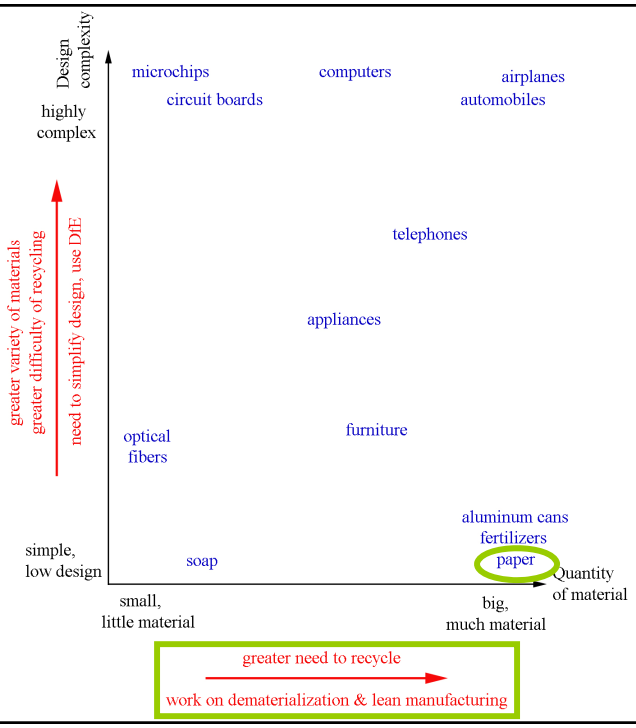
FOREST AND PAPER INDUSTRY

A mature industry that has done much to clean up its act.

http://individual.utoronto.ca/abdel_rahman/paper/fpmp.html



www.automation.com/sitepages/pid1988.php

Paper is a commodity:
low design, near impossibility of changing the product itself
huge amounts → huge impact nonetheless

Paper accounts for 2.5% of industrial production
2.0% of world trade

Paper consumption is related to population
and to wealth

What are the primary environmental issues concerning the forest and paper industry?

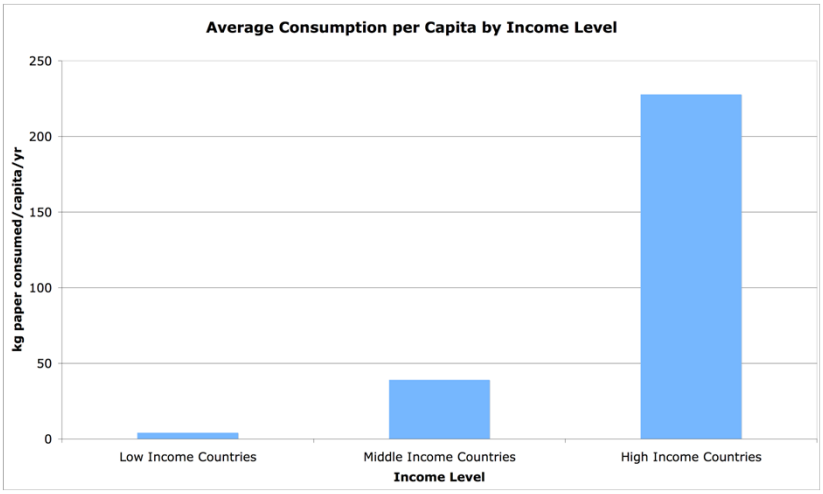
1. Sustainability of forest resources:
   trees + habitats + species + water

2. Clean paper making:
   transportation to and from paper mill
   energy consumption
   water usage
   bleaching and other chemicals

3. Paper consumption:
   Can it be reduced?

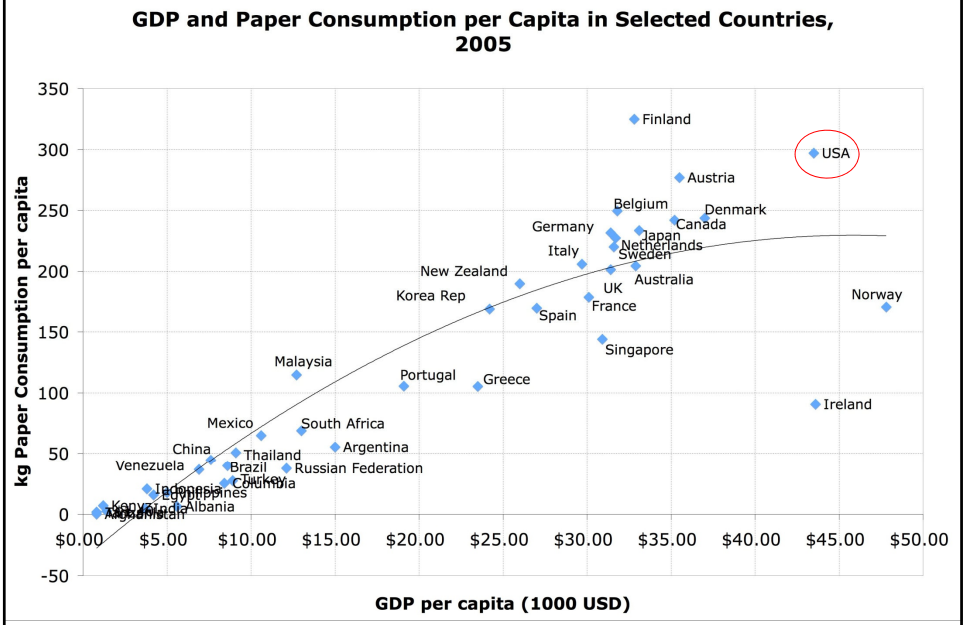
4. Recycling of used paper and cardboard
   energy, chemicals
   recycling *vs*. incineration

5. Alternatives to wood for paper?
   Alternatives to paper itself?

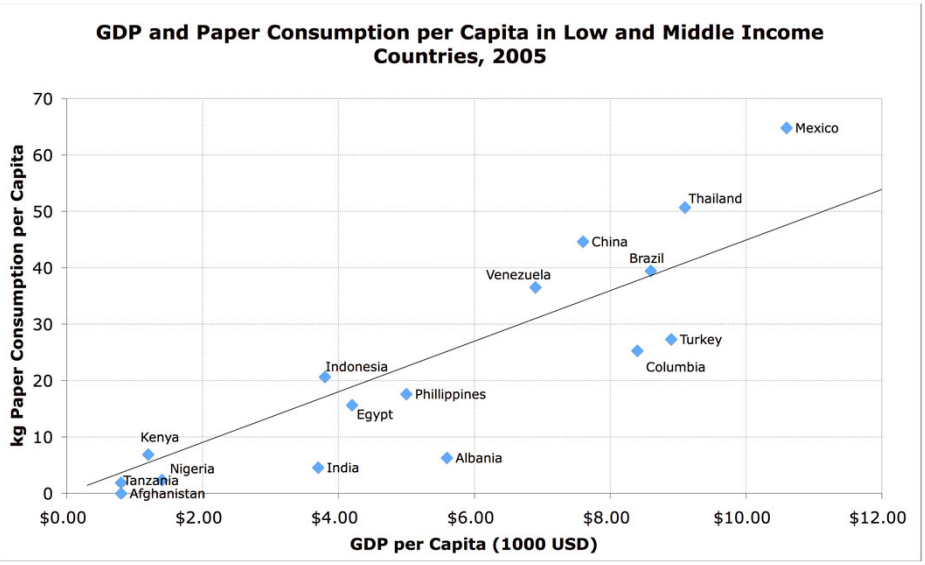


Hint: Paper consumption is highly correlated with wealth.

For a wide range of countries



Zoom on the less wealthy countries (bottom left of previous plot)



Look at historical data:
GNP is about the only factor affecting paper consumption.

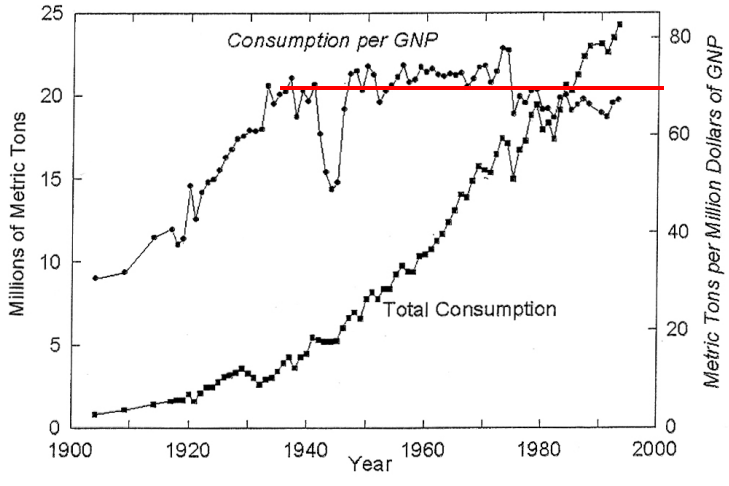


FIGURE 2 Absolute paper consumption and paper consumption per unit of GNP in constant 1982 dollars. DATA SOURCES: W. E. Franklin and Associates (1990) and US Bureau of the Census (1975, 1991).

So, roughly, paper consumption is occurring according to:

$$\frac{70 \text{ metric tons}}{\$1 \text{ million of GNP}} = 70 \text{ grams} / \$$$

With a footprint of 1.15 kg of CO_2 per kg of paper produced,

$$\frac{0.070 \text{ kg of paper}}{\$1} \times \frac{1.15 \text{ kg of } CO_2}{\text{kg of paper}} = 80.5 \text{ g of } CO_2 / \$$$

"Around 80% off all products sold in United States and the European Union are packaged in cardboard."

"In the United States, 850 million tonnes of **paper and cardboard** are thrown away annually.

This equates to around 1.4 billion trees, a terrifyingly high number.

To put this into further perspective, the average American uses around 3.6 trees per year in **paper and cardboard**."

… more

A few numbers from
How Bad Are Bananas? The Carbon Footprint of Everything
by Mike Berners-Lee, GreyStone Books, 2011

Item	Carbon footprint
Brown grocery bag	12 g CO_{2e}
Fancy paper bag from department store	80 g CO_{2e}
Paperback book on recycled paper*	400 g CO_{2e}
Book on thick virgin paper**	2 kg CO_{2e}
Daily newspaper on recycled paper	0.3-0.8 kg CO_{2e}
NYT Sunday paper, recycled afterwards	1.5 kg CO_{2e}
Roll of toilet paper (recycled/new paper)***	450/730 g CO_{2e}

* Assuming all printed copies are sold
** Assuming half printed copies are pulped
*** Amounting to 75 kg/person in US

1 ton of uncoated virgin (non-recycled) printing and office paper uses 24 trees.
1 ton of 100% virgin (non-recycled) newsprint uses 12 trees.
The average is 17 trees per metric ton of paper.

A "pallet" of copier paper (20-lb. sheet weight) contains 40 cartons and weighs 1 ton.

Therefore,

1 carton (10 reams) of 100% virgin copier paper uses 0.6 trees.
1 tree makes 16.67 reams of copy paper or 8,333 sheets.
1 ream (500 sheets) uses 6% of a tree.
1 ton of coated, higher-end virgin magazine paper (as used for high-end magazines) uses 15.4 trees.
1 ton of coated, lower-end virgin magazine paper (used for newsmagazines and most catalogs) uses 7.68 trees.

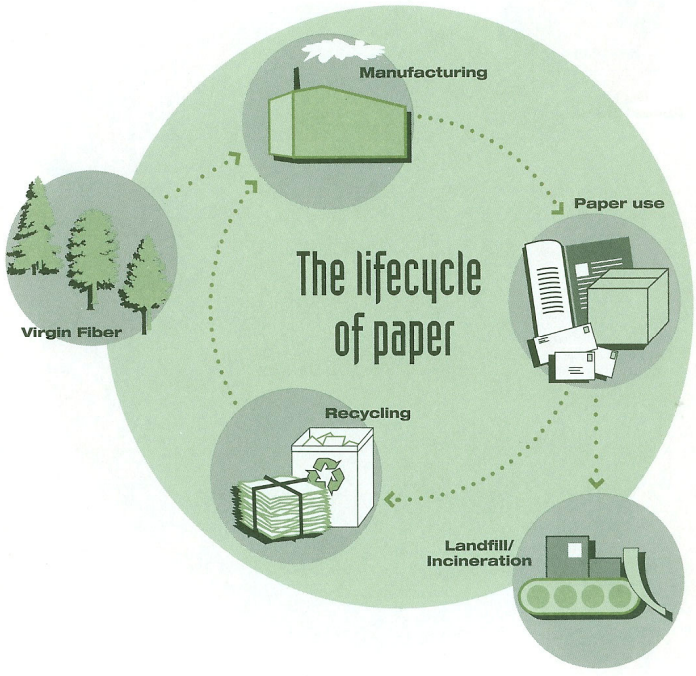
(*Source*: Cushman-Roisin & Tanaka Cremonini, *Useful Numbers*, Elsevier 2021)

Beware of claims in the media that it takes up to 10 or even 20 L (2.6 to 5.2 gallons) of water to make a single A4-sheet of paper!

Such alarming statements are usually based on a particular study posted by waterfootprint.org that includes the amount of rain consumed by a tree during its growth (which occurs even if no paper is made from the tree), ignores recycling of paper, and also ignores the fact that most of the water in a paper mill is treated and reused. In other words, it is a badly distorted account designed to generate concern.

Using the correct estimate of 17,000 gallons of water per short ton and considering that one metric ton of paper makes 440 reams of 500 sheets, one obtains only 0.32 L per sheet.

Actually, since office paper is generally made with the less-water-intensive kraft mechanical pulping to preserve long fibers, the better number to use is 4,500 gallons per short ton, which translates into 0.085 L of water per sheet of office paper.



Paper Task Force, © 1995 Environmental defense Fund

In brief,

Tree trunks = wood

Wood = Fibers + Lignin (glue)

Pulp = Loose fibers in water

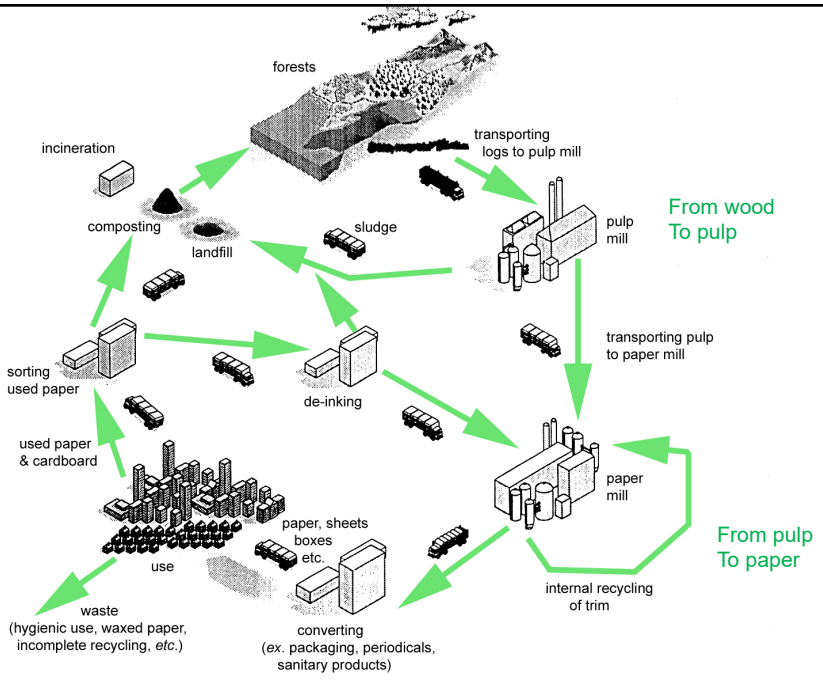
Paper = dried pulp in sheet form

A small batch of pulp

Wood fibers (magnified)

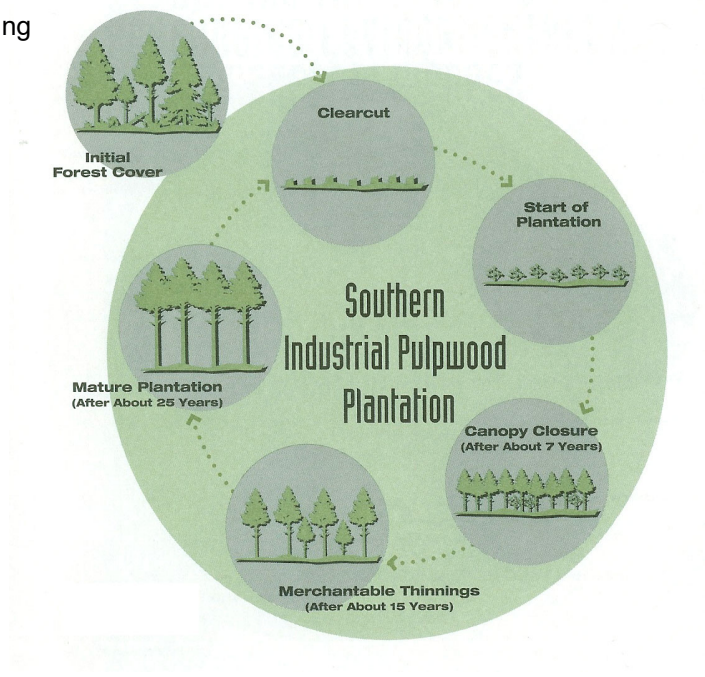
The longer the fibers, the stronger the paper.

Recycling shortens the average length of fibers.



The Paper Cycle

1. Forest logging



A tree = 25% branches and bark
75% trunk wood → logs

16 to 20 mature trees per acre

Wood log = 27% lignin (glue)
73% fiber (what goes into paper)

Every tree requires
130 gallons (490 L) of water for growth, some more than others
50 gallons (189 L) of water for processing into paper

Basic rule:

Trees cut + trees lost to forest fires and diseases
< trees reaching maturity (on annual basis)

But …

- Mind soil erosion
- Mind habitats
- Mind aesthetics

In other words, cut in an environmentally conscious way.

- Balance the various forest resources and services:
  - Lumber and firewood
  - Paper
  - Recreation
  - Carbon sequestration

Dartmouth College does a great job balancing these several objectives in its Second Grant Land in northern New Hampshire.

The Sustainable Forestry Initiative® (SFI) Program

On October 14, 1994, members of the American Forest & Paper Association agreed to adhere to a set of forestry principles that would meet the needs of the present without compromising the ability of future generations to meet their own needs. These principles call for a land stewardship ethic which integrates the reforestation, nurturing, and harvesting of trees for useful products with the conservation of soil, air and water resources, wildlife and fish habitat, and forest aesthetics.

SUSTAINABLE FORESTRY INITIATIVE®

Check out SFI's Forest Art Television Advertisements

(15 seconds)


(30 seconds)

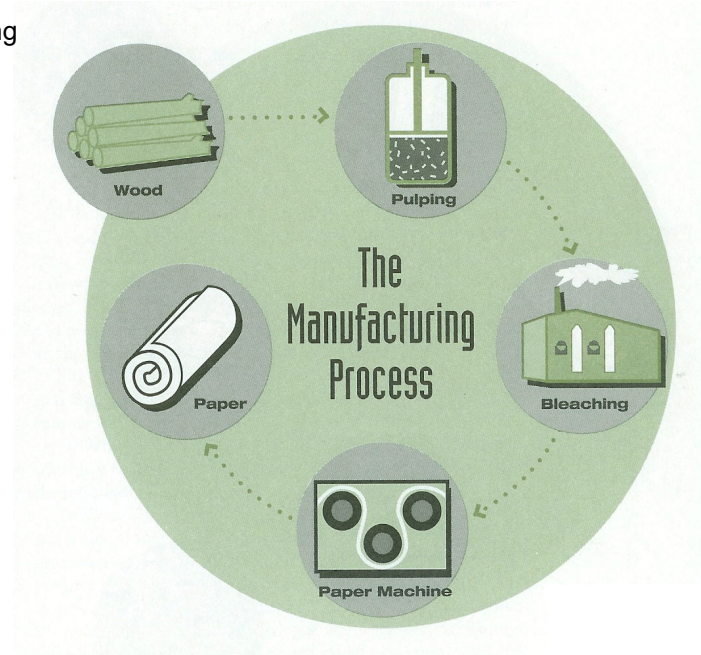
Fairly dated statement to prove that this is not new. Essentially: Problem solved!

http://www.rurdev.usda.gov/rbs/pub/jan00/trees.htm

www.fitzmorrishorselogging.com/

The most environmentally conscious form of logging is
- with draft horses,
- especially when a snow cover is present.

2. Papermaking



From logs to chips

Some brute force
is applied…

= energy consumption

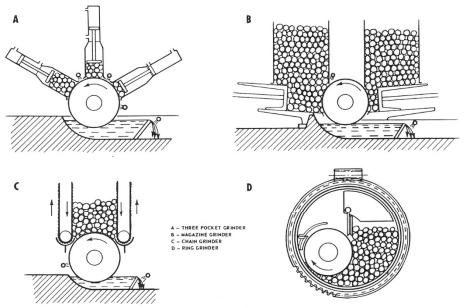


Fig. 5-13. Types of grinders.

Hydropower at the rescue

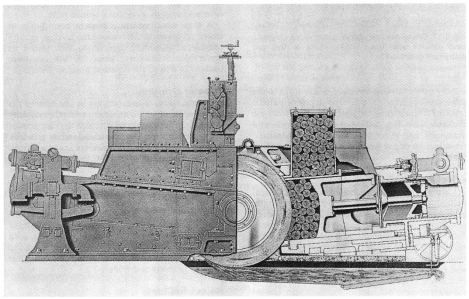


Fig. 5-14.Great Northern grinder (Koehring-Waterous Ltd.).

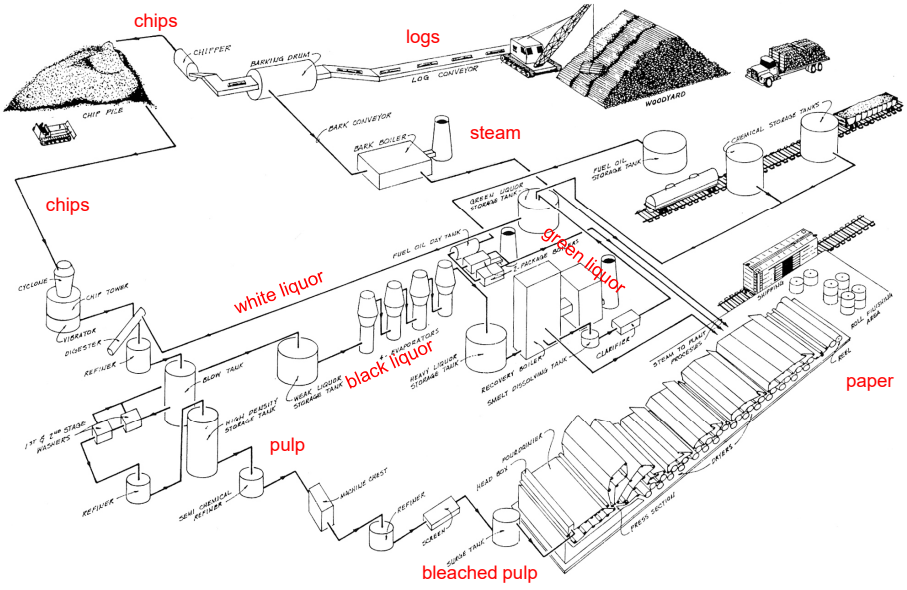


Fig. 20-12. Layout of mill to produce corrugating medium utilizing green liquor pulping (Virginia Fibre Corp.).

Pulping

From used chemicals
to new chemicals

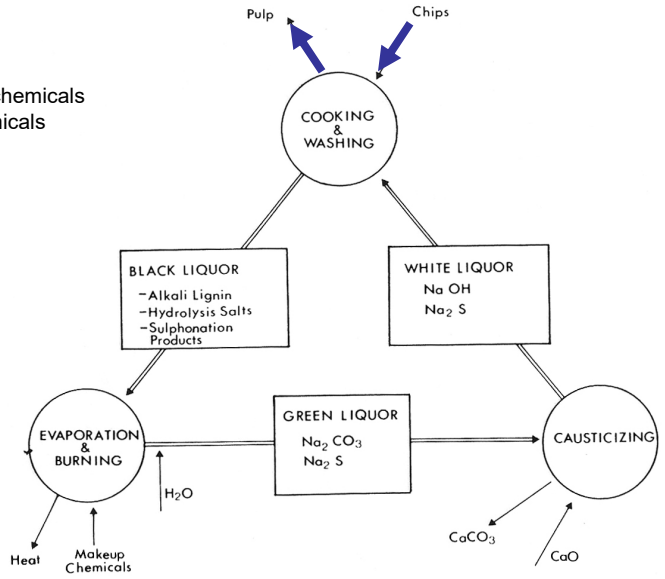
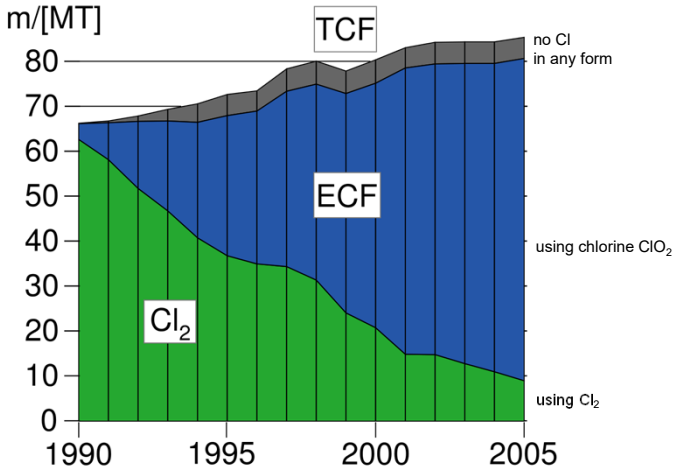


Fig. 7-1. The kraft liquor cycle.

Various bleaching technologies

ECF = Elemental Chlorine Free
(use of ClO_2 instead of Cl_2)
TCF = Total Chlorine Free (incl. ozone)



- ECF bleaching substantially reduces but does not fully eliminate chlorinated organic compounds, including dioxins, from the effluent.
- TCF bleaching, by removing chlorine entirely from the process, eliminates chlorinated organic compounds in the effluent.

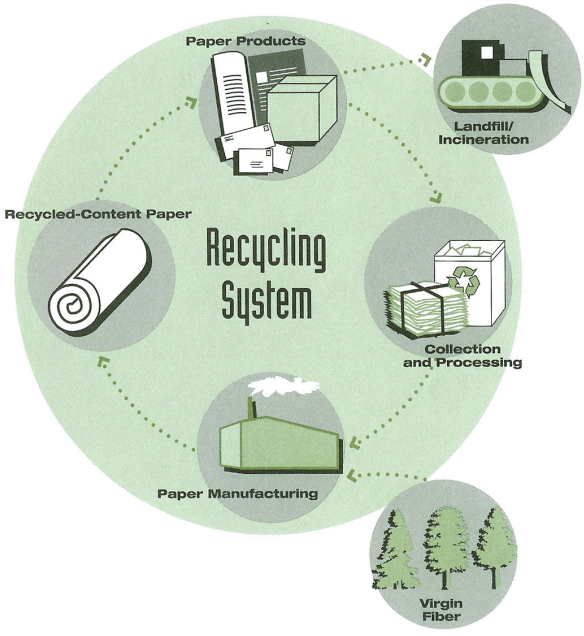
ECF = Elemental Chlorine Free (substitution of Cl_2 by chloride dioxide ClO_2)
TCF = Total Chlorine Free (no Cl in whatever form, use of O_3 and H_2O_2 instead)

The ECF vs TCF debate:

	Arguments pro-ECF or against TCF	*Arguments pro-TCF or against ECF*
TECHNOLOGY	- ClO_2 gives better bleaching - ECF fibers are stronger - Water loop can be closed - Efficiency of H_2O_2 is not great	- TCF technology exists - Easier to start/stop facility - Cl builds in closed loops → corrosion → leaks
ENVIRONMENT	- ECF is good enough* - Anti-Cl position is like a religion - Stronger fibers → fewer trees & more recycling - ECF generates no dioxin in practice	- TCF = only guarantee against release of Cl compounds - Easier to filtrate effluents - Theoretical possibility of producing dioxin from ECF
MARKET	- Weaker paper from TCF - Low demand for TCF in USA - European demand may not last	- Strong European demand for TCF paper
ECONOMICS	- Too costly to retrofit an existing plant from ECF to TCF - Higher production costs with TCF incl. cutting more trees	- Not more expensive to go TCF when building a new facility

* with primary and secondary treatment of wastewater

3. Recycling



First off: Is it better to recycle than to incinerate or landfill?

- Recycling → re-use of fibers but energy spent in transportation and remanufacture
  fibers get shorter, weaker paper, not for all applications.

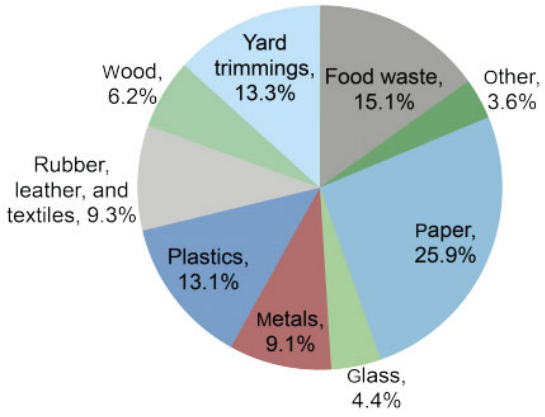
- Incineration → Getting energy without as much transportation
  Energy produced displaces fossil-fuel energy
  but cascading not as good as recycling, in principle
  Also: particulate air emissions!

- Landfilling → Least effort but methane emissions during decomposition

In general, landfill is the least preferable option, and there are conflicting opinions regarding incineration versus recycling.

In most cases, recycling results in lower total energy cost
but with a greater fraction coming from fossil fuel.

An additional reason to recycle paper:
There is a lot of it in your garbage, and it adds to landfill volume.



University of Michigan – Center for Sustainable Systems – Municipal Solid Waste Factsheet, Pub. No. CSS04-15, 2019.

Every ton of paper recycled saves more than 3.3 cubic yards (~3 m^3) of landfill space.

Table 4 Environmental releases under a recycling scenario for newsprint compared with an incineration scenario

Study	Total energy	Fossil energy	Net CO_2 equivalents	SO_2	NO_x	BOD	COD
a) **BNMA 1995** Current	H	n/a	H	H	L	L	L
b) **BAT**	L	n/a	H	L	L	L	L
Kärna *et al 1993*	n/a	n/a	H	H	L	n/a	S
EDF 1995	L	L	L	L	L	H	L
Johnson 1993							
a) production UK	L	n/a	H	L	H	H	H
b) production Scandinavia	-	H	H	H	H	H	H
IFEU 1993							
a) production UK	L	L	L	n/a	n/a	n/a	n/a
b) production Sweden	L	H	H	n/a	n/a	n/a	n/a

L, H, S: Lower, higher or same emissions/use under the recycling scenario as compared with an incineration scenario. See IIED Substudy no. 14 for details of the scenarios compared and key assumptions of the studies.

Grieg-Gran et al., Towards a Sustainable Paper Cycle **61**

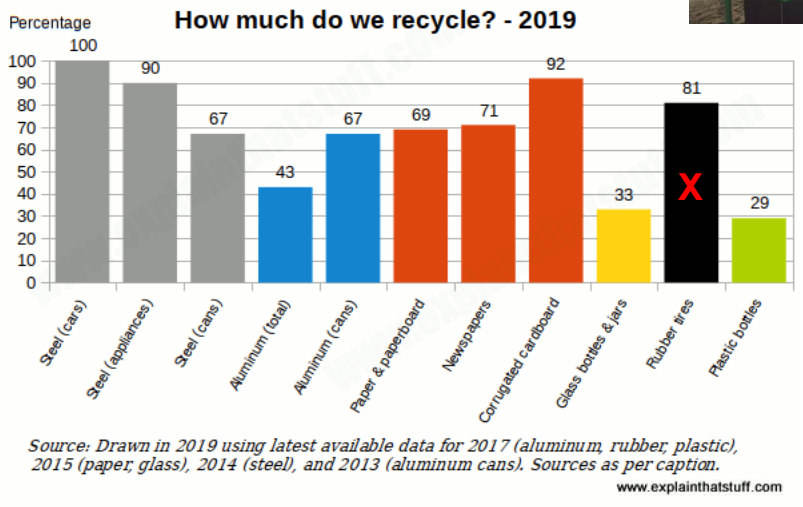
L = Lower emissions during recycling than during incineration
S = Same emissions during recycling as during incineration
H = Higher emissions during recycling than during incineration

Recycled versus virgin paper:

Recycling white office paper requires 44% less energy, generates 50% less wastewater, and produces 38% less carbon emissions than virgin paper. This is because most of the impacts in papermaking are in the delignification of wood into pulp.
Recycling only needs de-inking before pulping (fibers in water).

Recycled paper is not usually re-bleached and when it is, oxygen rather than chlorine is usually used. This reduces the amount of chlorinated compounds which are released into the environment as a by-product of the chlorine bleaching processes.

www.cartoonstock.com/.../r/recycling_paper.asp



Source: https://www.explainthatstuff.com/recycling.html

Basic issues faced in paper/cardboard recycling:

- Collection & Sorting
- Transportation to sorting/recycling center
- Recycling process itself: de-inking, loss in fiber strength, hazardous chemicals
- Marketing of recycled paper

Challenges in collection and sorting:

- Impossibility to capture all forms of paper used by consumers
  - Hygienic paper, waxed paper are not recyclable
  - Harder to collect from individuals than from companies

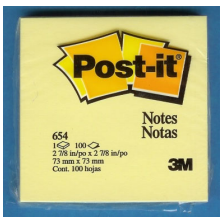
- What is captured ought to be sorted in grade categories
  - P&W = printing and writing (white office paper)
  - OCC = old corrugated cardboard
  - ONP = old newspapers
  - Mixed paper

- White office paper has the highest grade for recycling but is relatively hard to collect. Offices hang on to documents. Often mixed with magazines, which has the lowest grade (glossy, colors).

- Old newspapers are also relatively easy to capture because people pile them up at home. But they are now a vanishing breed.

- Collection of corrugated cardboard boxes is relatively easy in the back of retail stores such as Walmart.

A previous and now solved issue



Those handy Post-It ®

ISSUE FOCUS: PAPERMAKING

A new enzyme-based control system breaks macro-stickies into smaller particles that can be removed from the mill process, thus reducing their impact on runnability and paper quality

Esterase-type Enzymes Offer Recycled Mills An Alternative Approach to Stickies Control

By DAVID R. JONES and JAMES W. FITZHENRY

Many North American paper and board mills have to deal with the consequences of using recycled fiber. One major consequence is dealing with stickies that are a natural component of the recycled fiber used by these mills. Stickies can cause runnability and quality problems, and their variable nature makes them difficult to control. A new approach to stickies control has been developed that uses esterase-type enzymes to break down the stickies into smaller, less tacky particles. The successful use of these enzymes at three mills is described in this article.

WHAT ARE STICKIES? Stickies are tacky, hydrophobic, pliable organic materials found in recycled paper systems. They exhibit a broad range of melting points and different degrees of tackiness depending on their composition.

Stickies are composed of a variety of materials including adhesives, styrene-butadiene latex, rubber, vinyl acrylates, polyisoprene, polybutadiene, and hot melts. This, of course, is not a complete list of the materials that make up the broad range of stickies encountered at the mill.

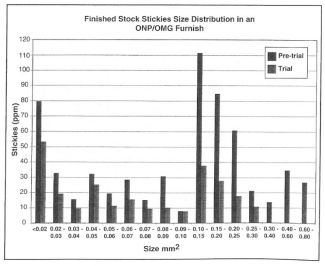
The variable nature of stickies is one of the main reasons controlling or removing them can be difficult. This variability is derived from two aspects: the broad range of the materials that make up the stickies material itself and the variability in the composition of recycled fiber used by paper and board mills. Mills often use a variety of different wastepaper grades, which fluctuate widely in quality and come from a range of sources and locations. In fact, certain types or sources of recycled fiber sometimes have to be avoided because problems caused by the stickies contained in the fiber are impossible to deal with. Other factors can also contribute to this variability, including, for example, the season of the year during which the mill is operating.

The use of recycled fiber has been increasing and is expected to continue growing, and the subsequent reduction in quality that occurs with this rise in use means problems due to stickies will not be going away. In fact, there is reason to believe that these problems will become even larger and more difficult to address for many mills.

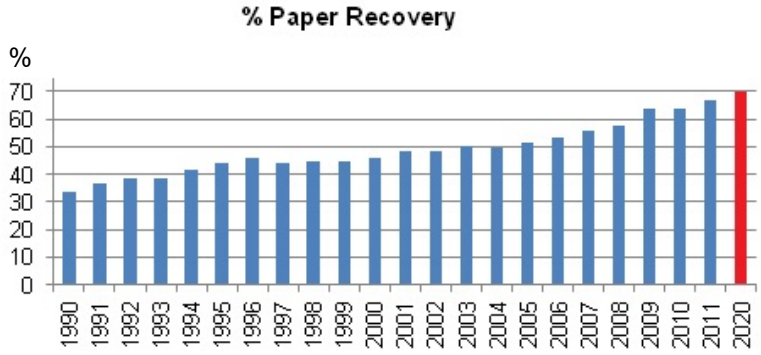
EXISTING CONTROL METHODS. A variety of approaches has been used to reduce the negative impact of these unwanted furnish materials on paper mill operations. Both mechanical and chemical means have been used for control or removal of these products. Screening, cleaning, flotation, and washing can all remove stickies, but none of these processes can deal with all types of stickies that a mill might encounter. The same limitation is true for chemical control programs. Chemical approaches to stickies control can tie up stickies in the furnish or clean stickies off surfaces once they are deposited, but these programs are not always completely successful.

The current approach used for stickies control typically involves both mechanical and chemical systems. Various pieces of equipment in the deinking plant and paper mill are designed to clean and/or mechanically remove contaminants. Screens, cleaners, dissolved air flotation (DAF) systems, and washing stages are all designed to remove contaminants, which can include dirt, shives, or stickies.

FIGURE 1: *Application of enzymes to an ONP/OMG furnish in order to control stickies reduced the size of sticky particles so that they were undetectable.*



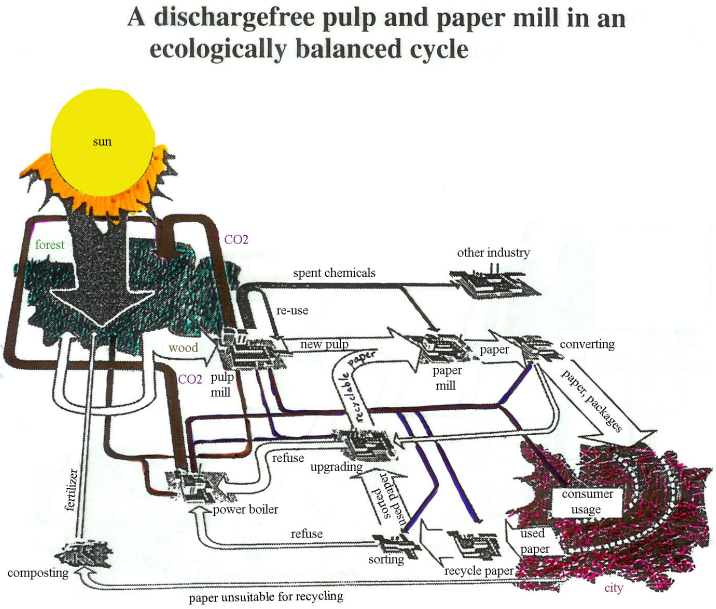
Percentage of post-consumer paper recycling in the USA



- Total paper recovery in the U.S. exceeded 51 million tons in 2012.
- Nearly three times more paper is recycled than is sent to landfills.
- By weight, more paper is recovered for recycling from municipal solid waste streams than glass, plastic, steel and aluminum combined.

Source: https://sites.psu.edu/congxuncibblog/2014/03/20/paper-recycling/

Industrial Ecology applied to the forest and paper industry



CONCLUSIONS

The paper industry is a mature industry that has had to face its environmental impacts for several decades already.

While the industry cannot redesign its products (office paper and cardboard boxes need to meet very standard requirements), it has been able to redesign its manufacturing processes.

- Its wastewater is now almost nil compared to what it used to be, and it is properly treated before release.
- It has established a closed loop for its chemicals used in pulp making.
- Bleaching is now performed in a much more benign form.
- Energy is consumed in much more efficient ways.
- Paper and cardboard are now heavily recycled.

In summary, a very happy story!

Paper alternatives:

The only requirement: Paper must be made from a fibrous material.

Fibers can be found in biomass other than wood. For example:

KENAF - Kenaf is a plant originating from Africa and is a member of the hibiscus family, currently being tested as an alternative to cutting trees. It can grow up to 12-14 feet in as little as 4 to 5 months. U.S. Department of Agriculture studies show that kenaf yields of 6 to 10 tons of dry fiber per acre per year are generally 3 to 5 times greater than the yield for Southern pine trees. Because kenaf is grown for the fibrous stalk, and not the fruit or flower of the plant, insecticides are not required.

(http://showcase.netins.net/web/creativecomposites/FAQs.html)

Paper alternatives – continued

HEMP - Industrial hemp is illegal in the United States, although it contains far less THC than marijuana. Hemp can produce 10 tons per acre in 4 months and can be grown in a variety of climates. The plant resists diseases and shades out weeds so the use of chemicals is not required during cultivation. **Additionally, hemp paper can be recycled 7 times versus 3 times for wood pulp paper.** It can also serve as an alternative for edible oil, automotive oil, cooking and heating fuel, fabric, medicine and construction beams.

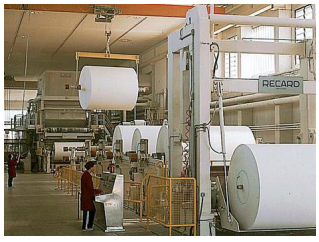
Hemp toilet paper and its virtues:
https://wamaunderwear.com/blogs/news/hemp-toilet-paper


(http://www.toneag.com/hemp.html)

COTTON - Cotton is the world's most widely used natural textile fiber, grown in over 70 countries and meeting nearly half of our clothing needs. About 35% percent of the cotton plant is used for fiber. The rest—seeds and gin trash—go into the food chain, either as industrially processed cooking oil or animal feed. Unfortunately, conventional cotton farming is extremely chemical-intensive. According to the California-based Sustainable Cotton Project, in the United States, nearly a third of a pound of chemical fertilizers and pesticides is required to produce the pound of fiber that goes into a T-shirt.


(http://www.cottonman.com/cotton_bolls.htm)

Paper alternatives – continued



Rice paper manufacturing

OTHER - Many of the fibers left from plants we already grow for food go to waste after harvest, including **rice**, **wheat**, **sugar cane** and **coffee**.

In the United States alone, an estimated 150 million tons of straw goes underutilized each year. Much of this waste is burned, only aggravating air pollution.
Instead, these remainders could easily and economically be turned into paper.

Scrap material such as the leftovers from the manufacturing of **denim jeans**, or **old money** can also create tough and beautiful paper products.