bionic μFuel

Catalytic Microwave Depolymerization (MWDP)

2nd Generation Green Fuels from Biomass and Waste Materials

engineered and manufactured by

bionic

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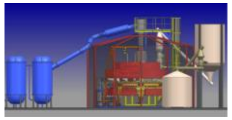
Changes due to technical improvement reserved. All technical data subject to confirmation.



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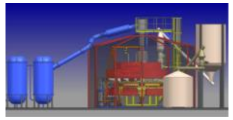
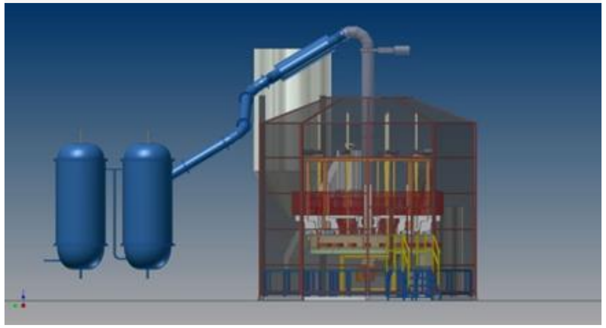


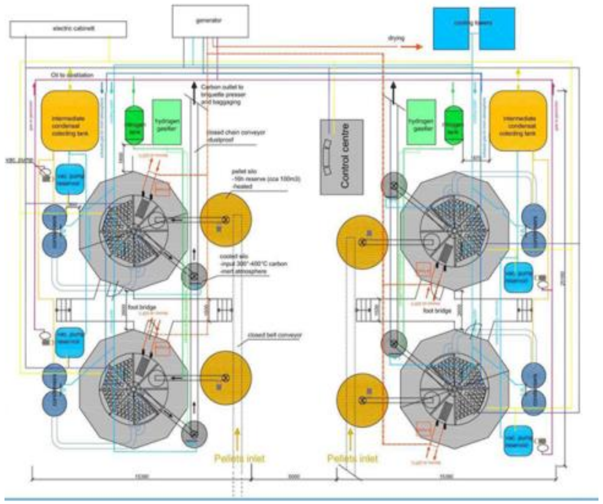


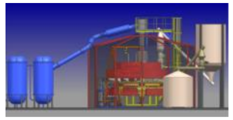
BIONIC µFUEL

ADDS A NEW DIMENSION TO STRATEGY FOR WASTE AND BIOFUEL MANAGERS

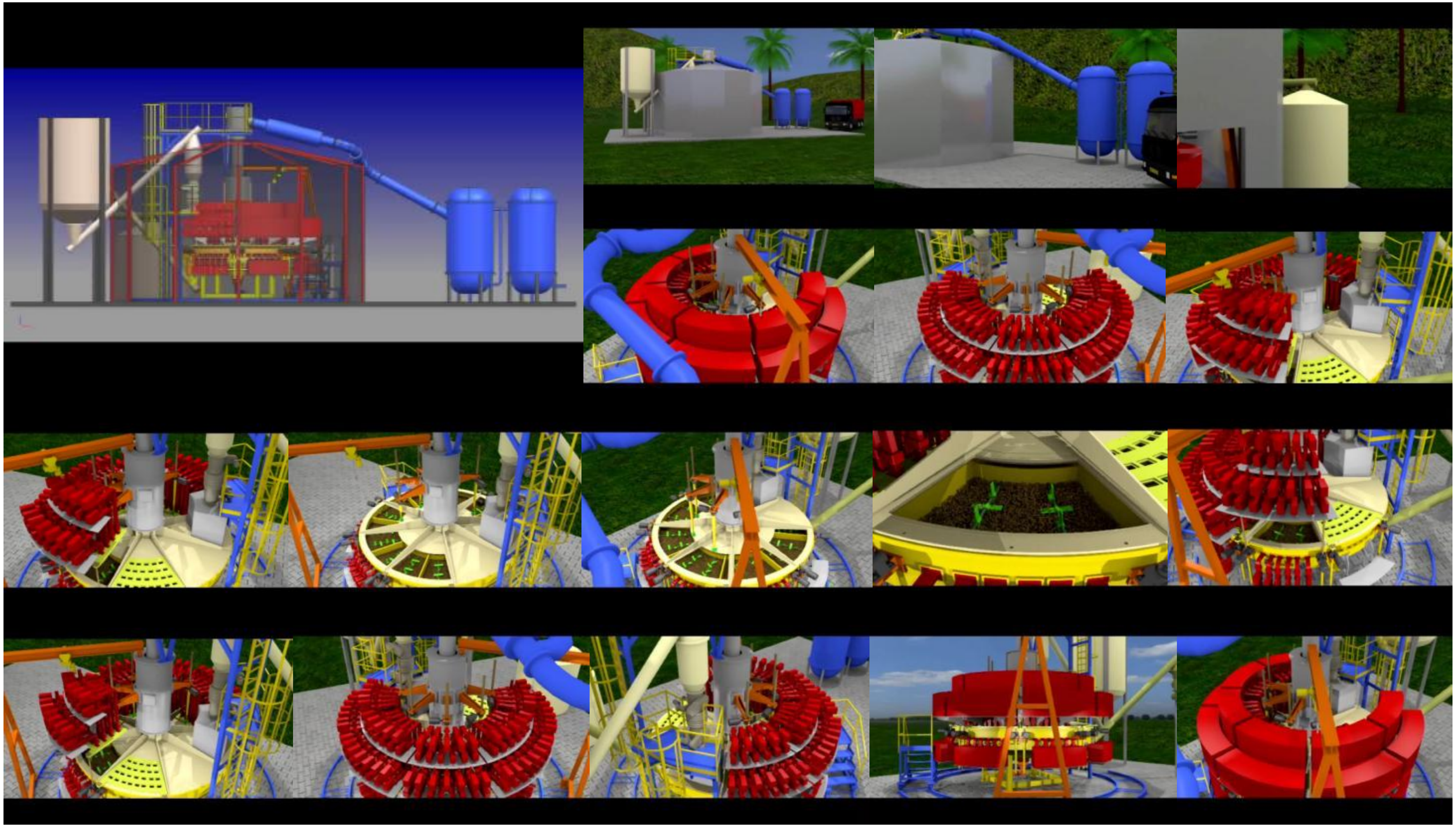
CONVERTING WASTE & BIOMASS INTO FUEL FOR DIRECT COMBUSTION AND TRANSPORTATION

- Reliable, Safe and Profitable
- All carbonaceous feedstock types
- Direct, single step conversion
- Hybrid process reactants: zeolite catalyst & microwave
- Hybrid energy application: microwave & excess heat
- Robust & scalable
- Advanced process control
- Unmatched product quality
- Return on investment 2-5 years

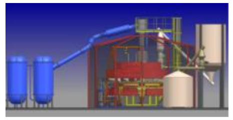




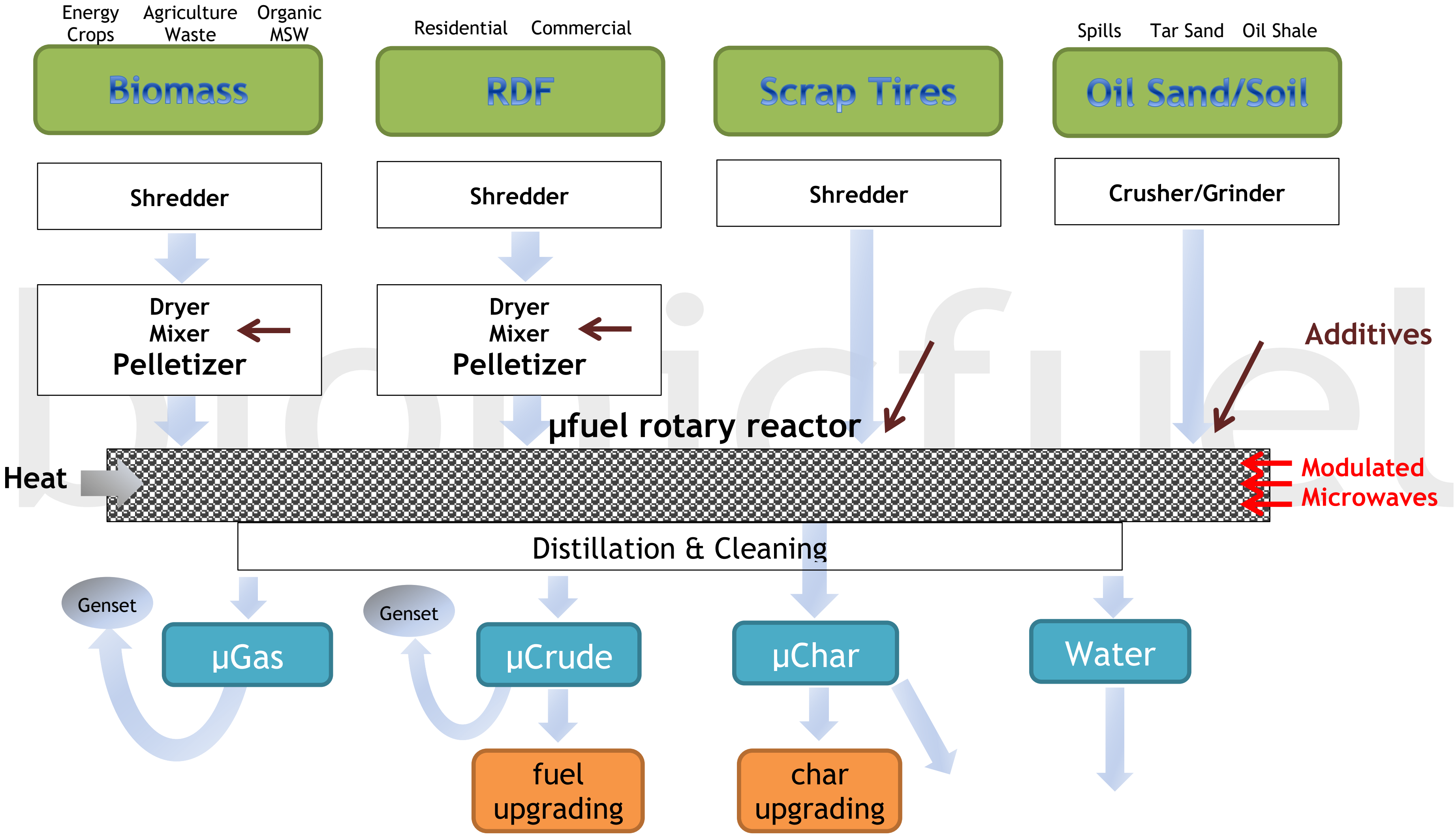
The mf480 core reactor

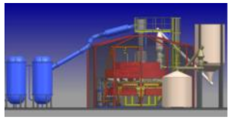


Manufacturing and Assembly of the mf60 Prototype



Feedstock Classes and their Process Flows





Overview

Fuel from waste and biomass – After decades still an unresolved issue

➢ **No technology is commercially ready**
Waste Streams and Biomass have been "discovered" as valuable energy sources decades ago. However, managers in the waste treatment and green fuel industries alike are still out on a painstaking search for conversion technologies that work.

The problems, however, remain unchanged or even more pressing. So it is really time to get going.

Picture 1 - New sources for fossil energy imply increased cost and risk for lower

➢ **Advancing climate change**
The energy mix has to shift drastically towards more sustainable sources to keep greenhouse gas emissions bearable. This is especially true for transportation fuels.

➢ **Depleting fossil ressources**
Given the depleted fossil oil reserves the development of alternative sources is without option.

➢ **Overboarding waste volumes**
The proper treatment and reuse of the overwhelming masses of waste materials modern societies generate is a permanent priority. Many methods need improvement.

The close links between those three pressing issues and the way how they are handled marks the threshold to a new sustainable framework for generations to come.

While energy consumption in the developed world is decreasing, that effect is more than counter balanced by the growing demand for energy in developing countries which are just approaching a new lifestyle of individual transport and high electricity use.

Picture 2 - Growth of demand for energy is not going to ease anytime soon

Bionic µFuel – a breakthrough in feed-stock flexibility and fuel quality

The µFuel process eliminates environmental, technical and economic roadblocks on the way forward to commercialization of 2nd generation biofuels. For the first time a hy-brid direct conversion technology driven by microwave and catalysts is ready for global deployment.

The use of microwave comes with numerous first-time features for green fuel production offering advantages that will become the benchmark for future industry standards:

➢ **Broad feedstock flexibility.**
No other technology can treat such a wide range of carbonaceous materials, from organic and plastic waste, scrap tires and all types of biomass to oil contaminated soils, tar sands and oil shale.

➢ **Efficient direct conversion.**
Direct conversion has always been recognized as the more challenging but superior approach. It combines high energy efficiency with the lowest equipment cost.

➢ **Highly accurate process control.**
Precise reaction control is the key to direct conversion. Bionic's hybrid process provides direct and instant control over all critical reaction parameters.

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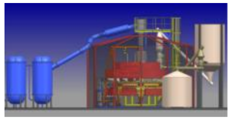


➢ Robust, upgradable reactor design.
A continuous base reactor with a near unlimited life time has been designed from scratch to accommodate the Bionic microwave systems. A strict separation of mechanical and microwave assembly allows any foreseeable upgrade to next generation microwave systems at the time of scheduled maintenance replacement.

➢ Meeting the latest fuel standards.
The hybrid technology enables an extra level of selective molecular upgrading. This integral function of the primary conversion process completely avoids the highly problematic quality issues of typical pyrolysis products.

➢ Scalable, compact plant size.
Bionic's standard plant design with a capacity of 60-80 tons of dry feedstock per day can be easily up- and down-scaled for individual project requirements. Size is determined by business parameters, not the technology.

➢ Low cost per barrel of Bionic µCrude.
As per barrel prices of fossil crude seem to settle above US$100, bionicfuel is extremely cost competitive. For some scenarios less than US$50/bbl all-in is possible. (see comparison table on next page)

➢ Sustainable profits offer return on investment within 3-5 years.
While exact numbers depend on dedicated business cases for individual projects exemplary calculations consistently show that bionicfuel projects offer excellent returns to investors at IRR levels above 30%.

The Bionic µFuel delivery system – A lifetime partnership approach

Bionic's standardized project approach enables fast and low risk implementations:

➢ Feasibility I - Conformity of Feedstock
*During a **technical feasibility phase** a thorough test and analysis program will be run at a Bionic test facility. The client's feedstock and the resulting products will be fully analyzed in cooperation with reputed fuel labs.*

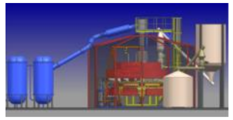
➢ Feasibility II - Detailed Business Plan
*In a **business feasibility phase** experienced Bionic consultants work with clients to develop concise business plans based on the technical data determined initially. Economic forecasts for plant operations are very reliable after local market conditions are explored thoroughly and integrated.*

➢ Reliable Performance
A feasibility study executed according to the Bionic guidelines will deliver technical and economic data which then enters into a project contract as Bionic approved plant performance parameters.

➢ Phased Capacity Scale-up
The completely modular, scalable design of bionicfuel technology allows phased project plans, reducing risk and easing funding.

➢ High Plant Availability
Designed for minimal down time availability can be expected above 90%. The modular, robust design in combination with the absence of any mechanical wear on the high tech components drastically reduce any risk of plant failure. Preventive maintenance, redundancy in critical areas, electronic sensory control and remote monitoring add their part. Standardized components and off-the-shelf parts help control cost.

➢ Full Maintenance at Fixed Terms
A full service maintenance contract including parts and scheduled preventive replacement components guarantees high availability and full cost control.



Bionic µFuel cost and profitability

Calculations are based on plants built around a single mf480 reactor. Project ramp up is in 2 consecutive phases.
Feedstock: 31K - 38K tons/yr
Operating hours: 24/7
IRR: < 30-40% ROI: < 4 yrs

Includes all reasonable operation cost including overhead. Feedstock cost/credits and revenues from by-products are taken into account.

	feedstock=scrap tire chips				feedstock=mixed/composite plastic			
	2014 (phase 1)		2015 (phase 2)		2014 (phase 1)		2015 (phase 2)	
production in million ltr	***10.9***		***18.2***		***9.3***		***14.3***	
marketable oil in million ltr	9.6		16.0		7.3		11.3	
in bbl	60,360		100,600		46,014		70,790	
feedstock cost(+)/ gate fee(-)	797,243		1,421,441		-483,990		-558,450	
revenues from byproducts (char, steel)	-1,601,442		-2,802,524		-416,779		-692,494	
operating cost	***1,783,198***		***3,036,632***		***2,111,151***		***3,036,632***	
capital cost (15yr amortization, interest)	865,203		960,996		1,110,444		1,378,545	
production cost per ltr	***0.102***		***0.104***		***0.165***		***0.159***	
capital cost per ltr	***0.090***		***0.060***		***0.152***		***0.122***	
total cost per ltr sold	***0.192***	***25%***	***0.164***	***20%***	***0.317***	***42%***	***0.281***	***34%***
revenue per ltr	***0.764***	***100%***	***0.825***	***100%***	***0.764***	***100%***	***0.825***	***100%***
profit per ltr	***0.572***	***75%***	***0.662***	***80%***	***0.447***	***58%***	***0.544***	***66%***

conversion to US$/barrel for better comparision with fossil oil/products

Note the quality difference between fossile crude and bionicfuel = diesel X-rate US$ per €: 1.3

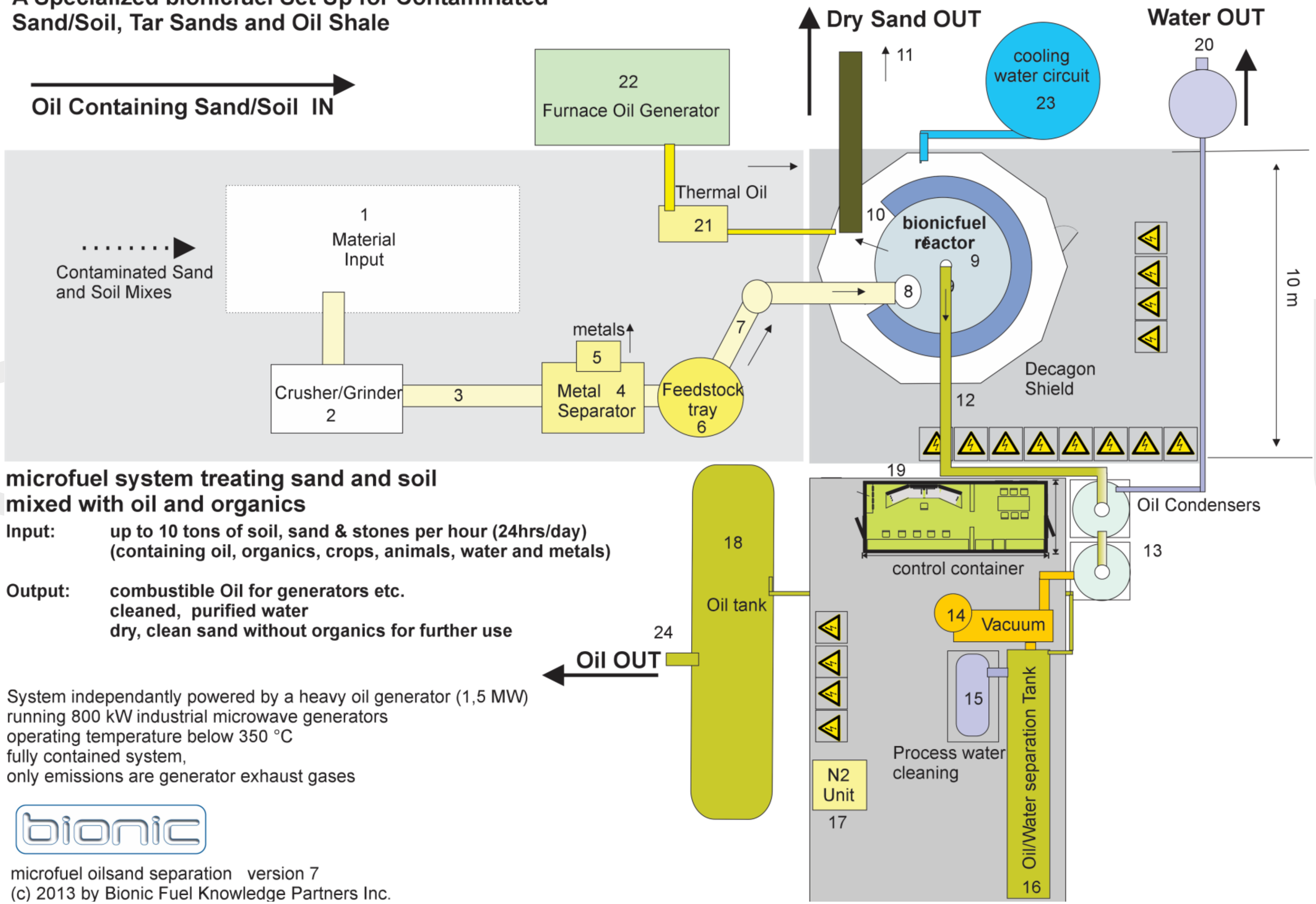
	€	US$	€	US$	€	US$	€	US$
production cost per gal (us)	0.39	0.50	0.39	0.51	0.63	0.81	0.60	0.78
capital cost per gal (us)	0.34	0.44	0.23	0.30	0.57	0.75	0.46	0.60
total cost per gal (us)	0.73	0.95	0.62	0.80	1.20	1.56	1.06	1.38
production cost per bbl	16.22	21.09	**16.46**	**21.39**	26.30	34.20	**25.23**	**32.79**
capital cost per bbl	14.33	18.63	**9.55**	**12.42**	24.13	31.37	**19.47**	**25.32**
total cost per bbl	30.55	39.72	**26.01**	**33.81**	50.44	65.57	**44.70**	**58.11**

Bottom line gross profit margins speak for themselves. The numbers have been extracted from full scale business plans developed by BIONIC for individual German clients.

A common indicator mostly used in the industry to judge and compare technologies. 1US$ is considered as a threshold by many commentators.

The bottom line we really care about: µFuel easily competes with any advanced fossil sources like deep sea, tar sand or shale even on the crude level, with a quality comparable to refined fossil products.

A Specialized bionicfuel Set Up for Contaminated Sand/Soil, Tar Sands and Oil Shale



microfuel system treating sand and soil mixed with oil and organics

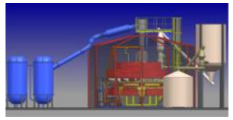
Input: **up to 10 tons of soil, sand & stones per hour (24hrs/day) (containing oil, organics, crops, animals, water and metals)**

Output: **combustible Oil for generators etc.**
cleaned, purified water
dry, clean sand without organics for further use

System independantly powered by a heavy oil generator (1,5 MW)
running 800 kW industrial microwave generators
operating temperature below 350 °C
fully contained system,
only emissions are generator exhaust gases

bionic

microfuel oilsand separation version 7



The Bionic µFuel development

→ In 2003 Bionic initiated the development of the unique bionic µfuel technology.

Picture 3 - An early lab reactor with oil treatment

Two depolymerization methods functioning independently were combined into a novel, hybrid conversion process capable of transforming any carbonaceous feedstock material into liquid and solid fuel. Bionic merged for the first time the direct conversion methods **Thermal Catalytic Depolymerization (TCDP)** and **Microwave Pyrolysis (MP)** into a single hybrid process: **Microwave Depolymerization (MWDP)**. TCDP was known for decades, but many hurdles impeded commercial implementation. Adding microwaves to the process not only eliminated all prior technical design issues, but added a number of beneficial effects unique to microwave applied to chemical reactions.

→ In 2007, after years of lab research, the first continuous reactor design was ready for testing.

Picture 4 - A pilot reactor opened up for inside maintenance

At a pilot plant operating in 2008 and 2009 confirmed the superior concept of the process and reactor design. Soon after the current standardized design of the commercial base reactor mf480 followed.

→ In August 2013 the first prototype of a technology demonstrator went online. The mf60d is a downscaled, very compact mobile variant of the standard mf480 design which is available for special applications and as a fully functional continuous demonstrator and test bed. This prototype marks the final step to commercialization.

Picture 5 - The mf60d prototype

A highly effective zeolite catalyst works together with other process reactants and the Bionic microwave technology. Bionic µFuel plants are the most economic and efficient way commercially available to date for the production of clean liquid fuels from biomass and waste materials. With minimal petrochemical upgrading the liquid fuel product can be used even in the latest diesel engines year round.

No carrier oils or complicated pump and heat transfer systems are required, which were always been susceptible to failure. Instead, a feedstock remaining completely dry throughout the process allows a simple and robust reactor design coupled with the advanced microwave and control technology developed by Bionic Laboratories.

The conversion process is preceded by a pretreatment stage greatly dependent on the type of feedstock used. Most materials must be dried to a humidity level of 10% and shredded or ground, before they get mixed with the process additives and are then pressed into pellets.

The pellets are fed into the reactor for processing. After preheating with excess heat from the internal power generation they enter the critical microwave radiation zone. Under precise temperature control high vapor pressure develops inside the pellets facilitating a first phase of chemical reactions before the steam escapes from the pellets.

At surface temperatures around 300°C the combined effects of pulsed microwave radiation, activated carbon particles and zeolite

Picture 3 - Oil vapors emerging from the reactor are subsequently condensed and cleaned in a quencher unit

catalyst sets in. The complex hydrocarbon molecules are cracked, still inside the feedstock, into smaller, more volatile molecules and vaporized. Most of the cracked hydrocarbon molecules are within the diesel range. These cracked molecules emerge from the reactor as an oil vapor which travels through a number of condensers and a quencher for treatment.

The resulting fuel product can be further upgraded to meet established fuel standards with typical petrochemical methods.

The solid residue remaining in the reactor once all oil contained has been vaporized consists of carbon mixed with any minerals from the feedstock. As a high calorific char product it represents the second valuable product stream deriving from the µFuel process.

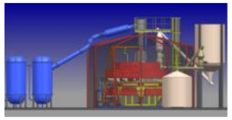
For the most part µFuel plants combine standard machinery and off-the-shelf components with a core reactor that has been developed from scratch by BIONIC for best results with the microwave application. The microwave packs themselves are built from 90% standard components upgraded with BIONIC technology and control software.

Scientific Background

One of the ground breaking technologies in the context of depolymerization, the flash pyrolysis, had been developed in the late 1950ties. Another improvement was introduced in the 1980ties by Prof Bayer at the University of Tubingen in Germany. His lab research demonstrated the effectiveness of zeolite catalysts in conjunction with thermal depolymerization of various feedstock types containing significant amounts of carbonaceous substances. He called his new process **Low Temperature Catalysis**.

Based on these findings it became possible to transform biomass including cellulosic compounds and a wide range of waste materials into short aliphatic hydrocarbon chains. The resulting liquid products are similar to light oils from fossil crude. They match the characteristics diesel and light heating oil.

A related process is in common use at oil refineries for the transformation of heavy oils into transportation fuel known as **Catalytic Cracking**. The Houdrey process was introduced for the first time in 1937 at the Marcus Hook refinery in Pennsylvania, USA. The process allowed for doubling of the quantity of gasoline produced from fossil crude oil and played a major role for the fuel supply to the Allied Forces during World War II.



While the heating effect of microwaves was discovered by accident in 1946 science did not show a lot of interest in the application of microwaves to chemical reaction processes until recently. However, over the last 10-15 years an increasing number of scientific studies begun to emerge about the use of microwave, including in the field of biomass pyrolysis. While many of the observed effects are still not completely understood there is wide consensus in scientific reports on a number of distinct advantages when compared to conventional pyrolysis methods.

The most mentioned advantages are the very energy efficient, rapid heating from the inside out and the selectiveness of microwave agitation based on molecular electric properties which take the effect beyond simple heating.

Not in the scientific focus yet is Bionic's hybrid use of zeolite and microwave together which consistently gives the results from the µFuel conversion process its distinct edge over those from scientific lab experiments with microwaves.

Picture 4 - Microwaves are heating from the inside out

Even more, Bionic has taken these superior results already from the lab to commercial implementation. Never the less, the still intensifying interest of the scientific community in microwave chemistry will facilitate further process improvements. Bionic works closely with scientists around the world.

The Feedstock - Product Mix

µFuel's flexibility regarding feedstock selection is outstanding. The reactor design itself sets no practical limitations for feedstock materials that can be shredded and fed through the dual heat up and radiation phases inside the chamber. Project feasibility is determined only by feedstock composition and energy content, not the technical equipment.

Bionic differentiates 4 major feedstock classes for treatment with a µFuel system:

- **Biomass**
  (including energy crops, lignin from the paper and pulp industry, agriculture and forestry waste and organic fractions of MSW).

- **Waste materials**
  (including all carbonaceous household and commercial waste streams, animal waste).

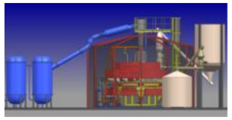
- **Scrap Tires**
  (no removal of metal or textiles from feedstock is necessary, scrap metal is recovered from residue after oil extraction).

- **Special Applications**
  (toxic waste, oil spillage and contaminated soil, tar sand, shale oil).

For all feedstock types the contained energy is extracted and concentrated in liquid and solid form, making it less volatile, better storable, transportable and usable like fossil fuel products. In many cases the Bionic products can be produced at a lower cost than their fossil counterparts, adding to the environmental advantages.

The solid µChar product is a much cleaner direct replacement for the combustion of fossil coal, but due to its high quality it can also be used as a raw material for activated carbon, carbon fibre and many other industrial applications. When pure Biomass is processed the resulting Biochar can also be used as a soil amendment.

The liquid Oil product is primarily a drop-in-fuel, but might also contain high value marketable chemicals that can be separated at advantageous cost levels compared with



traditional production methods. On-going research on bio-refinery concepts will open up new options in the future. The current marketing possibilities include:

- Sale to refineries as green feedstock,
- Direct upgrading to Diesel and/or Jet fuel,
- Direct electricity production via motor or turbine driven generators as an interesting option to buffer the supply gaps left by wind and solar power generation.

There are also some useful by-products:

- Gas, which is used to co-fuel the internal power generation,
- Highly purified water
- Excess heat usable for industrial applications nearby
- Valuable minerals might be extractable profitably for some feedstock configurations.

Emissions and disposable liquid/solid residues are minimal compared to other process.

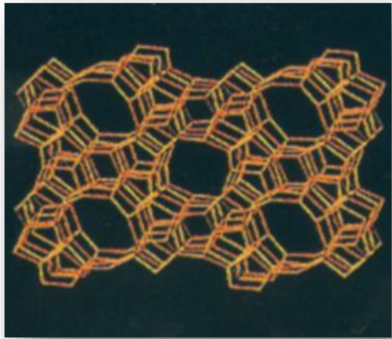
The Process in Detail

Catalytic Conversion

Many attempts have been made over the last 30 years to implement a commercially viable technical process for a direct catalytic conversion. What worked well in the lab and on small scale pilot implementations didn't make it to large scale commercial implementation for various technical design reasons. However, catalytic, low temperature conversion had proved its chemical and physical feasibility beyond any reasonable doubt.

Picture 5 - Zeolite Catalyst under the microscope

The zeolite catalyst used in the process has a constant pore diameter in its crystalline nano-structure, allowing only certain molecules to pass the crystal mesh and come in contact with the reactive centers. That's why zeolites are often also described as molecular sieves.



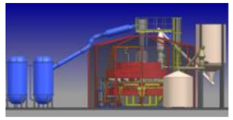
Picture 6 - Zeolite mesh model

Choosing the best fit zeolite increases control over the fuel products formed on the molecular level by the process.

Microwave Conversion (Pyrolysis)

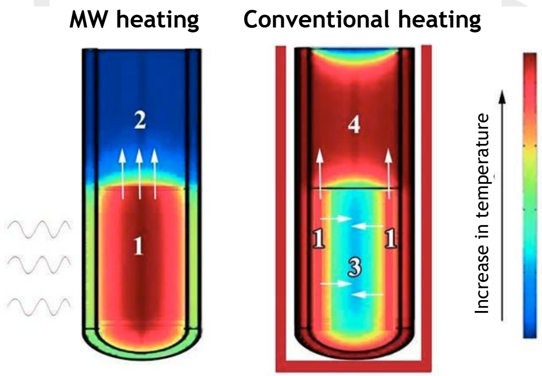
The modulated, pulsed microwave radiation induces a well-defined oscillation in the polar molecules within the reaction mass which in turn heats up the material. The oscillation and resonance cracks larger molecules, an effect that works even better in the presence of the zeolite.

The application of energy via microwaves is an environmentally friendly and most efficient method of heating.



For even higher efficiency a hybrid energy application is built into the reactor vessel which utilizes excess heat from the internal power generation to preheat the reaction mass before the microwave treatment begins.

Microwave radiation penetrates the material, heating it from the inside out, without the source of the radiation being subjected to any friction or other mechanical wear. Microwave heating affects the process in a very different manner than any conventional heating would.

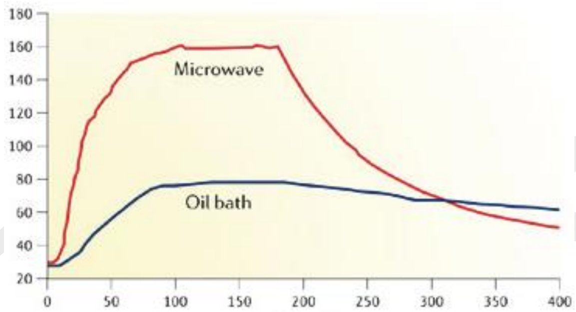


Picture 8 - Microwave and conventional heating
1-Areas of oil formation
2-Cold gas over the sample in microwave
3-Area of oil reaction with colder reaction mass
4-Hot gas over the sample in a heater

Contrary to common belief energy application with microwaves is most efficient. The industrial application of microwaves cannot be compared to typical household devices.

The long-life magnetrons (microwave generators) used are maintenance free during their lifetime. Replacing the magnetrons is easy and occurs annually as part of scheduled maintenance work.

Absolute safety of operating personnel is ensured by strict radiation shielding and an



Picture 7 - typical microwave heating curve compared to conventional heating

additional housing of the reactor excluding any possibility of radiation leaks.

The possible formation of highly toxic dioxins and furans from plastic feedstock was always a key disadvantage of conventionally heated depolymerization technologies. As they are produced only at temperatures above 550°C that danger has been completely eliminated with the µFuel technology where temperatures never rise above the 350°C threshold.

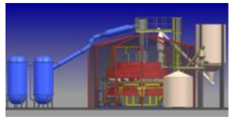
The Technical Implementation

Feedstock Preparation

The feedstock material needs to be dried to the right moisture level and shredded to the optimal particle size, subsequently blended homogeneously with the catalyst and finally pressed into pellets of 6 x 40 mm standardized size. It is of high importance that the used shredding technology is robust, low maintenance and efficient.

A typical production facility would use redundant preparation lines whenever possible. While acquisition cost is slightly higher, redundancy allows maintenance and repair without interrupting main production.

Picture 9 - Compressing most feedstock in pellet form is an important part of the process



Feedstock Conversion

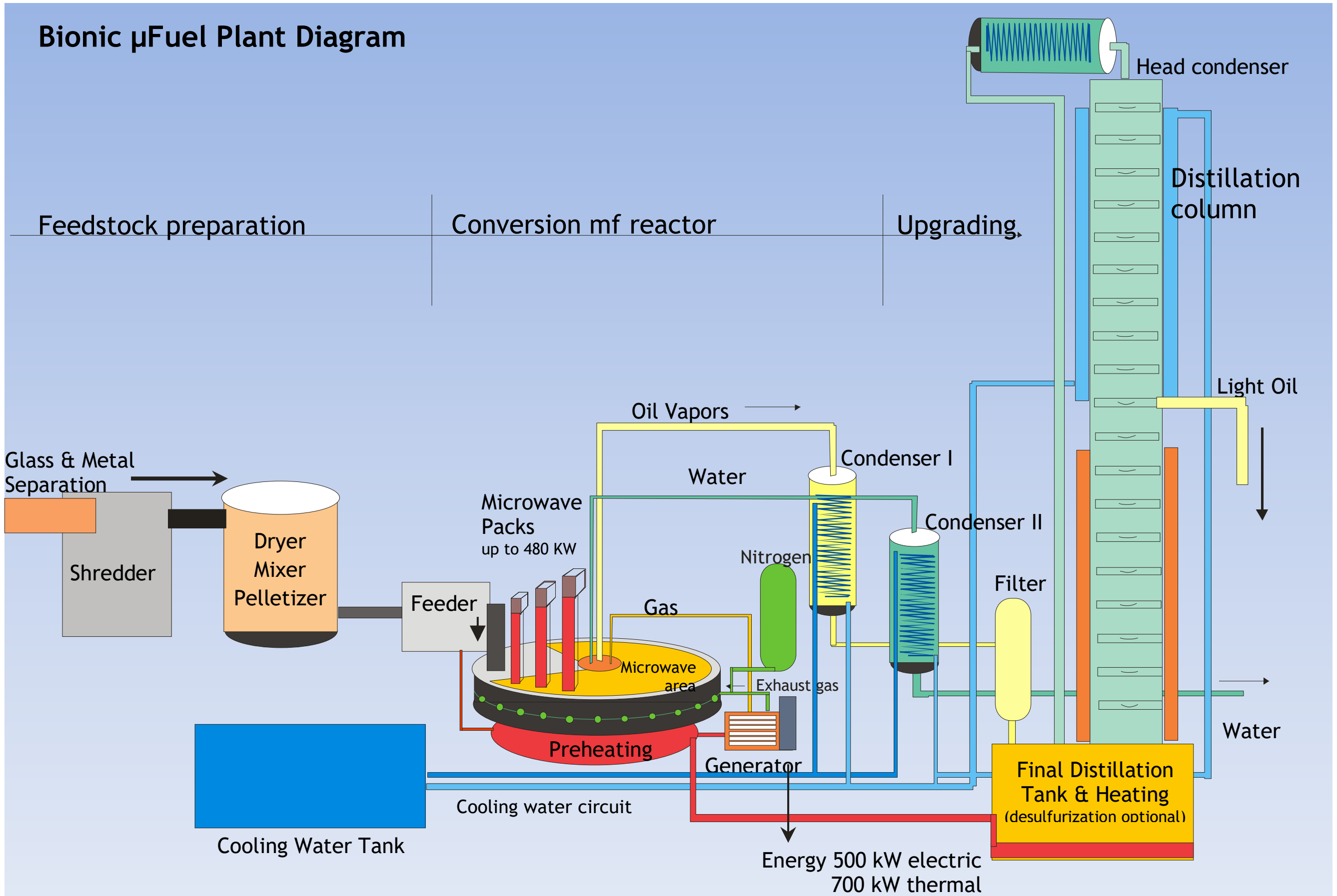
The prepared pellets are fed to the conversion reactor and treated in an inert atmosphere (N or CO2) with pulsed microwaves of 480 kW peak power after conventional preheating with excess heat from the CHP.

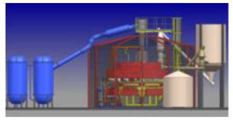
The impact of the concentrated microwave radiation on the compressed reaction mass results in rapid heating of the dielectric water molecules contained, breaking up organic structures before they evaporate together with the volatiles when the pellet surface opens up.

In a second phase carbon and the zeolite catalyst function as strong microwave receptors facilitating a series of cracking reactions breaking down larger carbonaceous molecules thus creating an oil vapor emerging from the reaction mass.

The presence of the catalyst causes an effect called “in-situ upgrading” by scientists. Vaporized hydrocarbon molecules are further upgraded before leaving the reactor for condensation. It is that effect which is responsible for the high oil quality unmatched by any other direct conversion technology.

The µFuel process is a “dry” process thus avoiding coking or plugging of the system.





Oil Upgrading

The oil vapors of the group C11-C64 (diesel type oils), are subject to the final distillation.

Hydrocarbons that have not yet been fully processed can be returned to the reactor. Depending on product requirements, the distilled oils are fed to hydration and desulfurization units for upgrading to conformity with the respective fuel norms.

The scope of delivery includes a high quality fuel laboratory with the required analysis equipment for continuous monitoring of product quality.

In cooperation with one of the most renowned manufacturer of analysis equipment a standardized analysis system has been developed.

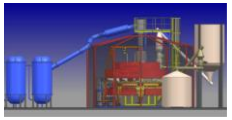
Picture 11 - Lab equipment for continuous quality control of feedstock and products

Internal Energy Supply

As a by-product the µFuel process yields hydrocarbon gases with a low boiling point. It fuels the internal CHP in combination with a small percentage of the liquid fuel product. Thus a plant is energetically independent from the grid.

Picture 10 - Internal heat and power generation for grid independence

One or more specially adapted CHPs with 400 - 1500 kW permanent electricity output supply sufficient energy and heat for feedstock drying and pre-heating. Depending on the individual project situation excess power and heat can be supplied to the outside.

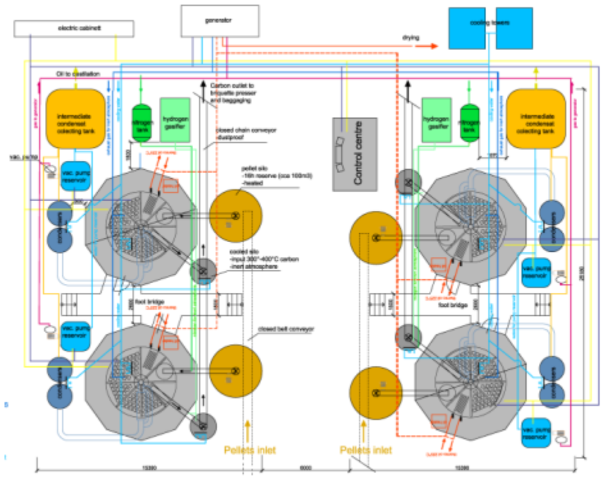


Scaling the Plant Capacity

The core reactor is designed for an output capacity of approx. 1.250 l/h. Average oil yields are 30%-35% for biomass and up to 80% for pure plastic waste.

A special design feature is the **possibility of down-scaling** capacity. This is achieved by mechanically reducing the volume of the reaction chamber in sync with a reduced number of microwave units. A reduced capacity of e.g. 30% is useful when the facility is used for research or testing. Later the capacity can easily be upgraded.

Up-scaling can be achieved by combining several reactors into clusters. With clustered reactors capacity can be increased to 5.000 l/h and more sharing the same feedstock preparation and fuel distillation equipment.

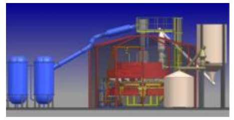


Picture 12 - A 4xcluster floor plan

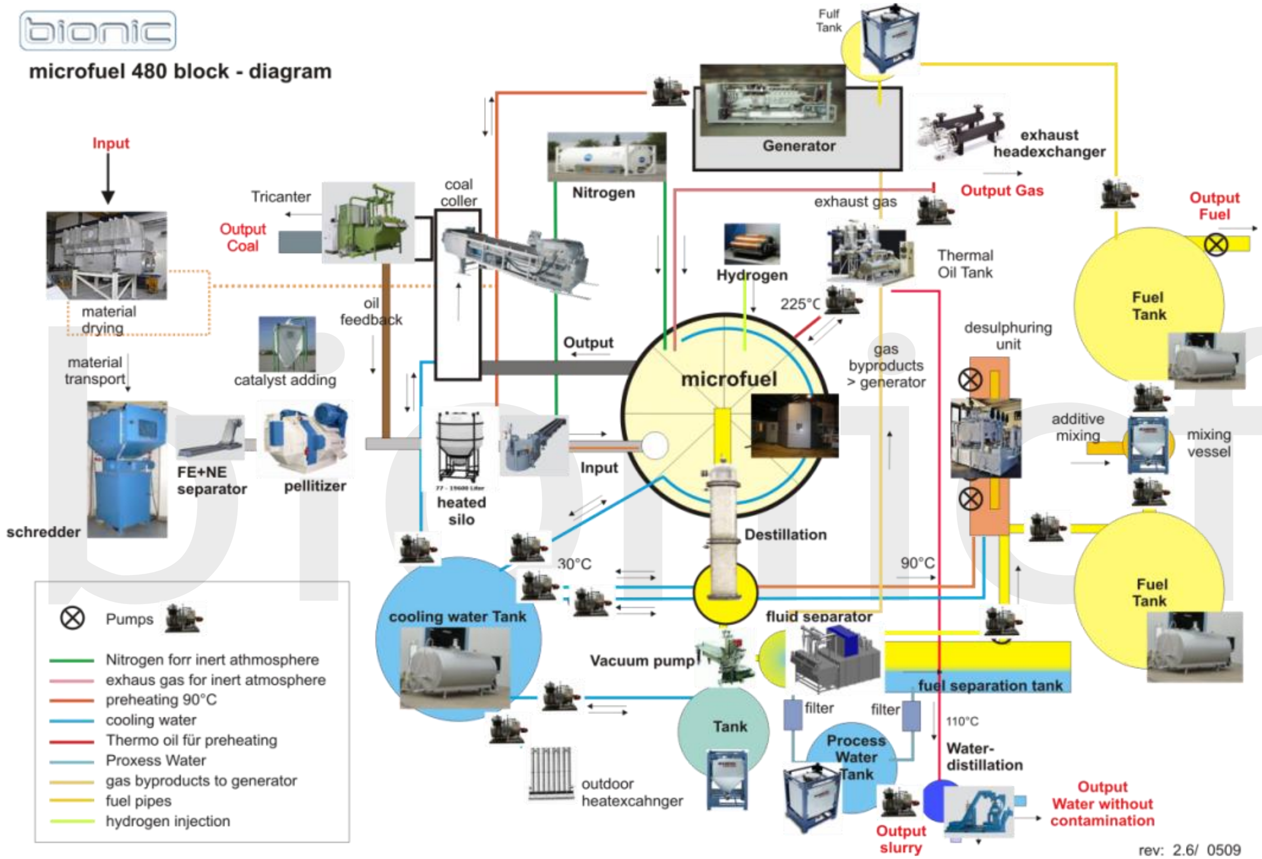
Components of a µFuel plant

A complete production plant typically consists of the following components:

- **Feedstock Storage**
  Ample area for dry storage of feedstock material
- **Shredder**
  Equipment to grind the feedstock material down to the right particle size
- **Pellet Press**
  Equipment to compact the grinded feedstock mixed with catalyst and additives into pellets
- **bionicfuel reactor**
  Flatbed, rotary reactor, hybrid heating and microwave application
- **Condensate Tank**
  Buffer tank for the reaction product
- **Distillation**
  Thermal distillation for product purification
- **Desulfurization Unit**
  For biomass feedstock, removal of sulfur from oil
- **Product Storage Tanks**
  Storage tanks for the liquid fuel
- **Mixing Vessels**
  Vessels to mix the liquid fuel with additives for upgrading.
- **Water Tanks**
  Storage tanks for water separated during conversion of the reaction mass
- **Char Storage Container**
  Storage for the char product
- **Supplemental Tanks**



Tanks for inert gas, hydrogen, process additives



- **Combined heat and power plant (CHP)**
  Motor and generator for internal energy production
- **Laboratory for Quality Control**
  For continuous product analysis

- **Bio-Elite Carbon-to-Fertilizer Unit**
  An optional module to upgrade Biochar into a highly valuable soil amendment

Plant control & safety

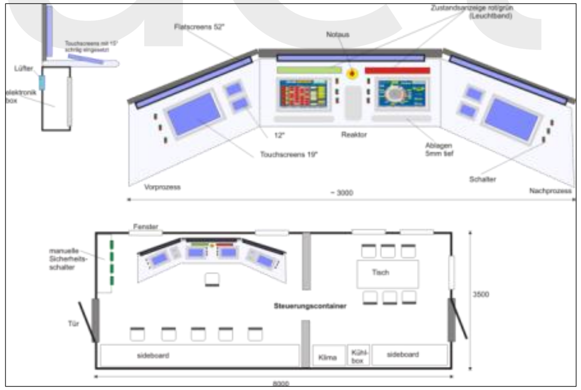
All control systems are centralized in a container which contains an operator control desk from where all critical process stages are monitored and controlled.

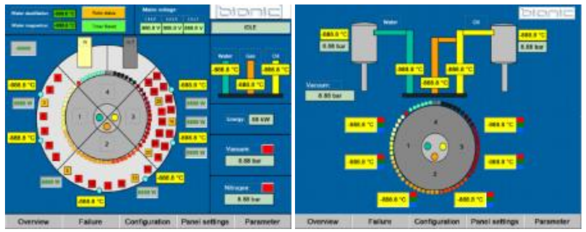
A special emergency shutdown procedure has been developed and programmed throughout the system to avoid risk and damage in unexpected emergencies.

Redundant power supplies are installed for all critical control functions.

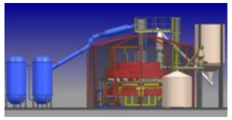
The µFuel facility is built in high-grade steel. The microwave units comply with all technical standards for high-frequency installations and are certified according to all current regulations.

While not required by regulations the facility is designed explosion proof according to the ATEX standard.





Picture 13 - The control center with some control screens



All components are built by certified German and Czech manufacturers observing the highest quality standards. Compliance with strict specifications and standards is continuously monitored by BIONIC quality control.

Site preparation requirements

In order to install a µFuel plant, the following site preparations are necessary:

Paved area of at least 800 m^2

A **building** of the dimensions 20 x 15 x 12m

Area for feedstock storage min. 1000 m^2

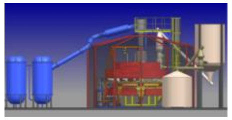
Power supply of 400 V/kW continuous load for emergency operation

Separate housing for the attached CHP (900 kW elec. energy)

Water connections and cooling water tanks, water drain (for cooling water, not contaminated)

Area for fuel tanks

All necessary legal permits need to be obtained.

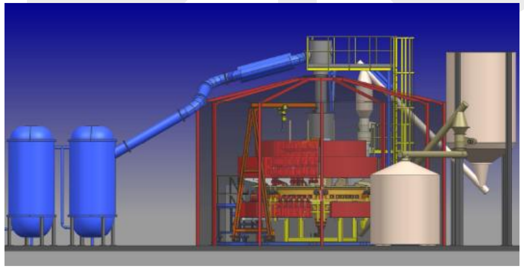


The Products

The table on the right provides an overview of the versatility of the process regarding possible feedstock. It shows typical oil yields for a wide range of materials varying greatly from feedstock to feedstock.

Yields can be further improved by the exact selection of catalyst, additives to the feedstock and precise determination of all process control parameters. Trials and process adjustments are part of the start-up phase of any plant.

Values in this table are indicative only and cannot be guaranteed before verification with the exact material intended for an individual project.

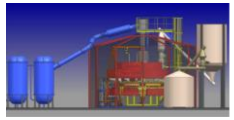


Feedstock type (dry matter, 10% hum.)	Oil Yield (in %)
Wood	34,0%
Sweet corn	35,0%
Slurry	44,0%
Miscanthus	39,0%
Biomass (average)	35,0%
Olives	47,0%
Palm cake	49,0%
Sewage sludge/ RDF mix	53,0%
RDF(42MJ)	54,0%
RDF hydrated	68,0%
Rapeseed cake	55,0%
Tire crumbs	60,0%
Saw dust	34,0%
Reed	36,0%
Fluff from recycling	78,0%
Straw	35,0%
Wax	89,0%
Wheat bran	42,0%

The Main Conversion Products

µCrude: as illustrated in the table on the left oil yields differ greatly depending on feedstock. The same applies to quality and upgrading requirements and opportunities. The liquid µCrude often can be used directly for power generation or upgraded to standard heating and transportation fuels. In countries with Biofuel mandates in force, like for all EU-members, µCrude deriving from renewable sources can help refineries meeting these legal obligations.

Picture 14 - Bionic µFuel oil has an unmatched level of quality



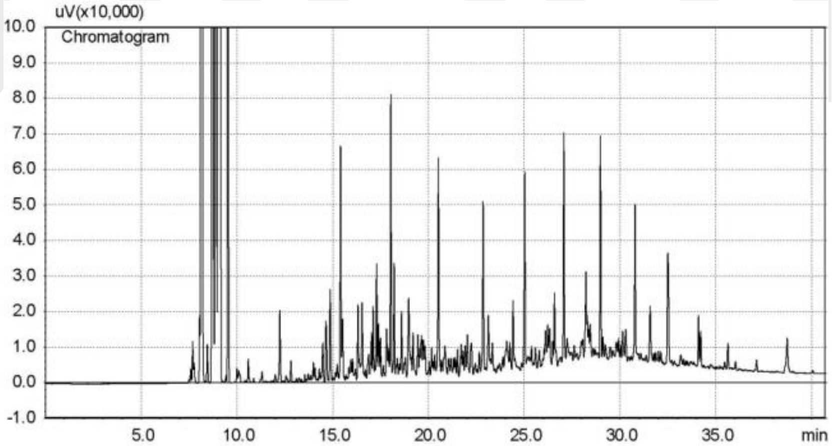
Oil Properties

The table on the right shows analysis data for the liquid product processed from a mix of plastic waste (RDF). It demonstrates how close the crude product already matches the EU standard for diesel fuel. The use of standard petrochemical upgrading options closes the remaining gaps.

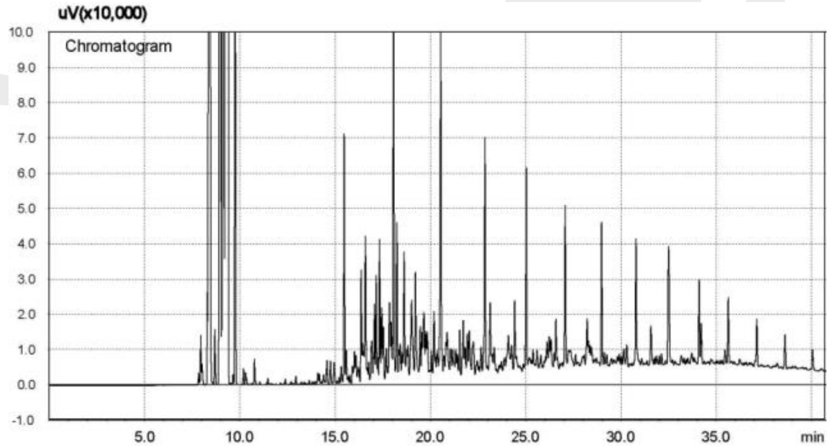
The chromatograms below show a µFuel sample's chemical composition compared with a Diesel sample from the filling station.

Parameter	EN 590	Distillate	Unit
Kin. viscosity at 40°C	2,00 to 4,50	2,94	mm^2/s
Density at 15°C	820 to 845	831,40	kg/m^3
CFPP	Max. -20	-15,00	°C
Cetane index	Min. 46,0	42,90	-
Distillate at 250°C	< 65	60,17	Vol. %
Distillate at 350°C	Min. 85	95,21	Vol. %
95% percentile	Max. 360	351,19	°C

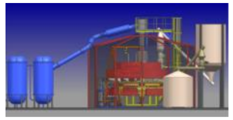
Table 1 - bionicfuel crude oil analysis



Bionic µFuel light oil fraction from straw
(distilled, hydrated, first peak is n-hexane as a solvent)



For comparison: Diesel straight from the filling station



µChar: a high purity, homogeneous carbon product for most feedstock types with a calorific value comparable to highest quality fossil coal. Besides the use as a combustible solid green fuel other product options exist.

Bionic µChar exhibits an unmatched microporosity of up to 1,300 m^2/g making it a candidate for typical activated carbon uses without any further treatment except grinding.

Extensive tests of µChar from biogenic feedstock as a soil amendment showed remarkable results:

Picture 15 - bionic-char helps increase and sustain valuable top soil

- The open, extremely porous structure has strong hydrophilic properties.
- As the carbon fraction contains most minerals (ashes) from the feedstock, the reuse of nutrients is optimal.
- NH3 contained in manure and most microbiological waste is eliminated during the µFuel process.
- The crystal structure of the carbon is polarized due to the microwave radiation increasing the capability of water absorption and storage.
- The char is completely sterilized and can be upgraded with beneficial microorganisms for improved fertilizer quality with e.g. nitrobacteria.
- The presence of the environmentally neutral zeolite catalyst (sodium-silica-aluminate) further increases water absorption of the char.

Picture 16 - Bionic µChar has extraordinary capabilities to preserve water and nutrients

Upgrading µChar into an organic fertilizer and soil amendment product offers a significantly higher revenue potential than its utilization as a simple solid fuel. Therefore Bionic has developed its innovative **Bionic µSoil** product line, modern versions of the historic Terra Preta discovered in the Amazon basin not too long ago.

Bionic µSoil combines the huge potential of the patented Bio-Elite process, an organic fertilizer production method licensed by Bionic, with the outstanding functions of **µChar** as a carbon rich soil amendment.

Bionic is currently building a franchise system centered in Germany for the production and marketing of this unique product.

In another series of live testing Bionic µChar was added to the bedding of chicken stables. Results turned out as expected. The µChar amendment eliminates a major industry problem, the ammonium emissions, to a level where emission control systems soon becoming mandatory in the EU will not be needed.

The resulting **Bionic µSorb** is another fascinating product utilizing the special properties of Bionic µChar for the reduction of greenhouse gas emissions and general improvement of animal health. Further application tests for animal husbandry outside of the poultry industry are under preparation.

Conversion By-Products

Gases: a mix of methane, propane, pentane and other highly volatile organic compounds escaping from the reaction mass at an early stage of heating. This fraction is added to the fuel mix of the internal generator.

Water: the remaining moisture of the feed-stock combined with process water delivers a significant amount of highly purified end product which is available for many uses.

For example Bionic has done a feasibility study for large dairy farm operations which are under strict regulations regarding their footprint of waste water, while at the same time there is often a shortage of available drinking water for the cows.

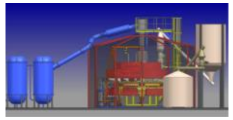
Picture 17: Recycling water from manure for dairy cows

In the Bionic concept dewatered manure is converted via the µFuel process into the typical µCrude and µChar products usually derived from biomass feedstock. At the same time the purified water can be treated and recycled as drinking water for the animals.

Such a solution does not only drastically improve the carbon footprint of the operation, but also impacts drinking water resources and waste water handling.

Sulfur: depending on the feedstock type and use of the liquid fuel product sulfur is separated during fuel upgrading in a desulphurization unit. Pure sulfur has its own market as a chemical commodity.

Inorganic residues: depending on feedstock small amounts of inorganic salts are present in the char fraction like sodium-, calcium-, potassium-salts in addition to catalyst residues in the form of environmentally neutral silicate.



Advanced research on innovative materials deriving from μFuel products

Bionic has established a network of prestigious research institutions which are actively working on utilizing the oil and char phases from various feedstock types for new, innovative applications.

Lignin Processing

The μFuel process is exceptionally effective when processing pre-treated lignin feedstock, a residue product from the cellulose industries when processing wood into fiber.

Given the fact that the pulp and paper industries put out an estimated 50 million tons of such lignin products annually, of which only 2% have at least a low value commercial use, huge opportunities exist in this field for the Bionic μFuel technology.

The liquid phase from the lignin feedstock breaks down in a light and a heavy fraction. The heavy, phenolic faction consists primarily of easily separable aromatic components of very low molecular weight. These components represent the only naturally occurring aromatic molecules which are often labeled as the main building blocks of a future bio-based chemical industry.

While these molecules have been extracted from the lignin residues by researchers in laboratory quantities using complex chemical processes, μFuel offers for the first time a commercially applicable, low cost process for large scale production.

It should be noted that a phenolic oil fraction with similar properties is also present when lignocellulose feedstock like wood or straw is processed, however at a smaller volume corresponding to the amount of lignin contained in the feedstock.

The second fraction of light oil can be easily slipstreamed into existing refinery processes thus covering a significant share of the various biofuel mandates in force.

Base Chemicals and Base Oils

Not only the μCrude from lignin processing offers completely new avenues to arrive at raw materials for the chemical industry. Many early studies suggest an interesting μFuel potential for biomass and waste material feedstock to extract marketable base chemicals and base oils. Usually they will be produced in a cheaper, more sustainable and environmentally friendly way than currently.

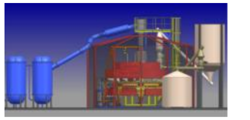
Innovative μChar Applications

Lignin and cellulosic biomass derived μChar exhibits some outstanding properties comparable or even exceeding the highest quality activated carbons, usually with little need for expensive upgrading processes other than grinding to the required granularity.

High value applications for the μChar will emerge over the coming years in areas as diverse as **electricity storage**, **waste water treatment**, **high tech filter processes**, **gold refining** and innovative, healthier **building materials**, just to name a few.

Examples for lower value innovative products exist in various future building materials:

Picture 18: Pressboard with 60% μChar



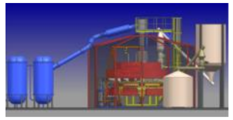
Pictures from the first pilot plant

Picture 20 - Microwave control cabinets

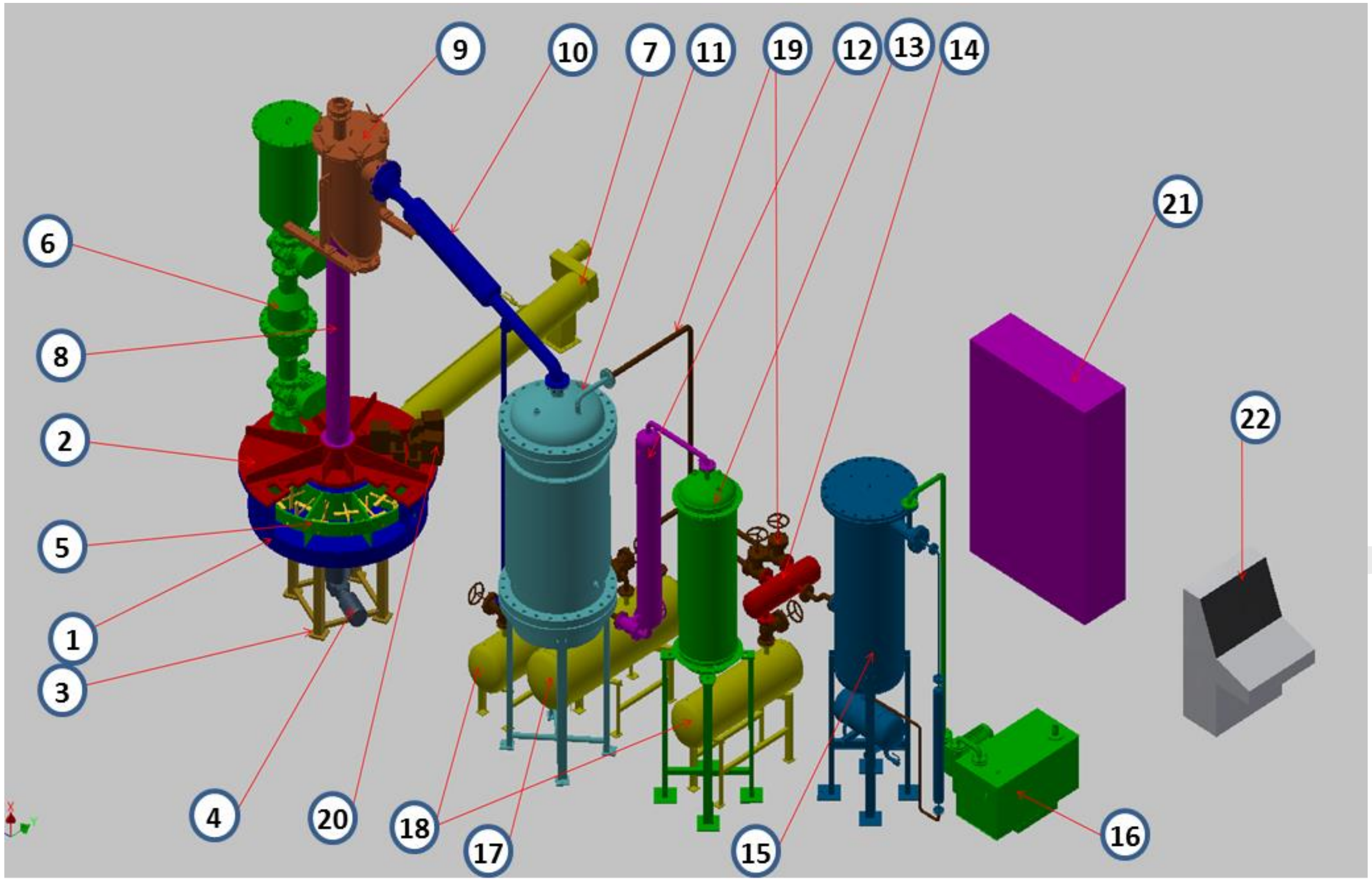
Picture 19 - the “octagon” protects the reactor and serves as an additional outer radiation shield

Picture 22 - highly concentrated microwave power

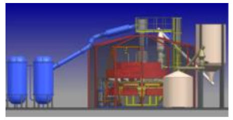
Picture 21 - the inventor and head of R&D checking system data



The core components of an mf60



1	Reactor Body
2	Reactor Cover
3	Reactor Stand
4	Engine, Gearbox, Rotor
5	Stirring Gear
6	Input Section
7	Extraction Screw
8	Steam-Tube
9	Gas-Output
10	Steam Precooler
11	Condenser 01
12	Steam Heater
13	Condenser 02
14	Steam Collection Vessel
15	Gas Quencher
16	Vacuum System
17	Vessel 300 ltr
18	Vessel 150 ltr
19	Pipes & Tubes
20	Microwave Pack
21	Electric Cabinet
22	Control Desk



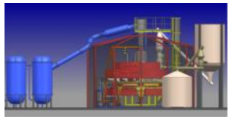
BIONIC Consulting

BIONIC promotes a low risk approach for its clients. A key part to meeting that goal is a diligent pre-project evaluation of all technical and business parameters.

BIONIC experts help clients to research and evaluate all background data necessary including extensive feedstock testing at BIONIC's lab. Feedstock and product samples are analyzed by independent external experts. Only with the most reliable technical data realistic business models can be developed that remove risk from a project.

Parameters determined during the pre-project can be included in a delivery contract and become part of a broad performance guarantee. Feasibility studies are conducted in close cooperation with the client and usually include activities like the following:

- Chemical analysis of the feedstock material for energy content, organic contents (PCB, PVC, PU, PAE etc.), inorganic salts , metals and metal compounds, water content, toxins, etc.
- Physical feedstock analysis for
  - odor structure
  - grain size, specific weight
  - hardness
  - process adaptability: solid/liquid
  - viscosity
  - porosity
  - temperature
  - storage requirements
- Sample processing in a lab unit for determination of yields.
- Analysis of the sample fuel against the applicable standards.
  - Test of the engine suitability
  - engine test run
  - exhaust testing
  - Cetane measurement
- Analysis of the char product.
- Analysis of all residues.
  - Disposal options where needed
- Determination of the scope of delivery, the parameters of the facility and its interfaces.
- Determination of the chemical specifications of the feedstock.
- Determination of the physical specifications of the feedstock.
- Determination of the drying requirements for the feedstock.
- Determination of feedstock quantities and quality including the mass/energy properties and permitted variations.
- Determination of statistical control samples for the operative use.
- Determination of the functionality parameters (input-output-relations).
- Review of the location.
- Determination of the interfaces with feedstock logistics.
- Determination of required client-side activities and deliveries with interface. Descriptions and schedule.
- Product market studies.
- Determination of operating cost factors.
- Development of a concise business plan and presentation material as required.
- Development of a detailed project plan with timeline and milestones.
- Development of a training plan.
- Compilation of all documentation and test results for permitting processes.



A comprehensive mass and energy balance (like the following example) always serves as a central deliverable of Bionic's consulting work during project preparation. It is based on the extensive analysis of the exact feedstock selected for a project and delivers the data framework that eliminates much guessing from the project planning process. It removes a major portion of the risk involved in a project's business plan.