



BIOMASS TORREFACTION

- BENEFITS OF EXTENSIVE PARAMETRIC STUDIES

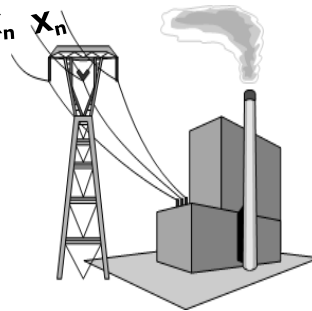
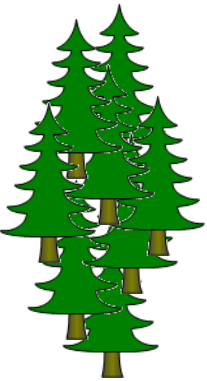
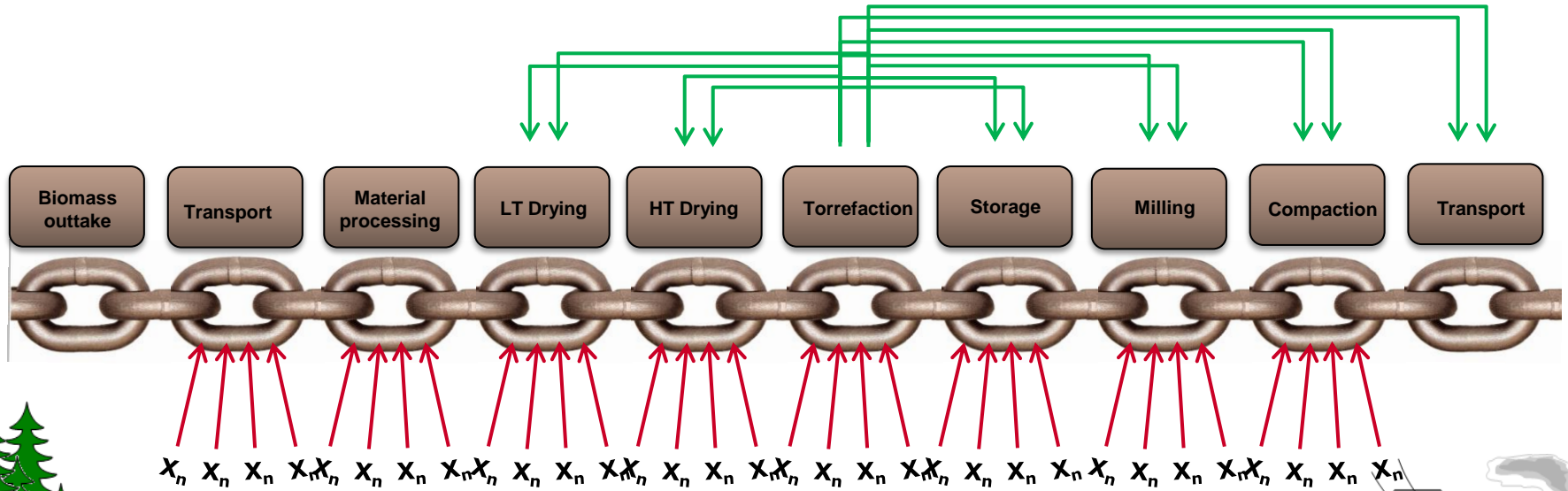
**Martin Nordwaeger, Ingemar Olofsson,
Katarina Håkansson, Linda Pommer,
Susanne Wiklund-Lindström, Anders Nordin**

Energy Technology and Thermal Process Chemistry



Umeå University

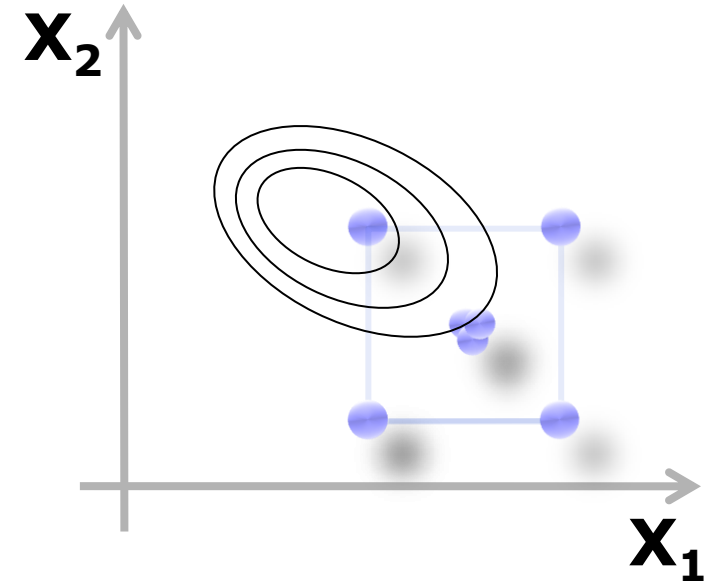
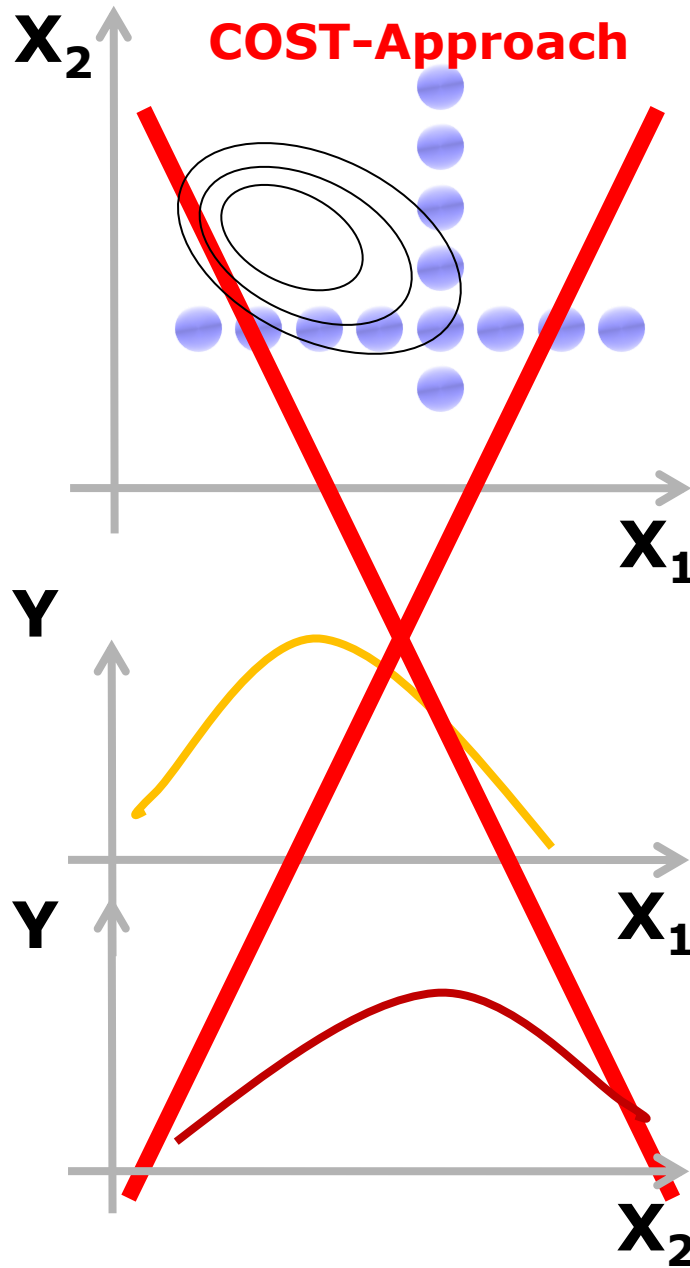
Total biomass supply and refinement chain



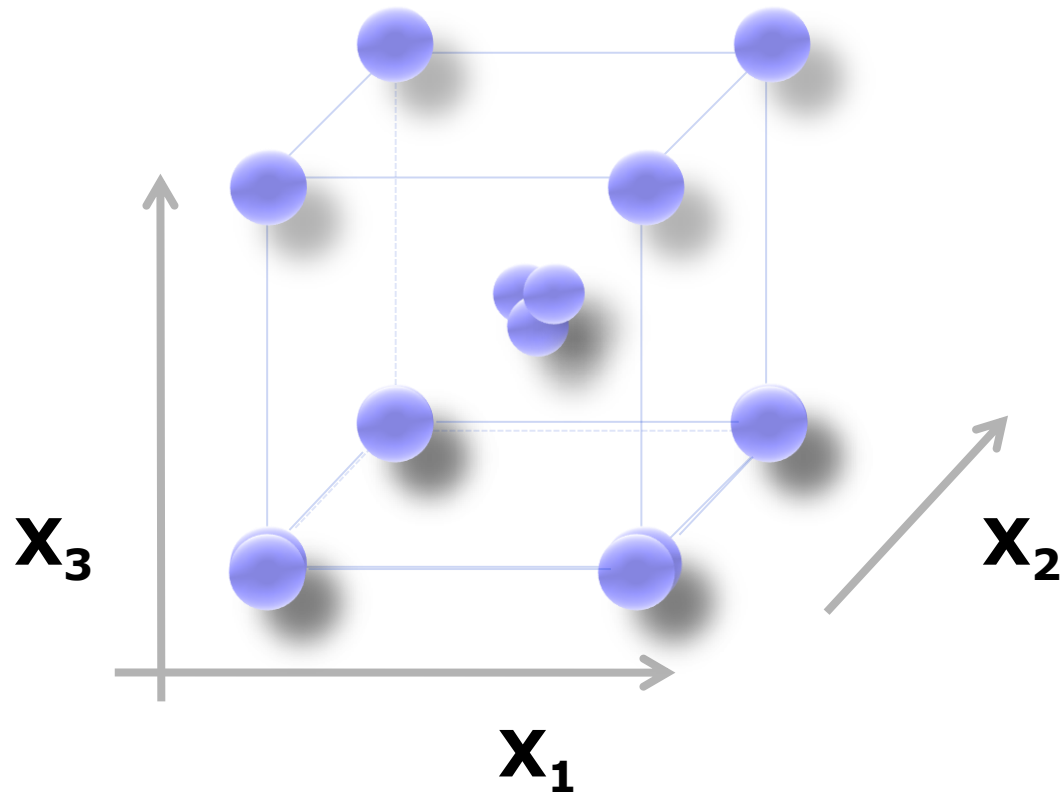
Total fuel costs at end customer is significantly influenced by both direct and indirect effects of several variables for each operation



Complexity need Systematic Approaches

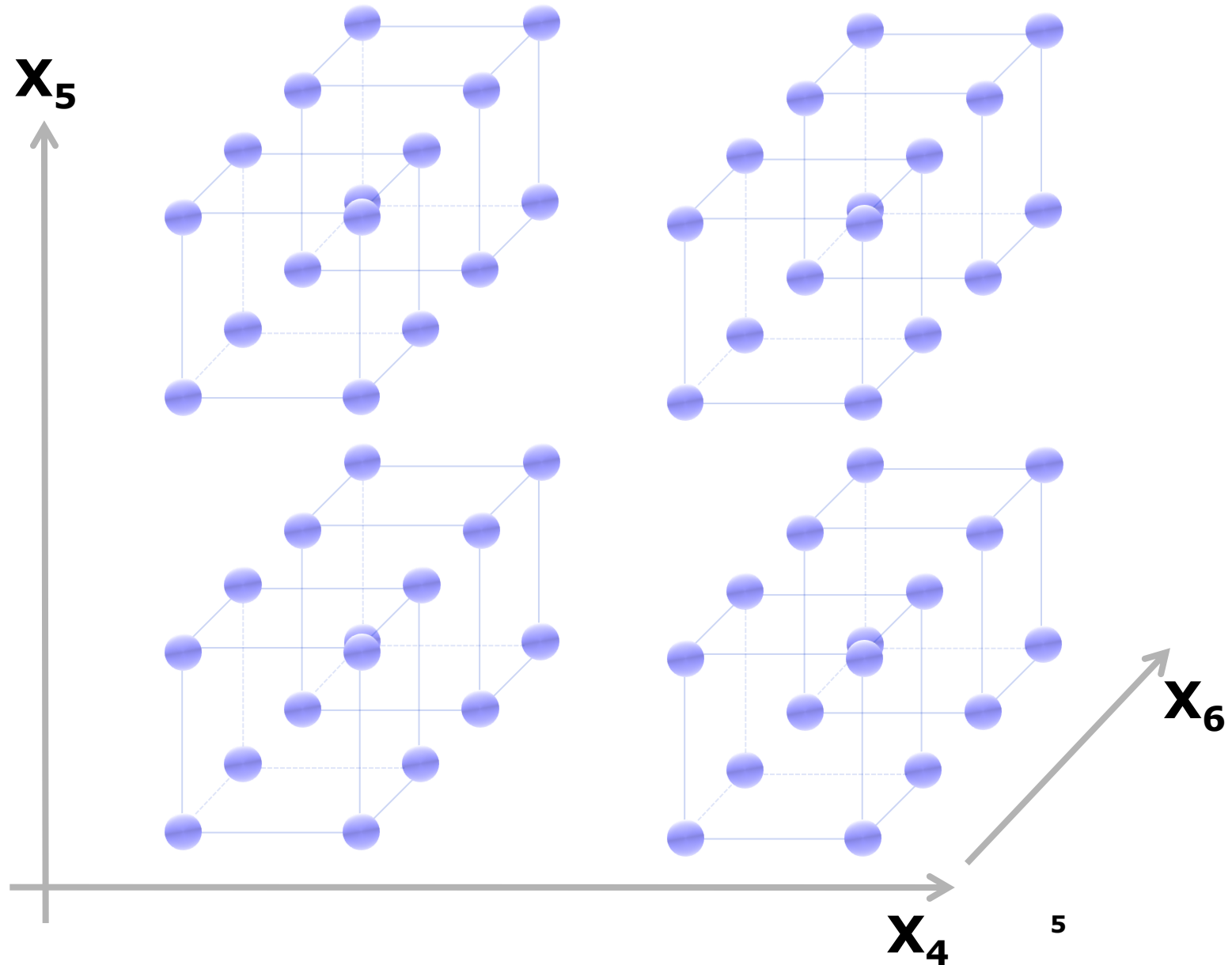


Three Variables

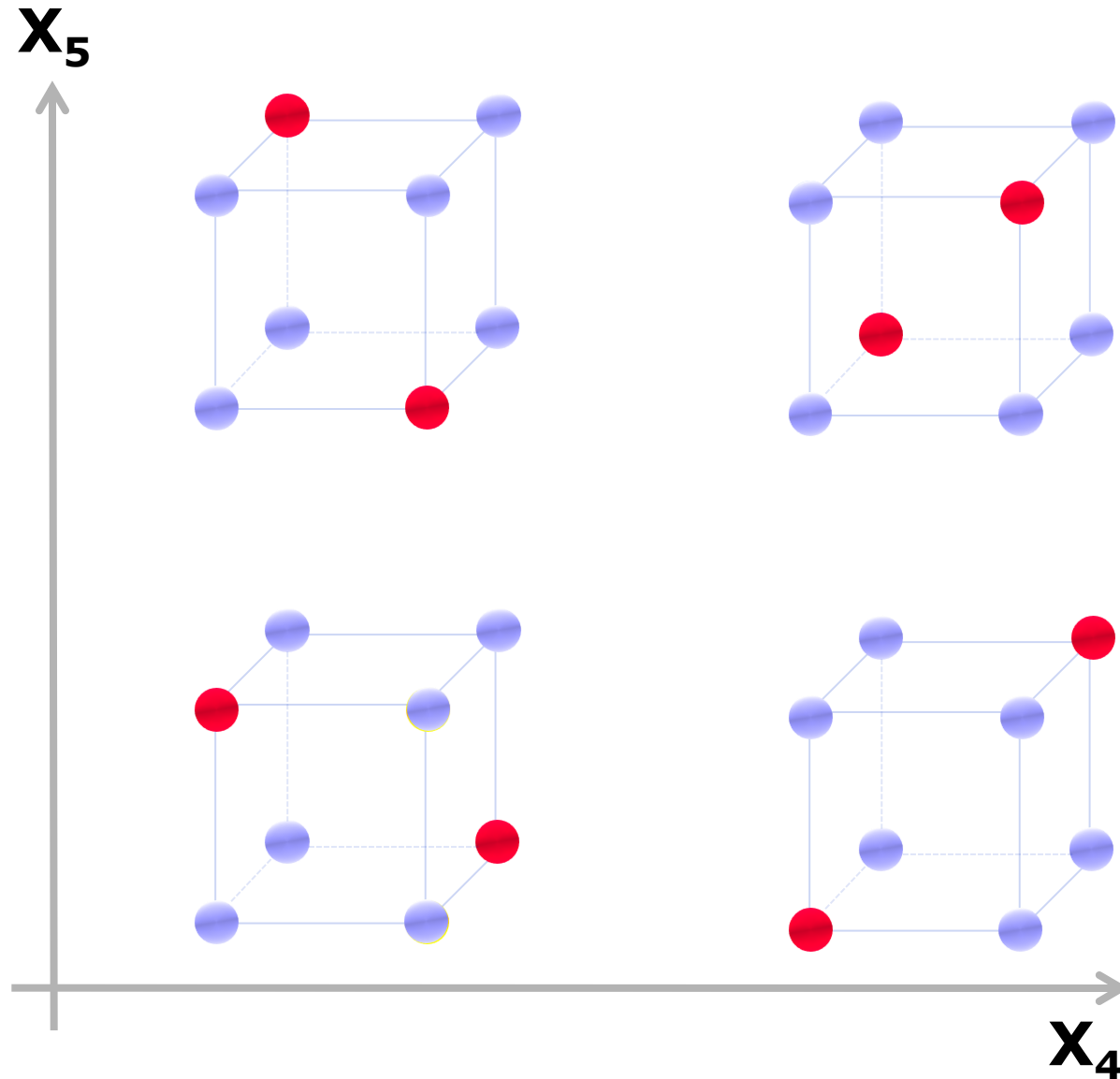




5-6 Variables



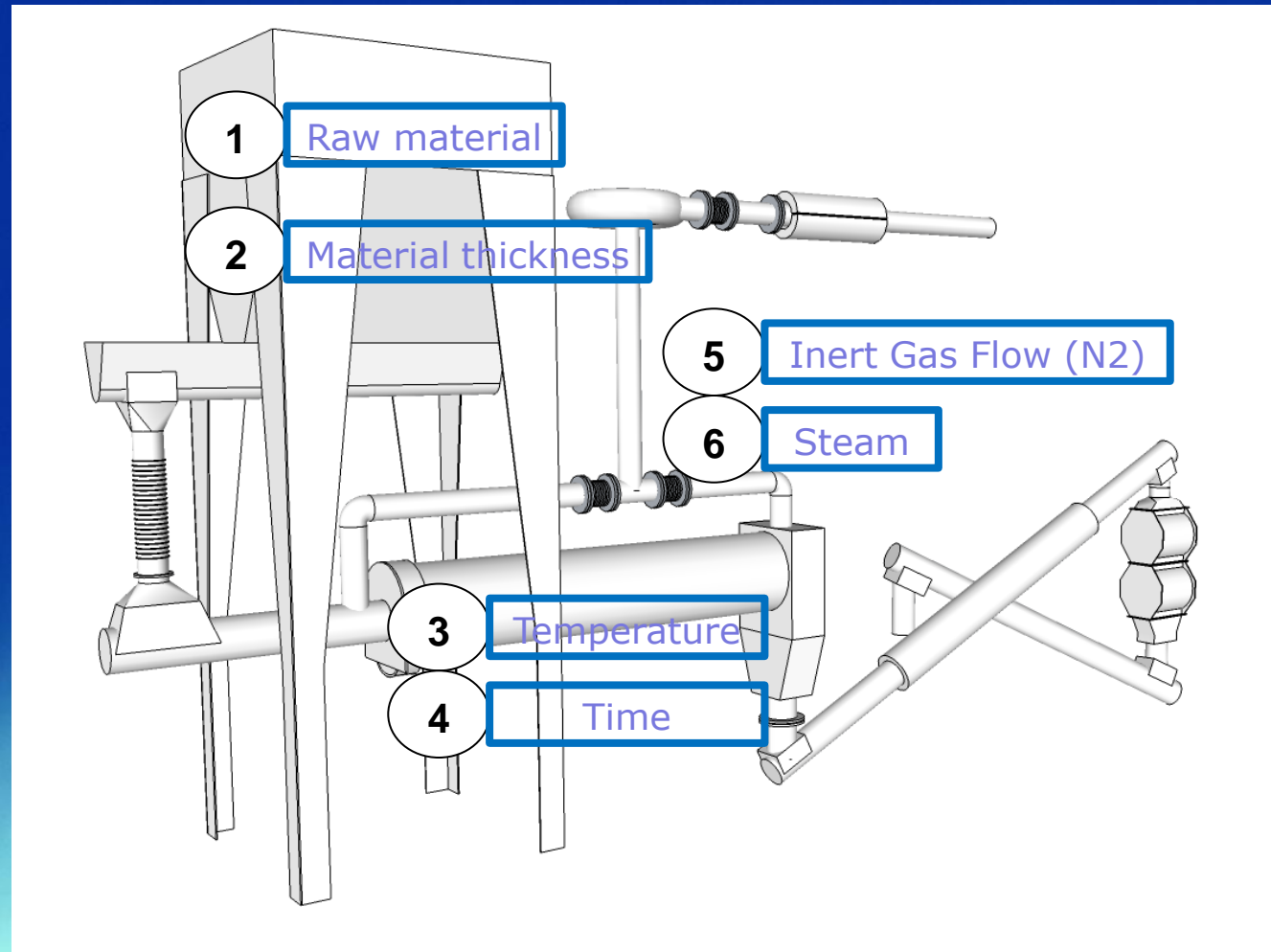
Reduced Factorial Designs - save lot of time





BioEndev's Pilot Plant (30 kg/h)

-dedicated for parametric studies



All Analyzed Responses

Content of Lignin, cellulose, hemicellulose

Xylose
Mannose
Lignin
Hemicellulose
Glukose
Galaktose
Arabinose
Acetone extracts

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Extractives

Carbohydrate fragmen
4-OH-3-methoxycinnar
C16:0 acid
C18:2 acid
C18:1 acid
C18:0 acid
Pimaric acid
Isopimaric acid
Dehydroabietic acid
Abietic acid
Glycerol

A: Incoming Fuel

Physical properties:

- 24 Energy density - chips/powder/comp.
- 33 Friability/brittleness
- 12 NIR
- 20 Density
- 21 Bulk denisty - chips
- 22 Bulk density - powder
- 23 Bulk density - compacted
- 29 Visual properties
- 26 Pore structure/volume/porosity
- 18 Heat conductivity
- 19 Specific heat capacity

Utilization and handling:

- 16 Reactivity
- 17 Hydrophobic properties
- 34 Compression strength
- 35 Fungal durability
- 27 Pelleting properties
- 28 Compacting properties
- 30 Dusting
- 31 Micro biological activity
- 42 Dust explosion

Others:

- 36 Massflöde in
- 38 Combustion tests
- 39 Gasification tests
- 40 Self ignition

Composition:

- 1 Heating values
- 2 Moisture content
- 3 Ash content
- 4 Solid residue
- 5 Volatile content
- 6 C, H, O, S, Cl, N
- 7 Alkali
- 9 Ligno Cellulose
- 37 Thermo gravimetric analysis
- 8 Ash analysis
- 41 Extractives

Milling/Feedeing/Size distribution:

- 11 Size distribution - powder
- 14 Visual analysis (powder)
- 13 Milling energy demand
- 10 Size distribution - chips
- 15 Feeding properties (powder)

Volatile Product

- 60 Mass flow gas
- 61 Gas composition
- 62 Tar sampling/analysis
- 63 Gas hetating values
- 65 Moisture content
- 68 Particles/aerosols with impactor
- 67 Particles with total dust
- 66 Condensate
- 69 Alkali in condensate
- 64 Theoretical flame temperature (TFT)

Torrefaction Process

- 80 Torrefaction enthalpy
- 81 Energy yield
- 82 Mass yield
- 83 Power consumption (heaters)

B: Torrefied Fuel

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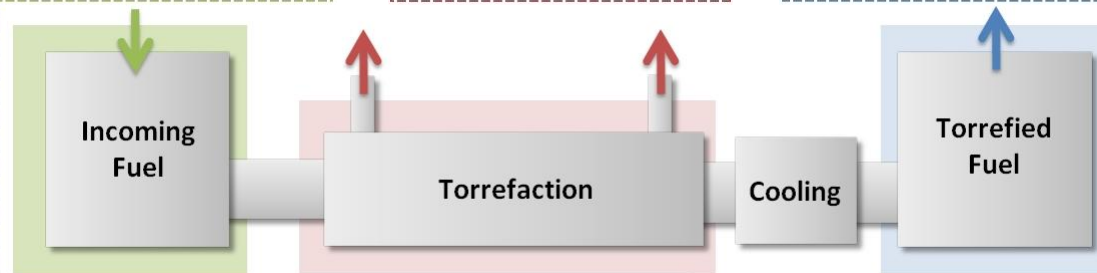
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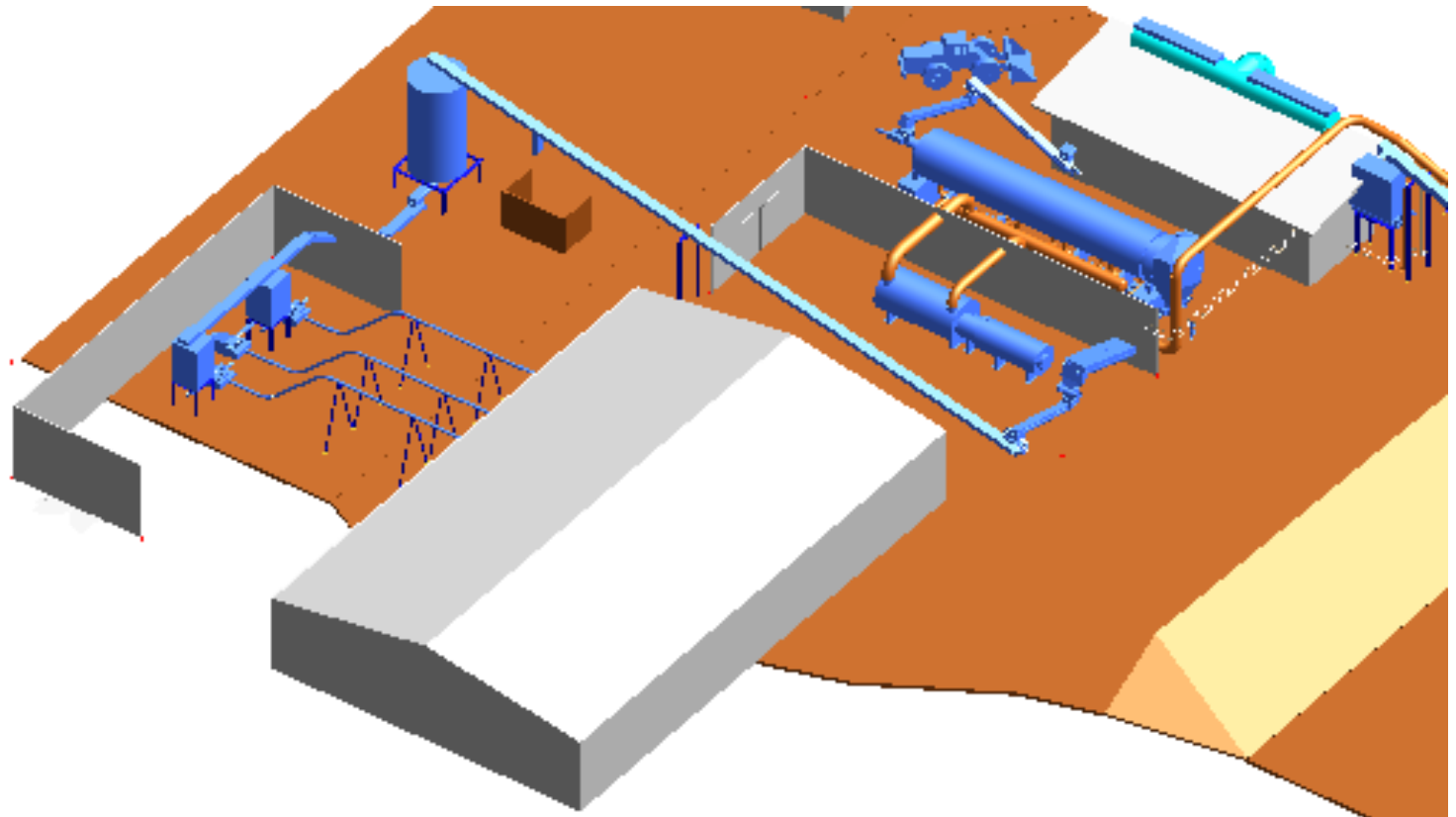


No.	Ret time (min)	Substance
1	4,05	acetaldehyde
2	4,61	Furan
3	4,82	Aceton
4	4,91	Acetic acid, methyl ester
5	5,09	2,3-dihydrofuran
6	5,16	2-propenal

No.	Ret time (min)	Substance
36	31,25	?
37	32,63	2-Pentenal, 2-methyl- ?
38	32,99	?
39	33,41	1,2-cyclopentadione
40	34,65	?
41	34,98	2-Cyclopenten-1-one, 2-hydroxy-3-methyl-

No.	Ret time (min)	Substance
71	55,17	2-Propanone, 1-(4-hydroxy-3-methoxyphenyl)-
72	55,67	1,3-Cyclopentanedione, 2-methyl-
73	56,06	
74	56,46	
75	62,18	
76	63,92	
77	64,55	

⇒ Design Criteria for the Torrefaction IDU, Ö-vik (25 MW, 4.5t/h)

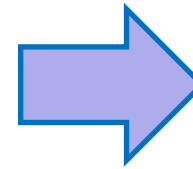


⇒ So What are the
CAPEX, OPEX and Minimal Costs?



Totally 12 Studied Variables

- Raw Material Cost
- Product Prize
- Investment Cost
- Reinvestment Cost
- Accessibility
- Operating Staff
- Torrefaction Degree
- Service Costs
- Low Temperature Heat Costs
- High Temperature Heat Costs
- Capital Costs

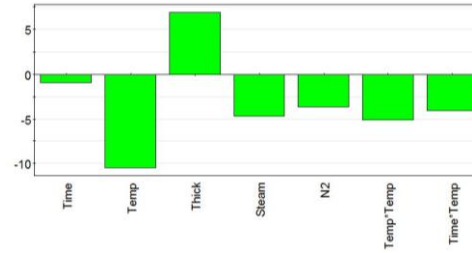
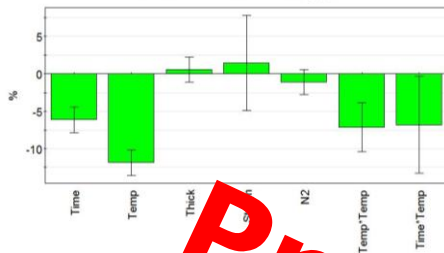


Effects on

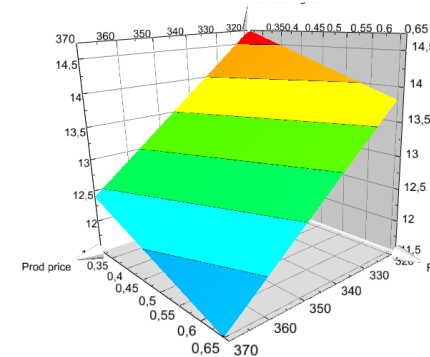
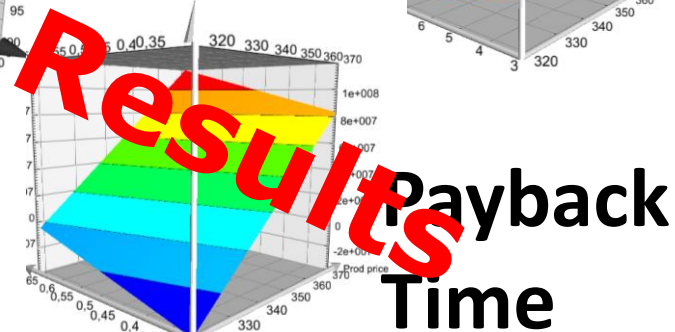
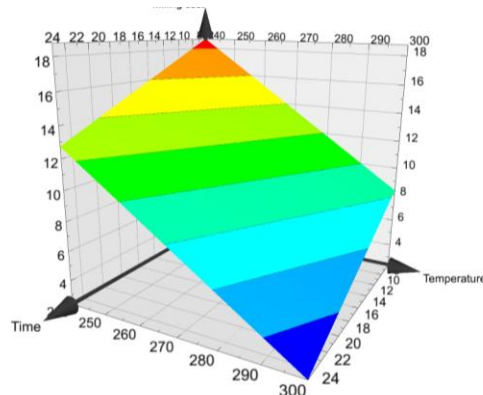
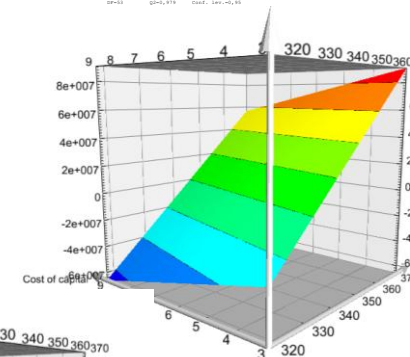
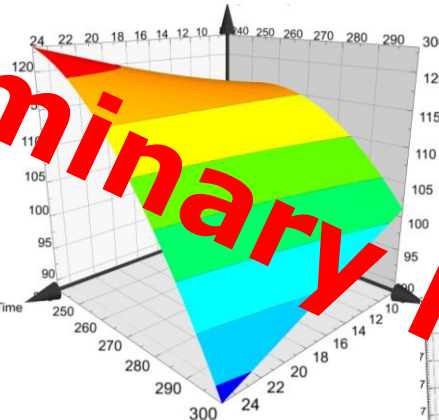
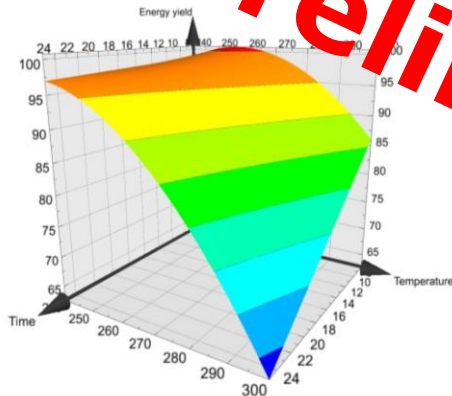
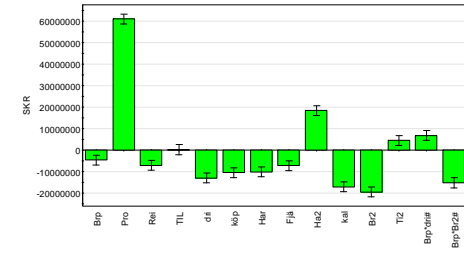
- Net Present Value
- Payback Year
- Profitability



Effects of process variables



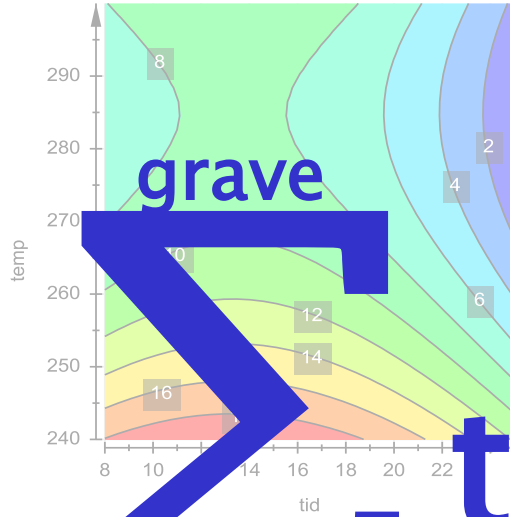
Economy



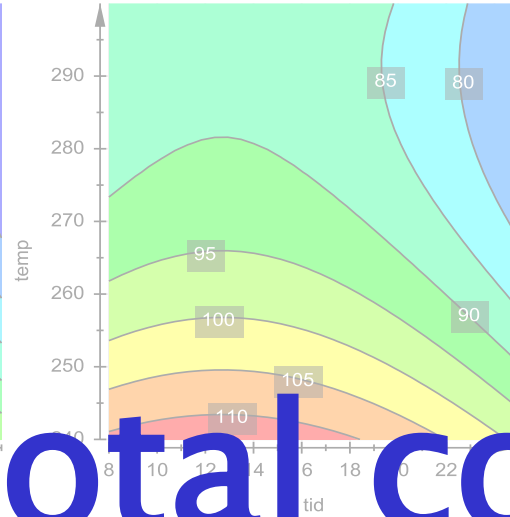
Preliminary Results



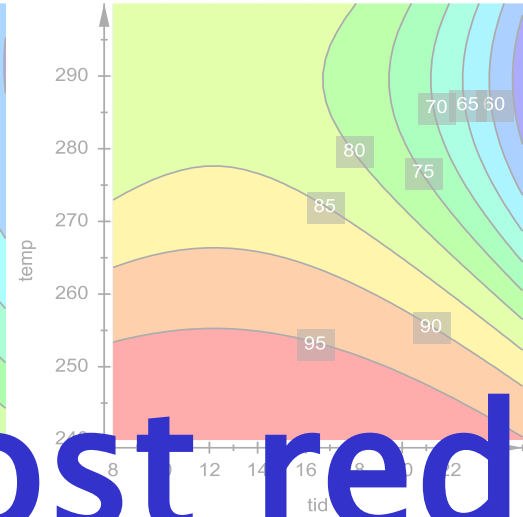
Milling cost



Energy yield



Mass yield



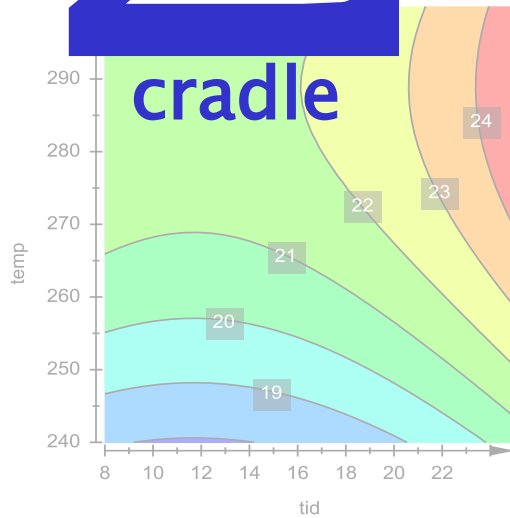
grave

Σ

cradle

total cost red

HHV



Hydrofob 5min medel

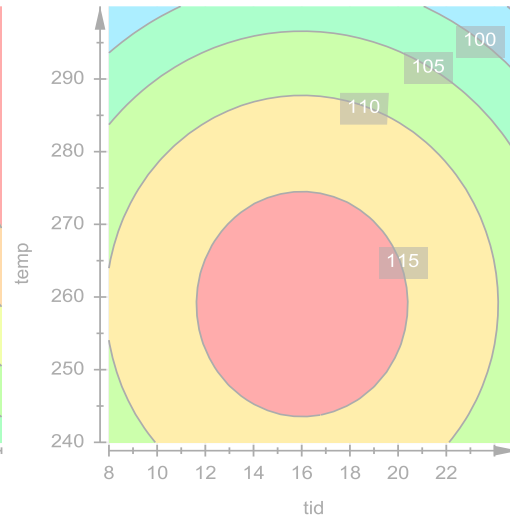
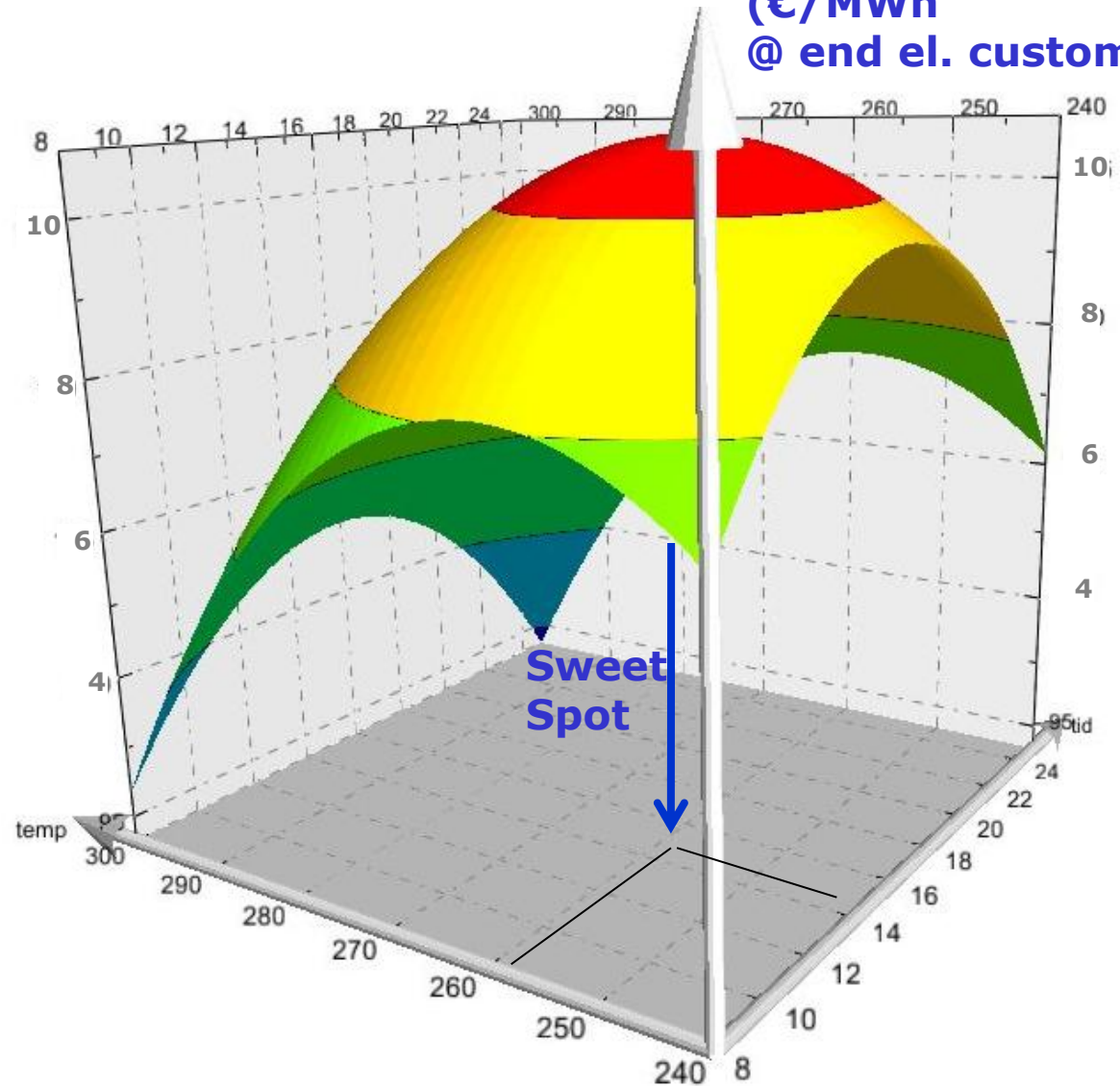




Illustration of Final Composite Response with economic weights - **always end customer specific**

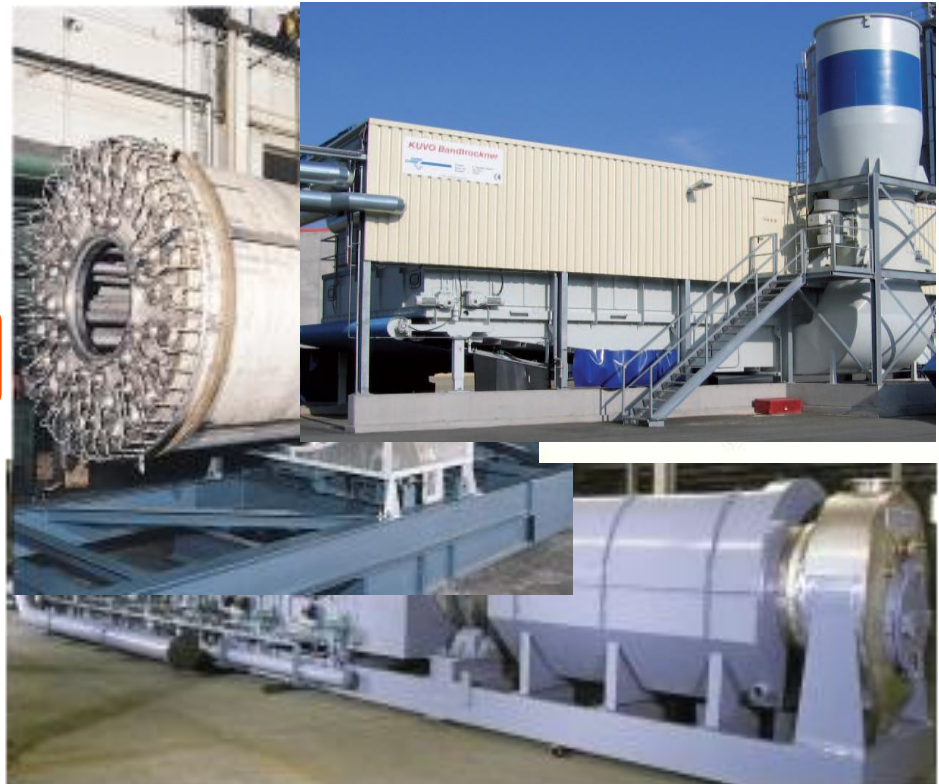
Total savings
(€/MWh
@ end el. customer)



Design Criteria of the Torrefaction Technology

Technology should be:

- *Robust & Simple*
- *Well Proven & Cost-efficient*
- *With High*
 - *Reliability & Availability*
 - *Flexibility (RD&D, parametric studies)*
 - *Controlability*
 - *Product Yield*
 - *Energy & Exergy Efficiency*
 - *Good HSE performance*
- *i.e. two separate processes*
 - *Drying based on LT bed dryer*
 - *Torrefaction based on indirectly flue gas heated rotary drum*



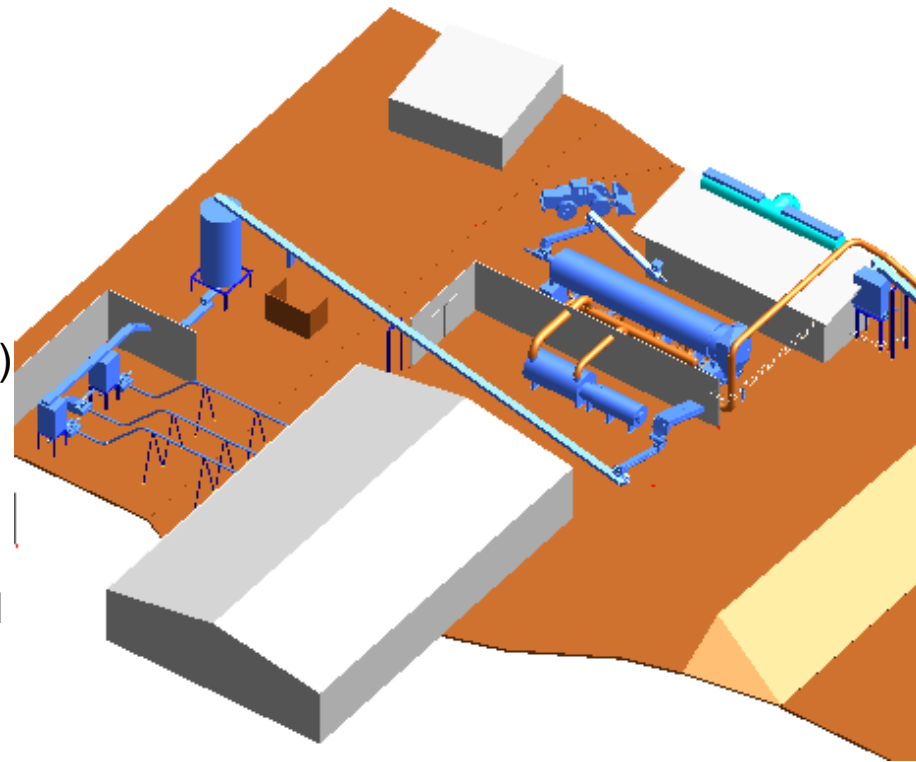
Design Data of the Bioendev Torrefaction-IDU (Industrial Development Unit)

- Fuel handling & Integration with new CHP
- Fuel capacity
 - in: 24 MW (4.9 ton/h)
 - out: 23-19 MW (4.3-3.3 ton/h)
- Gas thermal power 0.8-4.2 MW (LHV)
- Gas heat. value: 2.2-8.7 MJ/Nm³_{wet} (67-87%)
- Multi fuel: moisture 30-55%
- Operation: 250-300C, 25-10 min



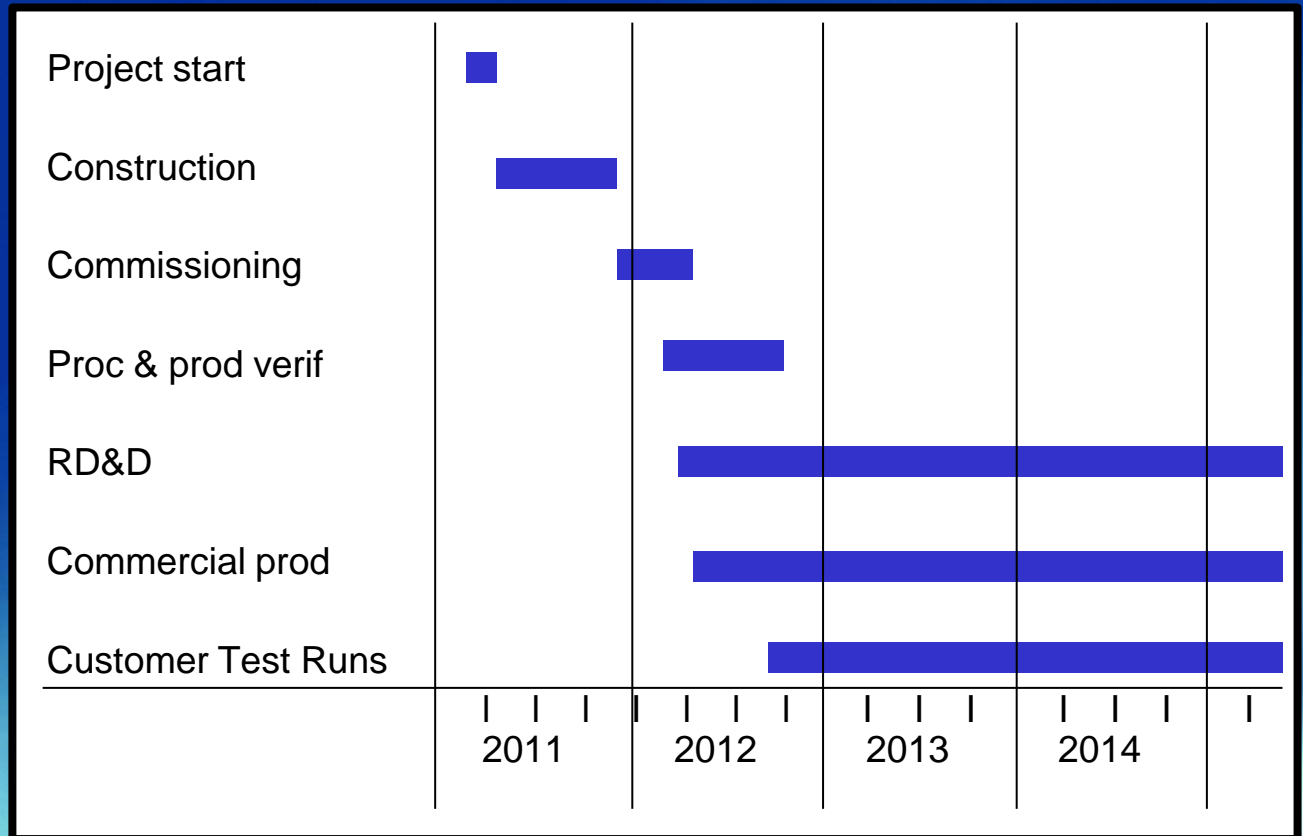
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- Operation: 250-300C, 25-10 min
- Products: Torrefied chips + densified biocoal
- Costs: ca 110 MSEK (11 MEuro)





Status for the IDU



Thank You

