Assessment of Alternative Thermal Waste Treatment Technologies with focus on Chemical Recycling of Plastic Waste

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Institut für Technische Chemie (ITC)

Outline

I. Studies overview
II. Thermochemical Processes
III. Possibilities for process evaluation
IV. Examples for the different process types
V. An evaluation approach for mixed waste(MSW)
VI. Techno-Economical Assessment for Chemical Recycling of plastic waste fractions
VII. Conclusion

Project Teams

1.) Alternative Thermal Waste Treatment Technologies

for UBA / Germany

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2.) Thermal Processes for Chemical Recycling of Plastic Waste

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Projectpartner for Analysis of the plasic waste: CONVERSIO Market & Strategy

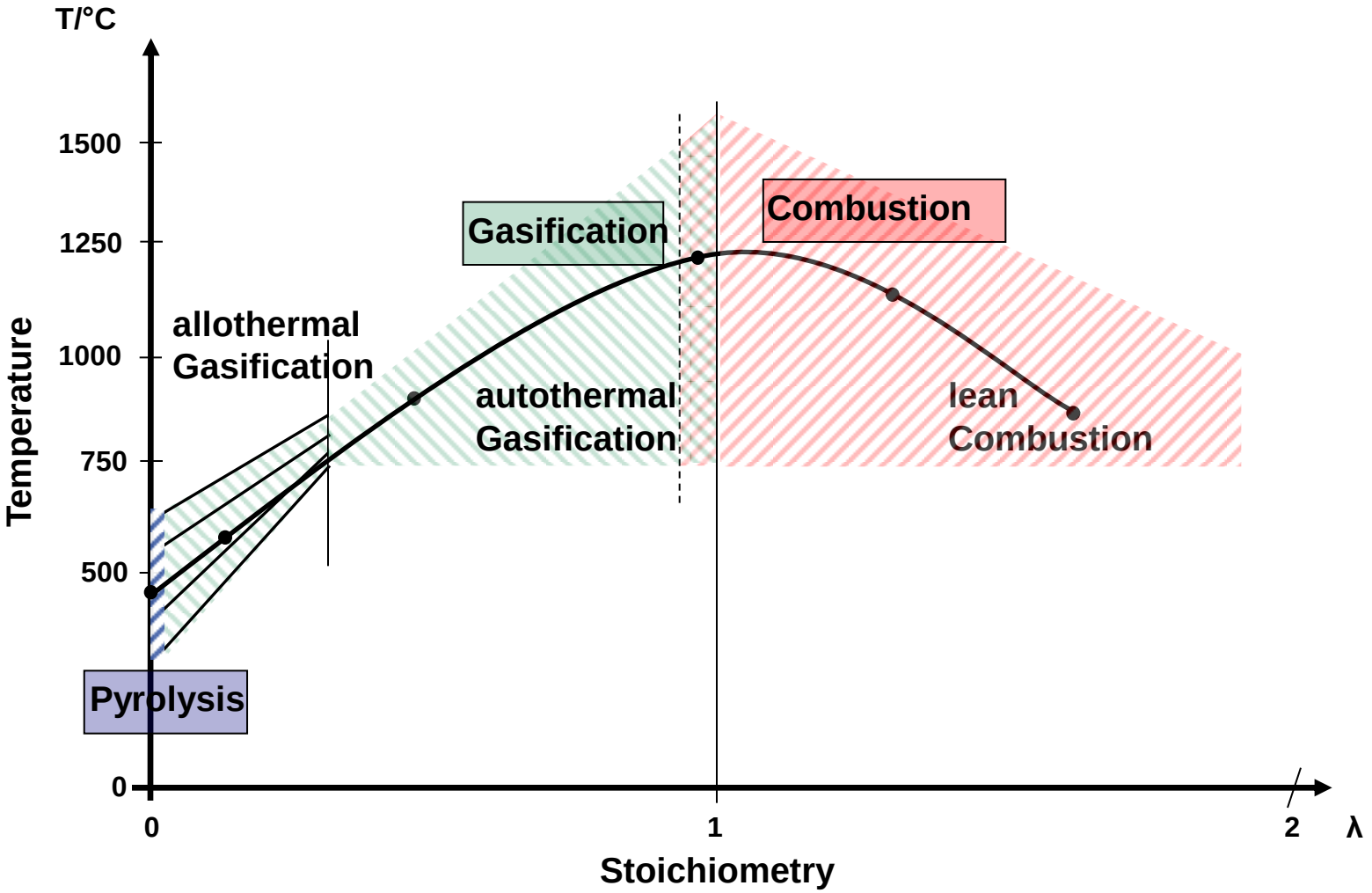
Projects Overview

- Projects goal
  - Evaluation of the state-of-the-art for Alternative Thermal Waste Treatment Processes
  - Evaluation of therm.Processes for chemical recycling of plastic waste
- Thematic focus
  - Mixed residual waste
  - Plastic waste fractions
- Geographical focus
  - Europe (esp. Germany) and Japan

- Method
  - Extended international literature study
  - Survey with questionnaire and interviews with suppliers and operators
  - Site visits in Germany (partly with product sampling)

Thermochemical Processes

High Temperature Processes



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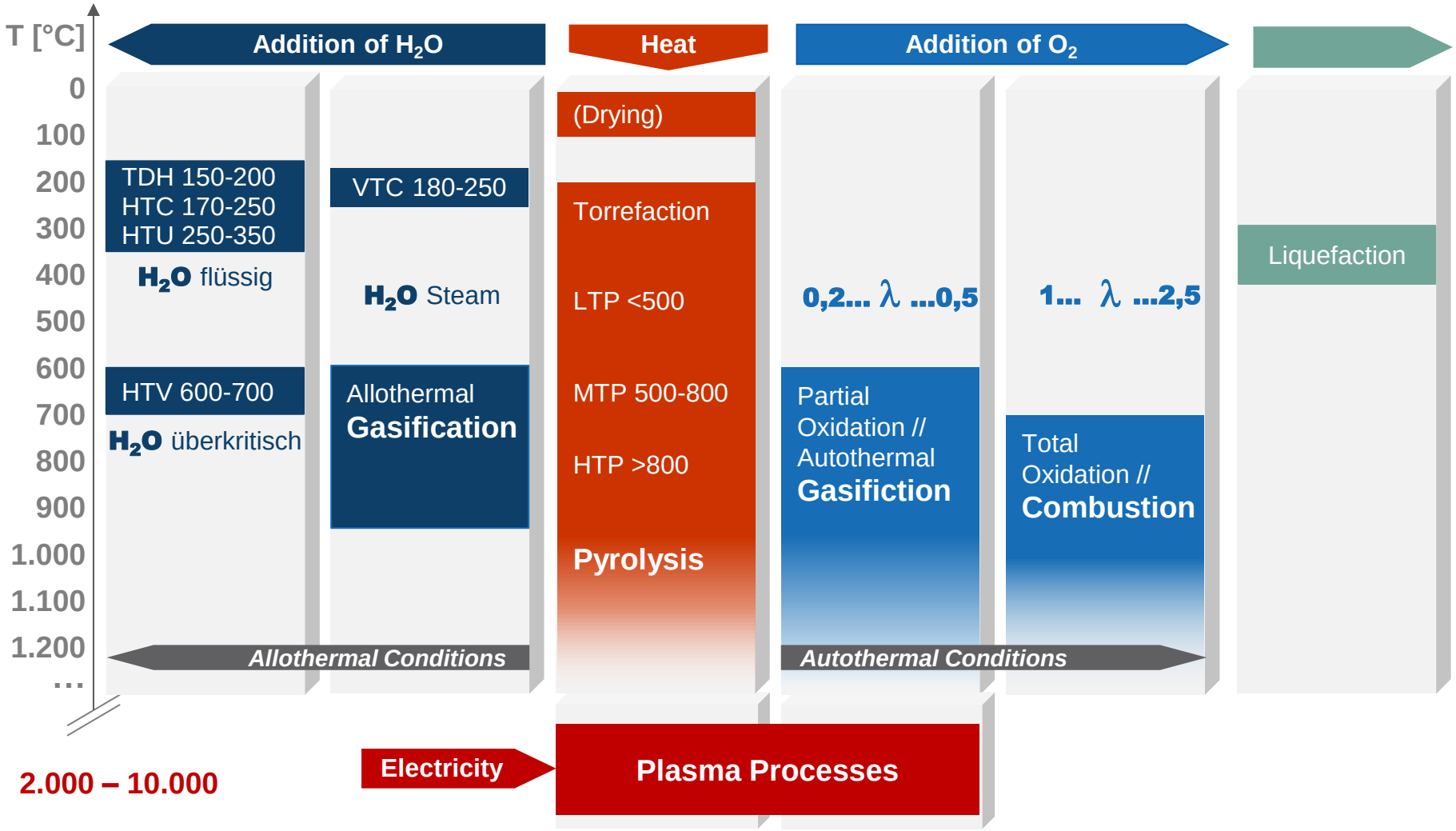
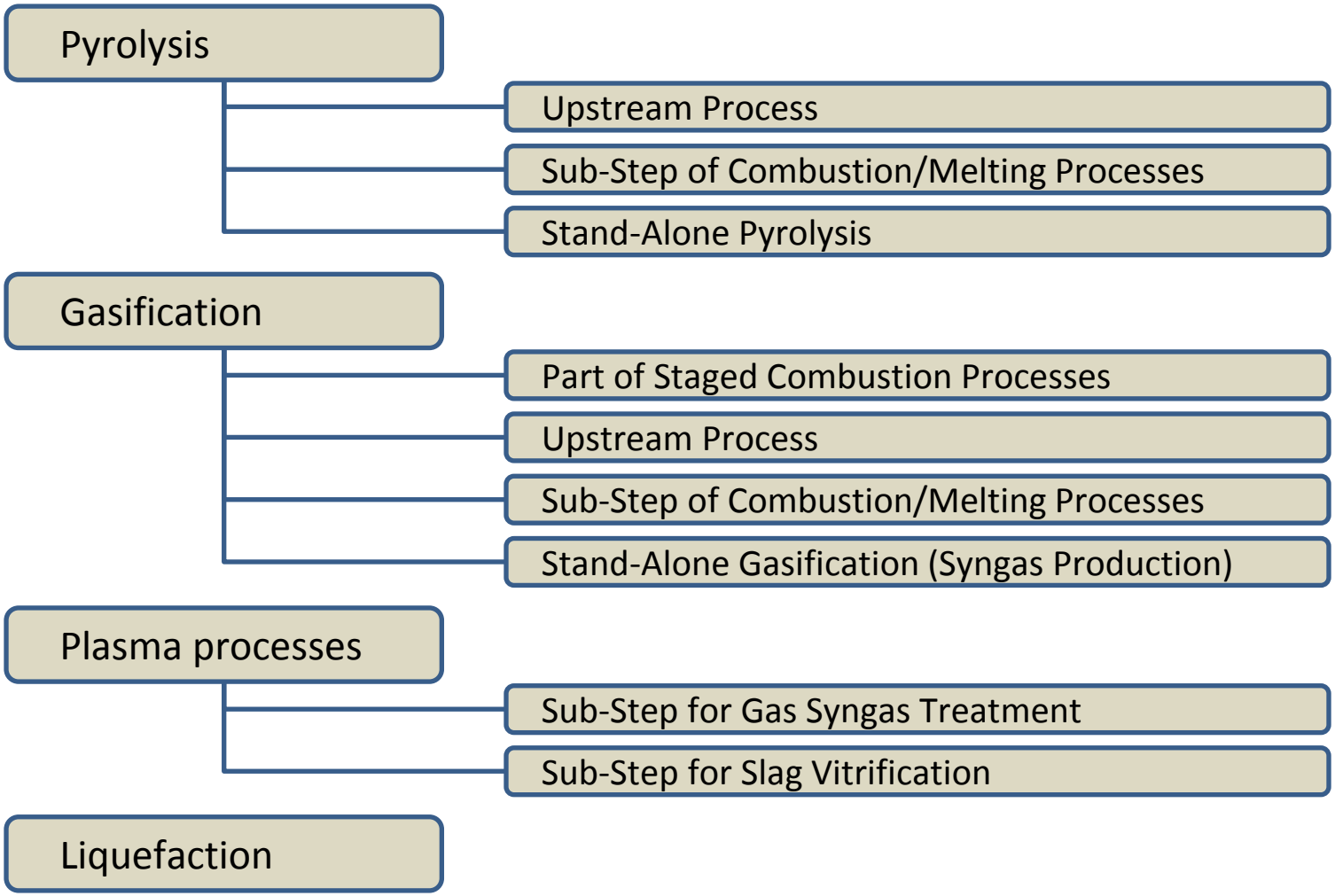
Classification of Thermochemical Processes



Classification of Alterantive Thermal Waste Treatment Processes



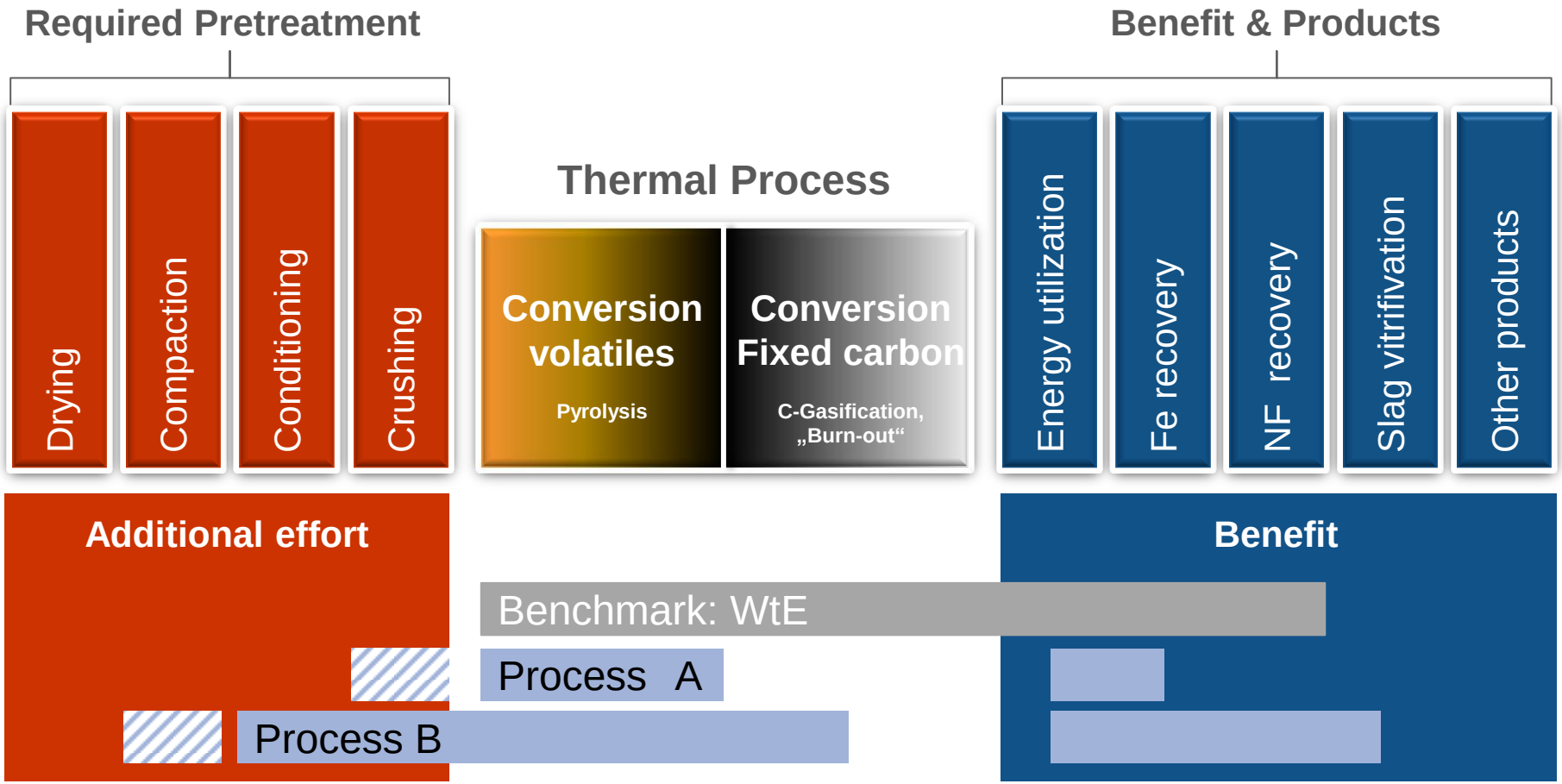
Possibilities for Process Evaluation

Development Status (VDI 3460)

DS	Criteria	Requirements
1	Plant/process	**Bench-scale tests**, **assessment of material and energy balances**
	Input/output materials	Descriptive analysis of input and output materials (quality/quantity)
	Market potential	Assessment of market potential of a full-scale plant based on bench-scale test results
	Scale-up	Description of risks and opportunities of a scale-up, design of a pilot plant
2	Plant/process	**Steady-state operation of a pilot plant**, **material and energy balances**
	Input/output materials	Analysis of input and output materials, discussion of input materials
	Market potential	Prediction of market potential of a full-scale plant
	Scale-up	Description of the technical conditions for a scale up, design of pilot plant
	Operation	Assessment of potential operating problems
3	Plant/process	**Stead-state operation of a pilot plant over a prolonged period, emission measurements,** validation of the material and energy balances derived from pilot-scale testing
	Input/output materials	Testing of the process-specific products for their environmental relevance and utilisation options
	Market potential	Description of market potential of a full-scale plant
	Scale-up	Technical and economic interpretation of the results related to a full-scale plant
	Operation	Assessment of expected run time, plant availability and service life of a planned full-scale plant
4	Plant/process	**Normal operation of a full-scale plant over a period of one to two years**, confirmation of material and energy balances, emission values
	Input/output materials	Demonstration of the suitability of the plant for the planned input materials, marketing potential
	Market potential	Validation of capital and operating costs (business plan)
	Operation	Demonstration of availability and runtime
5	Plant/process	**Normal operation of full-scale plant over several years**, assessment of environmental relevance of the process and plant
	Input/output materials	Demonstration of disposal of input materials, demonstration of the marketing of products
	Market potential	Traceable description of capital and operating costs over several years
	Operation	Optimisation of resource and energy efficiency, availability and runtime, e.g. by engineering, management and/or logistical measures

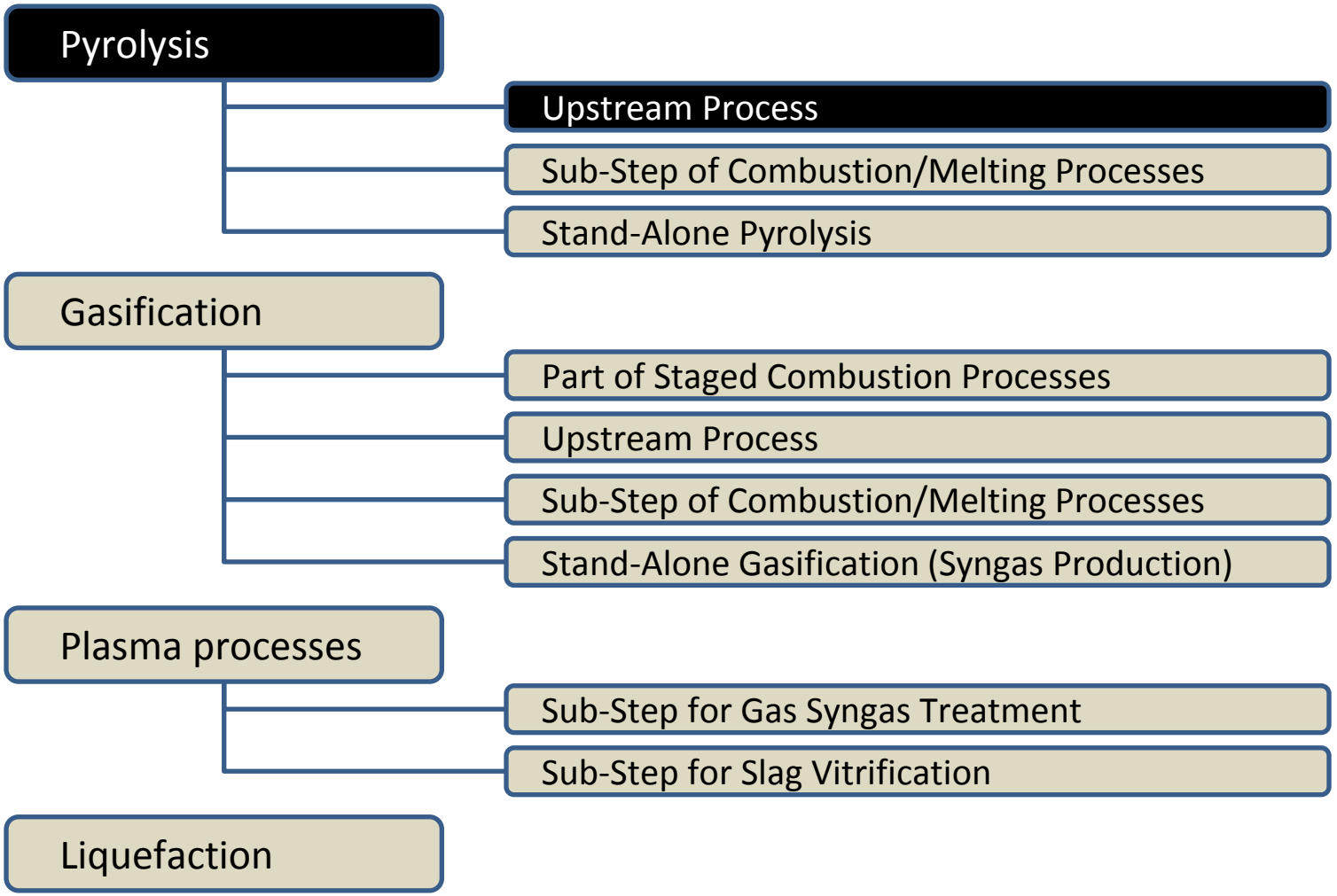
Complexity and Benefit of the Process

Characterization



Examples for some Processtypes

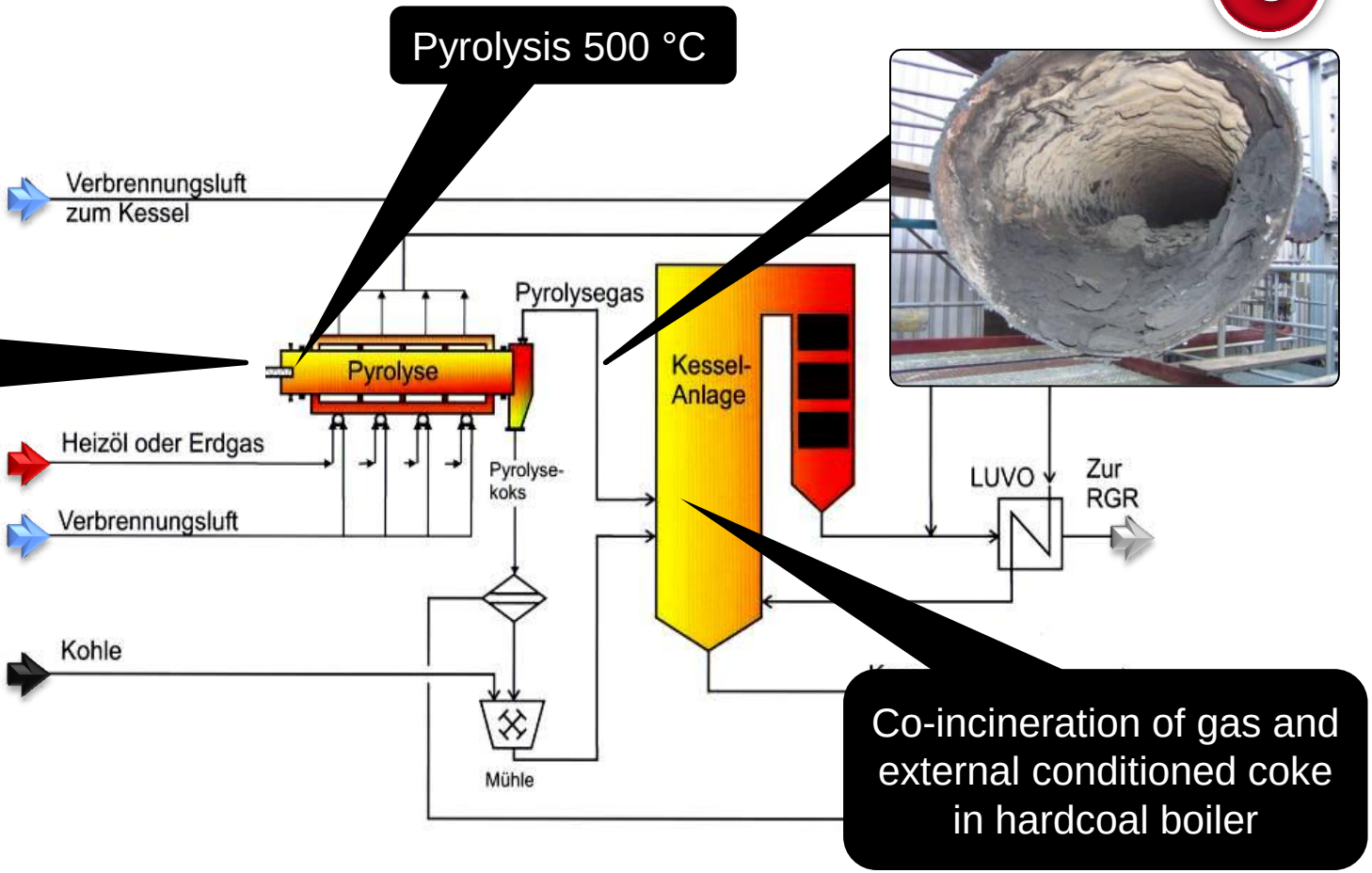
Classification



Pyrolysis – Upstream Process

Contherm Pyrolysis Hamm, Germany

DS 5



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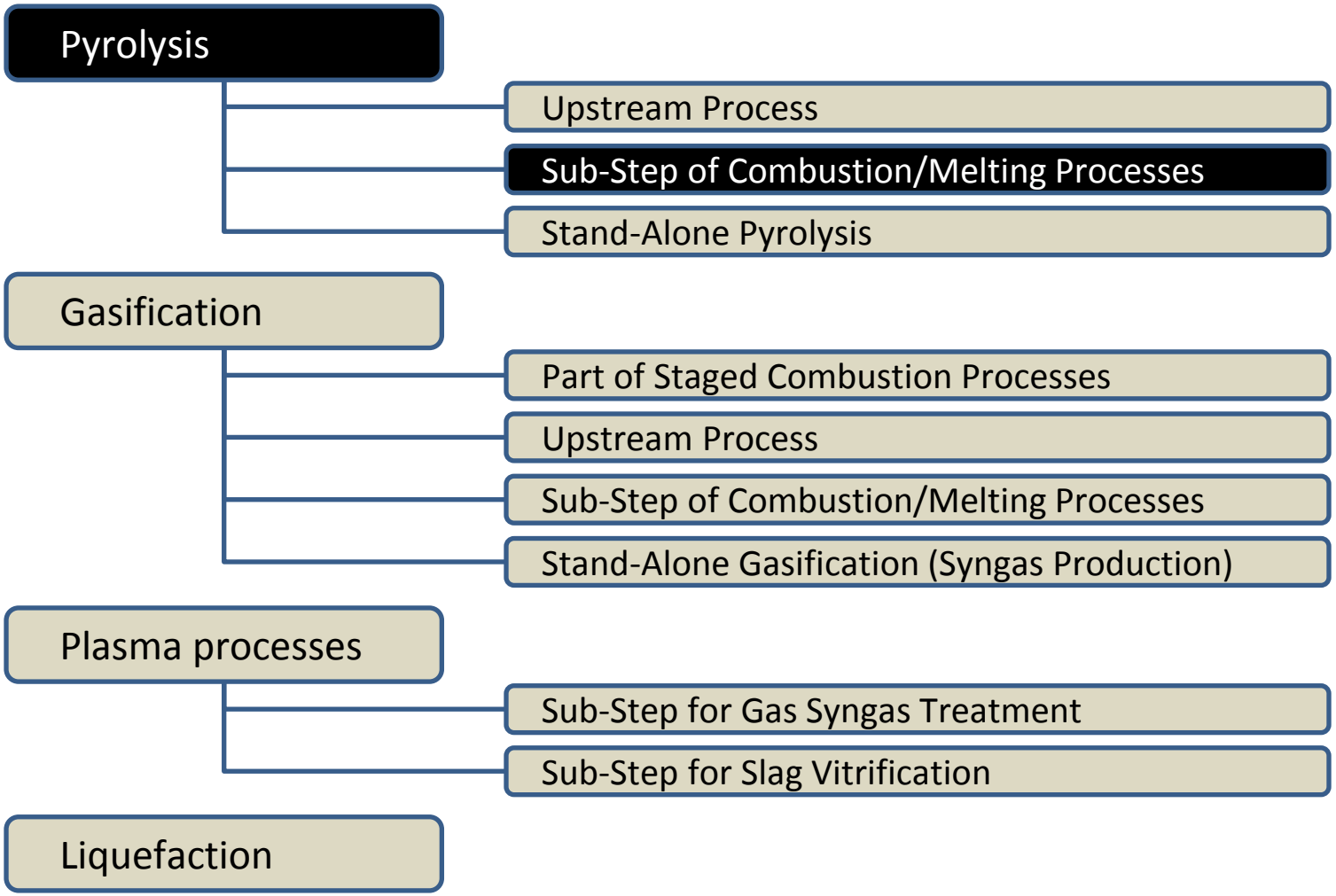
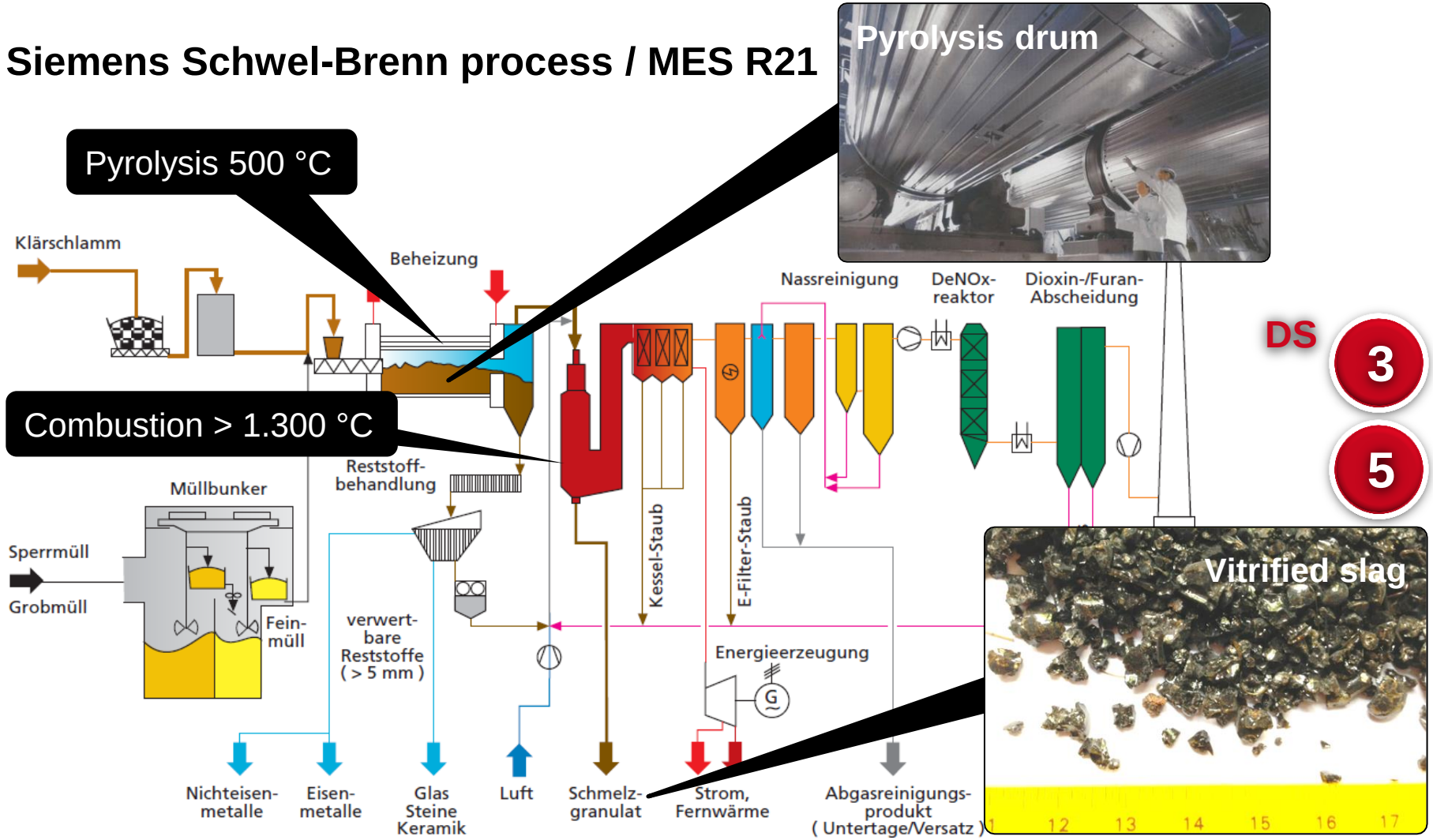


Pyrolysis – Sub-Step of Combustion/Melting Processes

Siemens Schwel-Brenn process / MES R21



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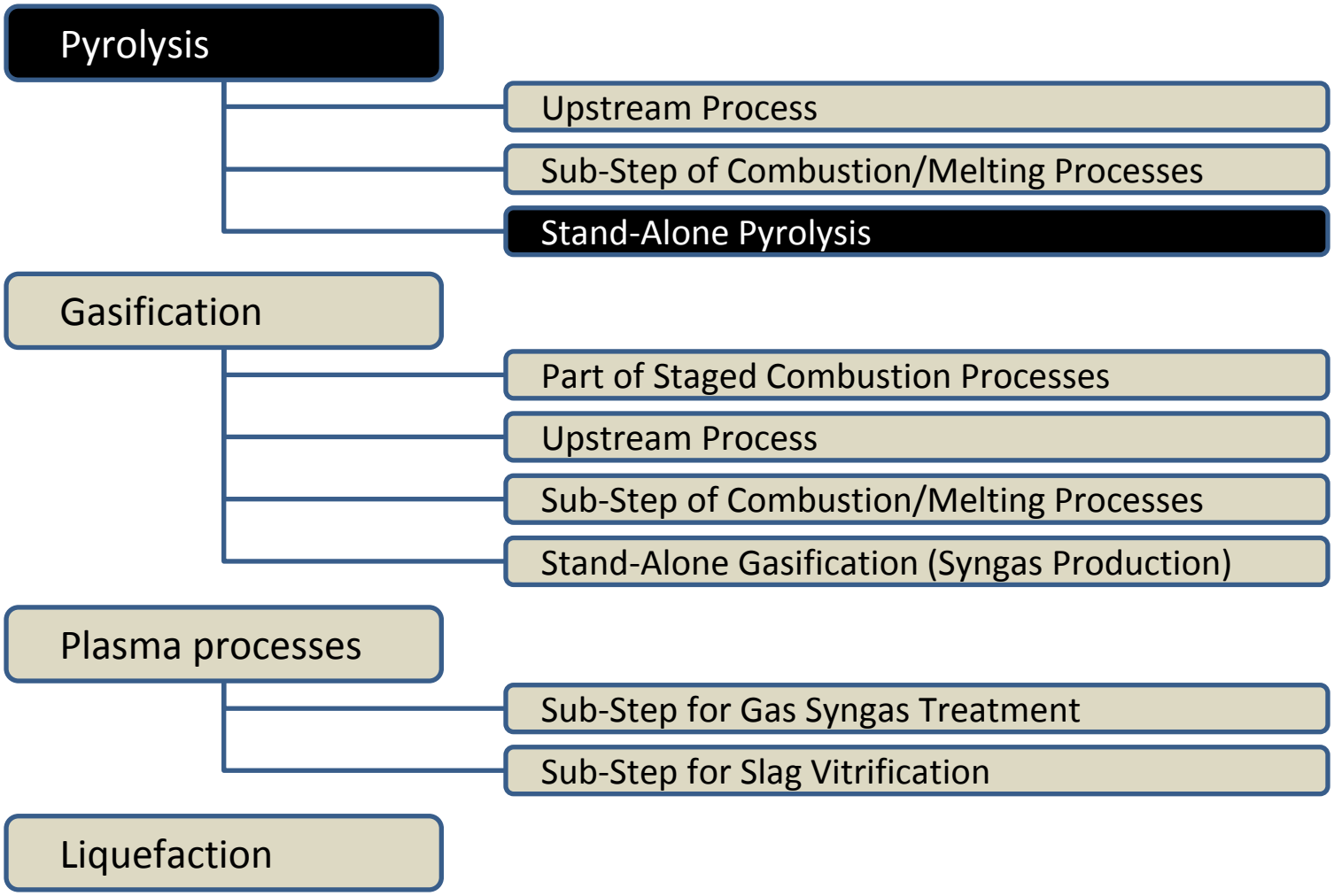
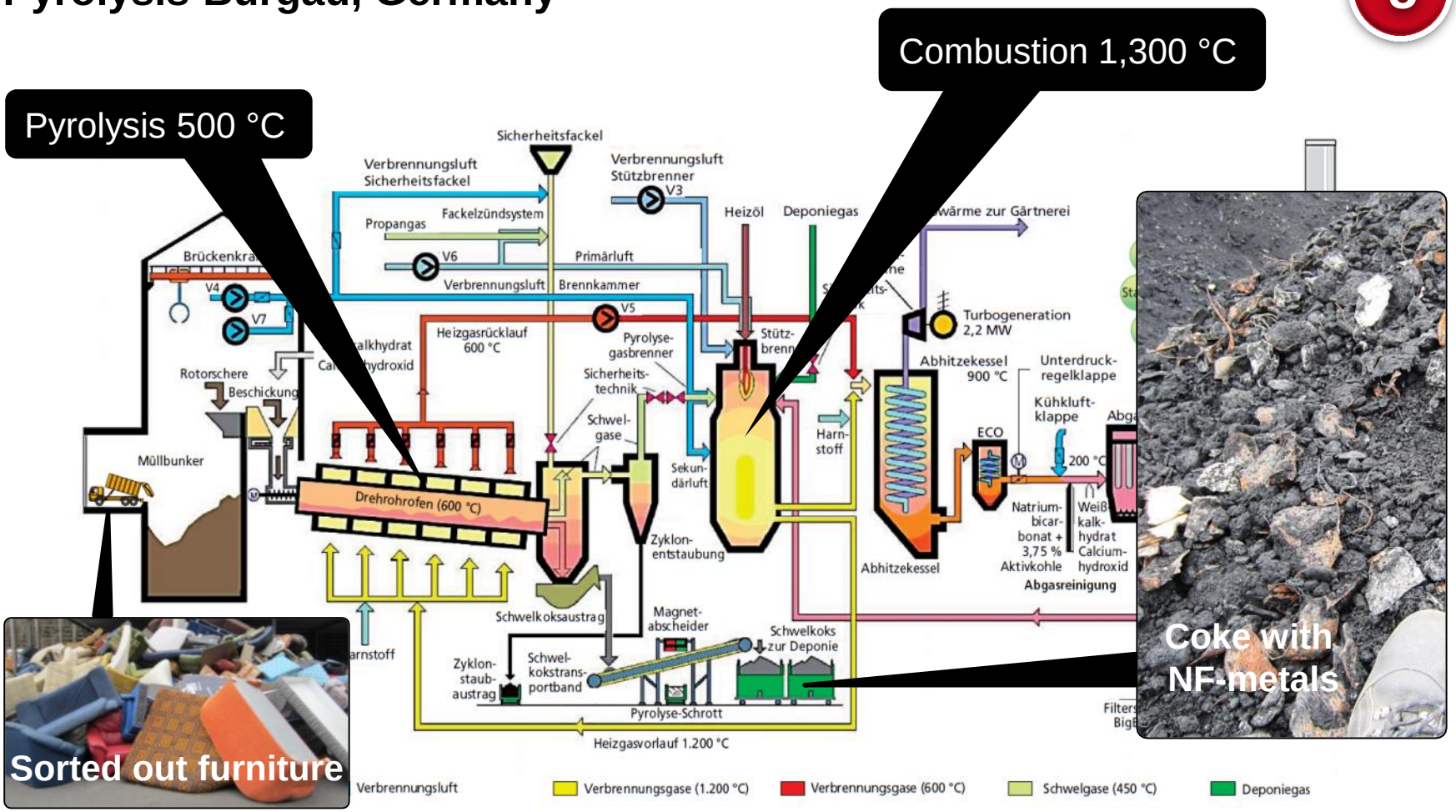


Pyrolysis – Stand-Alone Pyrolysis

DS 5

Pyrolysis Burgau, Germany



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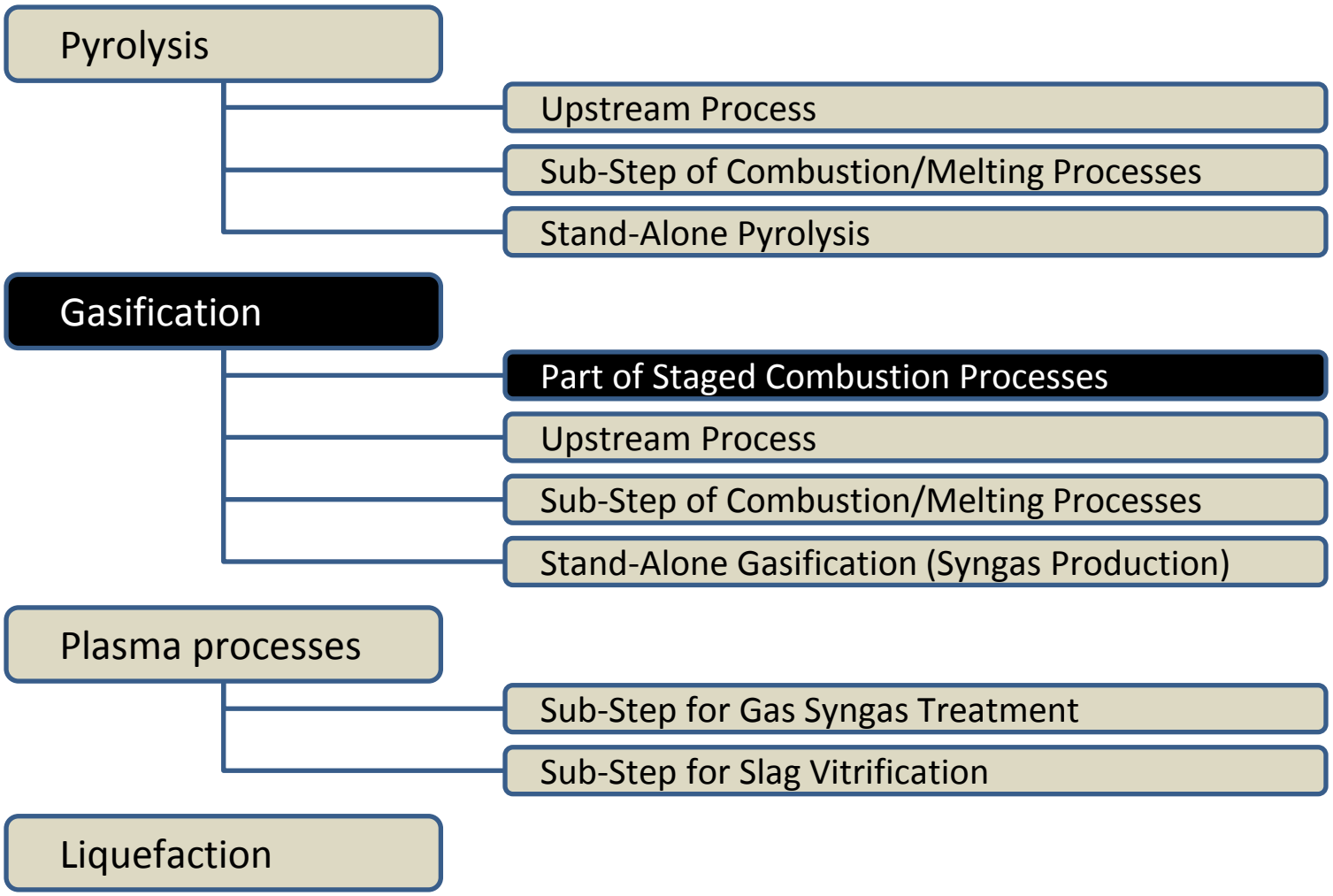


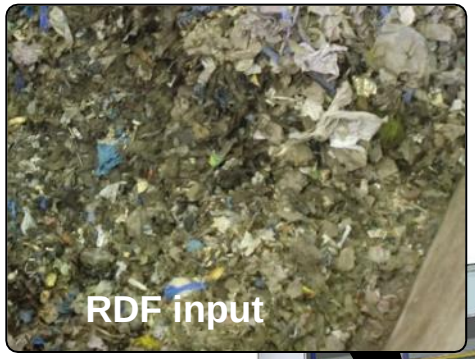
Gasification – Part of Staged Combustion Processes

DS 5

Energos

Gasification /understoichiometric combustion on the grate (900 °C), λ = 0,5

Gas combustion in secondary chamber (900 -1,100 °C)



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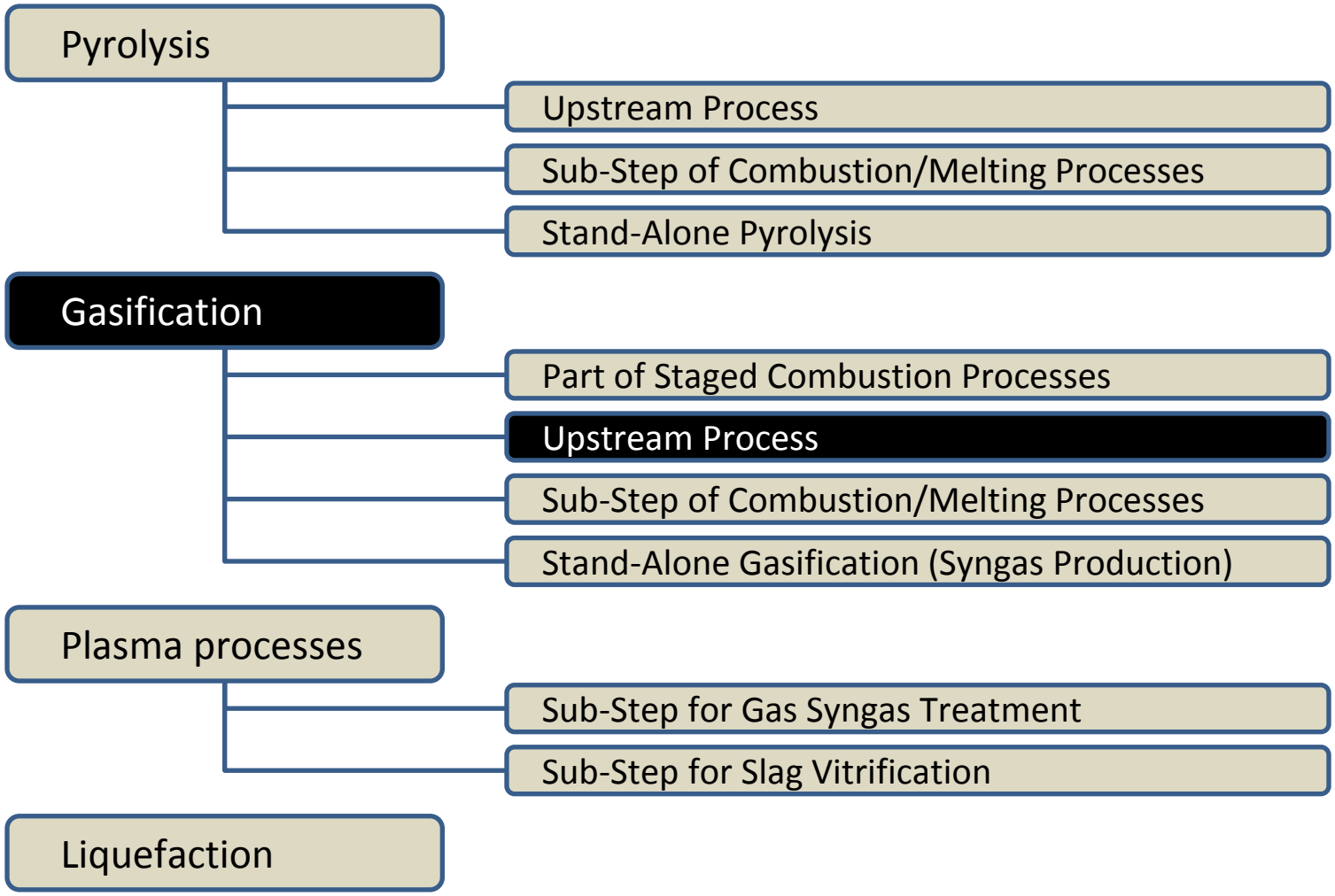


Gasification – Upstream Process

Envirotherm: CFB-Gasification Rüdersdorf, Germany

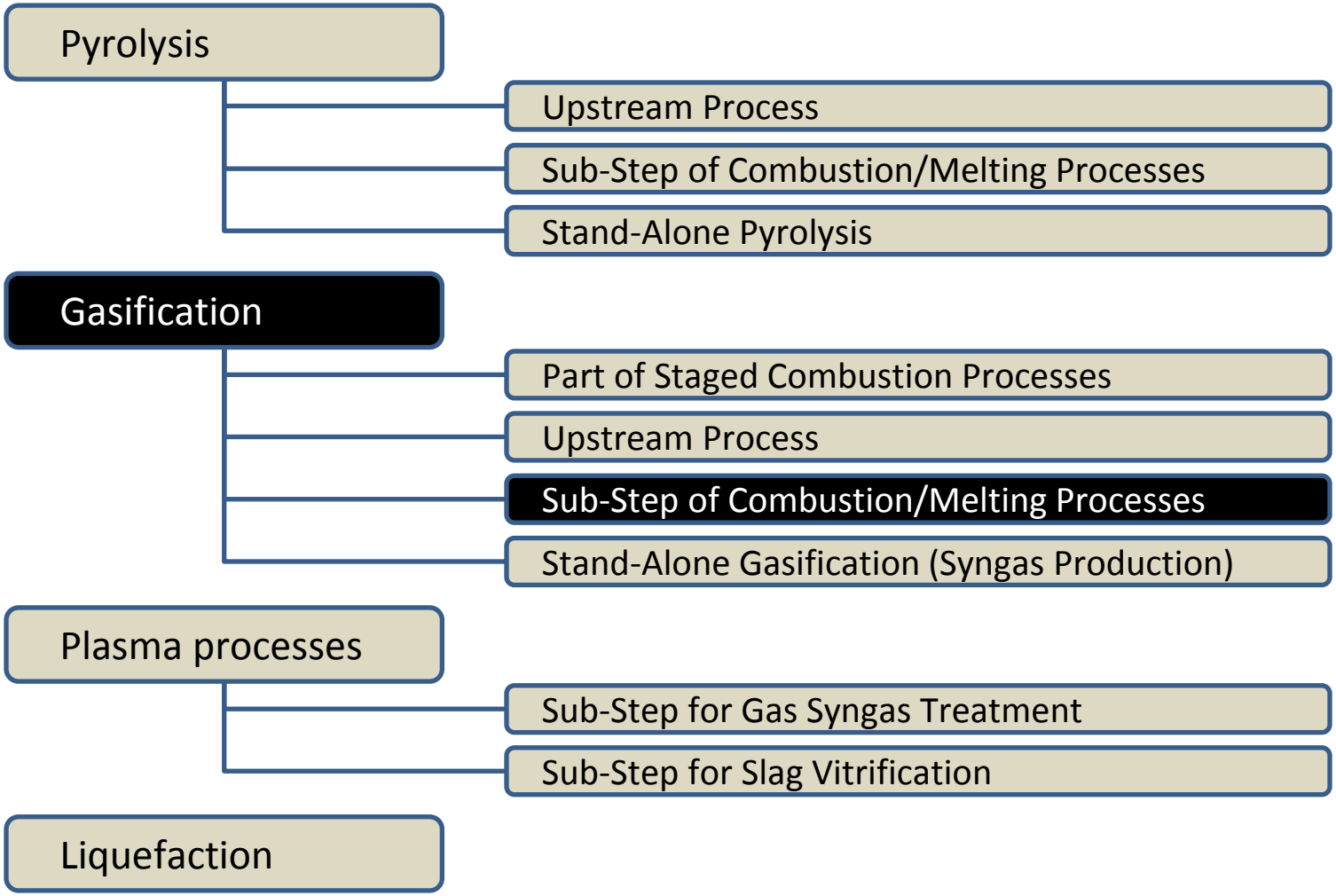
DS 5

Circulating fuidized bed gasification
(900-950 °C)

Gas to calciner of cement kiln
(900-900 °C)

Solid residues
to raw meal mill

Classification

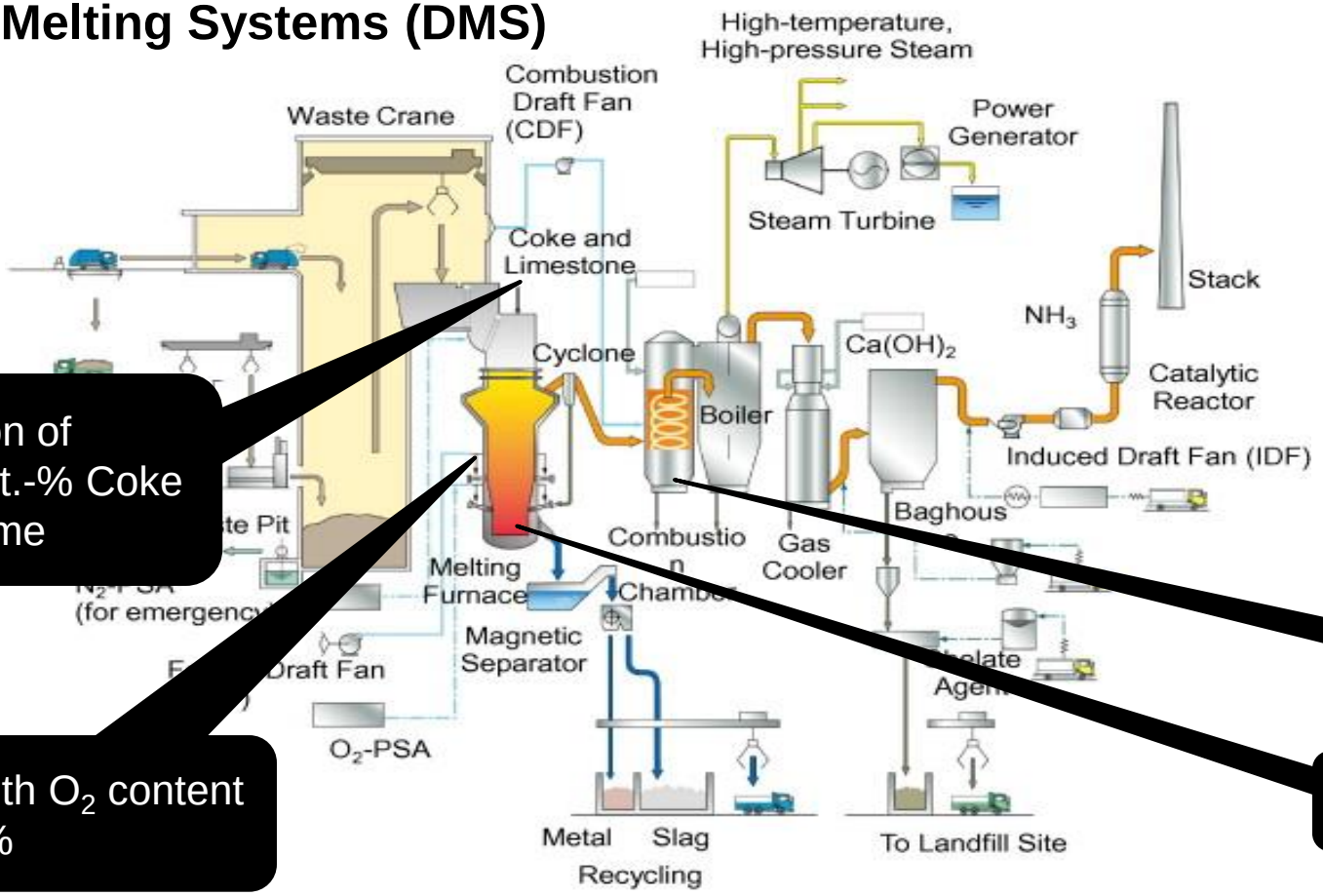


Gasification – Sub-Step of Combustion/Melting Processes

Nippon Steel

Direct Melting Systems (DMS)

DS 5



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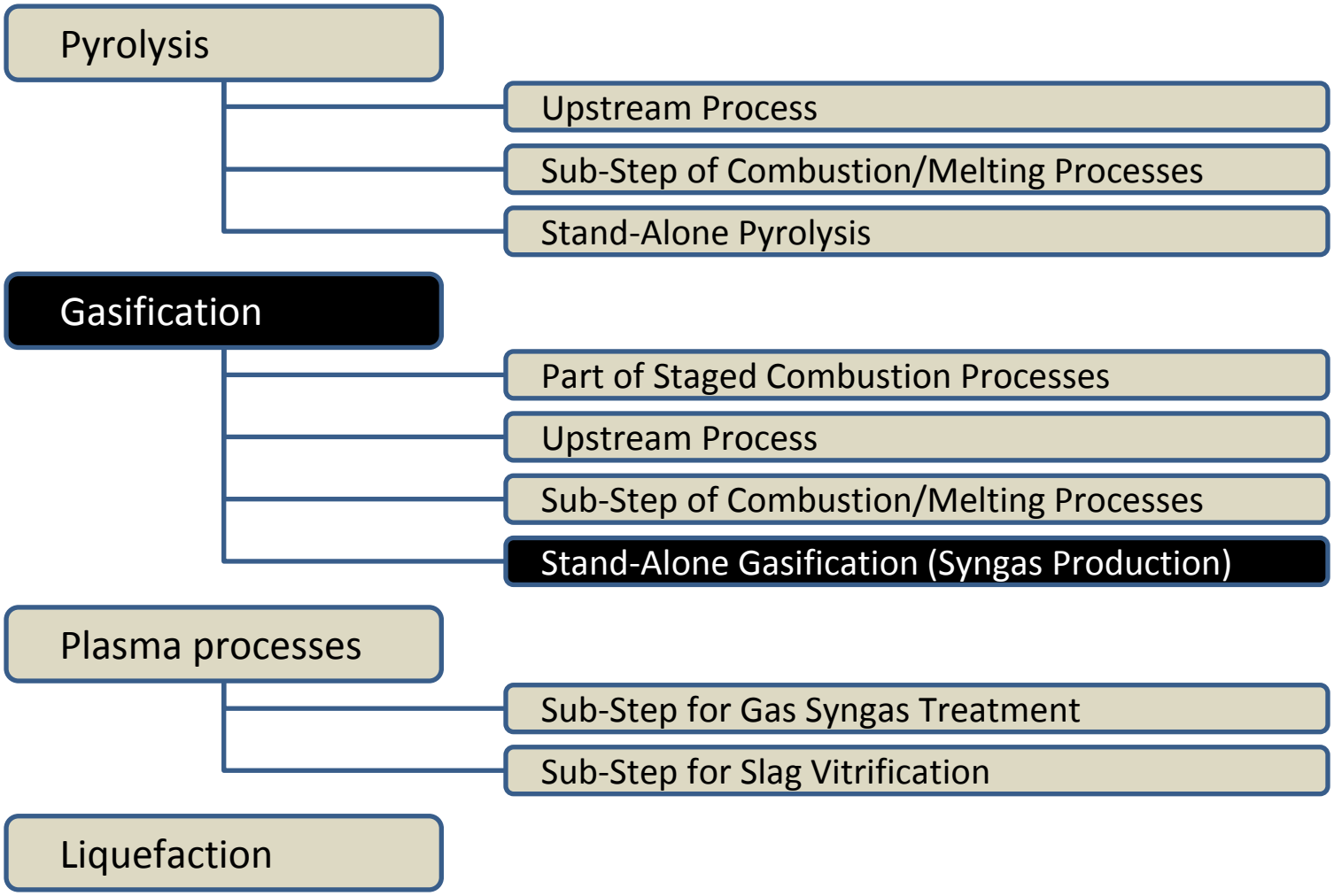
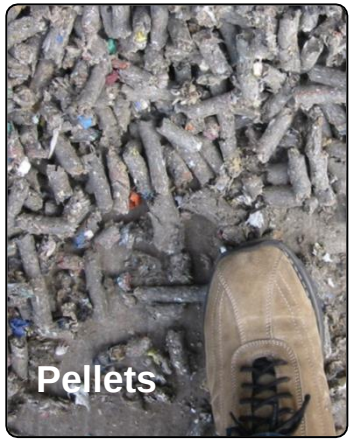
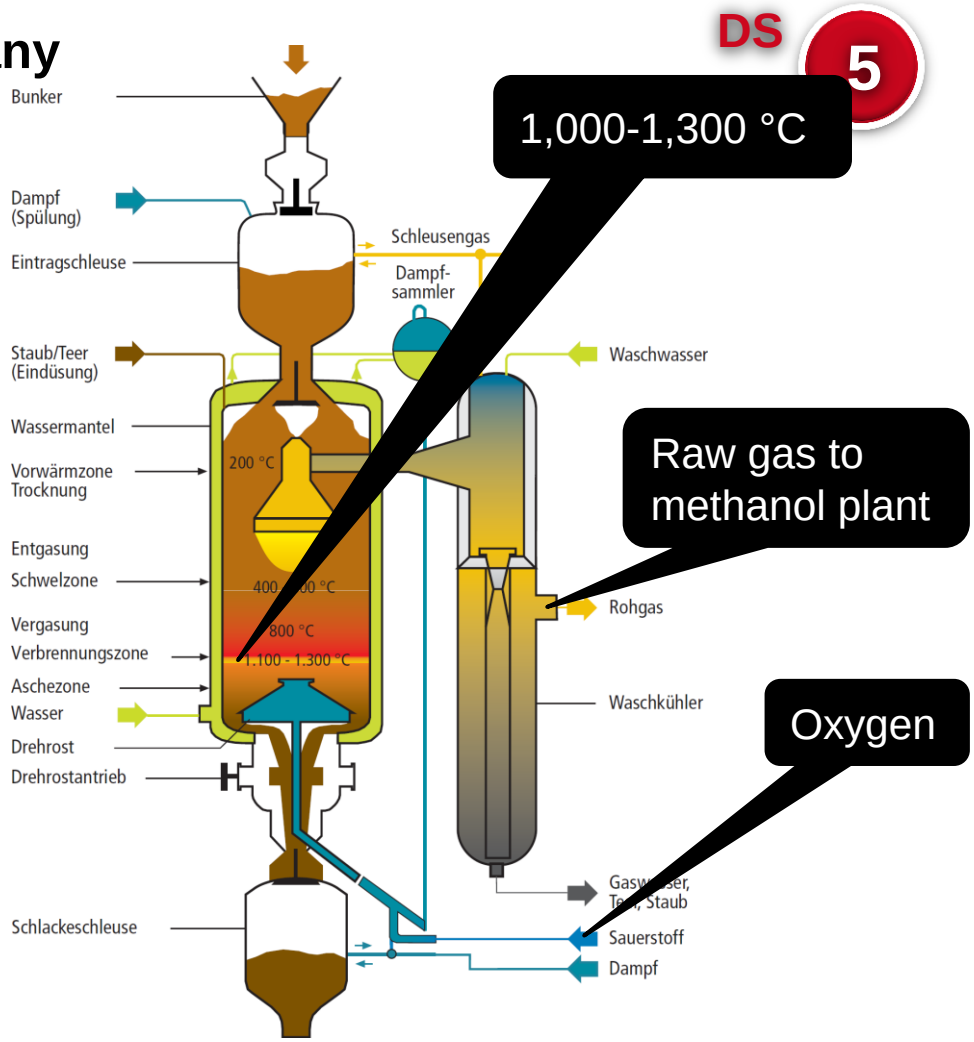


Gasification – Stand-Alone Gasification (Syngas Production)

SVZ Fixed bed gasification, Germany





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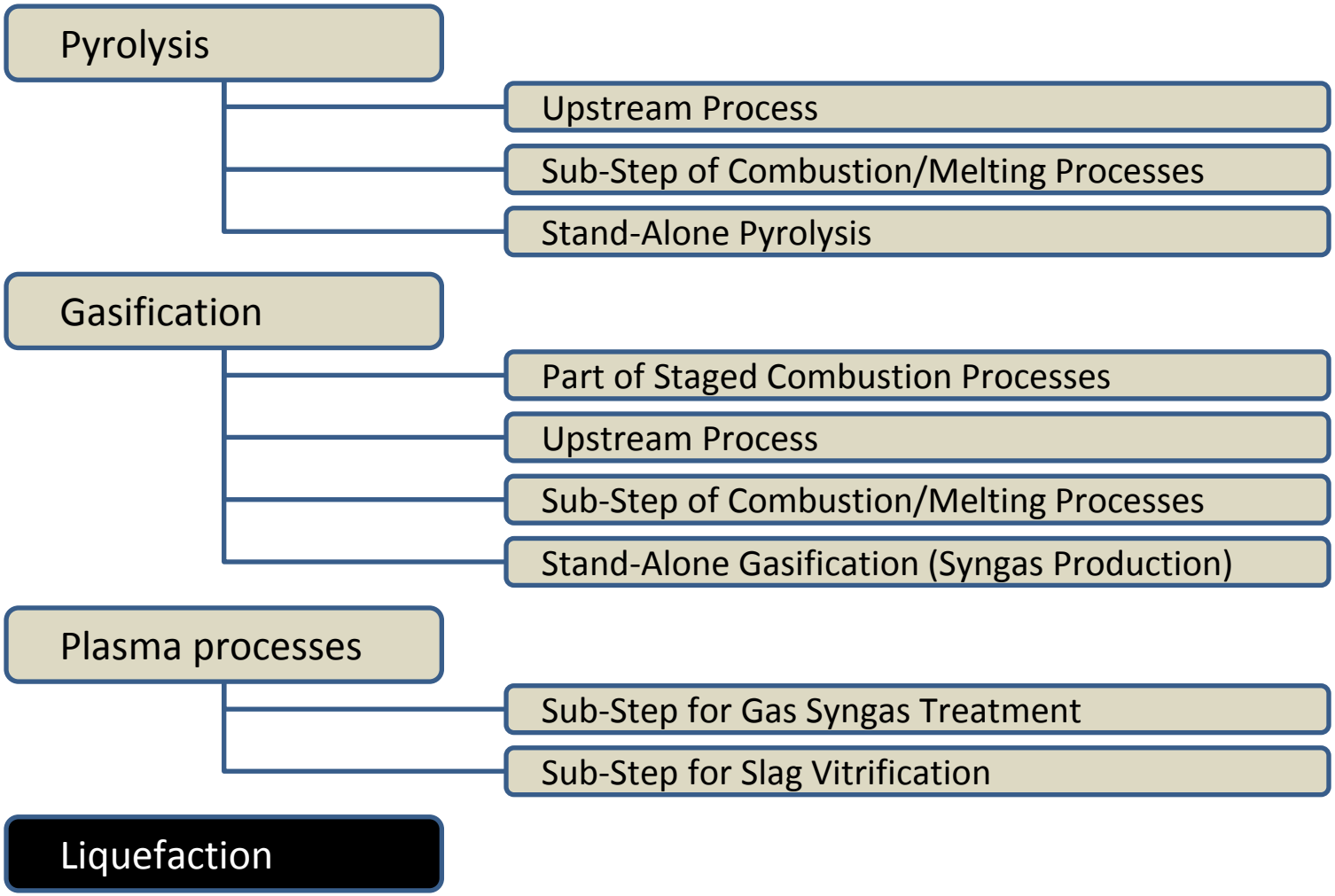
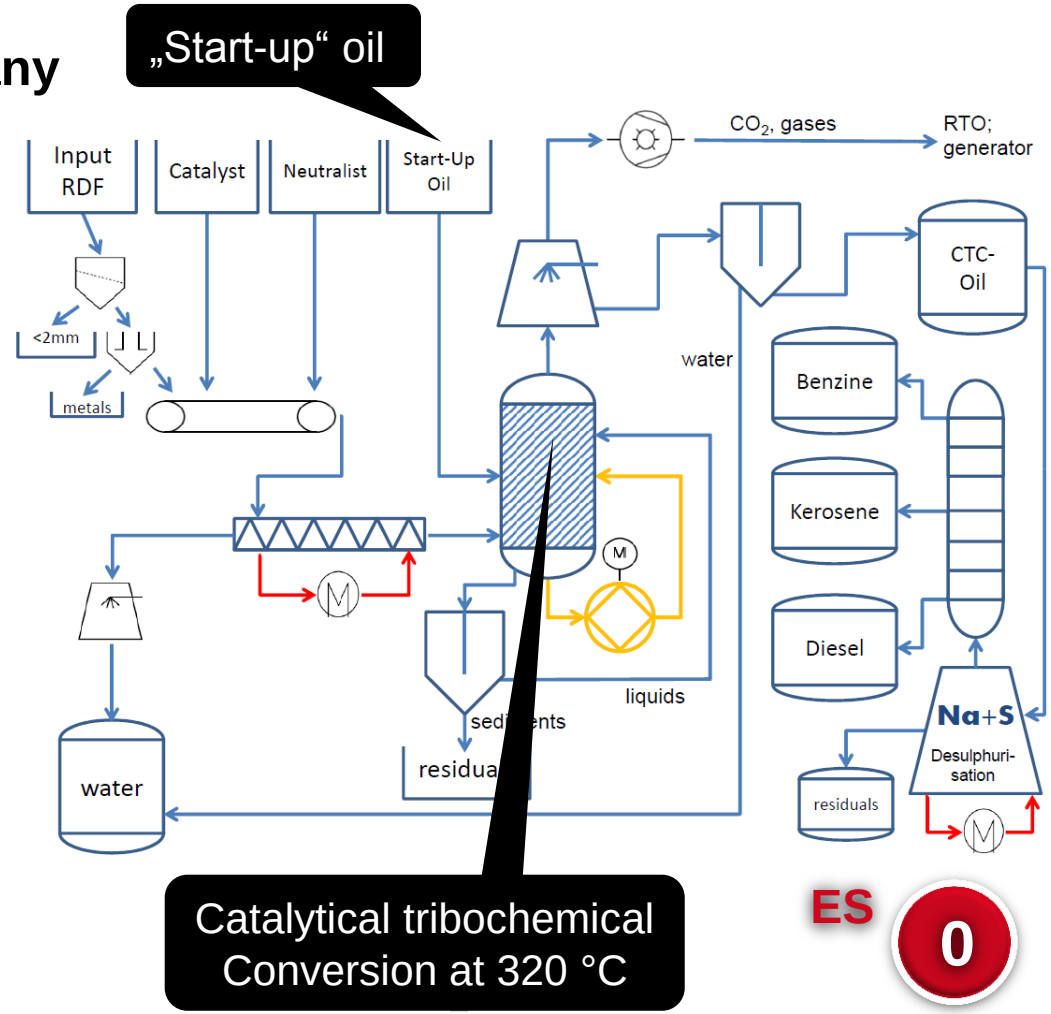


Liquefaction

Diesel West Ennigerloh, Germany



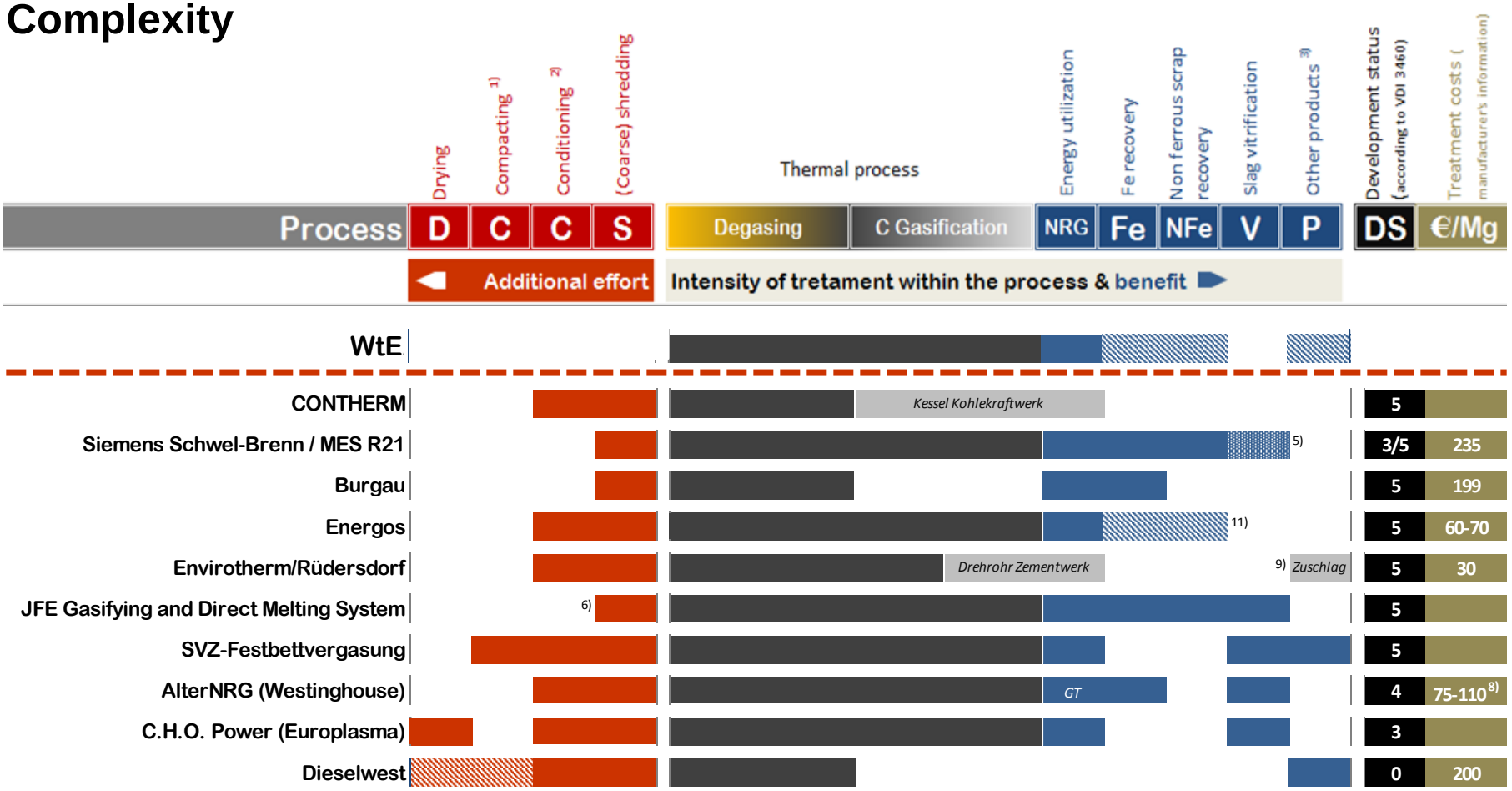
An Evaluation Approach

Evaluation

Erfolgt im thermischen Prozess
Optional erforderliche Vorbehandlung (je nach Edukteigenschaften)
Optional erzeilbarer Nutzen (z.B. durch Aufbereitung und Verbrennung von Pyrolysekoks, nachrüstbare Metallabscheidung)
xxx Erfolgt in nachgeschalteter Anlage

Karlsruher Institut für Technologie

Complexity



Evaluation for Mixed Residual Waste (MSW)

Interesting fields for alternative thermal processes

- ✓ Upstream processes in connection with cements kilns, power plants etc.
- ✓ Treatment of special fractions, e.g.
  - with high pollutant content (e.g. chlorine)
  - very low/high heating values
  - high ash content
- ✓ Achievement special features, like vitrified slag

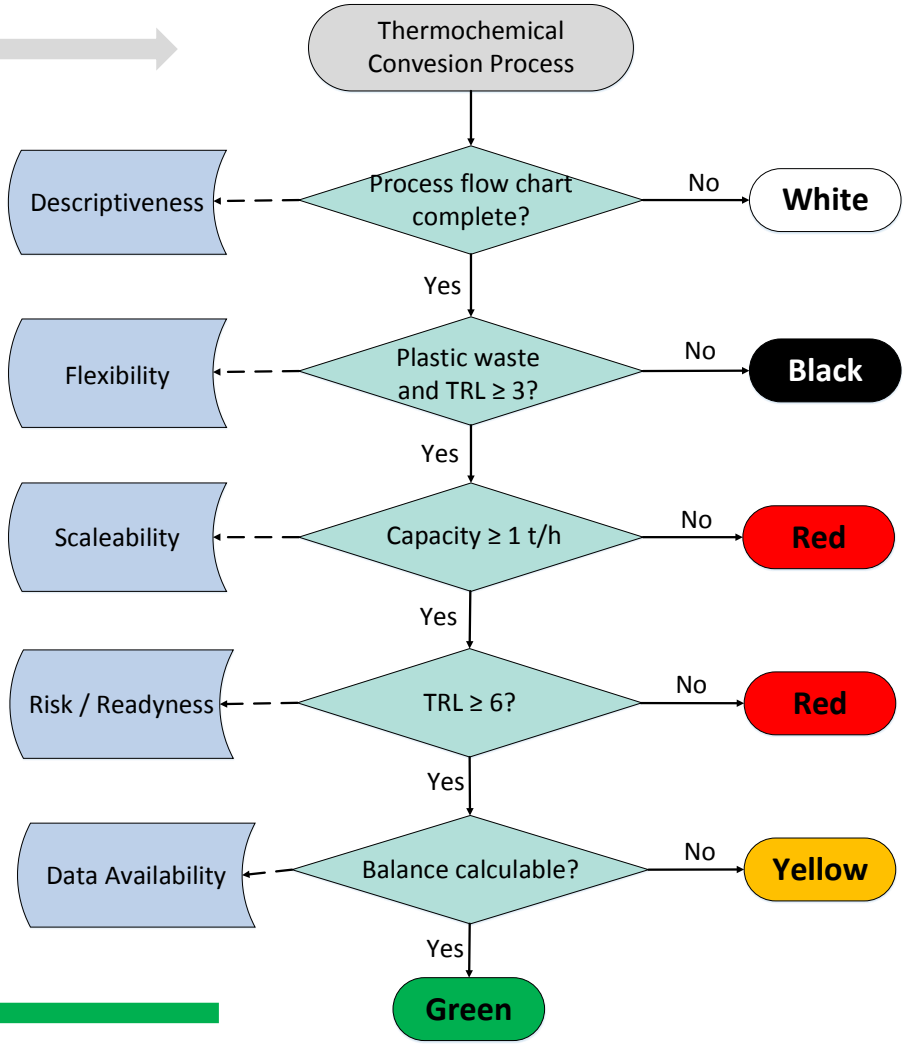
Problematic applications

- ? Stand alone facilities with no inertization / no product usage
- ? One-step low temperature processes with high effort for product treatment

Selection of Processes Suitable for Plastic Waste

Criteria, procedure, results

35	Gasification Processes
4	Gasification & Melting Processes
6	Metallurgical Processes
4	Plasma Processes
29	Pyrolysis Processes
6	Liquefaction Processes



3 (4)	Gasification Processes:
	British-Gas Lurgi (BGL) *SVZ (Schwarze Pumpe, Germany)*
	Circulating Fluidized Bed *CEMEX (Rüdersdorf, Germany)*
	bioliq Entrained Flow *KIT (Karlsruhe, Germany)*

Technology Readiness Levels

TRL 0: **Idea**. Unproven concept, no testing has been performed.

TRL 1: **Basic research.** Principles postulated and observed but no experimental proof available.

TRL 2: **Technology formulation**. Concept and application have been formulated.

TRL 3: **Applied research**. First laboratory tests completed; proof of concept.

TRL 4: **Small scale prototype** built in a laboratory environment ("ugly" prototype).

TRL 5: **Large scale prototype** tested in intended environment.

TRL 6: **Prototype system** tested in intended environment close to expected performance.

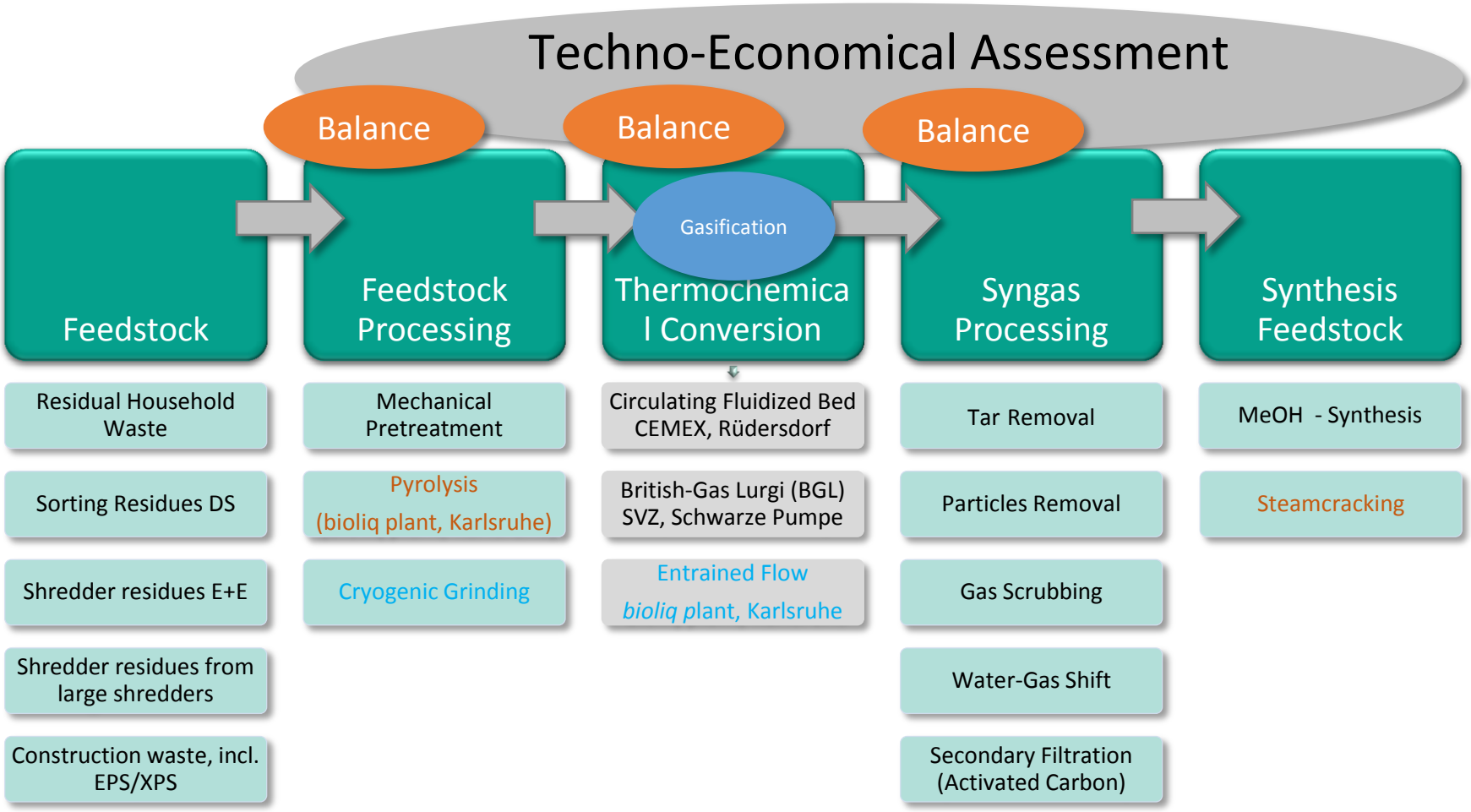
TRL 7: **Demonstration system** operating in operational environment at pre-commercial scale.

TRL 8: **First of a kind commercial system**. Manufacturing issues solved.

TRL 9: **Full commercial application**, technology available for consumers.

Scope Overview

Waste-to-chemicals process chains for plastic waste-recycling



Plastic Waste-to-Chemicals Process Chain

Example: Waste-to-Methanol (general)

pretreatment	conversion	upgrading
mechanical pretreatment	fluidized bed gasification	multi-step syngas purification

Household collection waste

Gasifier feedstock

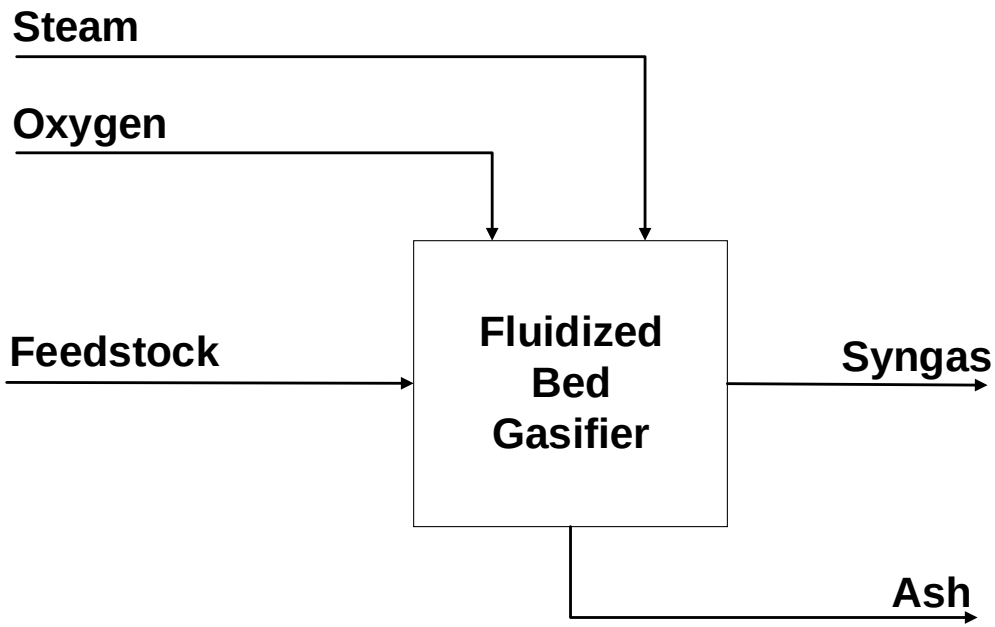
Raw syngas

CO_2, CO, H_2, CH_4, tar components, H_2S, HCl, Hg, …

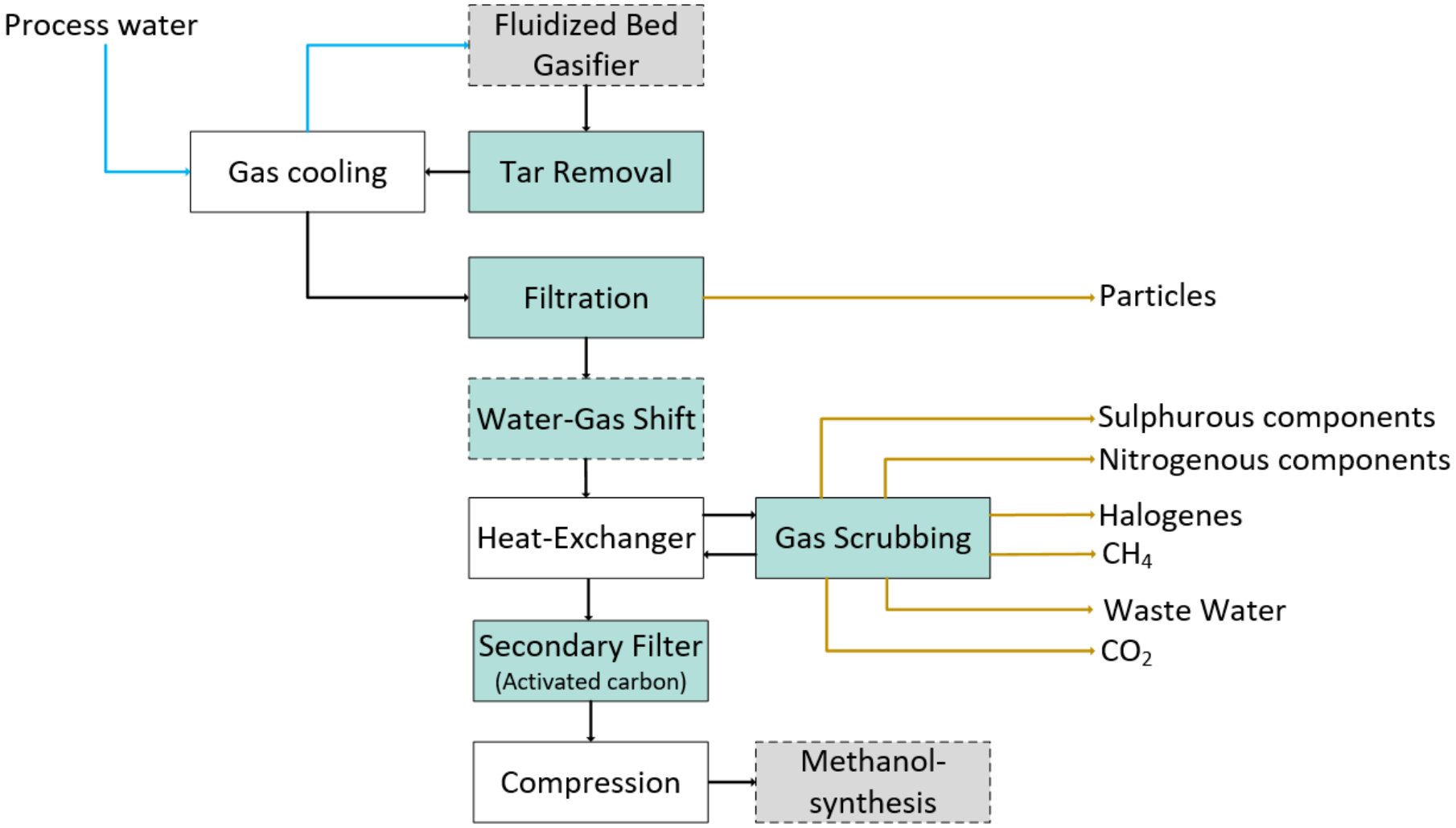
On-spec feed to methanol synthesis

H_2:CO = 2:1, tar free, contaminats concentrations below 0.1ppm, …

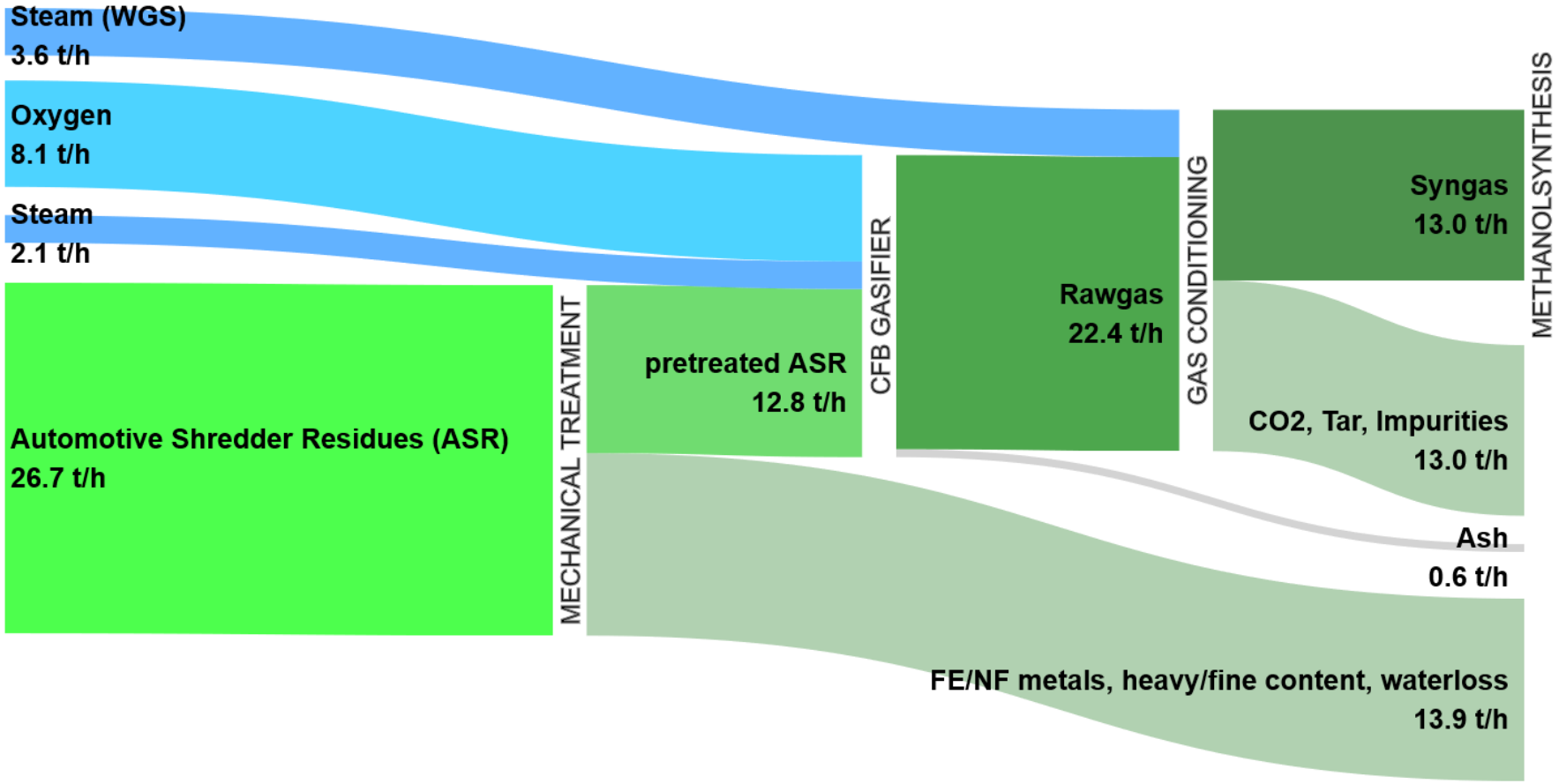
Circulating Fluidized Bed CFB Gasification of Automotive Shredder Residues ASR



Syngas Conditioning and Purification



Gasification of ASR in a CFB-Gasifier



Gasification of ASR in a CFB-Gasifier

ASR

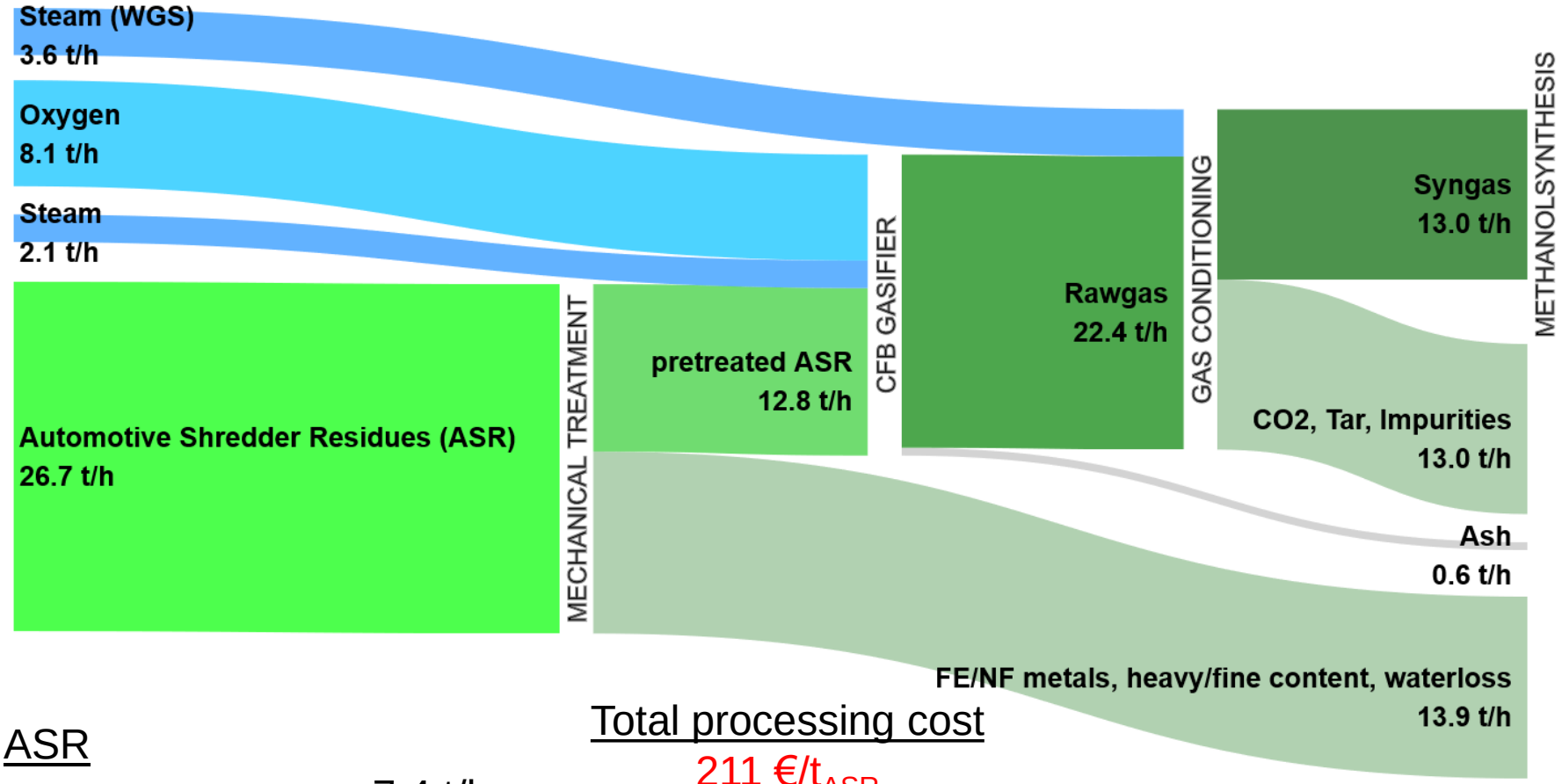
$m_{C,\ total}$	7.4 t/h
Plastic Fraction	~ 35 wt.-%
$m_{C\ from\ Plastic}$	~ 5.6 t/h*

*without composites, compounds, …

Syngas

$m_{C,\ total}$	4.8 t/h

Gasification of ASR in a CFB-Gasifier



Total processing cost

211 €/t_{ASR}

ASR

$m_{C,\ total}$ 7.4 t/h

Plastic Fraction ~ 35 wt.-%

$m_{C\ from\ Plastic}$ ~ 5.6 t/h*

*without composites, compounds, …

Syngas

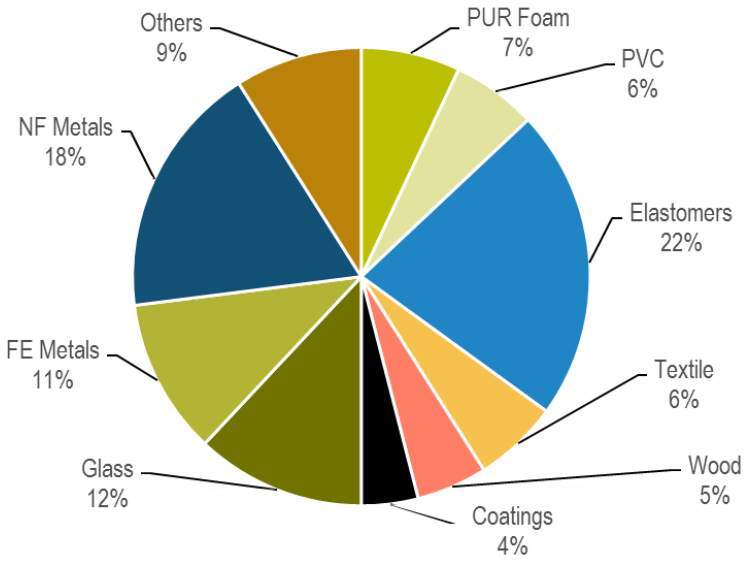
$m_{C,\ total}$ 4.8 t/h

Summary & Conclusions

Process Overview: Economics**

Shredder Residues large shredders (ASR)

Process	Pretreatment [€/t_{ASR}]	Conversion [€/t_{ASR}]	Upgrading [€/t_{ASR}]	Total processing cost [€/t_{ASR}]	Revenues* [€/t_{ASR}]
Gasification	-28	112	127	211	- 97
Pyrolysis	-28	152		124	- 86



*) Syngas @ 200 €/t
Naphtha @ 500 €/t

**) unit size ca. 100 MW / ca. 15 t/h of ASR

Process Overview: Economics**

Shredder Residues large shredders (ASR)

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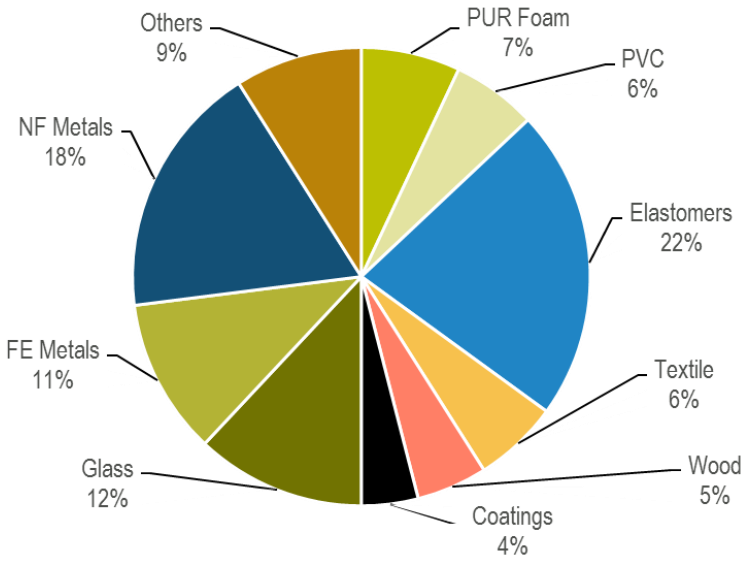

*) Syngas @ 200 €/t
Naphtha @ 500 €/t

**) unit size ca. 100 MW

Processing cost in the range of incineration market gate fees

Process Overview: Readiness & Risk

Technology Readiness Level TRL

Process	Pretreatment Feedstock	Conversion	Upgrading Rawgas / crude	Product utilization
Fixed Bed Gasifcation (BGL)	9	8	7	MeOH-Synthesis
Fluidized Bed Gasification (CFB)	9	8 - 9	7	MeOH-Synthesis
Entrained Flow Gasification (EFG)	5 - 6	6	9	MeOH-Synthesis
Pyrolysis	9	5 - 6	3	Steamcracker

- TRL 3: applied research
- TRL 5: large scale prototype
- TRL 6: prototype system
- TRL 7: demonstration system
- TRL 8: first of a kind commercial system
- TRL 9: full commercial application

Economical attractiveness vs. technology readiness

Conclusion

Alternative thermal waste treatment processes…

… can make sense in case of
- special framework conditions or regulations (like in Japan),
- special waste fractions (plastic waste, pollutant content, ash content etc.),
- (upstream) in connection with other thermal plants (cement & power plants)

… normally require high effort
- waste pretreatment
- product treatment
- additives (e.g. coke, lime, oxygen)
- of money

Waste incineration

… is state of the art for the treatment of **mixed municipal solid waste**

Chemical Recycling of plastic waste

- can be economically operated in special processes in the near future

Thank you for your Attention!

Prof. Dr.-Ing. Helmut Seifert
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