A Life Cycle Look at End of Life Vehicle Recycling

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Introduction

VRP
VEHICLE RECYCLING PARTNERSHIP

USCAR

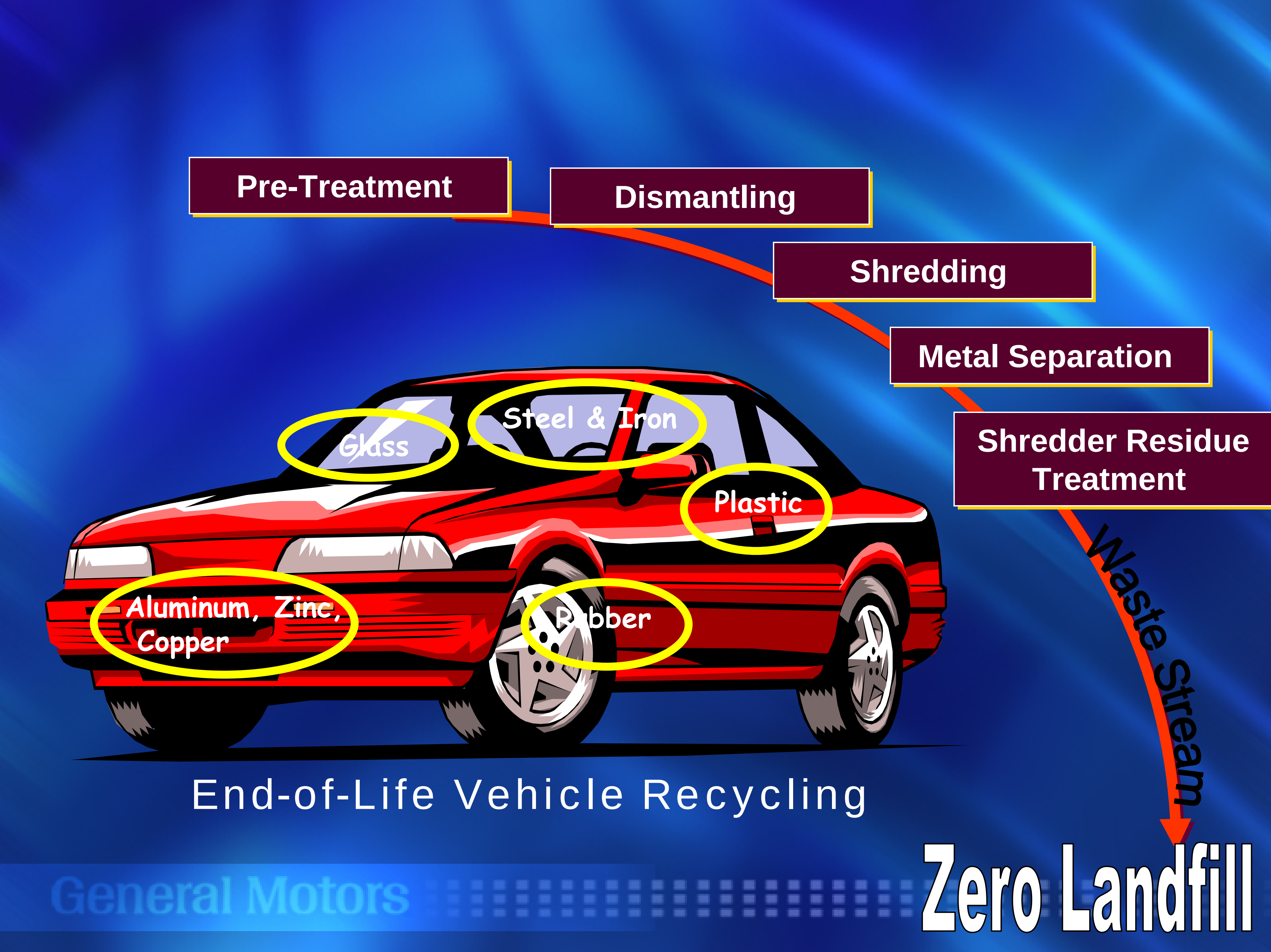
- Embrace sustainable development
- Committed to integrating
  - Economic
  - Environmental
  - Social objectives
- All areas of our business
  - Long term planning
  - Daily business decisions

Achieving this goal requires innovative thinking and action at all stages of the product life cycle

Material Production → Manufacturing → Use → End of Life

End of Life Vehicle Disposition

- Approximately 15 million vehicles reach the end of their useful life each year
- 95 % of these vehicles enter a complex infrastructure designed to recover materials of value
- 75 - 80% of the vehicle (primarily ferrous and nonferrous metals) are recovered while 20 – 25% of the vehicle is currently sent to landfill


Pre-Treatment
Dismantling
Shredding
Metal Separation
Shredder Residue Treatment
Steel & Iron
Glass
Plastic
Aluminum, Zinc, Copper
Rubber
Waste Stream
End-of-Life Vehicle Recycling
General Motors
Zero Landfill

Vehicle Recycling Drivers

- Regulation (EU ELV Directive)
  - No cost vehicle take back
  - Recovery quotas (85% 2006 and 95% 2015)
  - Material restrictions (SOCs)
  - Similar regulation in Japan, Korea, and China
- Pro-active Position in NA
- Optimal Resource/Material Use
- Environmental Impact (LCA)
- Customer Persception

Current Issues

- Advanced automotive designs and complex and lightweight materials will continue to present new recycling challenges
- Development of technology to recycle today's materials will provide the basis for recycling of future materials
- Focus should be on post-shredder technology demonstration
- The recyclability of ELV is presently limited by the lack of proven technologies to cost-effectively recycle SR
  - Separate and sort materials for material recycling
  - Thermochemically conversion to fuels
- Industry-wide collaboration is needed

CRADA

This work was done as part of a 5-year Cooperative Research and Development Agreement (CRADA) between

- **USCAR Vehicle Recycling Partnership (VRP)**
- **American Plastics Council (APC)**
- **DOE/Argonne National Laboratory (ANL)**

CRADA Purpose

- The purpose of the CRADA is to address the **sustainable recycling of future vehicles** from not only a **technical** prospective but an **economic** and **environmental** prospective as well

- To promote sustainable solutions, a life cycle approach (LCA) is used to assess the environmental burdens associated with various end of life options

CRADA Objectives

- Maximize Sustainable Recycling of Current and Future Automotive Materials
  - Ensure that all materials can be cost-effectively recycled
  - Ensure that materials are not de-selected due to the lack of recyclability
  - Ensure that recycling options minimize environmental impacts over the entire life cycle
  - Meet demands for SOC treatment

End of Life Model Development

Our goal is **to develop a modular, end of life, life cycle model** to help us better understand the environmental impacts of various EoL technology options

Specific LCAs Performed

- Mechanical separation processes (Salyp) (ANL)
- Thermoconversion processes (CWT)
- Comparative LCA (Salyp/CWT)
- Renewable materials (bioplastics)
- Hybrid batteries
- End of life infrastructure

Salyp's Mechanical Separation

Salyp NV, formerly located in Ypers, Belgium, developed a mechanical separation process to separate various material fractions from shredder residue


Shredder


Shredder Residue


Mixed Plastics


Foam


Fibers


Metals


Rubber


Wood

Salyp – Boundary Conditions

Emissions to air, water & soil

System boundary LCI model

GaBi
•Energy
•Transportation
•Materials

Sorted fractions

Emissions to air, water & soil

System boundary Salyp

SR

Inputs

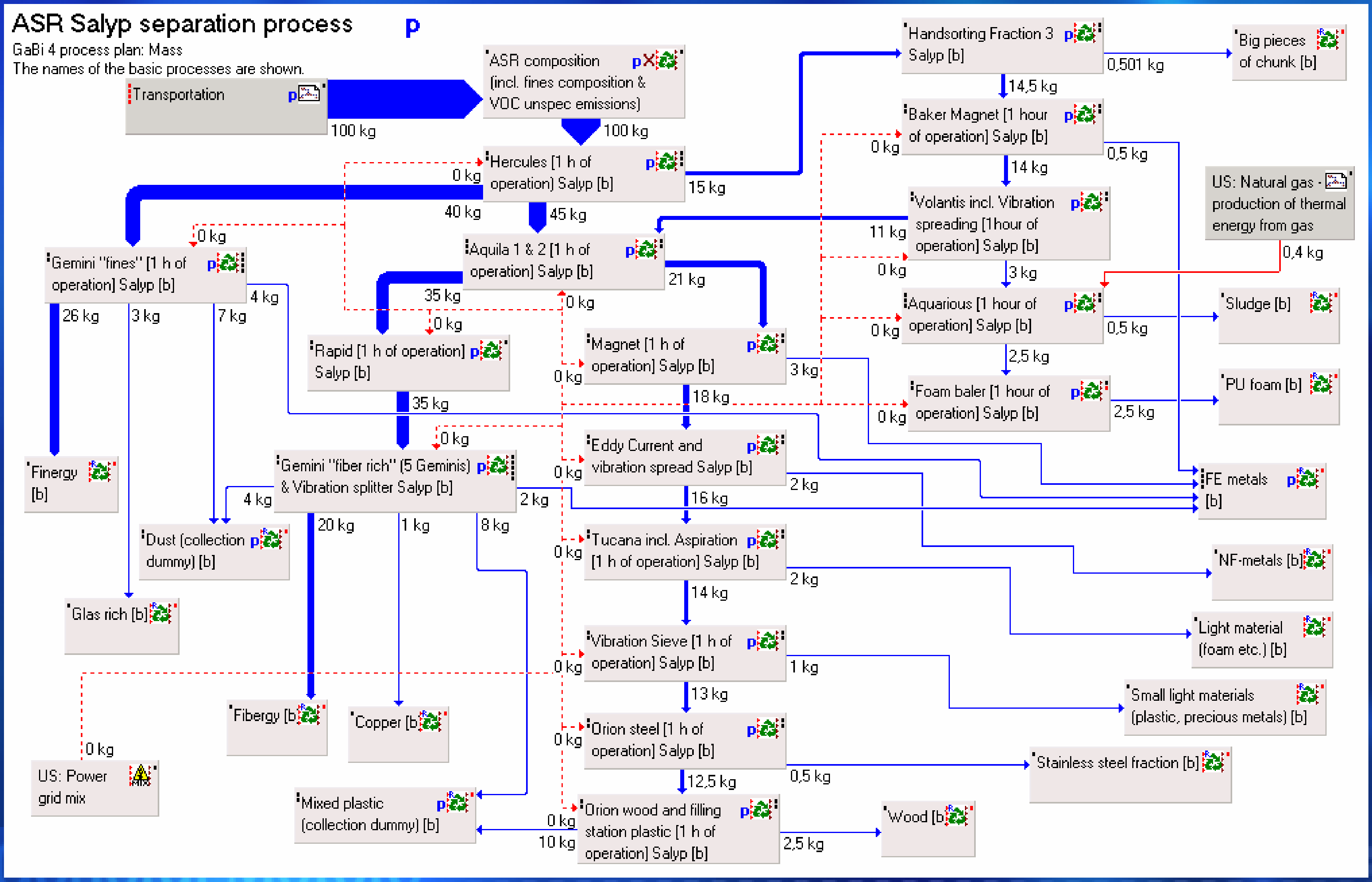
Material Composition of SR

Material	Percentage of SR
plastics	34,0%
Fe-metals	33,4%
sand, dirt	15,7%
unknown	4,0%
glass	3,4%
wood	2,8%
PU foam	2,8%
NF-metals	2,2%
copper	1,1%
stainless steel	0,6%

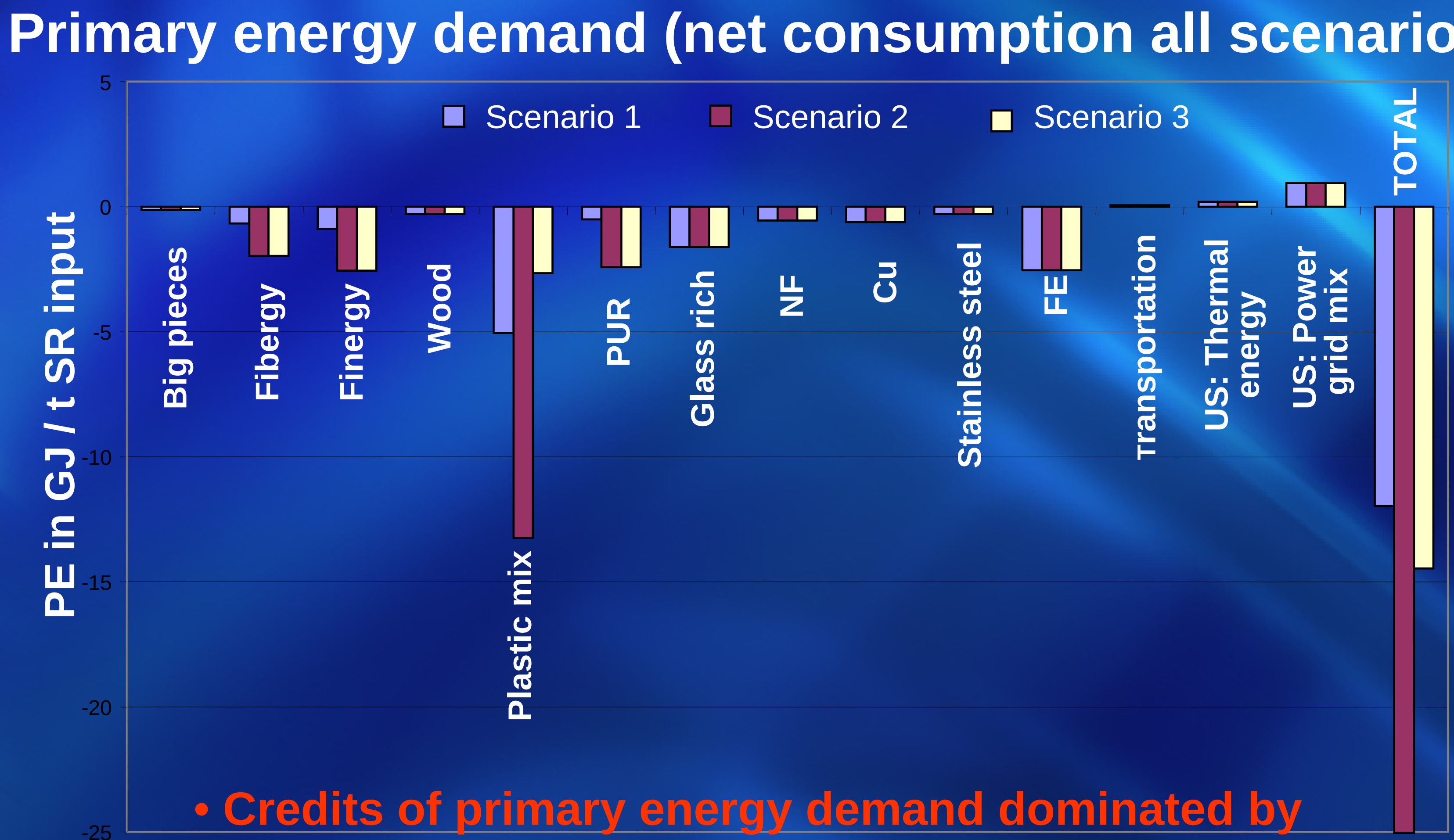
Scenarios Used for Salyp LCI

Separated fraction	Scenario 1	Scenario 2	Scenario 3
Ferrous metals	material recycling	material recycling	material recycling
Nonferrous metals	material recycling	material recycling	material recycling
Copper	material recycling	material recycling	material recycling
Fibergy	energy recovery	oil (cement kiln)	oil (cement kiln)
Finergy	energy recovery	oil (cement kiln)	oil (cement kiln)
Clean PU foam baled	energy recovery	material recycling	material recycling
Recovered glass	material recycling	material recycling	material recycling
Mixed plastic	**energy recovery**	**PP pellets**	**wood pallets**
Stainless steel	material recycling	material recycling	material recycling
Big pieces -hand sorted 50% plastic & 50% Fe	plastic -energy recovery Fe metals -material rec.	plastic -energy recovery Fe metals -material rec.	plastic -energy recovery Fe metals -material rec.
Wood	energy recovery	energy recovery	energy recovery

Mass Flow: Salyp Process

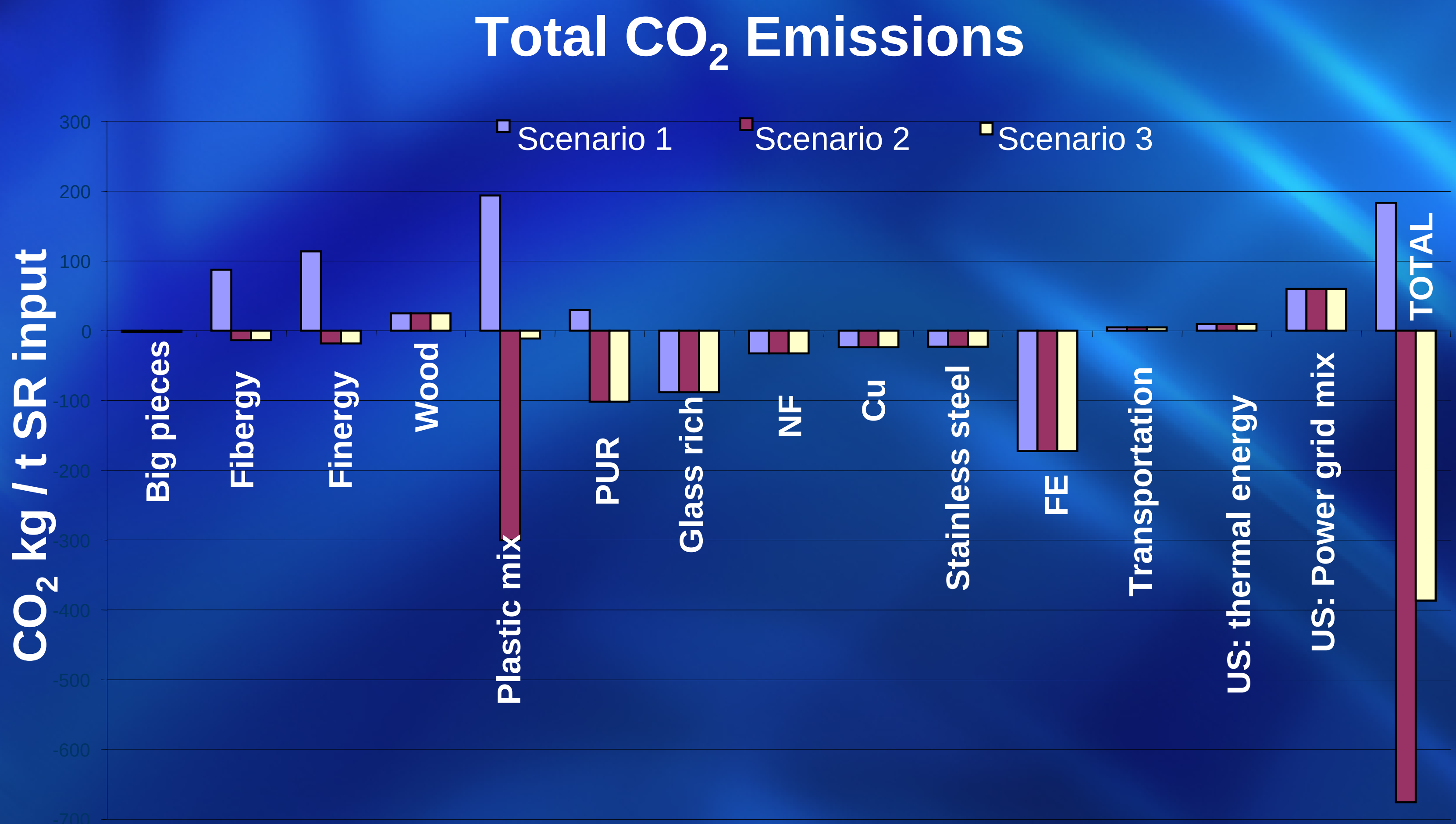


Total Energy Use: Salyp Process



- Credits of primary energy demand dominated by handling of mixed plastic fraction
- Incineration has less potential than material recycling

CO_2 Emissions: Salyp Process



- **Focusing on CO_2 emissions, material recycling shows advantages over energy recovery**

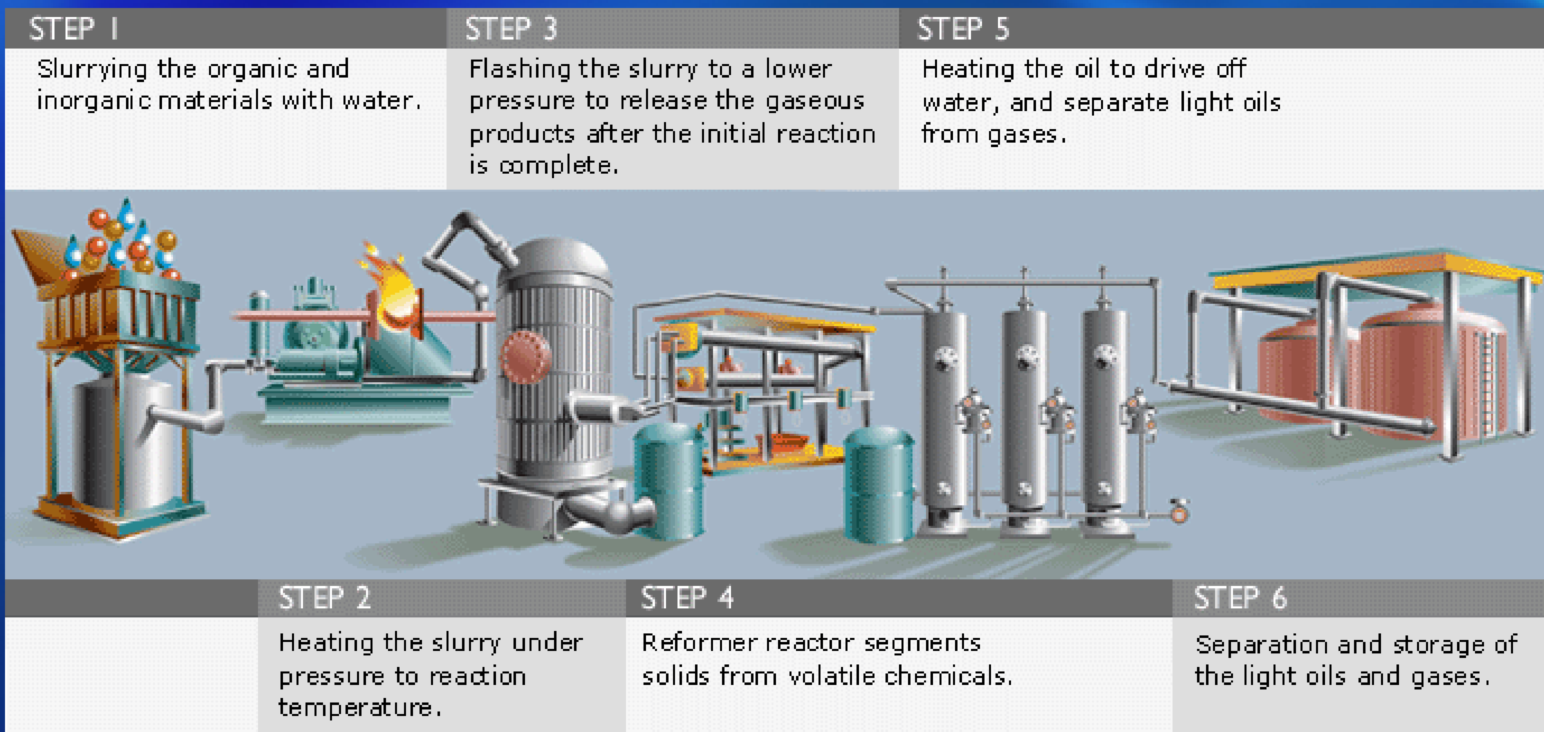
Summary of Salyp LCA

The analysis of the Salyp module showed that:

- The contribution of the separated material fractions is different for various impact categories or specific emissions
- Considering the total life cycle and analyzing different scenarios helps maximize the environmental credit and may prevent a shift of burdens

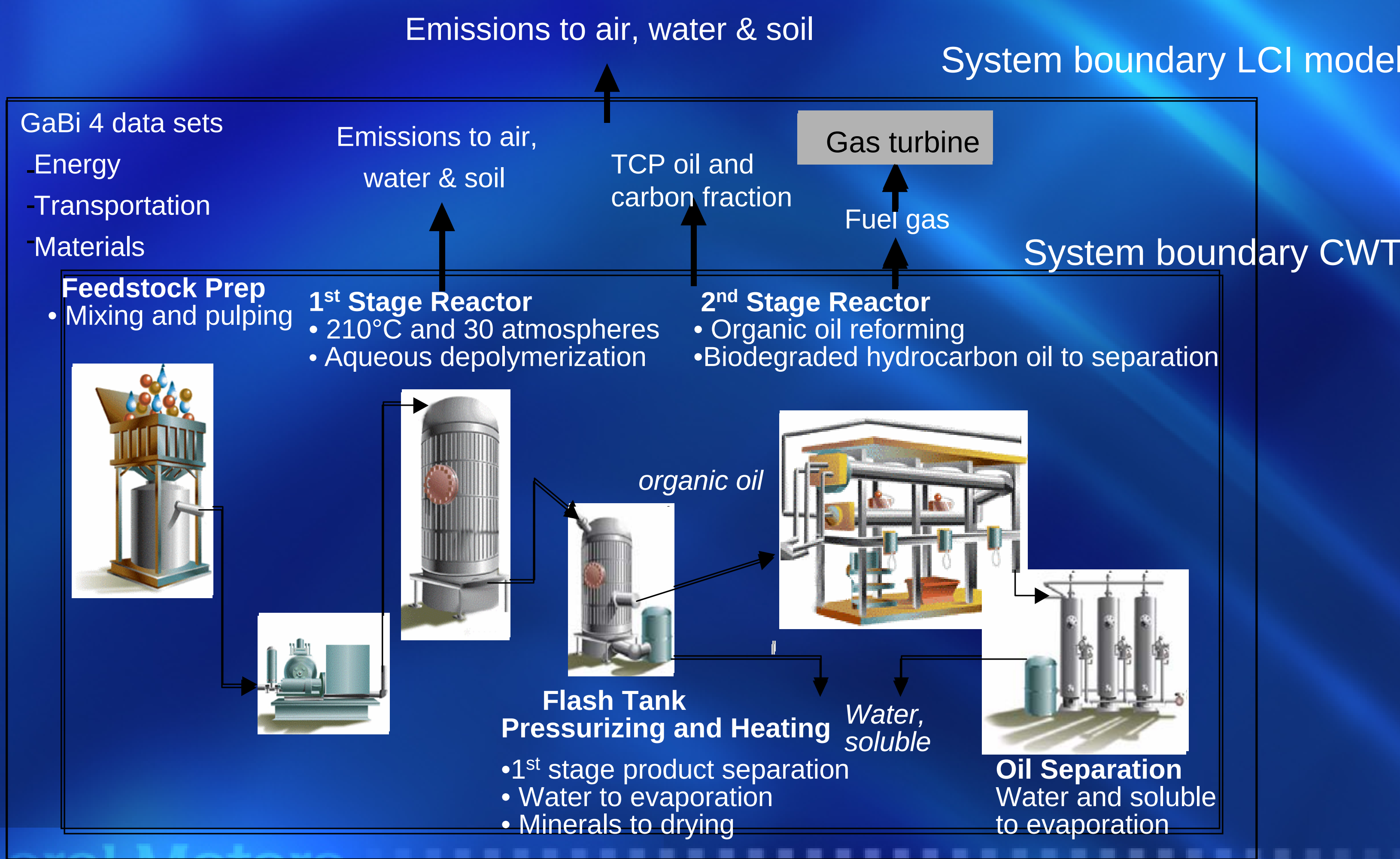
CWT's Thermoconversion Process

Changing World Technologies' thermal conversion process (TCP) converts organic material and hydrocarbons into fuels and other valuable products using water, heat, and pressure.



Distillation Cut	Industrial Uses	Temperature Range
Light Distillate	Gasoline; motor fuel	122-302F
Middle Distillate	Kerosene; jet fuel	302-482F
Diesel	Diesel fuel; heating oil	482-644F
Heavy Fuel Oil	Lubrication oil; industrial fuel	644-676F

CWT – Boundary Conditions



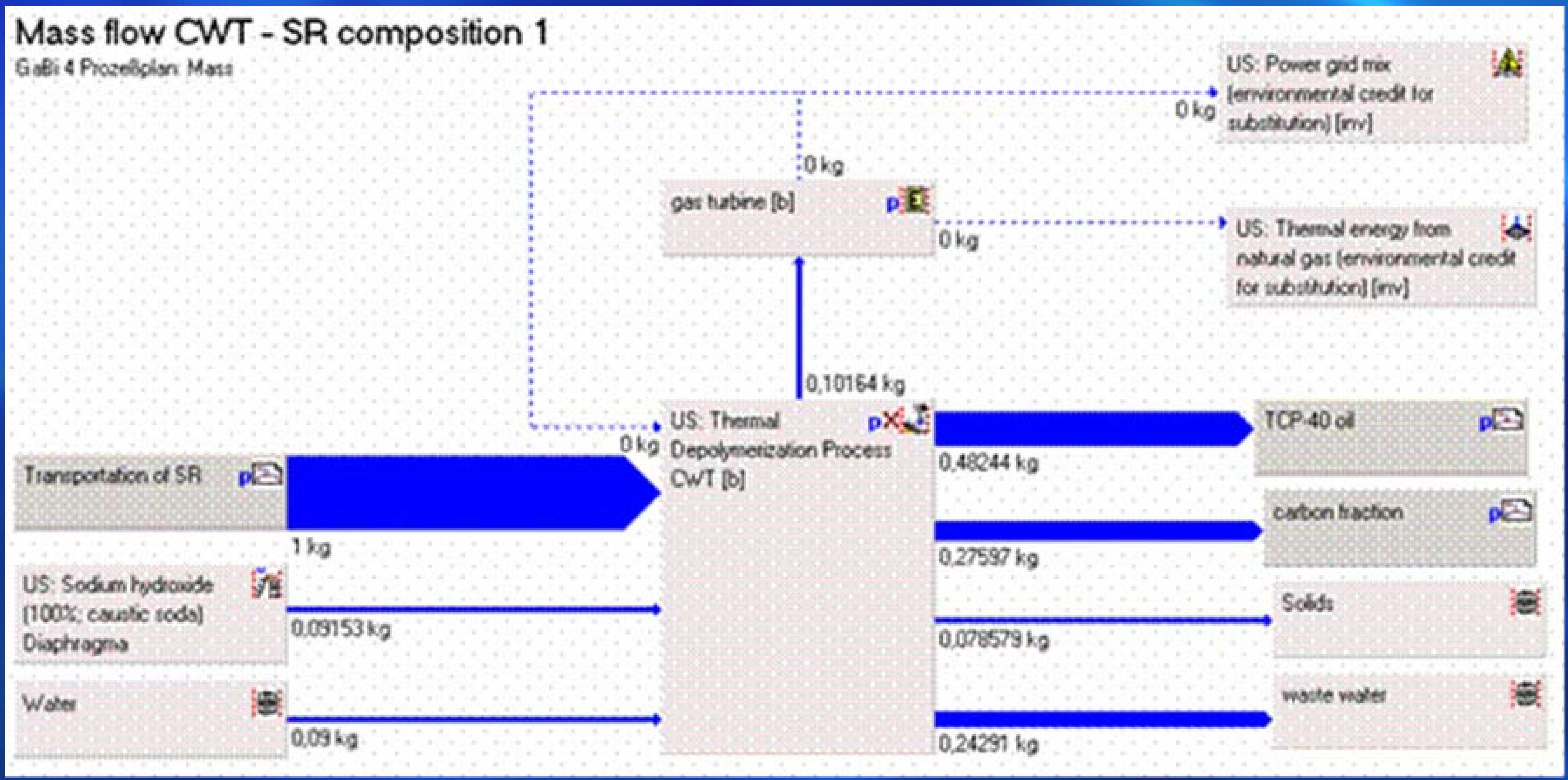
Material Composition of SR

SR Composition	1	2
Hydrocarbon Polymers	62,7%	76,59%
Condensation Polymers	4,3%	0,73%
Chlorinated Polymers	6,2%	3,68%
Ligno-cellulosics	0,8%	3,58%
Tires	14,0%	0,00%
PCB's	0,01%	0,00%
Insoluble	1,99%	5,42%
Water	10,00%	10,00%

Scenarios Used for CWT LCI

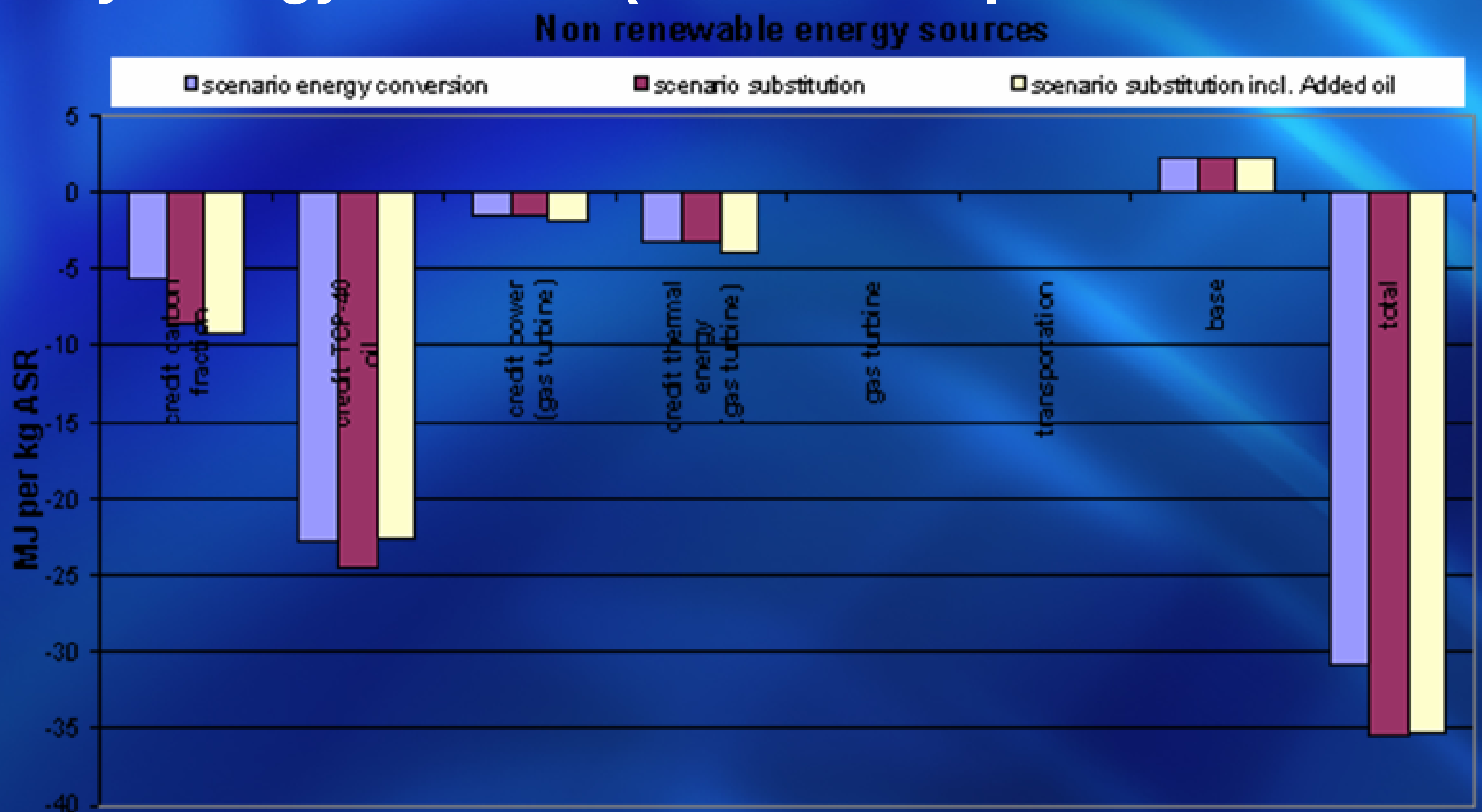
Produced fraction	Scenario 1	Scenario 2
fuel gas	energy conversion - gas turbine	energy conversion - gas turbine
TCP-40 oil	fuel oil used in electrical power	substitution of diesel
carbon	hard coal used in electrical power generation	substitution of carbonized coal - input activation process of activated carbon production
solids	waste for landfill	waste for landfill
waste water to waste water treatment	not connected output	not connected output

Mass Flow: CWT Process



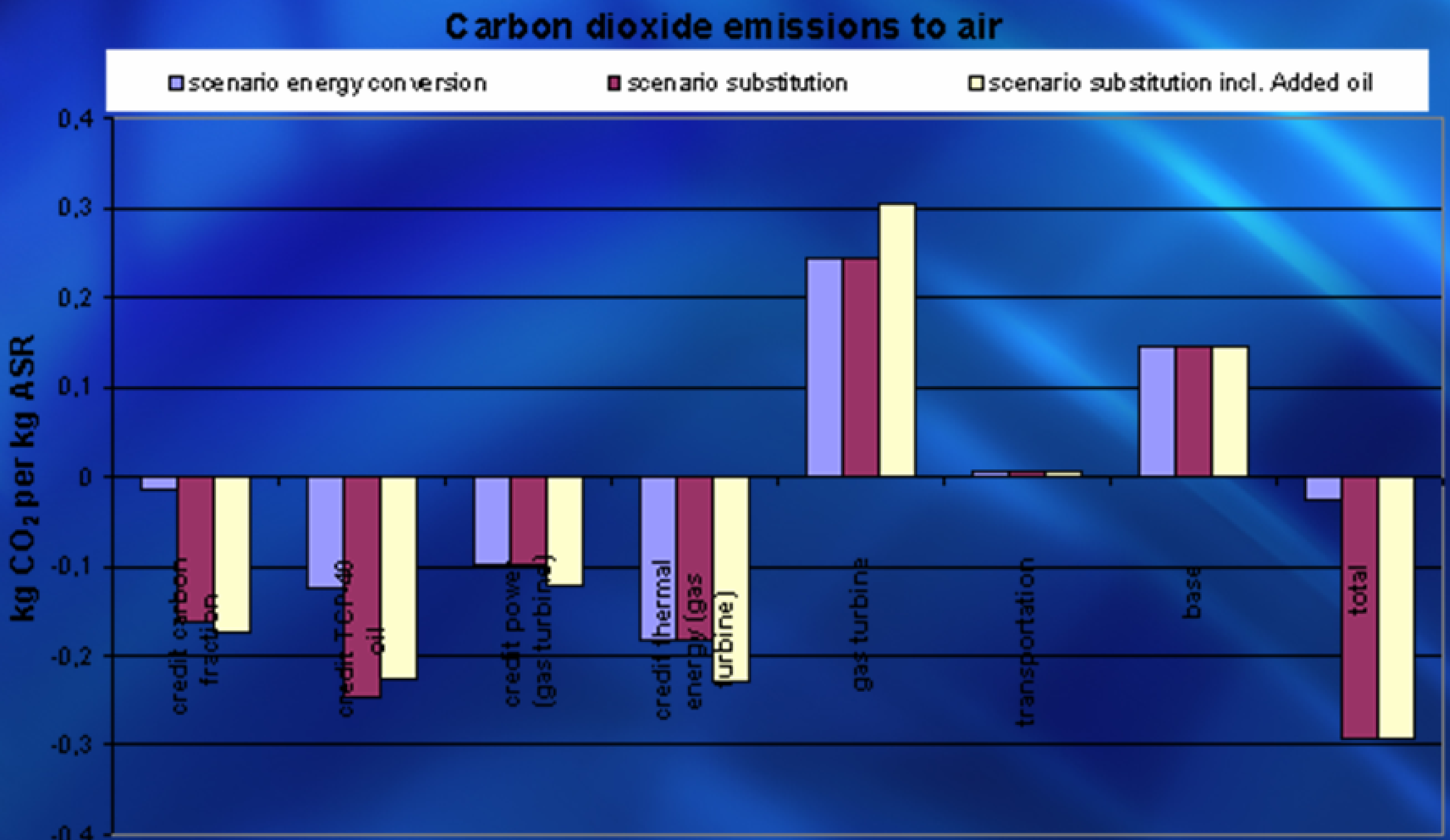
Total Energy Use: CWT Process

Primary energy demand (net consumption all scenarios)



- The influence of the transportation is not significant
- Energy conversion of products and substitution are within the same range
- Using TCP-40 oil internally does not affected overall PE, but shifts credits between fractions

CO_2 Emissions: CWT Process



- Material substitution shows advantages over energy recovery for CO2 emissions – carbonization of coal (coke production) and refinery
- Using TCP-40 oil internally does not really affected overall CO2 emission

Comparative Study CWT / Salyp

Output fraction	CWT	Salyp
Fuel gas	energy recovery	---
TCP-40 oil	energy recovery	---
Carbon	energy recovery	---
Solids	waste for landfill	---
Waste water	waste water	---
Ferrous metals	material recycling	material recycling
Nonferrous metals	material recycling	material recycling
Copper	---	material recycling
Fibergy	---	energy recovery
Finergy	---	energy recovery
Clean PU foam baled	---	energy recovery
Recovered glass rich	---	material recycling
Mixed plastic	---	energy recovery
Stainless steel	---	material recycling
Big pieces - hand sorted 50 % plastic / 50 % Fe	---	plastic - energy recovery Fe metals - material rec.
Wood	---	energy recovery

SR Compositions

SR Composition	Characterization analysis by ANL of different shredders	Characterization analysis by MBA adjusted to 30 % Fe, 2,5 NF and 9,9% moisture
polymer fraction	38,5%	32,4%
Fe-metals	31,8%	29,9%
sand, dirt	6,3%	6,3%
unknown	0,9%	0,6%
glass	2,1%	0,0%
wood	4,4%	10,5%
PU foam	3,7%	7,8%
NF-metals	2,3%	2,6%
copper		
stainless steel		
moisture	9,9%	9,9%

General Motors

Process Boundary Conditions

Salyp:

- The energy needed to clean the PU foam was not been considered, as the foam is handled by energy recovery
- Contamination (diesel and gasoline) is emitted during the process

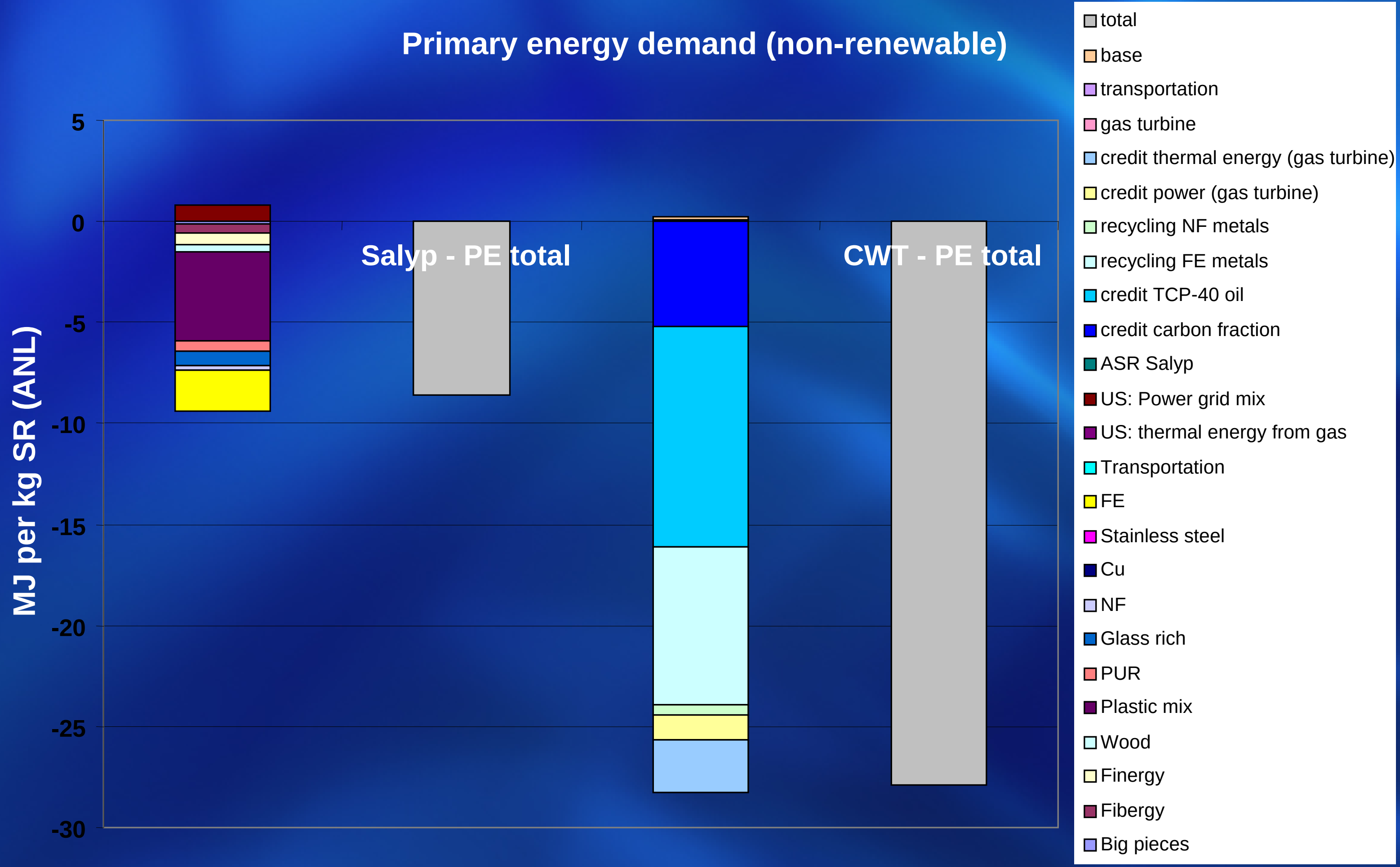
CWT:

- Efficiency of dissolver recovering solids (metals, stones etc.) has been assumed 95%
- During the process no emissions occur and it has been assumed the the solvent emissions during storage can be captured
- No extra energy besides 10% of hot TCP-40 oil has been considered for running the dissolver
- Power needed is produced internally by a gas turbine using fuel gas

Results – Processing 1 kg ANL SR

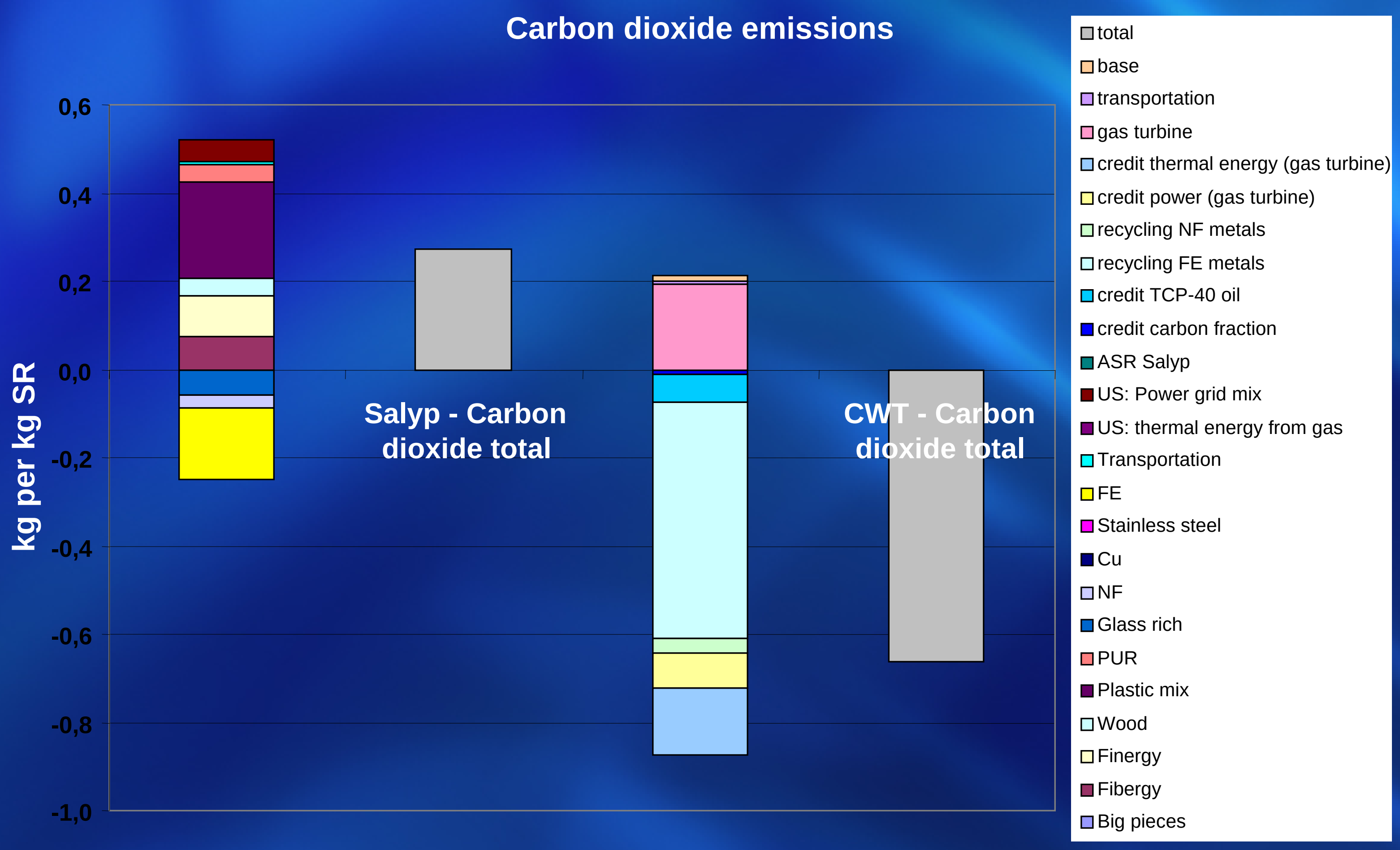
per kg processed SR (ANL)	Salyp without Aquarius	CWT	Comment
power	0,22 MJ	0,007 MJ	CWT - produced internally
natural gas	---	none	
base	---	0,0075 kg	depending on chlorine content
steam	0,099 kg	---	Salyp: moisture
waste water	---	0,163	Salyp: for energy recovery no extra cleaning is assumed CWT: amount of waste water depends on moisture content; additional water is added to the process
dust	0,11 kg	---	Salyp: 11 % of processed SR
sludge		---	Salyp: no washing of foam assumed, therefore no sludge
solvent emissions	0,007 kg	---	Salyp: according to contamination by fuel and diesel (added to SR weight) CWT: there might be solvent emission during storage
fuel gas	---	0,085 kg	depend on organic content of SR input
TCP-40 oil	---	0,225 kg	depend on organic content of SR input
carbon	---	0,133 kg	depend on organic content of SR input
FE metals	0,09 kg	0,302 kg	more than 2/3 of the metal input ends up in fines
NF metals	0,02 kg	0,022 kg	
Organics for energy recovery	0,31 kg	---	
Fines and fibers	0,382 kg	---	60 % metals, 25 % organics and 15 % sand, dirt etc.
glass for recovery	0,019 kg	---	Salyp: recovered because of solver content
solids	---	0,137 kg	CWT: is should be checked if silver from glass rich fraction can be recovered

Primary Energy Demand

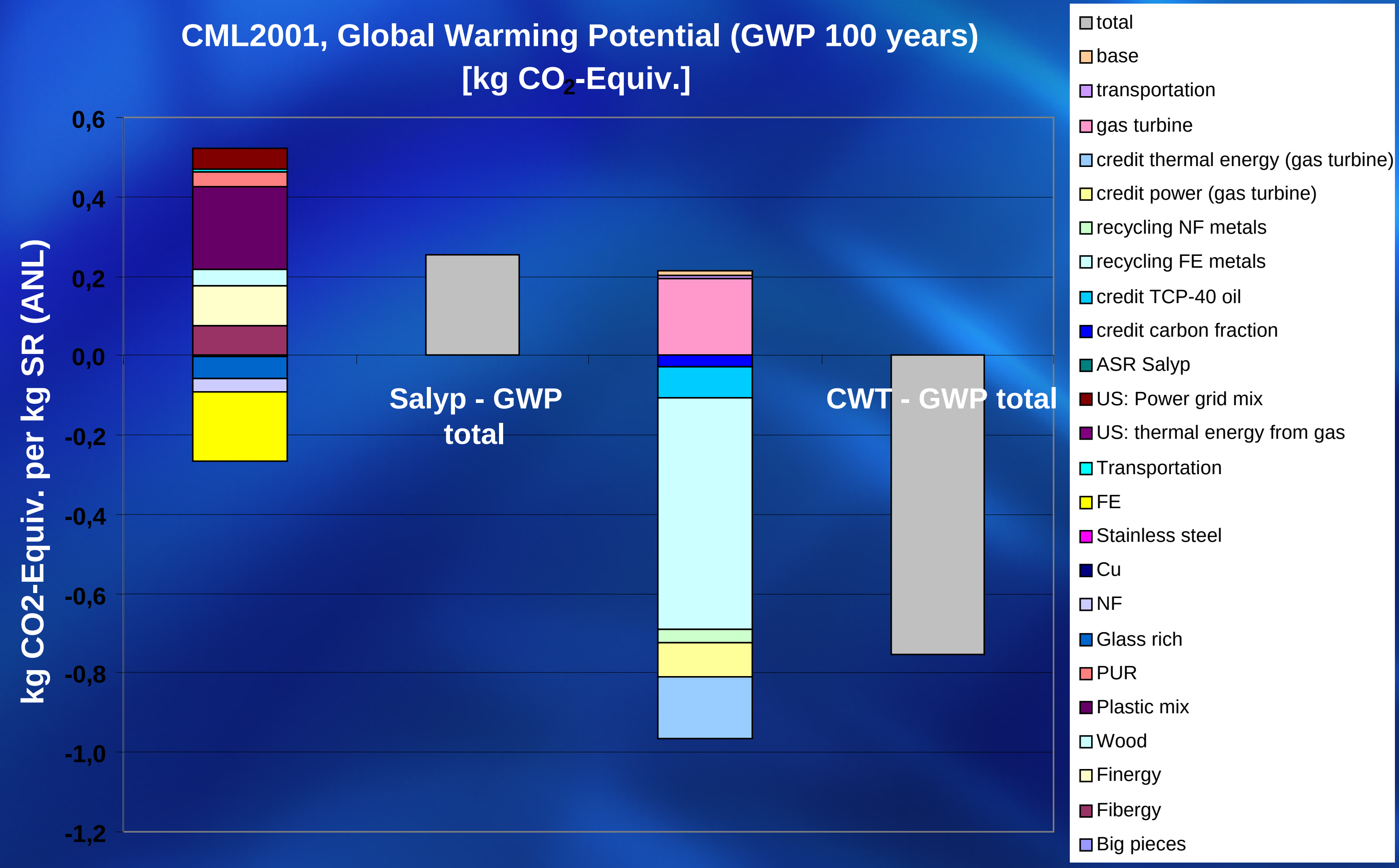


The credit for the organic fraction is more than double for CWT than for Salyp

CO_2 Emissions

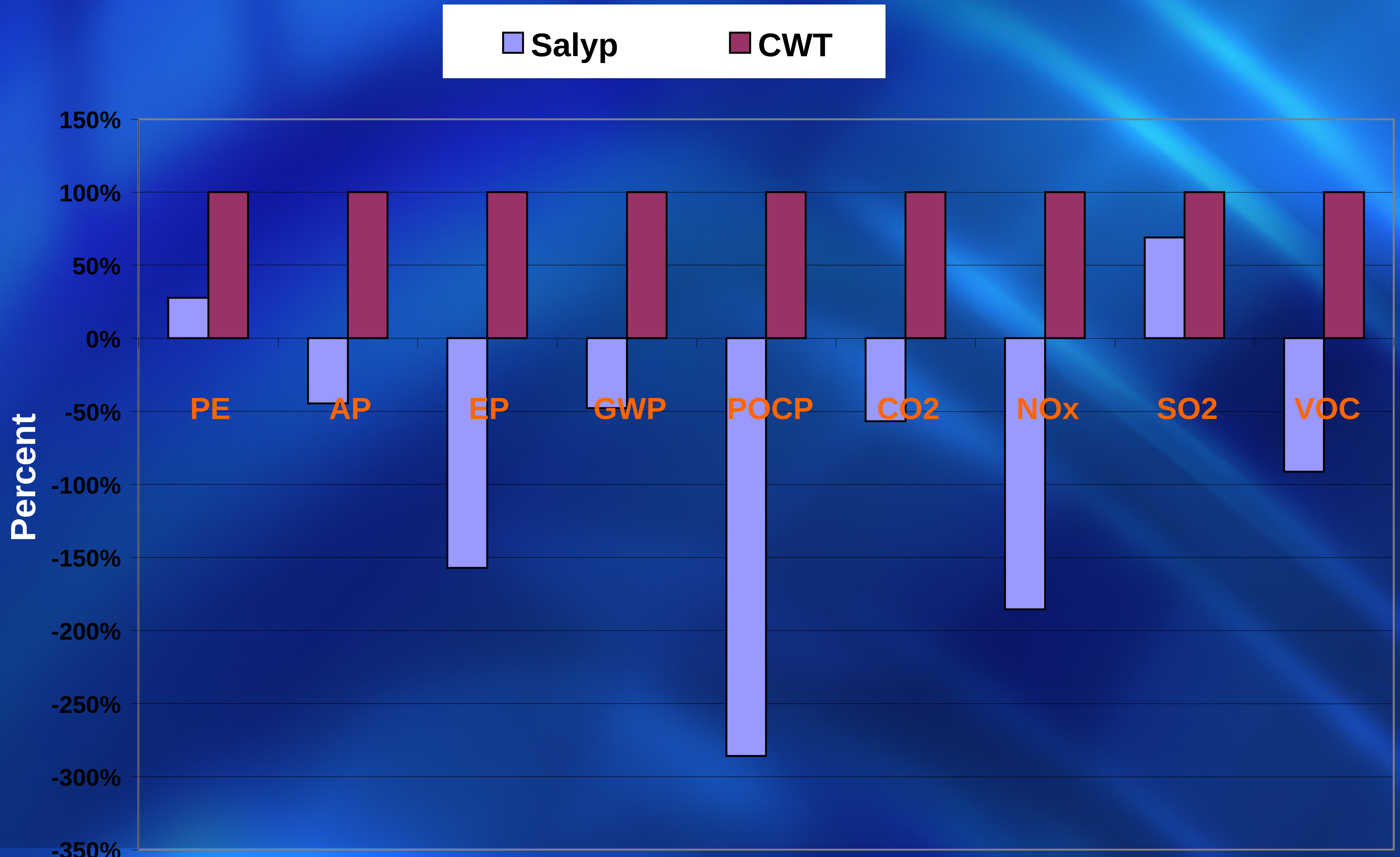


GWP



CML2001, Global Warming Potential (GWP 100 years)
[kg CO_2-Equiv.]
kg CO2-Equiv. per kg SR (ANL)
0,6
0,4
0,2
0,0
-0,2
-0,4
-0,6
-0,8
-1,0
-1,2
Salyp - GWP total
CWT - GWP total
total
base
transportation
gas turbine
credit thermal energy (gas turbine)
credit power (gas turbine)
recycling NF metals
recycling FE metals
credit TCP-40 oil
credit carbon fraction
ASR Salyp
US: Power grid mix
US: thermal energy from gas
Transportation
FE
Stainless steel
Cu
NF
Glass rich
PUR
Plastic mix
Wood
Finergy
Fibergy
Big pieces

Summary 1 kg SR



Comparison Conclusions

- Thermoconversion (CWT) shows an overall environmental benefit for all considered environmental issues over mechanical separation (Salyp)
- Benefits are dependent on the use of the output products
- Direct solvent emissions are crucial
- To increase the benefits of the Salyp process, the purity of the recovered fractions have to be increased and substitution applications found

Summary

- Changes in automotive materials and systems are anticipated in the future as we seek to increase fuel efficiency and decrease the consumption of imported petroleum
- These changes will require the development of new and advanced technologies for sustainable automotive materials recycling
- Ultimately, technical solutions to optimal ELV recycling must not only be environmentally beneficial but must also make good business sense
- Collaboration is the key to success in this endeavor
- Government and industry are working together to meet these challenges and to maintain sustainable automotive materials recycling

Thank you for your attention!