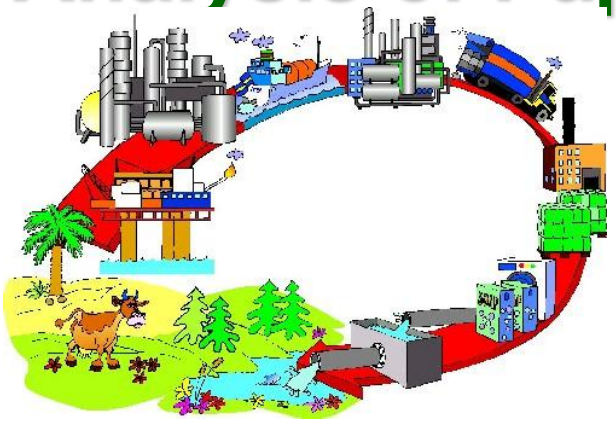
Life Cycle Analysis of Paper Products



Dr. Richard A. Venditti
Department of Forest Biomaterials
North Carolina State University
Raleigh, NC 27695-8005

Richard Venditti, Professor, Sabbatical Leave Jan-July 2011, Duke University, Center on Global Change, Room 109 Phytotron, Duke email: rav16@duke.edu, office 919 681 7180, cell 919 649-4017

Permanent Address: Dept of Forest Biomaterials, North Carolina State University, Biltmore Hall Rm 1204, 2820 Faucette Drive, Raleigh NC 27695-8005, (919) 515-6185, richard_venditti@ncsu.edu, website: go.ncsu.edu/venditti

Outline

- Introduction to LCA
- LCA of Paper
- North American Printing and Writing Grade LCA's
- Allocation methods in LCA's
- Recommendations

Sustainability?

- How do we supply societies needs without harming the environment or future generations' ability to meet their needs?
  - **People – Planet - Profit**

- We have many options to meet our demands.

- How to choose the "best" option?

- Life cycle assessment (LCA) helps to inform our choices.

- LCA has objective and subjective parts!!!

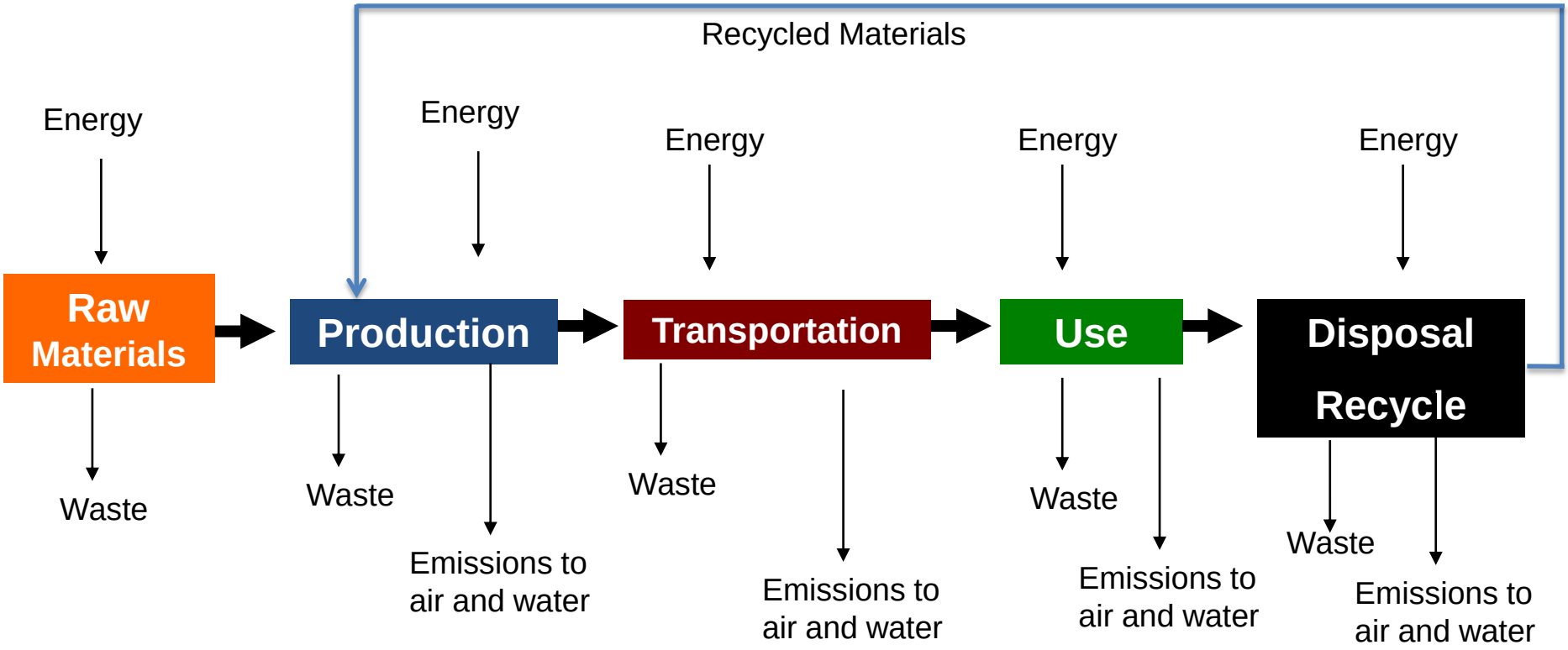
What is a Life Cycle Assessment ?

Life Cycle Assessment (LCA) is a tool to assess the potential environmental impacts of products, systems, or services at all stages in their life cycle [ISO 14001:2004].

Types of LCA

- **Cradle to Gate**: raw materials to finished good (no use or end life considerations)
- **Cradle to Grave**: Considers everything from harvesting materials to the disposal of the finished goods

Example LCA Process

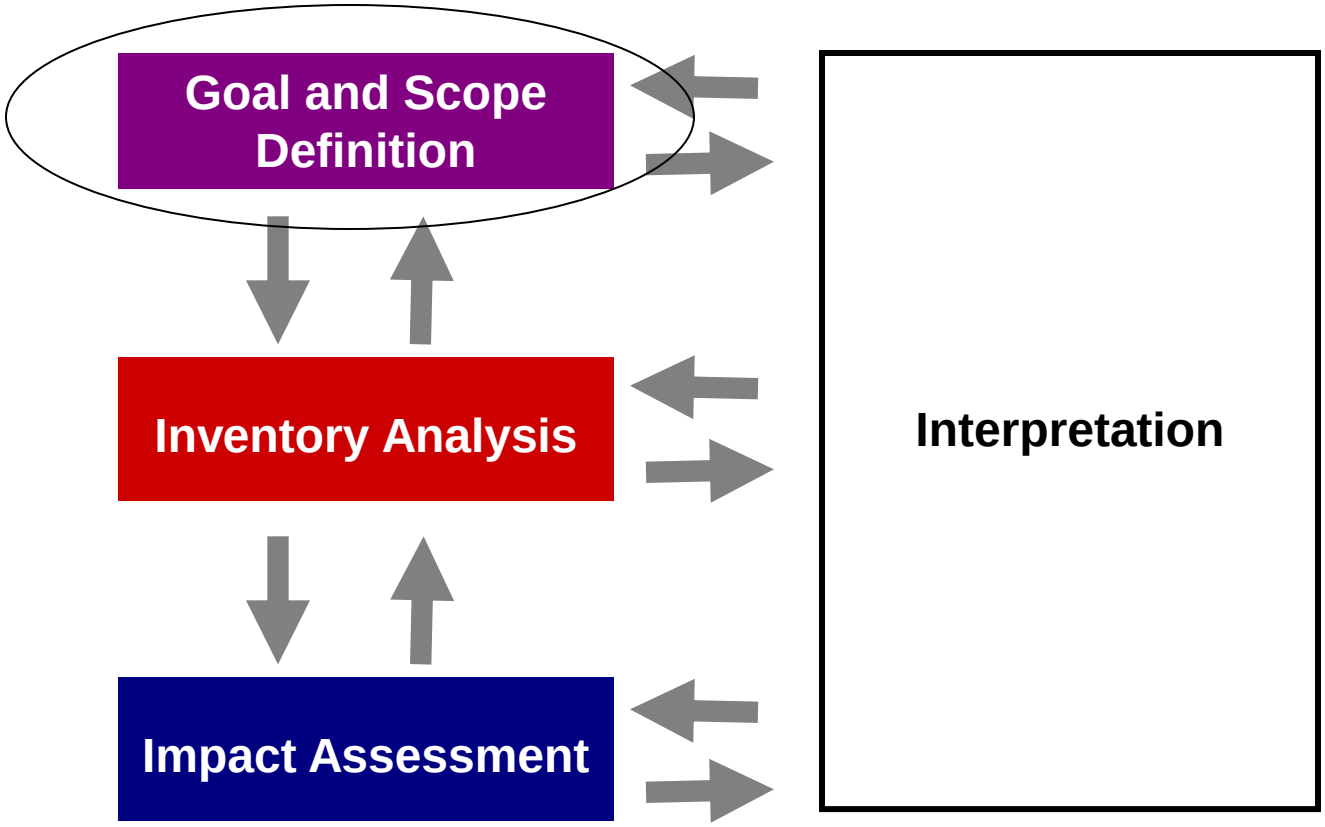


Why is an LCA Important?

- Helps ensure compliance with government regulations
- Helps decrease the environmental impact of a given product
  - Identifies ways to improve sustainability
  - Identifies ways to “green” all aspects of product’s life
- Can reshape company strategy
- Can help marketing
  - Can reshape company image
  - Develop product advantage of competition

Enid was finally ready to admit that compliance was a bit more complicated than she first thought.

Important Aspects of Life Cycle Assessment

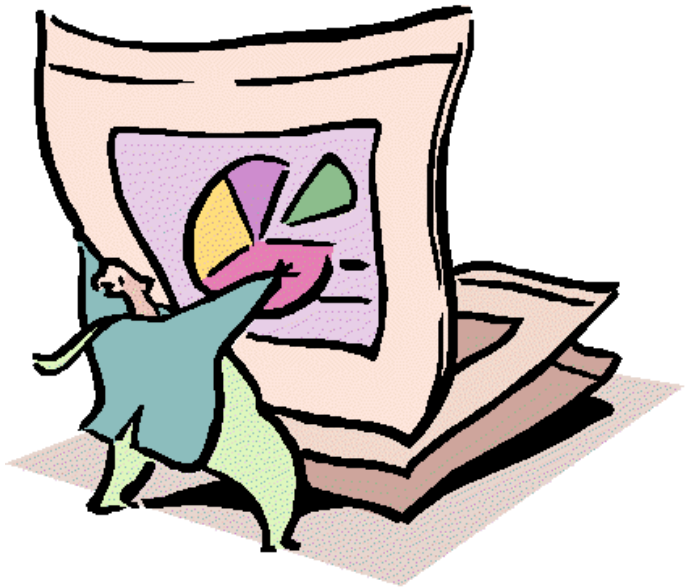


Defining Goals

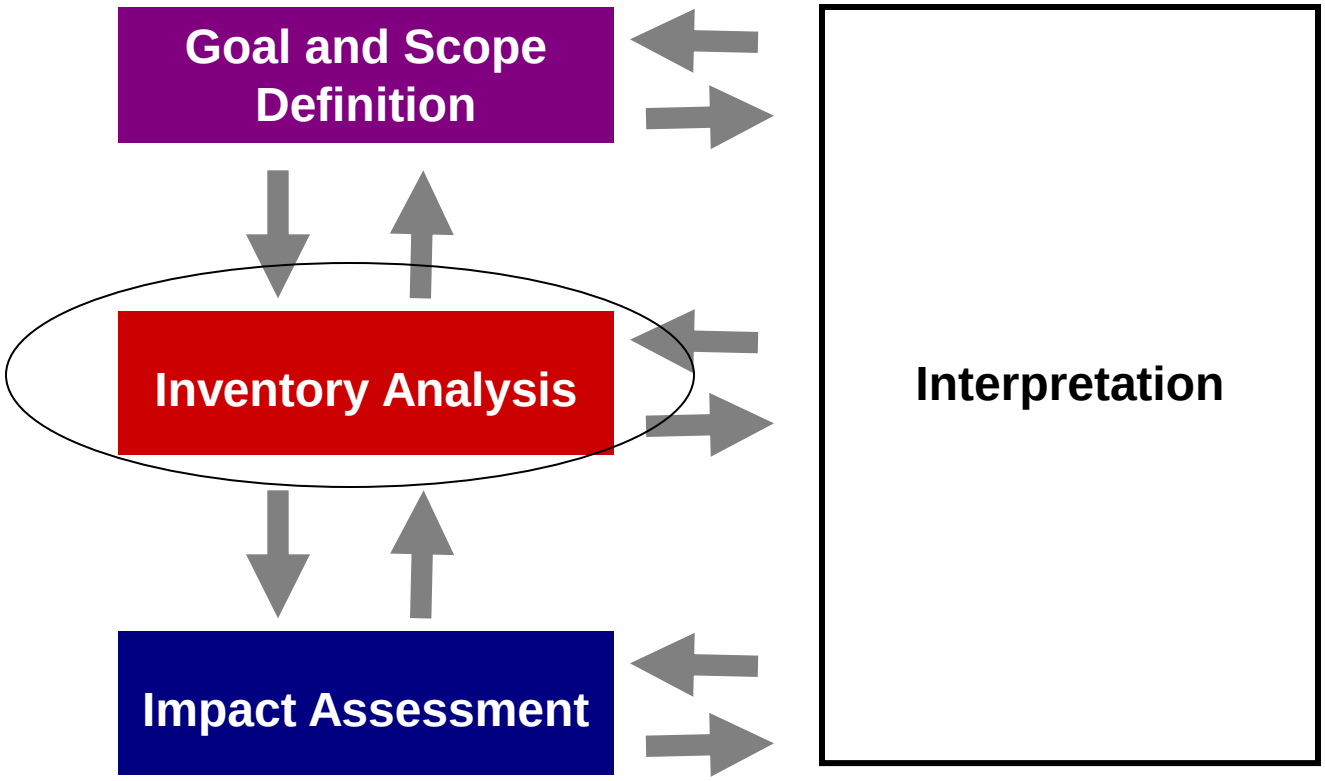
- Should state the intent of the study
  - Intended application
  - Intended use
  - Intended audience
- Should also include reason for the study

Defining Scope

- Define functional unit of product
  - Example: 100 disposable paper cups vs 1 glass container washed 99 times
- Help establish system boundaries for the LCA
- Determine data collection methods



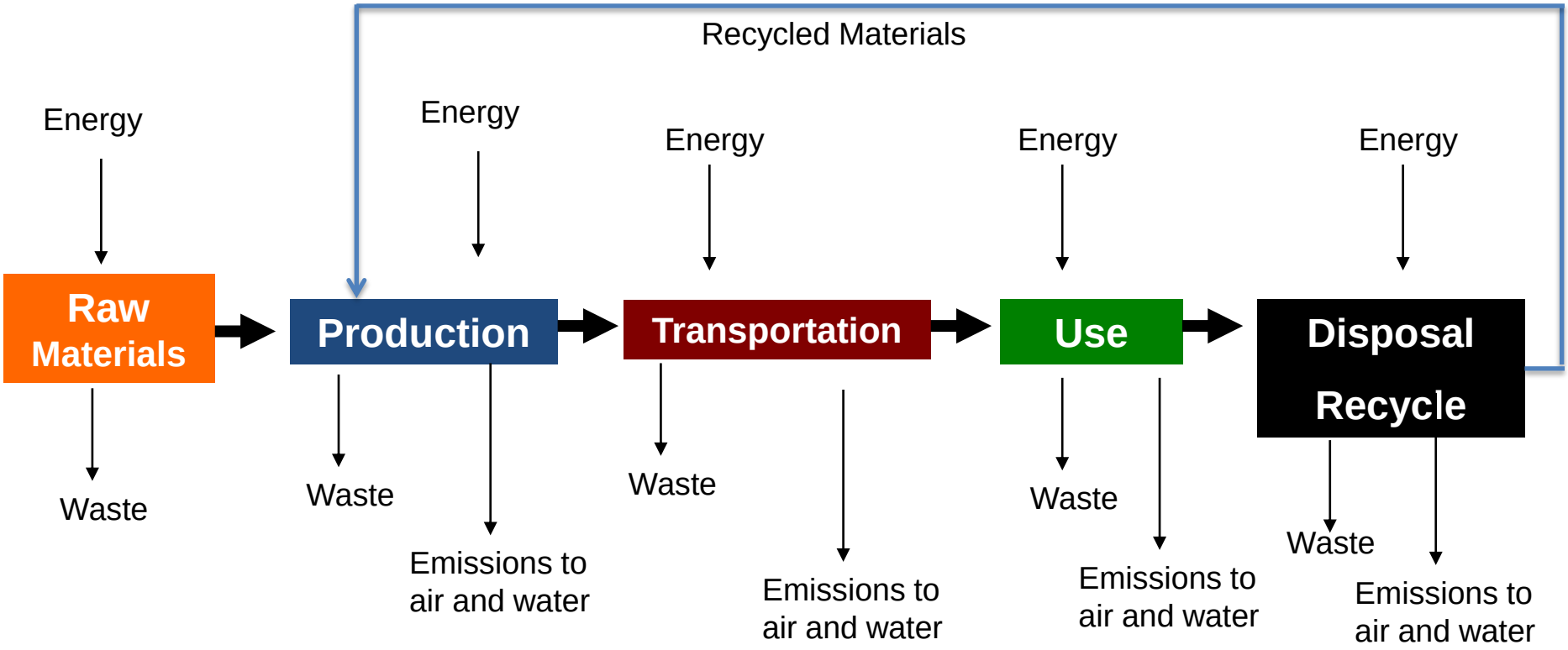
Important Aspects of Life Cycle Assessment



Inventory Analysis:

- **Definition of the process (flowsheet)**
- **Definition of all mass and energy inputs to the process**

Inventory Analysis: What Needs to be Included?



- **All relevant stages of the life of a product**

Inventory Analysis:

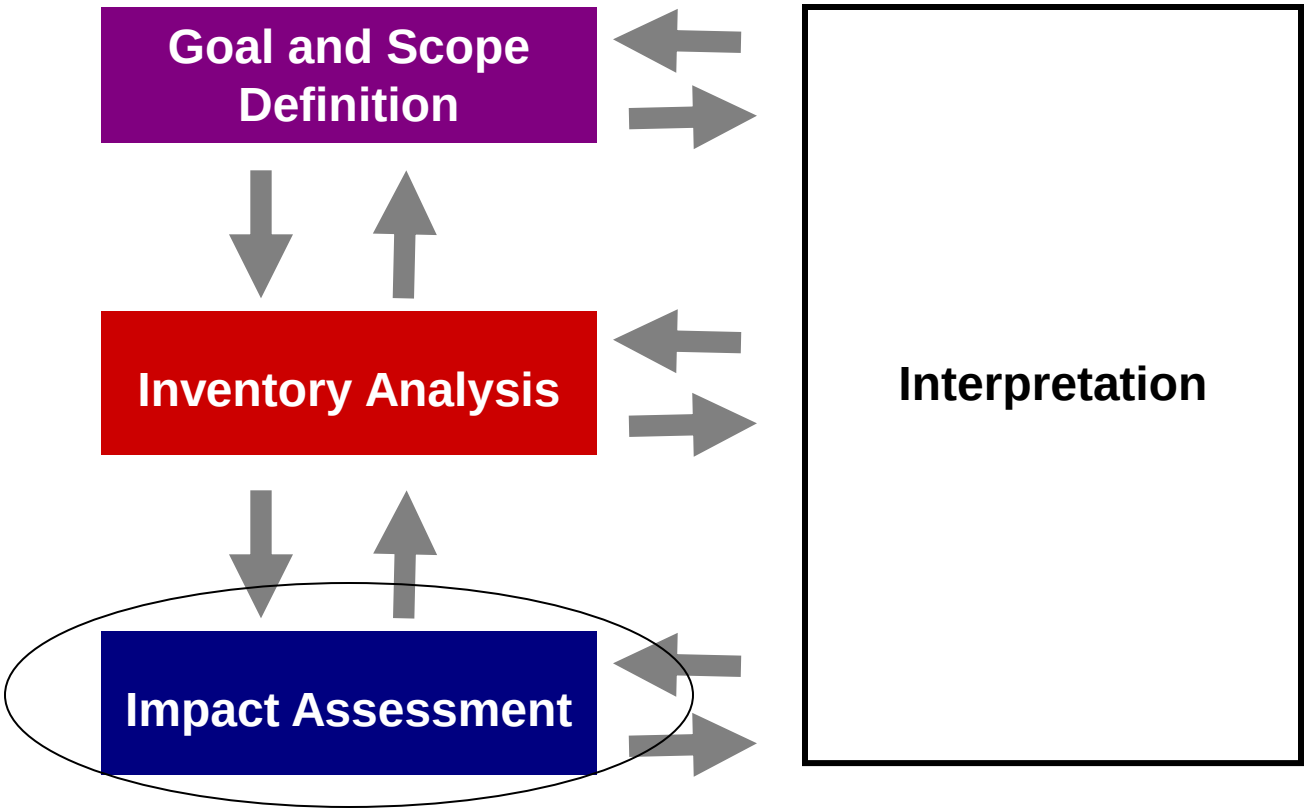
- **Foreground data – data specific to the model at hand**
- **Background data – generic data that can be found in available databases (examples, generic transportation or electricity)**

- **Tracking of who is in control of consumption/emissions:**
  - **Scope 1: owned production**
  - **Scope 2: purchased energy sources, like electricity**
  - **Scope 3: non-owned operations such as raw materials production, transportation in non owned vehicles, or non-owned operations**

Inventory Analysis: Example

- Example product: copy paper
- Raw Materials
  - Wood, water, various chemicals, energy
  - Chemical and Energy Recovery
- Manufacturing
  - Machinery, processes, packaging material
- Transportation and Distribution
  - Storage of paper in warehouses, selling of it via wholesalers/retailers
- Use
  - Products associated with the use of copy paper
- Disposal
  - Waste products, Recycling, landfilling
  - Energy recovery

Important Aspects of Life Cycle Assessment



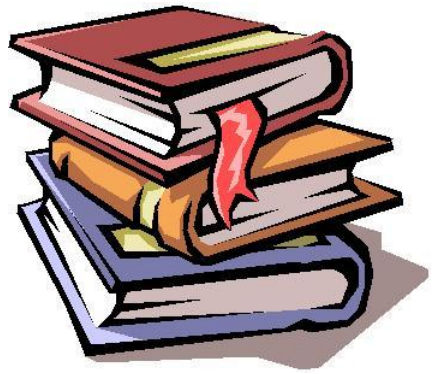
Impact Assessment

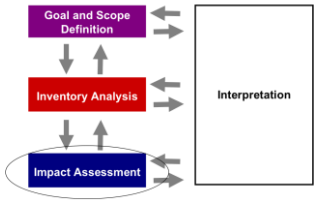
Definition:

Impact assessment is the process of identifying the future consequences of a current or proposed action. (cbd.int/impact)

It is used to ensure that projects, programs and policies are economically viable, socially equitable and environmentally sustainable. (cbd.int/impact)

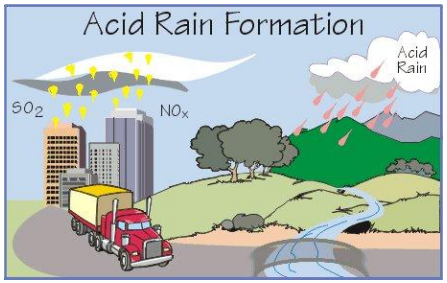
Developed with target audience in mind.





Example: Environmental Indices for given impact categories

1. I_{GW} – global warming
2. I_{SF} – smog formation
3. I_{OD} – ozone depletion
4. I_{AR} – acid rain
5. I_{INH} – human inhalation
6. I_{ING} – ingestion toxicity
7. I_{CINH} -human carcinogenic inhalation
8. I_{CING} – carcinogenic ingestion toxicity
9. I_{FT} – fish toxicity



Impact Assessment: ISO Standard

- **Characterization factors:** determine the relative contribution of an LCI output to the impact category

- For instance, 1 kg CH4 contributes to global warming 26 times 1 kg of CO2
- If, characterization factor for CO2 =1
- Then, characterization factor for CH4 =26
- From the inventory analysis,
  - GWP = 1* kg CO2 + 26*kg CH4

Carbon Footprint: Impact Assessment Method

- **Partial life cycle analysis**
- **A picture of the overall greenhouse gas impact (not just CO2) of a product over its lifecycle (cradle-to-grave).**
- **Reports the net amount of GHG's for a defined process, in units of kgCO2(equiv)/basis**

Revision Year	CO_2 equivalents for CH_4	CO_2 equivalents for N_2O
1996	21	310
2001	23	296
2006	25	298

Global Carbon Cycle and Forests?

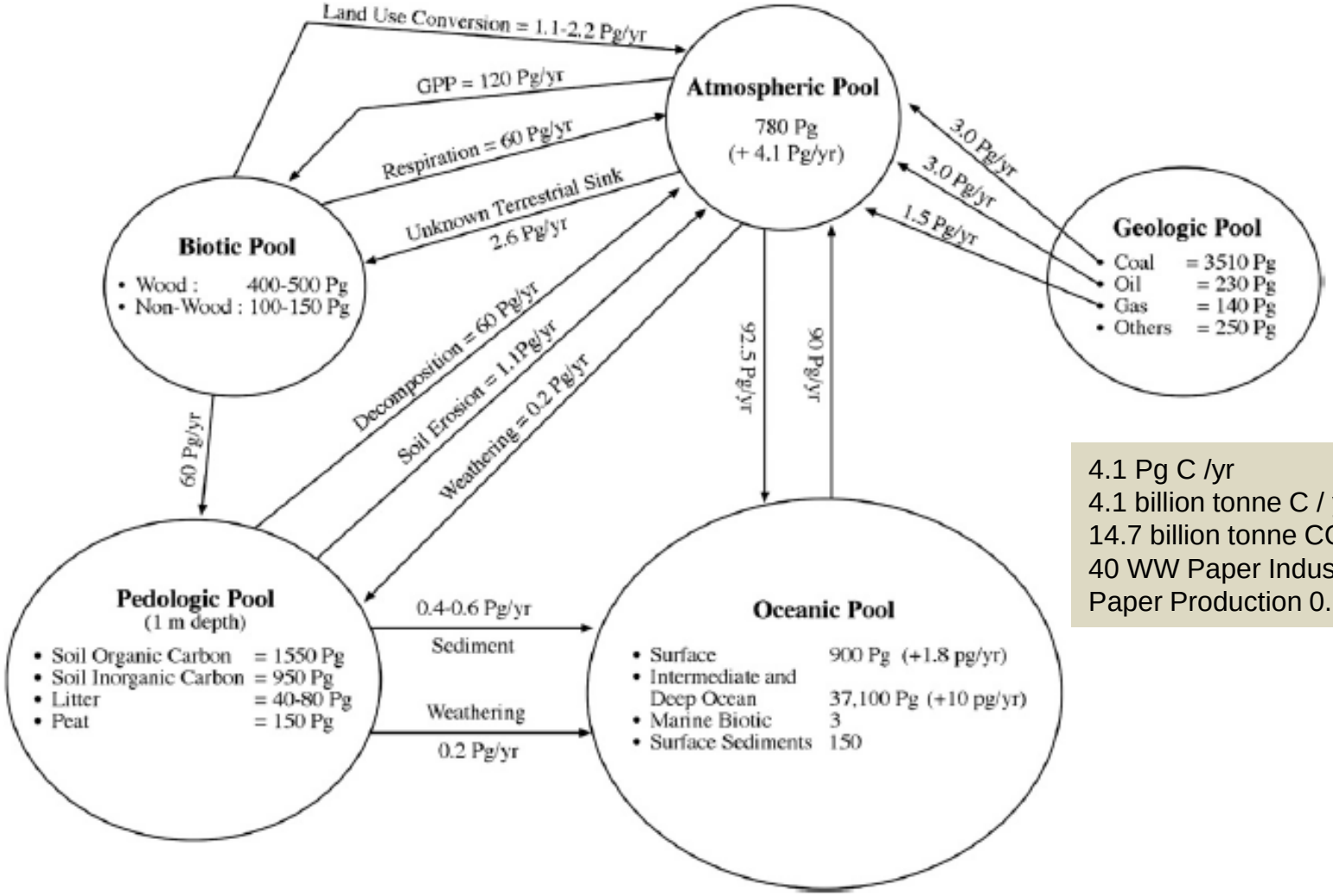
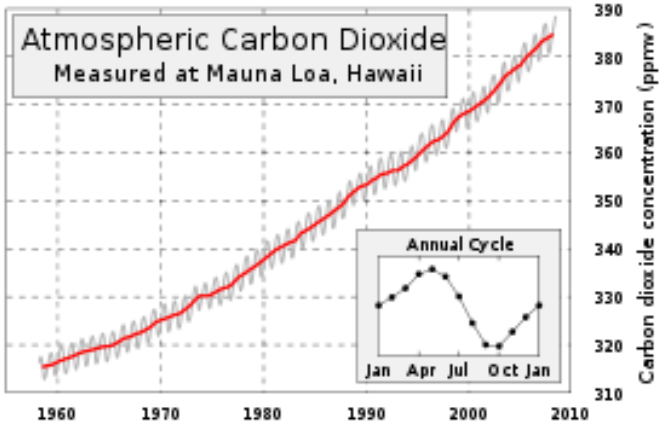


Fig. 1 Estimates of the global pools and fluxes between them.[1,4,5,7,152]

4.1 Pg C /yr
4.1 billion tonne C / yr
14.7 billion tonne CO2 / yr
40 WW Paper Industries
Paper Production 0.15 billion tonne C/yr

Global Carbon Cycle and Forests?

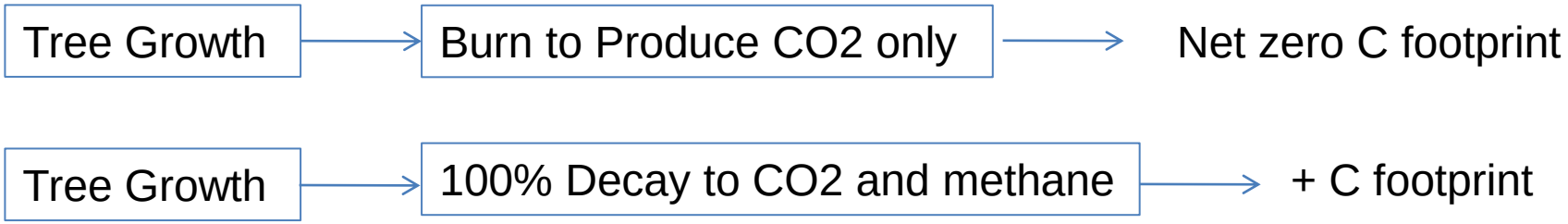
- ***Atmospheric concentration of CO2 has increased by 31% since 1750 (to 390 from 280 ppm) and by 1.5 ppm/yr for 1980-2000 (IPCC 2001)***



- **Forests are significant in global GHG (Landsberg & Gower, 1997):**
  - **Cover 65% of the total land**
  - **Contain 90% of the total vegetation carbon**
  - **80% of total soil carbon in terrestrial ecosystems**
  - **Assimilate 67% of the total CO2 removed from the atmosphere by all terrestrial ecosystems**

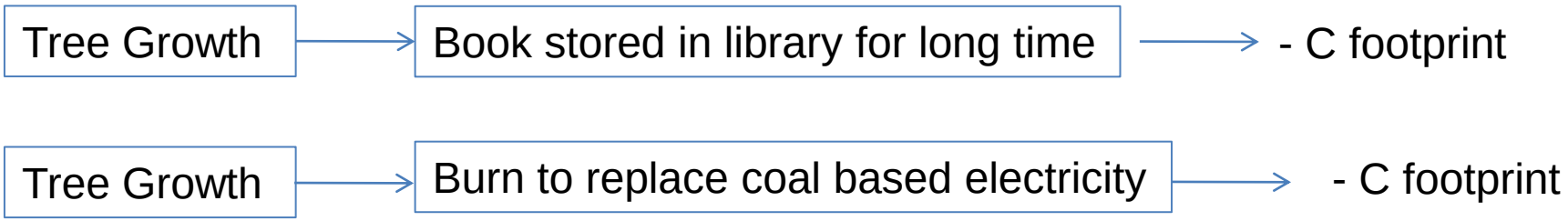
Carbon Footprint: Impact Assessment Method

- **Typically, a carbon footprint does not consider biogenic (from living processes) carbon nor does it consider CO2 emissions from the burning or decay of the biogenic material (they balance each other)**
- **Biogenic material decay/burning that produces methane or N2O must be considered**

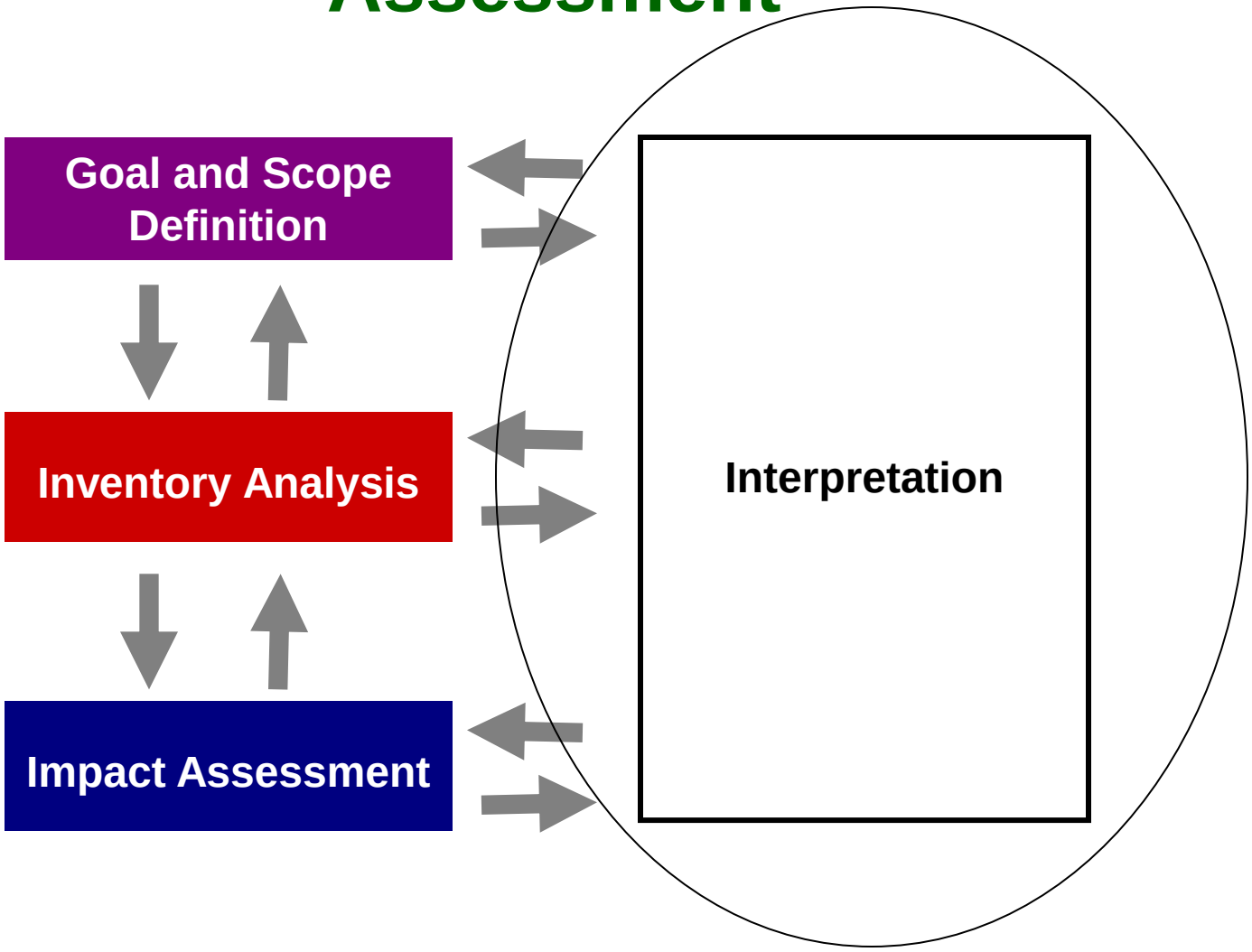


Carbon Footprint: Impact Assessment Method

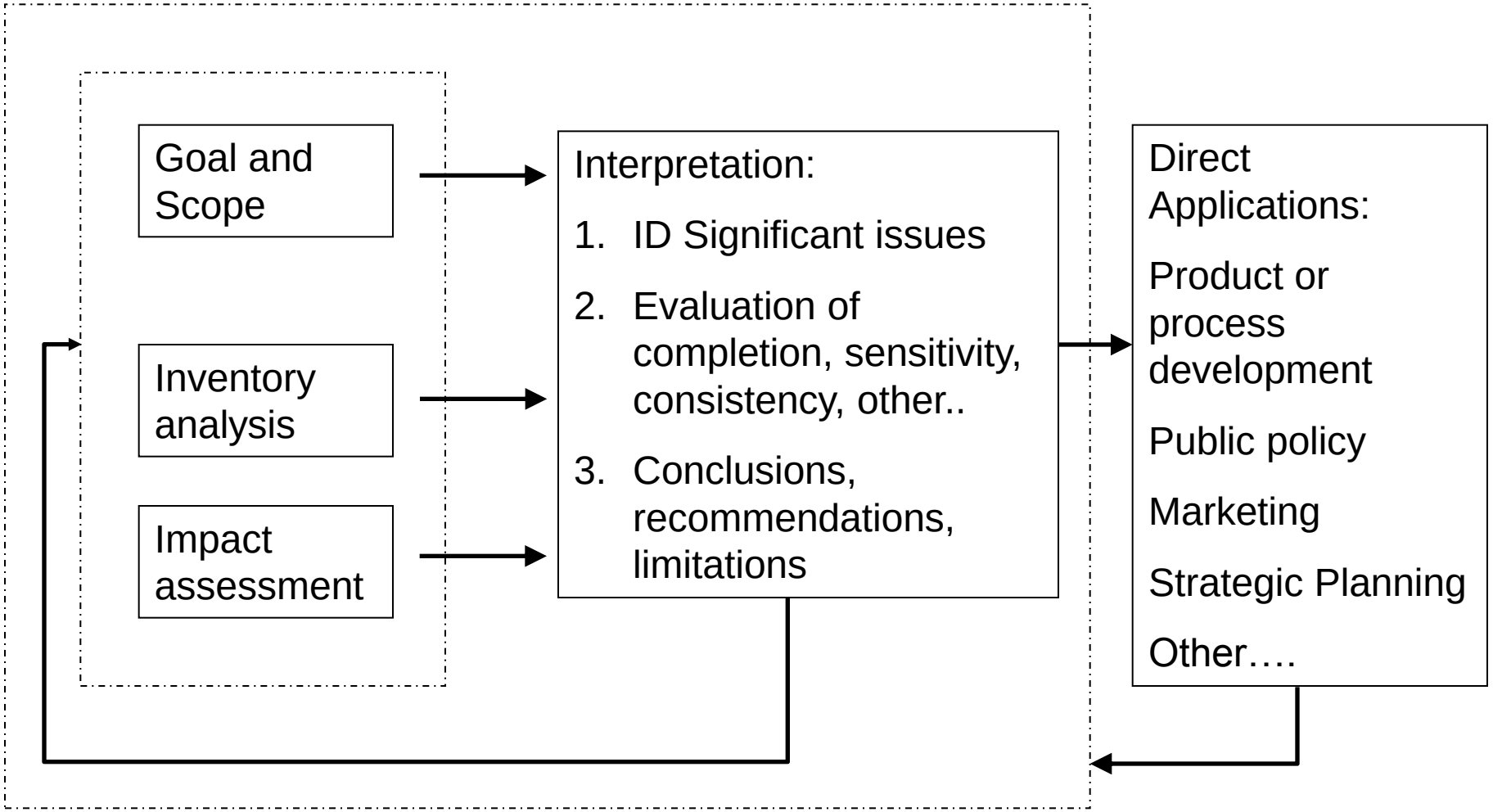
- **Non renewable resources (coal, oil) are considered since they have been formed over very long time scales and are not being formed over time scales of interest**
- **Materials, transportation, energy often have associated with them carbon emissions**
- **Long term storage of carbon away from the atmosphere is considered a negative C footprint contribution**
- **When one product with a lower C footprint replaces another with larger C footprint, an avoided C input to the atmosphere is claimed, a negative C footprint contribution**



Important Aspects of Life Cycle Assessment



Interpretation: ISO Standard



Outline

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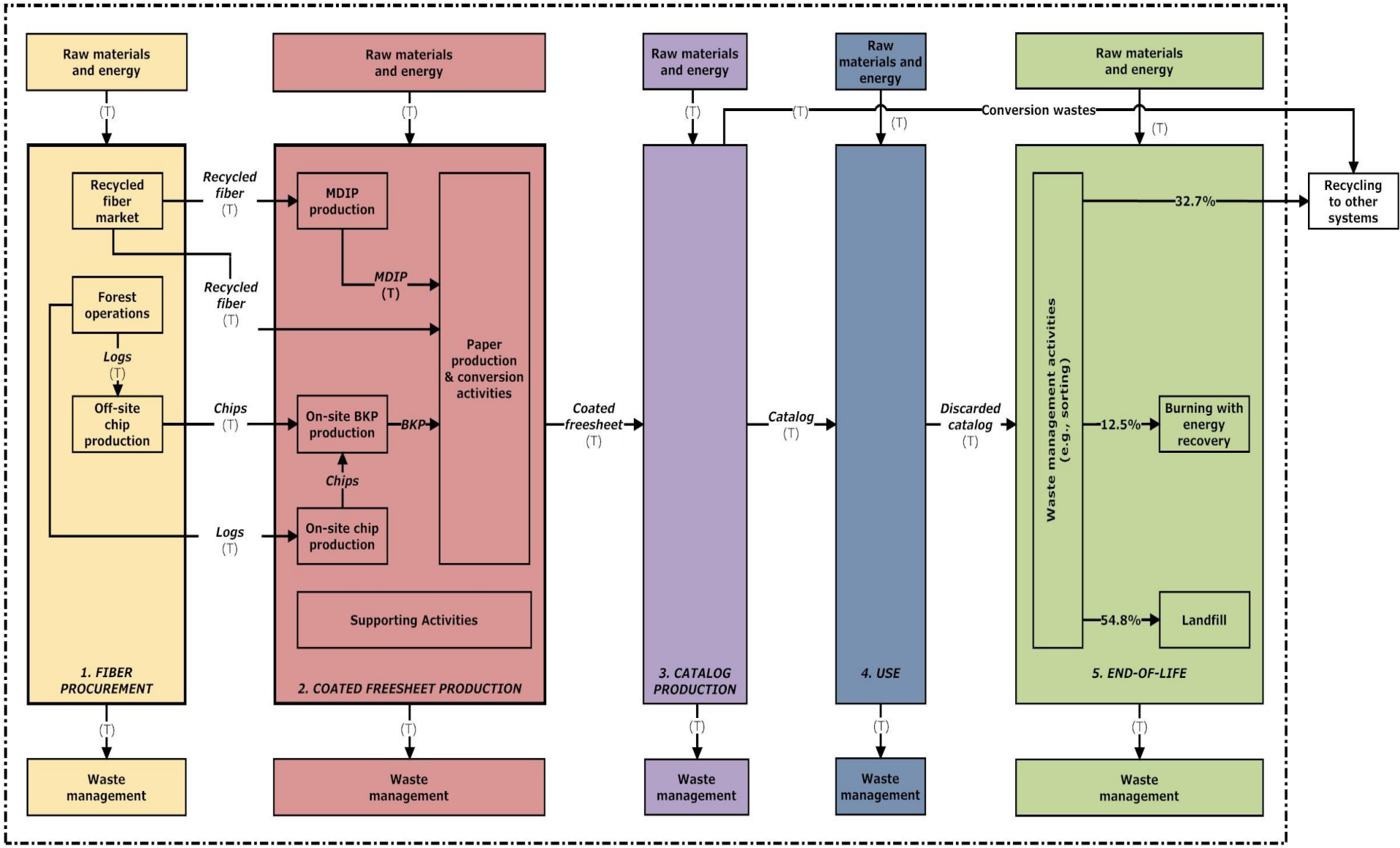
Life Cycle Analysis

for Pulp and Paper Products

- Paper is a measure of the quality of life of a society

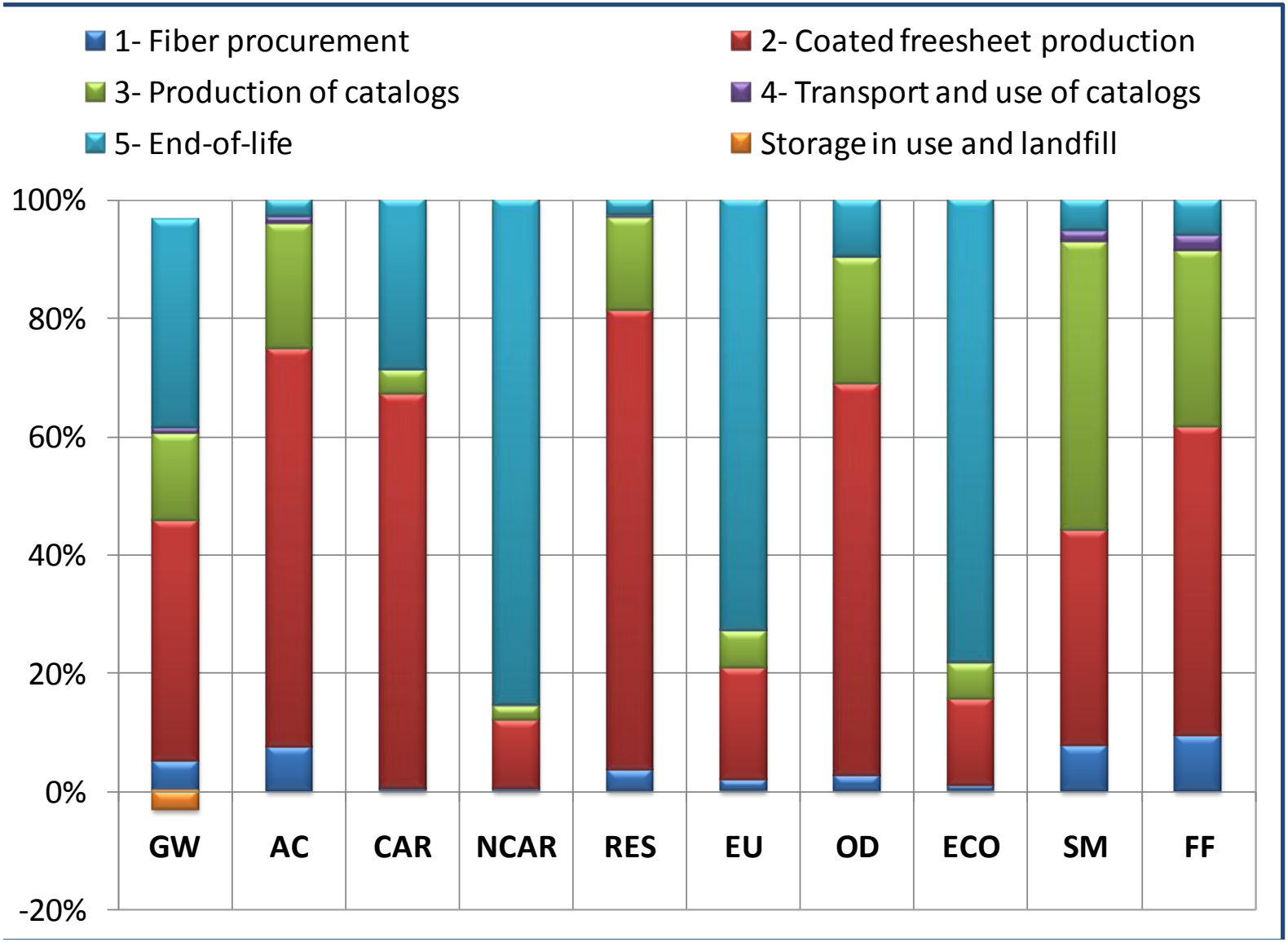
- Paper is mainly derived from renewable resources
- Complex furnish and manufacturing
- Extremely efficient manufacturing processes using a majority of renewable fuels
- Paper manufacturing has air/water/solid emissions
- Paper has several co-products manufactured
- A recyclable product (open loop)
- Paper is the major component in landfills and when degrades anaerobically forms methane

Life Cycle Analysis of Paper: Catalog System Boundary

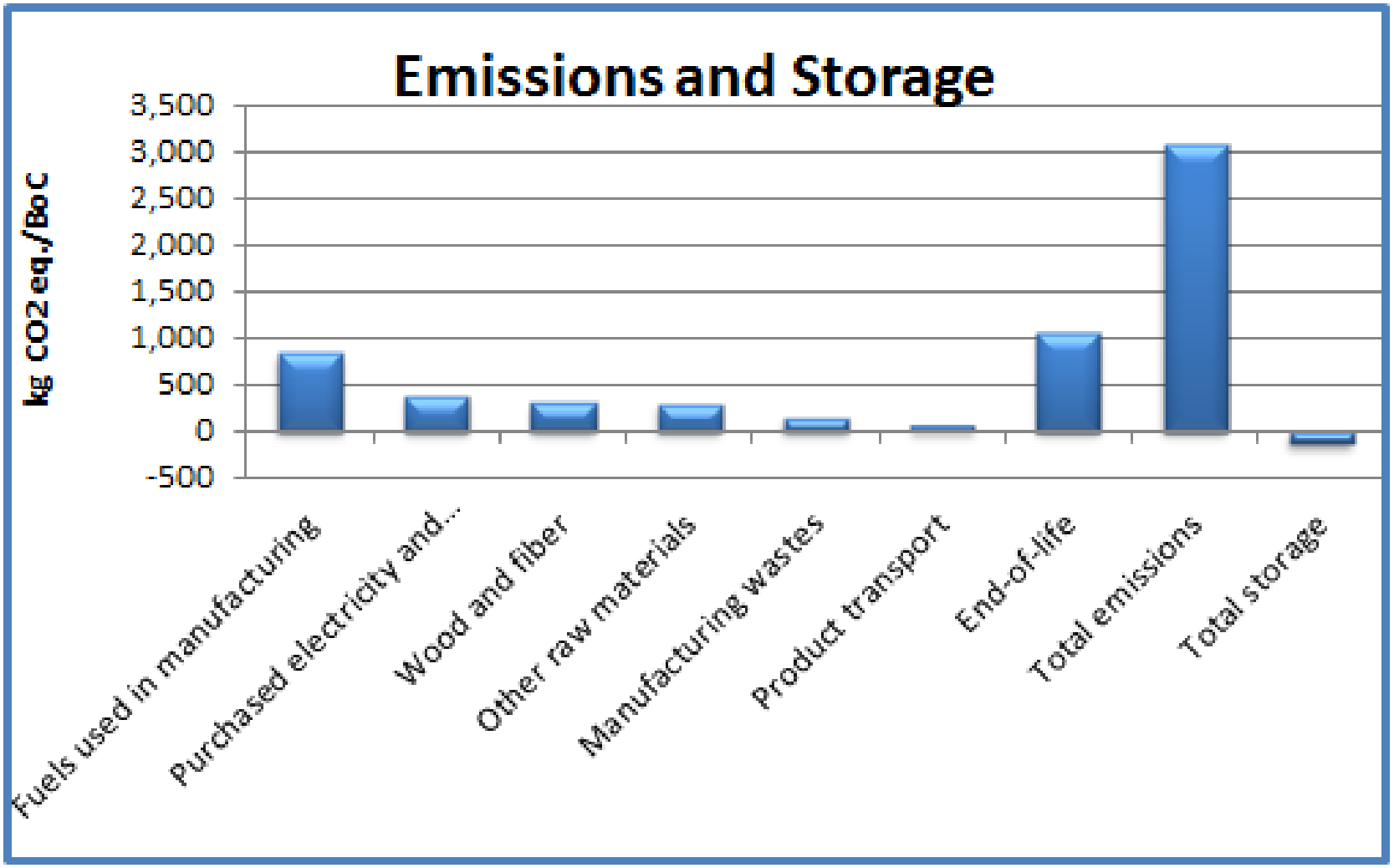


Life Cycle Analysis of Paper: Catalog

Impact category
Global warming (GW)
Acidification (AC)
Carcinogenics (CAR)
Non-carcinogenics (NCAR)
Respiratory effects (RES)
Eutrophication (EU)
Ozone depletion (OD)
Ecotoxicity (ECO)
Smog (SM)
Fossil fuel depletion (FF)



Life Cycle Analysis of Paper: Catalog: Carbon Footprint



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Major NA LCA Studies on Printing and Writing Grades

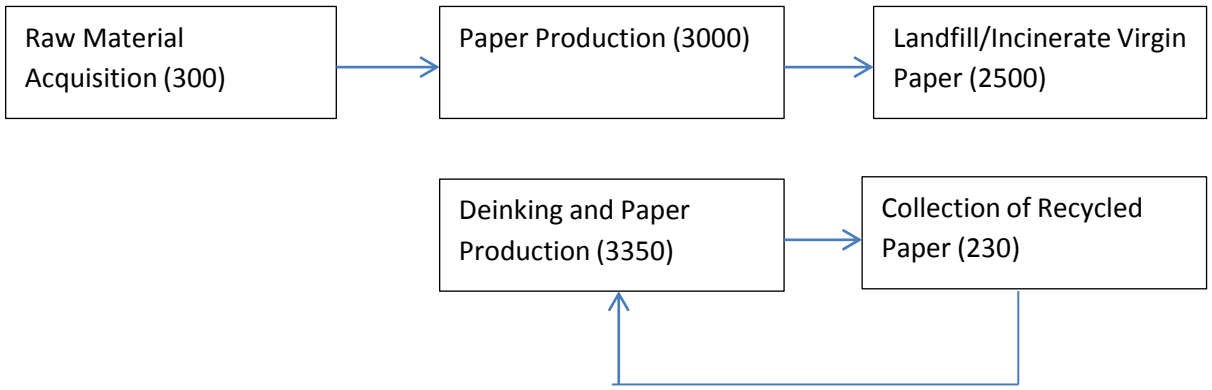
- **Paper Task Force White Paper No. 3 Lifecycle environmental comparison: virgin paper and recycled paper based systems. Originally published Dec. 19, 1995, updated February 2002 (Paper Task Force, 2002)**

- **The Heinz Center: Following the Paper Trail: The Impact of Magazine and Dimensional Lumber Grade Production on GHG Emissions: A Case Study, 2006. (Heinz, 2006)**

- **National Council for Air and Stream Improvement, Inc. Life Cycle Assessment of North American Printing and Writing Paper Products (NCASI, 2010)**
-

Paper Task Force (Paper Calculator):

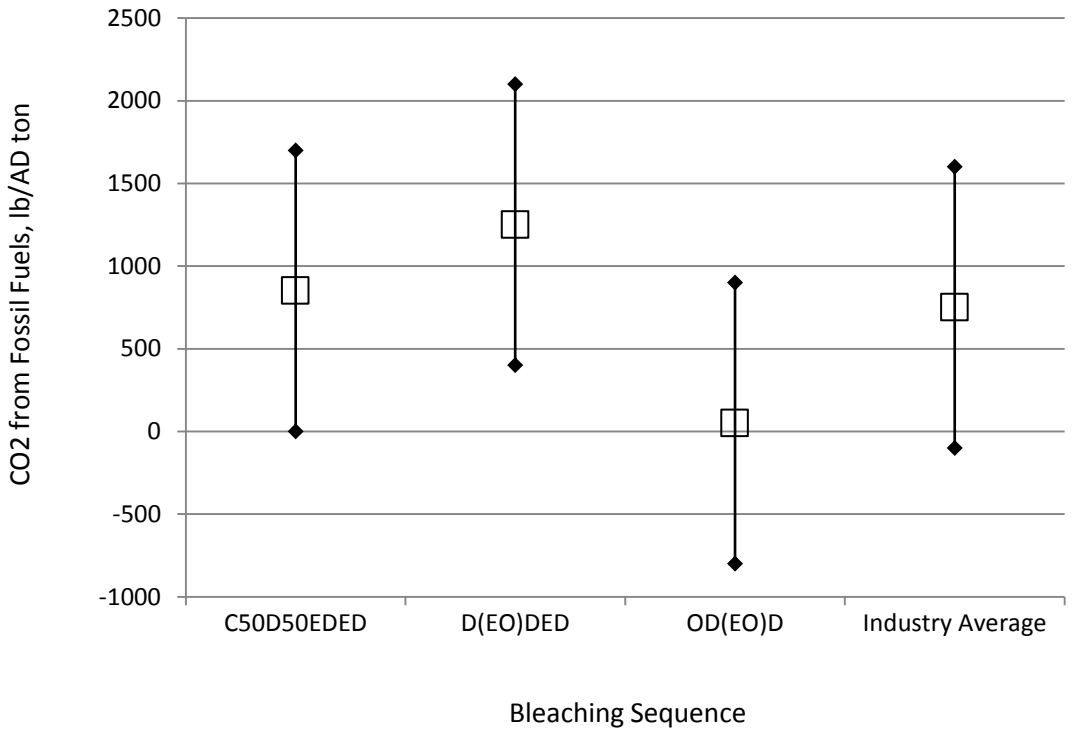
- **Data circa 1994**
- **Synthetic, simplistic separation of virgin and recycled systems**
- **Mainly indicates preferred disposal method**
- **Has been extensively mis-marketed and mis-used to promote the use of recycled fibers in specific products**



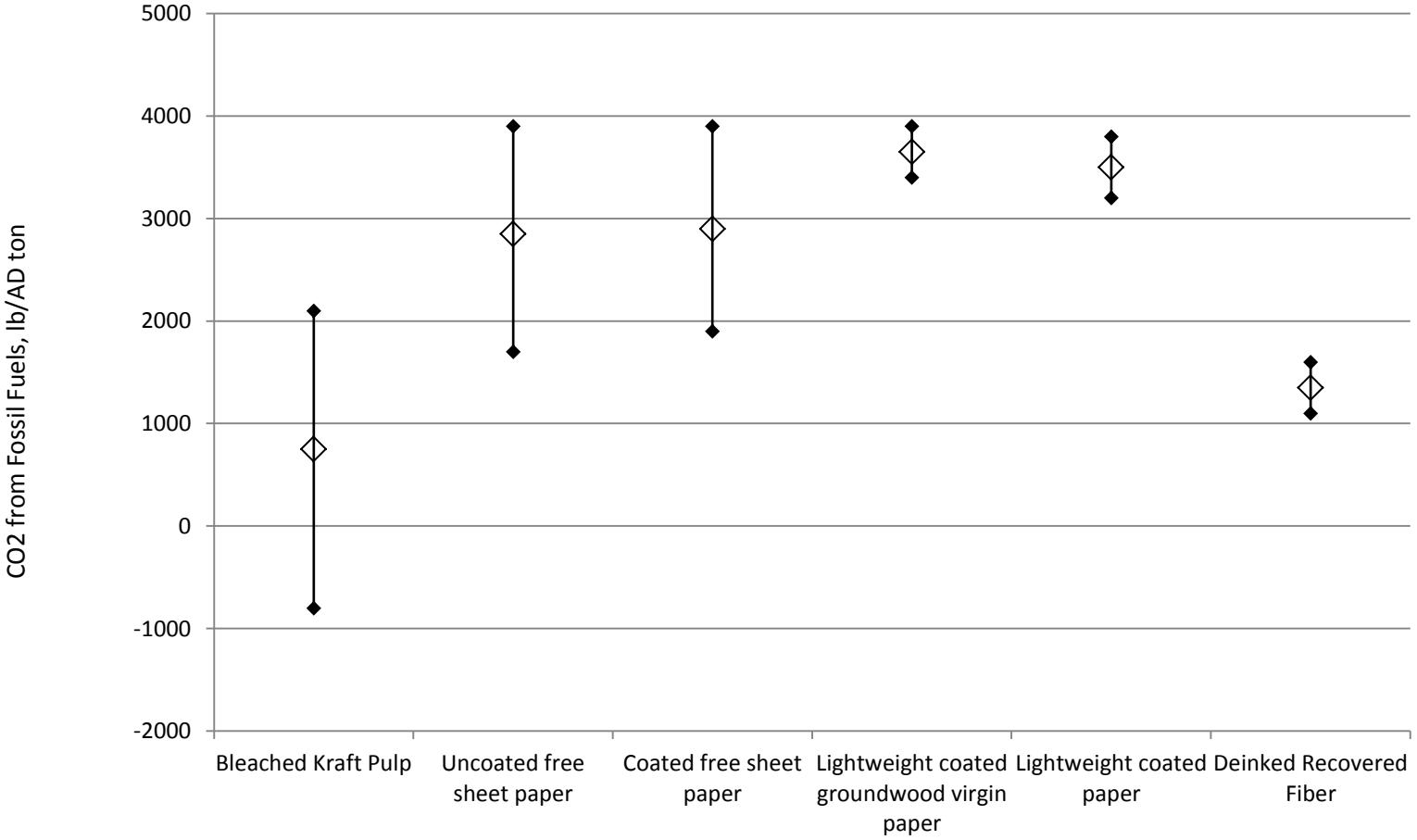
		Net GHG Emissions
Virgin Office Paper	Landfill	6700 (3.4)
	Incineration	2500 (1.3)
	Waste Management	5800 (2.9)
Recycled Office paper	Collect/Process	3580 (1.8)

Paper Task Force (Paper Calculator):

- **Producers of manufactured paper products are using national averages of the industry to represent their product. However, the range of environmental burdens are very large and using averages to represent specific products is misleading.**

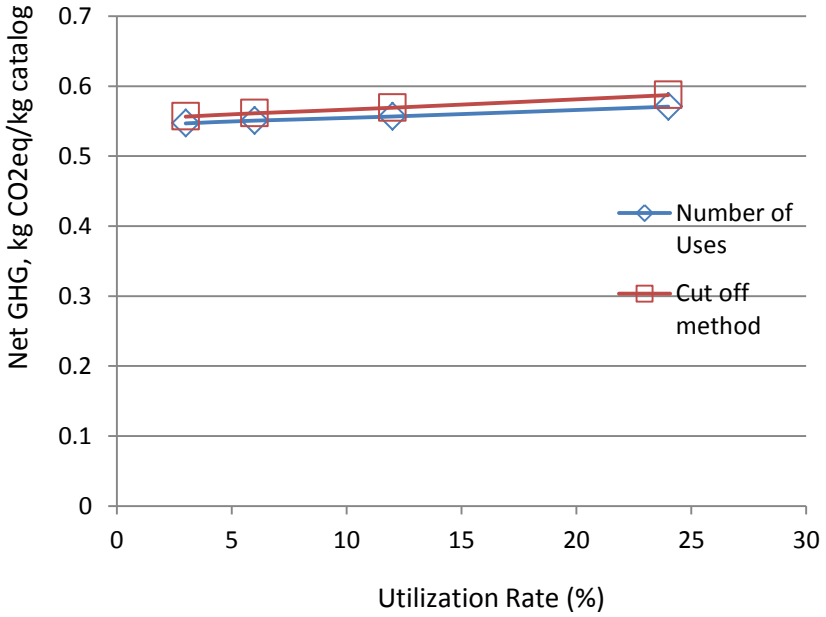


Paper Task Force (Paper Calculator):



Paper Task Force (Paper Calculator):

- **Producers of manufactured paper products are using the results to indicate that more recycled fiber content in a specific product is better, however, this is not necessarily true**
- **It is good to recycle in general**
- **However, in general, it is most efficient to recycle paper products to lower valued and not higher valued products**
- **Example:**



The Heinz Center: Following the Paper Trail: The Impact of Magazine

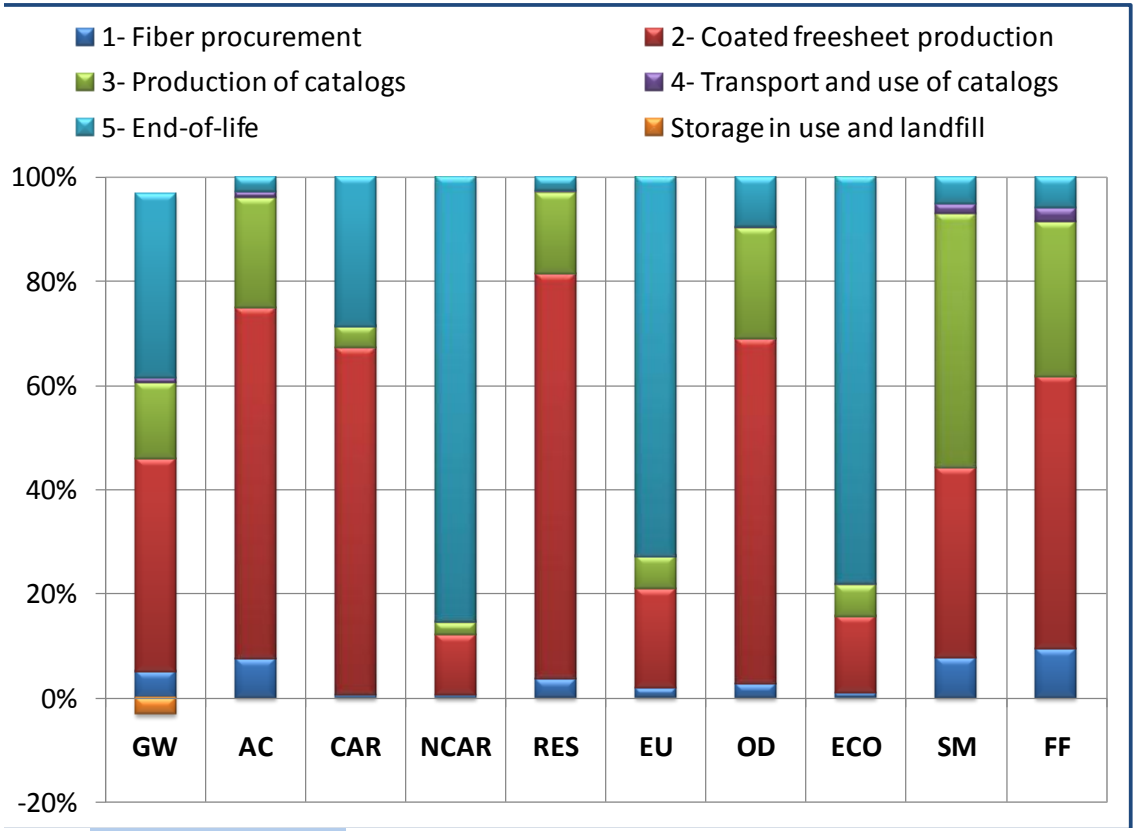
- **Data circa 2001**
- **A scope 1 (owned) and 2 (purch power) study for Carbon Footprint**
- **Omits scope 3 (non-owned) considerations**
- **Does not follow LCA procedures/fails to document adequately**
- **Underestimates carbon footprint**

Table 2. Activities in the net GHG Life Cycle tracked in the Heinz Center Study for the InStyle and Time magazines (ton CO2e/ton product listed)

<table>
<tr><td>Forest Management and Harvesting</td><td>Transport</td><td>Paper Manufacturing</td><td>Transport to Printers and Printing and to Distribution Centers</td><td rowspan="2">Final Fate: Landfill Recycle Incinerate</td><td>InStyle (1.11)</td></tr>
<tr><td colspan="4">Purchased Power</td><td>Time (1.17)</td></tr>
</table>

National Council for Air and Stream Improvement (NCASI)

- Most modern study
- Robust, scope 1-3 LCA of printing and writing grades
- Follows ISO procedures
- Complex allocation methods for virgin vs recycling products



Comparison of Three Studies:

Study:	ISO 14040	3rd Party Review	Published in a Peer Reviewed Journal	Clarity of Data	Impact Assessment	Uncertainty Analysis	Sensitivity Analysis	Allocation methods
Paper Task Force	No.	Reviewed by outside experts. Comments not provided in the report.	No.	Extensive presentation of the inventory data.	Net GHG.	None.	None.	Synthetic separation of virgin and recycled paper products. Inconsistent application of open loop recycling.
Heinz	No.	None.	No.	Did not define what data was included. Data in inventory results not presented.	Only GHG emissions reported.	None. Weaknesses in study discussed.	Not done. Results for individual printing operations were presented.	None used for recycling. Unclear assumptions on coproduct allocation methods.
NCASI	Yes	External peer review panel. Panelists comments and the responses to the comments appear in the report	No.	Extensive flowsheeting of processes and lists of data appear in report.	SimaPro software running TRACI.	Conducted with respect to inventory data.	Sensitivity on process conditions, allocations methods, impact assessment method, others	Co-product and recycling allocation methods used.

Comparing Difft LCA's

- Very Difficult:
- Example, coated paper:
  - PTF: .8-1.8 ton CO2e/ton product
  - Heinz: 1.11-1.17
  - NCASI: 2.36-3.45
  - VTT Study (Finland): 1.0-1.6
  - Springer/Stora/Canfor (Europe): 0.4-1.9
- Geographical differences, assumptions, data, calculation methods, scope, …….

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Allocation Methods in LCA:

- **Allocation: the partitioning of environmental burdens between two related products**
- **Controversial:**
  - **ISO methods recommend that allocation is avoided**
  - **ISO does not provide allocation rules, practitioner must decide the rules and justify their use**
  - **ISO requests that the sensitivity of the LCA results are evaluated with respect to the allocation methods**
- **Bottom line: allocation method can determine which related product in a life cycle is preferred**

Two Main Allocation Situations:

- **Co-products Allocation: a single process produces multiple products,**
  - **Burdens can be partitioned by mass flows, monetary values….**
  - **Example for paper production: paper, TOFA, turpentine**
  - **Emissions from pulping are partitioned to the paper, TOFA, and turpentine using a stated rule**

Two Main Allocation Situations:

- **Recycling Allocation: a virgin product is recycled or re-used in a subsequent life**
  - **There exists operations that are required by the virgin and the recycled products (shared operations)**
  - **Example shared operations: virgin raw material production, final disposal**
  - **Many ways to allocate the burdens of the common operations**

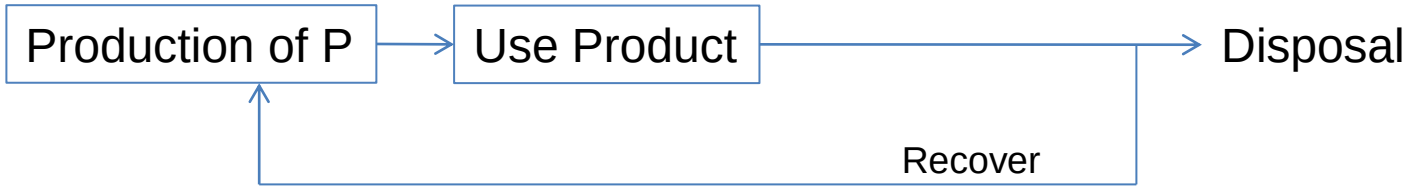
- **Open loop recycling allocation is the most controversial issue in LCA currently!!!!**

Allocation methods to share burdens reflect improved environmental efficiency.

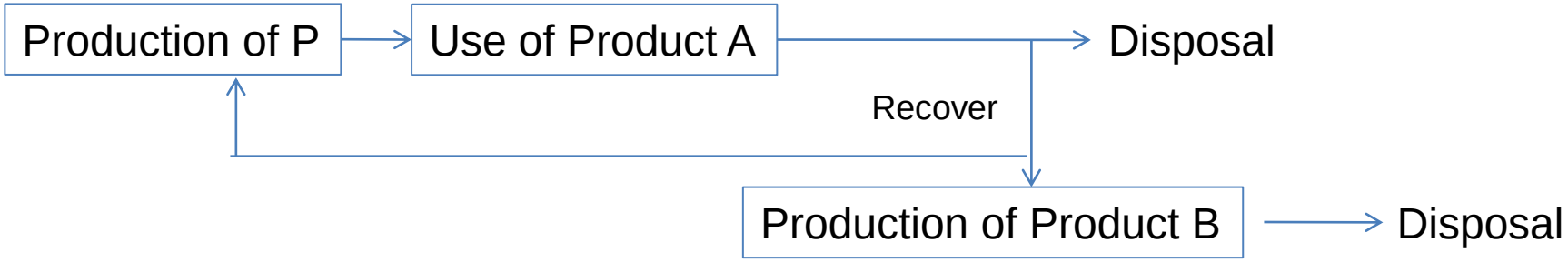
- **Example: want to understand the burdens of containing groceries during transport**
- **Reduce: don't use a bag, 0 burden/trip**
- **Re-use (production of bag = 1 burden)**
  - **Use bag once, 1 burden/trip**
  - **Use bag twice, 0.5 burden/trip**
- **Recycle (to recycle costs 0.4 burdens)**
  - **Then for using the bag and recycling once: (1 + 0.4) / 2 trips = 0.7 burdens/trip**
  - **(data for example only, not meant to represent an actual process)**

Closed and Open Loop Recycling:

- **Closed loop: material or products are returned to the same system after use and used for the same purpose again (Baumann, Tillman, 2004)**

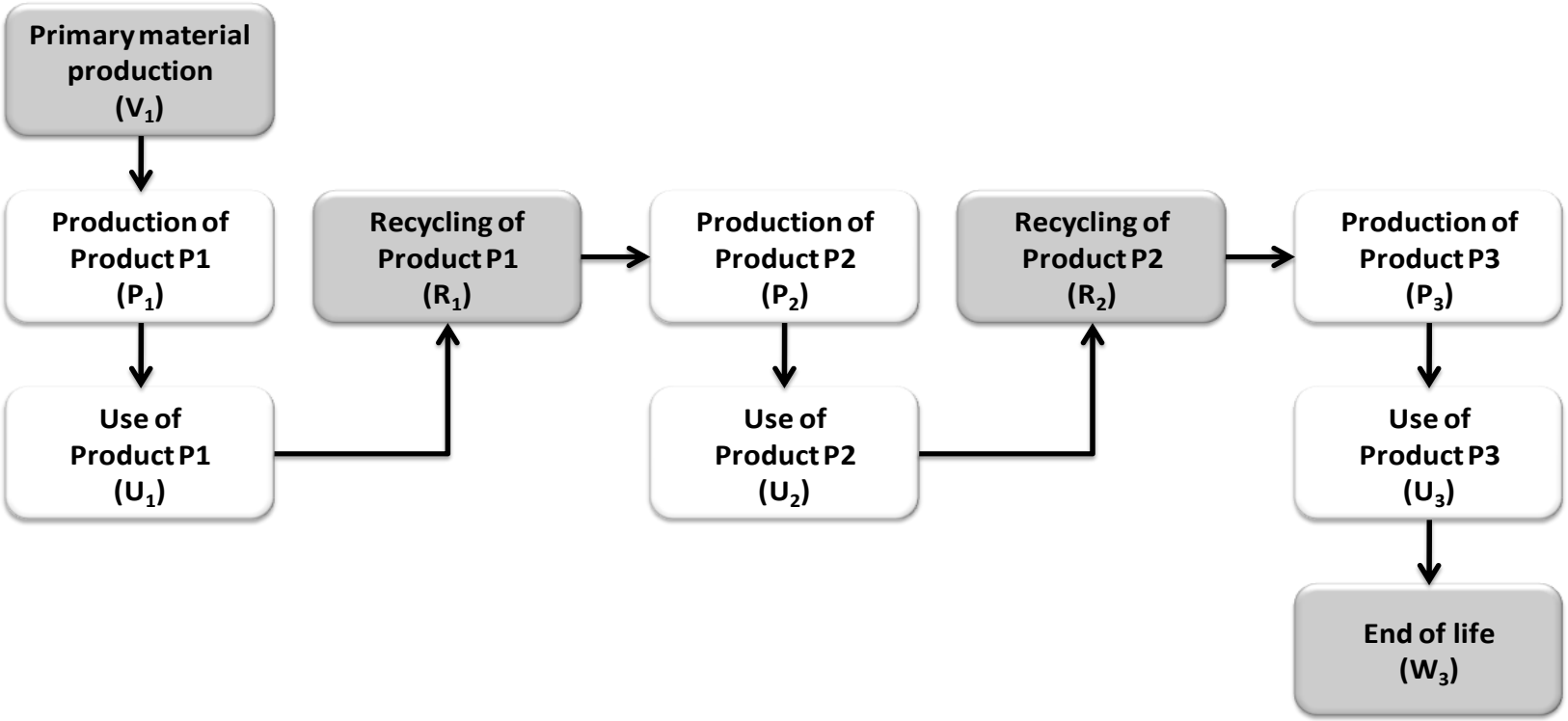


- **Open loop: a product is recycled into a different product**



Allocation Methods in LCA:

- **Example: virgin paper recycled twice and then disposed. Closed loop recycling example P1=P2=P3.**



Allocation Methods in LCA:

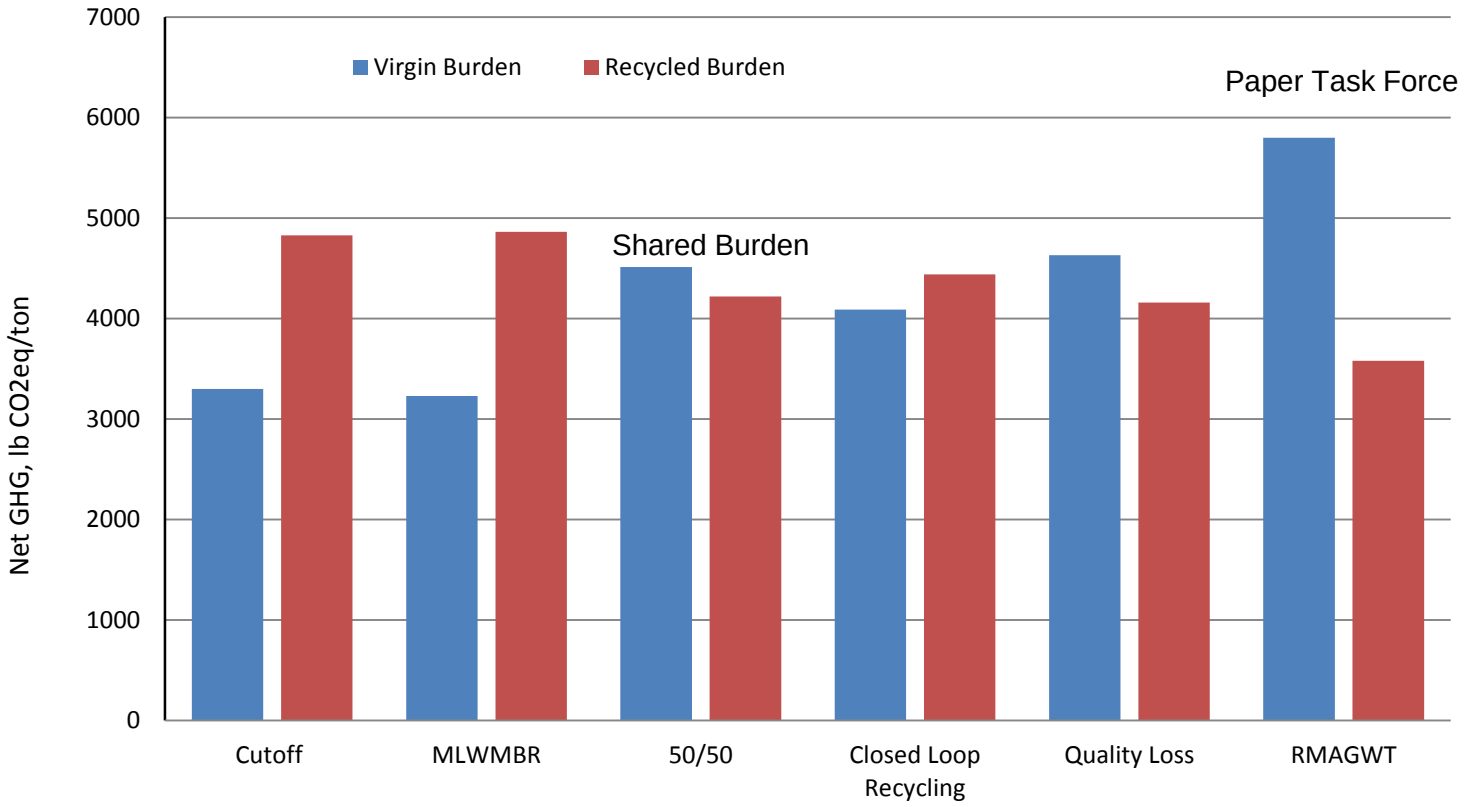
- **Example: virgin paper recycled twice and then disposed. Closed loop recycling example.**

	Raw Matl	Virgin Prod	Collect/transp	Recycle Process	Collect/transp	Recycle Process	Waste Mgmt
	V1	P1	R1	P2	R2	P3	W3
	Shared Operation	Potentially Shared Operation	Potentially Shared Operation	Not Shared Operation	Potentially Shared Operation	Not Shared Operation	Shared Operation
CO2e Lb/ton product	300	3000	230	3350	230	3350	2500
CO2e ton/ton product	.15	1.50	.12	1.68	.12	1.68	1.25

Table 7. Net GHG of office paper from various life cycle stages from the Paper Task Force (2002, pg. 132), waste management is 80/20 landfill/incinerate.

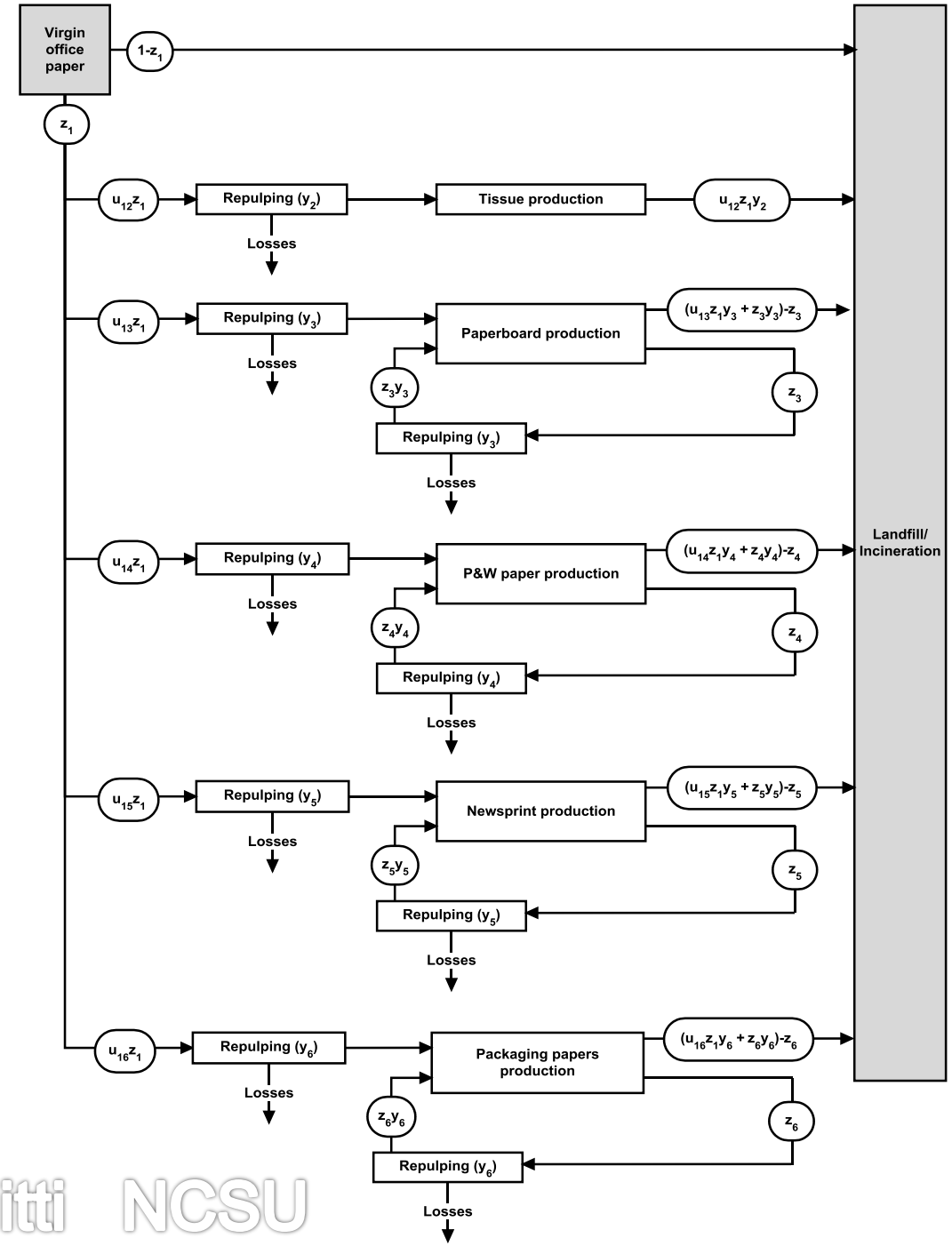
Allocation Methods in LCA:

- **Choice of allocation method determines whether virgin or recycled products are promoted:**



Paper Recycling: An Open Loop

- Paper products are recycled into other products with different yields upon recycling, closed loop recycling not a good model

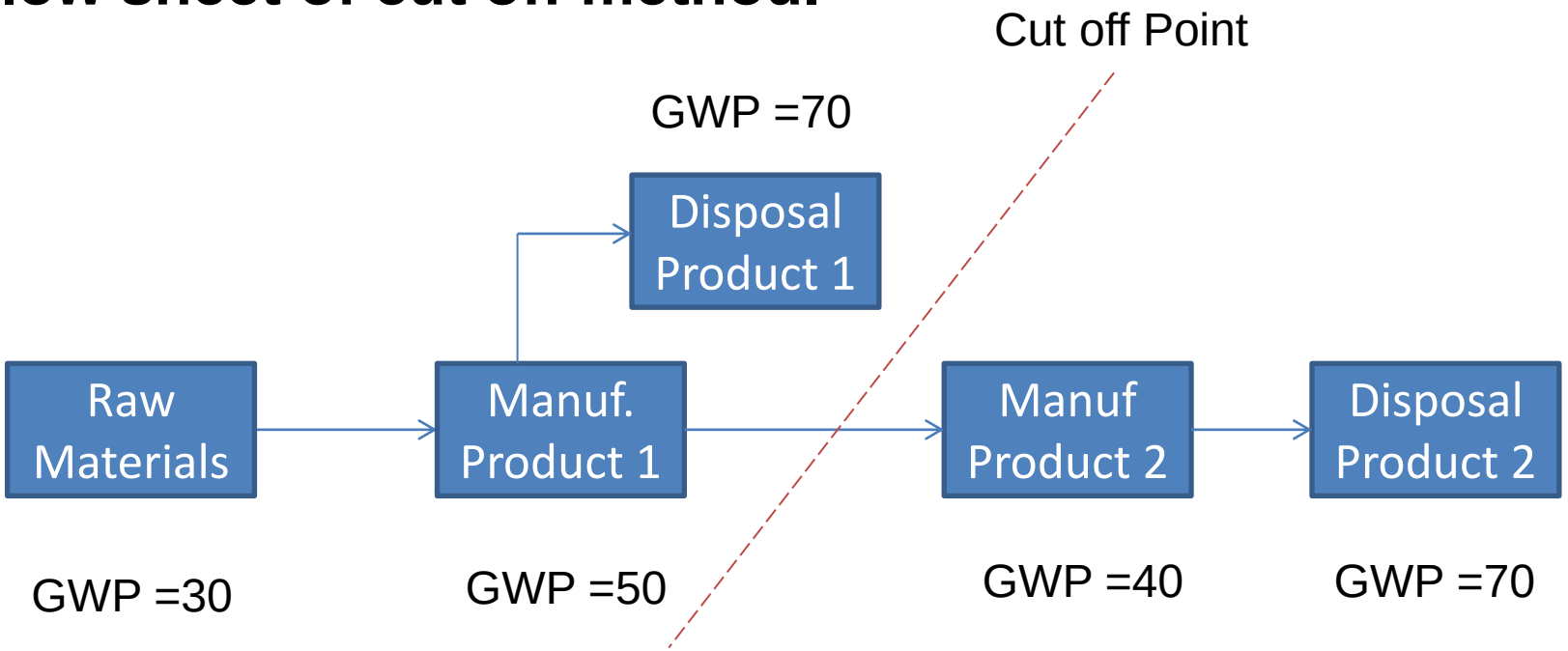


Allocation Methods in LCA:

- **Cut off method: no shared burdens**
- **Virgin product carries all virgin production burden**
- **Recycled products aren't assigned any virgin burdens**
- **Promotes recycling relative to disposal**
- **Doesn't acknowledge the value of recyclable materials**

Allocation Methods in LCA:

- **Flow sheet of cut off method.**



Product 1 Burden = 30 +50 + 70 = 150

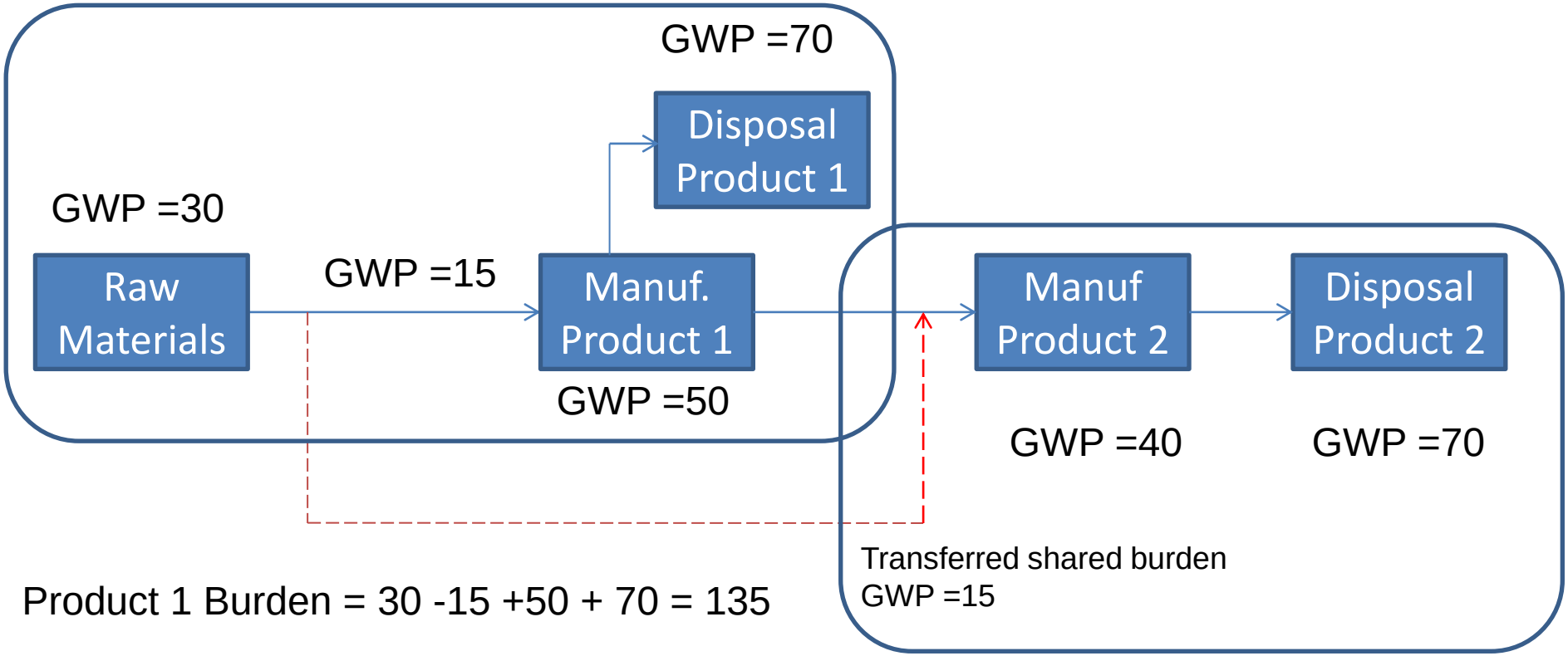
Product 2 Burden = 40 + 70 = 110

Allocation Methods in LCA:

- **Number of subsequent uses recycling allocation method: burdens associated with virgin material production are shared by all lives of the materials**
- **Acknowledges benefit to making recyclable materials**

Allocation Methods in LCA:

- **Number of uses method. Share common burdens.**



Allocation Methods Comparison:

- **Used FEFPro carbon footprint tool for paper products**
- **Determined carbon footprint for both number of uses and cut off method as a function of**
  - **Recovery rate of product**
  - **Utilization rate of recycled fibers in product**

RESULTS

Name of this fenterist	ed Freesheet NCASI Number of Uses Cradle to Grave
Product name	Coated Freesheet
Product type	coated woodfree
Basis of calculation (BoC, in mass units of kg)	861.82556
Number of products per BoC	
Recycling allocation method	ISO 14049 "number of subsequent uses" method

(machine-dry short tons (ST) water)

Number of uses: 1.752568354

All results are presented in terms of kg CO_2 equivalents per Basis of Calculation (BoC), by scope where appropriate.

Basis of calculation (BoC, kg): 861.82556

Basis of Calculation (BoC) is the metric upon which all of the data input, calculations, and result output are based. For example, a BoC of 1000 kg of product (one metric tonne) means that data input such as quantity of raw material consumed is entered per 1000 kg of production (e.g., a BoC of 1000 kg and log input of 2000 kg means that 2 tonnes of logs are consumed in the production of 1 tonne of product).

	Total	Scope 1	Scope 2	Scope 3
Total emissions, including transport (kg CO_2 eq./BoC):	3066	763.1	166.1	2066
Of which, total transport (included all transport components):	161	0	0	161
Emissions from fuel used in manufacturing (including transport)	826.1	638	0	188.1
Emissions from purchased electricity and steam	361	0	166.1	194.9
Emissions from wood and fiber production (including transport)	297.8	0	0	297.8
Emissions from other raw materials (including transport)	294.1	0	0	294.1
Emissions from manufacturing wastes	144.1	144.1		0
Emissions from product transport	62.53	0	0	62.53
Emissions from end of life (including transport)	1050			1050

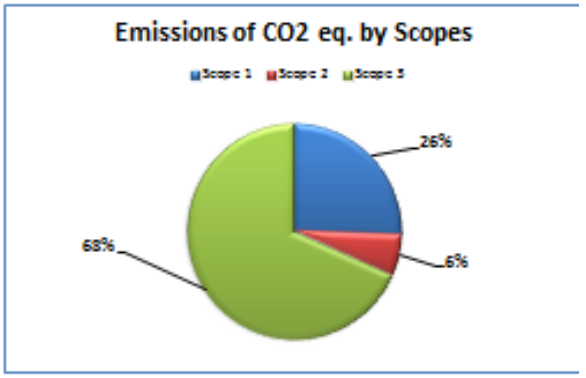
Carbon Storage:

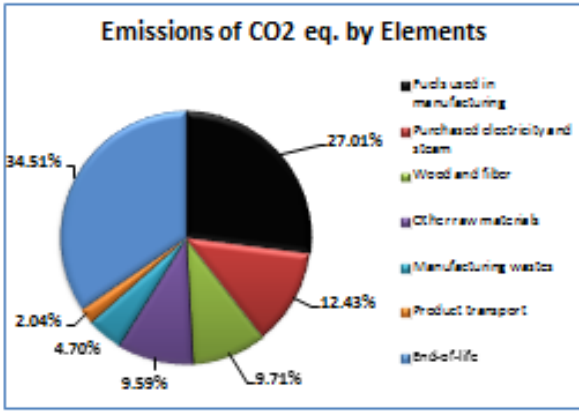
Total carbon storage changes (kg CO_2 eq./BoC)	1512.3
Changes in forest carbon (kg CO_2 eq./BoC)	0
Carbon in products in use (kg CO_2 eq./BoC)	332.4
Carbon in landfills from products at end of life (kg CO_2 eq./BoC)	536.76
Carbon in mill landfills from manufacturing wastes (kg CO_2 eq./BoC)	42.1

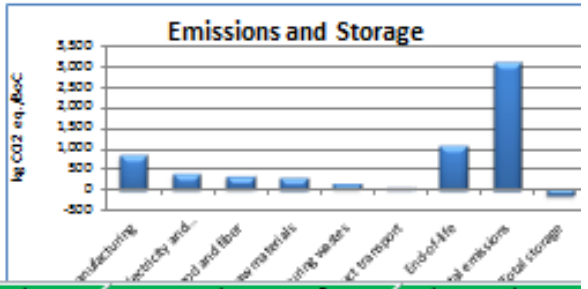
Method used to estimate amount of product in use: Weighted avg first order

Off balance sheet informational items:

Avoided emissions from generated electricity from burned products at EOL offsetting grid power (kg CO_2 eq./BoC)	-52.66
Avoided emissions from generated electricity from recovered landfill methane offsetting grid power (kg CO_2 eq./BoC)	-163.3
Difference in emissions between old power and offset grid power (kg CO_2 eq./BoC)	-13.8







Intro & Instruction | Versions | Set-Up | **Results** | 1. Forest Carbon | 2. Wood & Fiber | 3a. Fuel Prim Mfg. | 3b. Fuel Inte

297.8

4. Other Materials | 5

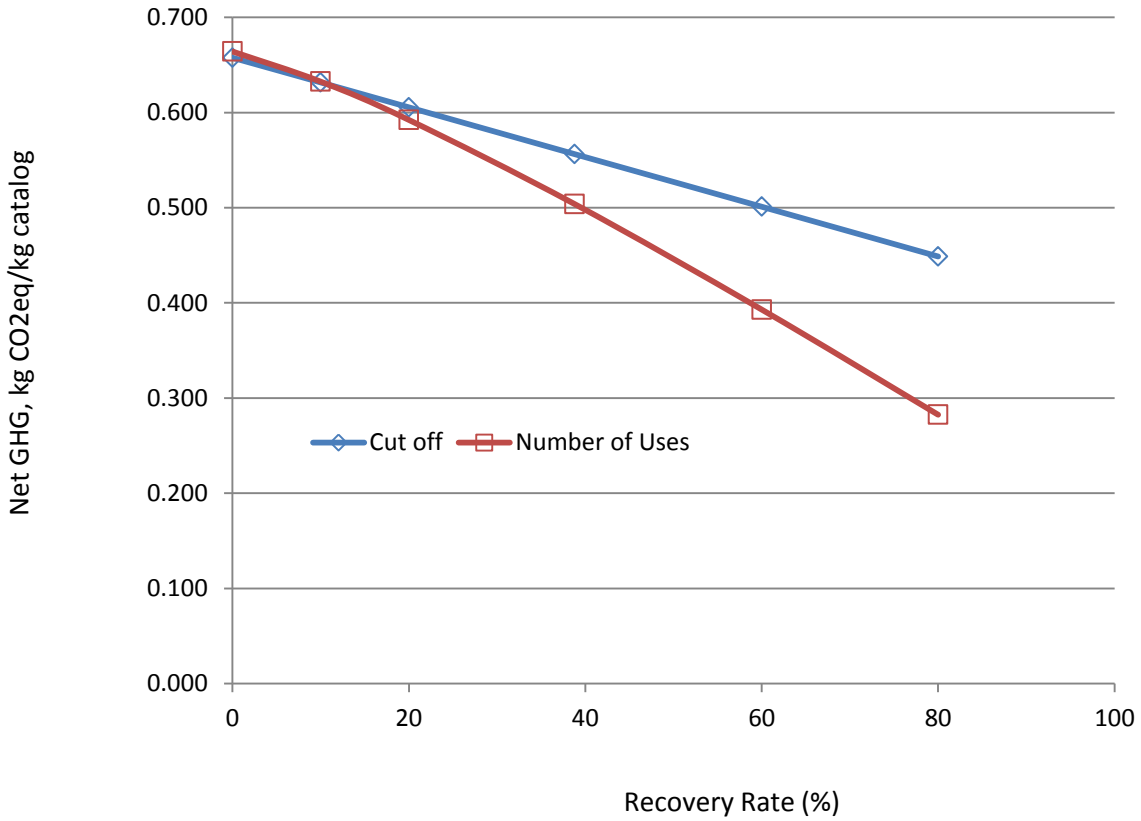
etween old power and offset grid power (kg CO_2 eq./BoC) -13.8

Electricity & Steam | 6. Manufacturing Wastes | 7. CO2 Capture | 8. Carbon in Products | 9. Product Transport | 9. End-of-Life | 11. Avoided Emissions

ck

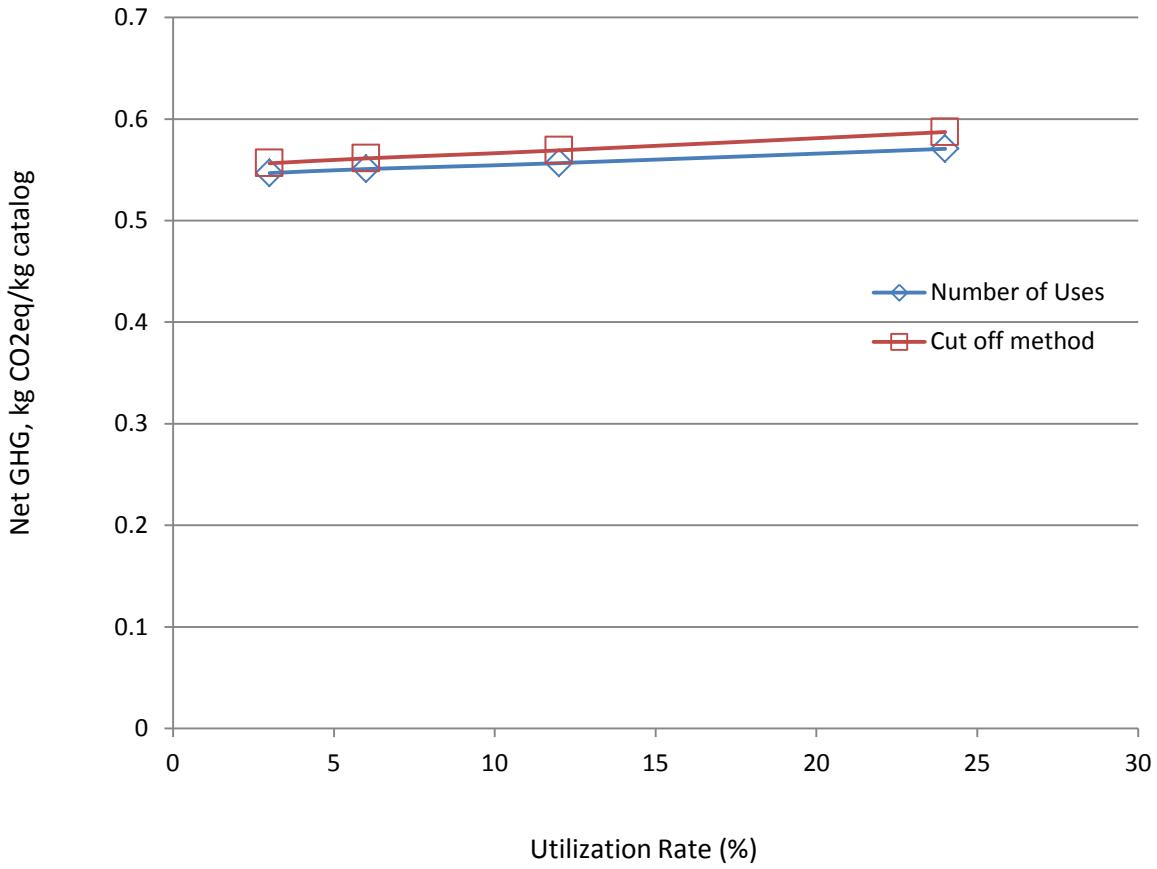
Allocation Methods Comparison:

- **Recovery Rate:**
  - **Increased RR decreases carbon footprint**
  - **Number of uses carbon footprint much less than cutoff**



Allocation Methods Comparison:

- **Utilization Rate:**
  - **UR does not significantly impact carbon footprint**
  - **Number of uses carbon footprint similar to cutoff**



Outline

- Introduction to LCA
- LCA of Paper
- North American Printing and Writing Grade LCA's
- Allocation methods in LCA's
- Recommendations

Recommendations:

- The comparisons of different LCA studies can be extremely difficult.
- The authority and reasonableness of LCA studies are not consistent.

Recommendations:

- When considering two related products in the same life cycle such as virgin or recycled materials, the choice of available allocation methods can determine whether virgin or recycled material is promoted.

- The number of uses method is an appropriate model for the life cycle analysis of paper products, which is most reasonably modeled as an open loop recycling process.

Recommendations:

- As based on data in this paper, the recovery of used paper for manufacture of new materials or use in incineration to create energy is more desirable than landfilling.

- With respect to the utilization of recovered paper in specific products, the data in this paper demonstrate that a blanket statement that all paper products should maximize use of recovered paper is not substantiated.

- Increased recycling of paper products and the design of paper products that are recyclable is environmentally beneficial.

Recommendations:

- Industry average data are useful for an industry to benchmark its overall performance.

- The use of industrial averages of environmental impacts to promote a specific paper product relative to other similar paper products is not reasonable.