Methanol Fuel Cells: Powering the Future
The Methanol Institute (MI) was established in 1989.

Three decades later, MI is recognized as the trade association for the global methanol industry.

Facilitating methanol’s expansion from our Singapore headquarters and regional offices in Washington DC, Brussels, and Beijing.
Committee Structure

- Marine Fuels Committee
  - Conversion technology
  - Environmental
  - Economics
  - Advocacy

- Product Stewardship Committee
  - Safe Handling Tools
  - Health effects research
  - Training
  - Bootleg Alcohol
  - Prevention Sub-Committee

- Market Development Committee
  - Technical assistance
  - Market research
  - Development

- Global Fuel Blending Committee
  - RD&D
  - Commerciality
  - Specifications
  - Policy

- Global Reach
  - Best Practice
  - Strategic Partnership
  - Technical Support

- Member Engagement
  - • RD&D
  - • Commerciality
  - • Specifications
  - • Policy

www.methanol.org/join-us
Methanol fuel cell
Powering the future
Webinar 30 June 2020
By Mads Friis Jensen, CCO and Co-founder of Blue World Technologies
Methanol fuel cells - a **green** alternative

**Markets**
- APU
- Automotive
- Heavy duty

**General USPs**
- CO₂ reduction
- Cost savings
- Zero harmful emissions
Making the technology competitive

- Production of core materials, key components, fuel cell stack
- Pilot production set up in progress (~1,000 per year)
- 750 MW capacity (50,000 units per year) to be set up in 2022/23
Renewable electricity from solar and wind energy

Municipal Solid Waste (MSW) is converted into a syngas containing hydrogen and Carbon dioxide (CO2)

Bio-syngas converted from biomass, agricultural and timber waste

Waste-Carbon dioxide (CO2) retrieval from industrial manufacturing and power plants as well as absorption from open air

Residential areas

Electric charging both to and from vehicle, as electric battery power can be used to charge home grid

Methanol (MeOH) produced from reformed syngas and with feedstocks from a variety of sources

Electrical power

Methanol feedstocks

MFCEV Methanol Fuel Cell Electric Vehicle

Methanol refueling is compatible with existing refueling infrastructure

Hydrogen (H2) production from electrolysis of water using renewable electricity
Superior High Temperature PEM technology

- No external heat needed as waste heat drives fuel evaporation process = higher conversion efficiency
- No gas clean-up needed = simple and cost effective system
- Water regeneration = increased energy storage
Methanol fuel cell product platform

- Operation on pure methanol (M100)
- Output power range: 7-25 kW
- System efficiency: 40-50 %
- Fuel consumption: 0,5 L/kWh
- Start-up time: 10 minutes
- Operation temperature: 160 ºC
The methanol fuel cell hybrid system

- Condenser
- HT PEM fuel cell stack
- System components
- Battery pack
- Methanol reformer
- Evaporator
Methanol fuel cell vehicle – a hybrid set-up

Key value proposition:

End user
✓ 1,000 km range
✓ 3 min refuelling time OR plug-in
✓ Significant fuel cost savings (typically 30-60%)
✓ Zero harmful emissions
✓ No noise or vibrations

OEM
✓ Same form factor and platform as battery pack (flatpack)
✓ CO₂ neutral and significant tailpipe CO₂ reduction
✓ Higher power density (than battery → light vehicle)

System components
- Methanol reformer
- Liquid methanol tank
- Fuel cell stack
- Battery pack
- Electric charging

Application
- 100 % methanol
- HT PEM fuel cell
- DC power
- Application
- Battery pack
- Plug-in option
Methanol FC as hybrid range extender

Component specification example:
- Engine size: 75 kW
- Fuel cell size: 25 kW
- Battery capacity: 15 kWh
Efficiency VS effectiveness

- **Battery electric**: 75%
  - Total system efficiency

- **Methanol fuel cell**: 25%
  - Total system efficiency

**Hybrid**
- A optimal solution combination

- Refuelling time
- Vehicle range
- Cabin heating
- Weight
- Infrastructure
- Energy storage
- Fuel cost
- Global / local emissions
Air pollution and CO₂ emission

Blue World Technologies makes a difference with zero harmful emission fuel cell technology

7 million people die every year from exposure to fine particles in polluted air

Out of the 7 million premature deaths 4.2 million die as a result of exposure to ambient air pollution

91% of the world’s population lives in places where air quality exceeds WHO guideline limits

The transport sector is responsible for a large proportion of urban air pollution

Zero harmful emission:
• No particle emission
• CO₂ tail-pipe reduced by 50-60%
• CO₂ well-to-wheel as hydrogen/electric

Neutrality = decarbonisation

Tank to wheel - methanol fuel cell:
• ~500 g CO₂/kWh
• 30-50 g CO₂/km
• Zero harmful emissions

Today:
• Energy mix: oil, coal, natural gas, wind, solar, biomass

2050:
• Renewable energy sources: biomass, solar, wind, biogas

Well-to-wheel CO₂ emissions (passenger car)

Source: Danish Department of Energy – Alternative drivetrains 2014
## Powertrain Comparison

<table>
<thead>
<tr>
<th>Cases</th>
<th>Economics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nissan Qashqai</strong></td>
<td><strong>Hyundai NEXO</strong></td>
</tr>
<tr>
<td>140 kW gasoline ICE</td>
<td>95 kW hydrogen FC and 120 kW electric motor</td>
</tr>
<tr>
<td>55 L gasoline</td>
<td>1.56 kWh battery + 6.3 kg H₂</td>
</tr>
<tr>
<td>800 km range</td>
<td>666 km range</td>
</tr>
<tr>
<td>1.9 tonne vehicle weight</td>
<td>2.3 tonne vehicle weight</td>
</tr>
<tr>
<td>3 minute refuel time</td>
<td>5 minute refuel time</td>
</tr>
<tr>
<td>CO₂ and particle emissions</td>
<td>Zero emissions</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Hyundai Kona</strong></td>
<td><strong>Passenger car with Blue World MFC</strong></td>
</tr>
<tr>
<td>150 kW electric motor</td>
<td>25 kW methanol FC and 140 kW electric motor</td>
</tr>
<tr>
<td>64 kWh battery</td>
<td>18 kWh battery + 75 L methanol</td>
</tr>
<tr>
<td>290 - 450 km range</td>
<td>900 km range</td>
</tr>
<tr>
<td>1.7 tonne vehicle weight</td>
<td>1.7 tonne vehicle weight</td>
</tr>
<tr>
<td>+ 60 minute recharge time</td>
<td>3 minute refuel time</td>
</tr>
<tr>
<td>Zero emissions</td>
<td>Zero harmful emissions</td>
</tr>
</tbody>
</table>

### Cases

- **Nissan Qashqai**
  - 140 kW gasoline ICE
  - 55 L gasoline
  - 800 km range
  - 1.9 tonne vehicle weight
  - 3 minute refuel time
  - CO₂ and particle emissions

- **Hyundai NEXO**
  - 95 kW hydrogen FC and 120 kW electric motor
  - 1.56 kWh battery + 6.3 kg H₂
  - 666 km range
  - 2.3 tonne vehicle weight
  - 5 minute refuel time
  - Zero emissions

- **Hyundai Kona**
  - 150 kW electric motor
  - 64 kWh battery
  - 290 - 450 km range
  - 1.7 tonne vehicle weight
  - 5 minute refuel time
  - Zero emissions

- **Passenger car with Blue World MFC**
  - 25 kW methanol FC and 140 kW electric motor
  - 18 kWh battery + 75 L methanol
  - 900 km range
  - 1.7 tonne vehicle weight
  - 3 minute refuel time
  - Zero harmful emissions

### Economics

- **Nissan Qashqai**
  - 1.33 €/liter
  - 0.08 €/km
  - 28,500 – 41,600 €

- **Hyundai NEXO**
  - 5 – 10 €/kg
  - 0.05 - 0.09 €/km
  - 80,000 € → ???

- **Hyundai Kona**
  - Fast charge: 0.7 €/kWh
  - Slow charge: 0.1 €/kWh
  - 33,000 – 41,300 €

- **Passenger car with Blue World MFC**
  - Fast charge: 0.24 – 0.52 €/liter
  - Slow charge: 0.02 – 0.05 €/km
  - 25,000 – 50,000 €
Other suitable applications

### Public transport

**Electric version**
- 243 kWh li-ion battery

**Methanol FC version**
- 30 kWh battery
- 35 kW FC
- 500 L methanol

**Benefits**
- Increase operation time from 8 to 28 hours
- 50% reduction in power pack costs
- 65% reduction in power pack weight
- Free fuel cell heat for user comfort
- 3 min refuelling instead of overnight charge

### Light commercial vehicles

**Electric version**
- 100 kWh li-ion battery

**Methanol FC version**
- 20 kWh battery
- 25 kW FC
- 100 L methanol

**Benefits**
- Increase range from 240 km to 520 km
- 20% reduction in power pack costs
- 60% power system weight reduction – more payload
- Free cabin heat
- 3 min refuelling instead of overnight charge

### Heavy duty trucks

**Electric version**
- 700 kWh li-ion battery

**Methanol FC version**
- 60 kWh battery
- 100 kW FC
- 900 L methanol

**Benefits**
- Increase operation time from 8 to 24 hours
- 50% reduction in power pack costs
- 100% weight reduction
- Free cabin heat for operator comfort and clear windows
- 3 min refuelling instead of overnight charge

### Maritime applications

**Electric version**
- 4.3 MWh li-ion battery

**Methanol FC version**
- 400 kWh battery
- 1200 kW FC
- 6500 L methanol

**Benefits**
- Unlimited availability of the E-ferry
- 190% reduction in power pack costs
- 250% weight reduction
- Free heat for operator and traveller comfort
- 30 min refuelling instead of overnight charge
Ready to make a difference

Commercialisation through large-scale production of methanol fuel cell stacks and reformers

Solid orderbook with customers from different markets - great worldwide interest for the technology

We believe in close partnerships with our customers for development of solutions for integration
For further information please contact

Mads Friis Jensen, CCO and Co-founder of Blue World Technologies

mfj@blue.world
Element 1 Corp
Methanol to H₂ Generation (M-Series)
For Low Carbon / Zero Emission Fuel Cell HD Trucks

Methanol Institute
Methanol Fuel Cell: Powering the Future Webinar
Tuesday, June 30th, 2020

Scalable.
Reliable.
Affordable.

www.e1na.com
Element 1 Corp
Overview

Scalable, Reliable, and Affordable H₂ Generation

→ e1 is the global leader in developing small-scale advanced H₂ generation systems supporting the fuel cell industry

→ e1 offers solutions for both stationary and mobile fuel cell systems
  • Extensive IP portfolio
  • Track record of commercial success

→ Business model is licensing and Joint Venture

→ The company maintains world-class product development and testing facilities in Bend, Oregon, with a subsidiary in Jiaxing, China

www.e1na.com
Solving “The H₂ Challenge”
The Case for on vehicle *Methanol to H₂ Generation*

→ Fuel cell solutions are being commercialized in the HD transportation industry

→ Fuel cell systems require new H₂ solutions to “Crack the H₂ Challenge”

→ Lowering H₂’s total cost per kilogram at the point of use is key to adoption of fuel cell power solutions
  
  • Compressed H₂ is >$12 kg

→ Compressed H₂ occupies too much volume to be practical for heavy vehicles requiring extended ranges
  
  • Limited space is available for H₂ storage which reduces range

On the vehicle H₂ supply technology using e1’s Methanol to H₂ Generator **Solves** “The H₂ Challenge”

www.e1na.com
**Break-through Solution for HD Fuel Cell Trucks**

Onboard Methanol to H₂ Generation

**Problem**

- Heavy-duty fuel-cell vehicles cannot store enough compressed H₂ to achieve target distance between fueling
- H₂ fueling infrastructure is lacking, expensive to build
- High-pressure compressed H₂ presents safety risk

**Solution**

- Convert methanol/water mix to high-purity H₂ onboard heavy-duty vehicles with a methanol to H₂ generator

www.e1na.com
What is a $\text{H}_2$ Generator?

Examples

A completely self-contained machine that converts feedstock to purified $\text{H}_2$

→ **Electrolyzer** (water split by electricity into $\text{H}_2$ and oxygen)
  - High CapEx and OpEx
  - 55 kWhrs electricity $\rightarrow$ 1 kg $\text{H}_2$ (US$8.25 at $0.15$/kWhr)

→ **Natural gas reformer** (methane plus water reacted to make $\text{H}_2$)
  - High CapEx, only possible where there is good NG pipeline infrastructure

→ **Methanol Reformer** (methanol plus water reacted to make $\text{H}_2$)
  - **Lowest** CapEx, no supporting infrastructure required
  - 8.3 kg methanol $\rightarrow$ 1 kg $\text{H}_2$

→ **Methanol mixed with water** is feedstock for e1 $\text{H}_2$ generators
  - 33% of product $\text{H}_2$ is derived from water
  - $\text{CH}_3\text{OH} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + 3\text{H}_2$
  - Cost of produced $\text{H}_2$ about US$4

e1’s methanol to $\text{H}_2$ generator has the lowest CapEx, produces the lowest total cost of $\text{H}_2$, and requires no supporting $\text{H}_2$ infrastructure
Methanol

Superior, H₂-Dense Transportation Fuel

A high-volume commodity liquid hydrocarbon fuel (methanol) allows for:

- **High-energy** fuel density onboard the vehicle
- **Low-cost** of fuel (with the right technology)
- **Low-cost** of liquid fuel storage onboard the vehicle (same tanks as diesel)
- **Low-carbon** fuel, with a **renewable future** – Just like H₂ and RNG
- **Reduces** Safety Risk – **No** onboard HP H₂ storage required
- **Clean** exhaust emissions: NO NOₓ | NO SOₓ | NO Particulate Matter

Requires technology onboard the Truck to unlock the H₂ in methanol
Why On-board H₂ Generation?

Think in Terms of kW-hours

- <1 kWhr
- Hundreds of kWhrs
- >1 MWhr

kW-hours = kW x hours = power x distance (time between refueling)

Battery EV

Fuel Cell EV

e1’s methanol to H₂ generator

www.e1na.com
Methanol
Methanol Energy Density **Exceeds** Gaseous H₂ Energy Density

→ High density H₂ storage remains a **significant** challenge for **transportation solutions**

→ Storage options typically require large-volume systems that store H₂ in gaseous form

→ On a volume basis, methanol has almost **six times** the energy density of compressed H₂ (350 bar or 35 MPa)

![Volumetric Energy Density Graph]

Source: Energy.gov. Comparison of specific energy and energy density (energy per volume or volumetric density) for several fuels based on lower heating values.
e1 Methanol to H₂ Generator
Vehicle Architecture

- **Operation:** The fuel reformer is driven by a pressure switch located in the H₂ Buffer tank.
- **Start / Stop:** Fuel reformer starts when the buffer tank is low and stops when its full.
- **Benefits:** Easy integration, simple controls, infinitely variable load following, the fuel cell always has a supply of H₂.
- **Zero Emission:** When renewable methanol is used.

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**H₂ Purifier**

**H₂ Buffer Tank**

**Fuel Cell** (H₂ converted to electricity)

**Electric Power to Wheels**

---

**CO₂**

**Burner**

**Methanol / Water Tank**

**Catalytic Reactor** (Water added to methanol, heated up and chemically separated)

**H₂ Purifier**

**H₂ Buffer Tank**

**Fuel Cell** (H₂ converted to electricity)

**Electric Power to Wheels**

---

CO, CO₂, H₂ (depleted)
M-Series Methanol to H$_2$ Generator (Mobile)
On-Board H$_2$ Generation for \textit{HD Transportation}

Overview

$\rightarrow$ **M-Series**: Designed to replace compressed H$_2$ to support HD mobile fuel cell solutions

$\rightarrow$ **Feedstock**: Methanol & DI water feedstock

$\rightarrow$ **H$_2$ Production**: Can scale to support from 30 kW to 300 kW

$\rightarrow$ **Product H$_2$**: $\approx 99.99\%$ with $<0.2$ ppm CO and $<0.2$ ppm CO$_2$

$\rightarrow$ **Target Uses**: HD trucks, buses, trains and marine vessels

Key Advantages

$\rightarrow$ **Vibration Resistant**: Designed for transportation applications

$\rightarrow$ **Operation**: Designed for cyclic and variable operation

$\rightarrow$ **Compact Design**: Occupies significantly less space than compressed H$_2$ storage solutions

$\rightarrow$ **Lifetime**: Designed for 20,000-hour lifetime (H$_2$ production)

$\rightarrow$ **Manufacturing**: Under e1 manufacturing license
M-Series is Small in Size
Fits in Location Previously Used for Cylinders of H₂

M-Series + methanol/water gives 5x range of compressed H₂ in same space on vehicle

Light-Duty Delivery Truck, 40 kW FCM

Space for 2,200 L methanol/water tank (equiv. to 190 kg H₂)
Sufficient for 67 hours operation at full power (40 kW)
(only 13 hours operation using compressed H₂)
Example of M-Series sized to support 60 kW FCM (100 kg/d)
Example of Fuel Cell Class 8 Truck
Toyota Kenworth Partnership

- Space dedicated to high-pressure H$_2$ storage
- 60 kg H$_2$
- Range is 300 miles

- Approximate volume occupied by M-Series H$_2$ generator
- Range is 1,000 miles from 650-gal methanol/water mix
## Payload & Energy Density

### Class 8 HD Truck Long Haul 1,000 Mi Range

<table>
<thead>
<tr>
<th>Diesel</th>
<th>Methanol to $H_2$ Storage</th>
<th>Compressed $H_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel Amount:</strong></td>
<td>210 gallons</td>
<td>650 gallons</td>
</tr>
<tr>
<td><strong>Fuel Wt.:</strong></td>
<td>1,500 lbs</td>
<td>4,710 lbs</td>
</tr>
<tr>
<td><strong>Tank Wt.:</strong></td>
<td>450 lbs</td>
<td>1,350 lbs</td>
</tr>
<tr>
<td><strong>Total Wt.:</strong></td>
<td>1,950 lbs</td>
<td>7,560 lbs</td>
</tr>
<tr>
<td><strong>Total Vol.:</strong></td>
<td>795 Liters</td>
<td>2,460 Liters</td>
</tr>
</tbody>
</table>

≈ 30% of Volume and 60% of weight of equivalent compressed $H_2$ solution

Heavier and reduced space available for transport

- 50,000 lbs. Load
- 42,440 lbs / 2,460 L.
- 37,040 lbs / 7,800 L.

[www.e1na.com](http://www.e1na.com)
# Fuel Cost Comparison

## Class 8 HD Truck Long Haul 1,000 Mi Range

<table>
<thead>
<tr>
<th>Diesel Fuel</th>
<th>Methanol/Water Feedstock</th>
<th>Compressed H₂ Fuel</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fuel Cost</strong></td>
<td><strong>H₂ Cost per kg</strong></td>
<td><strong>Fuel Cost</strong></td>
</tr>
<tr>
<td>$3.00 Gallon</td>
<td>$4.00 kg</td>
<td>$14.00 kg</td>
</tr>
<tr>
<td><strong>Miles</strong></td>
<td><strong>Miles</strong></td>
<td><strong>Miles</strong></td>
</tr>
<tr>
<td>500 Miles/D.</td>
<td>500 Miles/D.</td>
<td>500 Miles/D.</td>
</tr>
<tr>
<td><strong>Miles per Gallon</strong></td>
<td><strong>Miles per kg</strong></td>
<td><strong>Miles per kg</strong></td>
</tr>
<tr>
<td>5 Miles/G.</td>
<td>6 miles/kg.</td>
<td>6 miles/kg.</td>
</tr>
<tr>
<td><strong>Days</strong></td>
<td><strong>Days</strong></td>
<td><strong>Days</strong></td>
</tr>
<tr>
<td>300 Days/Yr.</td>
<td>300 Days/Yr.</td>
<td>300 Days/Yr.</td>
</tr>
<tr>
<td><strong>Total Fuel Cost:</strong></td>
<td><strong>Total Fuel Cost:</strong></td>
<td><strong>Total Fuel Cost:</strong></td>
</tr>
<tr>
<td><strong>$90,000 Year</strong></td>
<td><strong>$100,000 Year</strong></td>
<td><strong>$350,000 Year</strong></td>
</tr>
</tbody>
</table>

* Methanol Cost: $400 MT

≈ Methanol Feedstock mix is near cost parity to diesel fuel solution

≈ Compressed H₂ is four times cost of diesel fuel solution

www.e1na.com
e1 Fuel Reformers
Easy Integration with the PEM Fuel Cell

- e1 fuel reformers have been integrated with PEMFC’s from the major global suppliers
- Can work with all PEM fuel cell systems
- Simple controls and easy interface with the fuel cell
- Provides flexibility to the system integrator
Vehicle-Based H₂ Generator

Key Advantages

➜ Occupies smaller space on the HD vehicle compared to compressed H₂
  • Result is greater driving range between fueling

➜ Attractive Economics
  • Very low CapEx and OpEx, produce H₂ for $3 to $5 per kg

➜ Minimal Maintenance
  • Simple, routine servicing every 12 months

➜ Scalable
  • Support 30 kW to MW fuel cells

➜ Simple / Familiar Feedstock Storage
  • No stored high-pressure H₂ required, improved safety
  • No requirement to invest in gaseous H₂ fueling infrastructure

Accelerates the Adoption of Fuel Cell HD Trucks

www.e1na.com
The End

For More Information Contact:
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+1 (541) 678-5943
Robert@e1na.com

Scalable.
Reliable.
Affordable.

www.e1na.com
Renewable Energy Solution

—-Methanol Reformed fuel cell
Most Asian countries like China, India etc. are facing a major problem—Air Pollution

The "Global Air Condition 2019" report released by the American Institute for Health Effects recently (based on 2017 data) shows:

In 2017, nearly 5 million people died of stroke, heart disease, lung cancer, diabetes, and chronic lung disease due to long-term exposure to outdoor and indoor air pollution; in China, the number is 1.2 million.

Data from the "Global Air Condition 2019" report shows that in 2017, air pollution in China reduced the average life expectancy by 23 months. Among them, outdoor and indoor air pollution reduced the average life expectancy by 15 months and 8 months, respectively. Among non-communicable diseases, the contribution rate of air pollution to the incidence of lung cancer is 26%, and the contribution rates to heart disease and stroke are 17% and 12%, respectively.
The History of Energy Development

- **Charcoal**
  - Fire/wood
  - The birth of human civilization
  - 3-8%

- **Coal**
  - Steam engine
  - First industrial revolution
  - 10-15%

- **Oil**
  - Internal combustion engine
  - Second industrial revolution
  - 25-40%

- **Natural Gas**
  - Natural Gas Pipeline
  - Clean energy
  - 35-55%

- **Hydrogen**
  - Hydrogen age
  - Fuel cell
  - 40-65%

**Multi-carbon**

**Carbon free**
Problems in the promotion of hydrogen fuel cells

- $ \text{H}_2 $ is a gas with the smallest molecular weight and is very active. There is a safety problem in storage (hydrogen embrittlement).
- Hydrogen compression is very difficult.
- Hydrogen storage conditions are harsh.
- Hydrogen transport costs are high.
Problems in the promotion of hydrogen fuel cells

- Core equipment depends on import
- High construction cost
- Complex approval
- Site selection is difficult
American Nobel Laureate, Dr. George Ola - Methanol Economy: Methanol is the Best Secondary Energy Source.

- It is liquid at room temperature.
- It is easy to store and transport.
- Mature methanol production process.
- Perfect methanol matching chain.
China's coal resources are abundant. Coal-to-methanol can ensure China's century-long energy security. Future methanol can also be made from biomass, crop stalks, etc.

As of 2018, the global methanol production capacity is about 144 million tons per year, and China's methanol production capacity is 86 million tons per year, accounting for more than 60% of world production.

China is increasing the construction of the methanol industry and it is expected that 20 million tons of new production capacity will be added in the future.

Methanol production technology is mature, and the cost is lower than petrol and diesel.
15 years ago, methanol cars were listed as national key science and technology projects and pilot projects were promoted in multiple cities.

In 2014, the Ministry of Industry and Information Technology expanded the methanol car pilot to China’s “four provinces and one city” : Shanxi Province, Shaanxi Province, Shanghai Municipality, Guizhou Province, and Gansu Province. In the future, we will further expand the scope of the pilot.

The 2017 methanol car pilots have all been accepted by the State Ministry of Industry and Information Technology.
On March 19, 2019, China's eight Ministries, such as the Ministry of Industry and Information Technology, signed an agreement of the development of methanol vehicles in some regions in China.

The agreement encourages and supports enterprises to develop methanol hybrid vehicles, methanol extended-range electric vehicles, and methanol fuel cell vehicle products. Promote and accelerate the construction of methanol fuel production and filling systems.
The use of methanol as an energy source

1. Direct combustion
2. Internal combustion engine
3. MFC

Efficient Environmental protection
Methanol - Safer and easier transporting energy

Safer and easier to transport

Relative risk of several fuels
Divided in seven levels (1=low, 7=high)

US Energy Department - Comparison of Fuel Safety

<table>
<thead>
<tr>
<th>DANGER</th>
<th>PETROL</th>
<th>DIESEL</th>
<th>METHANAL</th>
<th>LPG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leakage</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>5</td>
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<tr>
<td>Evaporation</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Released to the atmosphere</td>
<td>5</td>
<td>6</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Released in a closed room</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>3</td>
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<tr>
<td>Automatic ignition</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Spark ignition</td>
<td>2</td>
<td>1</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>Flame propagation</td>
<td>2</td>
<td>1</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Flash fire</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>2</td>
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<tr>
<td>Radiation from the flame</td>
<td>6</td>
<td>7</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Health effects</td>
<td>7</td>
<td>5</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>41</td>
<td>34</td>
<td>28</td>
<td>36</td>
</tr>
</tbody>
</table>
## Analysis of advantages and disadvantages of different energy power systems

<table>
<thead>
<tr>
<th>Power System</th>
<th>Energy Density</th>
<th>Efficiency</th>
<th>PM2.5</th>
<th>Safety</th>
<th>Initial cost</th>
<th>Operation cost</th>
<th>Lifespan</th>
<th>Environmental adaptability</th>
<th>Promotion of social costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disel/petrol internal combustion engine car</td>
<td>★★★★★</td>
<td>★</td>
<td>★</td>
<td>★</td>
<td>★★★★</td>
<td>★</td>
<td>★</td>
<td>★★★★★★★</td>
<td>★★★★★★★★★★★★★★★★★</td>
</tr>
<tr>
<td>Lithium battery car</td>
<td>★★</td>
<td>★★★★★</td>
<td>★★★★★</td>
<td>★★★★</td>
<td>★★</td>
<td>★★</td>
<td>★</td>
<td>★★</td>
<td>★★</td>
</tr>
<tr>
<td>Hydrogen fuel cell car</td>
<td>★★★★</td>
<td>★★★★</td>
<td>★★★★★</td>
<td>★</td>
<td>★★</td>
<td>★★</td>
<td>★</td>
<td>★★</td>
<td>★★</td>
</tr>
<tr>
<td>Methanol hydrogen fuel cell car</td>
<td>★★★★</td>
<td>★★★★</td>
<td>★★★★★</td>
<td>★★★★</td>
<td>★★</td>
<td>★★</td>
<td>★</td>
<td>★★</td>
<td>★★</td>
</tr>
</tbody>
</table>

★ quantity indicates performance superiority
Palcan-A well established company

- Founded
- Launched in Shanghai
- World 1st portable hydrogen FC (using cost: 100RMB/kwh)
- World 1st MFC van
- Changzhou subsidiary founded, Shanghai Palcan founded
- Zhejiang Palcan founded (China's largest MFC production base)

- 1998
- 2000
- 2004
- 2009
- 2010
- 2014
- 2015
- 2016
- 2017
- 2018

- World 1st hydrogen bicycle
- Suzhou subsidiary founded
- China First Photovoltaic Hydrogen Storage Power Station
- World 1st MFC truck
- China 1st MFC vehicle announcement by Ministry of Industry and Information Technology
- Entering new energy vehicle related policy catalogues

(using cost: 10RMB/kwh)
Palcan Technology - Methanol Reformed Fuel cell system

Methanol: 60%  
Water: 40%

CH₄O + H₂O → CO₂ + 3H₂ + 1%CO

Liquid Methanol + Water

Evaporator

Mixed steam of methanol and water

Heat

H₂ and CO₂ mixed gas

Little CO and water vapor

High temperature fuel stacks

The output is DC current, it is connected to the battery

Rest of H₂ and CO₂

Flameless combustion

H₂O + CO₂

No hydrogen storage, safe and reliable!
**Palcan MFC system**

**5KW**
- Power: 5KW
- Weight: 65KG
- Dimensions: 280mm x 480mm x 780mm

**300W**
- Power: 300W
- Weight: 12KG
- Dimensions: 285mm x 233mm x 525mm
Technical Advantages

- Highest energy conversion efficiency

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petrol Engine</td>
<td>25-32%</td>
</tr>
<tr>
<td>Diesel Engine</td>
<td>28-38%</td>
</tr>
<tr>
<td>MFC</td>
<td>40-46%</td>
</tr>
</tbody>
</table>
CO₂ emission is lower than current pure electric emission!

To make the current level of electricity average emission reach the level of methanol, it needs to reduce the proportion of coal thermal power generation to below 45%!
The National Laboratory of Dalian Institute of Chemical Physics, Chinese Academy of Sciences has completed the preliminary pilot test of the solar fuel synthesis industrialization technology route. In July 2018, a solar fuel thousand-ton methanol industrialization demonstration was launched in Lanzhou.

The project plans to build a methanol plant with an annual output of 1,000 tons. After the plant is stable, the scale of carbon dioxide hydrogenation to methanol will be expanded to 3000 tons per year.
公共充电桩电价大约是每度电1.0~1.5元，加上0.8元/度服务费，最后价格约为2~2.3元/度。

民电：0.65元/度（只限用于从自家电表接线，物业安装充电桩按工业电价收费，价格为0.8~1.5元/度）

技术优势

以东风T7为例，运营成本最低！

汽油/柴油（每升）
- 90号汽油：6.75元
- 98号汽油：7.48元
- 0号柴油：7.97元

平均价格：2.87元/kWh
平均18升/100km
平均135元/100km

MFC
- 0.9元/kWh
- 47kWh/100km
平均42.3元/100km

纯电
- 1.1元/kWh
- 47kWh/100km
平均51.7元/100km

高压氢制氢
- 52元/kg
- 4kg/100km
平均200元/100km

公开数据

甲醇价格
- 2019年
- 平均价格：2000元/吨

图片说明：
- 中国甲醇价格
- 2019年
- 甲醇平均价格：2000元/吨
Palcan's advantages in traffic applications

“Extended range - to solve the problem of short mileage”

Take electric bus for example

- **Lithium battery**
  - 540V, 600Ah
  - 324 kWh, 3600 kg

- **Fuel Cell + Methanol Tank**
  - About 800 kg, 330kWh Reserve
  - 492 kWh, 2600 kg
  - About 1800 kg, 162kWh Reserve

- **Controller**

- **Electric Machinery**

- **Palcan's solution**

- Save 50% batteries, reduce 1 ton weight of the car
- Electricity increased from 324 kWh to 492 kWh
Palcan's advantages in traffic applications

“Low-temperature operation - Solving the problem that lithium batteries cannot be charged or discharged at -20°C”

We use “high-temperature fuel cell stack”, the temperature of the heat exchanger is about 140 degrees, the heat energy can be fully utilized to heat the lithium cell and the car.
Palcan's advantages in traffic applications

“Compared with hydrogen FC, MRFC is more economical and feasible”

MRFC Logistics vehicle

- Various ways to add methanol: methanol station, partial refit of gas station, tank truck, etc.
- Same volume, twice the energy of high-pressure hydrogen tank.

Hydrogen FC Logistics vehicle

- Hard to find hydrogen station
- Construction costs and transportation costs are higher
- Two times higher cost than gasoline
- Safety hazard
Applications

- Mobile charging
- Backup power
- Distributed generator
- Portable power
- EV Applications
Silent Mobile power

“Silent Mobile Charging Car”
Backup Power

“Communication base station backup power”

<table>
<thead>
<tr>
<th>Project</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output Power</td>
<td>2.5~10KW</td>
</tr>
<tr>
<td>Output voltage</td>
<td>−48DCV</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>−20~50℃</td>
</tr>
<tr>
<td>Stack Type</td>
<td>HT-PEMFC</td>
</tr>
<tr>
<td>Cooling method</td>
<td>Air cooling</td>
</tr>
<tr>
<td>Certified product</td>
<td>CTTL certificate</td>
</tr>
<tr>
<td>Fuel Type</td>
<td>Aqueous methanol solution</td>
</tr>
<tr>
<td>Water tank capacity</td>
<td>100L*2</td>
</tr>
<tr>
<td>Dimensions</td>
<td>900<em>900</em>2200mm</td>
</tr>
<tr>
<td>Weight</td>
<td>425~500kg</td>
</tr>
<tr>
<td>Communication Method</td>
<td>RS485/SNMP</td>
</tr>
<tr>
<td>Monitoring method</td>
<td>Wireless remote monitoring</td>
</tr>
</tbody>
</table>
Distributed, island Power

“Island power generator”

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size (mm)</td>
<td>1350 <em>650</em>1070 (except fuel tank)</td>
</tr>
<tr>
<td>Quality (kg)</td>
<td>230 (except fuel tank)</td>
</tr>
<tr>
<td>Output power (kW)</td>
<td>5</td>
</tr>
<tr>
<td>Fuel tank capacity (L)</td>
<td>200-500</td>
</tr>
<tr>
<td>Fuel (Volume ratio)</td>
<td>60%methanol / 40%water</td>
</tr>
<tr>
<td>Single injection power generation (kWh)</td>
<td>~2200</td>
</tr>
<tr>
<td>Characteristic</td>
<td>Stable energy output, free from weather, sunshine and other conditions; zero emissions without pollution; high energy efficiency; low noise; convenient infrastructure, safe operation; low operating costs.</td>
</tr>
<tr>
<td>Output voltage</td>
<td>220VAC</td>
</tr>
<tr>
<td>Sustainable running time</td>
<td>Long-term</td>
</tr>
</tbody>
</table>
“300W portable power generator”

Suitable for power sources such as single station power supply, field camping power supply, small drone power supply, and street small sweeper.

### Parameters

<table>
<thead>
<tr>
<th>Performance</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>power range [W]</td>
<td>300~350</td>
</tr>
<tr>
<td>DC Output voltage range [V]</td>
<td>24DC/48DC/220 AC</td>
</tr>
<tr>
<td>System efficiency (%)</td>
<td>33(peak)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Working characteristics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>fuel type</td>
<td>60% vol methanol / 40% vol water</td>
</tr>
<tr>
<td>Fuel consumption@300W [KWh/L]</td>
<td>1.015</td>
</tr>
<tr>
<td>Operating power consumption [W]</td>
<td>&lt;77</td>
</tr>
<tr>
<td>Ambient temperature [°C]</td>
<td>-20~50</td>
</tr>
<tr>
<td>Communication methods</td>
<td>485/LAN</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Connection characteristics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel interface [mm]</td>
<td>Ø6</td>
</tr>
<tr>
<td>Exhaust port [mm]</td>
<td>Ø60</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical characteristics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>size [mm×mm×mm]</td>
<td>525×233×285</td>
</tr>
<tr>
<td>Volume[L]</td>
<td>34</td>
</tr>
<tr>
<td>Weight [Kg]</td>
<td>~12</td>
</tr>
</tbody>
</table>
“China's first 30kW Methanol Reformed FCV (Co-op with Dongfeng)”

2016.05.24 Chairman of Dongfeng Yanfeng Zhu pays close attention to MRFC car
“China's first 30kW Methanol Reformed FCV (Co-op with Dofeng)"

► Developed the 1st methanol reformed hydrogen FCV in China.

► Fist MRFC issued by the Ministry of Industry and Information Technology in China.

► Developed the technical standard for methanol reformed hydrogen FCV.
“China's first 30kW Methanol Reformed FCV (Co-op with Dofeng)”

- Has been issued by the Ministry of Industry and Information Technology "new energy automotive product announcement" (2017/12/29)
- Has entered the "new energy vehicle promotion recommended list" (3rd batch of 2018)
- Has entered the "Exemption Vehicle Purchase Tax New Energy Vehicle Model Catalog" (17th batch of 2018)
- Mass production has started.
2018/10/25, the world's first MRFC logistics vehicles were officially put into commercial operation release ceremony at the Kunshan International Auto Show.

The car has been driving in Suzhou-Inner Mongolia of China, which is highly valued by the Inner Mongolian government.

- **capacity of 800km+**

- Meet the special needs of new energy vehicles with low temperature and vast territory in Inner Mongolia.

“10kW MFC used in MPV”
Target market: passenger cars and combined heat and power etc.

Using micro-inverted technology to improve the energy conversion efficiency and extend the service life while increasing the module power density.
“High Power Fuel Cell System Module R&D (60~80kW)”

Targeted market: ships, construction temporary power supply, electricity used during rail transit construction, power stations, collectors and combined heat and power supply, etc.
Our Target

“Using Methanol to Replace Traditional fuel by Fuel Cell Technology”
THANK YOU!
Roland Gumpert
for Methanol Matters - June 2020
Methanol Fuel Cell: Powering the Future
Hello,

My name is Roland Gumpert and I want you invite to show our revolutionary driving technology with hydrogen generated from methanol.

https://www.youtube.com/watch?v=KfJ774HSkQ
“My idea was to build a car which didn’t stop when the battery is empty”
• Batteries only have a range of 100-350km
• The entire charging infrastructure would require a doubling of the existing electricity network and the implementation would take decades
• The waiting times at the charging stations are not technologically acceptable - long waiting times do not have to be with our technology
• For me, driving means freedom. When I get a phone call, I have to be able to get into my car and drive to another city without any planning
Is electric driving the future?

Yes this is undoubtedly the case!
Because:

• No risk of explosion because we do not work with high pressures up to 800 bar, our highest pressure is below 30 bar
• No new petrol stations required (conversion from diesel to methanol approx. 2000 €
• Transporting H2 is extremely energy-intensive and higher hazard classes than methanol
• A hydrogen filling station costs between € 1-3 million and must not be close to other buildings for explosion protection reasons (distance between residential buildings 100 meters; distance filling station 300 meters, German law)
Nathalie
“First Edition”

Key Facts & Parameters
<table>
<thead>
<tr>
<th>Feature</th>
<th>Specification</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>820 km</td>
<td>Range</td>
<td></td>
</tr>
<tr>
<td>300 km/h</td>
<td>Top speed</td>
<td></td>
</tr>
<tr>
<td>Sports coupé</td>
<td>With two seats</td>
<td></td>
</tr>
<tr>
<td>3 min</td>
<td>Refueling</td>
<td></td>
</tr>
<tr>
<td>2.5 s</td>
<td>Acceleration 0-100 km/h</td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>Chassis</td>
<td></td>
</tr>
<tr>
<td>4-wheel drive</td>
<td>4 engines, 4 wheels (4×4)</td>
<td></td>
</tr>
<tr>
<td>400 kW</td>
<td>Power</td>
<td></td>
</tr>
<tr>
<td>Grille frame</td>
<td>Made for the race track</td>
<td></td>
</tr>
<tr>
<td>Recuperation</td>
<td>Energy recovery</td>
<td></td>
</tr>
<tr>
<td>190 kWh</td>
<td>System power capacity</td>
<td></td>
</tr>
<tr>
<td>Rear spoiler</td>
<td>Aerodynamic rear</td>
<td></td>
</tr>
<tr>
<td>65 l methanol</td>
<td>Tank volume</td>
<td></td>
</tr>
<tr>
<td>120 km/h</td>
<td>When battery is empty</td>
<td></td>
</tr>
<tr>
<td>Dimensions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Length</td>
<td>4370 mm</td>
<td></td>
</tr>
<tr>
<td>Width</td>
<td>2076 mm (from mirror to mirror)</td>
<td></td>
</tr>
<tr>
<td>Height</td>
<td>1306 mm</td>
<td></td>
</tr>
<tr>
<td>Wheel base</td>
<td>2648 mm</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>1800 kg</td>
<td></td>
</tr>
<tr>
<td>Parameter</td>
<td>Value</td>
<td></td>
</tr>
<tr>
<td>---------------------------</td>
<td>----------------------------</td>
<td></td>
</tr>
<tr>
<td>Quantity</td>
<td>500 pcs.</td>
<td></td>
</tr>
<tr>
<td>Lifetime</td>
<td>4 Years</td>
<td></td>
</tr>
<tr>
<td>SOP</td>
<td>2021</td>
<td></td>
</tr>
<tr>
<td>EOP</td>
<td>2024</td>
<td></td>
</tr>
<tr>
<td>Torque</td>
<td>&lt; 1000 Nm</td>
<td></td>
</tr>
<tr>
<td>System Voltage</td>
<td>400 V</td>
<td></td>
</tr>
<tr>
<td>Average Consumption</td>
<td>20 kWh</td>
<td></td>
</tr>
<tr>
<td>Charging Mode</td>
<td>37 (15+22) kW, ~2h</td>
<td></td>
</tr>
<tr>
<td>Refueling</td>
<td>3 min</td>
<td></td>
</tr>
<tr>
<td>Recuperation</td>
<td>0.3 m/s²</td>
<td></td>
</tr>
<tr>
<td>Empty Battery Velocity</td>
<td>80 km/h</td>
<td></td>
</tr>
<tr>
<td>Fuel Cell Capacity</td>
<td>65l Fuel = 118 kWh</td>
<td></td>
</tr>
<tr>
<td>Fuel Cell Power</td>
<td>Up to 15 kW</td>
<td></td>
</tr>
<tr>
<td>HV-Battery Capacity</td>
<td>60 kWh</td>
<td></td>
</tr>
<tr>
<td>HV-Battery Power</td>
<td>450 kW</td>
<td></td>
</tr>
<tr>
<td>Engine Power</td>
<td>4x100 kW</td>
<td></td>
</tr>
<tr>
<td>Rpm</td>
<td>12,000 U/min</td>
<td></td>
</tr>
<tr>
<td>Gearbox</td>
<td>2 Gears</td>
<td></td>
</tr>
</tbody>
</table>

1. 0 - 170 km/h
2. 170 - 300 km/h
The future of hydrogen from a fuel cell is beyond question!

And methanol is the carrier!
Methanol is the perfect solution and our vision for all vehicles (small and big) in the future
Here is an example of a small car with a methanol reforming fuel cell (this is a working test vehicle from us)

- From 40 HP car to 40 t truck
- The fuel cell is the size of a medium-sized travel case
- Already installed in an electrically operated Smart, one of our test vehicles
- This is the emission-free future without mineral oil
We already have the car of the future here in Ingolstadt/Bavaria (Germany)

- We manufacture the vehicles here in Ingolstadt
- We have orders from all over Europe
- We expect the first vehicles to be delivered to customers in the first half of 2021
We need support from business and politics to bring this technology to a wider range.

https://youtu.be/uOHzT-gATEc
Imprint

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