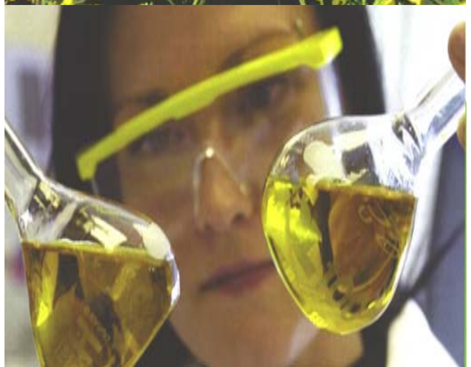


The XI. International Scientific Conference of Central- and Eastern European Institutes of Agricultural Engineering (CEE-AgEng)

The importance of biofuels within the Renewable Energy Directive (RED II) for sustainable mobility and climate protection

Значение биотоплив в рамках обязательств директивы по возобновляемых источниках энергии (RED II) для устойчивой подвижности и охраны климата

28. – 29. 11. 2019

Petr Jevič

Research Institute of Agricultural Engineering, p.r.i. (RIAE, p.r.i. - VÚZT, v.v.i.)
Prague

Agenda

- Background
  - Legislation
    - Directives on the promotion of the use of energy from renewable sources – RED II
    - Mandates in CZ
  - Characteristics of biofuels
  - Renewable energy in transport in CZ
- Balance of biodiesel in CZ
- Balance of ethanol in CZ
- Balance of sugar beet and cereals
- Technology overview – dual fuel technology in diesel engine
- PTR technology
- E-fuels
- Conclusion

Legislative – European framework steers biofuels consumption and technologies

- Europe continues to:

  - Safeguard crop-based (first generation) biofuels at current levels (with a cap at 7pc)

  - Safeguard waste-based biofuels from UCO, tallow (levels at 1.7pc), incentivise advanced biofuels (3.5pc), but uncertainty over technologies remains (e.g. Annex IX Part A feedstocks)

- Tariffs and Duties will play role:

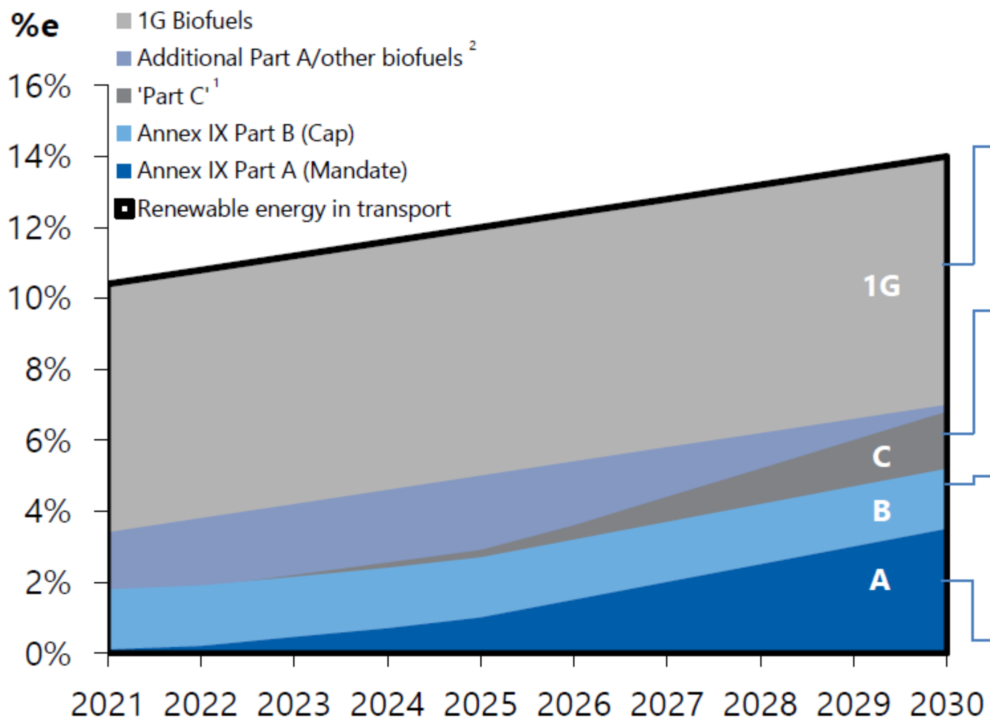
  - Countervailing duties on EU imports resolved but palm oil ban by 2030?

  - EU anti-subsidy duties now on Argentinian biodiesel but minimum price undertaking introduced

  - European Commission recognises US soybeans as sustainable feedstock for biofuels production until July 2021

RED II overview

Graphical representation of RED II caps and mandates



Note: [1] 'Part C' refers to renewable electricity, renewable fuels of non-organic origin and other eligible fuels'
[2] Area of uncertainty resulting from caps on 1G and Part B biofuels; disappears in double-counted markets as Part B will cover

Key features of RED II

Renewable energy in transport target 14pc by 2030

RED II includes a clause to revise the general 14pc transport target in 2023

Advanced biofuels sub-targets of 0.2pc in 2022, 1pc in 2025 and 3.5pc in 2030

Double-counting for Annex IX Part A / B feedstocks

Part B of Annex IX capped at 1.7pc

First Generation biofuels:

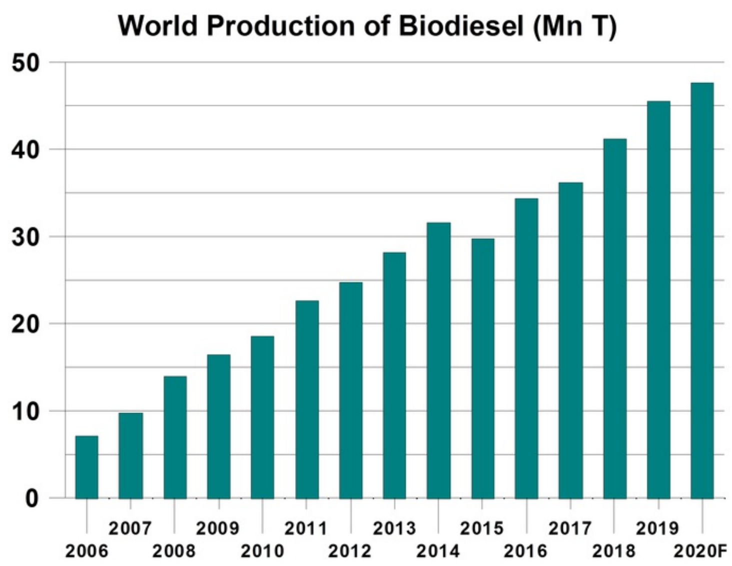
- High ILUC risk frozen at 2020 levels until 2023 + 1pc (max 7pc)
- Low ILUC risk no upper limit
- Review in 2023

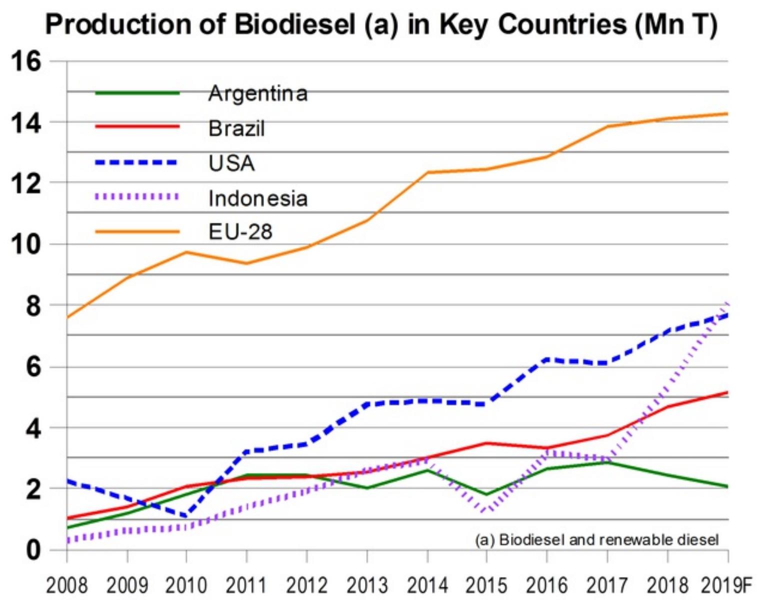
Multipliers for: aviation and marine 1.2x; renewable electricity in road transport 4x

Source: Argus Media group, 7. – 9. May 2019

Legislative – RED II overview

- European Commission (EC) classified biofuel feedstock from palm oil but not soybean as of high risk of indirect land-use change (ILUC) in areas of high carbon stock
- High ILUC biofuel feedstocks fall under gradual phase-out by 2030 unless firms can certify sustainable production
- EC has tightened exemption given for palm oil from smallholders with ownership or lease rights on agricultural land of up to two hectares





Biofuel and energy from renewable sources for transport mandates in the Czech Republic, 2014 – 2020

<table>
<tr><th></th><th>Shares of biofuels and renewable electricity in transportation of total consumption (% cal)</th><th>Obligation to reduce total GHG emissions by 1), 5) (%)</th><th>Biodiesel 1), 6) (% vol)</th><th>Bioethanol 1), 6) (% vol)</th><th>Double counting 1)</th></tr>
<tr><td>2014 – 2016</td><td rowspan="4"></td><td>2</td><td rowspan="5">6</td><td rowspan="5">4.1</td><td rowspan="3">No</td></tr>
<tr><td>2017</td><td>3.5</td></tr>
<tr><td>2018</td><td>3.5</td></tr>
<tr><td>2019</td><td>3.5 3), 4)</td><td rowspan="2">Yes 2)</td></tr>
<tr><td>2020 and onwards</td><td>10</td><td>6 3), 4)</td></tr>
</table>

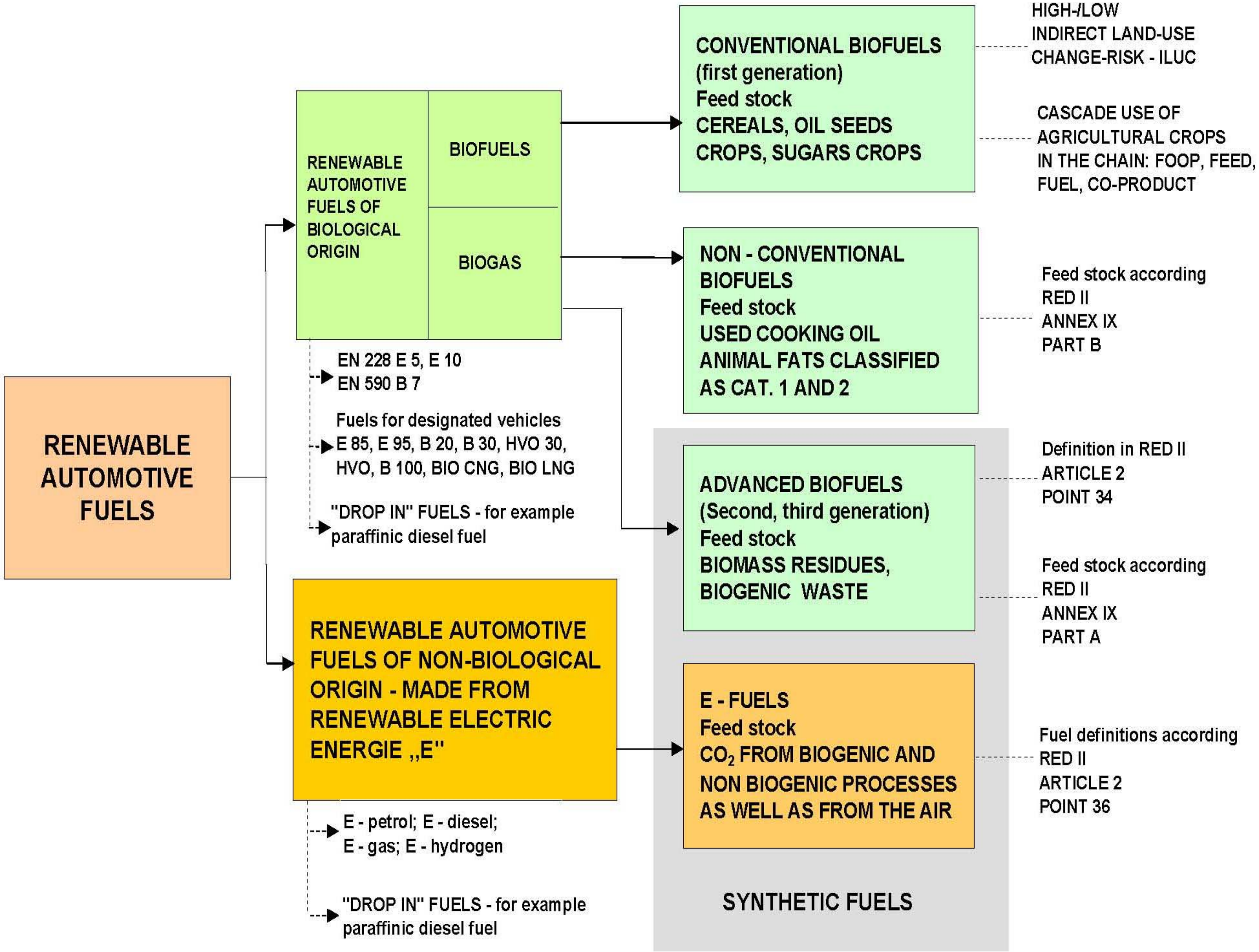
1) According to act No. 201/2012 coll., on air protection, as amended by act No. 172/2018 coll.
2) Double counting for: biofuels from used cooking oil, animal fats classified as categories 1 and 2 accordance with Regulation (EC) No. 1069/2009 of the EP and of the Council, and low indirect land-use change-risk biofuels (advance biofuels).
3) The possibility of using liquefied petroleum gas (LPG), compressed natural gas (CNG), liquefied natural gas (LNG), high-percentage blends of bio- and fossil fuels and pure biofuels, electricity, hydrogen.
4) To take into account upstream emission reduction (UER) of greenhouse gases claimed by a supplier – max. 1 %.
5) Penalty – failing to meet the obligations (reduce total GHG emissions) in sanctioned 10 CZK per kg CO2eq the failure to fulfil obligations which caused.
6) Penalty – 40 CZK per litres of non-delivered certified biofuel

Current excise tax rates for transport fuels in the Czech Republic (CZK/thousand litres)

Petrol fuel	Diesel fuel	High FARME diesel fuel B30	Ethanol E85 fuel *)	Vegetable oil	FAME /FARME	High HVO diesel fuels HVO 30 *)
12 840	10 950	8 515	10 970	1 610	2 190	7 665

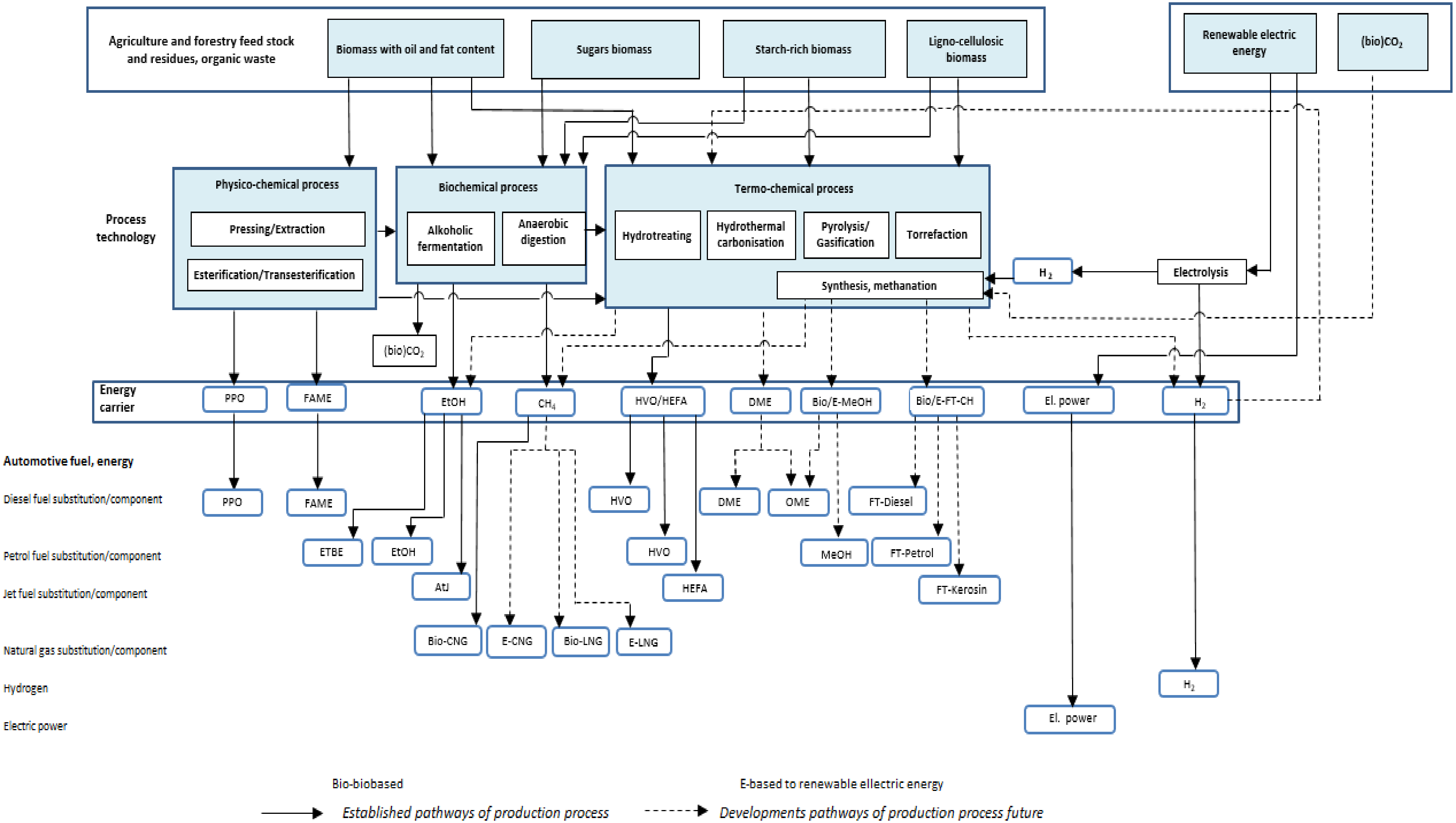
*) This is the amount of tax refund that corresponds to the bioethanol content of petrol and HVO (min. 30% V/V) in diesel after being put into free tax circulation.

Renewable automotive fuels specifications



Source: VÚZT, v.v.i. (RIAE) 2014, DBFZ 2016, 2019

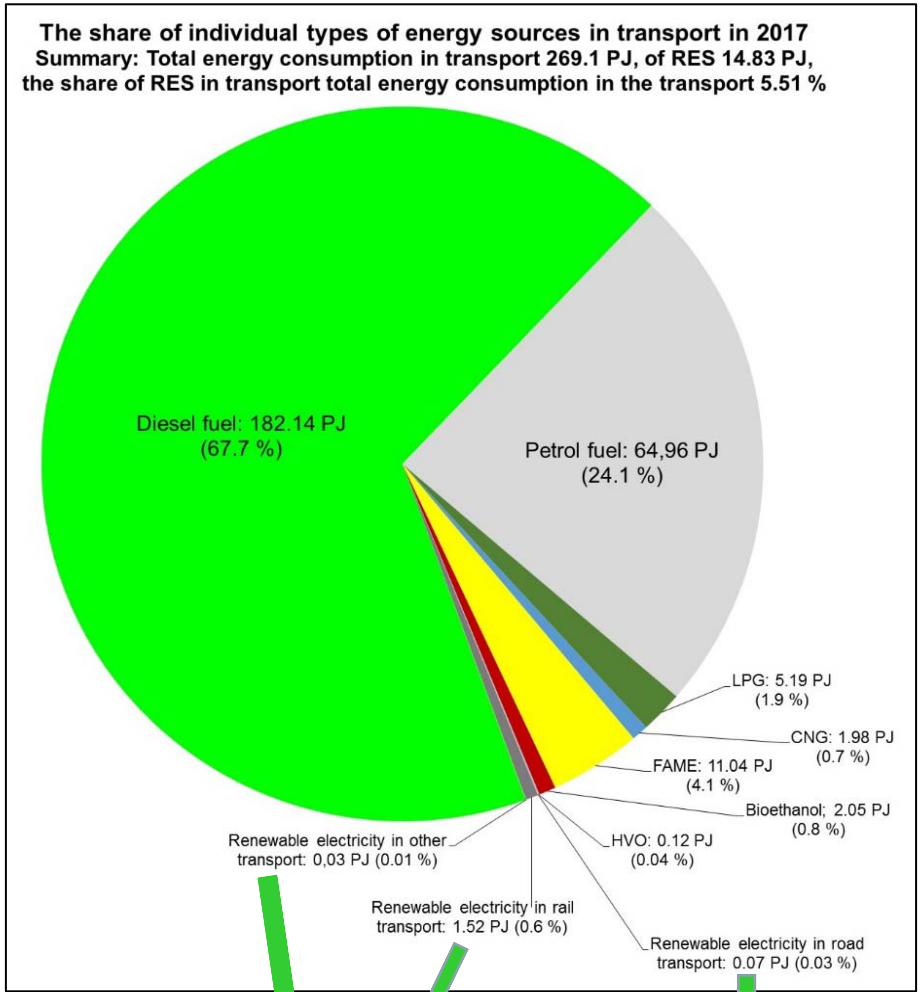
Pathways and synergies sustainable biofuels and renewable transport fuels of non biological origin production



PPO – Pure plant Oil; FAME – Fatty acid methylester; EtOH – Ethanol; CH_4 – Methan;
HVO – Hydrotreated vegetable oil; HEFA – Hydroprocessed esters and fatty acids; AtJ – Alcohol to jet;
CNG – Compressed natural gas; LNG – Liquefied natural gas;
DME – Dimethylether; OME – Oxymethylenether; ETBE – Ethyl-tertio-butyl-ether;
MeOH – Methanol; FT-CH – Fischer Tropsch hydrocarbon; H_2 – Hydrogen

Source: VÚZT, v.v.i. (RIAE) 2014, DBFZ 2016, 2019

Fuels and biofuels balance from GHG emissions report in the Czech Republic, 2017



RED II multiplier 1,5x

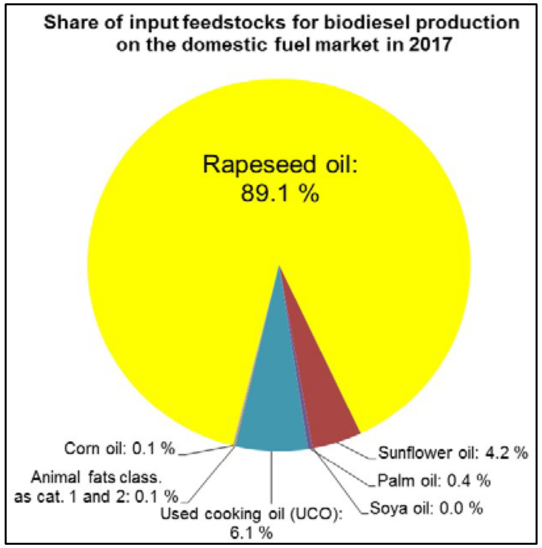
RED II multiplier 4x

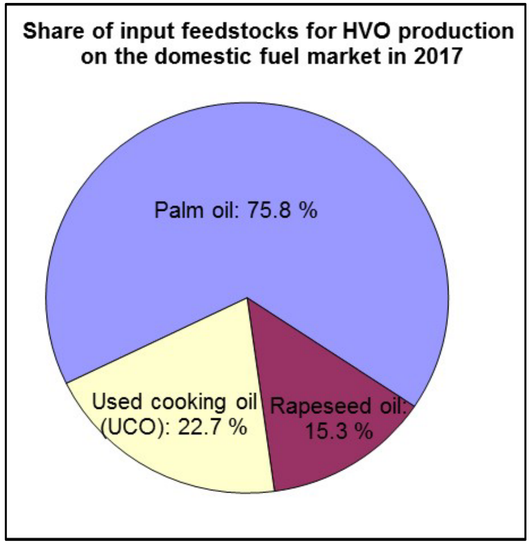
	PJ	% e.o.		
Diesel fuel	182.14	67.68	94.49	94.49
Petrol fuel	64.96	24.14		
LPG	5.19	1.93		
CNG	1.98	0.74		
Biodiesel	11.04	4.10	5.51	4.91
Bioethanol	2.05	0.76		
HVO	0.12	0.05		
Renewable electricity In road transport	0.07	0.03		0.60
Renewable electricity in rail transport	1.52	0.56		
Renewable electricity in other transport	0.03	0.01		
Total	269.10	100.00	100.00	100.00

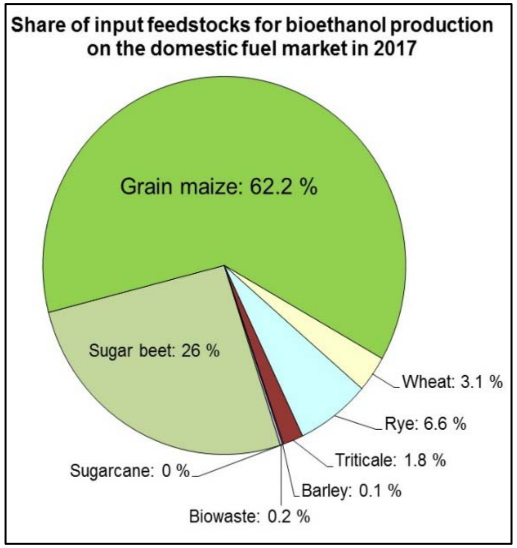
- Share of RES in transport total energy consumption in transport = 5,51%
  - Related to 10% transport target by 2020 in RED Directive
  - Related to 14% in RED II incl. multiplier
- Share of electricity 0,601% in total
  - Road transport 0,07 x 4 = 0,28 PJ
  - Other and rail (1,52+0,03) x 1,5 = 2,32 PJ

0,965%

Fuels and biofuels balance from GHG emissions report in the Czech Republic, 2017







83,6% | 0,9% | 15,5%

CONVENTIONAL	NON-CONVENTIONAL	CONVENTIONAL	NON-CONVENTIONAL	CONVENTIONAL	NON-CONVENTIONAL
PJ	%	PJ	%	PJ	%
10.331	93.60%	2.043	99.76%	0.095	77.33%
0.706	6.40%	0.005	0.24%	0.028	22.67%

CONVENTIONAL	12.47	4.63%
NON-CONVENTIONAL	0.74	0.27%
TOTAL	13.21	4.91%

- Conventional RED II cap max 7%
- Non-conventional – Other biofuels RED II (Annex IX, PART B) 1,7%, multiplier 2
  - 0,74 x 2 = 1,48 PJ

Others biofuels

→ 0,55% → 4,63%+0,55%+0,965%= **6,145%**

Balance FAME/FARME/B100, B30 and HVO/HEFA in the Czech Republic, 2010 - 2018

	2010 (t)	2011 (t)	2012 (t)	2013 (t)	2014 (t)	2015 (t)	2016 (t)	2017 (t)	2018 (t)	Index 18/17	
Domestic production of FAME/FARME [1]	197 988	210 092	172 729	181 694	219 316	167 646	148 832	157 429	194 278	**1.23**	
Import of FAME/FARME	84 609	99 661	119 873	125 815	119 033	201 899 [4]	163 658 [4]	164 668 [4]	194 348	**1.25**	2nd highest import
Export of FAME/FARME [1]	35 232	16 796	6 703	43 216	35 221	67 623	40 823	18 196	74 448	**4.09**	highest export
Gross domestic consumption of FAME/FARME [2], [3]	247 090	290 583	283 825	268 348	301 168	303 329 [4]	271 196 [4]	303 531 [4]	314 324	**1.04**	
FARME/B100 as pure fuel [2]	25 150	31 669	56 312	63 467	107 112	108 480	173	36	1 000	**27.78**	
High FARME diesel fuel B30 [2]	105 960	155 812	131 023	124 125	157 404	135 106	86	44	0	**-**	
HVO/HEFA for blending [2]	-	199	1 034	1 246	1 273	1 371	1 718	2 171	2 547	**1.17**	constantly growing

[1] Source: Ministry of Industry and Trade - Eng (MPO) 6-12
[2] Source: General Customs Directorate
[3] Take into account beginning and ending stocks
[4] Revised

Notice: For this balance of use value the density at 15 oC: FAME/FARME: 891.9 kg/m3, B30: 853.6 kg/m3, diesel fuel: 837.2 kg/m3.
HEFA: Hydrogenated Esters of Fatty Acids

Balance of oilseed rape used for production of FARME in the Czech Republic, 2011 - 2018

	Unit	2011	2012	2013	2014	2015	2016	2017	2018	Index 18/17
Production of FAME: [1] of which FARME	t	210 092 197 492	172 729 159 979	181 694 181 694	219 316 217 315	167 646 167 646	148 832 148 432	157 429 152 291	194 278 140 463	1.23 0.92
Oilseed rape consumption for FARME production [2]	t	487 805	395 148	448 784	536 768	414 086	366 627	376 159	346 944	0.92
Rape harvest area [3]	ha	373 386	401 319	418 808	389 298	366 180	392 991	394 262	411 802	1.04
Oilseed rape yield [3]	t/ha	2.80	2.76	3.45	3.95	3.43	3.46	2.91	3.43	1.18
Oilseed rape production [3]	t	1 046 071	1 109 137	1 443 210	1 537 320	1 256 212	1 359 125	1 146 224	1 410 769	1.23
Oilseed rape field area, with the given yield, allocated for the production of FARME	ha	174 216	143 170	130 082	135 891	120 725	105 962	129 264	101 150	0.78
Share of oilseed rape field area used for FARME production out of the total oilseed rape field area	%	46.7	35.7	31.1	34.9	33.0	27.0	32.9	24.6	0.74

lowest production

significant decrease

lowest share

[1] *Source: Ministry of Industry and Trade - Eng (MPO) 6-12*
[2] *Source: RIAE, p.r.i. & ABP with regard to effectiveness of obtaining of rapeseed oil and its transesterification - oilseed rape 2.47 kg for production of 1 kg FARME*
[3] *Source: Czech Statistical Office*

Balance bioethanol, ETBE and ethanol E85 in the Czech Republic, 2010 - 2018

	2010 (t)	2011 (t)	2012 (t)	2013 (t)	2014 (t)	2015 (t)	2016 (t)	2017 (t)	2018 (t)	Index 18/17
Domestic production [1)]	94 523	54 412	102 195	104 488	104 112	99 725 [4)]	110 740 [4)]	86 900 [4)]	75 096	**0.86**
Import	15 441	30 411	5 184	1 980	4 010	14 531	12 535	19 704	3 055	**0.16**
Export [1)]	36 556	7 378	37 940 [4)]	40 782 [4)]	37 812 [4)]	37 066 [4)]	52 489	30 160	3 071	**0.10**
Gross domestic consumption [2), 3)]	74 118	73 676	68 295	63 125	70 700	68 633	63 312	75 848	79 835	**1.05**
ETBE for blending [2)]	15 352	6 609	8 190	6 863	8 629	5 279	10 223	19 747	26 497	**1.34**
Automotive ethanol E85 fuel [2)]	**4 266**	**7 807**	**15 094**	**21 553**	**22 585**	**11 707**	**3 611**	**3 412**	**2 865**	**0.84**

1) Source: Ministry of Industry and Trade - Eng (MPO) 6-12
2) Source: General Customs Directorate
3) Take into account beginning and ending stocks
4) Revised

Notice: For this balance of use value the density at 15 ºC: bioethanol 777.8 kg/m^3, ETBE 750 kg/m^3, ethanol E85 (77.27 % V/V bioethanol) 770.2 kg/m^3, gasoline 744.2 kg/m^3

Balance of sugar beet and cereals used for the production of bioethanol in the Czech Republic, 2011 – 2018, Part 1

	Unit	2011	2012	2013	2014	2015	2016	2017	2018
Production of bioethanol fuel from [1]	t	54 412	102 195	104 488	104 112	99 725 [3]	110 740 [3]	86 900 [3]	75 096
- technical sugar beet	t	54 412	69 920	80 852	66 000	51 813 [3]	64 928 [3]	34 554 [3]	53 395
- wheat	t	-	-	-	2 875	-	-	-	-
- corn grains	t	-	32 275	23 636	35 234	47 912 [3]	45 812	52 346	21 701
Consumption of starting materials for bioethanol from	t								
- technical sugar beet	t	636 620	818 064	945 968	772 200	606 212 [3]	759 658 [3]	404 282 [3]	624 722
- wheat	t	-	-	-	9 497	-	-	-	-
- corn grains	t	-	103 603	75 872	113 101	153 798 [3]	147 057	168 031	69 660
Harvest areas of [2]	ha								
- technical sugar beet	ha	58 300	61 161	62 401	62 959	57 612	60 736	66 101	64 760
- wheat	ha	863 100	815 381	829 393	835 941	829 820	839 710	832 062	819 690
- grain maize	ha	109 700	119 333	96 902	98 749	79 972	86 407	85 995	81 851
Yield: [2]	t/ha								
- technical sugar beet	t/ha	66.84	63.26	60.00	70.28	59.38	67.81	66.56	57.51
- wheat	t/ha	5.79	4.32	5.67	6.51	6.36	6.50	5.67	5.39
- corn grains	t/ha	8.12	7.78	6.97	8.43	5.54	9.79	6.84	5.98

[1] *Source: Ministry of Industry and Trade - Eng (MPO) 6-12*
[2] *Source: Czech Statistical Office*
[3] *Revised*

Balance of sugar beet and cereals used for the production of bioethanol in the Czech Republic, 2011 – 2018, Part 2

	Unit	2011	2012	2013	2014	2015	2016	2017	2018
Production: [2)]									
- technical sugar beet	t	3 899 000	3 868 829	3 743 772	4 424 619	3 421 035	4 118 356	4 399 521	3 724 309
- wheat		4 993 400	3 518 896	4 700 696	5 442 349	5 274 272	5 454 663	4 718 205	4 417 841
- corn grains		890 500	928 147	675 380	832 235	442 709	845 765	588 105	489 154
Area:									
- technical sugar beet	ha	9 525	12 932	15 766	10 987	10 209 [3)]	11 203 [3)]	6 074 [3)]	10 863
- wheat		-	-	-	1 459	-	-	-	-
- grain maize		-	13 317	10 886	13 416	27 761 [3)]	15 021	24 566	11 649
whit the given yield, allocated for the production of bioethanol									
Share of area									
- technical sugar beet	%	16.3	21.1	25.3	17.5	17.7 [3)]	18.4 [3)]	9.2 [3)]	16.8
- wheat		-	-	-	0,2	-	-	-	-
- grain maize		-	11.2	11.2	13.6	34.7	17.4	28.6	14.2
used for bioethanol production out of the total area									

[1)] Source: Ministry of Industry and Trade - Eng (MPO) 6-12
[2)] Source: Czech Statistical Office
[3)] Revised

Technology – Overview conversion for advanced biofuels production and development

	Technological process	Input feedstock	Product	Development status and traffic	Wearer or knowledge about technology
Biomethan	Anaerobic fermentation and purification	Residual biomass, biowaste	CH_4	Production in operation	Many operating technologies
	Pyrolysis, gasification				
PtG – Power to Gas	Electrolysis by renewable electricity	H_2O CO_2 H_2		Pilot	DECHEMA
PtL – Power to Liquid	Electrolysis by Renewable Electricity, FT synthesis (catalysis)	H_2O, CO_2, H_2	Diesel fuel, aviation fuels	Pilot	Sunfire
GtL – Gas to Liquid	Partial oxidation + FT synthesis	Methan - CH_4, O_2	Diesel fuel, aviation fuels	Production in operation	Shell, Sasol, Air Liquide
	Fermentation	CO_2, CO, H_2	Ethanol	Demonstration	LanzaTech (USA)
BtL – Biomass to Liquid	Pyrolysis + gasification + synthesis	Lignocellulose, especially residual stalks	Dimethyl-ether, petrol fuel	Demonstration	KIT, Air Liquide, CAC
	Torefication + gasification + FT synthesis	Lignocellulose, especially residual wood	Diesel fuel, aviation fuels	Pilot	Total, Thyssen-Krupp
	Gasification + FT synthesis	Lignocellulose	E.g. diesel	Pilot	CUTEC
				Demonstration	TU Freiberg, Air Liquide, CAC
WtL – Waste to Liquid	Gasification + synthesis	Residual biomass, biowaste	Methanol, ethanol	Demonstration	Enerkem (Kanada)
DL – Direct Liquefaction	Rapid pyrolysis - hydrotreating	Residual biomass	Petrol fuel	Demonstration	Ensym (Kanada)
				Pilot	BTG Bioliquids
	Hydropyrolysis				GTI (USA)

	Technological process	Input feedstock	Product	Development status and traffic	Wearer or knowledge about technology
Lipids- oils and fats	**Rafination + hydro-treating**	**UCO, waste oils and fats, free fatty acids, tall oil**	**Diesel fuel (HVO/ HEFA), aviation fuels**	**Production in operation**	**Neste Oil, UOP, ENI, UPM, Dynamic Fuels LLC**
	Cracking vegetable oils CVO			Pilot	Nexxoil, HAW Hamburg
Bio-refinery	Hydrolysis + fermen-tation	Ligno-cellulose	Ethanol	Demonstration	Clariant, DECHEMA
				Production in operation	BIOCHEM-TEX

Source: DECHEMA e.V., 2018

Available technologies on commercial basis:
- Biomethan from biogas
- Diesel from methan
- HVO/HFA from FFA, biowaste
- Bioethanol from lignocellulosse

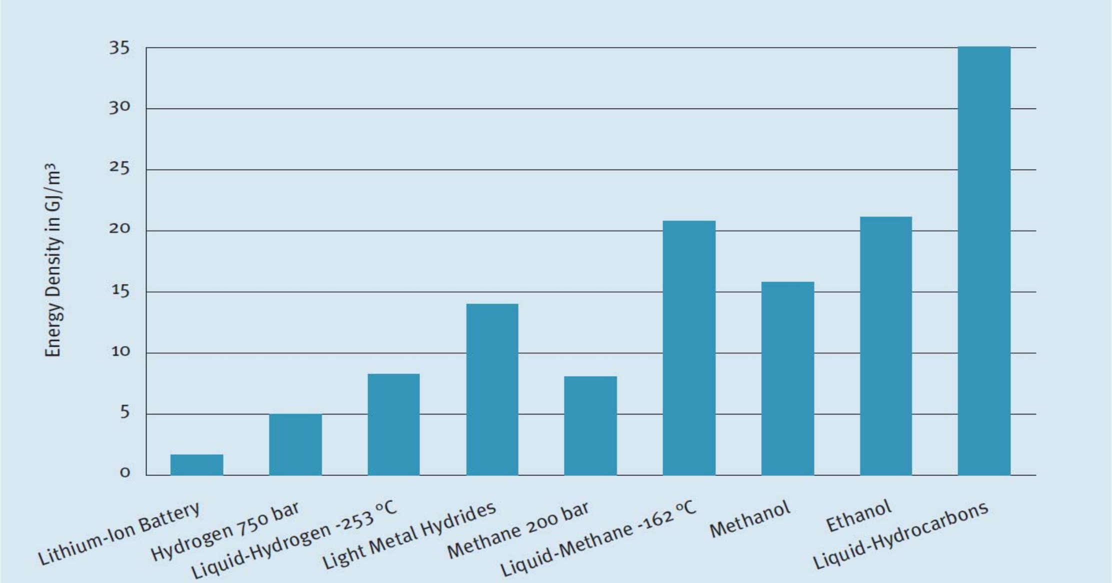
All other in pilot/demonstrated phase

Example/Project:	Lignocellulosic ethanol
Capacity production	50 000 MT / year
Feedstock	350 000 MT / year
Investment	180 mil EUR

→ 514 EUR/t of feedstock

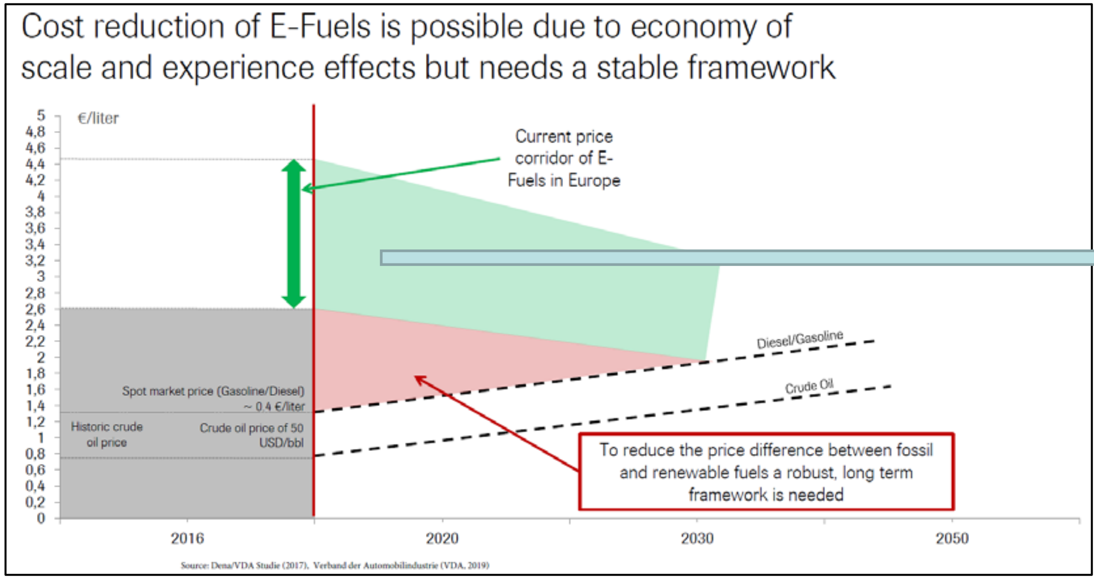
Facts about advanced alternative liquid fuels

- Highest energy density
- Handling, transport and storage
- Use of existing infrastructure
- Compatibility with conventional fuels
- High level of development of optimized emission minimization
- Quality improvement due to admixture
- Quality assurance with regard to stability
- Important basis for certain transport sectors
- Etc.



Source: DECHEMA e.V./VD1, Willner, T., 2017

Competitiveness of E-fuels



Range 2.6 EUR/l – E.5 EUR/l

E-fuels are needed for reaching the log-term climate protection goals in transport (and other sectors) **but**…

- E-fuels are not inherently sustainable
  - Additional RES generation required – purchase of green power not sufficient
  - Comprehensive sustainability criteria must be the basis for support strategies
  - No estimate of global potential for sustainable e-fuels available
- E-fuels are the most expensive GHG mitigation measure in transport

Product	GHG savings	Density t/m^3	Net calorific value GJ/t	Price EUR/t	Term of delivery	Price EUR/GJ	EUR/l
FAME-10	65%	0.892	37.0	806.50	DAP CZ	21.80	0.719
RME	65%	0.892	37.0	835.50	DAP CZ	22.58	0.745
FAME 0	65%	0.892	37.0	749.00	DAP CZ	20.24	0.668
UCOME	90%	0.892	37.0	895.00	DAP CZ	24.19	0.798
TME	90%	0.892	37.0	877.50	DAP CZ	23.72	0.783
HVO	65%	0.7791	44.0	1290.00	DAP CZ	29.32	1.005
HVO	75%	0.7791	44.0	1370.00	DAP CZ	31.14	1.067
Bioethanol	70%	0.7778	27.0	698.55	DAP CZ	25.87	0.543
E fuel	90%						2.6 - 4.5
Diesel		0.8372	43.0	659.00	DAP CZ	15.33	0.552
Petrol		0.755	43.0	698.00	DAP CZ	16.23	0.527

Source: E-fuel – VDA Study, others: prices in weeks 10-20, 2019

Dual fuel technology in diesel engine

Tractor ZETOR 10540 with built in precision device and control unit of the dual fuel system diesel fuel – compressed gas (bio)CNG

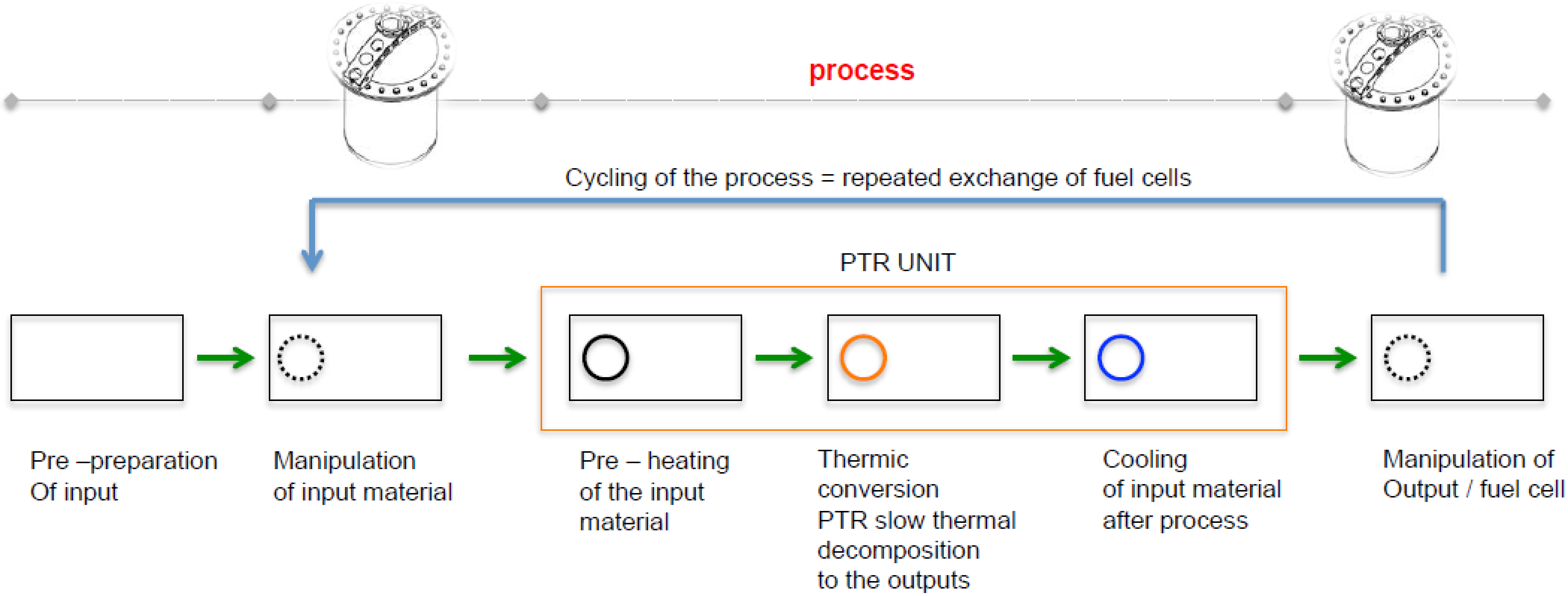
See detail in papers “Engine performance and exhaust emission characteristics of the tractor with built in dual fuel system diesel – compressed (bio)methane“

Exposition in the 15th International exhibition of agricultural engineering
TECHAGRO 2018 – GRAND PRIX

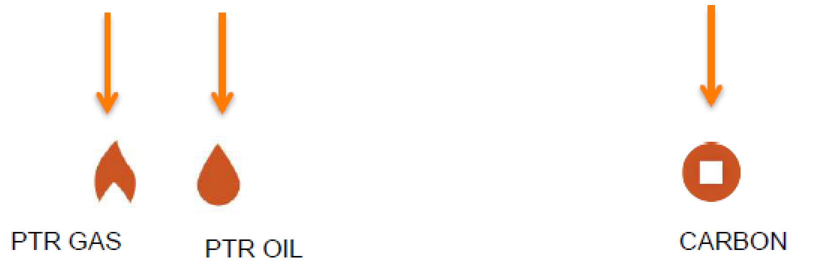
PTR technology – slow thermal decomposition

- Non oxidized processing of organic substances especially biomass residues and wastes
- Solution of the National Agency for Agricultural Research (NAZV) project No. QK1820175 “Processing of residual biomass by combined thermolysis on advanced energy carriers and soil additives”.

PTR TECHNOLOGY - PROCESS



The movement of the cells between the particular positions is controlled automatically, in the so-called mode Time Control, which provides continuous production of primary thermal gas.



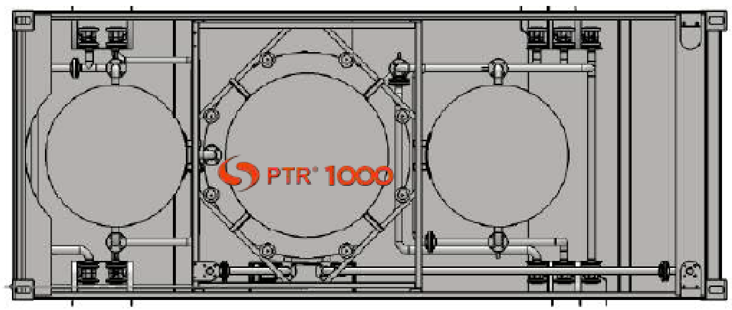
Description of the PTR technology

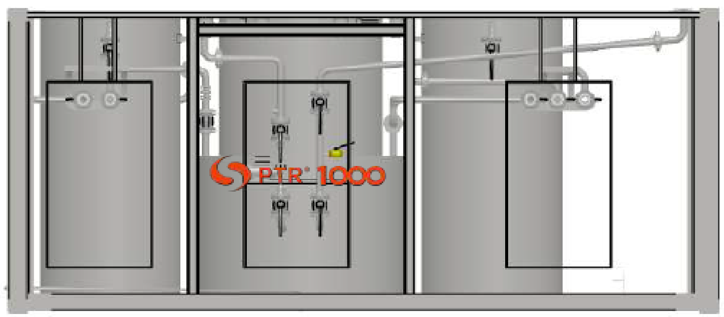
Each individual PTR module consists of three zones: preheating zone, the zone of active process and the zone of passive process and of interconnected heat transfer system for ensuring the transfer and circulation of the secondary heat.

Pre–heating zone to 120 °C

Active zone PTR process to 500°C

Passive zone cooling zone to 100 °C





The **thermic of the PTR process** in the PTR system is ensured by a combined method of heating-up by an electric heating system in the zone of Active Process (3) up to a temperature of 500 °C and the transfer of the heating medium between the zones (2, 3, 4) and the heat transfer system of the CHP oil exchanger at max. temperature of 280 °C.

- Fuel cells – the volume is 1.1 m^3
- Liquid, solid and gaseous product

PTR process – PTR typical value products

	Biomass	Sludge	Tyre
Solid - char	40 %	55 %	50 %
Gaseous	35 %	40 %	20 %
Liquid	25 %	5 %	30 %

Description of the PTR technology

Conclusion

- Increasing the share of renewable energies in total energy consumption to 32% and in the transport sector to 14% by 2030 is the key at the core of RED II. The Commission is to review these targets.
- Biofuels currently make the largest contribution to CO_2 savings in the transport sector due to constantly improved greenhouse gas balance.
- Improved efficiency means lower biofuels volumes in diesel and petrol, as the current greenhousegas reduction obligation is too lax and must be made more stringent promptly.
- Market established, affordable biofuels from cultivated biomass, residues and waste are the most important building blocks for further reducing CO_2 emissions in the transport sector, along with improved engine efficiency, alternative drive technologies and optimized transport infrastructure.
- E-fuels are needed for reaching the long-term climate protection goals in transport, but…
- Priorities until 2030:
  - Reducing energy demand in transport (eg. E-mobility)
  - Cost reduction and upscaling of e-fuel technologies

Thanks for your attention!

This conference and proceeding were realized within solution of the National Agency for Agricultural Research (NAZV) project No. QK1820175 “Processing of residual biomass by combined thermolysis on advanced energy carriers and soil additives” and project of long-term development of Research Institute of Agricultural Engineering, p.r.i. No. RO0618.

Petr Jevič

Head researcher and development worker
of Research Institute of Agricultural Engineering, p.r.i. (VÚZT, v.v.i) Prague

Drnovská 507, 161 01 Prague 6
tel.: +420-233 022 302
e-mail: petr.jevic@vuzt.cz