

***GTBE[®] & reduction of
Particulate Matter emissions:
Fata Morgana or Panacee?***

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Particulate Matter (PM)

The GTBE[®] Company NV
For greener and cleaner fuels

□ PM by natural events:

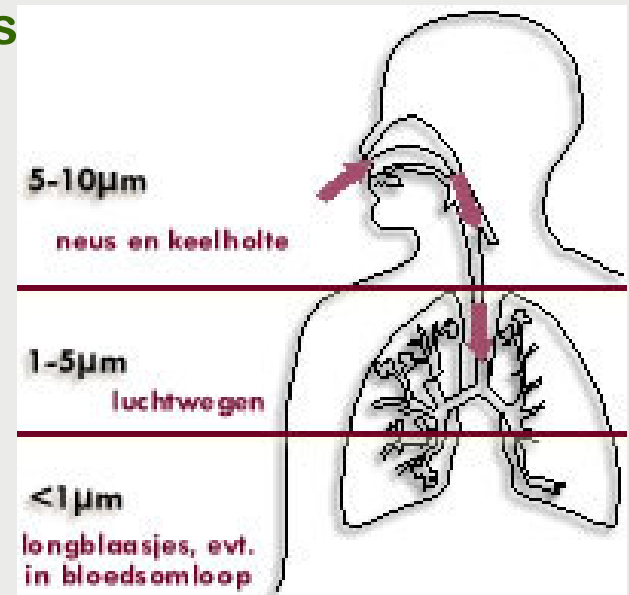
- Sand, silicates en salt;
- Considered as (almost) harmless.

□ PM by man :

- From combustion engines;
- Structure: mainly C and CH molecules
- Harmful for living creatures.

□ Size and effects:

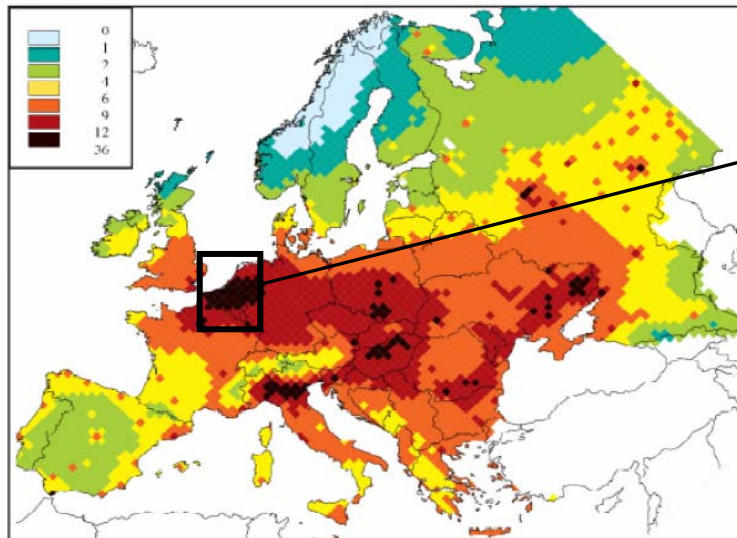
- PM_{10} = < 10 μm
- $PM_{2,5}$ = < 2,5 μm : **harmful**
- $PM_{0,1}$ = < 0,1 μm : **ultra fine PM**
most harmful



Effects of PM (1)

Life expectancy in areas with considerable PM concentration is lower!!

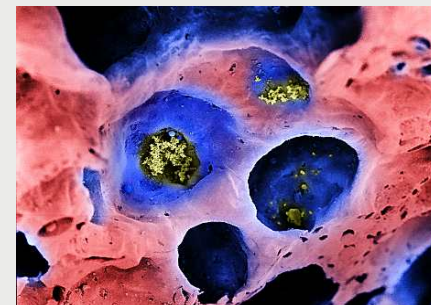
Life-expectancy loss through PM_{2.5}



In 2000 the average loss in statistical life expectancy due to man-made contributions to PM_{2.5} was 8.1 months.

Effects of PM (2)

- ❑ **Year 2000: Loss in life expectancy because of man-made contributions to $PM_{2,5}$ was 8,1 months**
(European Environmental Bureau, 2004)
- ❑ **EC face a yearly loss of 350.000 death because of PM**
(www.euractiv.com, 2006)
- ❑ **Asia (China, India) face a yearly loss of 335.000 death because of PM**
(UNEP, Atmospheric Brown Clouds, 2008)



Measures: EC legislation

Directive 1999/30/EC.

- In force from 19/7/1999 onwards;
- Yearly average PM : max. 40 $\mu\text{m}/\text{m}^3$;
- Daily average PM : max. 50 $\mu\text{m}/\text{m}^3$, 35 exceedings of this limit allowed.

Directive 2008/50/EC.

- New EC directive regarding pollution/air quality (repeals and replaces Directive 1999/30/EC from 11 June 2010);
- Additional thresholds for PM_{2.5} (new);
- Yearly average PM : max. 25 $\mu\text{m}/\text{m}^3$ in 2015;
- Yearly average PM : max. 20 $\mu\text{m}/\text{m}^3$ in 2020.

Measures: Transports

❑ Road transports.

- ❑ Considered as most polluting;
 - ❑ Measures to reduce pollution:
 - ❑ Road-related measures (reduce maximum speed, (partly) abandoning of HGV's, cars, vans etc. in larger cities);
 - ❑ Improvements of engines (PM filters, Euro 5 and Euro 6 standards):
 - ❑ PM filters do reduce PM emissions, but offer **no solution for (ultra) fine PM.**
 - ❑ New HGV's, cars, vans etc. do have improved combustion, and therefore produce relatively **more (ultra) fine PM.**
- No fundamental solutions, but end of pipe measures.



PM filters:

- ❑ **Open filters: not effective enough**
 - ❑ Dutch Minister stopped subsidy for retrofit filters in February 2009 after report from TNO that HGV's did not reduce PM with targeted 50% (5-20% → short distance, 40% → long distance).
- ❑ **Closed filters: good, but good enough?**
 - ❑ The more PM you want to reduce, the more power the engine has to deliver to let the exhaust gasses pass the filter (extra energy use?);
 - ❑ Modern diesel engines have better combustion → total PM molar weight is reduced, but less large PM and more (ultra) fine PM.
- ❑ **Costs (consumer/end-user price):**
 - ❑ Open/retrofit filters: approx. € 1.000.-;
 - ❑ Closed/new car filters: approx. € 2.000.-
- ❑ **Maintenance and life cycle:**
 - ❑ every 1000 hours/100.000 to 150.000 km (depending on type)
- ❑ **Total costs at 150.000 km (estimate, consumer/end-user price).**
 - ❑ When consumption of 10 L diesel/100 km and maintenance € 400.-
 - ❑ Closed filters: € 0,16/liter or € 0,016/km.

Conclusion (1)

- ❑ EC is aware of negative effects of PM, and especially PM_{2,5} and smaller;
- ❑ Measures have been taken to reduce future amounts of PM, until now through PM filters;
- ❑ PM filters do provide a solution for larger PM, but effects diminish when (ultra) fine PM are concerned;
- ❑ And: PM filters need inspection, maintenance and/or replacement;
- ❑ Being a mechanical device, costs for a PM filter are relatively high during the lifetime of HGV's, cars, vans etc.;
- ❑ Additional measures have to be taken to reduce most dangerous (ultra) fine PM, at reasonable costs!

(Ultra) fine PM:

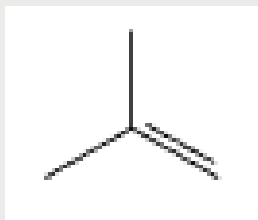
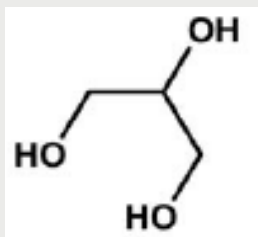
***GTBE[®] as a diesel additive
provides the solution***

GTBE[®] : The starting point (1)

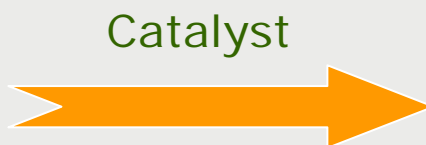
- ❑ **When creating new solutions, following conditions have to be met:**
 - ❑ USP of the output must be clear;
 - ❑ Environmental friendly input (i.e. “green” resources), or even better: solve the problem of another industry sector;
 - ❑ Availability of resources and skilled people;
 - ❑ Do not try to implement rocket science (ensure production process without risks, no extreme pressures, temperatures, etc.);
 - ❑ Process and materials used have to guarantee a feasible market price for the output;
 - ❑ Be aware of International legislation and conditions of the trade (a.o. tests to satisfy car manufacturers).

GTBE[®] : The starting point (2)

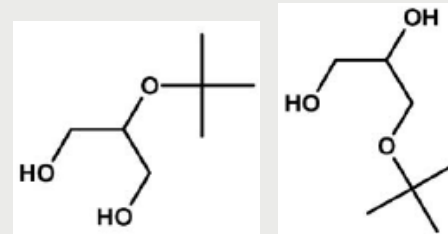
Glycerol



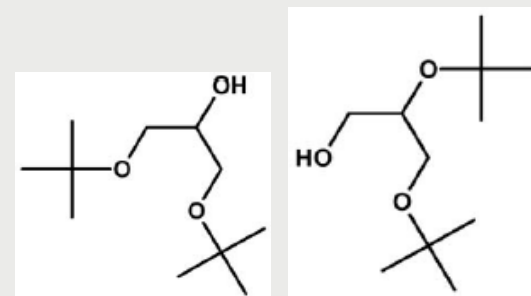
Isobutylene



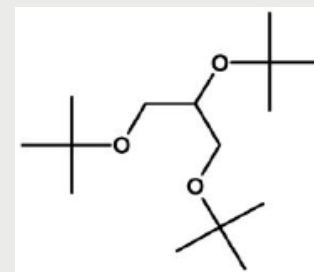
Mono



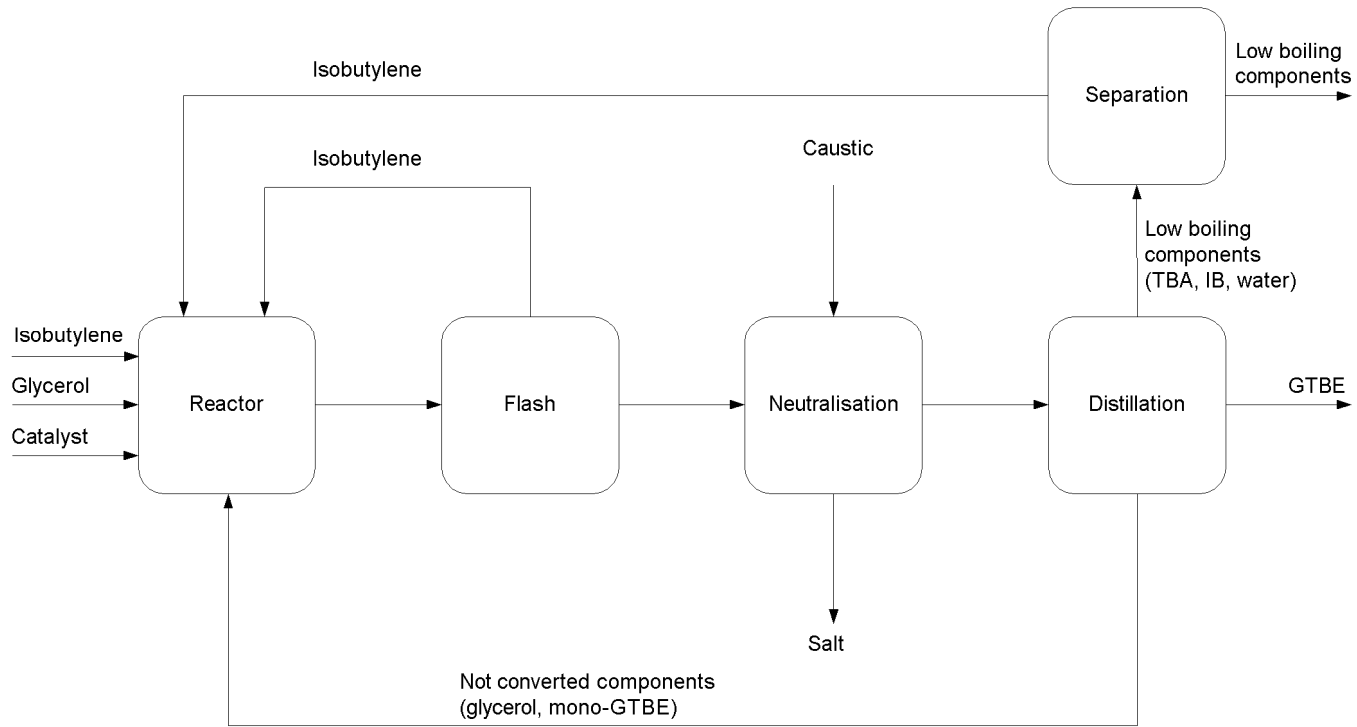
Di



Tri



GTBE[®] : The starting point (3)



GTBE[®] input: Glycerol (1)

- ❑ A very old, well known, valuable substance;
- ❑ Is well known: from Food, Pharmacy, Personal Care up to Explosives;
- ❑ Supply and use of glycerol moved until the end of the last century in a more or less stable pattern;
- ❑ Large scale bio-diesel production with the unavoidable 10% glycerol output will lead to an oversupply of crude glycerol;
- ❑ Prices of refined glycerol have decreased from > € 1.000.-/ton beginning of this decade to < € 400.-/ton due to lower prices for crude glycerol;
- ❑ Prices of crude glycerol also dropped, nowadays there are great differences (due to a wide range of impurities), from > € 100.-/ton to a negative price.

GTBE[®] input: Glycerol (2)

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- ❑ Traditional markets for Glycerol in Europe between 300.000 and 400.000 tons/year (world: approx. 700.000 tons);
- ❑ Diesel consumption in EU 25 is expected to grow from 147,7 Mtoe in 2000 to 223,6 Mtoe in 2030 (EU25, Energy and transport outlook to 2030);
- ❑ Percentage of mandatory blending of biodiesel in diesel will go up in the forthcoming years (although slower than agreed/expected);
- ❑ Oversupply of glycerol is therefore evident: 5,7 mln tons of biodiesel produced in Europe (2007) equals 570.000 tons of glycerol (and this concerns only EU);
- ❑ Less favourable market conditions for biodiesel and imports from USA are temporary but heavy setbacks;
- ❑ Other uses for Glycerol do come up, but not very fast and are not able to consume the glut (selective reduction or oxidation, dehydration, halogenation, etc.).

The solution: GTBE®

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❑ GTBE®:

- ❑ Full name: Glycerol Tertiary Butyl Ether;
- ❑ is an additive for both bio- and fossil diesel;
- ❑ is being produced from glycerol: a green, unavoidable by-product of the biodiesel production process;
- ❑ **reduces (ultra) fine PM emissions substantially!**
- ❑ provides the solution where it should: in the combustion section of the motor!
- ❑ has improved or no adverse effects on fuel quality, a.o. cetane numbers (50/51), CP (-6 °C), CFPP (-18 °C), oxidation stability (>24 hrs) and solubility;
- ❑ Is not involved in the feed or food discussion, all glycerol – from 1st, 2nd or 3^d generation production processes – can be used;
- ❑ is a proven and known product, now economically feasible because of improved production methods;
- ❑ **costs for the end-user will be much lower when compared to PM filters.**

Biodiesel

Glycerol



GTBE[®] production

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- Most important components: Glycerol and MTBE/IB;**
- Patented process;**
- Production based on proven technologies;**
- No high pressures, high temperatures or the like;**
- Efficient process, safeguards to avoid spill of products;**
- Effective process, no time consuming steps;**
- And: European vehicle manufacturers (ACEA):**
 - ethers are preferred over ethanol;

GTBE[®] tests

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- ❑ **Research in Europe and USA: various tests with GTBE[®] and DBG (Di-Butoxy Glycerol, different name but same product):**
 - ❑ Spooner-Wyman, Appleby, Yost (P&G/Southwest Research Institute, 2003);
 - ❑ Jaecker-Voirol, Delfort, Montagne, Durand, Hillion (IFP, 2005 and 2008).
- ❑ **Overall conclusion:**
 - ❑ GTBE[®] most interesting from PM emissions and economical point of view;

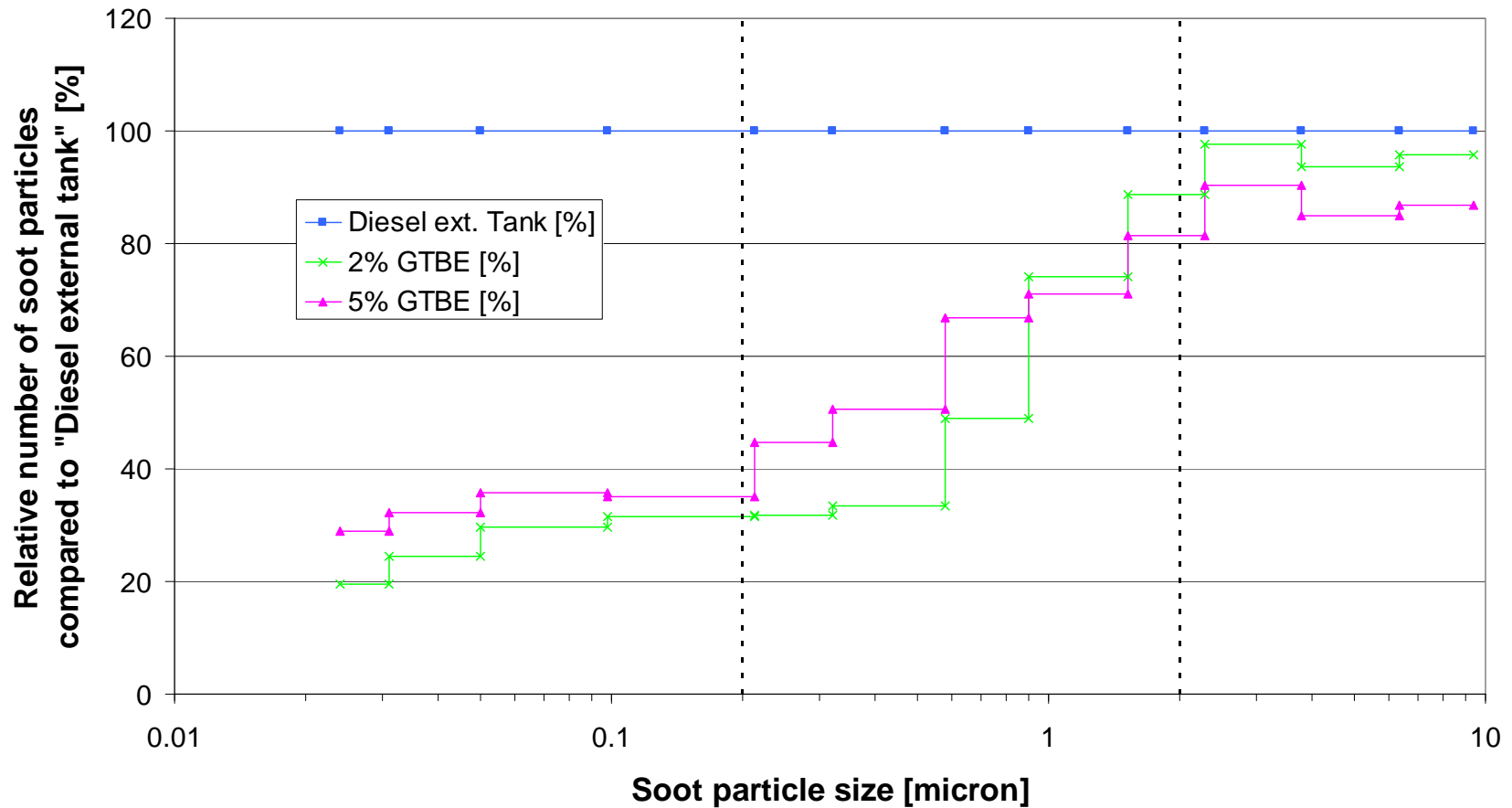
TNO motor emission tests (2007)

- **Typical test results:**
 - **CADC test cycle to simulate 'real life driving'**
 - **Effect on emission of NO_x, HC + NO_x and PM**

Fuel blend	Relative emission reduction compared to unblended diesel [%]		
	NO _x	HC + NO _x	PM10
2% GTBE in diesel	-6	-6	-33
5% GTBE in diesel	-2	-2	-30

TNO motor emission tests (2007)

CADC



TNO motor emission tests overall conclusions

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- ❑ On average **25% emission reduction** of total PM when blending 2% GTBE[®] with diesel;
- ❑ Up to **80% emission reduction** of – the most harmful - ultrafine particles!!
- ❑ **No adverse effects on fuel quality;**
(Intertek Laboratory Test Report No. 08-008072-0-WTHU, 2008)
(Glycerin for new Biodiesel Formulations, IFP, 2008)
- ❑ **The effect of GTBE[®] has been proven unconditionally.!!**



Realizing the reduction of PM!!

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- ❑ **The GTBE[®] Company NV (2006):**
 - ❑ **Procede Group & partners: Process development and resources;**
 - ❑ **Private Investors.**
- ❑ **Production of 20.000 tons/year GTBE[®] in the North of The Netherlands, starting end of 2010:**
 - ❑ **Sufficient amount to blend with 1.000.000 tons of diesel (equals 15% of total annual Dutch diesel consumption).**
- ❑ **Production of 600.000 tons/year GTBE[®] asap after 2010:**
 - ❑ **Mix of smaller and larger production sites;**
 - ❑ **Sufficient amount to blend with 30.000.000 tons of diesel (equals 18% of total annual EU diesel consumption).**
- ❑ **Most polluted area's in Europe because of HGV's, cars, vans etc. can benefit within reasonable time!**

GTBE[®] : Final remarks

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- ❑ EC must treat GTBE[®] in the same way as biodiesel (tax, EN regulations, etc.);
- ❑ Future blends of diesel should contain GTBE[®]
 - ❑ Realise “BO12” instead of “B10” in 2020;
- ❑ Further economies of scale in the second and much larger GTBE[®] plant are feasible;
- ❑ GTBE[®] production on a smaller scale, next to biodiesel plants will reduce up-time and money (permits, OPEX, CAPEX) of the GTBE[®] plant and is an attractive opportunity;
- ❑ Further process research is going on to reduce the future price of GTBE[®];

Conclusion (2)

- Yes, we must reduce PM emissions to improve health and save lives;
- Yes, we can reduce all kinds of PM emissions because next to PM filters we will also have GTBE[®] ;
- Yes, we can help to find a way out of the glycerol glut, using it to produce a valuable by-product for diesel;
- Yes, we can produce GTBE[®] at a reasonable price;
- Yes, the biodiesel industry can benefit from all of this!

Thank you for your attention!

Questions?