Innovative Synthetic Transport Fuels from Bamboo

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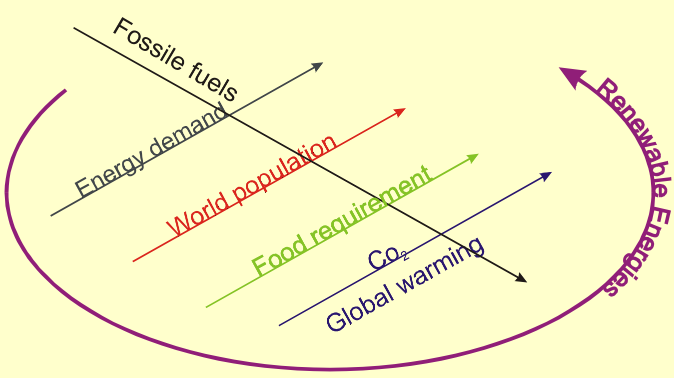
„We are approaching the point where the energy consumption for exploration and transportation outside the Middle East is higher than the energy which is extracted from it. Our national economies should be steered by energy balances and not mainly through monetary dimensions. Money is relative and transient, but energy is essential and eternal. We should realise that problems of energy, environment, climate and development are interconnected".

	Alexander King, Former President of the Club of Rome (1985)	Pflanzenbau FAL/El Ba 1999

G. H. Brundtland (1987)

„We need to conserve some of the fossil fuel resources for the future and create adequate substitutes in quantities which could meet the requirements of the people and enable future development." „ ... every effort should be made to develop the potential for renewable energy which should from the foundation of the global energy structure during the 21st century."



Pflanzenbau FAL/El Ba	Global Context	03 2573b 2001

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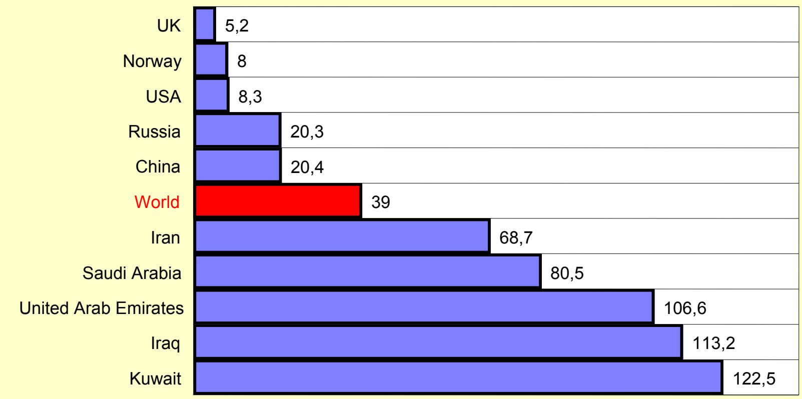

Pflanzenbau FAL/EI Ba	Availibility of oil reserves in years - Oil extraction level: year 2000 -	03 2596b 2001

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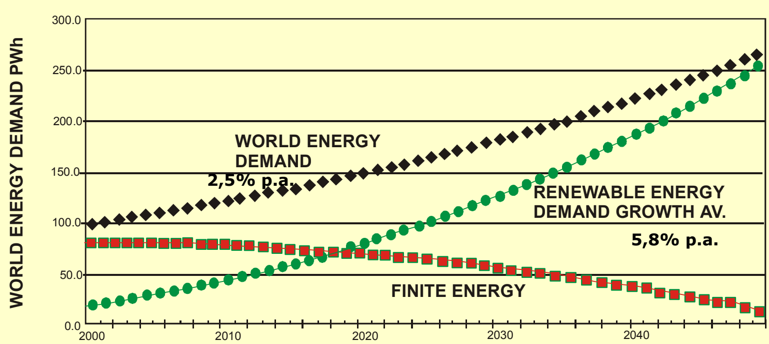


Source for Finite Energy: ASPO-ODAC www.energiekrise.de & Kyoto Protocol

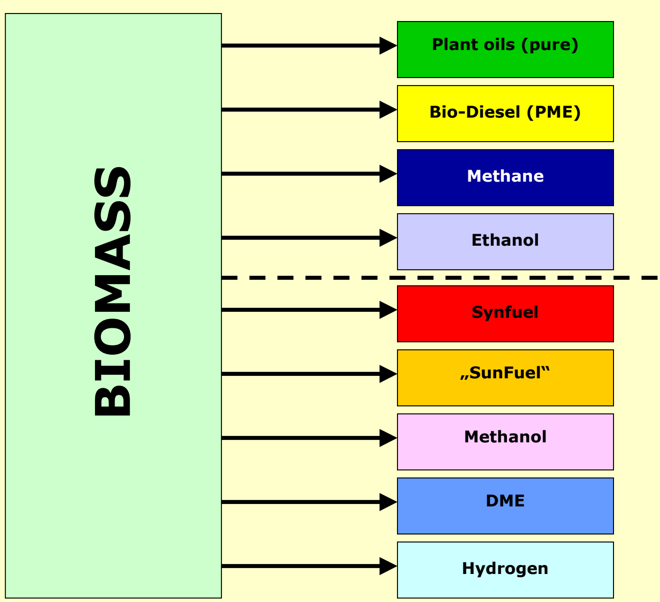
Pflanzenbau FAL/EI Ba	World Energy Scenario 2000 - 2050	03 2636 2002

Biomass

Fuels derived from biomass and other renewable sources are not only potentially renewable, but are also sufficiently similar in origin to be the fossil fuels to provide direct substitution. They can be converted into a wide variety of energy carriers as of recent through conversion technologies, and thus have the potential to be significant new sources of energy into the 21st century.

The input/output energy balance ratio may reach up to 1:25. The CO_2 mitigation potential of energy crops as energy sources is considerably large.

Transport Fuels



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- Cordgrass (*Spartina spp.)*
- Fibre sorghum *(Sorghum bicolor)*
- Giant knotweed (*Polygonum sachalinensis)*
- Hemp (*Cannabis sativa)*
- Kenaf (*Hibiscus cannabinus)*
- Linseed (*Linum usitatissimum)*
- Miscanthus *(Miscanthus x giganteus)*
- Poplar *(Populus spp.)*
- Rape *(Brassica napus)*
- Reed Canary Grass (Phalaris arundinacea.*)*
- Rosin weed *(Silphium perfoliatum)*
- Safflower (*Carthamus tinctorius)*
- Soy bean (*Glycine max)*
- Sugar beet (*Beta vulgaris)*
- Sunflower (*Helianthus annuus)*
- Switchgrass *(Panicum virgatum)*
- Topinambur *(Helianthus tuberosus)*
- Willow *(Salix spp.)*

IFEED	Representative Energy Plant Species for different climate regions - Temperate Climate -	Pflanzenbau FAL/El Ba 2000

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- Argan tree (*Argania spinosa)*
- Broom (Ginestra) *(Spartium junceum)*
- Cardoon (*Cynara cardunculus)*
- Date palm (*Phoenix dactylifera)*
- Eucalyptus (*Eucalyptus spp.)*
- Giant reed (*Arundo donax)*
- Groundnut *(Arachis hypogaea)*
- Jojoba *(Simmondsia chinensis)*
- Olive (Olea europaea.*)*
- Poplar *(Populus spp.)*
- Rape (*Brassica napus)*
- Safflower (*Carthamus tinctorius)*
- Salicornia (*Salicornia bigelovii)*
- Sesbania (*Sesbania spp.)*
- Soybean *(Glycine max)*
- Sweet sorghum *(Sorghum bicolor)*

IFEED	Representative Energy Plant Species for different climate regions - Aride and Semiaride Climate -	Pflanzenbau FAL/El Ba 2000

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- Aleman Grass (*Echinochloa polystachya)*
- Babassu palm *(Orbignya oleifera)*
- Bamboo (*Bambusa spp.)*
- Banana (*Musa x paradisiaca)*
- Black locust (*Robinia pseudoacacia)*
- Brown beetle gras (*Leptochloa fusca)*
- Cassava *(Manihot esculenta)*
- Castor oil plant *(Ricinus communis)*
- Coconut palm (*Cocos nucifera)*
- Eucalyptus *(Eucalyptus spp.)*
- Jatropha (*Jatropha curcas.)*
- Jute *(Crocorus spp.)*
- Leucaena (*Leucaena leucoceohala)*
- Neem tree (*Azadirachta indica)*
- Oil palm (*Elaeis guineensis)*
- Papaya (*Carica papaya.)*
- Rubber tree *(Acacia senegal)*
- Sisal *(Agave sisalana)*
- Sorghum *(Sorghum bicolor)*
- Soybean *(Glycine max)*
- *Sugar cane (Saccharum officinarum)*

	Representative Energy Plant Species for different climate regions - Tropical and Subtropical Climate -	Pflanzenbau FAL/El Ba 2000

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Biodiversity is an Economical Necessity for Cultivated Forests

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Proportions of Carbon, Hydrogen and Oxygen in Fuels

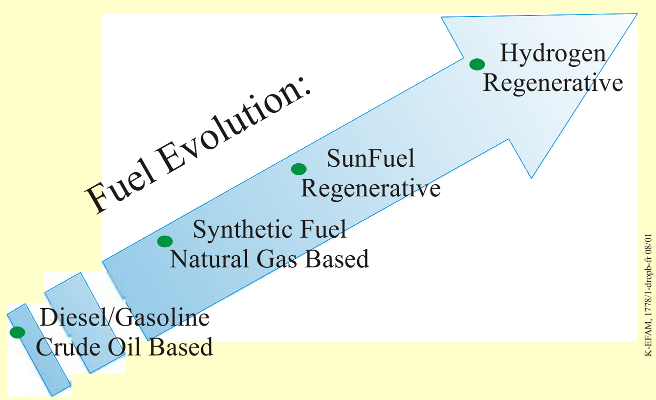
Fuel	*Ratio of atoms*			*% by weight*		
	C	**H**	**O**	**C**	**H**	**O**
Coal	**1**	**1**	**<0.1**	**85**	**6**	**9**
Oil	**1**	**2**	**0**	**85**	**15**	**0**
Methane	**1**	**4**	**0**	**75**	**25**	**0**
Wood	**1**	**1.5**	**0.7**	**49**	**6**	**45**

Ash an Sulfur Contents in % Dry Matter

		Wood	Straw	RES	Cereals	Browncoal
Ash	% of DM	1-2	4-8	7-7,5	2-4	2-10
Sulfur	% of DM	0,1-0,5	0,1-0,2	1,0	0,1-0,2	0,5-1,5

Composition of Dry Biomass

Carbon	45%
Oxygen	42%
Hydrogen	6%
Others	7%



Source: VOLKSWAGEN AG, Group Research

Pflanzenbau FAL/El Ba	VOLKSWAGEN Fuel Strategy	03 2591 2001

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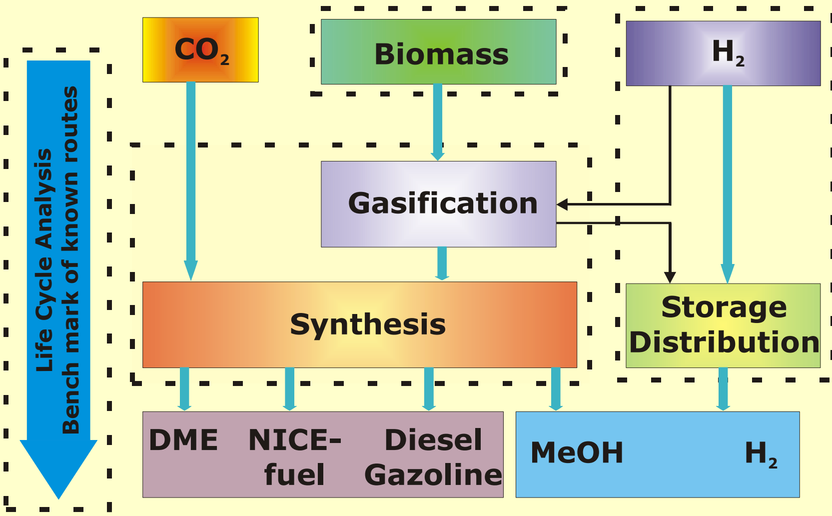

VW Forschung, Umwelt und Verkehr

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Combustion Process

Oxygen supply characterized as □:

Pyrolysis	$\lambda = 0$
Gasification	$0 < \lambda < 1$
Combustion	$\lambda > 1$

CHOREN Industries

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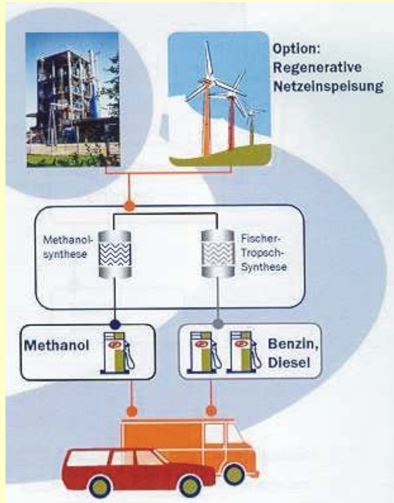

Decentralized Hydrogen from Biomass for the Transport Sector

(ELECTRO-FARMING™ Approach)

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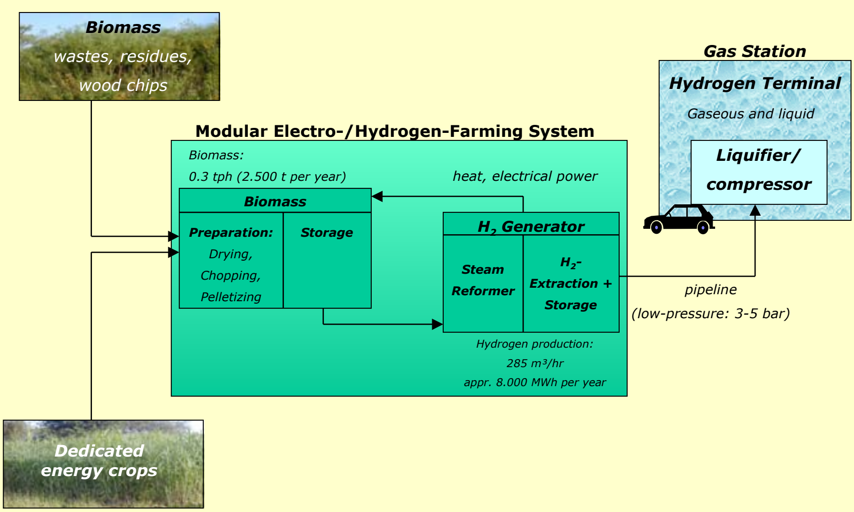

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Particle size	2-4 [mm]	
Ash contents	1,03 [m%]	
Water contents	7,37 [m%]	
Chemical analysis	**Stems**	**Leaves**
C	47,43 [m%]	46,65 [m%]
H	5,99 [m%]	6,26 [m%]
N	0,36 [m%]	1,40 [m%]
O	45,56 [m%]	44,73 [m%]
P	0,08 [m%]	0,13 [m%]
K	0,54 [m%]	0,76 [m%]
Mg	0,036 [m%]	0,073 [m%]
Lignin content	10,7 [m%]	8,7 [m%]
Cellulose content	40,9 [m%]	22,0 [m%]

Pflanzenbau FAL/El Ba	Physical and Chemical Constituents of Bamboo (Sasa keguma)	03 2594 2001

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Specifications of the feedstock.

Feedstock:	Bamboo stems (*Bambusaceae* L.)
Particle size:	2-4 [mm]
Glow residue (850°C@4h):	≈ 1.03 [wt.%]
Moisture content:	7.1 [wt.%]

Experimental conditions.

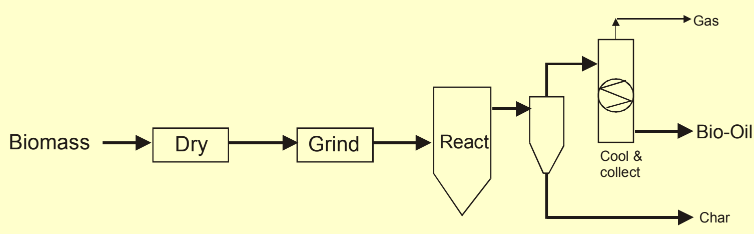
Name of experiment		TP 29
Temperature	[°C]	488
Vapour residence time	[s]	1.36
Particle size feed	[mm]	3
Particle size sand bed	[mm]	0.55
Run time	[h]	1.5
Gas flow (cold)	[m³/h]	5.23
Gas flow (hot)	[m³/h]	12.93
Throughput	[g/h]	1961

N, P, K and Mg contents of the stems and the leaves of bamboo in %.

	N	P	K	Mg
Leaves	1.54	0.13	0.76	0.073
Stems	0.47	0.08	0.54	0.036

Laboratory analysis of bamboo lignin, cellulose and energy contents.

Lignin content (%)		Cellulose content (%)		**Energy content (MJ/kg DM)**
Stems	Leaves	Stems	Leaves	Stems
10.7	8.7	40.9	22.0	17.1



Pflanzenbau FAL/El Ba	Conceptual fast pyrolysis process	03 2588 2001

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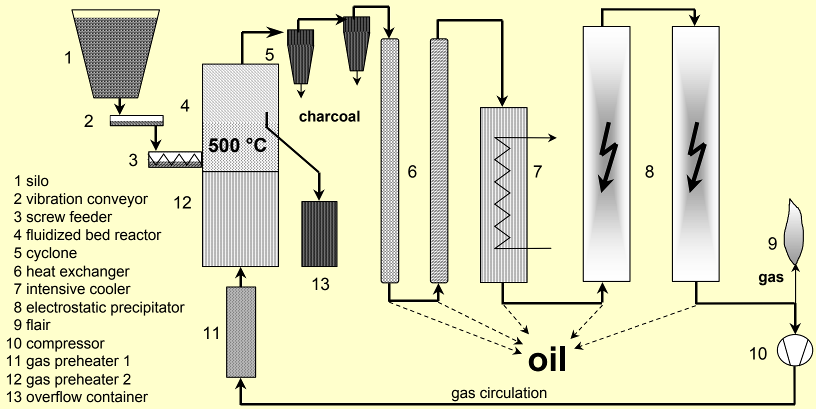
Scheme of the flash-pyrolysis plant for biomass.



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		Liquid	Char	Gas
Fast pyrolysis	Moderate temperature, short residence time particularly vapour	75%	12%	13%
Carbonization	Low temperature, very long residence time	30%	35%	35%
Gasification	High temperature, long residence times	5%	10%	85%

Pflanzenbau FAL/El Ba	Typical product yields (dry wood basis) obtained by different modes of pyrolysis of wood	03 2590 2001

Volatile compounds in pyrolysis-oil (corrected by wood moisture), wt.% based on dry oil.

Carbohydrates (Main components)	wt.%
Acetic acid	24.18
Hydroxypropanone	9.95
Hydroxyacetaldehyde	5.76
Levoglucosan	3.49
2-Furaldehyde, 2-Furfural	2.49
(5H)-Furan-2-one	0.96
2-Hydroxy-1-methyl-1-Cycolpentene-3-one	0.70
Dihydro-methyl-furanone	0.69
alpha-Angelicalactone	0.51
gamma-Butyrolactone	0.43
2-Furfuryl alcohol	0.33
4-Hydroxy-5,6-dihydro-(2H)-Pyran-2-one	0.30
3-Methyl-2-Cyclopentene-1-one Öl	0.14
2,5-Dimethoxy-tetrahydrofuran (cis) Öl	0.10
Σ	50.04

Syringyl components	wt.%
Syringol	0.65
Acetosyringone	0.36
4-Vinyl syringol	0.35
4-Methyl syringol	0.31
4-Propenyl syringol (trans)	0.31
Syringaldehyde	0.24
4-Allyl- and 4-Propyl syringol	0.19
4-Propenyl syringol (cis)	0.16
4-Ethyl syringol	0.10
Syringyl acetone	0.08
Sinapaldehyde	0.04
Isomer of Sinapyl alcohol	0.02
Propiosyringone	0.01
Σ	2.83

Volatile compounds in pyrolysis-oil (corrected by wood moisture), wt.% based on dry oil.

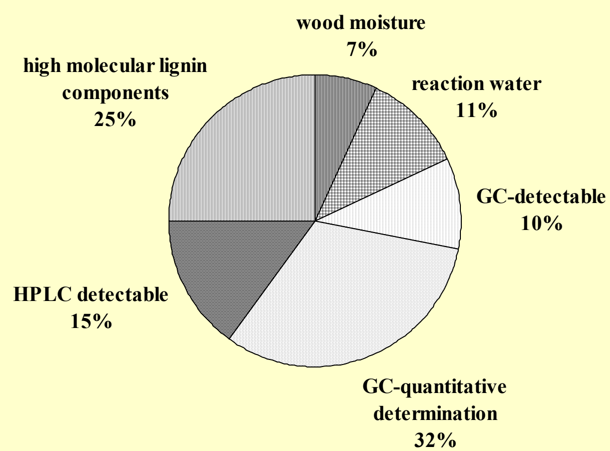
Decomposition products of lignin	wt.%
Guajacyl components	
Isoeugenol (trans)	1.07
Guaiacol	0.71
4-Methyl guaiacol	0.51
Vanillin	0.33
Isoeugenol (cis)	0.26
Guaiacyl acetone	0.13
Coniferylaldehyde	0.13
Acetoguaiacone	0.12
4-Propyl guaiacol	0.07
4-Ethyl guaiacol	0.07
Eugenol	0.06
Σ	3.46

Other Lignin components	wt.%
3-Methoxy catechol	3.87
1,2 Ethanediol	1.04
Phenol	0.66
4-Hydroxy benzaldehyde	0.26
Meta-Cresol	0.22
4-Vinyl phenol	0.17
2,4- and 2,5-Dimethyl phenol	0.14
4-Methylanisol	0.12
Resorcin	0.12
Ortho-Cresol	0.11
3- and 4-Ethyl phenol	0.10
3-Methyl catechol	0.08
Acetophenone	0.05
Benzylalcohol	0.03
2,6-Dimethyl phenol	0.02
Σ	6.99
Σ, Total	63.33

Pyrolysis Products of Bamboo

Gas	21 %
Charcoal	22 %
Oil	57 %

Analytical accessibility of the bio-oil from bamboo.



Typical properties of bio-oil and mineral oil.

	Bio-oil	Mineral oil
pH	2.6	-
Water content, wt.%	20	0.03
Viscosity (50 °C), cSt	30	6
Density (15 °C), g/cm^3	1.24	0.89
Heating capacity (H_u), MJ/kg	17	40
Ashes, wt.%	0.03	0.01

Fuel Yields from Biomass

Biomass Yield ***($t\ ha^{-1}.\ y^{-1}.\ kg^{-1}$)***	***Energy content*** ***($MJ\ .\ kg^{-1}$)***	***eta Conversion Efficiency***	***Fuel Yield*** ***($t.\ ha^{-1}.\ y^{-1}$)***	***Fuel Yield*** ***($l.\ ha^{-1}.\ y^{-1}$)***
10	***17,5***	***0,48***	***1,9***	***2448***
20	***17,5***	***0,48***	***3,8***	***4895***
30	***17,5***	***0,48***	***5,7***	***7343***

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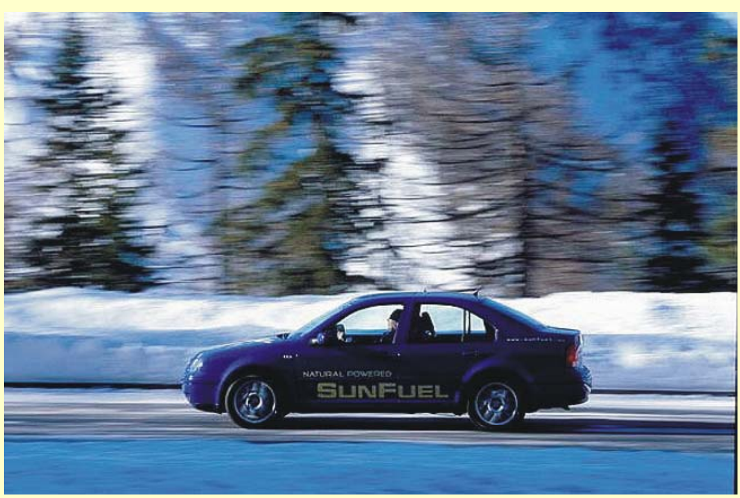
SunFuel

VW Bora HY.POWER



Simplon – Pass (Italy)

VW Lupo3L

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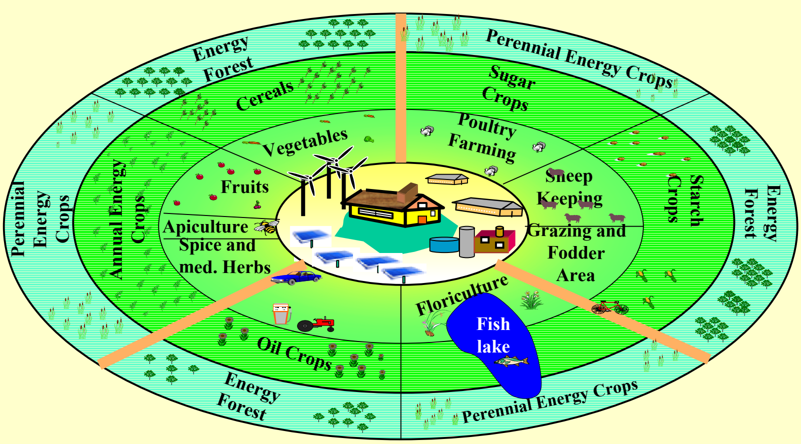

IFEED	**Basic Elements of the Integrated Energy Farm (IEF)** (Farm dwelling, Storage/Garage/Warehouse, Animal stables, Biofuel Heat & PowerStation, Wind power and Solar energy generation)	FAO 2000 FAL

-Oilfields of the 21st century-

Conclusion

Of all Options, Biomass Represents the Largest and Most Sustainable Alternative to Substitute Fossil Transport Fuels as „Win–Win" Strategy.

Thank you for your attention !

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