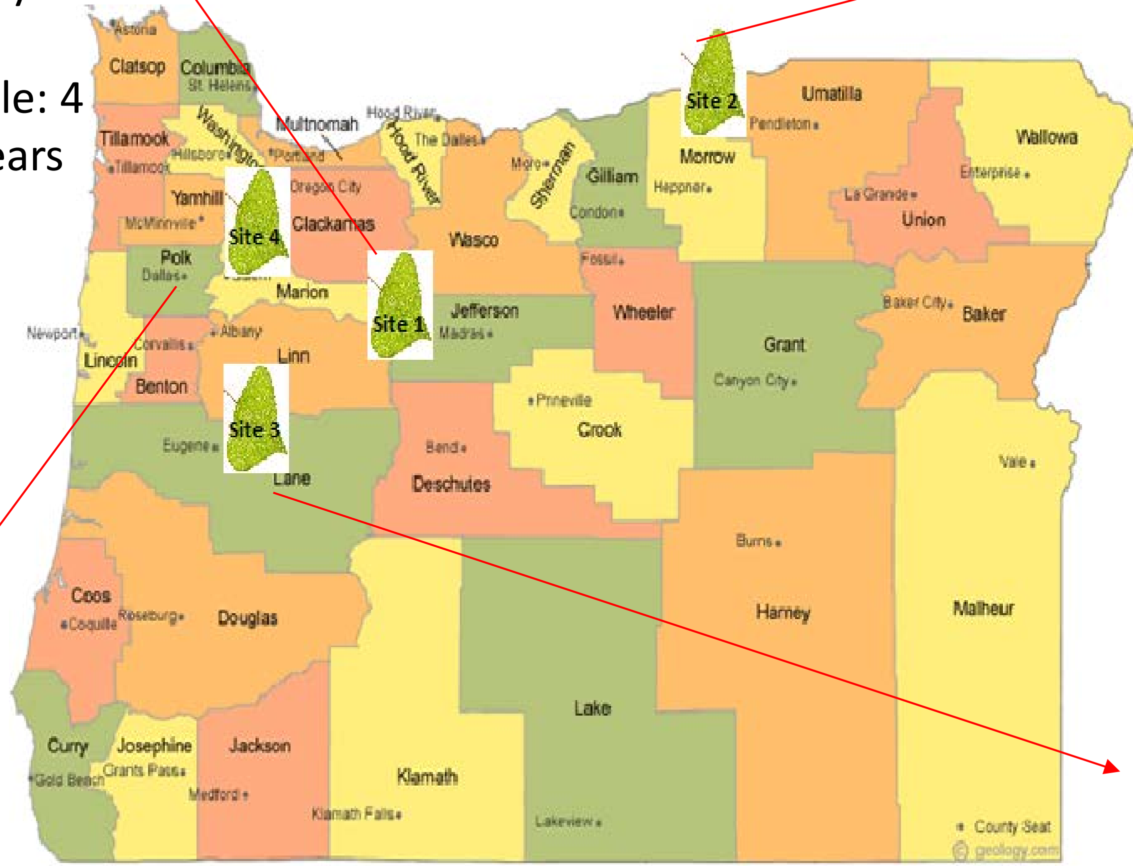


Irrigation with treated wastewater

Irrigation with landfill leachate

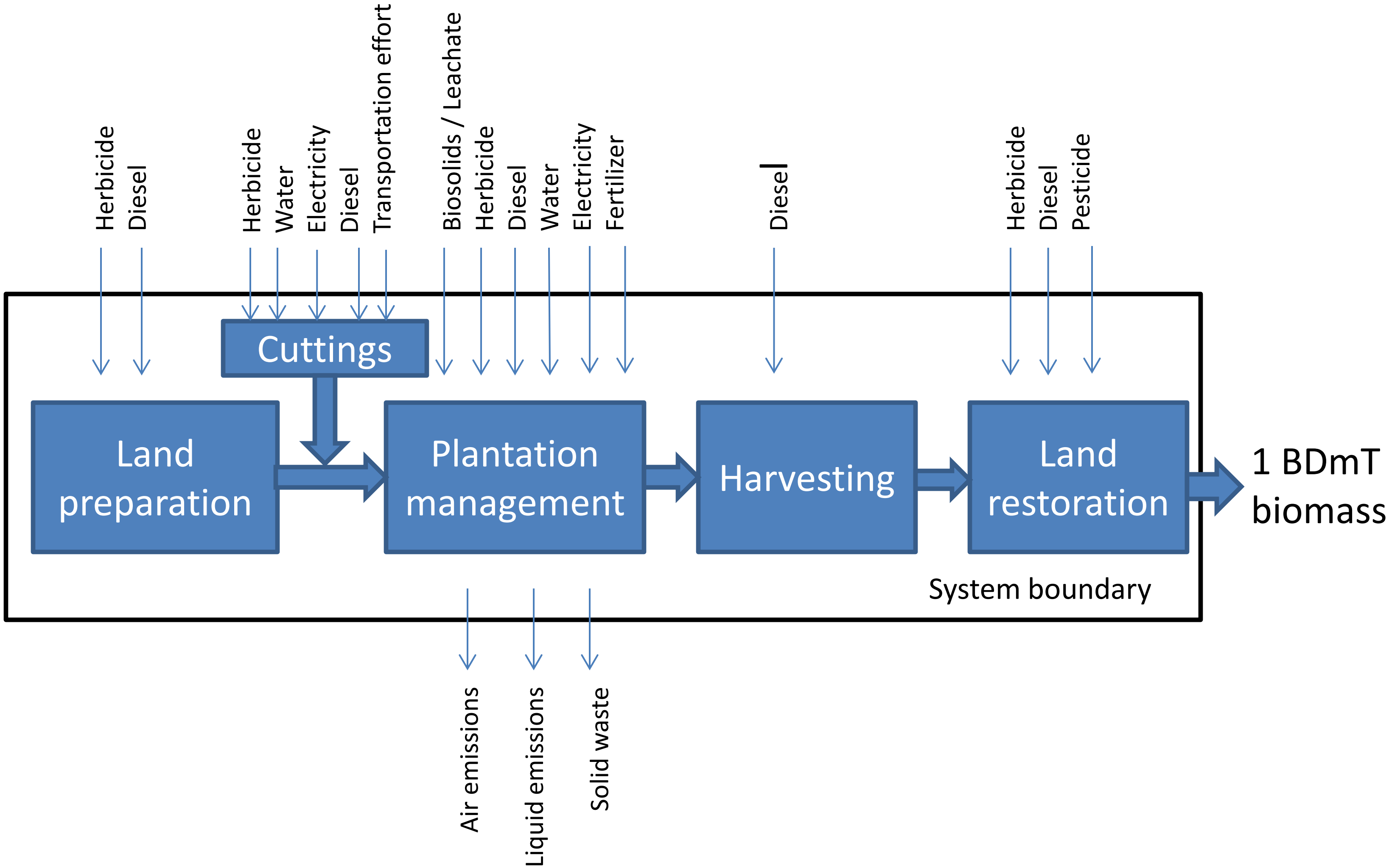
Site 1
Area: 28.63 ha
Planting density: 3586
clones: 11
Harvesting cycle: 4
Lifetime: 11 years
Soil type: Clay

Site 2
Area: 315 ha
Planting density: 470
clones: 3
Harvesting cycle: 4
Lifetime: 12 years
Soil type: Sandy



Site 4
Area: 4.45 ha
Planting density: 1375
clones: 1
Harvesting cycle: 1
Lifetime: 12 years
Soil type: Clay

Site 3
Area: 21.05 ha
Planting density: 553
clones: 3
Harvesting cycle: 1
Lifetime: 10 years
Soil type: Clay


Herbicide
Diesel
Herbicide
Water
Electricity
Diesel
Transportation effort
Biosolids / Leachate
Herbicide
Diesel
Water
Electricity
Fertilizer
Diesel
Herbicide
Diesel
Pesticide
Cuttings
Land preparation
Plantation management
Harvesting
Land restoration
1 BDmT biomass
System boundary
Air emissions
Liquid emissions
Solid waste

Methodology

- LCA
- LCI (Questionnaire, Report –PD & Papers– SD)
- 3PG biomass estimation
- SimaPro v.8 with USLCI & Ecoinvent databases
- TRACI (Tool for the Reduction and assessment of Chemical and other Environmental Impacts)
  - Global warming [kg CO_2 eq per ton]
- Inventory
  - Sources of energy [MJ per ton]

Processes	Input/BDmT	Unit	Site 1	Site 2	Site 3	Site 4
Land Preparation	Herbicide	kg	0.021	0.008		
	Diesel	l	0.21	1.24	0.30	0.012
Stock for initial planting	Cuttings	#	33.42	3.08	4.39	9.05
	Transportation	t·km	1.12		0.18	0.27
Plantation Management	Herbicide	kg	0.44	0.19		
	Diesel	l	1.36	1.01	12.5	7.98
	Water	l		472350	66938	54000
	Electricity	kWh		14.88	9.25	17.04
	Biosolids	kg N eq			35.70	
	Leachate	kg N eq				35.44
	Fertilizer	kg N			0.36	6.39
	Pesticide	kg		0.11		
Harvest	Diesel	l	7.91	10.18	11.44	13.71
Land Restoration	Herbicide	kg	0.021			0.008
	Diesel	l	0.15	0.11	4.9	0.05
	Pesticide	kg	0.023			

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Results

Biomass yield [odt ha^{-1} yr^{-1}]

Site 1	Site 2	Site 3	Site 4
9.48	12.70	12.60	12.66

http://www.eereblogs.energy.gov/bioenergy/post/2013/01/28/Developing-Willow-Biomass-Reducing-the-Delivered-Cost-of-Feedstock.aspx

http://forestnet.com/TWissues/Jan_feb_12/oregon_plantation.php

		Process or Inputs	Site 1	Site 2	Site 3	Site 4
GWP	Impact [kg CO_2eq · t^{-1}]		79.5	54.7	93.1	90.6
	Process Contributions, %	Cutting	54.4	7.3	5.5	11.4
		Harvesting	31.4	58.7	34.9	42.3
		Management	5.4	21.0	43.1	33.9
Energy	Consumption [MJ·t^{-1}]		1381.8	877.43	1406.94	1484.13
	Inputs Contributions, %	Oil	34.7	63.0	80.1	56.3
		Coal	28.1	15.9	7.9	11.9
		Natural gas	24.7	14.5	9.4	26.2

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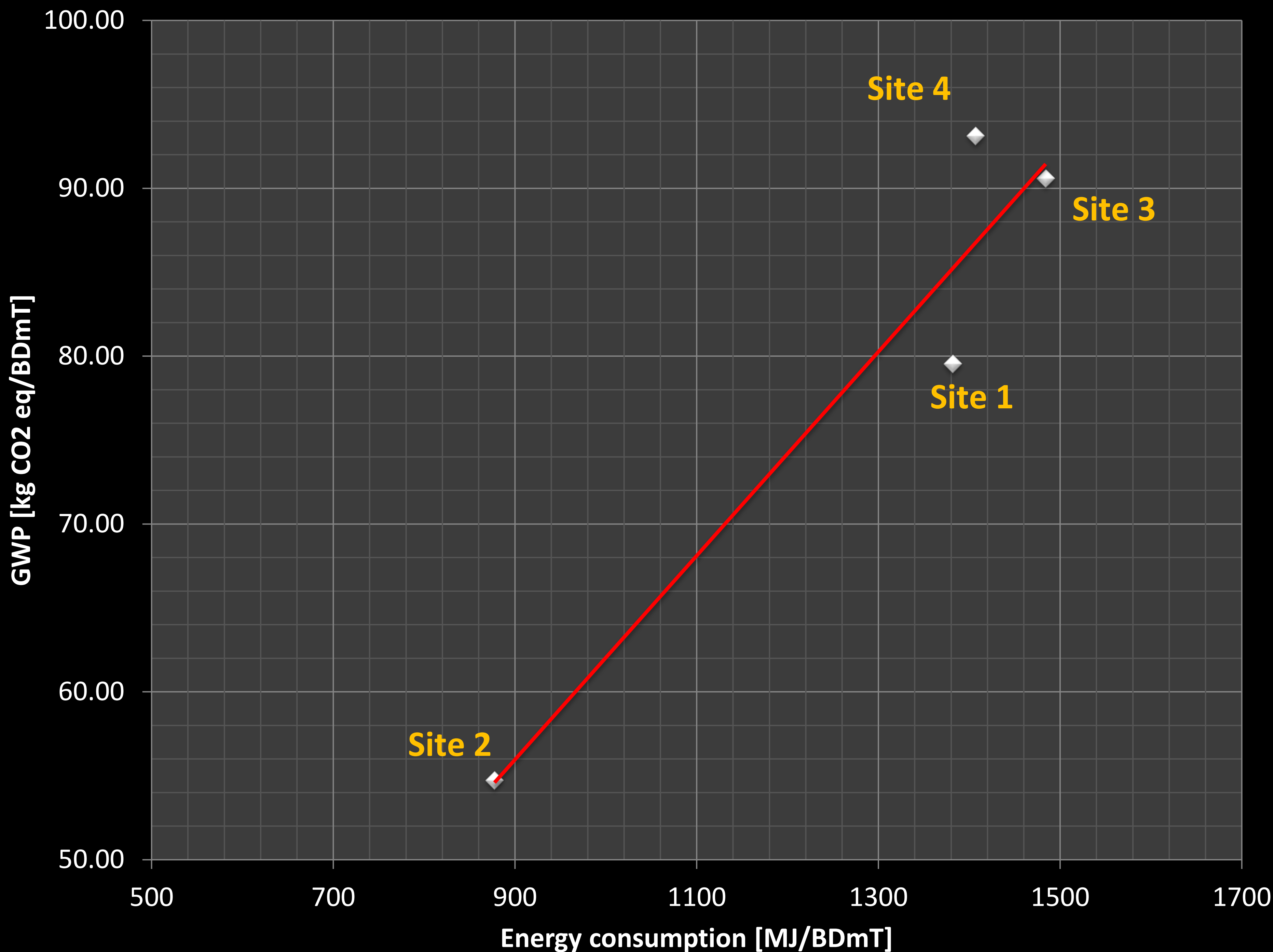


100.00
90.00
80.00
70.00
60.00
50.00
GWP [kg CO2 eq/BDmT]
500
700
900
1100
1300
1500
1700
Energy consumption [MJ/BDmT]
Site 4
Site 3
Site 1
Site 2

Is poplar GWP higher/lower than other sources of energy?

Fuel	LHV MJ per kg	GWP Kg CO_2 per ton	GWP Kg CO_2 per MJ
Poplar	18.0	54.7- 93.1	0.003-0.005
Mix Douglas-fir& Hemlock		20.0	0.001
Hard coal (2.7%)*	27.0	73.6	0.003
Natural gas (24%)*	50.0	855.0	0.02
Oil (6.6%)*	43.10	297.4	0.007

* GWP only includes extraction and treatment of raw material

Sources

Dinca *et al*. 2010

http://cta.ornl.gov/bedb/appendix_a/lower_and_higher_heating_values_of_gas_liquid_and_solid_fuels.pdf

Main findings

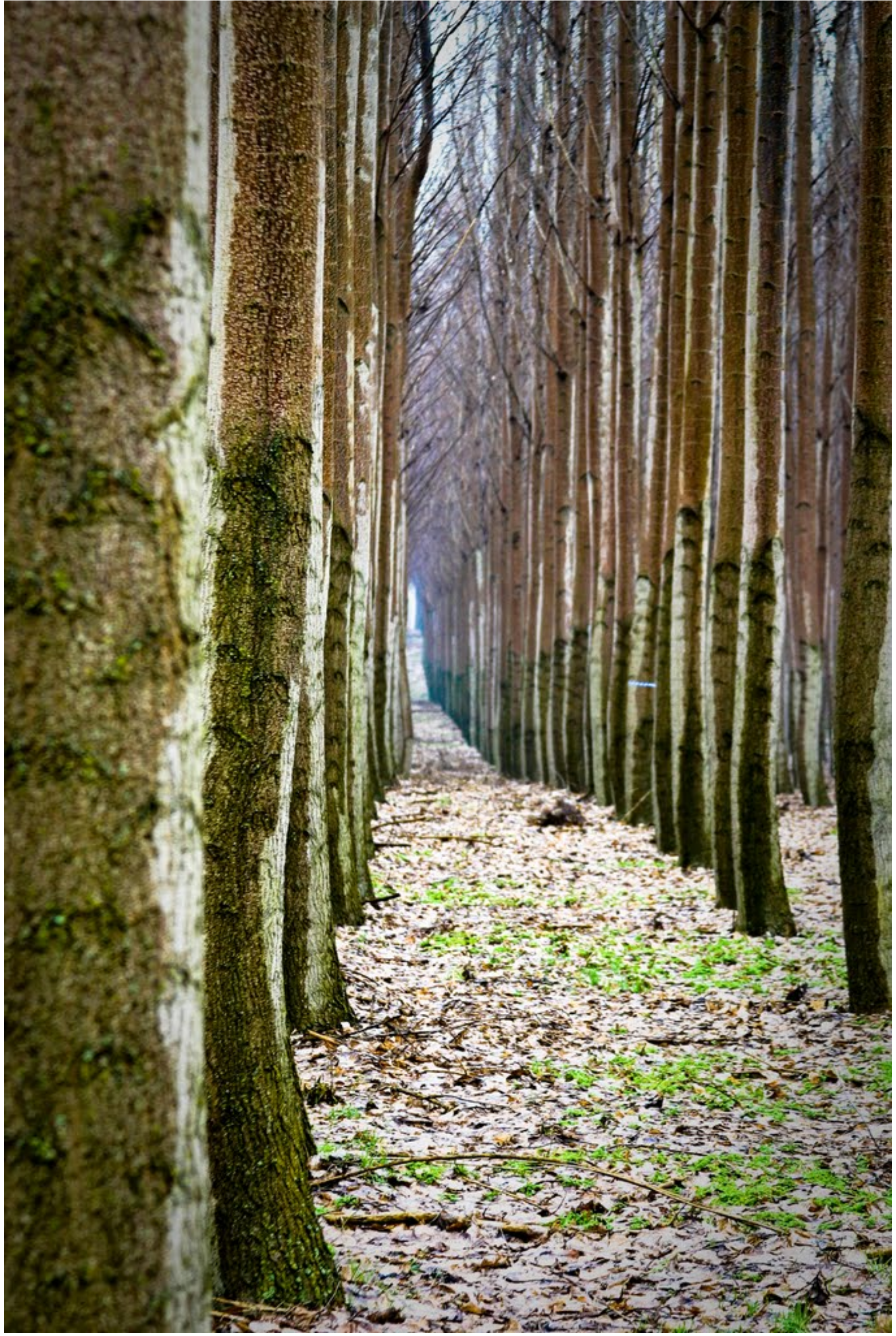
- GWP was low in plantations with low rotation.
- GWP in site 2 was the lowest due to reduced amount of chemicals.
- Harvesting process had the highest contribution to GWP and energy consumption in all sites.
- Sites 3 and 4 had higher energy consumption due to applications of treated wastewater and landfill leachate.

Suggested research

- Do irrigation with treated wastewater and landfill leachate have an effect on biomass yield?
- Can integrating waste in a poplar plantation reduce operational and disposal costs?

Conclusions

- Biomass compared with fossil fuel as source of energy can contribute to reduce GWP.
- Biomass energy can be environmentally friendly if plantation managements and operational systems are carefully selected to reduce chemical and fuel consumptions.

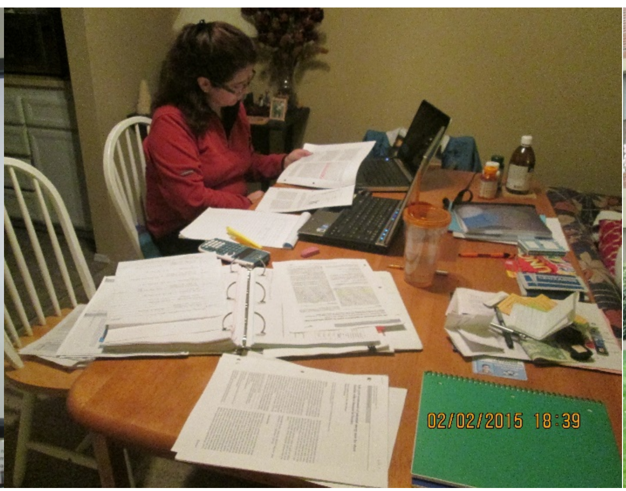


Source http://www.panoramio.com/photo/49539530

Questions?

More about this topic

- Graduate Seminar – May 13th
- Ph.D. Final defense – June 30th



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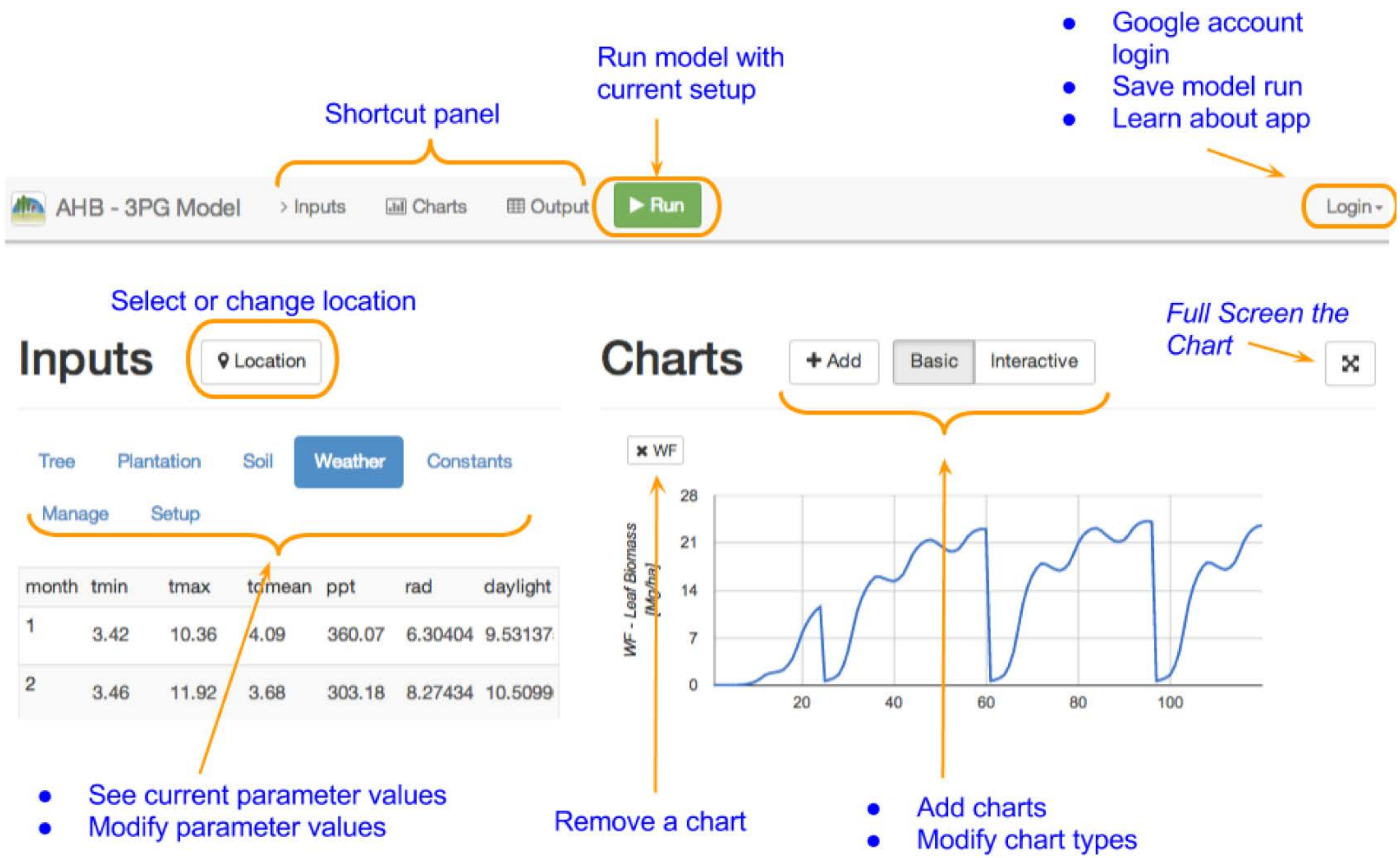
Estimation of biomass

- 3PG simulation software

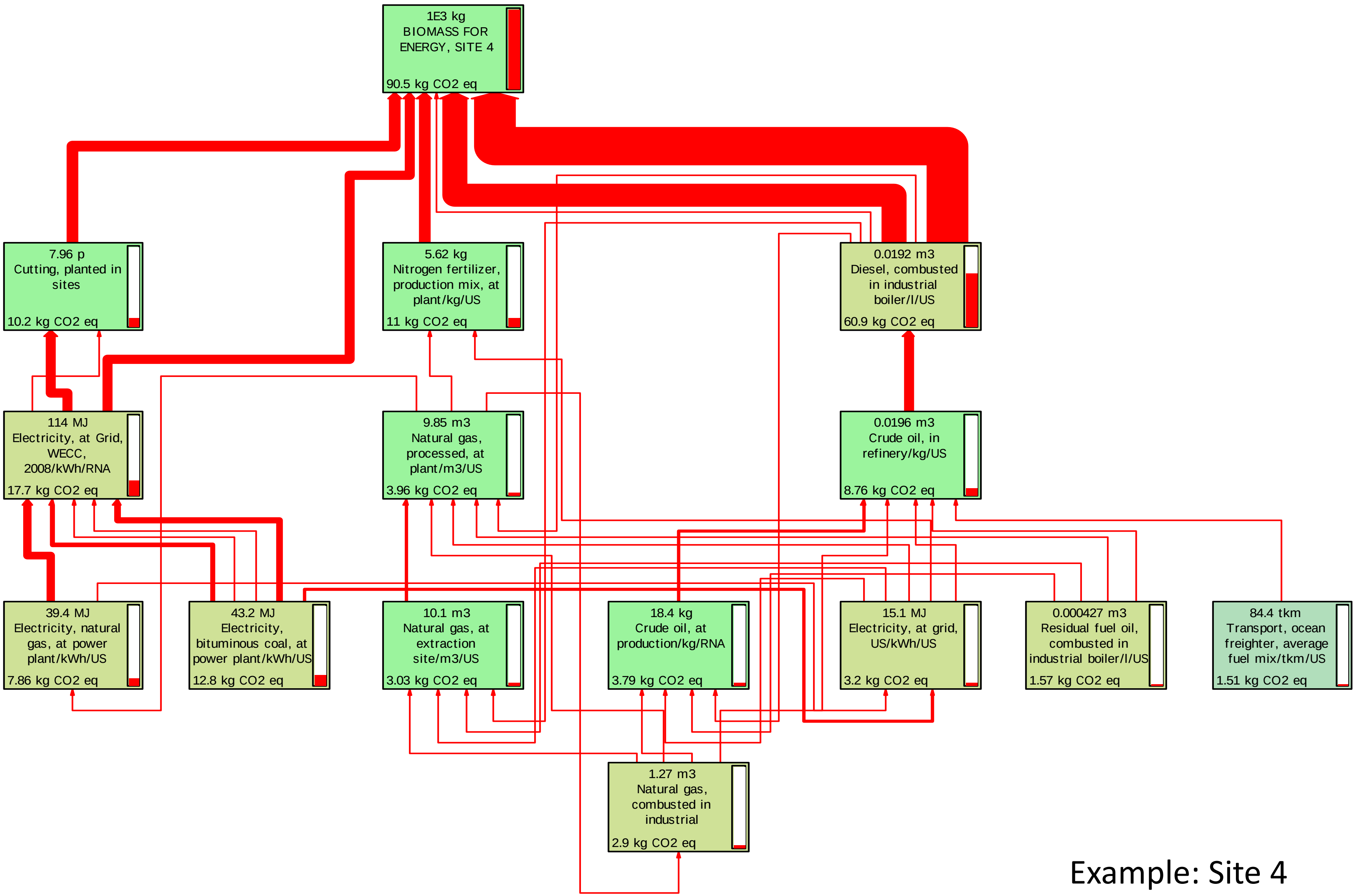


Source http://www.mdpi.com/ijgi/ijgi-03-00929/article_deploy/html/images/ijgi-03-00929-g002.png

TRACI impact categories

- Ozone depletion [kg CFC-11 eq]
- Global warming [kg CO_2 eq]
- Smog [kg O_3 eq]
- Acidification [kg SO_2 eq]
- Eutrophication [kg N eq]
- Cancerogenic [CTUh]
- Non-cancerogenic [CTUh]
- Ecotoxicity [CTUe]
- Fossil fuel depletion [MJ surplus]

SimaPro network



Example: Site 4