Industrial Ecology of Acetylated Wood

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Global Warming

- Main greenhouse gas is CO_2
- Level in pre-industrial era 280 ppm
- Level now 380 ppm, increasing at 1.5 ppm per year
- If we continue to emit CO_2 at present rate, level will reach 700 ppm in 2100
- If present trends continue, mean global temperatures will rise by 1.5 to 4.5^{o}C by 2050

Global Warming

- We are balanced on the edge of a catastrophe
- Given a global warming of about 2^{o}C
- Amazon rain forest will become savanna
- Tundra will release vast quantities of methane
- Methane clathrates will melt

We must develop technologies that sequester as much carbon as possible and we must do it NOW!

Both modified wood AND preservative treated wood will have important roles to play

What is Industrial Ecology?

- Systems approach to industrial processes
- Using methods often applied to ecological systems
- Studies of energy and mass flows through processes
- LCA is a tool that is often used

Industrial Ecology

- First mentioned by Frosch and Gallopoulos (Scientific American, 1989)
- Wastes from one industrial process become feedstock for another
- Eco-industrial parks with factories operating in symbiotic relationships

Example

- **Use of captured sulphur dioxide from a coal burning power plant to make gypsum for plaster board**
- **Waste becomes a feedstock**

Industrial Ecology

- Could go one step further
- Integrate the industrial process into a natural cycle
- Integrate wood acetylation into the forest carbon cycle
- Examine what is done now

Felling as % of NAI

- Europe 59%
- N. America 79%
- CIS 17%
- For temperate and boreal countries NAI minus felling amounts to 1.2 billion m^3
- This is equivalent to 0.5 billion tonnes of wood (about 0.7 billion tonnes $C0_2$)

Annual Emissions CO_2

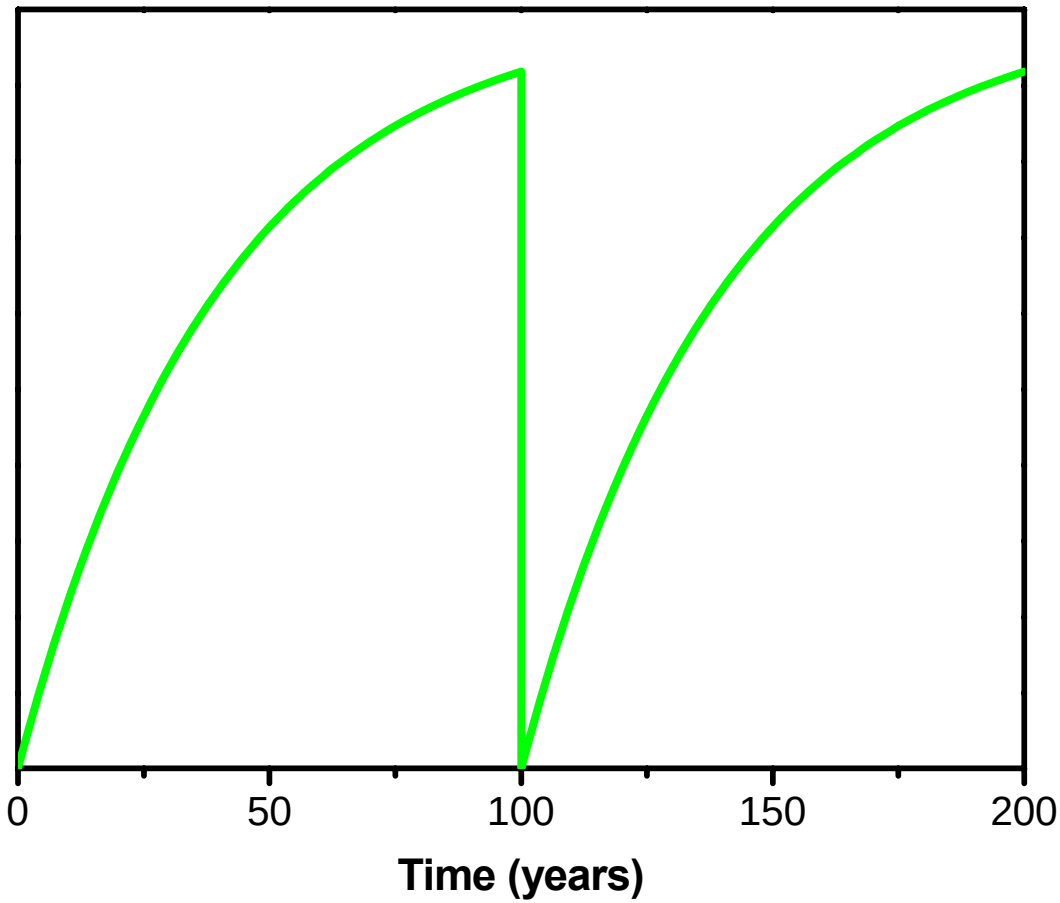
- **Combustion ca. 22 billion tonnes CO_2**
- **Deforestation ca. 6 billion tonnes CO_2**

- **NAI of N. America, Europe and CIS combined represents about 2.5% of CO_2 emissions sequestered**

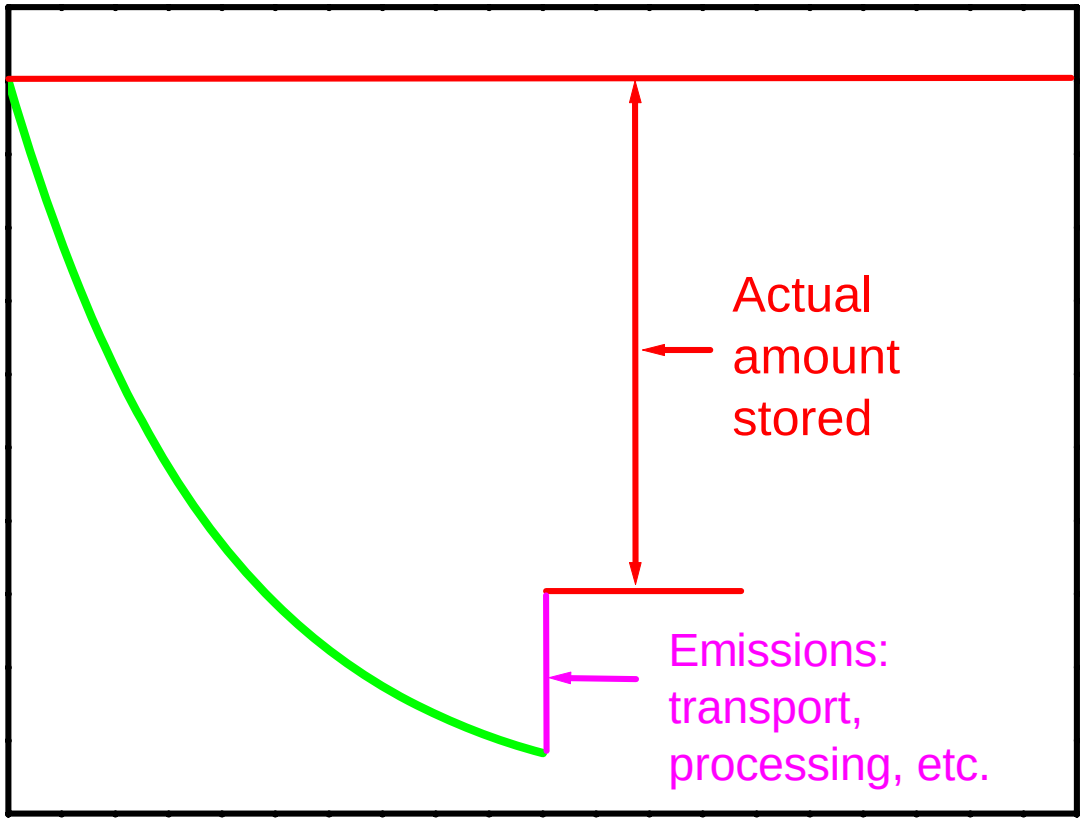
Carbon storage in forests

- **Increasing the size of a carbon reservoir in a forest can only be achieved before the forest achieves a steady state**
- **An undisturbed natural forest is in a neutral position with regard to long-term carbon emissions**
- **Planting of new forests will act to mitigate CO_2 emissions over a relatively short time frame (about 75 years)**

Carbon storage in a forest



Carbon storage



Materials Flow Analysis

Follow the atoms

Caron storage

- **Storage of carbon in wood-based products is not a permanent solution to the CO_2 problem because all products have a finite life, such that continued use eventually results in a steady state level of storage**
- **But it will buy us some time**

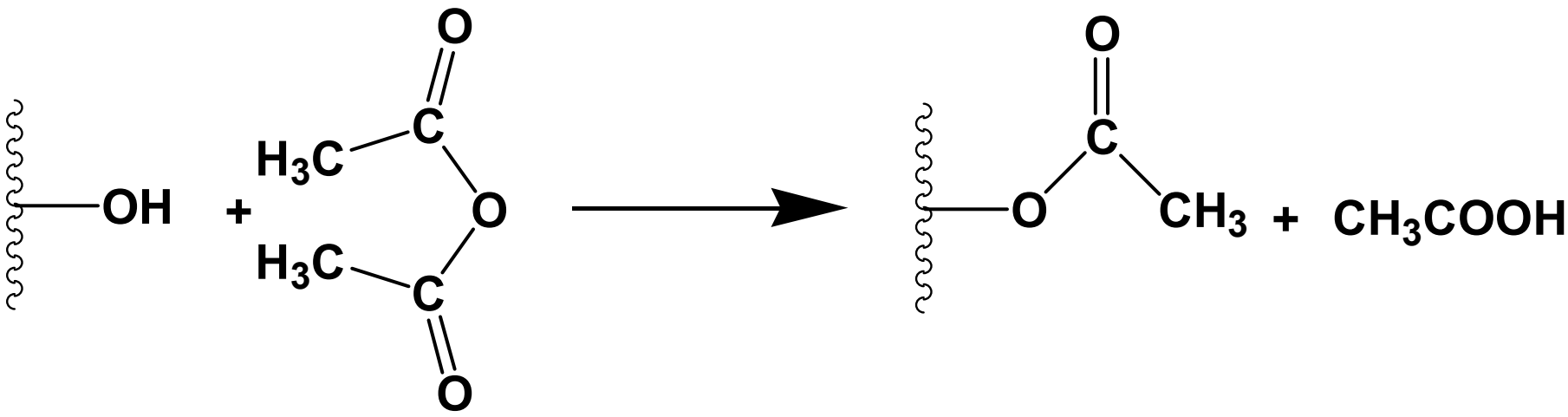
Acetylation of Wood

- First studied in 1928
- Industry is immature
- Only one process is now nearing commercial production
- Accoya produced by Titanwood™
- 30,000 m^3 per annum production

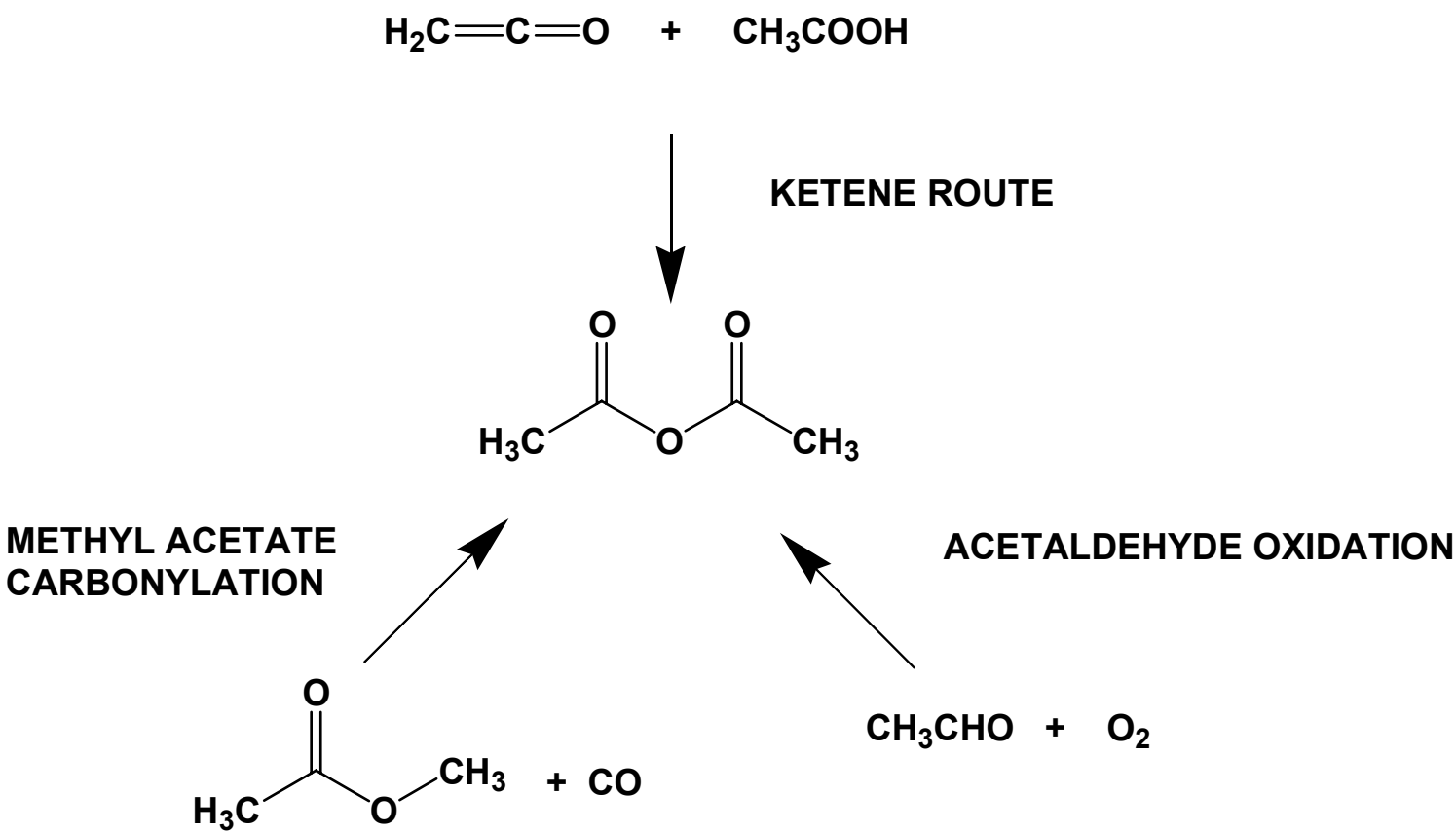
Acetylation of Wood

- **At the present time, acetic anhydride is derived from non-renewable resources (primarily natural gas or coal)**
- **Due to long expected lifetime of acetylated wood products (60 years) there has been relatively little attention paid to disposal of the material**

Acetylation Reaction



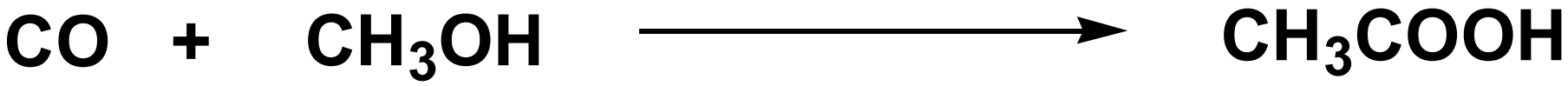
Acetic Anhydride Production



Ketene Production

730 to 750°C in presence of triethyl phosphate

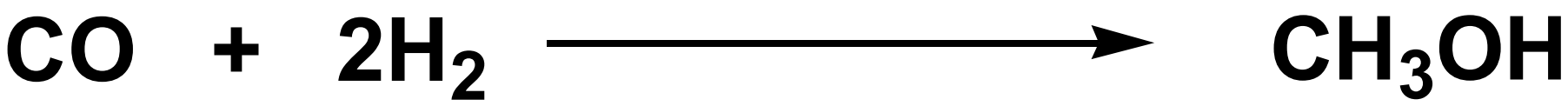
Acetic Acid Production



Monsanto process: used rhodium catalyst 30-60 atm., 150-200^{o}C

Largely supplanted by Iridium-based catalytic carbonylation of methanol, BP chemicals' Cativa process

Methanol Production



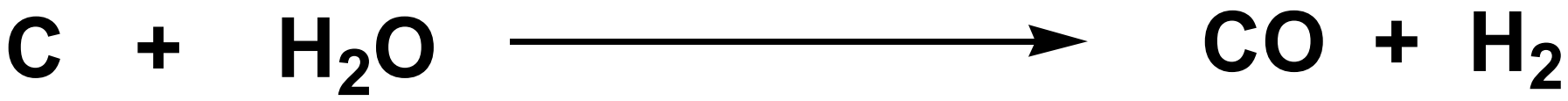
Produced from synthesis gas

First developed by BASF in 1923

Used zinc chromate catalyst, 30-100 atm., 400°C

Now commonly uses copper, zinc oxide, alumina catalysts at 50-100 atm., 250°C

Syngas Production

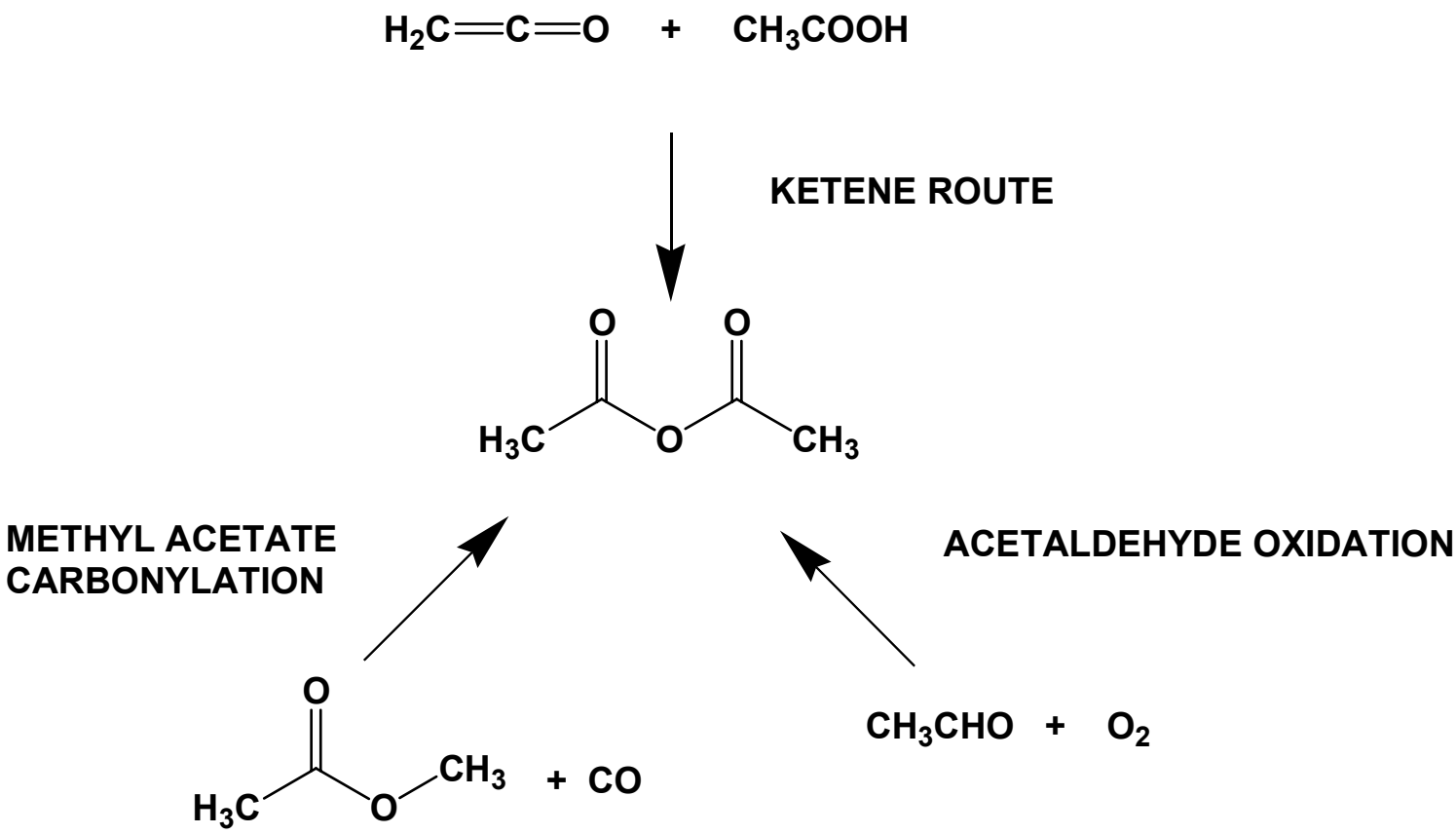


Eastman (USA) and Sasol (S. Africa) use coal as a carbon source

Can use reaction of steam with natural gas:

$CH_4 + H_2O \rightarrow CO + 3\ H_2$

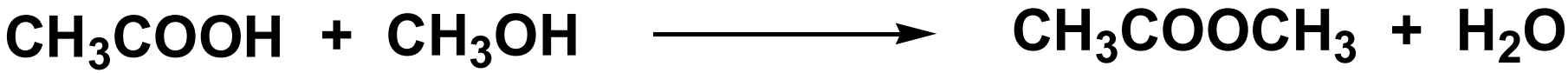
(10-20 atm. 850^oC nickel catalyst)


H2C=C=O + CH3COOH
KETENE ROUTE
O
O
H3C
O
CH3
METHYL ACETATE CARBONYLATION
ACETALDEHYDE OXIDATION
O
CH3
H3C
O
+ CO
CH3CHO + O2

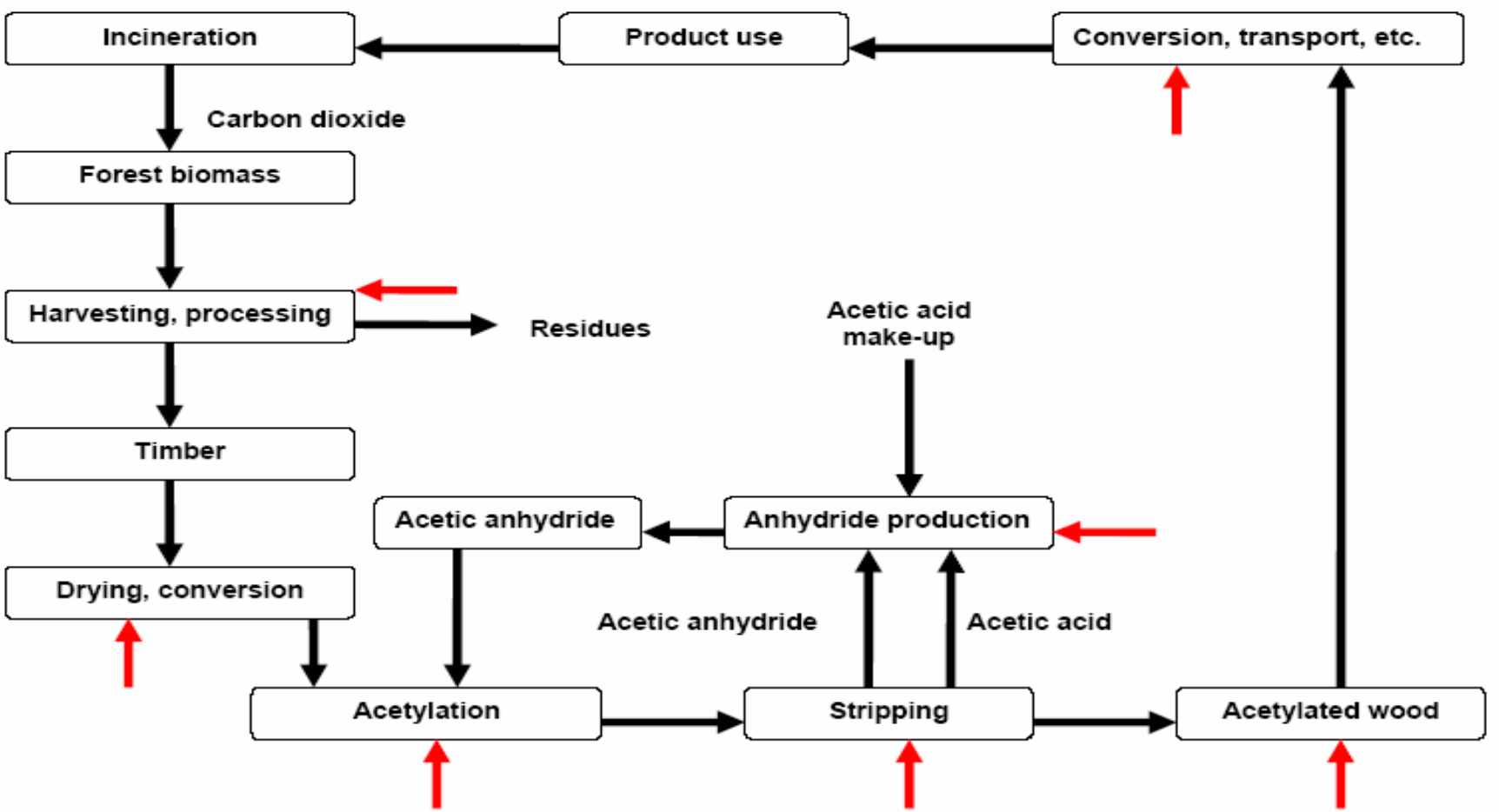
Acetaldehyde Route

- **Does not appear to be used anymore**

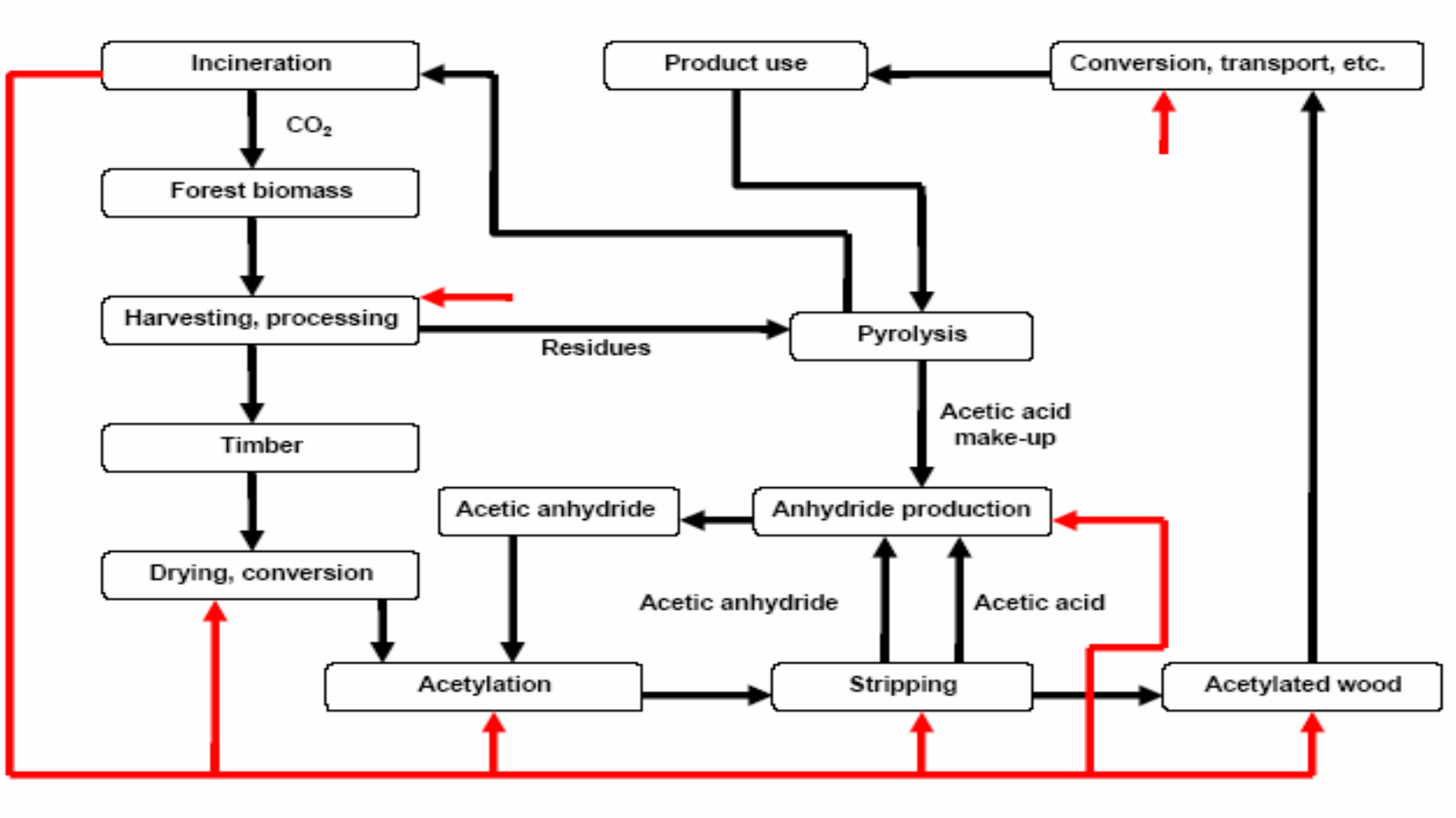
Methyl Acetate Production



The Carbon Cycle

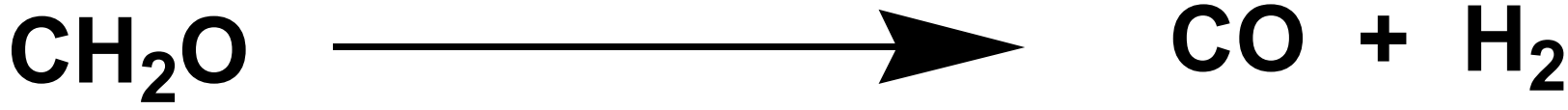


Carbon Cycle



Other Disposal Options

- **Most biomass will be converted in very large syngas facilities (biorefineries)**
- **Syngas will be converted to a range of platform chemicals**



Production from lignocellulosics is complicated by variable moisture content, which may be less of an issue with acetylated wood

Other Disposal Options

- **Composting is not desirable due to release of methane (about 25x more potent than CO_2 as a greenhouse gas)**
- **Incineration with energy recovery is to be balanced against syngas production or pyrolysis then incineration**

Conclusions

- **Best disposal options would involve:**
- **Recovery of acetic acid from acetylated wood**
- **Use of acetylated wood in syngas production**
- **This is a guess**
- **This needs to be researched properly**