LCA SUPPORTED SUSTAINABLE PRODUCT DEVELOPMENT FOR FURNITURE INDUSTRY

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LCA as a Tool

LCA is an internationally accepted tool for assessing the environmental impacts associated with a product, process or service throughout its life cycle, i.e.

From:

Growing harvesting raw material

Processing

Transport

Use and maintenance

Use, reuse recycling or disposal

LCA could also be a powerful tool for designers (product developers), manufacturers, and consumers to compare the environmental credentials of similar products and services.

Materials

- What a product is made of and where the materials come from can make a huge difference in environmental outcomes.

Production

- From the time the raw materials enter one of factories until the product is ready for packaging, opportunities abound to reduce environmental impacts.

Transportation and Packaging

- How a product is transported, what kind of packaging is used and the distance it travels can sometimes have the greatest environmental impact.

Product Use

- Just because a product is out of sight doesn’t mean it’s of mind. Even though products have little environmental impact in use, intention is to limit emissions and preserving indoor air quality for users. Maintenance and repair can also extend the product’s life.

End of Use

- Recyclability and reuse are critical elements in the environmental impact of our products. Maximize clean recycled and recyclable content and design products for easy disassembly. Help customers with end-of-use options so they can responsibly dispose of products they no longer need.

Assumption:

It is believed that LCA will continue to bridge the design, engineering, production, and marketing communities,

and leading to products that inspire customers while reducing environmental impacts.

Are we ready to apply this tool effectively in furniture design process?

Presentation Outline:

1. Leading furniture producers using LCA tools were evaluated and challenges of applying LCA were summarized.

2. LCA tools should be included into teaching concepts. Methodology to teach furniture design based on aesthetic, strength, manufacturing and environmental concepts was developed to teach this subject effectively.

1. Case study of LCA conducted on a simple wooden furniture product with different design options and is presented.

1.

Green Furniture Showcase

http://www.eco-structure.com/office-and-business/green-furniture.aspx

Haworth Inc.

HAWORTH INC., Holland, Mich., combined modern commercial spaces with sustainability at its new 31,000-square-foot (2880-m2) New York showroom. Emphasis was placed on **using recyclable, non-toxic and regionally sourced materials, as well as third-party-certified products**.

Designed and built in partnership with Perkins+Will | Eva Maddox Branded Environments, New York, and Turner Construction Co., New York, the showroom is registered to become LEED for Commercial Interiors Gold certified by the U.S. Green Building Council, Washington, D.C.

Green Bay, Wis.-based KI

The Phoenix Convention Center recently debuted Phase One of its environmentally friendly facility. The center purchased 7,000 Daylight chairs from Green Bay, Wis.-based KI and plans to buy an additional 21,000 when construction is completed. **Designed for disassembly** with **100 percent recyclable components**. The molded seat and back frames are **made of plastic from recycled car batteries**.

Steelcase

HEIFER INTERNATIONAL HEADQUARTERS, Little Rock, Ark., includes open-plan workspaces. Think chairs from Grand Rapids, Mich.-based STEELCASE received **Cradle to Cradle Gold certification** from MBDC, Charlottesville, Va., and are SCS Indoor Advantage Gold certified for IAQ from Emeryville, Calif.-based Scientific Certification Systems.

Kimball Office

Furniture manufacturer, KIMBALL OFFICE, Jasper, Ind., produces furniture **using recycled content**, Reston, Va.-based Forest Stewardship **Council-certified wood and rapidly renewable materials**. The Hum workspace solution is manufactured with **30 percent post-consumer recycled-content steel and aluminum**; and **medium-density fiberboard made from 100 percent postindustrial waste**. It also incorporates **rapidly renewable materials, like wool felt; is chrome-, chlorofluorocarbon- and polyvinylchloride-free; and features LED lighting**.

2.

Approach to Furniture Design at Purdue University, WRL

Aesthetic Design

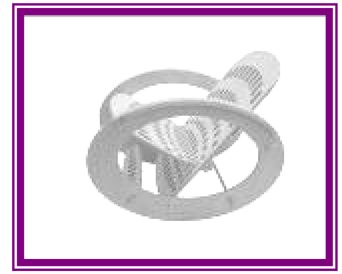
Strength Design

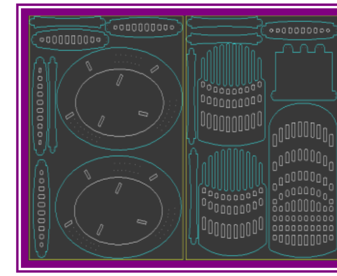
Furniture

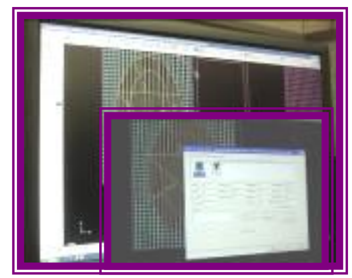
Design for Manufacture

Design for Environment

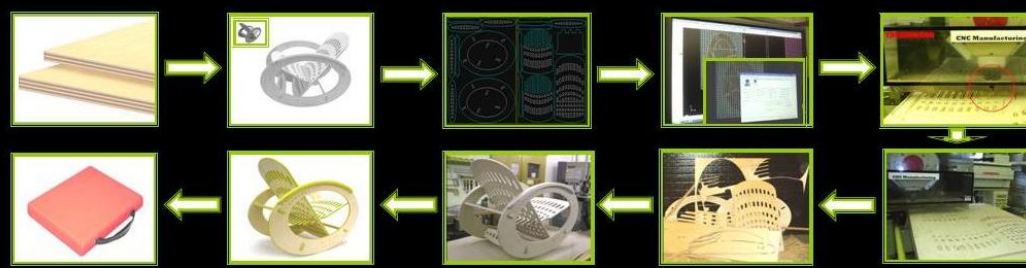
CNC Adjustable Furniture – Design for Environment







CNC Adjustable Furniture – Design for Environment



Preliminary finger joint test:

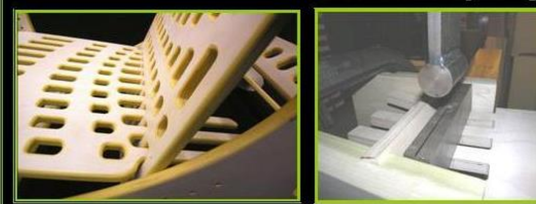


Table 1: Results of seat board test

Board No.	Finger size	Type of test	Ultimate loads	Failure type	Notes
#1	1 inch	Top load	5,600 lb	Finger failed at the cross section	Defects found in the in plywood fingers
# 2	1 inch	Top load	9,600 lb	Finger failed at the cross section	

Table 2: Results of back board test

Board No.	Horizontal distance (H)	Type of test	Ultimate loads	Failure type
#1	0.2 inch	Top Shear	3,375 lb	Shear failure in back board
# 2	0.2 inch	Top Shear	3,510lb	Shear failure in back board
#3	0.4 inch	Top Shear	5,600lb	Shear failure in back board
#4	0.6 inch	Top Shear	>9,500lb	Seat board failed first when load reach 9500lb

Functions related to adjustability:

1) Conversation position: seating angle: 95°- 110°;
2) Leisure position: seating angle: 110°- 135°;
3) Rest/sleep position: seating angle: 135°- 150°.

Preliminary customer evaluation (university community, 50 subjects):

1) The user tested adjustable rocking chair and found best adjusted position,
   Position preference: conversation 96%, leisure 93%, rest & sleep 71%;
2) Willingness to pay for adjustable rocking chair: average price $167;
3) Overall evaluation: excellent (93%).

CNC Furniture – Design for Environment

CNC Furniture – Design for Environment

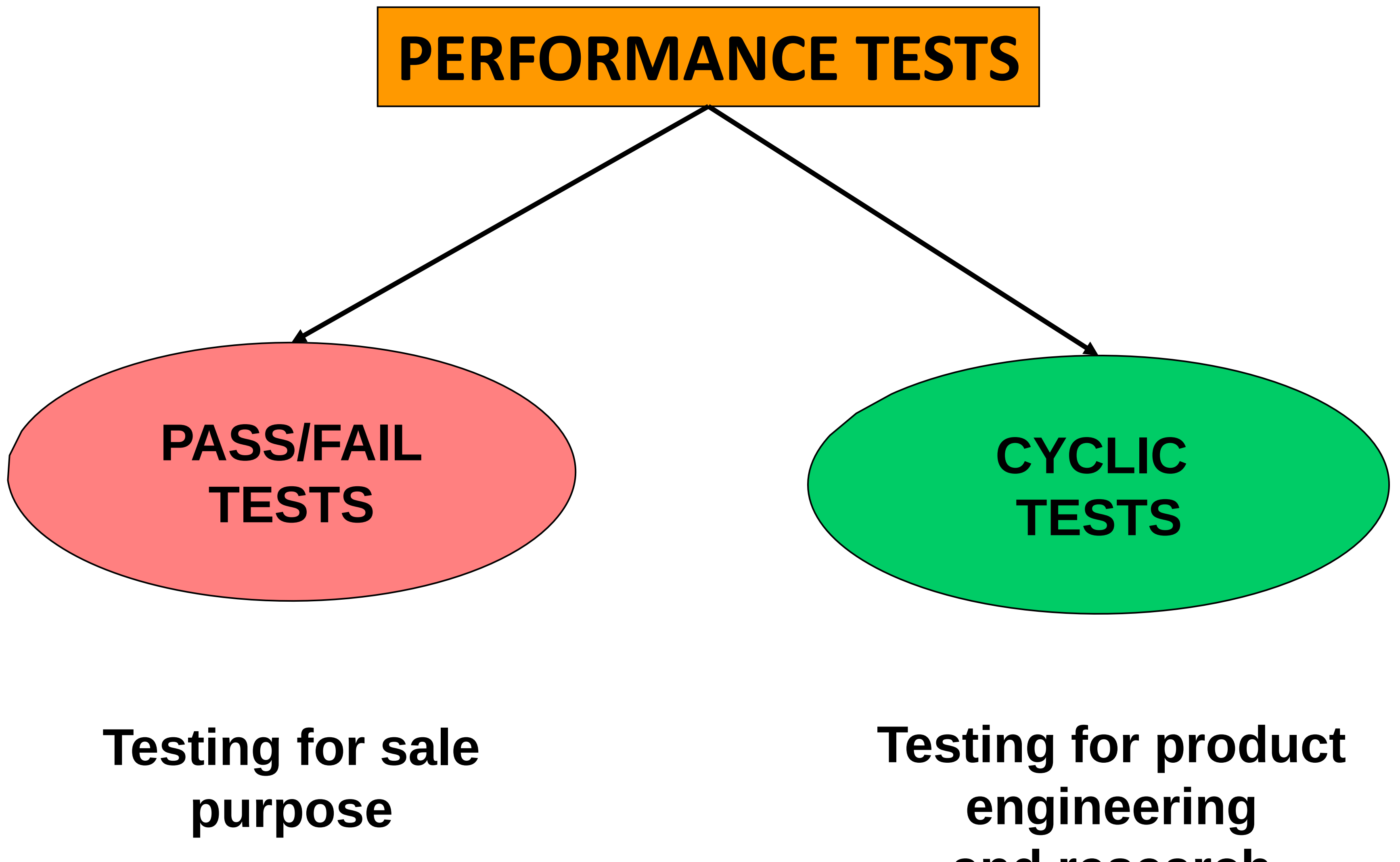
School Furniture for Developing Countries
Sustainable Furniture

Use of:

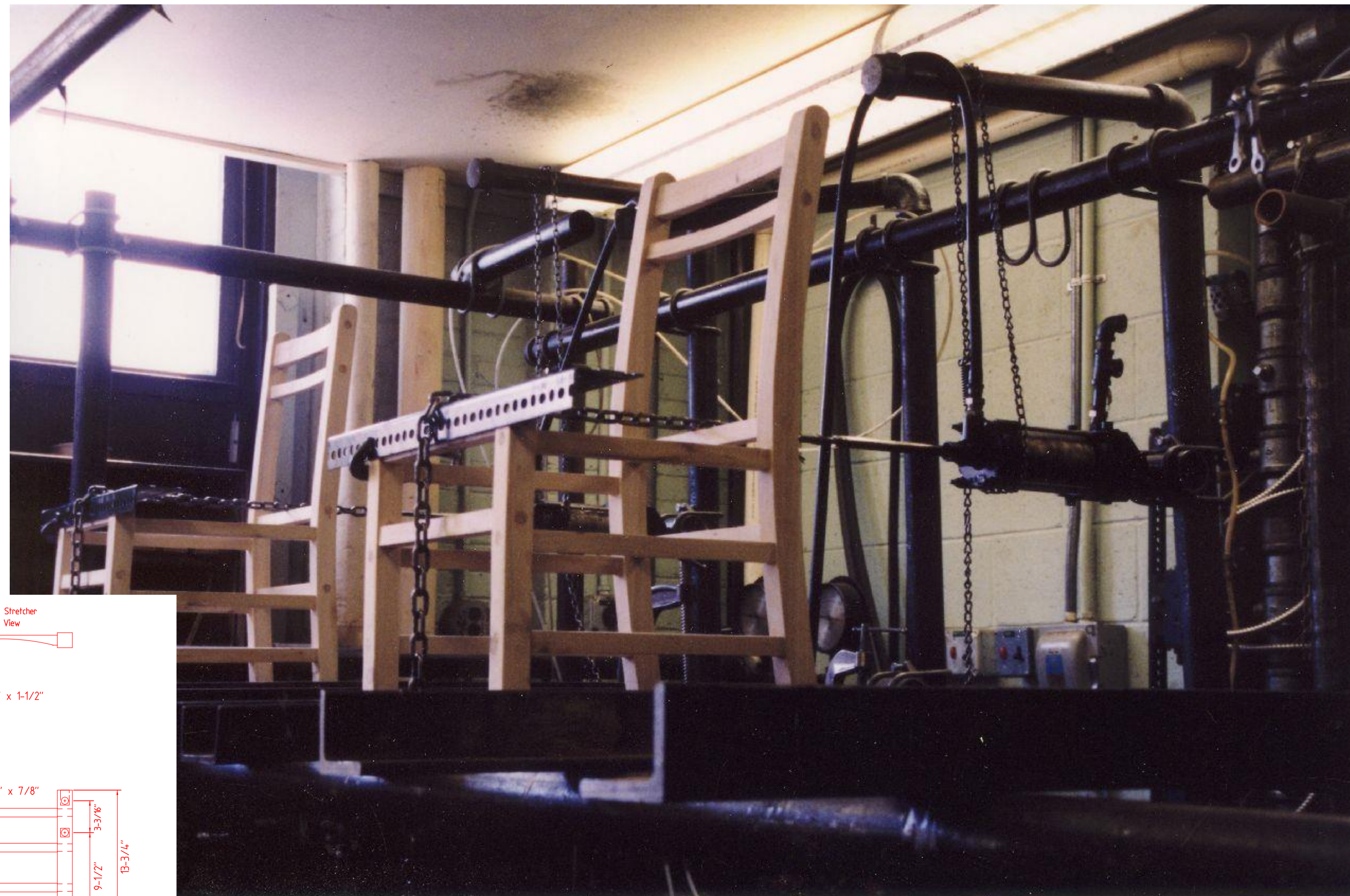
- **Materials** - local, residue, recycled, all wooden products;
- **Design** - traditional, high strength, durable, affordable;
- **Processing** - local, low-end technologies;
- **Labor** - local, easy to train;

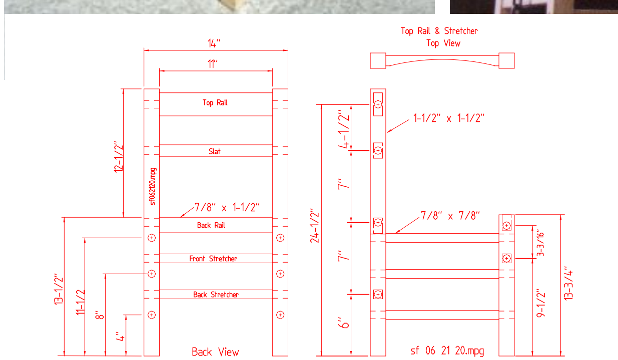
Product Durability - Extending Product Life

- Material evaluation
- Joints design
- Product strength design - use of computation techniques
- Prototyping and performance testing


PERFORMANCE TESTS
PASS/FAIL TESTS
CYCLIC TESTS
Testing for sale purpose
Testing for product engineering and research

Performance Testing





3.

Case Study of LCA Conducted on Wooden School Furniture Chair - SF14

- As a means to analyze the environmental impacts of the SF14" chair, SimaPro 7, was used.
- For impact assessment the European Eco-Indicator 99 (H) method was applied.
- The scope included raw material extraction, manufacturing and use.
- The scope excluded disposal of waste wood and sawdust and also excluded end of life scenarios such as disposal or reuse of chair parts. (This will be explored in future research.)
- Variables in the analysis models used were wood species, transportation distance, and types of finish.

LCA of SF14

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SimaPro 7 Limitations and Assumptions:

- Selection of wood species - The database is not explicit as to what forestry and silviculture methods were implemented when calculating the aggregate data in the database. Forestry and silviculture practices vary widely geographically depending on factors such as culture and industrialization. Therefore, appropriate wood species had to be selected purely based on wood density, land use density (trees/square kilometer), and global applicability. Included in the LCA model are a hardwood species for the stretchers and softer plantation species for the chair legs .
- Impacts associated with electricity consumption - It differ based on a country to country. Because the chair prototypes have been implemented in a Central America, the energy profile modeled in the LCA is based on aggregate data of energy resources of Brazil.
- Other limiting assumptions were avoided by reducing processes to their most basic material consumption - To accurately quantify the material and energy consumption in the manufacturing stages, a laboratory test scenario was performed by the Wood Research Laboratory at Purdue University. Data for the transportation and extraction energy usage were modeled indepently from wood species from the software to avoid assumptions based upon using a product in the inventory that made assumptions from specific country's aggregate data.
- All the chairs made have same lifespan - Functional unit was not yet defined. SimaPro 7 and the Eco-Indicator 99 method in our study does not consider life span of a product even wood species selection, joining methods, the finish of the furniture are significantly affecting the lifespan of the chair, At this point, the scoring methodology does not adjust the overall score based on product lifespan.

LCA of SF14

The scope of the LCA includes - extraction, transportation, manufacturing and finishing.

(Environmental impacts during the use phase are considered negligible. The waste wood and sawdust produced during manufacturing, as well as end of life scenarios were not considered in the LCA scope.)

Extraction

Extraction data includes growth of plantation species (chair legs) and growth of hardwood species in forest - natural stand (chair stretchers) to a 20 inch diameter tree. It also includes harvesting of wood using a chain saw, transportation of an assumed average distance of 2 miles to the sawmill and cutting of rough boards using a portable Woodmizer Mill.

Model Inputs:

- 168 cubic inches per chair of hardwood species from natural stand for stretchers (14 cutting units)
- 336 cubic inches per chair of plantation species for seat and legs (28 cutting units)
- 2081 BTU (0.61 kWH) of gasoline per chair consumed by 4.6 HP chain saw, 90 hp antique tractor to transport from tree stand to sawmill, and 35 HP Woodmizer sawmill. Tractor was assumed running during loading process, a common industry practice.

Transportation

A comparative analysis showing the affects of varying transportation distances (5 to 100 miles) was performed. The assumed transportation vehicle was a pickup truck weighing less than 3 tons with an approximate capacity of 150 board feet of lumber.

Manufacturing

The energy usage of the following parts was considered as an impact of the following manufacturing tools: 2 HP band saw. 3 HP radial arm saw, 2HP jointer, 10 HP planer, 5 HP table saw, 0.5 HP drill press, 0.75 HP tenon machine, 2 HP band saw, 0.25 HP orbital sander, 1.75 HP hand router, and a 20 HP dust collector. The manufacturing stage (excluding the seat) has an input of 27.4 cutting units of wood (328.8 cubic inches), whereas the final product is only 143.5 cubic inches of wood. Therefore 44 % of wood is lost during machining. This excess wood could be burned in order to power a wood drying kiln.

Model Input:

- 1.400 kWH electricity/chair

Finishing

A comparative analysis was performed of different types of finish. The three finish types considered were a natural plant oil finish, a finish using water based paint and water based lacquer that would not need hazardous chemical solvents. (and a traditional oil based paint and lacquer finish).

Model Inputs:

- 2.5 oz paint per chair
- 5 oz lacquer or plant oil per chair

Eco-Indicator 99 H

Bias:

Correct interpretation of the data requires understanding the weighting system. Experts weight some effects more heavily than others!

- Human Health and Ecosystem Quality account for 40% each
- Respiratory effects and greenhouse effects dominate Human Health damages
- Land use dominates Ecosystem Quality
- Fossil fuels dominate Resource Use

Not included in the Eco-Indicator 99 method:

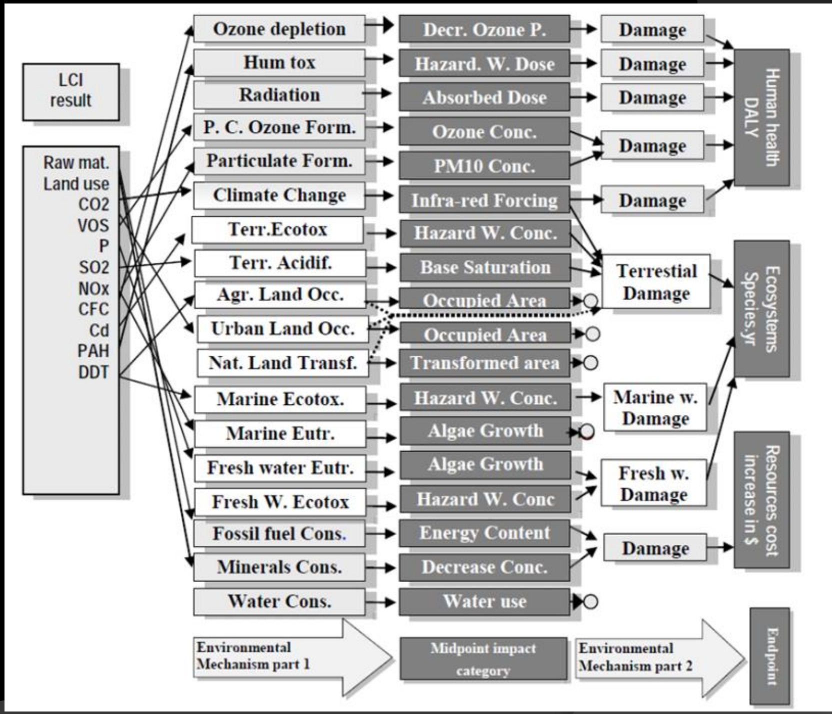
- Environmental impacts are assessed for EU scenarios
- Durability of individual materials is considered but not longevity of the product as a whole
- Product's purpose or mode of use was not included

Eco Indicator 99 Units Interpretation

- Human Health 40%: DALY=Disability life adjusted years, a measure of number of "healthy" years of living lost by a single persons due to illnesses from health affects related to environmental damage
- Ecosystem Damage 40%: PDF or PAF=Potentially affected or disappearing species. Measure of loss of species biodiversity, 1 PDF is loss of a single population
- Damages to Resources minerals and fossil fuels 20%: are expressed as surplus energy for the future mining of resources
- Single Score system (out of 1.0) allows comparison between products. Score of 0 has no environmental impacts, score of 0.5 is average, 1.0 is unsustainable.

For more info:

http://www.pre-sustainability.com/content/eco-indicator-99



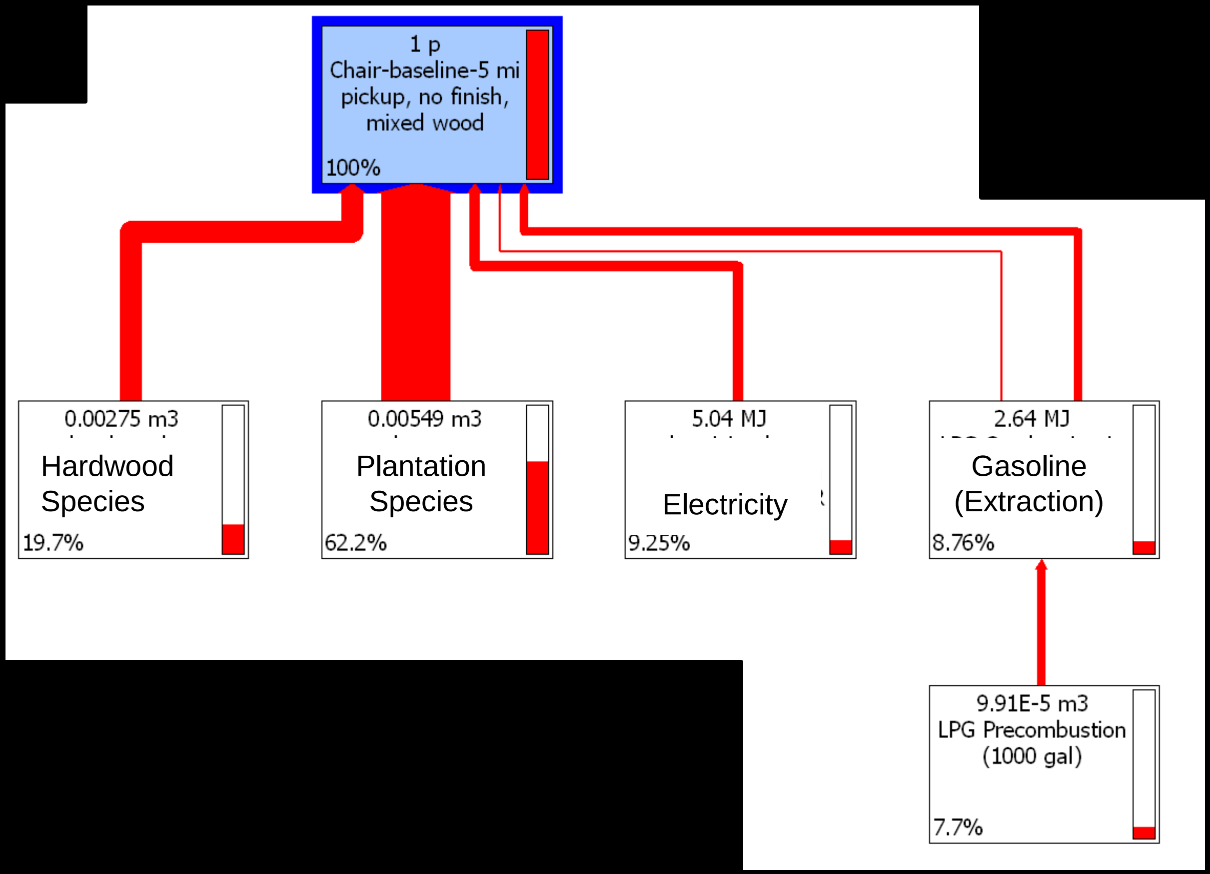
Baseline Model for LCA of SF14

Was developed for comparison, using available resources

Variable Inputs:

- No finish
- 5 miles transportation between sawmill and factory
- Hardwood from natural stand in deciduous forest for stretchers, seat and legs from plantation species

Baseline Model-Flowchart

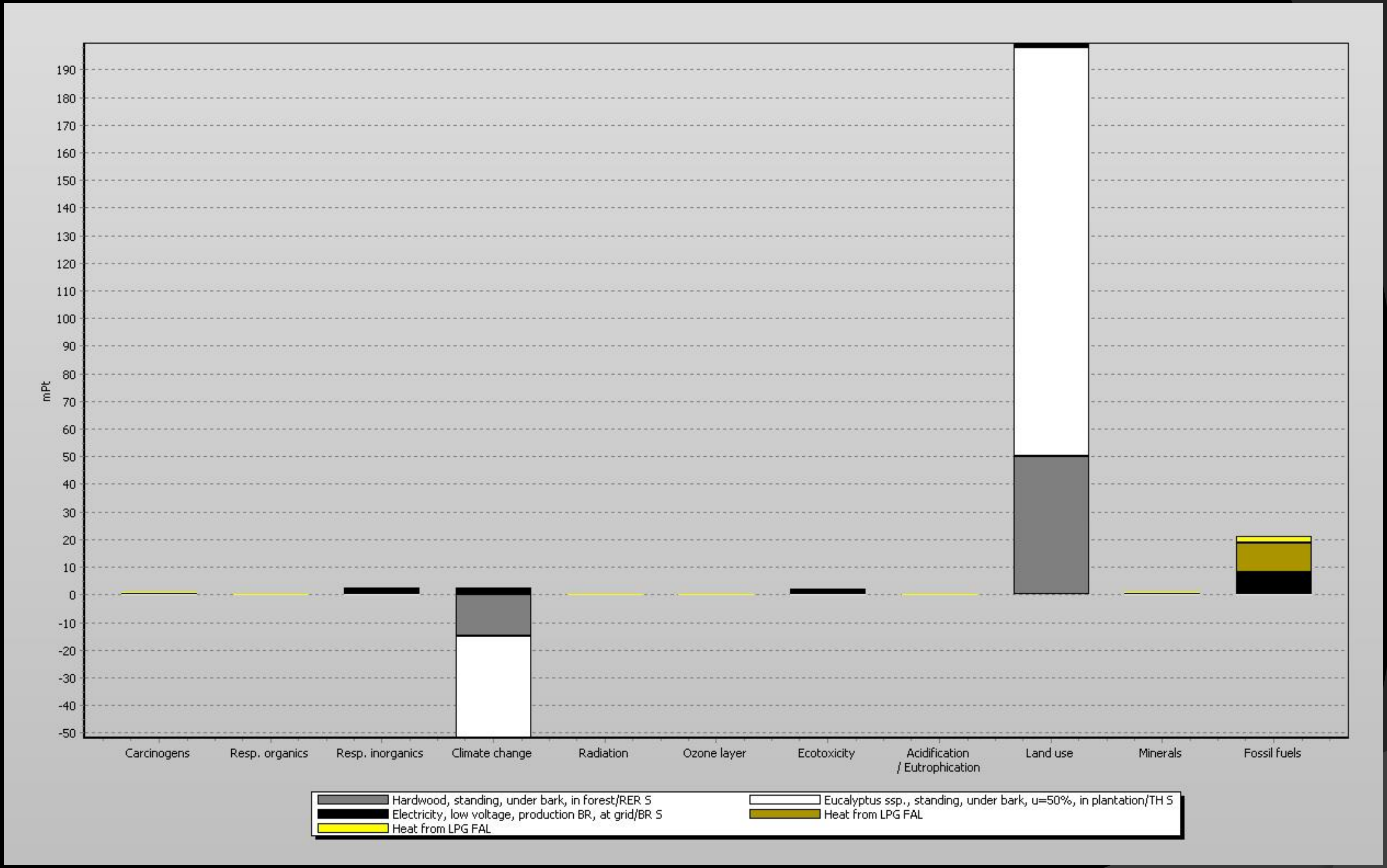


Flow Chart Key:

- Arrow width = percent material contribution to overall production
- Arrow color = overall environmental impact - positive (green) or negative (red)
- Percentage at bottom = percent contribution to EI-99 single score as does the "thermometer" at right

Baseline Model - Weighted

Unit = 1/1000 of a point of environmental load due to an average EU resident.



Key:

Grey=Impacts from Hardwood Species Resource

White=Impacts from Plantation Species Resource

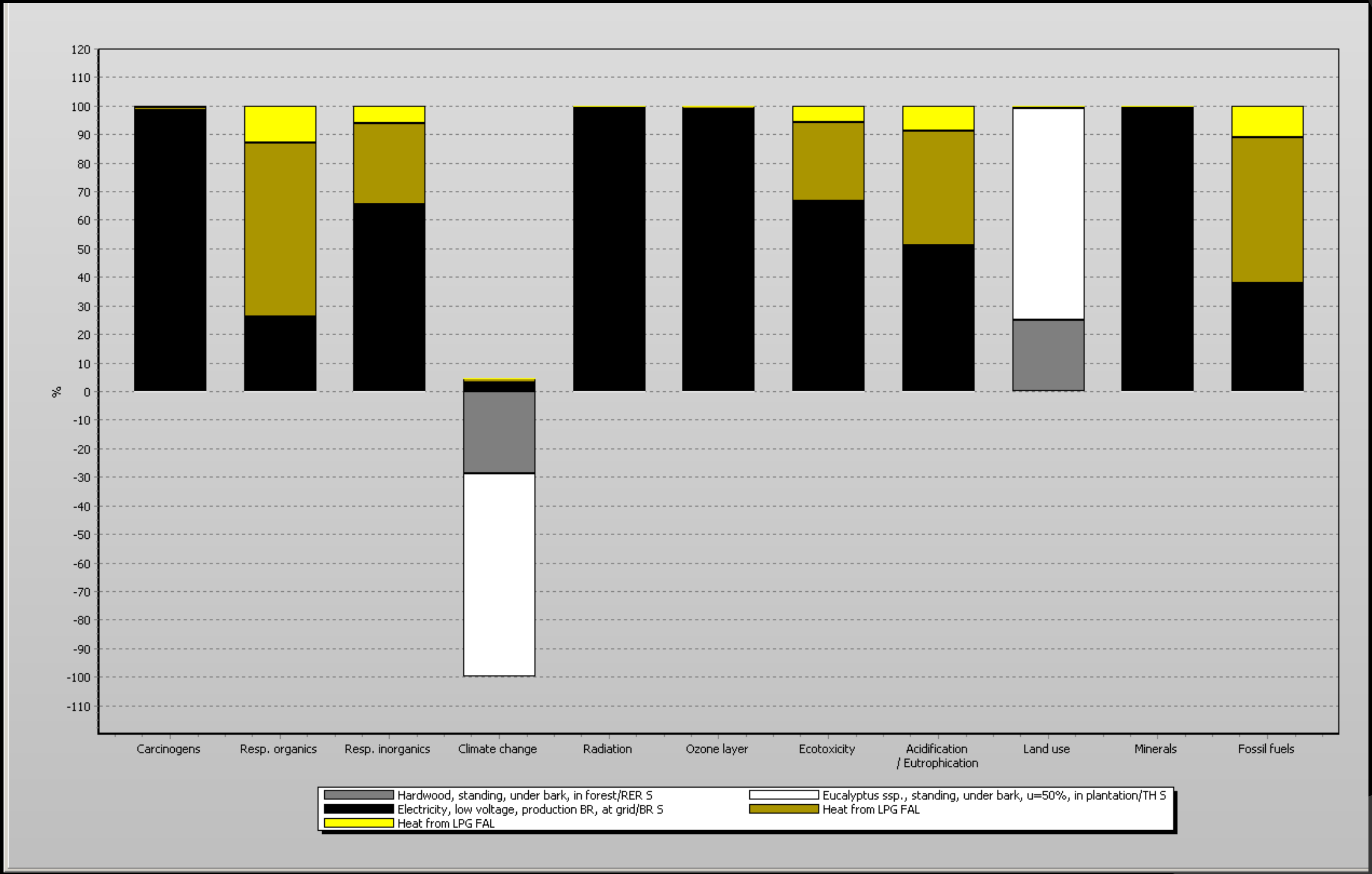
Gold=Impacts from Extraction

Yellow=Impacts from Transportation

Black=Impacts from Electric Consumption of Manufacturing

Characterization

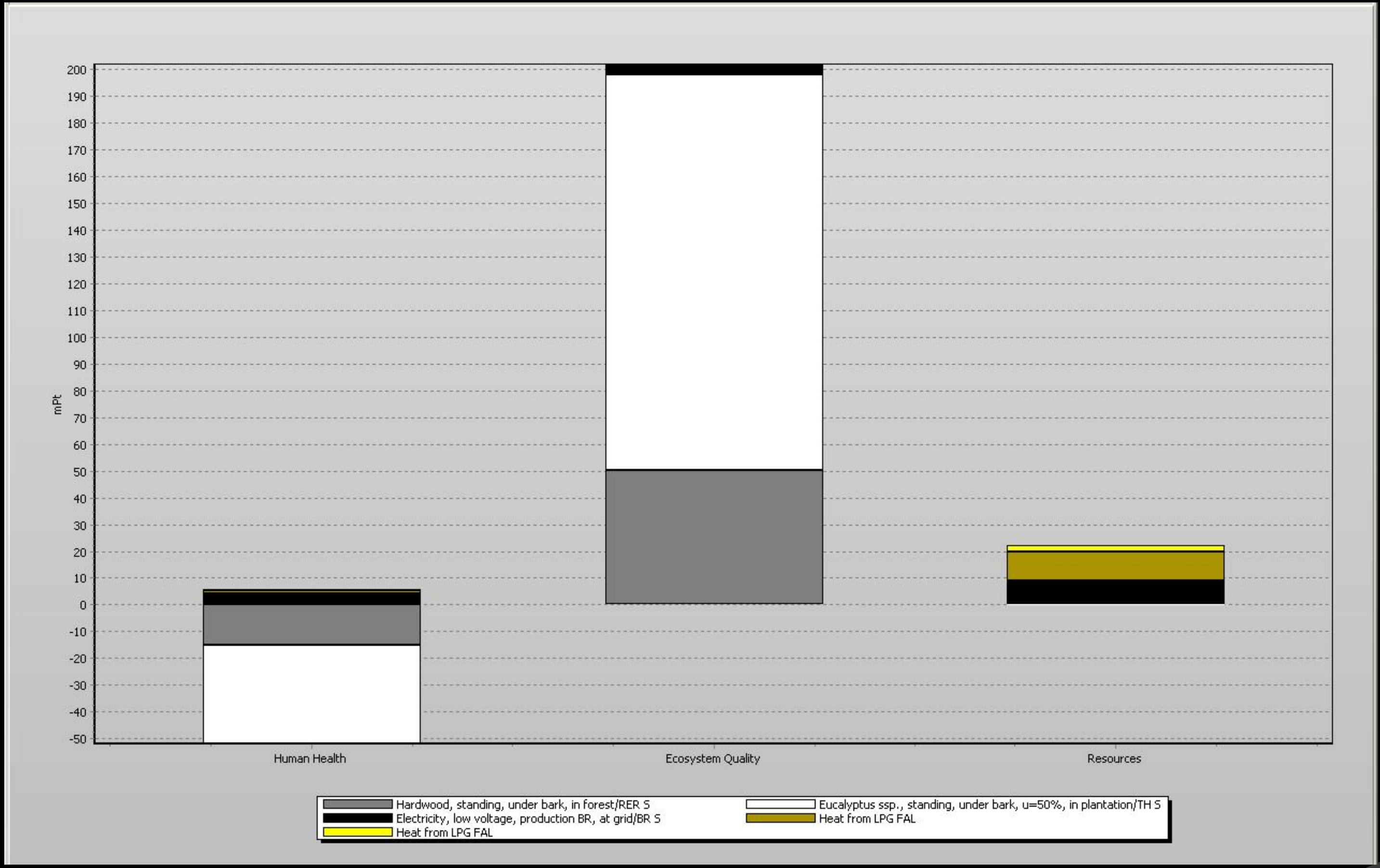
(Percentage of Total Impact In a Category of Each Model Input)



Key:
Grey=Impacts from Hardwood Species Resource
White-Impacts from Plantation species Resource
Gold=Impacts from Extraction
Yellow=Impacts from Transportation
Black=Impacts from Electric Consumption of Manufacturing

Baseline Model Weighted

(Unit is thousandth of a point)



Key:
Grey=Impacts from Hardwood Species Resource
White-Impacts from Plantation Species Resource
Gold=Impacts from Extraction
Yellow=Impacts from Transportation
Black=Impacts from Electric Consumption of Manufacturing

Baseline Model Analysis Outcomes

- Largest favorable environmental impact of the chair is the Carbon Sequestration of the wood

  Note: if product is burnt at the end of life, carbon will be released back to atmosphere so the actual carbon sequestration value will be smaller.

- Largest unfavorable impacts come from Land Use and Fossil Fuel Consumption
- Fossil Fuel Consumption at such a small transportation distance is dominated by Extraction Energy

Wood Species Selection & Potential Environmental Impacts

- **Carbon Sequestration**
  - Different species sequester carbon at different rates. Carbon sequestration removes greenhouse gasses from the atmosphere. This reduces potential impacts of global climate change.
- **Land Use Changes**
  - Land use changes effect soil and water toxicology, habitats, local biodiversity, and resource availability.
- **Effects on Eutrophication**
  - Eutrophication is the depletion of oxygen in water due to dissolved nutrients, particularly nitrogen and phosphorous. Reducing oxygen levels in the water leads to fish kills, biodiversity loss, and algal blooms. Trees absorb nitrogen and phosphorous from the soil naturally, but only at a certain rate. Nitrogen and phosphorous are the primary nutrients found in fertilizers, so wood growth via plantation species that are heavily fertilized causing runoff. Or removing species near water resources that absorb excess nutrients can have large negative impacts on the local ecosystem.

Wood Choice Comparison

- Baseline Model – ideal for longest product lifespan is a combination that uses a hardwood species for stretchers and a softer plantation species for the seat and legs

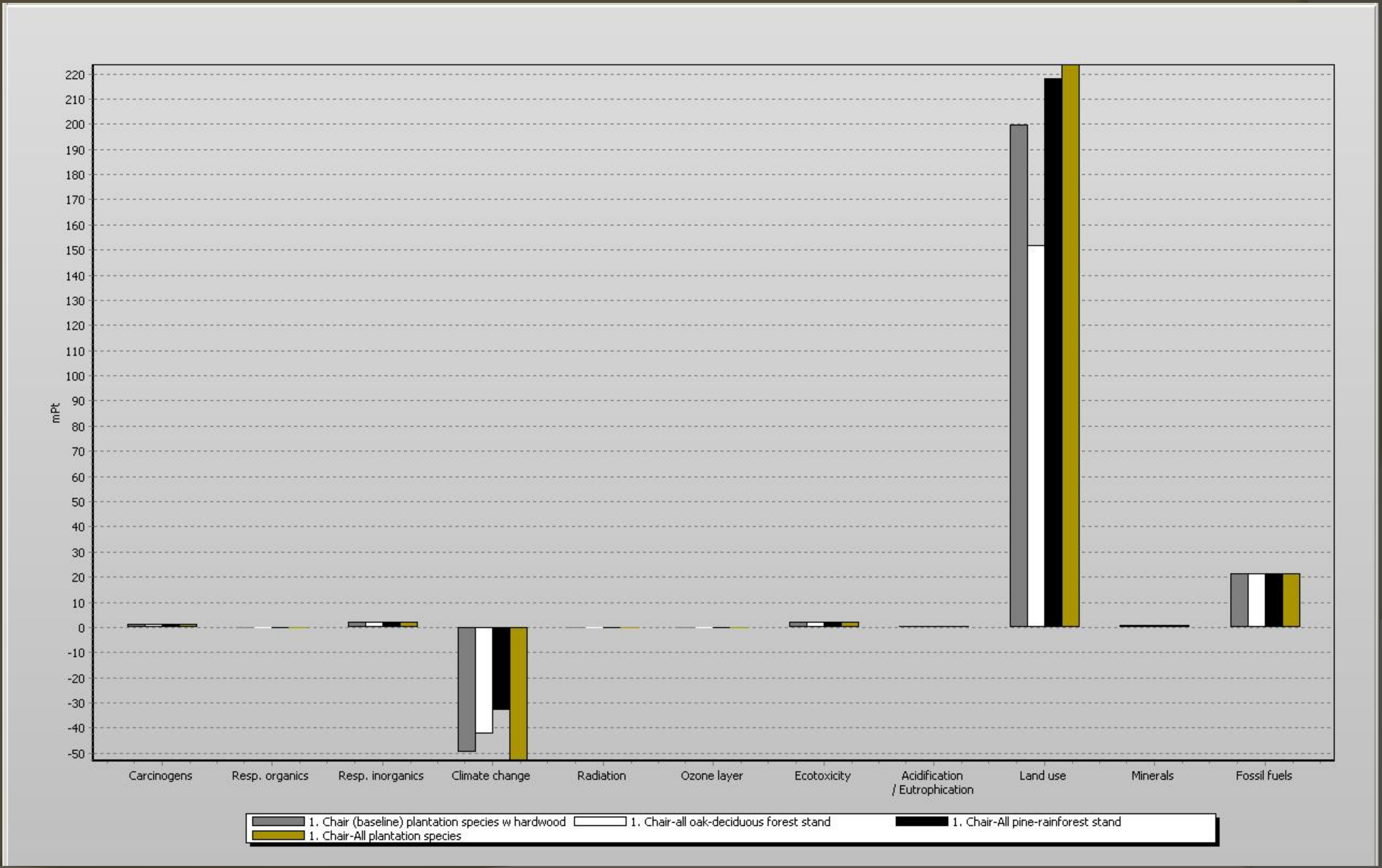
- Shown are environmental impacts comparing the ideal model to a chair of uniform material, either completely composed of hardwood species from natural stand, tropical softwood species from natural stand, or tropical plantation species

*How to Interpret Varying Parameters

- **For this comparison the two varying parameters are Land Use and Climate Change**
- Land Use can be thought of as a total land footprint needed to grow a certain volume of wood. Therefore, in a natural forest stand where a variety of species are found, the land footprint will include land area value includes land used to grow not only the harvested species, but other plants as well. Land value is the natural density of the species in a forest.
- A plantation harvested species will still have a slightly larger land footprint because species are carefully spaced in equidistant rows wide enough for agricultural machinery.
- Climate Change has a positive and negative value. The negative value reflects CO2 sequestered by plant growth. The positive value reflects GHG emissions from the combustion of fossil fuels.

Weighted Results

(Unit is thousandths of a point)



Wood Choice Analysis Outcomes

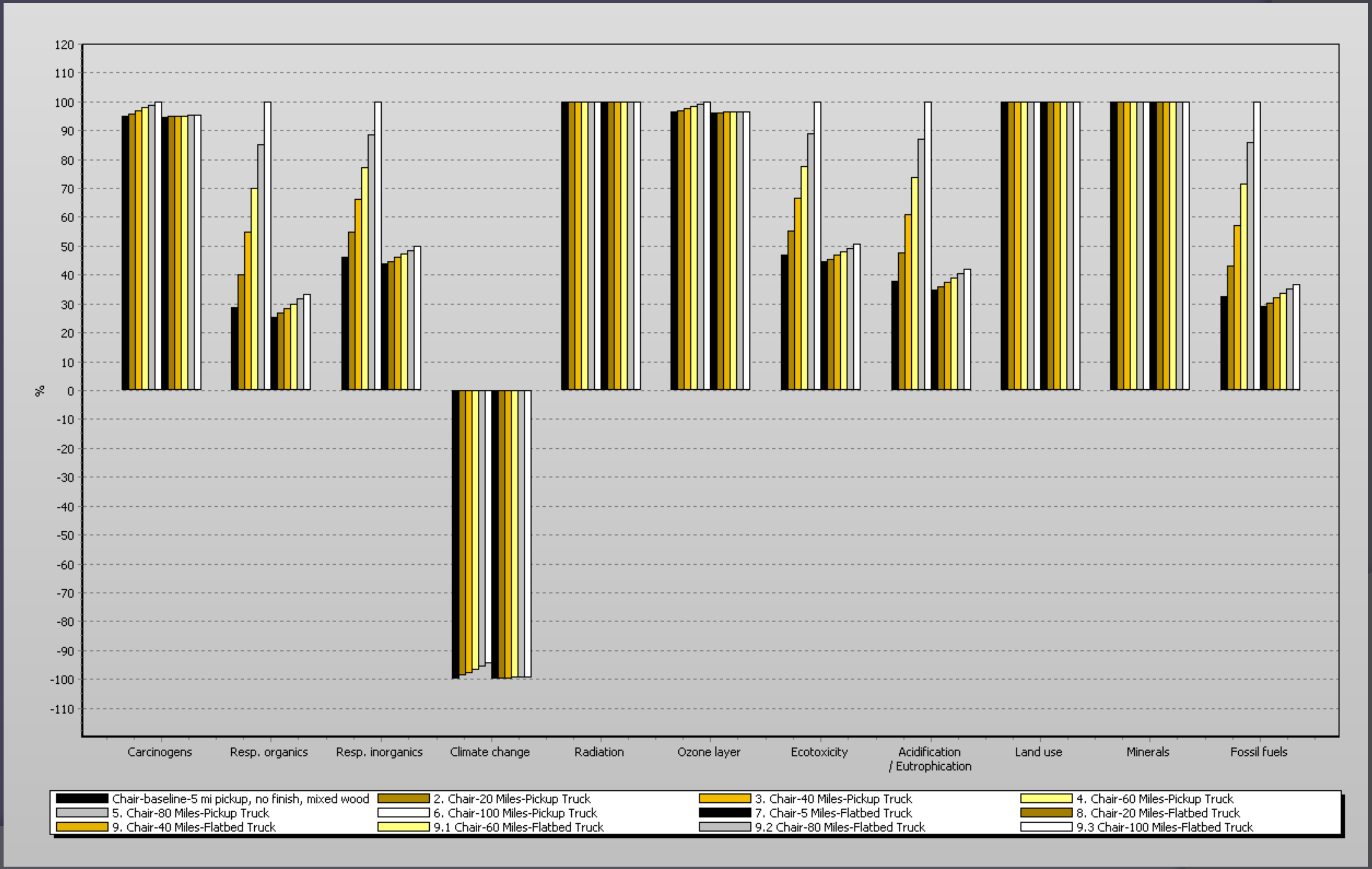
- Based on land use, using strictly Plantation Species is the least sustainable option according to the model.
- Land footprint for a hardwood species extracted from a natural deciduous forest stand is smallest.

Transportation Comparison

- Varying parameter is transportation distance: 20, 40, 60, 80 and 100 miles are compared to the baseline model of 5 miles.
- Scenarios 1: The assumed transportation vehicle is a pickup truck less than 3 tons hauling 150 board feet of lumber. 18 MPG avg. efficiency is assumed.
- Scenario 2: The assumed transportation vehicle is a flatbed truck carrying 8,000 board feet of lumber. 3 MPG avg. efficiency is assumed.

Characterization: Pickup Truck vs. Flatbed Truck

Impacts from 100 Miles of Transportation set at 100%, and lesser values compared



Transportation Analysis Outcomes

- Impact categories that increased transportation affects include:
  - Respiratory organics and inorganics - due to combustion emissions of volatile fluids
  - Climate change from the burning of GHGs in fossil fuels,
  - Exotoxicity-due to combustion related emissions and fossil fuel extraction
  - Fossil fuel consumption
- Weighted scores show the largest impacts are from carbon sequestration, fossil fuel consumption, and land use
- Aggregate scores for worst case scenario (100 miles transportation) are still a sustainable value of 0.27
- It is better to use a truck that can carry more total board feet of lumber such as a flatbed truck.

Hard Data

Impact category	Unit	Chair-baseline-5 mi pickup, no finish,	2. Chair-20 Miles-Pickup Truck	3. Chair-40 Miles-Pickup Truck	4. Chair-60 Miles-Pickup Truck	5. Chair-80 Miles-Pickup Truck	6. Chair-100 Miles-Pickup Truck
Carcinogens	DALY	5.65E-8	5.7E-8	5.76E-8	5.82E-8	5.88E-8	5.95E-8
Resp. organics	DALY	6.49E-10	9.03E-10	1.24E-9	1.58E-9	1.92E-9	2.26E-9
Resp. inorganics	DALY	1.19E-7	1.41E-7	1.7E-7	1.99E-7	2.28E-7	2.56E-7
Climate change	DALY	-2.53E-6	-2.51E-6	-2.48E-6	-2.46E-6	-2.43E-6	-2.4E-6
Radiation	DALY	1.31E-9	1.31E-9	1.31E-9	1.31E-9	1.31E-9	1.31E-9
Ozone layer	DALY	1.6E-11	1.61E-11	1.62E-11	1.63E-11	1.65E-11	1.66E-11
Ecotoxicity	PAF*m2yr	0.255	0.3	0.36	0.421	0.481	0.541
Acidification/ Eutrophication	PDF*m2yr	0.00392	0.00493	0.00629	0.00764	0.00899	0.0103
Land use	PDF*m2yr	2.56	2.56	2.56	2.56	2.56	2.56
Minerals	MJ surplus	0.0265	0.0265	0.0265	0.0265	0.0265	0.0265
Fossil fuels	MJ surplus	0.594	0.79	1.05	1.31	1.57	1.83

Impact category	Unit	Chair-baseline-5 mi pickup, no finish,	2. Chair-20 Miles-Pickup Truck	3. Chair-40 Miles-Pickup Truck	4. Chair-60 Miles-Pickup Truck	5. Chair-80 Miles-Pickup Truck	6. Chair-100 Miles-Pickup Truck
Total	Pt	0.178	0.186	0.197	0.208	0.219	0.23
Carcinogens	Pt	0.0011	0.00111	0.00112	0.00114	0.00115	0.00116
Resp. organics	Pt	1.27E-5	1.76E-5	2.43E-5	3.09E-5	3.75E-5	4.41E-5
Resp. inorganics	Pt	0.00232	0.00275	0.00331	0.00388	0.00444	0.00501
Climate change	Pt	-0.0494	-0.0491	-0.0485	-0.048	-0.0475	-0.047
Radiation	Pt	2.57E-5	2.57E-5	2.57E-5	2.57E-5	2.57E-5	2.57E-5
Ozone layer	Pt	3.12E-7	3.14E-7	3.16E-7	3.19E-7	3.21E-7	3.24E-7
Ecotoxicity	Pt	0.00199	0.00234	0.00281	0.00328	0.00375	0.00422
Acidification/ Eutrophication	Pt	0.000306	0.000385	0.00049	0.000596	0.000702	0.000807
Land use	Pt	0.2	0.2	0.2	0.2	0.2	0.2
Minerals	Pt	0.000945	0.000945	0.000945	0.000945	0.000945	0.000945
Fossil fuels	Pt	0.0212	0.0282	0.0375	0.0468	0.0562	0.0655

Hard Data

Impact category	Unit	7. Chair-5 Miles-Flatbed Truck	8. Chair-20 Miles-Flatbed Truck	9. Chair-40 Miles-Flatbed Truck	9.1 Chair-60 Miles-Flatbed Truck	9.2 Chair-80 Miles-Flatbed Truck	9.3 Chair-100 Miles-Flatbed Truck
Carcinogens	DALY	5.64E-8	5.64E-8	5.65E-8	5.66E-8	5.66E-8	5.67E-8
Resp. organics	DALY	5.74E-10	6.03E-10	6.41E-10	6.79E-10	7.17E-10	7.55E-10
Resp. inorganics	DALY	1.12E-7	1.15E-7	1.18E-7	1.21E-7	1.25E-7	1.28E-7
Climate change	DALY	-2.54E-6	-2.54E-6	-2.53E-6	-2.53E-6	-2.53E-6	-2.52E-6
Radiation	DALY	1.31E-9	1.31E-9	1.31E-9	1.31E-9	1.31E-9	1.31E-9
Ozone layer	DALY	1.6E-11	1.6E-11	1.6E-11	1.6E-11	1.6E-11	1.6E-11
Ecotoxicity	PAF*m2yr	0.241	0.247	0.253	0.26	0.267	0.274
Acidification/ Eutrophication	PDF*m2yr	0.00362	0.00373	0.00389	0.00404	0.00419	0.00434
Land use	PDF*m2yr	2.56	2.56	2.56	2.56	2.56	2.56
Minerals	MJ surplus	0.0265	0.0265	0.0265	0.0265	0.0265	0.0265
Fossil fuels	MJ surplus	0.536	0.558	0.588	0.617	0.647	0.676

Impact category	Unit	7. Chair-5 Miles-Flatbed Truck	8. Chair-20 Miles-Flatbed Truck	9. Chair-40 Miles-Flatbed Truck	9.1 Chair-60 Miles-Flatbed Truck	9.2 Chair-80 Miles-Flatbed Truck	9.3 Chair-100 Miles-Flatbed Truck
Total	Pt	0.176	0.177	0.178	0.179	0.18	0.182
Carcinogens	Pt	0.0011	0.0011	0.0011	0.0011	0.00111	0.00111
Resp. organics	Pt	1.12E-5	1.18E-5	1.25E-5	1.33E-5	1.4E-5	1.48E-5
Resp. inorganics	Pt	0.0022	0.00224	0.00231	0.00237	0.00243	0.0025
Climate change	Pt	-0.0496	-0.0495	-0.0495	-0.0494	-0.0493	-0.0493
Radiation	Pt	2.57E-5	2.57E-5	2.57E-5	2.57E-5	2.57E-5	2.57E-5
Ozone layer	Pt	3.12E-7	3.12E-7	3.12E-7	3.12E-7	3.13E-7	3.13E-7
Ecotoxicity	Pt	0.00188	0.00192	0.00198	0.00203	0.00208	0.00213
Acidification/ Eutrophication	Pt	0.000282	0.000291	0.000303	0.000315	0.000327	0.000339
Land use	Pt	0.2	0.2	0.2	0.2	0.2	0.2
Minerals	Pt	0.000945	0.000945	0.000945	0.000945	0.000945	0.000945
Fossil fuels	Pt	0.0192	0.0199	0.021	0.022	0.0231	0.0241

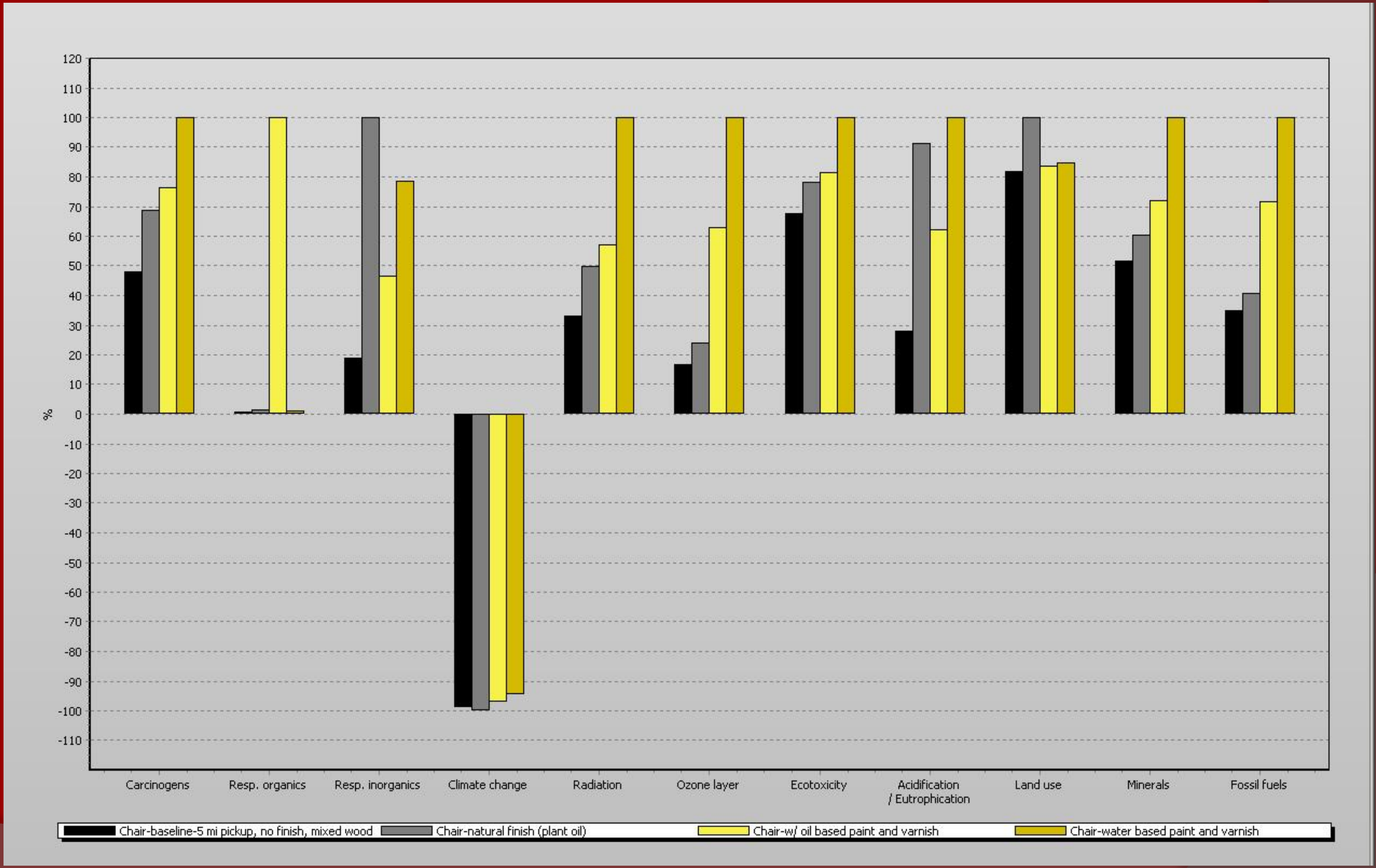
Finish Comparison

The parameters varied for this analysis based on types of finishes used. For consistency, the volume of finishes were considered equivalent for each type of finish. (Paint volume 2.5 oz per chair, Lacquer or Plant Oil volume 5 oz per chair)

- Model 1: No finish
- Model 2: Natural Plant Oil finish (extracted through cold press technique)
- Model 3: Water Soluble Paint and Lacquer
- Model 4: Traditional Oil Based Paint and Lacquer

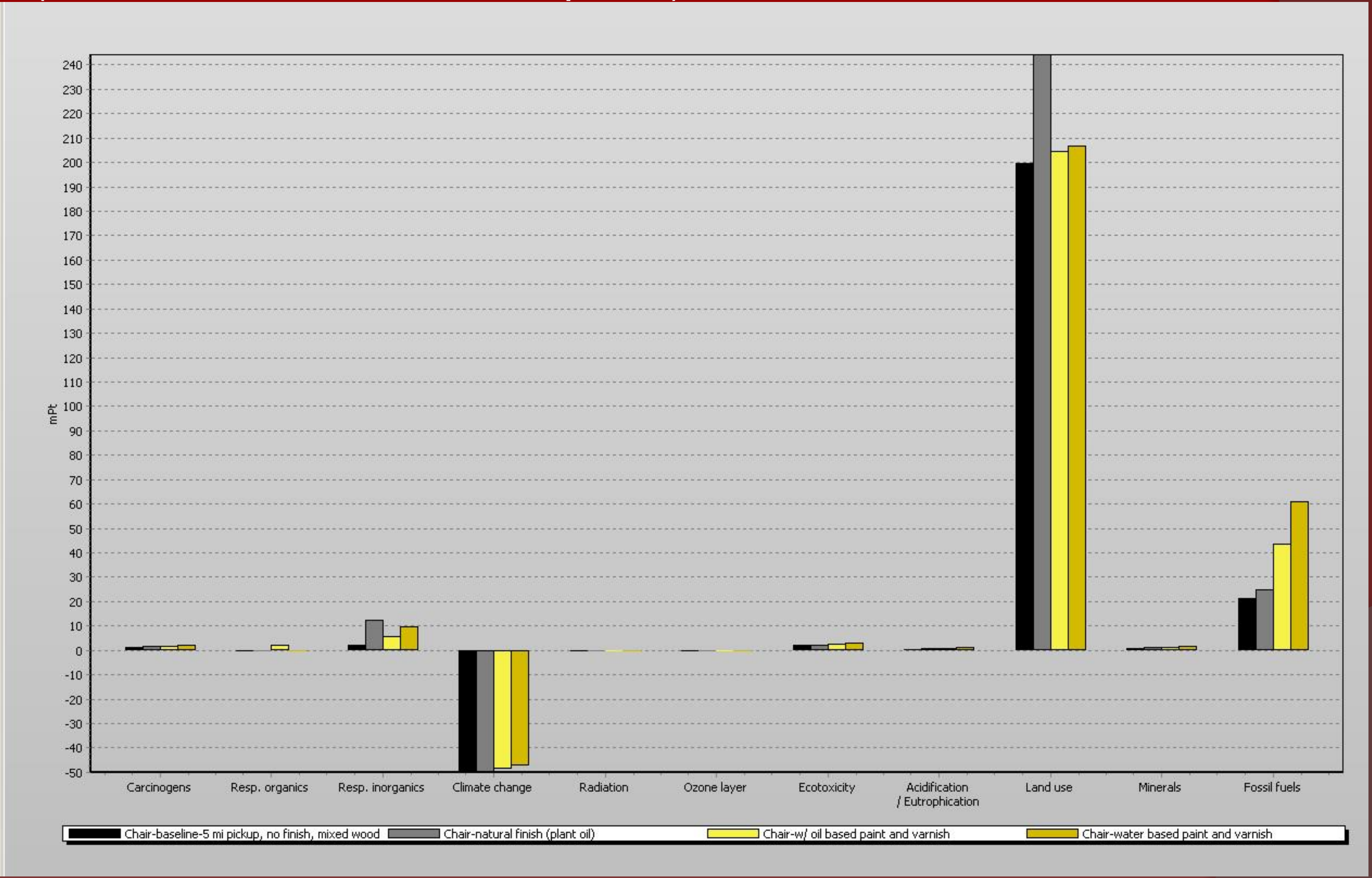
Characterization

Impacts from the most harmful finish is set at 100% in each category.



Weighted Results

(Unit is thousandths of a point)



Hard Data

Impact category	Unit	Chair-baseline-5 mi pickup, no finish,	Chair-natural finish (plant oil)	Chair-w/ oil based paint and varnish	Chair-water based paint and varnish
Carcinogens	DALY	5.65E-8	8.11E-8	8.99E-8	1.18E-7
Resp. organics	DALY	6.49E-10	1.78E-9	1.14E-7	1.21E-9
Resp. inorganics	DALY	1.19E-7	6.33E-7	2.95E-7	4.97E-7
Climate change	DALY	-2.53E-6	-2.56E-6	-2.49E-6	-2.43E-6
Radiation	DALY	1.31E-9	1.98E-9	2.27E-9	3.96E-9
Ozone layer	DALY	1.6E-11	2.29E-11	5.95E-11	9.47E-11
Ecotoxicity	PAF*m2yr	0.255	0.295	0.308	0.377
Acidification/ Eutrophication	PDF*m2yr	0.00392	0.0128	0.00869	0.014
Land use	PDF*m2yr	2.56	3.13	2.62	2.65
Minerals	MJ surplus	0.0265	0.0309	0.0369	0.0512
Fossil fuels	MJ surplus	0.594	0.694	1.22	1.71

Impact category	Unit	Chair-baseline-5 mi pickup, no finish,	Chair-natural finish (plant oil)	Chair-w/ oil based paint and varnish	Chair-water based paint and varnish
Total	Pt	0.178	0.237	0.214	0.238
Carcinogens	Pt	0.0011	0.00158	0.00175	0.0023
Resp. organics	Pt	1.27E-5	3.48E-5	0.00224	2.36E-5
Resp. inorganics	Pt	0.00232	0.0124	0.00575	0.00971
Climate change	Pt	-0.0494	-0.0501	-0.0487	-0.0474
Radiation	Pt	2.57E-5	3.86E-5	4.43E-5	7.73E-5
Ozone layer	Pt	3.12E-7	4.47E-7	1.16E-6	1.85E-6
Ecotoxicity	Pt	0.00199	0.0023	0.0024	0.00294
Acidification/ Eutrophication	Pt	0.000306	0.000999	0.000678	0.00109
Land use	Pt	0.2	0.244	0.204	0.207
Minerals	Pt	0.000945	0.0011	0.00132	0.00183
Fossil fuels	Pt	0.0212	0.0248	0.0436	0.0609

Finish Analysis Outcomes

While no finish has the least environmental impacts, adding a finish may sometimes be necessary to enhance furniture surface durability.

- A water based finish, actually proved to be the least sustainable choice due to the fossil fuels associated with its production and transportation.
- Using a natural plant oil may be the most sustainable option depending on the region's resource availability. However the model showed it to be unsustainable due to the land and fertilizing resources of growing the plant the oil is extracted from.
- The natural plant based finish has less environmental impact compared to the synthetic finishes in all categories except respiratory inorganics, eutrophication, and land use.

Global Warming Potential

A comparison of the Global Warming potential was performed using the IPCC model of the best and worst case scenarios in terms of climate change effects or wood choice, finish, and transportation.

The result was that all scenarios for the chair have a beneficial impact on global warming. The effects of carbon sequestration outweigh the effects GHG air emissions.

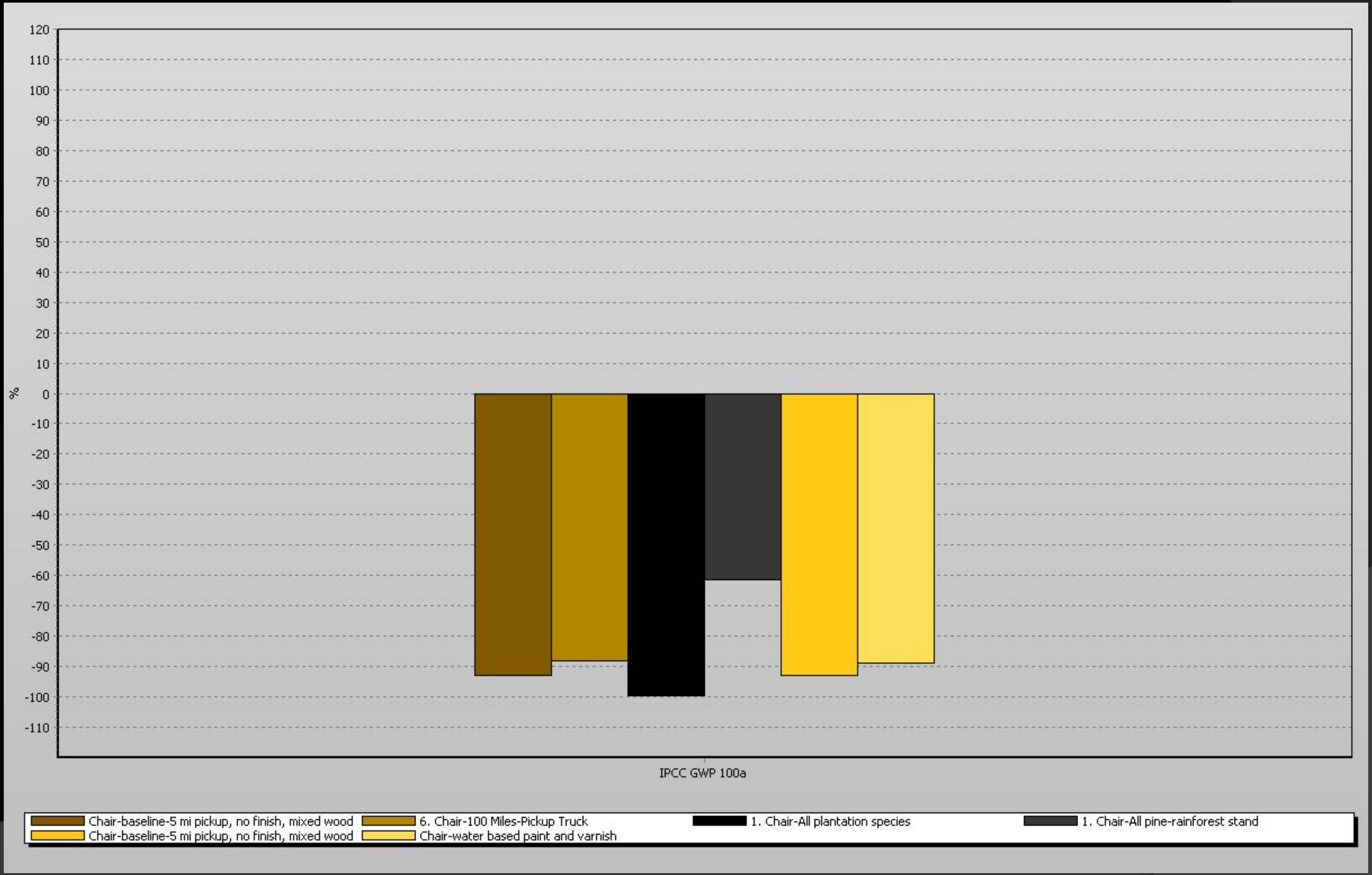
Global warming Impact in kg CO2_eq.					
Transportation		Finish		Wood Choice	
Best	Worst	Best	Worst	Best	Worst
-12	-11.4	-12.9	-7.89	-12	-8.9

The definition of a GWP for a particular greenhouse gas is the ratio of heat trapped by one unit mass of the greenhouse gas to that of one unit mass of CO_2
-EPA

Examples (100-year GWP):
1 kg of methane (CH_4) = 251 (should be 25) kg of CO_2
1 kg of NO_2 = 298 kg CO_2

http://www.epa.gov/methane/scientific.html

Global Warming Potential



Sustainable Product Development Conclusion

- Green, Sustainable, Environmentally Friendly Products
  - validation is missing.
- The use of the LCA tool is helping to validate.
- Is this an user friendly tool for designers and product developers?
- Simplified form is needed (EDPs)?

General issues:

- Material selection (identification, extraction and transport),
- Design decisions – product durability,
- Processes & technology decisions.

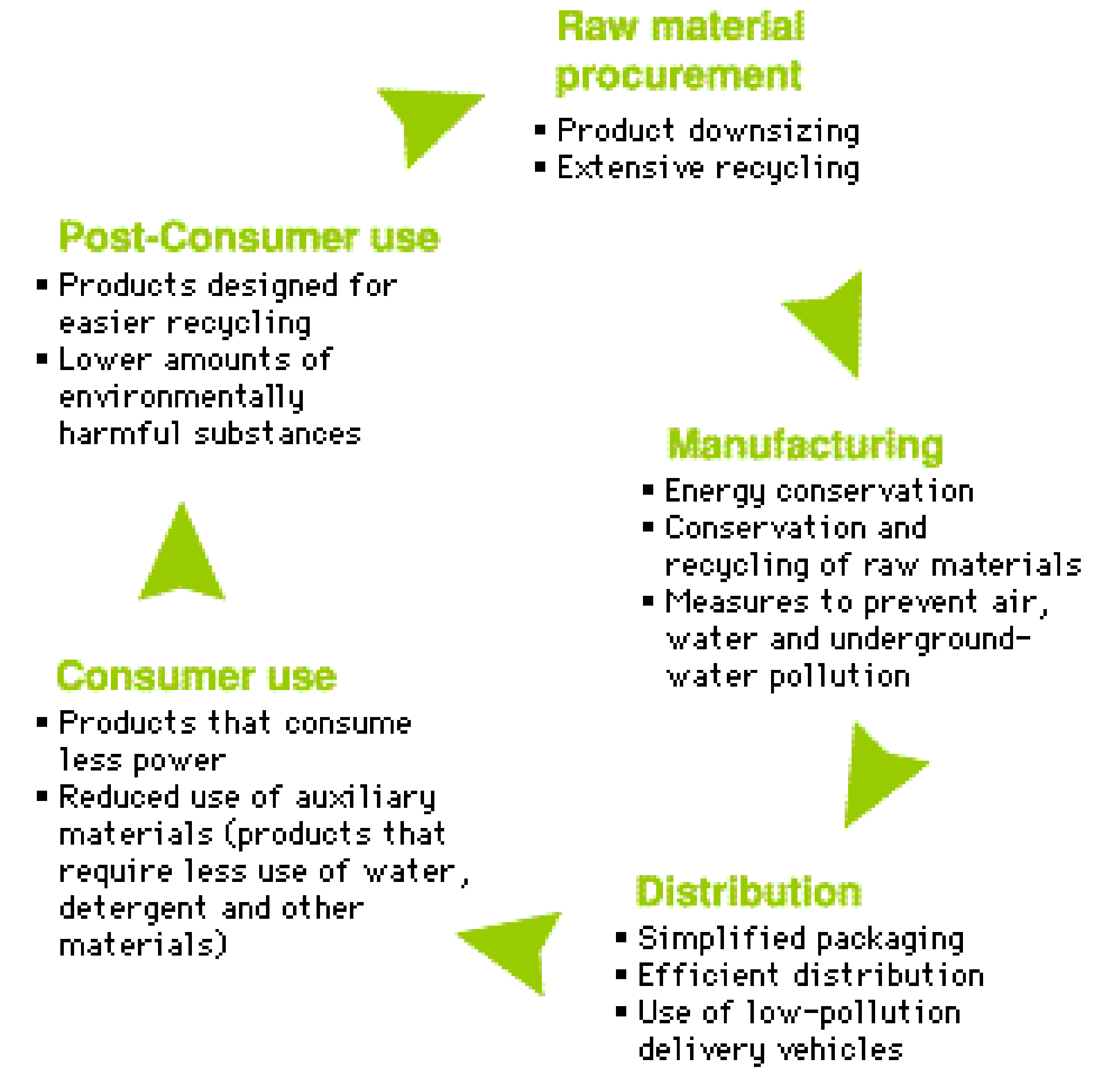
Green/Sustainable Furniture Guidelines

- Wood furniture should use **material** that has been **certified by an organization** such as the Forest Stewardship Council or an equivalent.
- **All materials used** within sustainable furniture should be **formaldehyde free**.
- **Low-VOC or water-based foams, glues and finishes** should be used.
- **Metal** should include recycled content and be **recyclable**.
- **Organic fabrics**, such as natural latex rubber or soybeans mixed with polyurethane, are good environmental choice.
- **Wrapping and batting** should be **bio-based instead of oil-based**; (examples of bio-based materials are down, feathers, organic cotton and wool).
- **Longevity and durability** also contribute toward furniture's sustainability; the longer a product is used the less often it needs to be replaced and fewer resources are consumed.

Green/Sustainable Furniture

- Life-cycle assessment also is important when considering sustainable furniture. LCA takes into account from **where materials are sourced**, **how the item is manufactured** and whether it is **recyclable or biodegradable** at the end of its useful life.
- Furniture manufactured close to its final destination reduces environmental impact from shipping.

Life cycle assessment process:



- Matsushita Graphic Communications Systems Inc.